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The adaptation of public spaces to climate change. Case study: Léon Jamin street, Nantes, France: prospects for the integration of climate adaptation solutions in the design of an urban canyon

Marcelle Alkhatib

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Double Degree Master program:

Master of Science in Urban Planning & Policy Design

(POLITECNICO DI MILANO)

Master en ville et environnement urbain/ Architecture, Ambiance et urbanité

(ÉCOLE CENTRALE DE NANTES – ENSA NANTES)

L'adaptation des espaces publics au changement climatique. Cas de la rue Leon Jamin, Nantes, France:

*Perspectives d'intégration de solutions d'adaptation au climat
dans la conception d'une rue canyon*

**The adaptation of public spaces to climate change.
Case study: Leon Jamin street, Nantes, France:**

*Prospects for the integration of climate adaptation solutions
in the design of an urban canyon*

DECEMBER 2020

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ABSTRACT

Global warming, a global phenomenon, is likely to have effects on a local or even micro-local scale, due to pre-existing unfavorable factors. The rise in temperatures and the successive heatwaves since 2003 have clearly shown the incapability of french cities to be resilient in the face of the heat. In response, cities have accepted the empirical nature of climate change which led the local authorities to now recognize the need for adaptation in order to cope with heatwaves episodes and fight against urban heat islands.

Faced with extreme heatwaves and to improve thermal comfort conditions, urban policy is concerned with the city's mitigation and adaptation strategies. The climate-resilient urban design has not yet emerged as a major consideration in standard urban design practice. Thus, the issue of climate adaptation in public spaces requires the development of a simple design methodology capable of cross-analyzing the quantitative and qualitative data of microclimate that can be communicated easily with various multi-disciplinary actors. Leon Jamin street in Nantes was used as a case study to showcase prospects for the integration of climate adaptation solutions in the design of an urban canyon. The complexity of cross-analyzing the measurable and the unmeasurable information led to the simplification of the assessment by choosing a set of relevant indicators convenient to the study area. However, the outdoor thermal comfort is subjective which depends on the users' experience. Street design recommendations are outlined as a result and encouraged to be shared at the preliminary phase of an urban project and evaluated at the delivery.

KEYWORDS

Climate change, urban canyon, Adaptation, microclimatic analysis, morphological indicators, microclimate indicators, global warming, public space, resilience

In partial fulfillment of the requirements for a double degree Master program in Urban Planning and design policy from Politecnico di Milano and a Master in “City and urban environment” (Ambiances Architectures Urbanités), I have completed an internship of eight months at Nantes Metropoles in the department of energy transition and urban services/ adaptation and climate unit. This paper is a description and critique of work accomplished while in this position. My appreciation goes to Alban Mallet, Climate Plan Officer, and Jean-Pierre Brindel, Director of Nantes Métropole Aménagement for making this job opportunity and report possible. The case study in this report was presented to the department of energy transition and urban services and discussed during two group work sessions composed by:

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PART I

INTRODUCTION

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PART I: INTRODUCTION

1.1 Background of the problem and the problem statement

The climate is changing, and the global temperature is expected to rise to 4.8 ° C by 2100 (GIEC, 2014). The rising temperature and the extreme events resulting from this fast and abrupt climate change put humanity and biodiversity at risk (Bellard et al., 2012). The contemporary cities are facing now more than ever the phenomena of urban heat island (UHI) and its impacts on the environment (ecosystem, air quality), human health, and energy consumption. It is not a surprise that environmental issues have been highlighted as a priority in the political agenda.

According to the assessment reports of the IPCC (IPCC, 2013, IPCC, 2007), the greenhouse gas emissions must be urgently limited to hinder the impact of global warming and adaptation strategies to climate change should be prioritized and of prime significance.

A new paradigm in urban planning and design is required to develop resilient cities that can adapt to the dynamicity and the unpredictability of the climate and its disastrous impacts. The city analysis goes beyond its urban and architectural facets, it involves other disciplines such as geography and climatology.

In the European context, the laboratories, EU funded projects, and numerous government efforts have led to achieving high environmental quality and innovation in the meteorology of the city. The 2003 French heatwaves showed the incapacity of the system to adapt to the heat and killed nearly 15,000 people in France (Lalande, F, 2003) In this situation, Nantes, the 6th largest city in France, solidly adopted in December 2018 its Territorial Air Climate Plan (PCAET) and it will serve as a case study for our research work.

The Territorial Climate Air Energy Plan (PCAET) has two main components:

- mitigation to limit greenhouse gas emissions
- adaptation to reduce the vulnerability of the territory

The adaptation component of the PCAET is structured around two major strategic orientations, corresponding on the one hand to trend changes in climatic parameters, and on the other hand to crises:

- "live better with a warmer climate"
- "prepare for new types of climatic events".

The adaptation to climate change is an attempt to respond to global warming and the possible heatwave which will cause summer thermal discomfort.

The interaction of climate and cities, especially concerning urban morphology, vegetation, topography, and thermo-aeraulic phenomena generates the creation of **microclimates**. At the same time, the latter has an impact on energy consumption, through the effect of heat exchange between the **built environment** and the **urban public space**.

1.2 Research aim and objectives

The main aim of the research is closely linked to the purpose of my internship at Nantes metropolises as my work was essential for the “climate/adaptation” department to build a framework and a methodology on **“the adaptation of public spaces to climate change.”**

The following objectives are to be able to measure progress towards meeting the aim of the thesis:

- a) To analyze and quantify, using a set of microclimatic and morphological indicators, the effect of the UHI phenomena on the comfort of the users, for a case of “Leon Jamin” street in Nantes.
- b) To Cross-reference quantitative/scientific and qualitative data of the public space.
- c) To define the cooling potential of different adaptation strategies in the summer (or during the heatwaves) in order to integrate them into the design and the development of urban projects.
- d) To easily communicate the outcome of the research (qualitative/quantitative) with various actors of the “*Fabrique de la Ville*” (technical services, planners, architects, urbanists, ...)

1.3 Topic relevance and research questions

Theoretical level

By linking climate change to the urban public space, this thesis offers a way to integrate multiple scientific approaches along with the qualitative evaluation of the public space in the adaptation strategies. Moreover, it intends to add to the understanding of urban planning and design, using the environmental indicator and the microclimate simulation to predict the often-overlooked dimensions of the pedestrian microclimatic comfort.

Practical level

This paper aims to provide an example of a multidisciplinary method for the adaptive department at the metropolises to integrate adaptive tools and solutions at the upstream

planning stage of a public space project. And also, to be able to monitor the result at the operational phase. The adaptation component intends to define prerequisites regarding adaptive tools and cooling solutions to the urban public space project's tools to envision a different way of shaping outdoor comfort in the urban space. This means that this research gives an unusual lens to consider the scientific microclimate approach along with the usual urban analysis.

Research questions

A set of questions is a starting point that will embody an understanding of adaptation to climate change in its intersection with urban public space. The first two questions constitute the essence of the investigation, while the third one opens a track for further research:

- I. What are the urban heat islands and what are the reasons behind them? How do adaptation strategies can address its impact and ensure thermal comfort?
- II. Which are the indicators used for quantifying and qualifying the microclimate of urban space? Which methods we should use to analyze the comfort of users? How can a different paradigm in urban planning and design transform the development of urban public space?
- III. What are the design solutions and tools to adapt an urban canyon (public space) to climate change?

1.4 Research framework and methods

Research framework

This research profits from the academic studies and work conducted during the double degree program in Urban Planning and design policy at **Politecnico Di Milano** and city and urban environment (Ambiances Architectures Urbanités) at **Ecole Centrale de Nantes** with a partnership with **ENSA Nantes**. We have Undergone an internship of eight months at Nantes Metropoles (Nantes, France) in the department of Energy Transition and urban services, adaptation, and climate unit. about “**the adaptation of public spaces to climate change**”. During the internship, we started developing my research about solutions and tools for urban design aimed at improving thermal comfort and reducing urban heat in public spaces where we took Leon Jamin street as a study area. We visited and investigated best practices and case studies in Europe, and we took part in several ongoing projects in Nantes during my internship (COOLPARKS, ICLEI, GROOF(see Annex), Coolscape), looking for innovative strategies and solutions for designing low carbon and resilient cities.

Our collaboration with the CRENAU Laboratory and its researchers lent a tremendous boost in acquiring the tools to undergo a **quantitative** study on the selected urban space.

This study will mainly consist of theoretical analysis and a case study (internship work). The core logic is to identify the joint area of climate change and public space by reflecting on a quantitative method that takes into account the environmental and energetic stakes and a qualitative approach that evaluates the components of an urban public space and its users.

The thesis starts with PART II, a **literature review** on the UHI and the local urban climate at a micro-scale level. The second chapter frames the adaptation and the fight against UHI.

In part III, we will expose my internship outcome at Nantes metropolises where we were trusted to conceive a vision for “Leon Jamin street” in Nantes, France. The study of Leon Jamin street is used as a case study to review the impact of global warming on the urban public space in a practical way,

A **quantitative** and **qualitative** approach to my proposed intervention led my research in chapter 5 to some considerations and suggestions for future work. The research framework shows in (Figure 1)

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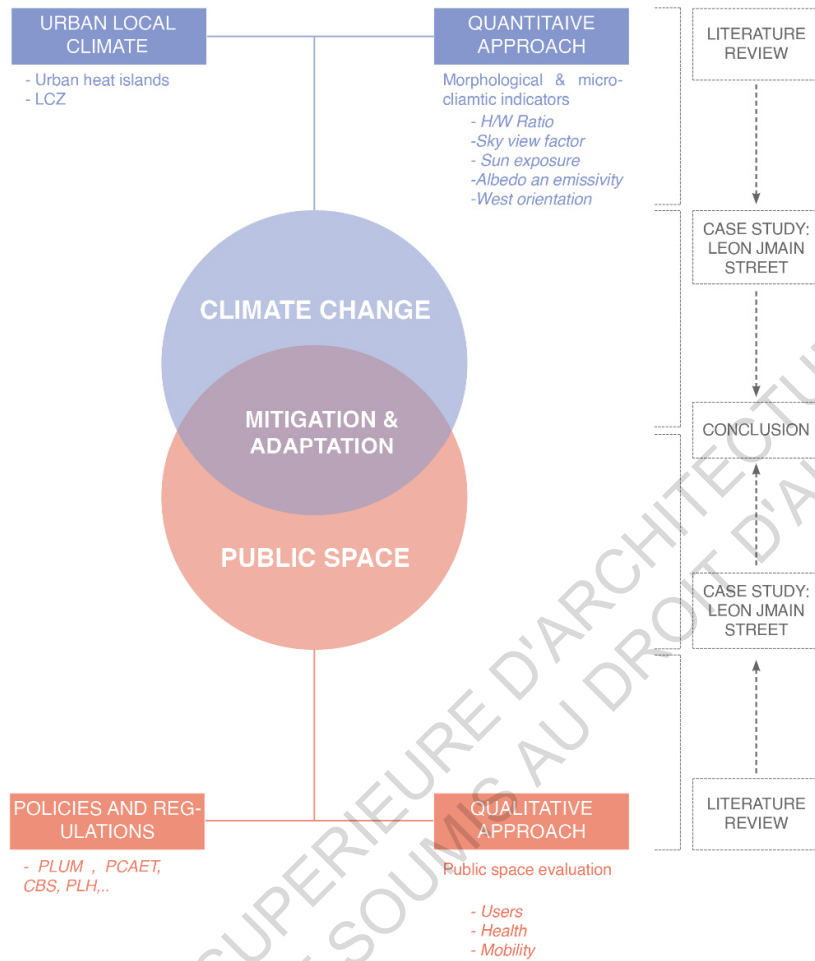


Figure 1: Thesis Framework. Drawn by the author

Research methods

The main research methods adopted are literature review, qualitative analysis, and quantitative analysis. The data is collected through different resources, including scientific journals, official public documents, open on-line maps, and other internet research methods.

We can summarize the research method in four steps:

- **Archival and bibliographical** research of documents and maps.

four or six?

- **Microclimatic simulation:** Collaboration with researchers from CRENAU like Thomas Leduc and Ignacio Requena to help with the choice of the environmental indicators and to help in the microclimate simulation.

Their contribution was important to find fundamental references to choose the

- **Meeting with professionals in the field** (Fig 2)

- **Field visit:** Several site visits were conducted in August 2020 during a different time of the day to track the behavior of users.

- **Workgroup:** 2 group works were done on the 15th of September and the 13th of October where the outcome of the internship was presented and discussed thoroughly.

- **Recomposition of the thesis work:** After gathering most of the needed information, we started to write the thesis and make reasoned schemes and diagrams.

A good methodology of research was the key to get all the information we needed and to compare with a critical approach the correct parameters for the case study of Leon Jamin street and to find a good strategy for adaptive urban design.

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M. Ignacio REQUENA	Coolscape	CRENAU- Researcher
M. Thomas LEDUC	Microclimatic simulation	CRENAU- Researcher

Table 1:List of a conducted interview. Drawn by the author

1.5 Research limitations

This thesis is based on the work that has been done during an internship at Nantes metropolises in the department of DIRECTION ENVIRONNEMENT, ÉNERGIES, CLIMAT (DEEC) from March till October 2020. The study faced a few constraints and limitations that are going to be discussed below:

Limitation of Time and resources (Internship in the time of COVID-19)

On the 17th of March 2020, a few days after starting the internship, a national lockdown was announced in France. So, the internship was interrupted from March till mid of July where we started to work as a part-timer from home (smart working).

Therefore, the unfortunate pandemic was our main limiting factor regarding the methodology and the required technicality used for this research (such as SOLENE, ENVIMET, QGIS, 3D visualization, and design software). We were not able to meet all the actors and the professionals for the data collection. We failed to associate laboratories to help in the microclimate simulation and the choice of trees and vegetation. As time was very short, it was very difficult to carry out the study precisely and to go in-depth analysis. For that reason, interviews with residents and an environmental expert and exhaustive simulation were not included in this research.

Limitation of relevant studies

This study focused on peer-reviewed sources, in which work published in languages other than English, Italian, or French were excluded.

The urban planning to mitigate and adapt to climate change is a new position assigned at Nantes metropolises in September 2019. The application of the adaptation to climate change in urban projects is not common in practice. In most cases, they are applied in different ways with different prime objectives. So, there are some limitations to the exact and relevant study in this sector.

1.6 Thesis structure

The research is articulated in six sections (figure 3): the first part is an introduction to the thesis exposing the methodology and the objectives of this research. The second part which is the state of art is composed of two sections where we define a general overview of meteorology in the city and problems influencing the urban heat islands. We also reveal the relevance of carrying out strategies to adapt urban spaces to climate change.

In the third part, we present the concrete case of Leon Jamin street in the center of Nantes. Chapter four focuses on a quantitative and qualitative approach to investigate urban local climate on a street level. We choose a non-exhaustive set of indicators (bioclimatic and morphologic) to consider environmental and energy issues that can open a door for possible intervention. The main purpose behind analyzing Leon Jamin

The adaptation of public spaces to climate change. Case study: urban canyon Leon Jamin street, Nantes, France

street (qualitatively and quantitatively) is to cross-referenced the quantitative and qualitative approaches to envision innovative solutions to integrate the public space.

Maps, photos, works of literature, 3d visualizations, and environmental simulation will be used in this section

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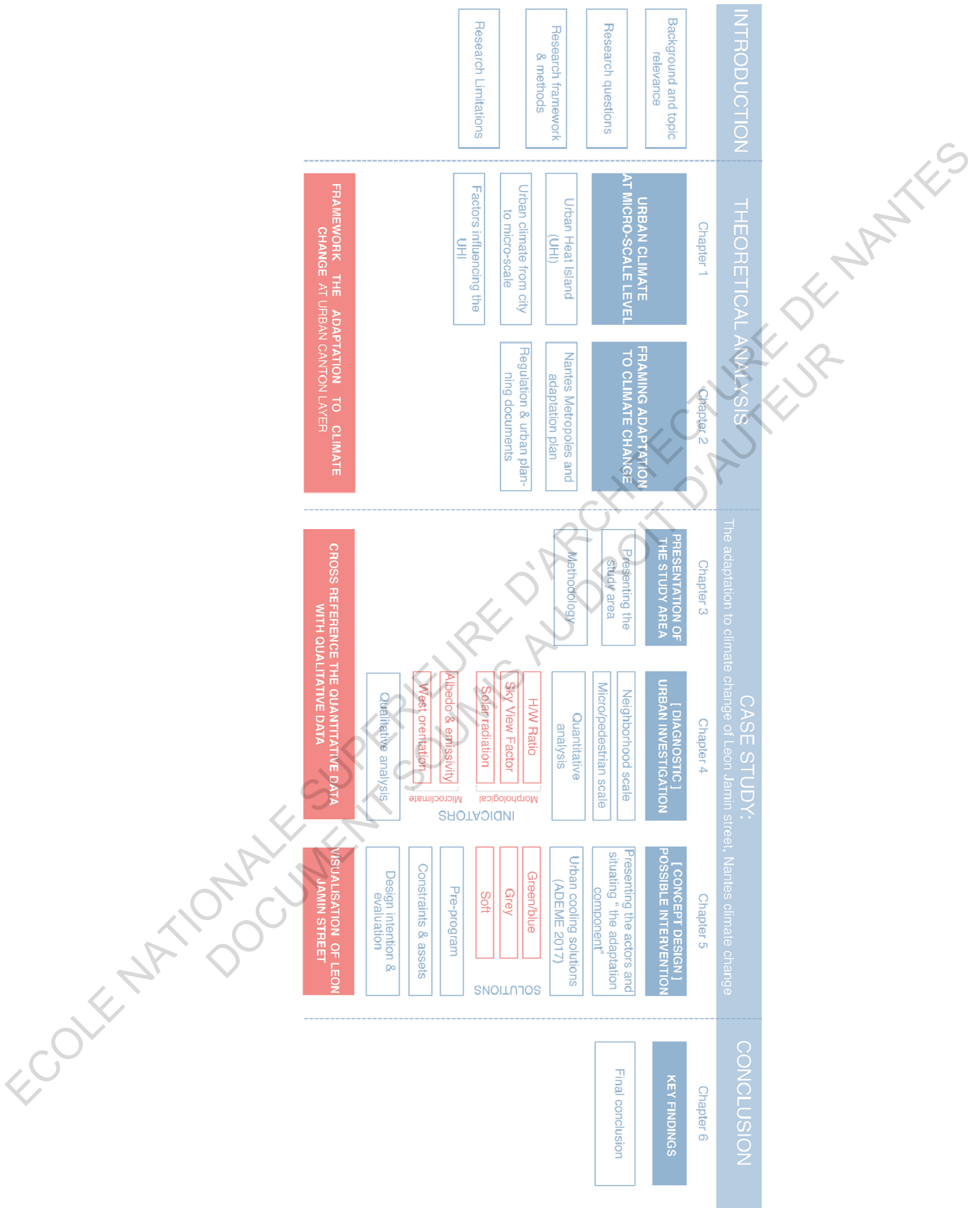


Figure 2: Thesis structure. Drawn by the author

PART II

ETAT DE L'ART

« La forme d'une ville change plus vite, on le sait, que le cœur d'un mortel. Mais avant de le laisser derrière elle en proie à ses souvenirs – saisie qu'elle est, comme le sont toutes les villes, par le vertige de métamorphose qui est la marque de la seconde moitié de notre siècle – il arrive aussi, il arrive plus d'une fois que, ce cœur, elle l'ait changé à sa manière, rien qu'en le soumettant tout neuf encore à son climat et à son paysage, en imposant à ses perspectives intimes comme à ses songeries le canevas de ses rues, de ses boulevards et de ses parcs » Julien GRACQ, La forme d'une ville, José Corti, 1985

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Part II: STATE OF THE ART THEORIES/CONCEPTS

CHAPTER 1: URBAN CLIMATE AT A MICRO-SCALE

Urban climate adaptation is defined by the *UNFCC and UNDP* as follow:

“Actions are taken to help communities and ecosystems cope with changing climate conditions”. (UNFCC) (OECD, 2006)

“Process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented”

(UNDP, 2005 as quoted in OECD, 2006)

This chapter explores the problem definition of the thesis framework underlining the UHI phenomena as the main component of urban climate, its factors, and climate adaptation measurements. Since urban planning is the field of this research, the urban climate is going to be tackled through its urban environmental factors that are considered **controllable variables** rather than the **uncontrollable** meteorological influence. Moreover, the scale that is considered for this study is going to be defined.

1.1 Urban heat island (UHI)

Cities are considered the foremost vulnerable to **climate change** which highly impacts the urban environments (World Bank, 2011). The impact of **heatwaves** is noticeable in the urban environment due to the **urban heat island (UHI)**, which results in higher air and surface temperatures in dense urban areas or cities comparably to the peri-urban and rural areas. (Rizwan et al., 2008; Bowler et al., 2010; Sharifi and Lehmann, 2015). In general, the intensity of the UHI is negatively correlated to the wind speed and positively linked to the density and the size of the city. (Oke, 1987).

Urban **Overheating** is provoked by the high urban density which is defined as a solar radiation trapping effect. The reasons behind this phenomenon are the lack of porosity of land, the materials that store heat, solar heat accumulation capacities, and an anthropogenic source. Each city has its own specific UHI depending on its size, morphology, weather conditions, geographic location, and human activities (Mestayer and Anquetin, 1995).

Heatwaves exacerbated by the UHI apply a series of changes on the whole environmental system (water, air quality/climate, and green infrastructure), and influence the health, security, and economy. The significant outcomes are: aggravating the outdoor thermal comfort at street level as well as the indoor thermal comfort which leads to an increase in energy consumption due to the need for air conditioning which can affect the

air quality. During heatwaves, heat induces stress and anxiety for the inhabitants and increases the death rates (Mora et al, 2017).

Timothy R. Oke, from the University of British Columbia, is a preeminent expert in microclimatology studies and the intersection of two disciplines: environment and biology, According to Oke, little contribution was made to improve urban planning studies. Therefore, he defined a framework where urban planning crossed with an urban climate which requires an improvement in the communication and the scientific approach to make urban planning an interdisciplinary process (Oke, 2006, p. 179).

1.2 Urban climate from City to Micro Scale

Oke T. R. among the first leading theorist that defines a “**boundary level**” as the layer of atmosphere related to the urban structure (which might be 1 kilometer or more by day, contracting to many meters around evening time) and recognized by two layers with distinct practices (Figure 4).

Initially, the “urban boundary” layer is the layer of air directly above the urban structure. The climate here depends on the nature of the general urban ‘surface’ and “roughness”. This scale is considered **a neighborhood to a mesoscale**.

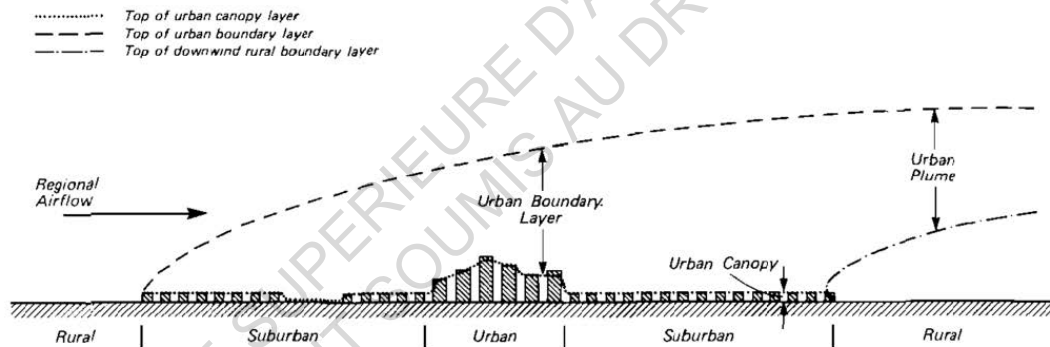


Figure 3: Representation of the atmosphere showing a two-layer classification of thermal modification (Oke, 1976, p. 275)

The main studies on urban climatology were dependent on the difference between urban and rural contexts (Oke, 1987). The latest urban climate studies have consequently developed towards a more contemporary categorization, with a dedication to the local scale landscape in the city such as the classification of (Stewart, 2013) known as the “**LCZ, local climate zones**”.

a) Local climate zones (LCZ)

The LCZ system consists of ten categories according to urban fabric and geometry and seven according to land cover; the latter categories are subject to seasonal variations, which is why the system offers four variations to be added, if necessary, in the description of the surface coverage. Given the difficulty of describing all the possible types of existing urban form, the creation of subcategories is also possible from the combination of two or more standard climatic zones.

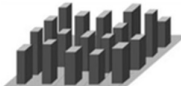
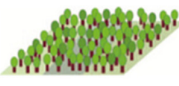


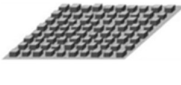
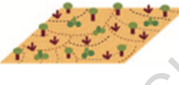





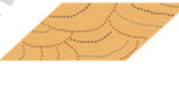
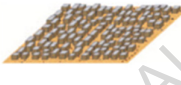
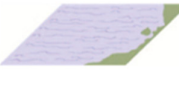



Built types	Definition	Land cover types	Definition
 <p>1. Compact high-rise</p>	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	 <p>A. Dense trees</p>	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
 <p>2. Compact midrise</p>	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	 <p>B. Scattered trees</p>	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
 <p>3. Compact low-rise</p>	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	 <p>C. Bush, scrub</p>	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
 <p>4. Open high-rise</p>	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	 <p>D. Low plants</p>	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
 <p>5. Open midrise</p>	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	 <p>E. Bare rock or paved</p>	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
 <p>6. Open low-rise</p>	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	 <p>F. Bare soil or sand</p>	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
 <p>7. Lightweight low-rise</p>	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	 <p>G. Water</p>	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
 <p>8. Large low-rise</p>	Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	VARIABLE LAND COVER PROPERTIES	
 <p>9. Sparsely built</p>	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.	
 <p>10. Heavy industry</p>	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	<p>b. bare trees</p> <p>s. snow cover</p> <p>d. dry ground</p> <p>w. wet ground</p>	<p>Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.</p> <p>Snow cover > 10 cm in depth. Low admittance. High albedo.</p> <p>Parched soil. Low admittance. Large Bowen ratio. Increased albedo.</p> <p>Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.</p>

Figure 4: Local Climate zone (Stewart, 2012)

The authors of the LCZ system also estimated the values corresponding to each of the zones. This is a strong point of the method since these values make it possible to rank sites objectively and relatively easily. Moreover, the authors offer a simplified sheet containing the characteristics by zone with the ranks of value by parameter, as well as images and sketches that promote the identification of zones. Table 5 shows the description of the standard zones.

b) Limitation & Advantage:

The main problem with the method was to achieve an ideal correspondence between the values defining each class and the reality on the ground when it comes to fairly large urban fragments (neighborhoods for example).

Another advantage of LCZs is that this method simplifies the language for non-experts in climatology, which is our case. So, it makes itself accessible to an audience that is not in this field but needs this knowledge: town planners and architects. Thus, we see approaching the probability of solving the communication problems between these fields. An equally important remark, from the point of view of language, is that the method speaks of climatic zones, whereas it is a morphological classification according to the variables likely to modify the microclimate. We must understand this well so as not to be confused. Lately, the authors have started to give quantitative values to each zone according to the observations of the temperature variations, and they confirm that the classes have differentiable thermal properties.

c) Microscale: Scale definition of the study:

Oke defines the “urban canopy layer” as comparable to the “canopy” of a tree. Here, the climate is created by micro-scale elements that are bounding the urban space, such as the street and between the buildings. The solar radiation is entrapped in such a layer of air and absorbed, and wind and humidity conditions may exist. (Oke, 1976) (Figure 5 -6)

As (Oke, 1976) stresses, the micro-scale focus is necessary to identify the microclimate that is created by the environmental factors in the immediate surrounding within the “urban canopy level”

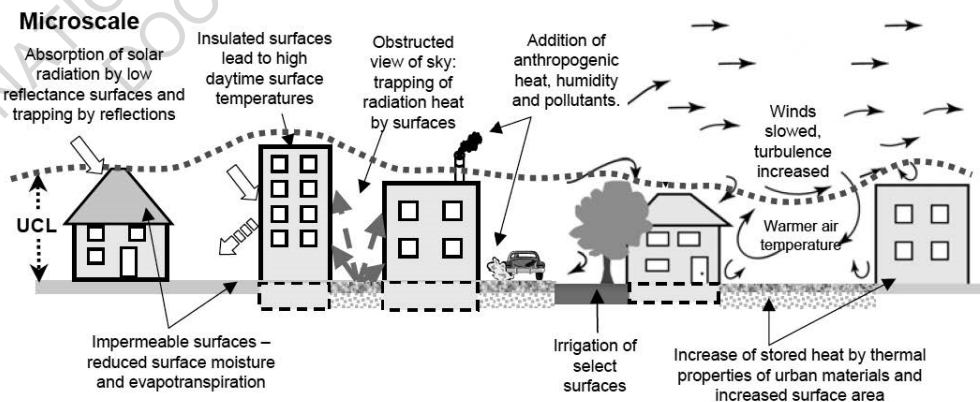


Figure 5: Mico-scale and urban canyon level (Voogt, 2007, p. 6)

In this study, a **micro-scale** is more relevant for the possible intervention that urban planners may suggest and that the research may expose in the following chapters. We conclude that many factors are closely related to urban climate: (Table 1)

- a) Urban morphology
- b) Built materials
- c) Surface cover
- d) Urban metabolism and people's activity

Therefore, a proper micro-scale focus fits the scope of understanding the relationship within the canopy level and its factors. (Sharifi and Lehmann, 2015)

Scale	Urban level	Horizontal distance	Vertical layer
<i>Micro (Study focus)</i>	Streets, squares, gardens, trees, etc	< 200-300 m	Roughness sub-layer
<i>Local</i>	Neighborhood	100m-10 km	Inertial sub-layer
<i>Meso</i>	City	> 10km	Mixing layer

Table 2: Horizontal and vertical scales of the urban atmosphere (Oke 2004)

1.3 Factors influencing the UHI

The urban heat islands occur due to natural and anthropogenic factors. The three main categories of natural factors are climatology, meteorology, and city topography. These factors are considered as uncontrollable where the urban planners cannot intervene nor monitor such as climate conditions (anticyclone conditions, overcast cover, and seasons). Conversely, the "controllable factors" which comprise the urban design and structure related factors as well as anthropogenic, can be the subject of studies for urban planners to integrate adaptive solutions to limit the UHI. (Rizwan et al., 2008)

The main anthropogenic factors are urbanization, urban morphology, building materials (the albedo of exterior surfaces), Anthropogenic heat (pollution, cooling, heating), transport, industry,) and the reduction in green areas. (Figure 7)

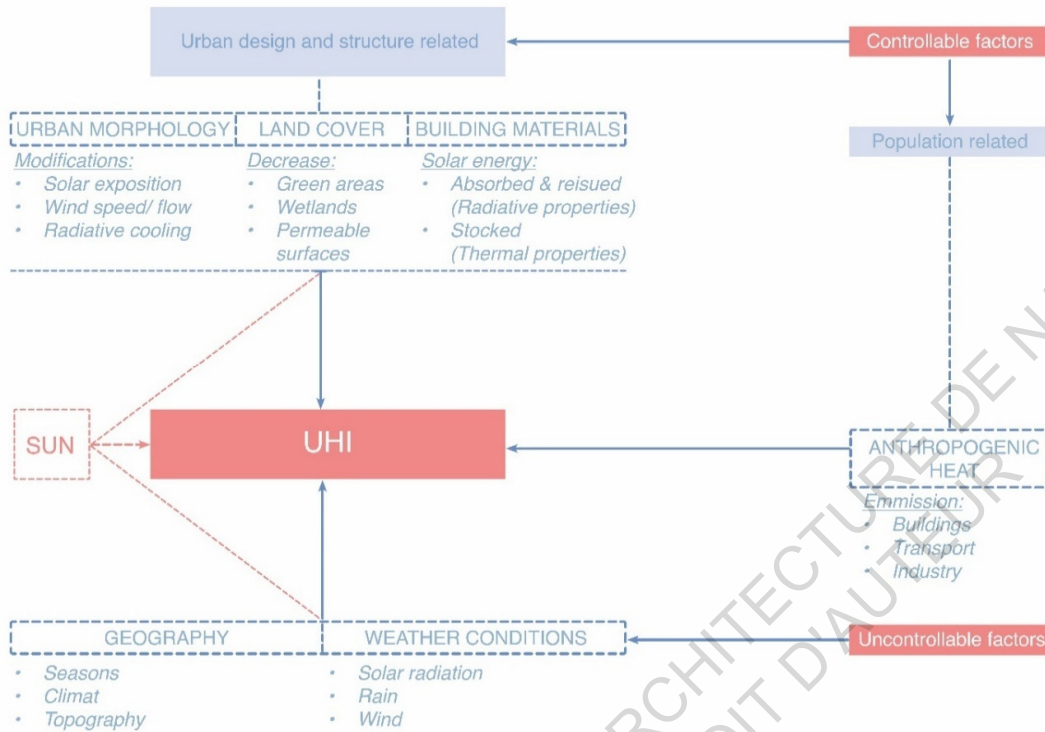


Figure 6: Factors influencing the intensity of the urban heat island (Rizwan et al., 2008) (Dubois, 2014) Drawn by the author

a) Urban morphology

Cities' urban morphology is a UHI factor that can influence the urban microclimate by affecting the dominant wind and solar irradiance. The buildings that cast shadows limit the access of urban surroundings to solar resources and decrease the temperature of the surface. (Adolphe, et al., 2002).

According to (Sacre, 1983), the street orientation concerning dominant winds can influence the intensity of the ICU by affecting the wind speed and its turbulence. For instance, in a dense neighborhood with tortuous streets, the winds will be slowed down, and the heat of the city will be trapped within the urban canyon level. This phenomenon is called the “**canyon effect**” or **Radiation trapping**. A large amount of solar radiation will thus be stored by urban materials and then emitted again in the form of long-wavelength radiation. (Colombert, 2008) (Figure 8).

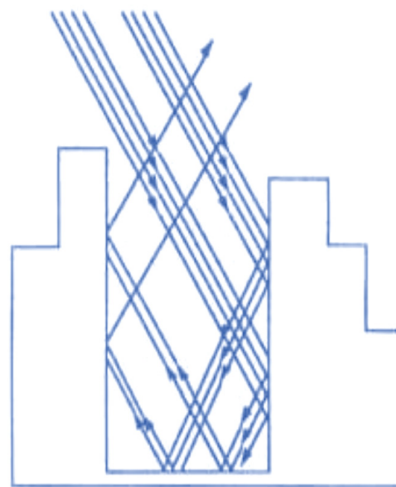


Figure 7: Radiative trapping (Ringebach, 2004)

The urban canyons are characterized by a narrow space surrounded by buildings on both sides. We distinguish two main parameters with a significant influence on the microclimate:

- Sky view factor (SVF)
- H/W Ratio: building's height over the street's width
- Urban canyon orientation

Sky view factor

The Sky View Factor, as defined by Oke, is calculated as the form factor between the evaluation surface and the unmasked areas of the sky hemisphere. This indicator makes it possible to characterize the phenomenon of radiative trapping and therefore plays an important role in the modeling of microclimatic phenomena at the urban scale such as the urban heat island effect (ICU).

The percentage of access to the sky is an indicator that is more architectural than energetic, making it possible to assess the visual comfort experienced by an observer, distinguishing between the visible part of the sky and the hidden part. Unlike the sky view factor, it gives as much importance to the parts of the sky on the horizon as it does to the vertical parts of the observer. According to Rizwan et al. (2008), when the sky view factor is decreased, the heat will be trapped within the urban structure because of the capability to dissipate the heat. However, when the SVF is high in a given area, it can be correlated to higher solar irradiance since a big amount of the sky is seen.

H/W Ratio

The H/W ratio, or the aspect ratio, is related significantly to the effects of UHI. It depends on the orientation, the amount of direct and diffuse solar radiation penetrating the urban canyon could be controlled (Oke, 1988).

The intensity of the radiative trapping is strongly related to the ratio " H / W ", whereas H= the height of the buildings, W= width of the street.

- $H / W = 1$ (*Uniform canyon street*)
- $H / W = 2$ (*Deep*)
- $H / W < 0.5$ (*Shallow*)

According to the study conducted by Johansson, he measured the air temperatures in two different streets of the city of Fez in Morocco. The study focuses on a narrow street in the old town with a W / H ratio of 0.1, and another wider street in the new town with a W / H ratio of 1.6. The results showed that the air temperatures in summer do not exceed 32°C in the old town, while in the street of the new town temperatures reach 41°C (Johansson, 2006)

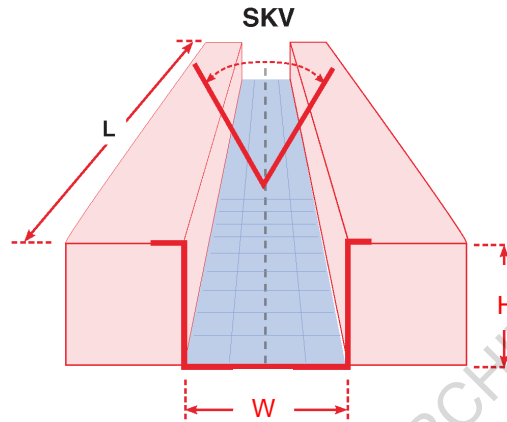


Figure 8: Schema showing an urban canyon. Drawn by the author

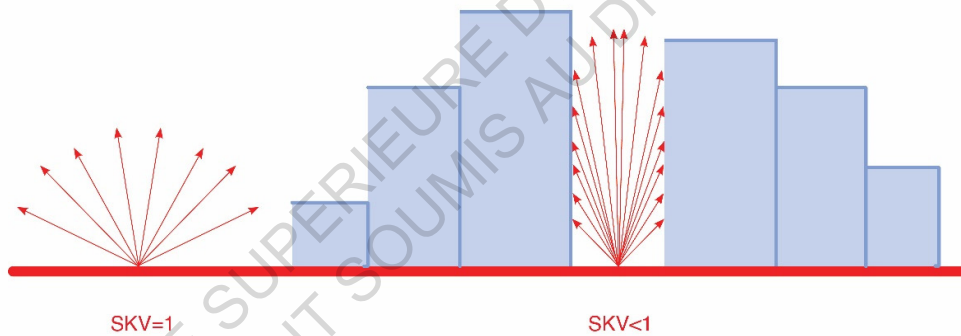


Figure 9: Illustration explaining the how the SKV can affect the night-time radiative cooling in an urban context. Drawn by the author

Urban canyon Orientation

The orientation of urban canyon is an essential quantitative component of solar and wind exposure and it has a drastic influence on solar exposure and shadow cast. When the orientation of a deep urban canyon with a high aspect ratio is perpendicular to the flow of the predominant wind, then the wind tunnel effect will be replaced with wind whirls entering from the top of the street. (Erell,2010)

In urban canyons, we can distinguish three wind flow patterns: parallel, perpendicular, or at an angle to the street axis. The Wind speed inside the street decrease from parallel to perpendicular approach flow. Thus, the highest wind speeds can be expected to take place from the west canyons in Nantes. (Fig 12-13)

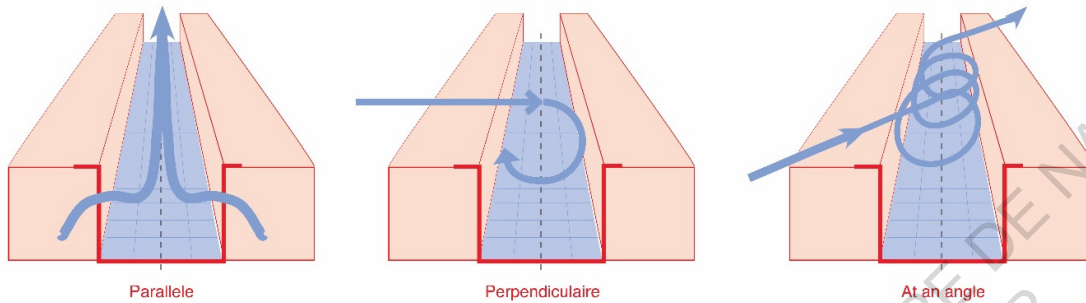
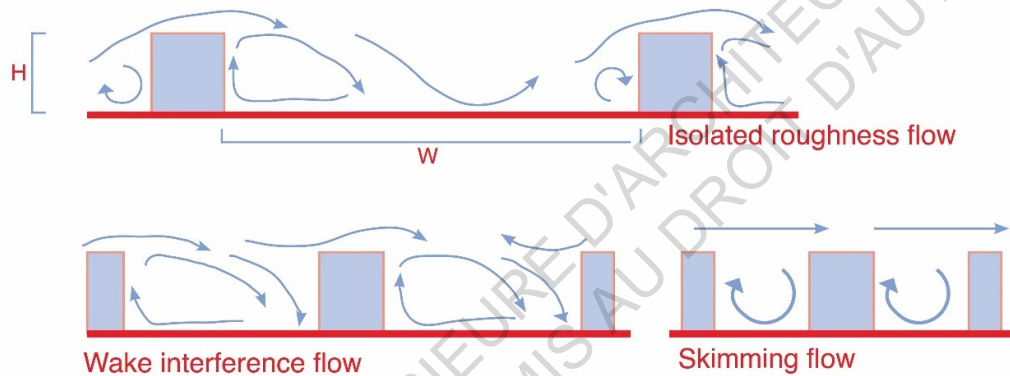


Figure 11: Wind flow in an urban canyon. Drawn by the author



Flow regime	H/W	Vortices characteristics
Isolated roughness flow	< 0.1	2 co-rotative vortices
Wake interference flow	0.1 - 0.7	1 main vortex
Skimming flow	> 0.7	2 or more contra-rotative vortices

Figure 10: Flow pattern in an urbancanyon with wind perpendicular to the canyon axis. Adapted (urbancliamte.nl). Drawn by the author

b) Built materials

The built materials including the pavements, flooring, paving, and building envelopes have an impact on the ICU. The materials of urban environments tend to absorb heat during the day and reemit it at night. (Apur, 2012) This explains why the intensity of the ICU is greater during the night because of the release of heat by the materials. The ability of materials to capture heat depends on the reflective power of a surface "Albedo" and

the ability of a material to radiate heat "emissivity". It is possible to measure the intrinsic physical quantities of materials: emissivity and albedo.

Emissivity

The emissivity characterizes the ability of materials to radiate at night and therefore to cool, which is equivalent to all materials. The work carried out in the Apur laboratory is going to be discussed and the values used are going to be used later on for the project in part 3. Their measurement makes it possible to qualify their ability to the reflection of direct sunlight (albedo) and measure their ability to emit radiation infra-red (emissivity).

Albedo

Albedo indicates the proportion of solar energy reflected from a surface to the absolute sunlight received by that surface. This ratio is utilized to decide the measure of warmth consumed by materials.

Prado states that the albedo of urban areas is generally lower than that of rural areas which contribute to the rise in temperatures of urban materials creating an urban heat island (Prado & Ferreira, 2005). According to Ringenbach who performed simulations on the urban canyon, he observed that when the intensity of solar radiation is maximum, an increase in the surface temperature of 3 ° C occurs when there is a reduction of one-tenth of the albedo (Ringenbach, 2004). On the other hand, Asaeda's experimental work has shown that heat storage and there Surface temperatures of asphalt and concrete are much greater than in the case of bare soil (Asaeda, et al., 1996).

The laboratory Apur conducted a series of measurements of the thermal properties of 5 typical soil materials encountered in Paris public space. Laboratory measurement is generally opposed to in situ measurement. Both protocols have their advantages and disadvantages. The in-situ measurement is quite complex to carry out because it is necessary to install on the same site a range of materials. You also have to be opportunistic to take advantage of the right conditions climatic. Laboratory measurement is inherently complex since it involves reconstituting artificially the thermal environment in which the materials are immersed "in the real-life". An experiment by Apur (Atelier Parisien d'Urbanisme), shows the difference in thermal behavior between mineral surfaces and vegetation. (Figure 11)

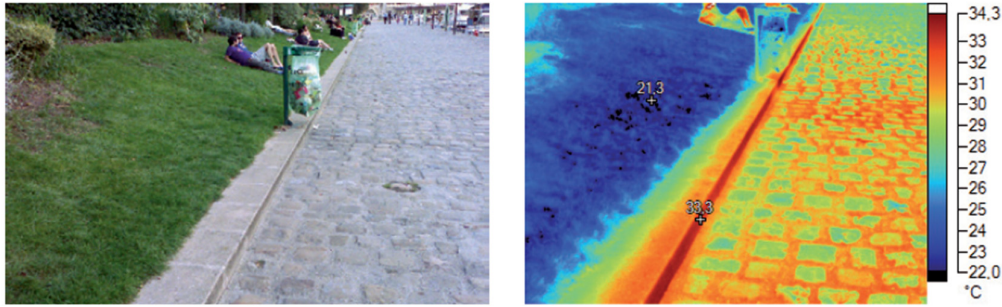


Figure 12: Arsenal basin, August 1st, 2011 at 20h00. (Apur, 2012)

Echantillon	Chaussée classique	Trottoir asphalte	Stabilisé	Trottoir granit	Gazon
Albédo	0,098	0,155	0,369	0,313	0,25-0,30
Émissivité	0,99	0,93	0,91	0,99	0,98

Table 3: Albedo and emissivity measurements in-situ Paris public space (except the grass) for which the data come from the literature) (Apur, 2012)

c) Land cover

This indicator designates 2 main categories:

- Green spaces and trees
- water features

Green spaces and trees

The green spaces influence the distribution of solar air temperature and humidity. Trees play a role in reflecting a big part of the solar irradiance and in shadowing. (Fig 14) The impact resulted from the trees depends on the leaf density and the height of the trees. The vegetation through transpiration can absorb the water from the soil and reemit it into the atmosphere. (Figure 14)

Therefore, trees and vegetation increase the level of humidity in the air (Musy, 2005). Thus, plants affect the urban microclimate thanks to the phenomenon of evapotranspiration, which is based on the evaporation and transpiration of water simultaneously in the atmosphere. This phenomenon contributes to the decrease in air temperature and can enhance thermal comfort.

Besides, thanks to their insulating power in winter and cooling in summer, the use of green walls and green roofs have positive consequences on the energy performance of buildings. The maximum temperature of a green wall is 30 ° C while a normal wall reaches 60 ° C (Adolphe, et al., 2015)

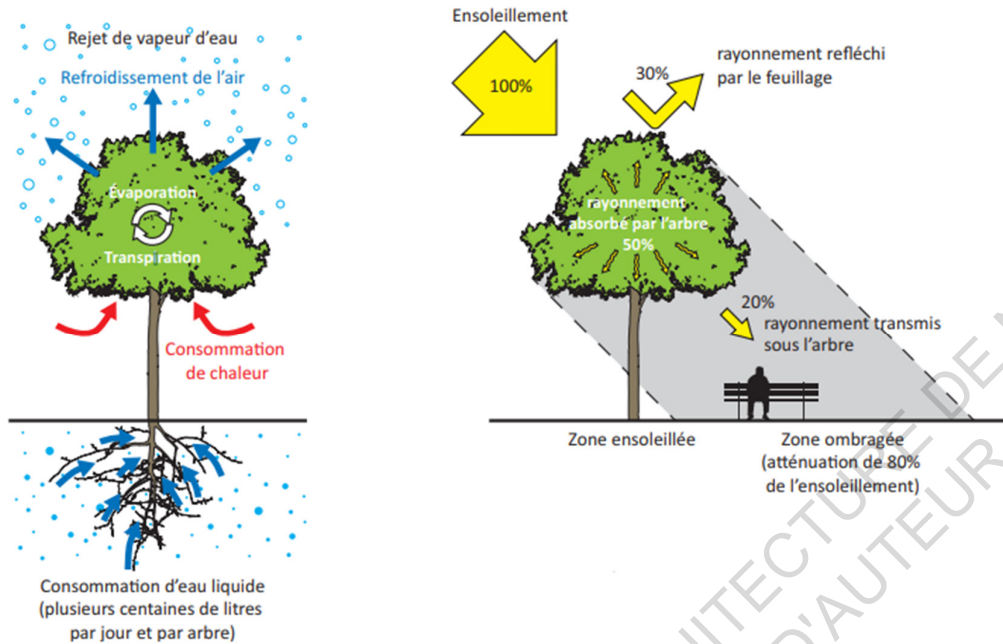


Figure 13: Tree benefits in an urban space (Apur 2012)

Water features

The presence of water features such as water basins, fountains or water jets, or even the installation of porous mineral surfaces with water circulation contributes to enhance the thermal comfort, reduce the air temperature, and therefore reducing the urban heat island. The phenomena of evaporation of water in the atmosphere make the air more humid and help cool down the area. According to a case study in Seville conducted by (Brophy, et al., 2000), the evaporative cooling techniques reduced the ambient temperature by 5 ° C. And also, Nikolopoulo's work has shown that the installation of fountains, ponds, and swimming pools in the Olympic Village in Athens have contributed in cooling down the temperature by 4 ° C (Nikolopoulou, 2004).

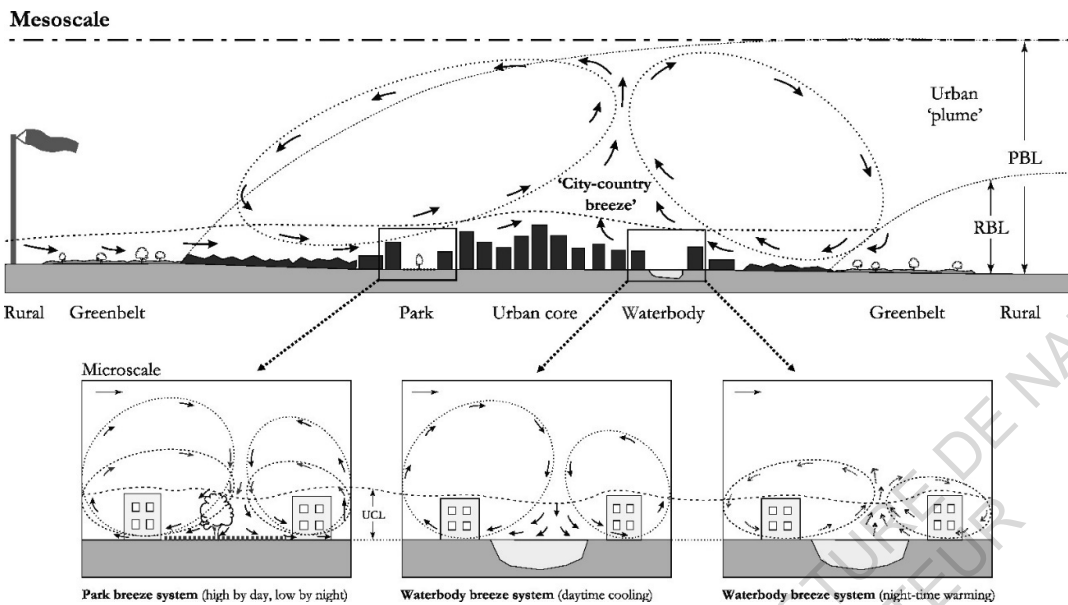


Figure 14: Illustration of greenspace and bluespace interactions with the urban climate (K.R. Gunawardena, 2017)

According to Oke, in the mesoscale or planetary boundary layer (PBL), the greenbelt or big green surfaces create an advection flow and cool down its urban surroundings. (Oke, 1987)

However, in the microscale or urban canopy layer (UCL), the presence of trees due to evapotranspiration contributes to creating a micro park breeze system that has an immediate influence in decreasing the heat of the surroundings.

In some recent studies, it was proven that even shallow water features < 1m can contribute to lowering the temperature and reducing the UHI. (Abis and Mara, 2006; Song et al., 2013)

However, in some extreme events such as very hot heat waves, the cooling effect of water during the day becomes reverse during the night as the water becomes the hottest element in the urban context. (Kalkstein and Davis, 1989)

d) Anthropogenic heat

Anthropogenic heat is the heat released to the atmosphere as a result of human activities, such as transportation, industry, transport, and air conditioning. According to Oke, anthropogenic heat flux can reach 117 W / m^2 per year and it depends on the number of residents, their daily activities, and the characteristics of the urban structure (size, density, and function) (Oke, 1987). In extreme weather events, whether cold or hot waves, people tend to double their energetic consumption by using air conditioning (heater or cooler). This phenomenon is explained by a self-amplification, where an increase or decrease in normal temperature could lead to a double-up of the consumption in energy and conditioning power. (Adnot, et al., 2004).

CHAPTER 2: FRAMING ADAPTATION TO CLIMATE CHANGE

2.1 Nantes Metropoles and adaptation plan (PCAET)

Climate change is a reality that is threatening not only the environmental and ecological system but also the city and its inhabitants. The impacts of climate change are already visible today, with extreme heat and increasingly frequent and intensive rainfall around the world. The urban climate should be a key consideration in the planning and design of cities.

The metropolis of Nantes (La metropoles de Nantes), the 6th biggest city in France, adopted a climate and energy plan for its territory in December 2018 the Plan Climat Air Énergie Territorial (PCAET).

The particularity of PCAET is its compulsory generalization to all inter-municipal authorities of more than 20,000 inhabitants on the horizon of January 1, 2019, and from 2017 for inter-communalities of more than 50,000 inhabitants. The Plan Climat Air Energy Territorial is a document that includes two main components:

- Mitigation to limit greenhouse gas emissions
- Adaptation to reduce the vulnerability of the territory

The adaptation component of the PCAET is structured around two major strategic orientations, corresponding on the one hand to trend changes in climatic parameters, and on the other hand to crises:

- "Live better with a warmer climate"
- "Prepare for new types of climatic events".

The orientations of the PCAET document are broken down and classified according to the following issues:

- Promoting changes in practices and solidarity: to be classified as soft adaptation strategies, aimed at increasing the knowledge and expertise of local actors on the climate issue
- Preserving health and improving quality of life
- Protecting the resources of the territory: costly measures, concerning natural, energy, and economic resources
- Strengthening the resilience and managing the crises: to be classified as tough adaptation strategies, aimed at ensuring the safety and protection of populations, and adapting organizations in the event of a crisis.

2.2 Fight against UHI through urban planning documents:

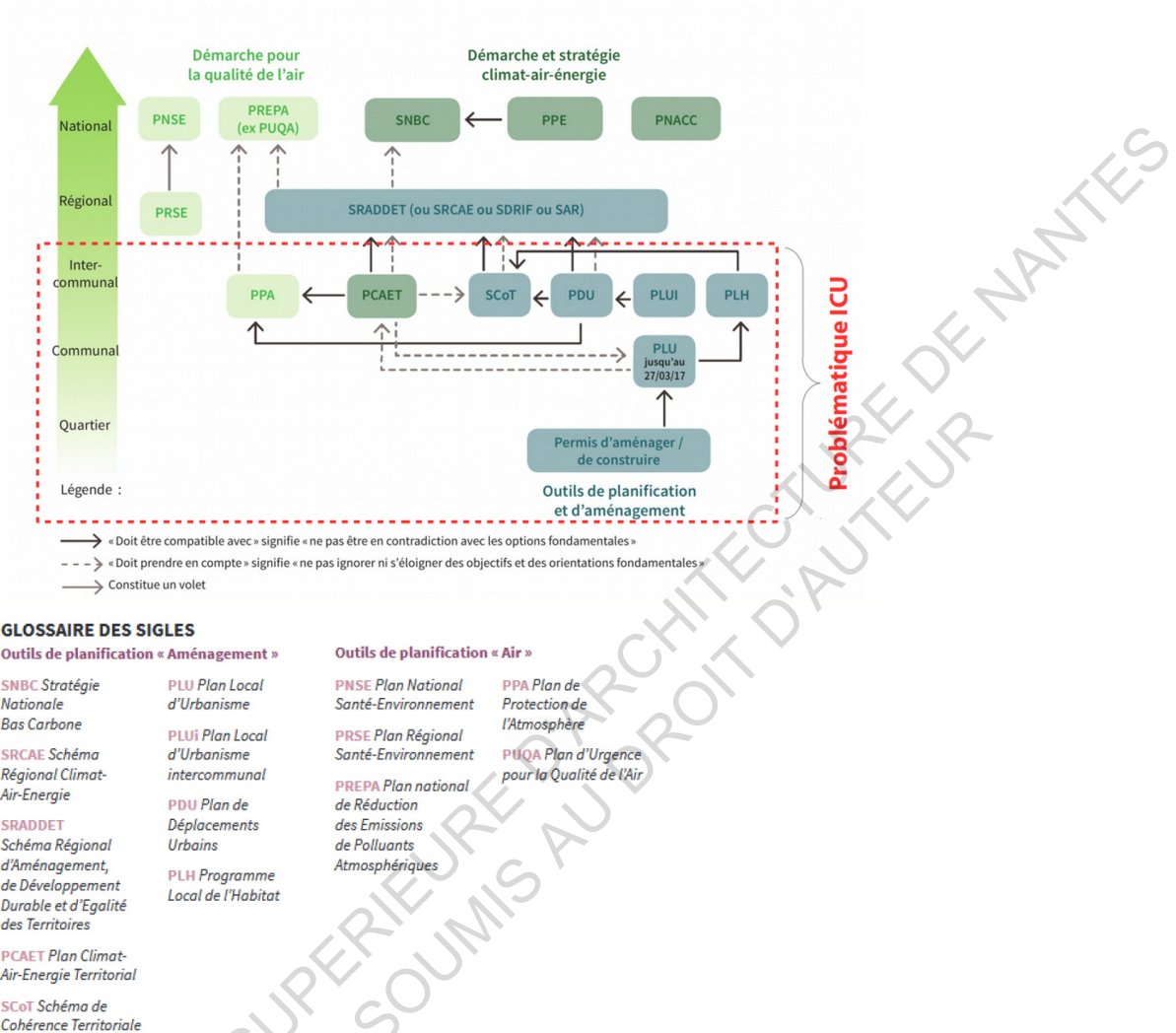


Figure 15: Diagram showing the relationship between the different planning documents that have an impact on the energy-climate plan (PCAET) Adapted by (ADEME, 2016)

Urban planning documents are an essential lever for the implementation of the PCAET. What are the "compatibility" or "consideration" links shown in (Figure 16)?

- PCAET must be compatible with SRCAE or SRADDET rules and SAR
- The PCAET must also take into account in its development the SCoT (Schéma de Cohérence Territoriale), thus making it possible to integrate the provisions relating to town planning (mobility, consumption of space, respect for the urban framework, etc
- The PLU / PLUi must take into account the PCAET
- The PCAET must be compatible with the PPA

They will make it possible to anchor and perpetuate its ambitions (eg sectors with enhanced energy and environmental performance in town planning regulations and OAPs)..).

As a conclusion, the ADEME 2016 report explains briefly to which level each document contributes to the adaptation and mitigation of UHI:

Strategic orientation documents: (Regional and national level)

- Integrate the fight against urban heat islands in the planning guidelines.
- Preserve green spaces, wetlands, and peri-urban agriculture as a cool zone able to limit the size of urban heat islands.

Urban planning documents:

- Identify priority areas of intervention in the PLUs and PLHs (mapping of urban heat islands).
- Integrate regulatory measures against urban heat islands in the PLU regulations (Integrate measures for adaptation to climate change in town planning documents).

In the previous chapters, we stated many studies on urban climatology and the impact of UHI on the urban space on a different scale and we explored the relevance of different factors that influence these phenomena in order to integrate cooling solutions to reduce the effects of ICU. The cooling devices represent the elements of architectural and urban planning that contribute to a reduction in the climatic effects of urbanization and an improvement in pedestrian thermal comfort.

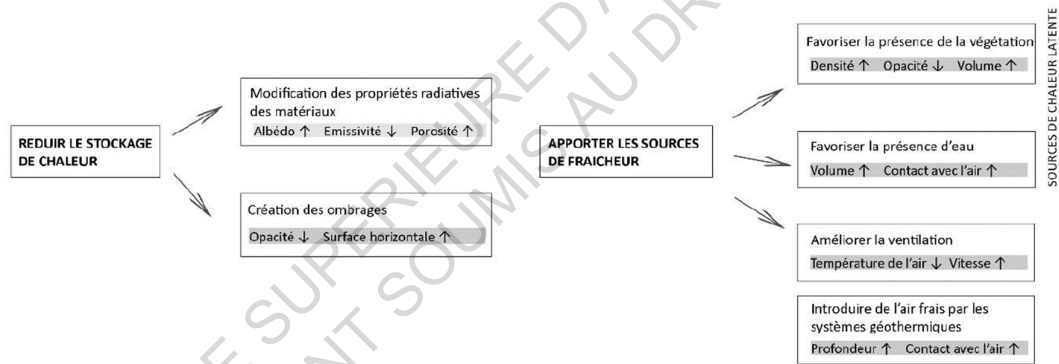


Figure 16: Urban fabric adaptation strategies to decrease temperature through spatial planning devices. Diagram inspired by Colombert (2008) and Musy et al (2016).

According to Musy and Colombert, the adaptation strategies illustrated in (Figure 17) are an example of how urban planners can intervene within the factors influencing the UHI to reduce the heat storage and to bring about cooling sources. On one hand, an increase in the albedo and porosity of the materials used in urban projects can decrease the heat storage, as well as the shadow cast, which plays an important role in that matter. On the other hand, encouraging the presence of greenscape and bluescape as well as enhancing the air quality and good ventilation in the urban space can create cooling sources in the contemporary city. (Colombert, 2008) (Musy et al, 2016).

This Part II introduced the urban heat islands and their impacts on the environment and human comfort. It focuses on factors that influence the urban climate as a micro-scale or urban canyon layer. It stressed the problems caused by the stocked heat and global warming on which urban planning and climate orientation documents has a big role in

mitigating and adapting the cities to climate change. Since the study focus is a micro-scale level, therefore this research emphasizes how urban planning can define local micro measures to adapt urban canyon to climate change, specifically to heatwaves.

The next part will explore a study project in Nantes conducted for 8 months internship at Nantes metropoles to test how urban planners can conceive an adaptive urban public space.

ECOLE NATIONALE SUPERIEURE D'ARCHITECTURE DE NANTES
DOCUMENT SOUMIS AU DROIT D'AUTEUR

PART III

THE PROJECT

« Je dénommerai espace public tout espace où je me sens à l'aise, dans lequel je perçois chez les autres le même sentiment de bien-être et où je n'ai pas à justifier ma présence (...). En conséquence, dès que l'un d'entre nous se trouve en instance d'être interpellé, l'espace public manque à sa vocation. » Pierre SANSOT - Jardins publics, Payot, 1995.

ECOLE NATIONALE SUPERIEURE D'ARCHITECTURE DE NANTES
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PART III: THE PROJECT (The adaptation to climate change of public space: *Leon Jamin street*)

CHAPTER 3: PRESENTATION OF THE STUDY AREA

The shift from the state of the art and the literature knowledge on UHI, its influence on an urban canyon layer, and the adaptation strategies toward operational design are crucial for reaching resiliency of the urban space and sustainable development of urban projects. The third component of this paper reveals the outcome of an 8-month internship at the Metropoles of Nantes in the department of climate where we were delegated to explore ways of intervention in urban projects in the city under the theme of adaptation.

We were able to assist with several projects shown in (Figure 18) that improve our understanding of adaptation strategies in France in general and in Nantes in particular. Additionally, we had the opportunity to connect and collaborate with other institutions working on the same topic. However, the main scope of work during the internship was to address the UHI in the public space.

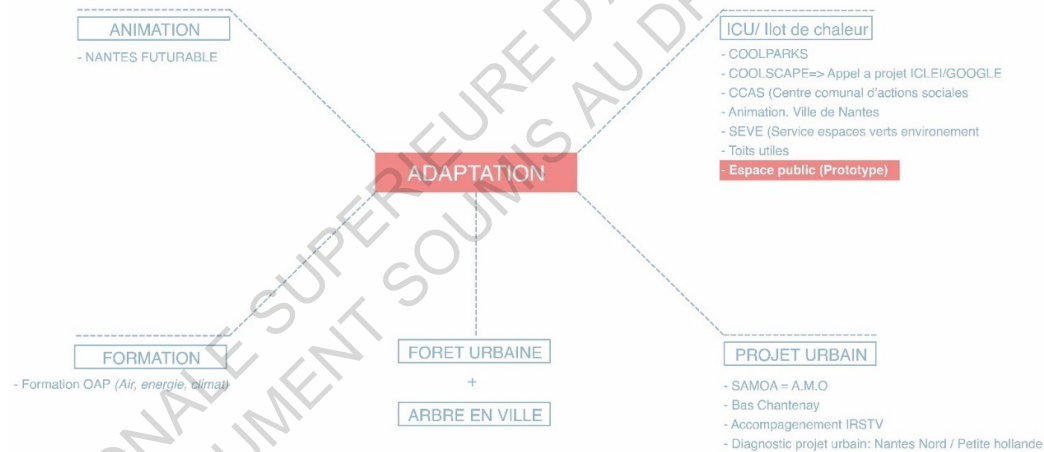


Figure 17: Adaptation plan at Nantes Metropoles. Drawn by the author

3.1 Introducing the study area

a) Defining a Public space and the new urban challenges

“Urban public space plays a fundamental role in the city’s economy, ecology, society, etc. It is used as a spatial focus for urban planners to implement strategies for urban resilience”.

(Public Spaces 2015).

Beforehand, it is essential to define the domain of public space before locating the study area in order to know at which operational phase of urban planning and design should the intervention be integrated, and in which form.

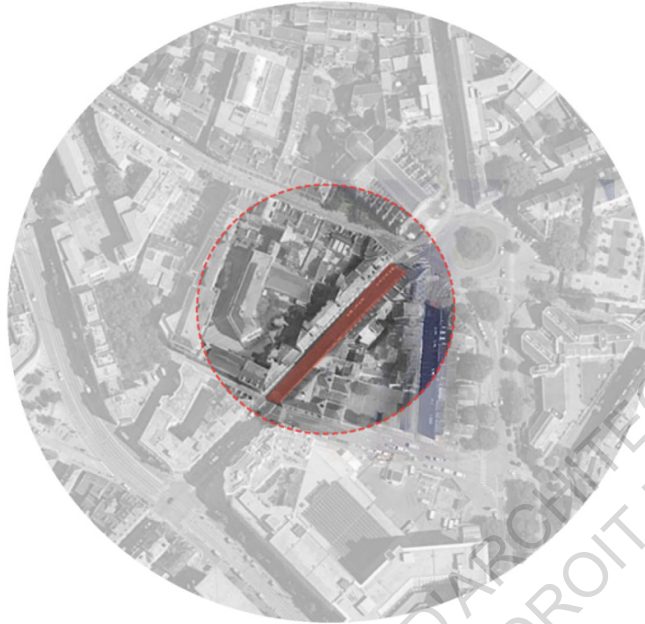
Definition of the public domain: “the public domain is constituted, except special legislative provisions, of goods that belong to a public person and are either assigned for direct use by the public or assigned to public service.” (article L. 2111-1 of the CGPPP)

The first foundation of a public space policy is the delimitation of the public domain on which the responsibility of the community is applied. While the terminology used reflects the diversity of approaches, whether urban planning (urban public space, public spaces) or technical (roads, street), a public space policy must be based on solid legal foundations. The rules that apply to the public spaces concerned must be clarified. Therefore, it is vital to take into account the fact that the scope of intervention of the public space policy corresponds from a legal point of view based on urban planning regulations stated in official documents to the Community public. (CGPPP)

Along with the growth of cities in France, urban planners and architects are facing many challenges with regards to the urban environment, and specifically to the climate since the climate has not been one of the priority criteria in the management of these cities for a long time. The planning of cities and urban spaces must respond to the socio-economic and cultural context whereas these considerations are often in conflict with the environment. Thus, framing the thermal comfort and the microclimate as a priority among other urban challenges has changed the usual way of developing cities and design public spaces in particular.

b) Leon Jamin street: Localization and History

“Leon Jamin street” is taken as a case study of public space to outline urban design recommendations with the aim to ensure pedestrian thermal comfort. (Figure 19)



Rue Léon Jamin, Nantes

Figure 18: Map showing the Leon Jmain street. Drawn by the author

The rue Léon-Jamin is a paved street, located in the historic center of Nantes. It is open to car traffic with an on-street car park, connecting the rue Edmond-Prieur to the place Saint-Similien. The old name was SAINT SIMILIEN (rue) [untill 1922]. And the current street name refers to homage to the Belgian painter Léon Jamin (1872-1944). (Pied, 1906)

Historically, until the beginning of the 20th century, the street was extended to Place de Bretagne. During the Second World War, the district surrounding the Place de Bretagne was bombarded and damaged in 1943. During the reconstruction of the city, the part located to the south of the current rue Edmond-Prieur disappeared, and it is replaced. the central post office of Nantes, while the north side preserves the constructions that survived the bombardments. It is for this reason that the street currently begins at No. 26 (at the level of the La Poste buildings) and ends at No. 45. (Pressorient, 2017)



Figure 19: Leon Jamin street (<https://www.facebook.com/rueleonjamin>)

c) Addressing the metropolitan challenges when applying the strategic and urban planning documents in Nantes

The study of strategic and planning documents drawn up at the agglomeration level makes it possible to understand the major metropolitan issues and to include the developments to be carried out in a comprehensive and coherent sustainable development urban project.

In terms of town planning and development, there is a hierarchy of applicable regulatory documents.

- **Le Schéma de cohérence territoriale (SCOT)** sets the main strategic orientations of the territory. It, therefore, defines the general orientations of the development and determines the objectives in terms of housing balance and social diversity, public transport, and commercial or economic facilities.
- **Le Plan de Déplacements Urbains (PDU)** is an integral part of the plans or documents which must be legally compatible with the SCOT orientation and programming document.
- **Le Plan Local d'Urbanisme (PLU)** summarizes the main rules to be observed at the level of each municipality in the agglomeration (pending the development of an inter-municipal local urban planning plan). In particular, it includes a planning and sustainable development plan.

Other consultable strategic and planning documents:

- Regulatory documents
 - PLUs (their PADDs, and advertising regulations)
 - The Safeguarding and Enhancement Plan (Nantes) (*Le Plan de Sauvegarde et de Mise en Valeur*)
 - The PLH Reference documents
- Sustainable development
 - Agenda 21
 - The climate plan
- Landscape and urban form
 - The guide to eco-districts (*Le guide des éco-quartiers*)
 - The guide to urban forms (*Le guide des formes urbaines*)
 - Landscapes and urban forms of Nantes (*Paysages et formes urbaines*)
 - The network erasure guide (*Le guide des effacements de réseau*)
 - The lighting master plan (*Le schéma directeur de mise en lumière*)
- Mobility
 - The master plan for the accessibility of public transport
 - Annex 2 of the PDU- and the road accessibility plans (PAVE) of the municipalities
 - The bike plan
 - Communal soft travel plans (*Les plans communaux de déplacements doux*)
- Health - The Local Environmental Health Action Plan
- Others - Le schéma directeur du jalonnement

3.2 Methodology and tools

The main aim of adaptation is to reduce gas emissions and limit the impact of global warming. The adaptation strategies require an interdisciplinary approach such as urban planners, architects, landscapers, meteorologists, engineers, economists, sociologists, and many others. Thus, the ongoing rapid change of climate along with the evolving of urban areas make the task even more challenging. Taking all these aspects into consideration, we then ask: How to intervene on a street level while respecting urban planning factors? If there is no approved model for 'adaptation to climate change' in public spaces, then which indicators to choose in order to adapt the city to the heatwave and global warming? And how to communicate the indicators with all stakeholders and reach a consensus? We will examine these approaches in the context of their application to "Leon Jamin street" and we will introduce a systemic modeling approach to the problem. (Figure 21)

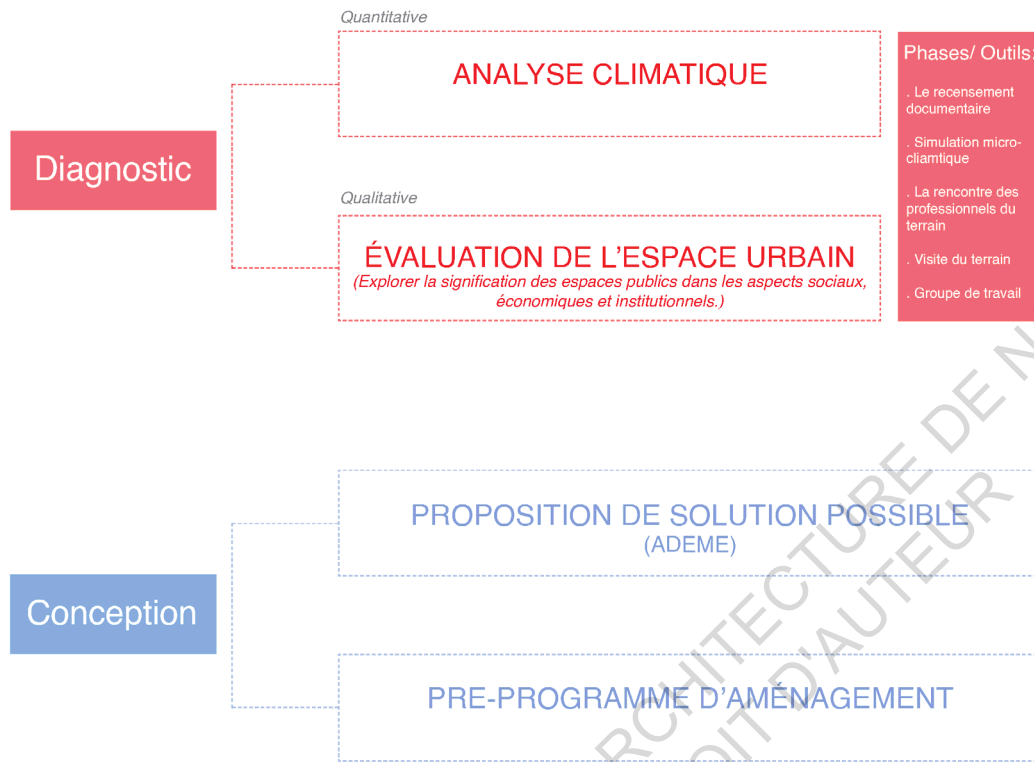


Figure 20: Intervention model. Drawn by the author

The methodology consists of two stages:

- I. **Diagnostic**
- II. **Design recommendation (Conception)**

- I. The urban diagnostic stage is divided into two key points:

The quantitative analysis involves choosing a set of scientific indicators and running a microclimatic simulation on Leon Jamin street. The outcome is going to be a map that can be easily communicated with all the actors.

The scientific approach to climate is not enough, therefore, a qualitative analysis is needed to explore the significance of the public space in its economical, social, and institutional context. The Interdisciplinary model appears to fit the evaluation of adaptation strategies for a wide scope of topics.

- II. The design recommendation is divided into two key phases:

Based on state of the art on adaptation solutions done by ADEME (Agence de la transition écologique), a set of possible interventions is going to be explored to finally

be able to propose a pre-program or a preliminary program to express the pleased intention for the future urban design of Leon Jamin street.

Tools and phases:

(Qualitative + Quantitative) Documentary census: Through statistics, reports, surveys available on the community. For more convenience, we should contact organizations that are familiar with the problem.

(Quantitative) Microclimatic simulation T4QG: T4QG is a Quantum-GIS plugin developed at the Laboratory of CRENAU in Nantes. This tool aims at assembling morphological indicators about the open space. The collaboration of the researcher Thomas Leduc in developing the python script for this plugin is key for the quantitative analysis.

(Qualitative) Meeting with field professionals/ interviews: These meetings make it possible to collect more qualitative data. They are also the first step for the constitution of a partnership for action. the objective was to question one or more representatives of each type of structure presented in the table above in order to obtain the opinion of each professional body. (Figure 2)

(Qualitative) Specific investigation with the population (young people and professionals): This step was intended to be conducted during the internship. However, due to the lockdown, it was not achieved. This tool complements the previous ones and provides more sociological data. It allows on the one hand to measure the gap between the expressed needs and the real needs and on the other hand to help establish a participatory dynamic. Indeed, the participation of the population (young people and professionals) is an essential contribution to lead a project.

CHAPTER 4: [DIAGNOSTIC] URBAN INVESTIGATION

The urban investigation is based on:

Firstly, the need for simulation, modeling, visualization, assessment, communicating and managing urban data while referring to experimentation and stare at the art of ADEME, Apur, and CRENAU. We realized that the huge amount of data coming from and stored in multiple devices and sources is hardly managed and accessible. This leads to the second key point of the urban investigation. the need for integrating qualitative analysis to the urban context, where the site visits conducted by us as architects and urban planners and meeting with some of the merchants on the street, providing more accurate analysis for sounder intervention.

4.1 Quantitative analysis: MODELISATION OF URBAN CLIMATE: Microclimate and morphological Indicators

The urban investigation is explored through two scales: neighborhood scale and micro/pedestrian scale.

a) Neighborhood scale

According to the map of AURAN of the urban heat island in Nantes, the area delimited in the (Figure 22) represents the study area situated in UHI where the temperature varies between 26°C and 36 °C.

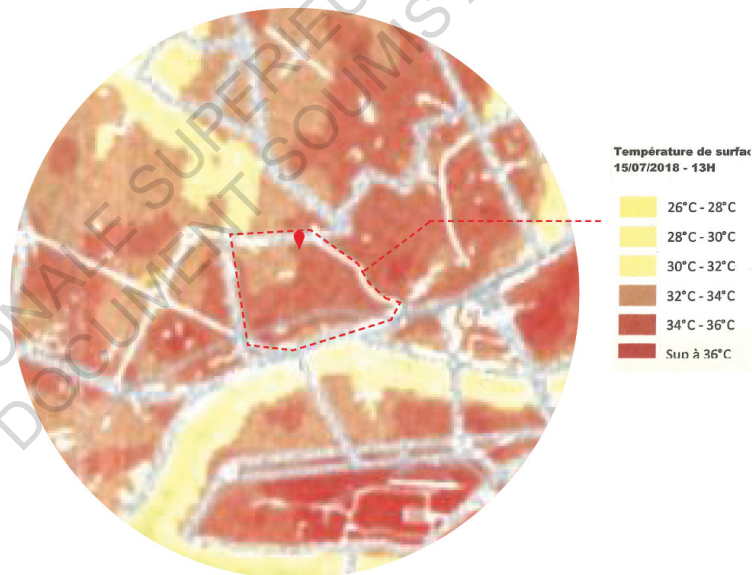


Figure 21: UHI in Nantes Metropoles (AURAN)

b) Micro/pedestrian scale

Through our state of the art, we have defined and identified certain indicators of morphology and microclimatology that interact with the urban climate at a street level. For this case study, we chose the following indicators to approach the thermal comfort of the inhabitants on a pedestrian level:

- i. (Morphology) H/W Aspect ratio
- ii. (Morphology) Sky view factor - SKV
- iii. (Climatology) Direct solar Insolation
- iv. Albedo
- v. Emissivity
- vi. West orientation

Our investigation will allow us to establish the elements that we consider essential to achieve consistency between urban design and microclimatology. (Figure 23)

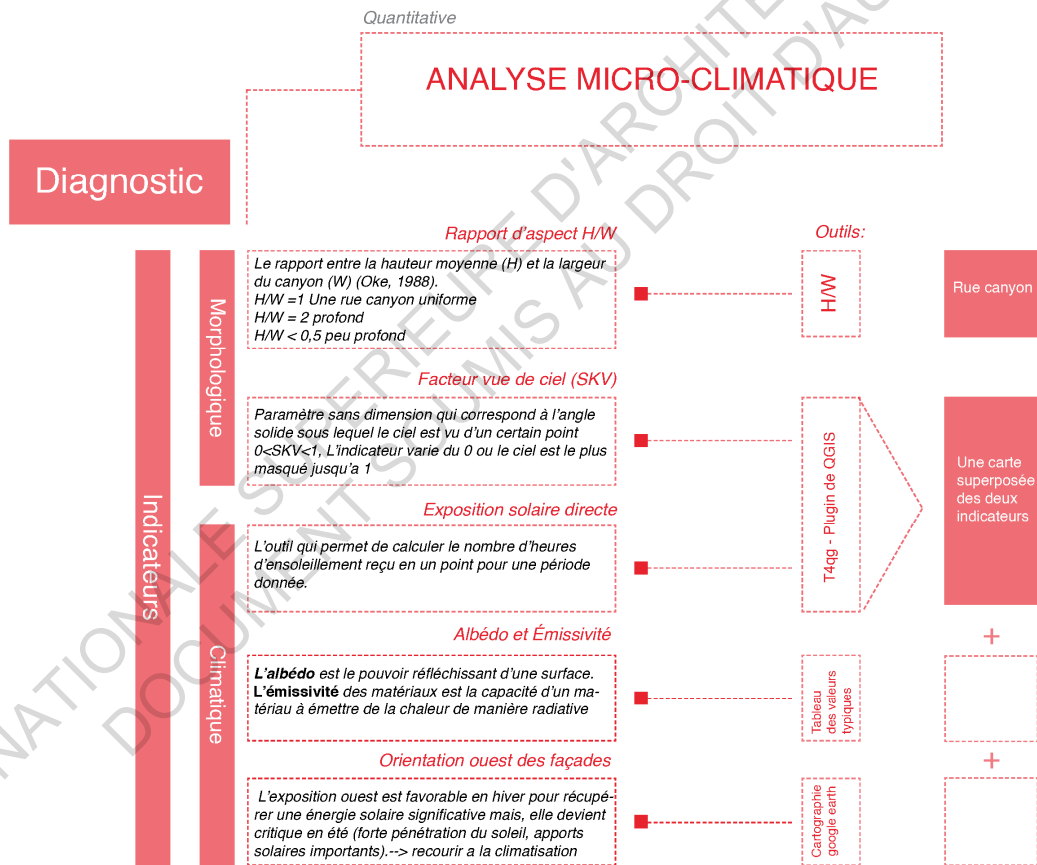


Figure 22: Urban diagnostic diagram. Drawn by the author

i. (Morphology) H/W Aspect ratio

After measuring the average height and width of Leon Jamin street, the aspect ratio $H/W = 1.2$ which means that this street is defined as an “urban canyon” and has its morphological characteristic (Figure 24)

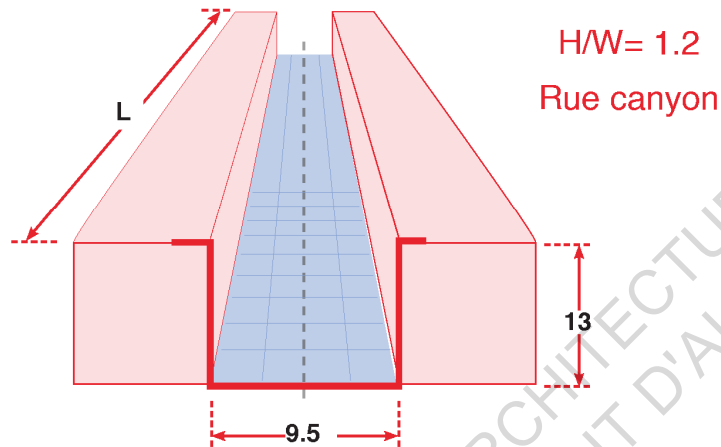


Figure 23: Aspect ratio in Leon Jamin street. Drawn by the author

i. (Morphology) Sky view factor - SKV

In order to explore to which level the contribution of urban morphology contributes to the conditions of outdoors thermal comfort for pedestrians, we choose to simulate the street to measure the sky view factor using QGIS with plugin T4Q that uses python language. (Figure 26)

Steps:

- Create a base map on QGIS composed of (roads, buildings, buildings heights arranged by colors, vegetation) and crop out the study zone
- Mesh by triangulation 2.5 m²
- Create sensors in the middle of each triangulation (Figure 25)
- Apply the simulate by script according to the heights of the buildings

Finding:

The red, orange and yellow areas represent the least shadowed zones by the buildings. the sky view factor is 40-60% of the sky in these areas.


```

1 import sys
2 sys.path.append("C:\Users\marce\OneDrive - Politecnico di Milano\ECN\M2\Master_-_Architecture-Ambiances-Urbanisme\PRUB1_-_approche-theorique-et-indicateur-environnementaux")
3 from t4qg_0_1_7 import *
4 T4qgVersion.version()
5
6 iface.mainWindow().blockSignals(True)
7 QgsProject.instance().clear()
8
9 dirname = 'C:/Users/marce/OneDrive - Politecnico di Milano/ECN/M2/Master_-_Architecture-Ambiances-Urbanisme/PRUB1_-_approche-theorique-et-indicateur-environnementaux/nantes'
10 roi = loadLayer(dirname, 'ROI-NM')
11 vegetation = loadLayer(dirname, 'vegetation')
12 setFillSymbol(vegetation, color='lightgreen', outline_color='green', style_border='solid', width_border='0.0')
13 buildings = loadAndClipLayer(dirname, 'nantes_buildings_rgf93', roi)
14 roads = loadAndClipLayer(dirname, 'nantes_roads_rgf93', roi)
15 setSimpleOutlineFillSymbol(roi, color='black', width='0.75', penstyle='dot')
16 setLineStyleSymbol(roads, color='grey', penstyle='solid', width='0.55')
17 - setGraduatedSymbol(buildings, 'HAUTEUR', fieldValueRanges=(
18     ('Elevation < 2.0m', -999.0, 2.0, '#ffff00'),
19     ('R-R+3', 3.0, 10.0, '#cccccc'),
20     ('R+3--R+7', 10.0, 21.0, '#666666'),
21     ('>R+7', 21.0, 999.0, '#333333')
22 ))
23
24

```

```

1 [road_leon_jamin = STSelect(roads, "ID" like '\TRONROUT000000029473551', filterFieldNames='*', outputLayername='rue Leon Jamin').run()
2 showFeatureCount('rue Leon Jamin')
3
4 _buff = STSpatialCommand(Buffer([road_leon_jamin, 20], _road_leon_jamin, '_buff')).run()
5 _env = STSpatialCommand(MABR(_buff, '_env')).run()
6
7 setRoiSymbol(_env)
8
9 #~-----
10 _zoi_1 = STExtractOpenSpaces(_env, buildings, removeCourtyards=True).run()
11 _zoi_2 = STSimplifyGeometries(_zoi_1, tolerance=0.1, method=0, outputLayername='zoi').run()
12 setRoiSymbol(_zoi_2)
13 saveLayer(_zoi_2, dirname, 'zoi')
14
15 #~-----
16 tin = GmshTriangulator(_zoi_2, characteristicLength=2.0, outputLayername='tin', gmsh='C:/Program Files/QGIS 2.18/apps/qgis-ltr/python/plugins/gmsh-2.11.0-Windows/gmsh.exe').run()
17 setSimpleOutlineFillSymbol(tin, color='red', width='0.15', penstyle='solid')
18 saveLayer(tin, dirname, 'tin')
19
20 QgsLayerUtilities.removeMapLayers([_road_leon_jamin, _buff, _env, _zoi_1])
21

```

```

34 |
35 saveLayer(tinWithSh, dirname, 'tin_indics')
36
37
38 - svf = SkyViewFactor(buildings, nRays=64, maxRayLen=100.0,
39     elevationFieldName='HAUTEUR', method=2018, background=True, nsegm=1)
40 tin_indics = STSpatialAttributeCommand([svf], tin, 'tin_indics').run()
41
42 setBlueRed5GraduatedSymbol(tin_indics, 'svf', ndigits=2, labelFieldName=None)
43
44 QgsMapLayerRegistry.instance().removeMapLayers([node, discZoi, zoi, _buildings, _open_spaces, tin])
45

```

Figure 24: Python script- From top to bottom- Base map - creating sensors- SKV Simulation (Thomas Leduc-T4q plugin)

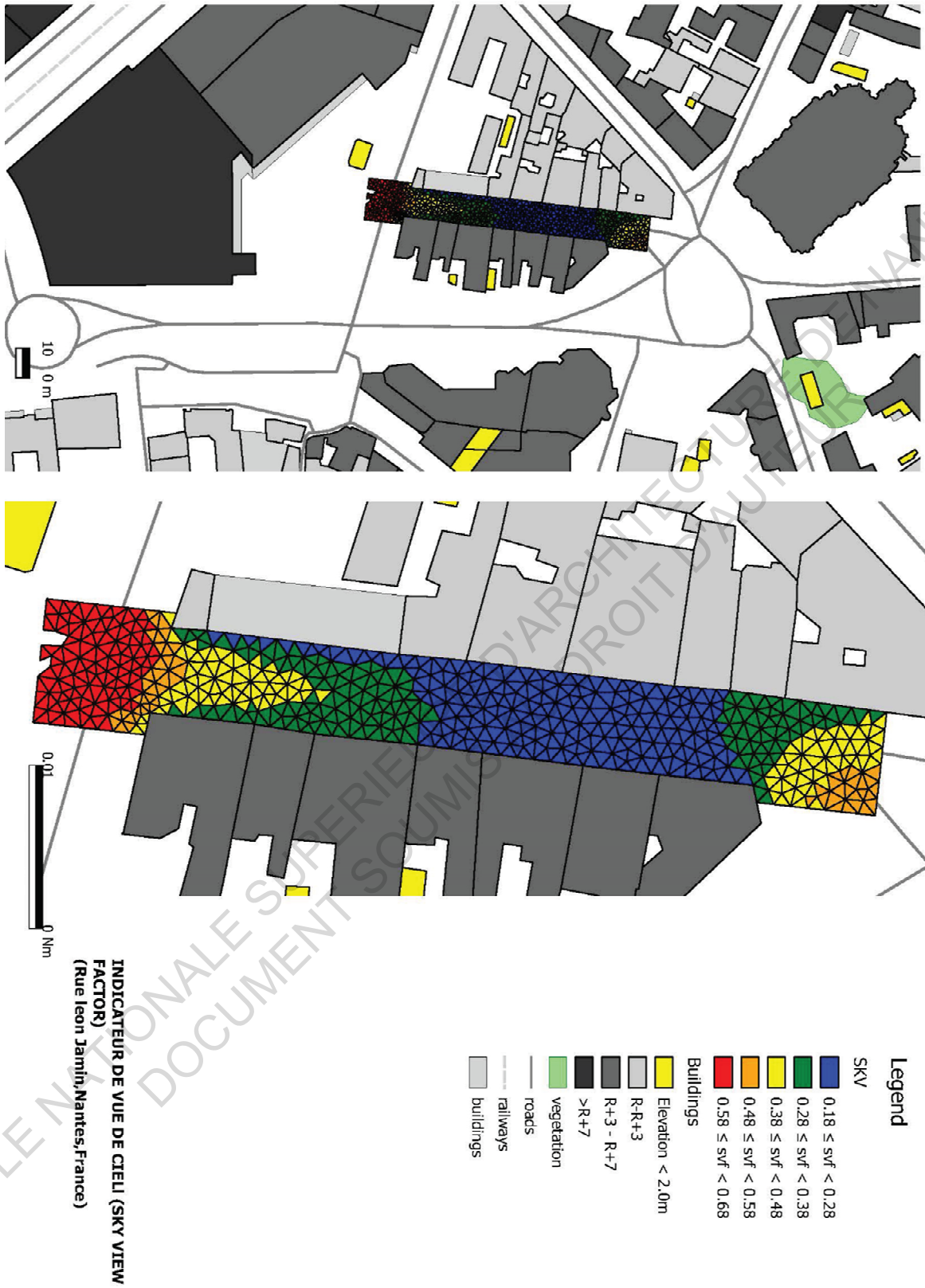


Figure 25: SKV of Leon Jamin street. Drawn by the author

ii. (Climatology) Direct solar Insolation

The direct solar insolation is a microclimate indicator that is calculated using QGIS with plugin T4Q that uses python language.

Steps:

- Create a base map on QGIs composed of (roads, buildings, buildings heights arranged by colors, vegetation) and crop out the study zone
- Mesh by triangulation 2.5 m2
- Create sensors in the middle of each triangulation (Figure 25)
- Simulate by script the accumulation of solar rays of 06-21-2019 - 12-21-2019 / Every 30 min and for 10 days. (Figure 27)

Finding:

The red, orange and yellow areas are the areas most exposed to the sun and receive significant solar radiation for half of the year. (Figure 28)

However, the blue and green zones receive a ratio of cumulation of solar insolation from 0.06 to 0.32, which means these are the areas that collect the least sun exposition, and they are masked by the urban fabric.

```
20 #~-----
21 _sensors = STSpatialCommand(Centroid, tin, '_sensors').run()
22
23 #~-----
24 - dt = DateTimeGenerator('2019-06-21', '2019-12-21', time0=None, time1=None,
25   sliceTimeInMinPerDay=30, sliceTimeInDaysBetweenDates=10).run()
26 - sh = STSunshineHours(_sensors, buildings, 'HAUTEUR', dt, latitude=47.2,
27   longitude=-1.55, timezone=0, outputLayername='sunlights').run()
28   setBlueRed5GraduatedSymbol(sh, 'sun_ratio', ndigits=2, labelFieldName=None)
29
30   renameField(sh, 'gid', '_gid')
31   tinWithSh = STJoinQuery(tin, sh, 'gid', '_gid', 'tin+sh', outputFieldNamePrefix="").run()
32   QgsLayerUtilities.removeFieldNames(tinWithSh, ['_gid'])
33   setBlueRed5GraduatedSymbol(tinWithSh, 'sun_ratio', ndigits=2, labelFieldName=None)
```

Figure 26: Python script- Direct solar exposition Simulation (Thomas Leduc-T4q plugin)

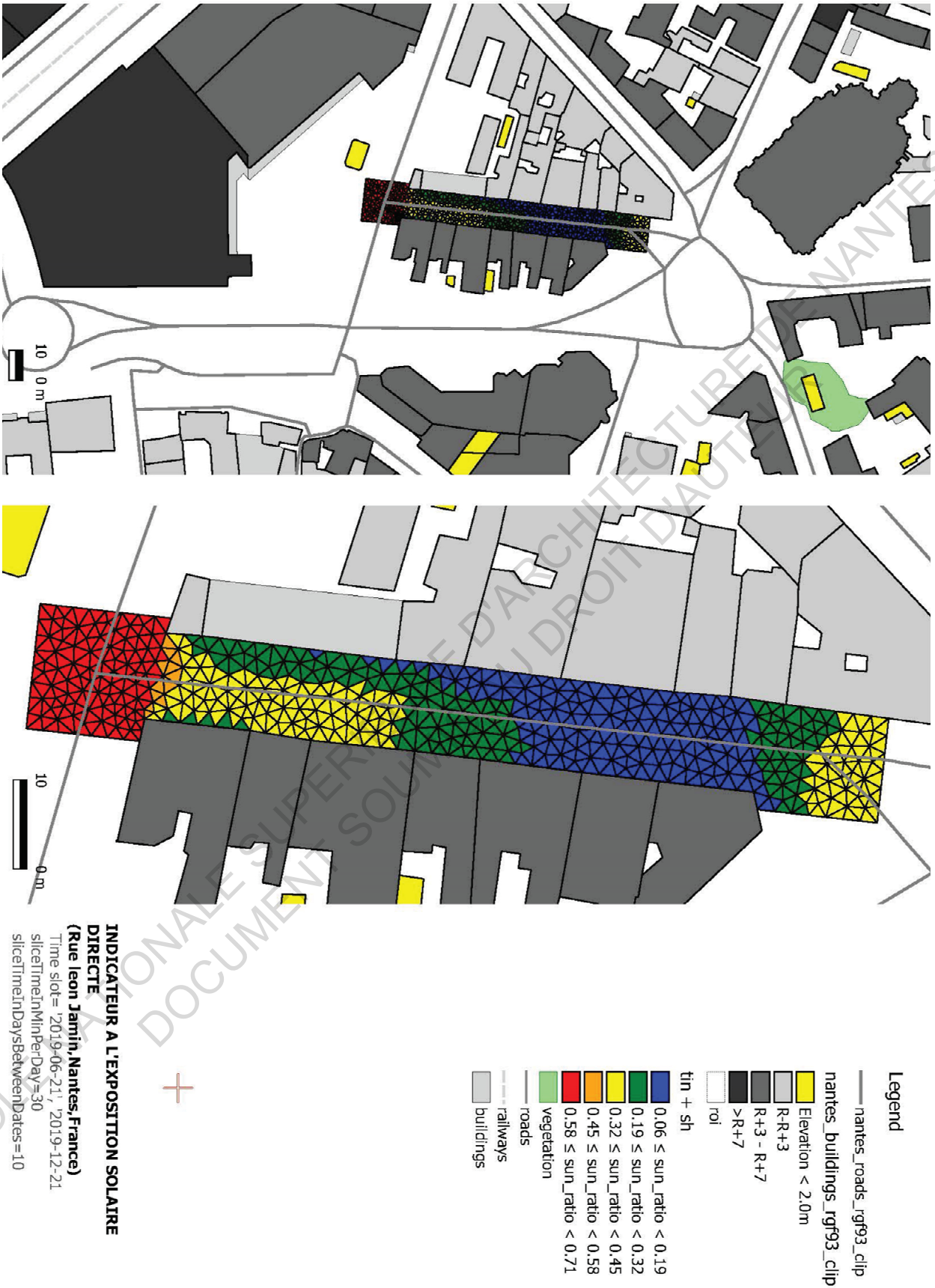


Figure 27: Direct solar Insolation. Drawn by the author



Overlapping the direct solar insolation and sky view factor maps

In order to spatially understand and estimate the thermal discomfort, we overlapped the two maps to combine the result of the two in one common map (Figure 28).

Finding:

To adapt?

The results of the two maps simulations of the two indicators are similar, and when they are overlapped, we can identify two zones (Zone 1 towards the north and zone 2 towards the south) susceptible to thermal discomfort as results of heat waves or future increase of temperature (global warming).

Therefore, we can question whether these two zones are shown in red (Figure 28) have the most justifiable need for adaptation solutions.

Figure 28: Overlapping map. Drawn by the author

iii. Albedo & Emissivity

Albedo is the reflective power of a surface. And the emissivity of materials is the ability of a material to radiate heat. The tools used to measure the values are based on a table of values measured by Apur in their experiments on pavements in Paris. (Apur, 2012)

The materials in the urban space affect the potential for evapotranspiration, as well as the albedo of the ground surface, façade, pavement, and roofs. The heterogeneity of building heights produces inter-reflections which alter the energy balance. On the other hand, the thermal properties of materials can promote heat storage. Finally, human activity has an important part of the responsibility, since the increase in the vehicle fleet, the use of air conditioners, and industry among others, are noted sources of heat production.



Figure 29: Albedo and emissivity of the Leon Jamin street, Nantes. Drawn by the author

Findings:

The asphalt sidewalk and the classic asphalt of the sidewalk, with an albedo value of between 0.1 - 0.1, are the most problematic because they have a capability of heat storage. The surface layer of the used materials captures insolation very well and the underground layer acts as a reservoir to stock heat. (Figure 29)

The influence of the types of floor materials is particularly noticeable in places highly exposed to daily insolation. The surface temperature decreases with increasing the albedo. The albedo of a new asphalt mix increases with time due to pavement weathering and bitumen oxidation while the albedo of surface coatings decreases over time due to traffic and other factors. (Dumais, 2014)

Furthermore, the street is located in a protected and heritage protection perimeter, where wooden facades are generally recommended. The used plywood facades in the commercial ground floor add character to the storefront and have an albedo of 0.35. and as for the upper floors of the buildings are made of stones with paint with an albedo 0.2-0.3. (Table 4)

Élément	Matériel	Couleur	Rugosité	Albédo	Émissivité
chaussée	Asphalte	Noire	Rugueuse	0.09-0.1	0.93
Façade	Pierre avec peinture	Blanche et grise	Lisse a relativement rugueuse	0.2-0.3	0.9
	Contreplaqué/ bois			0.35	0.9
Ouvertures	Verre simple	Transparente	Lisse	0.08	0.87-0.94

Table 4: The used materials and their albedo and emissivity values. (adapted Apur). Drawn by the author

Re-examine the role of asphalt?

According to (Table 4), the possibility of intervention in the choice of materials is mainly advisable to be on the pavement and sidewalk, since the black asphalt has the highest albedo. However, it is impossible to intervene within the facade materials (ground floor and upper floors) since the materials should be preserved to respect the heritage aspect of the street.

Echantillon	Chaussée classique	Trottoir asphalte	Stabilisé	Trottoir granit	Gazon
Albédo	0,098	0,155	0,369	0,313	0,25-0,30
Émissivité	0,99	0,93	0,91	0,99	0,98

Table 5: Samples of materials used for pavements. (Adapted by Apur) (Drawn by the author)

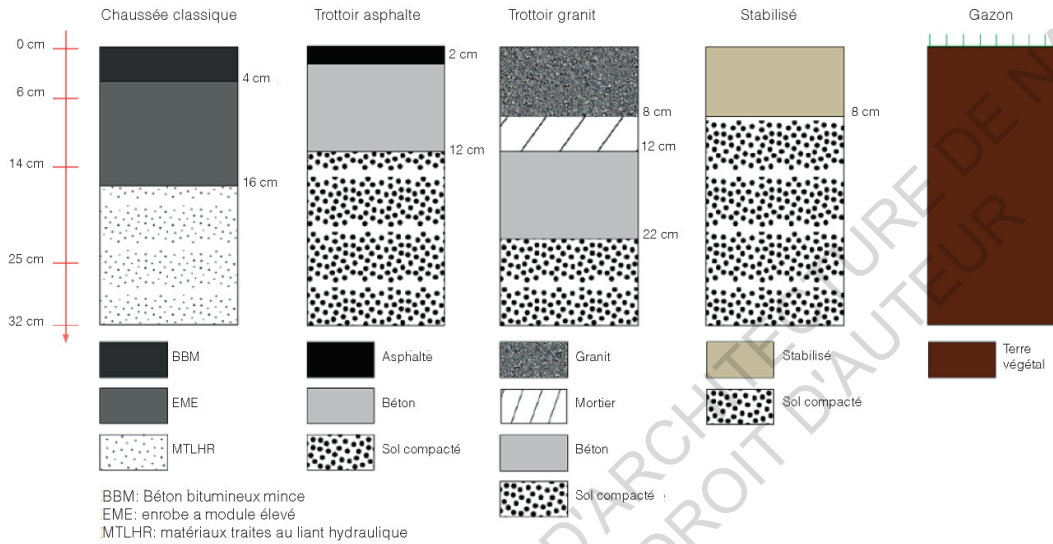


Figure 30: Section showing the materials of the pavements. (Apur 2017)

The albedo values show that asphalt pavements and asphalt sidewalks are very absorbent. Much of the solar energy they receive is transmitted into the material.

On the other hand, the stabilized, the granite sidewalk, and the grass are twice as reflective. Some of the energy they receive (about 30%) is reflected and does not participate in heat storage. (Figure 30) (Apur 2017)

	JOUR	NUIT
Asphalte noir (trottoir)	Très chaud	chaud
Béton bitumeux	Très chaud	chaud
Trottoir granit	Modéré chaud	Modéré chaud
Stabilisée	Modéré chaud	Frais
Gazon	Frais	Frais

Table 6: The characteristics of the materials used in the urban space (Apur,2012)

According to table 6 and the experiments conducted by Apur, we can identify several pavements materials as follow:

Black Asphalt/ Beton bitumeux: These materials store energy in-depth solar that they receive, and return it in the form of warmth to the atmosphere at night. They are the least efficient of the materials used in Paris concerning insolation. (Apur 2012)

Granite slabs: take a long time to heat up during the day. They are well suited to spaces with little exposure, especially places that have exclusively morning exposure. They have a very strong energy storage capacity, so when overexposed they take a long time to cool down at night. The smoother the slabs, the lower the cooling capacity.

The stabilized is powdery on the surface. It doesn't have an energy storage capacity. It is considered a good solar reflector by day (which can create visual discomfort) and can be immediately cool down after sunset. Its nocturnal properties are close to that of turf, which is to say excellent.

The grass is the best type of soil, it is the climatic benchmark. It allows both evapotranspiration and direct evaporation of water from the soil. He has no inertia, he is immediately cold at night.

Here, we can question the usage of asphalt for the ground while the concrete layer on which the asphalt rests has many superior climatic qualities, comparable to "stabilisé" which are among the most resilient materials of public space as shown in (Table 5) (Apur)

iv. West orientation

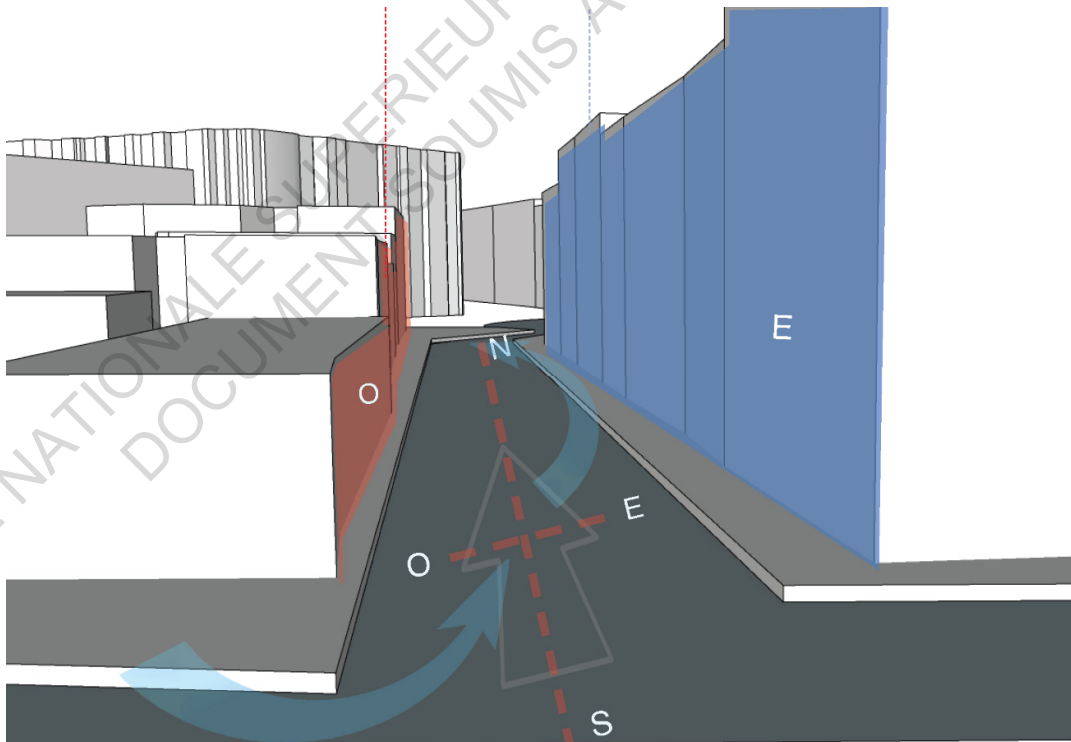


Figure 31: 3D Visualisation of Leon Jamin street. Drawn by the author

Léon Jamin street is oriented North-South.

The prevailing winds are those from the west/southwest and south (directions from 180 to 280 °) which represent 36.5%. From (Figure 11), since $H/W > 0.7$, it can be seen that one vortex must form from an angle as shown in (Figure 32).

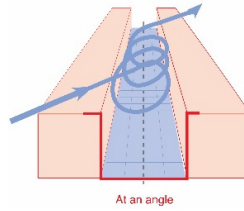


Figure 32: Wind flow in Leon Jamin street at an angle. Drawn by the author

This indicator works as a means of alerting the urban fabric which may prove to be critical from a microclimatic point of view regarding comfort and energy.

Findings:

According to the orientation of Leon Jamin street illustrated in (Figure 31)

The elevations oriented west (red elevation) are:

- Favorable in winter to recover significant solar energy
- Critical in summer (strong solar insolation, significant solar gain).

The elevations oriented east (Blue elevation) are:

An east-facing building receives heat from the sun from sunrise to midday. This gives it a satisfying temperature. The apartments are sufficiently heated and can also release surplus heat before sunset.

4.2 Qualitative analysis: PUBLIC SPACE EVALUATION

Climate change affects urban microclimate and citizens' health (discomfort). Nonetheless, the unavailability of supported models, and local data (i.e.temperature at the street level), makes the task of decision-makers challenging to address public and private efforts on different aspects such as urban form, built materials, land cover, and anthropogenic heat.

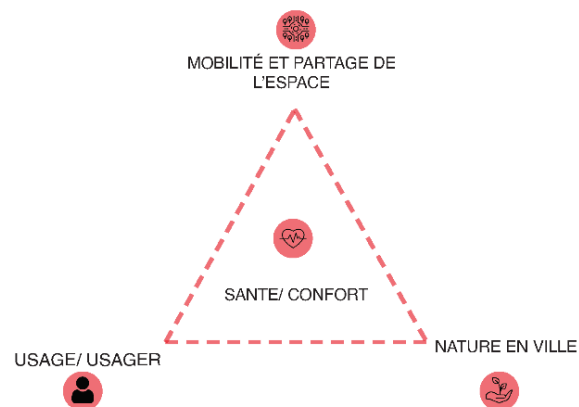


Figure 33: Diagram showing the relation between the main axis of urban space. Drawn by the author

we first explored Leon Jamin street from a scientific approach by simulating and calculating morphological and microclimatic indicators that quantify the effect of factors influencing the UHI. Moreover, it is essential to look at an urban space from an

architectural, urban planner point of view by focusing on the scope of study on human comfort and health.

Following, a document from the DEP « Programme d'actions de la direction de l'espace public- Nantes métropoles », We can identify three-axis that define an urban space : (Figure 33)

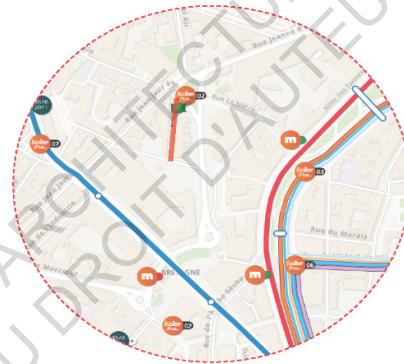
- Mobility and shared space:
- Usage and users:
- Greenscape/ Nature en Ville

Tools:

For this qualitative approach, mapping is the urban planning tool that is going mainly to be used to analyze the urban context Mobility and shared space:

a) Mobility and shared space

This map (Figure 35) makes it possible to show the roads and squares in dark grey. It also focuses on the bicycle paths which are in red. Moreover, we can identify the small dots with different colors to be associated with the mobility means of transport within the city of Nantes. We categorize three modes of mobility: soft mobility (bicycles, scooters, and their bike racks/shelter), private cars, and shared mobility (buses, trams, shared cars). The case study is highlighted with a star and a circle of 500 m is drawn to assimilate the proximity of Leon Jamin street to other mobility amenities found within the city center.



Proximity:

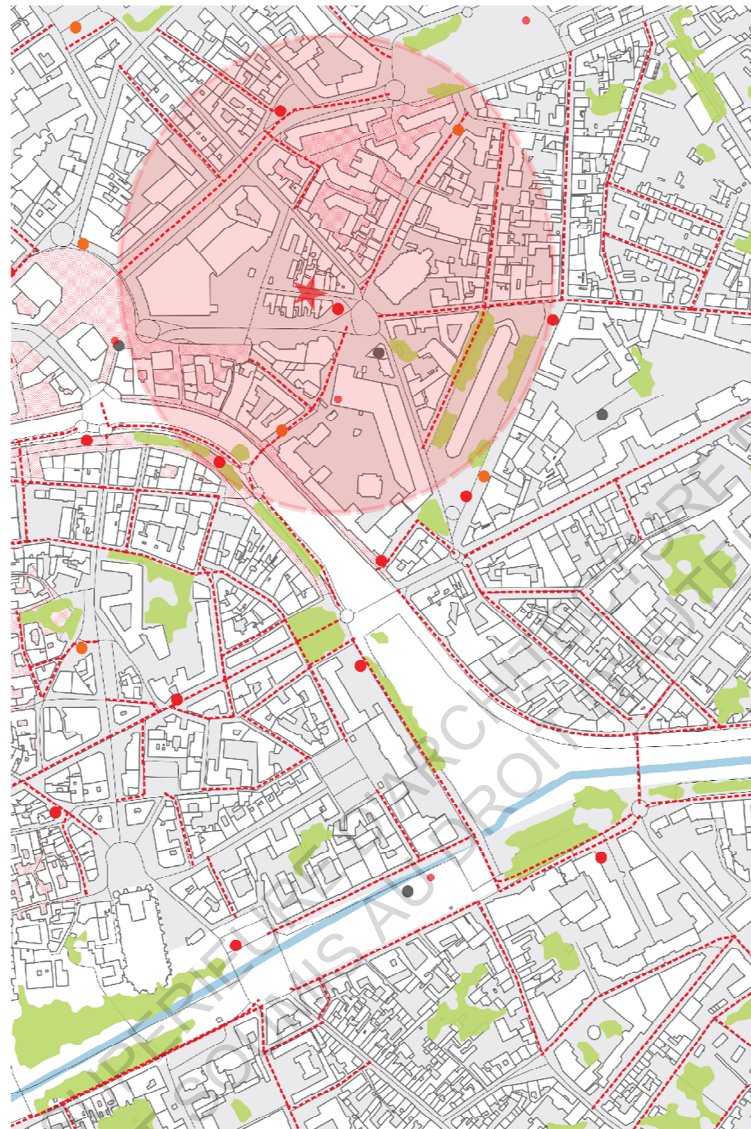
- 166,180, 260 m from Marguerite station (3 carpooling stations)
- 70 m, 160 m parking (2 parking spaces)
- Public Transport: 3, 2, 12, 23, C2

Figure 34: Leon jamin public transportation map. (TAN)

Findings:

"Leon Jamin street, a pedestrian street throughout the whole year?"

Leon Jamin street is well connected to different bus lanes and trams. It has within its proximity (500m) several mobility amenities (such parking, carpooling stations, public transportation, and bike lanes (Figure 34)) which makes us question the possibility of making this street a slow mobility street. This question arises from the fact that during the summer of 2020, cars and parking on the street are forbidden, and instead, the street is used for pedestrians, terraces for restaurants, and other social activities.



- Legend**
- group 1
 - Wifi public
 - Abris vélos
 - Stations vélos libre-service
 - Parkings publics
 - Stations marquerite
 - group 2
 - Aménagements cyclables
 - group 3
 - Vegetation
 - Jardins familiaux
 - Bâtiments
 - Hauteurs des bâtiments
 - Elevation < 2.0m
 - R-R+3
 - R+3 - R+7
 - >R+7
 - Voies routières
 - Stationnement payant
 - Zones piétonnes
 - Rivière
 - ★ Zone d'étude

MOBILITÉ ET PARTAGE DE L'ESPACE



Figure 35: Mobility and shared space. Drawn by the author

b) Greenspaces / Nature en Ville (Consultation of PLUM et le CBS)

This map (Figure 38) makes it possible to differentiate between green spaces (green) and in contrast the mineral areas in white and grey.

Trees, and nature in cities more generally, are great tools in the fight against urban heat islands and in adapting to climate change. (Cerema, 2019)

For the fight against urban heat islands, trees offer two spectacular assets, although they are often forgotten:

- They provide shade and thus limit solar radiation by nearly 80%
- They evapotranspire and thus naturally air condition the city because the evaporation of one liter of water cools 1000m³ of air by 2 degrees. It is often said that a mature tree is the equivalent of 5 air conditioners. (Cerema, 2019)

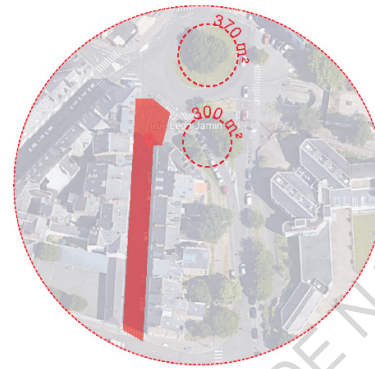
During the site visit in august and using google maps, we can approximately calculate the vegetation area and its perimeter that are found in the proximity of the street. The street is completely mineral with no presence of greenery.

Findings:

As shown in (Figure 36), the vegetation area is around 935 m² in total. According to planning documents (PLUm), we calculate the Coefficient of Biotope per Surface (CBS) which helps us to assess the environmental quality of a plot, an island, a neighborhood, or a larger territory.

The street falls within a zone and Development sector of current or emerging centralities (Uma) which recommends a CBS equivalent to 0.4

After the calculation, the CBS in the zone shown in (Figure 37) is equal to 0.06 while the minimum CBS to be reached is 0.4 (required by the PLUM). Different scenarios are therefore could be proposed to achieve it.



Air = 934.17 m²
L*1 = 88*9.8= 217.43 m

Figure 36: Green space in proximity of Leon Jamin street. Drawn by the author

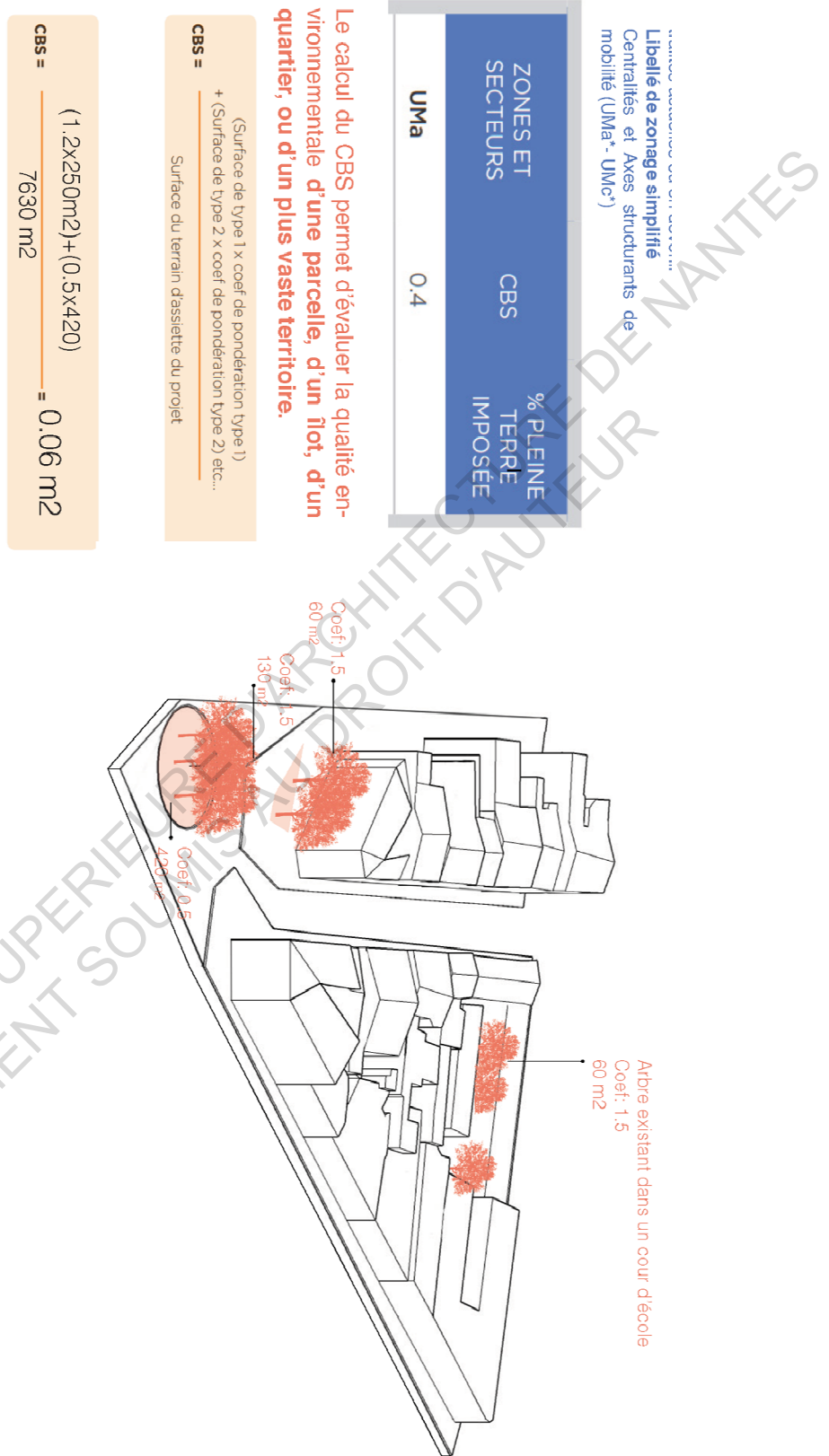


Figure 37: Diagrams explaining the CBS calculation. Drawn by the author



- Legend**
- group1
 - Wifi public
 - Abris vélos
 - Stations vélos libre-service
 - Parkings publics
 - Stations marquerite
 - Aménagements cyclables
 - group2
 - Vegetation
 - Jardins familiaux
 - group3
 - Bâtiments
 - Hauteurs des bâtiments
 - Elevation < 2.0m
 - R+R+3
 - R+3 - R+7
 - >R+7
 - Voies routières
 - Stationnement payant
 - Zones piétonnes
 - Rivière
 - ★ Zone d'étude
 - Les zones de desserte à pied (r=500m)

0
100 m

SURFACE VEGETAL VS MINERALE



Figure 38: Greenspaces VS mineral areas. Drawn by the author

c) Usage and users (Behavioral mapping)

People's activities seem to be an effective lever for reducing energy consumption in buildings and urban space. (Cerema, 2019). The usage and the users in the urban space in the face of extreme climatic events question the sensitivity of users to temperature differences is reflected spatially at the scale of the city. Adaptation to climate change must therefore be able to take into account social and spatial inequalities as factors of vulnerability at a local scale (such as age, origins, and health), however in this research due to limitations mentioned above (shortage of time, lockdown), these factors are excluded in that research.

Tools:

The methodology that consists of mapping the behavior helps to identify the used and under-used spaces on the street. It is measured through direct observations by an urban planner/architect myself taking into account both passive (sitting, standing, lying down) and active (walking, running) occupancies during a weekday, in August 2020, in the two-time frame: August (12h00-14h00) and August (18h00-21h00). The observations were illustrated in maps and through commented pictures.

Findings:

How do people use space?

Leon Jamin is a busy pedestrian street during summer.

The usage of the street during August or summertime when the street is temporarily car-free is managed by the commerce and used by the residents of the street and its neighborhood. During that time, the street became an extension of terraces for the restaurants and the game bar "sur plateau".

"Sur un plateau" is a game bar that attracts more customers during the evenings, so users are more frequent in the middle of the street.

However, the cafes/bars are most popular at lunchtime, and during this time the people's concentration tends to be on the sidewalks of the street where it is mostly shadowed. (Figure 39)

From the pictures taken, we can see the intention of the residents in introducing vegetation through flower boxes. (Figure 40)

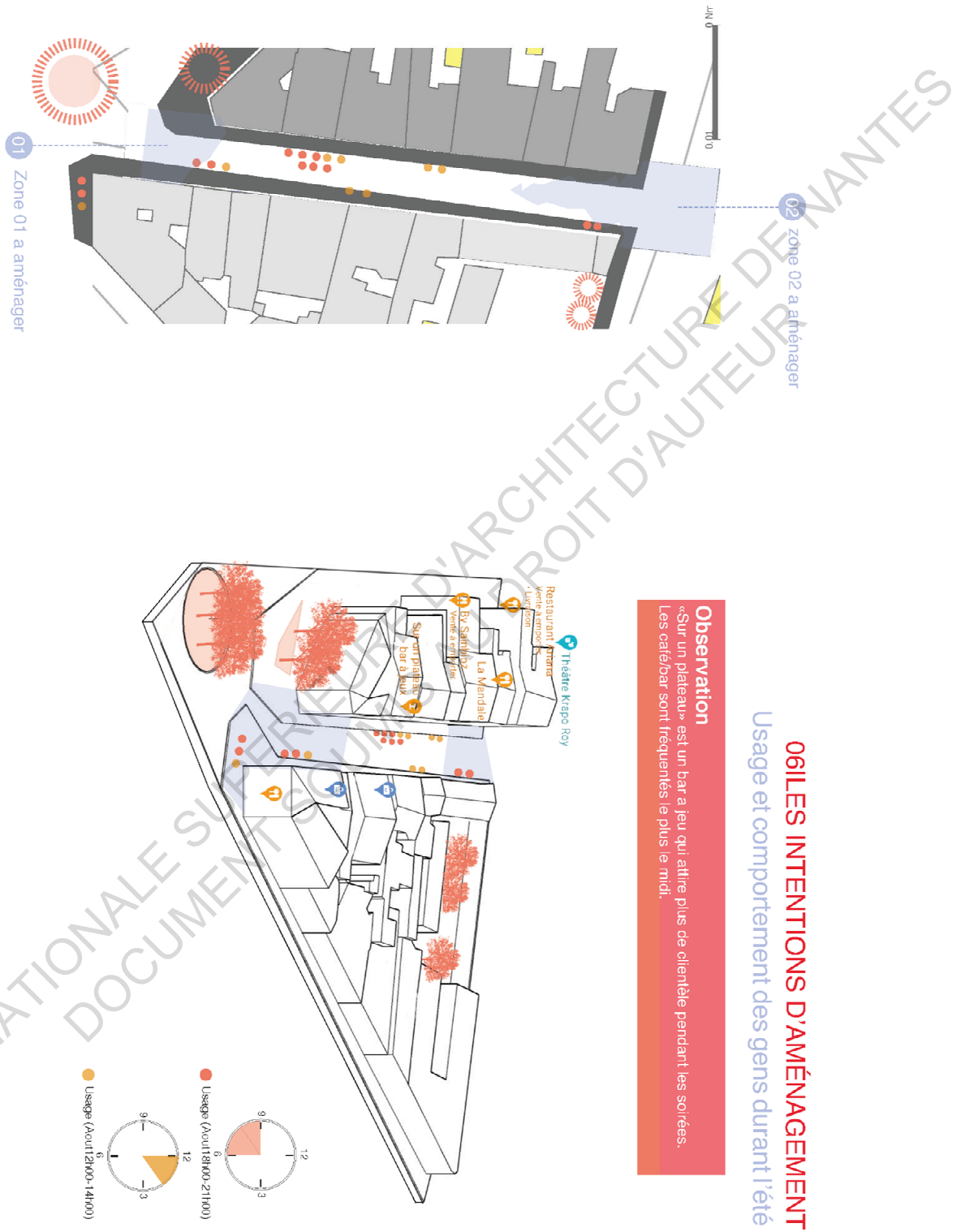


Figure 39: Diagram of users and usage during August 2020 in Leon Jamin street. Drawn by the author

Dialogue citoyen:

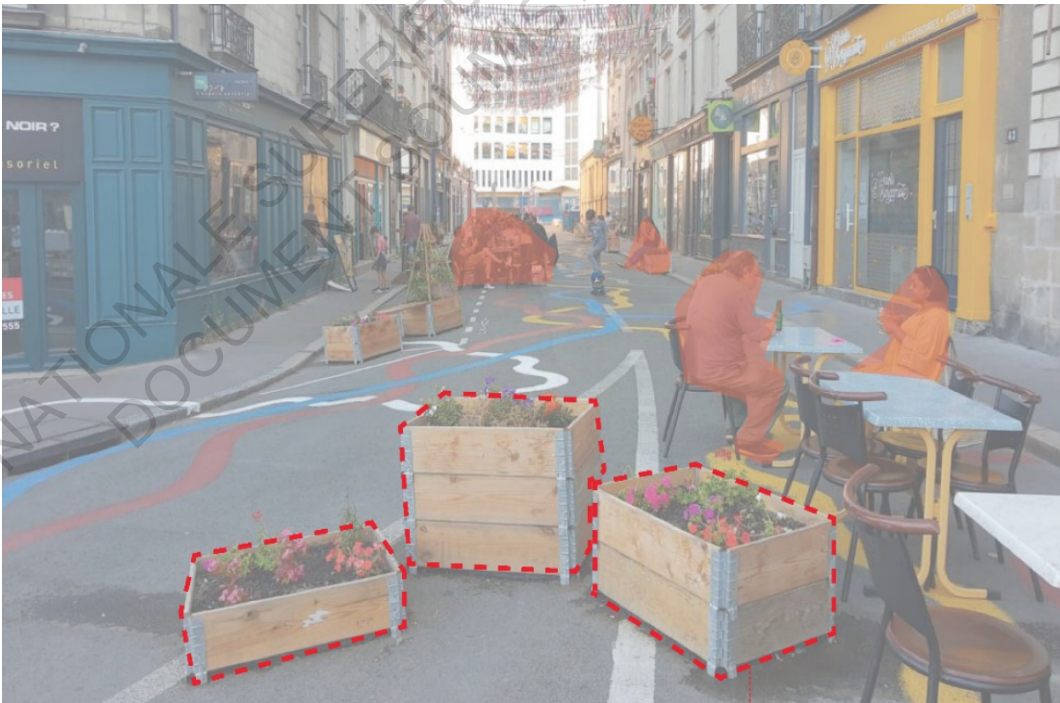


Figure 40: pictures taken during site visit in Leon Jamin street. Pictures taken by the author

Besides the previous mapping, it is essential to mention “Dialogue citoyen” which is an online platform by Nantes Metropoles that recruits 40 citizens-evaluators with diverse profiles on the criteria of gender, age, socio-professional category, place of residence, and main modes of transport, so that they deliver a reasoned opinion around the effectiveness, relevance, and sustainability of the proposed urban development projects. According to the website of dialogue citoyen, under the topic of Leon Jamin a car-free street, the answers were as follow:

Do you think these arrangements are useful?

“The pedestrianization of rue Léon Jamin does not seem useful to me (from my point of view). The vehicles that passed in the street never really bothered me. However, I understand that the point of view of the traders in the street may be different since they can widen their terrace (I am thinking of bars/cafes/restaurants). I specify that my living room is on the street.

What does this change for you?

“During the day, it must be recognized that the street is calm. On the other hand, after 5/6 p.m., there can start to be too much noise, especially at the game bar, when a lot of people are sitting in the street and talking loudly.”

If these arrangements were to be kept, what would have to be changed or taken into account?

“We must take into account the tranquility of residents. You do not need terraces arranged in an anarchic way (as I have already seen). And avoid seeing the street as a playground where anything goes.”

CHAPTER 5: [CONCEPT DESIGN] RECOMMENDATION AND POSSIBLE INTERVENTION

The methodology used for this case study consists of two keys attributes: Diagnostic and concept design. The previous chapter scrutinizes both quantitative (termed as measurable) and qualitative (termed as intangible) criteria of a public space taking Leon Jamin in Nantes as a case study. The intention of this multidisciplinary model is not to lead to solutions, but instead, to help local architects, urban planners, and decision-makers in considering various factors composing the public space that could define spatially possibilities of cooling solutions and adaptative strategies.

1. Presenting the actors and situating the “ adaptation component”

Chapter five explore ways of interventions in public space under the theme of adaptation to climate change. The work should start by understanding the dynamics of actors in Nantes Metropoles in the development of an urban public space project in order to locate the work of the “adaptation component”. (Figure 41)

The operational development projects are attained using procedural models where actors from Nantes metropoles and Ville de Nantes work respectively in the separate institution following a 3-phases model: preamble phase – development of the project-delivery (operation).

For several years, scientific literature has highlighted the obstacles to integrating energy and climate issues in spatial planning. These obstacles are strongly dependent on the territory and the actors of the territory within which this integration takes place. In order to tackle energy and climate issues in urban planning, guides and documents have been developed as mentioned previously. The crossing of the scientific literature and guides allows a contrasted reading of the same climatic problematic which can be confusing for the development of an urban project. And also, Certain solutions (linked to future technological innovations, scientific approaches for example) or limits (such as calculation) are not mentioned in the guides. These bibliographic and documentary analyzes converge to indicate that the “energy-climate” issues are unsurprisingly represented overwhelmingly by energy issues (in terms of production, distribution, savings, renewables), while conversely, questions related to adaptation appear less mature, less precise, and underrepresented.

Therefore, the new proposed model consists of creating a component adaptation that is introduced in the preliminary phase with the aim to tackle the question of adaptation in advance of any urban project and to evaluate the delivery of the project. The following diagram (Figure 41- bottom) summarizes the questioning of this research work.

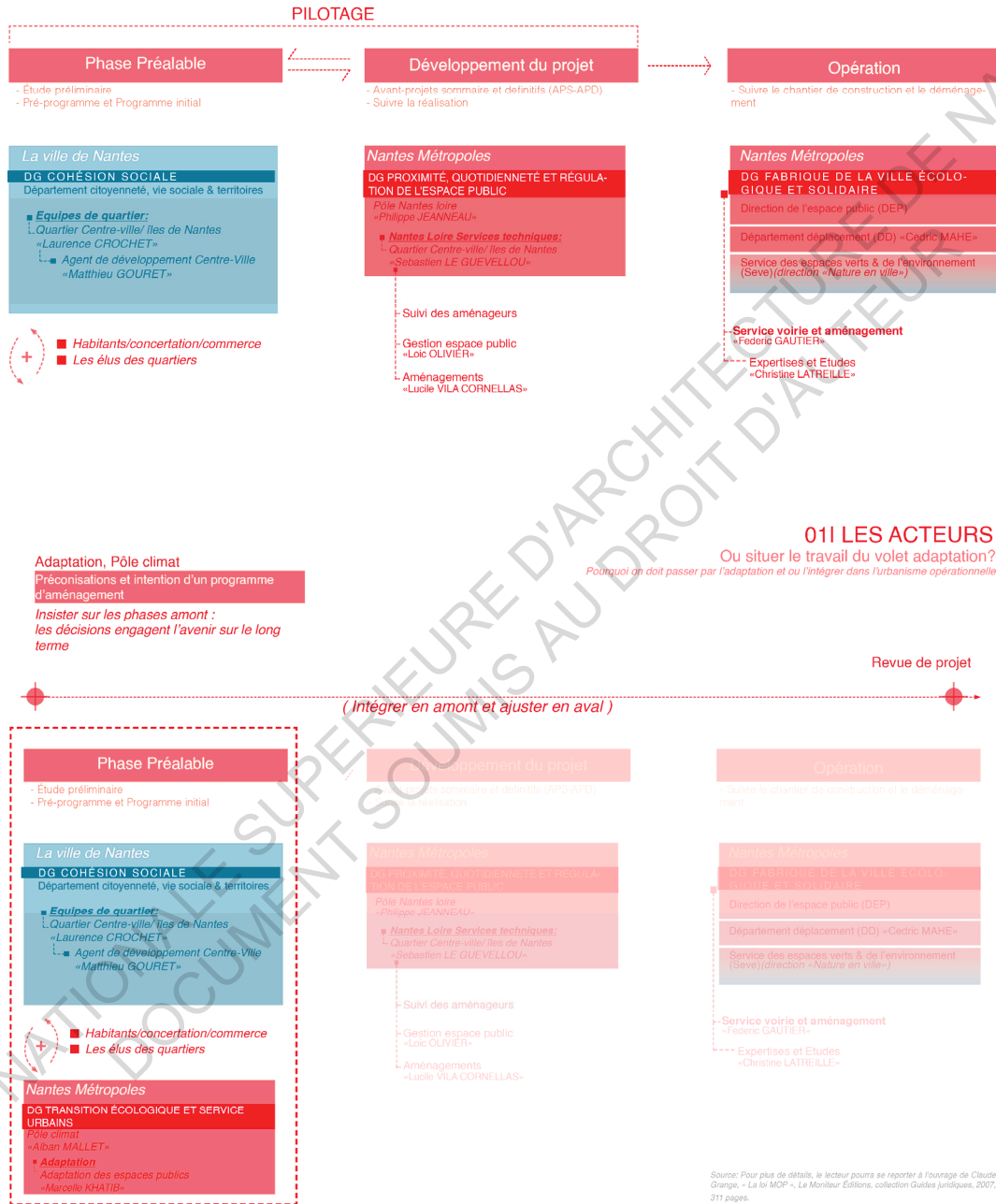


Figure 41: 3D Visualization of possible spatial intervention on Leon Jamin street. Drawn by the author

2. Urban Cooling Solutions (ADEME 2017)

In this section, we will expose a study which is carried out on behalf of ADEME byIRSTV – Centrale Innovation, TRIBU and Anne Bonlarron Coordinated by Céline PHILLIPS.

This study explores a panorama of urban cooling solutions published during a technical day under the name of “ Solutions de Rafraîchissement Urbain -Journée technique - 27 Juin 2017).

There are a variety of solutions to refresh cities, here is a panorama, not comprehensive solutions, carried out based on state of art. Urban cooling solutions are classified according to 3 types: (Figure 42)

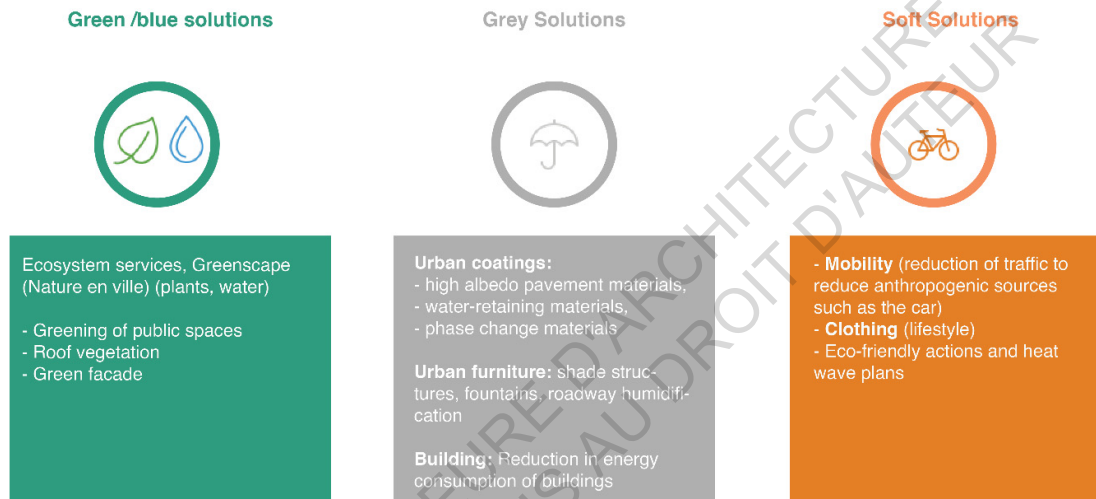


Figure 42: Diagram showing the cooling solutions. Adapted from the ADEME. Drawn by the author

a) Green/ Blue solutions:

- **High stratum vegetation** (Alignment trees in the streets, Trees in public spaces Trees in parks): Night temperature decreases by 0.3 ° C when vegetation density increases by 10% (Fenner, 2014; Pigeon, 2006). During the daytime, refreshment is not always observed and depends on the type of vegetation encountered (Petralli, 2014; Pigeon, 2006).
- **Low stratum vegetation** (grass, diversified vegetation on the ground,...): The difference between the air temperature and the surface of grass can reach 14 ° C, while 25 ° C for mineral surfaces (sunny floors and walls). The amount of water present in the soil increases the cooling potential (by evaporation) during the daytime but may lead to less cooling during the nighttime (Spronken-Smith and Oke, 1999). On the contrary, drying out of the soil in intense periods of drought may cause an increase in temperature.
- **Green roof:** On a sunny day of 26 ° C (in the shade), a roof exposed to the sun can reach a temperature of 80 ° C if its color is dark, 45 ° C if its color is white and only 29 ° C, if it is covered with vegetation (Fischetti M., 2005). Simulations applied to the city of Nantes, have shown that an 8% increase in roofs covered

with vegetation (15 cm substrate) allows the temperature to be reduced by 0.25 ° C 2 m, and reduce rainwater runoff by 4% (VEGDUD, 2014).

- **Green façade:** the temperature decreases by 20 ° C compared to a green façade to a regular wall. The greening of the facades of a canyon street (21 m high and wide, facing north-south and located at the latitude of Nantes) allows in summer to reduce the temperature by nearly 3 ° C at 4 p.m. (VEGDUD, 2014).
- **Water features:** Depending on their size, water bodies can have a either positive or negative effect on the UHI as explained previously in the state of art. The effect is generally positive for large water surfaces, certain low-rise stagnant water surfaces stores heat and become hot enough to warm air during the night rather than contributing to its cooling (Revaud et al., 2015; Robitu, Musy, Groleau, & Inard, 2003; Steeneveld, Koopmans, Heusinkveld, Van Hove, & Holtslag, 2011).

b) Grey solution:

- **Watering the pavements:** (*la Buire street, Lyon (Véolia Project)*) This method involves spraying the pavements with water during periods of heatwaves (Hendel, 2015; Morille & Musy, 2016; Musy et al., 2016). According to (Coutts, Beringer, & Tapper, 2007; CSTB et al., 2013; Hendel, 2015; Tanaka, Okazaki, & Horikoshi, 2004), the use of 2.2 to 3 mm of water/day for watering 2,550 ha of surfaces (i.e. 25 to 35 L / day/people) would reduce the night temperature up to 1 ° C compared to a few tenths of a degree for the average temperature. However, this cooling solution depends on the morphology of the neighborhood and the soil types, and the number of watering surfaces available.
- **Mist, fountains:** use of fountains is common in architecture however its impact on the temperature is average (between 2 and 7 ° C) but higher than the humidification of pavements. Certain adjustment parameters may influence greatly on the performance of the device. This is for example the case of the size of the drops generated (Yamada, Yoon, Okumiya, & Okuyama, 2008).
- **Choice of materials:**
 - **materials with high albedo:** (Fahmy & Sharples, 2009) a street whose aspect ratio is greater than 1.5, the effect of increasing albedo is negligible. They also have shown that the same aspect ratio changed the amount of solar energy absorbed by a neighborhood according to the orientation of the streets. In regions where there is a lot of sunshine, the modification of the albedo of the roofs is more interesting than their vegetation (Santamouris, 2014). Most of these results come from simulations.
 - **Water-retaining materials:** (Gravelled structures, Porous pavement) According to (Santamouris, 2014), water-retaining materials are cooling devices which, if they are effective, should be implemented in rainy and humid regions in order to avoid conflicts over water use.

- **changing phase materials:** have primarily been tested to reduce the energy demand in buildings (Santamouris, 2014). However, a few studies have shown that the use of such materials made it possible to reduce the temperature of surfaces during a certain time of the day.

c) Soft solutions:

related to the uses and practices of the city: Clothing

- Mobility (traffic reduction)
- parks opening at night
- Eco-friendly actions and heatwave plans

3. Presenting the pre-program

In response to the intention of the climate department at Nantes metropoles in coordination with the DEP, we propose a pre-program for the redevelopment of Léon Jamin street while taking into account the main aim of creating an attractive neighborhood centrality while reducing the impacts of UHI. The program targets are based on the following:

- Make the street car-free and no parking zone within
- Promote the circulation of soft mobility
- Return “ the water feature” as a refreshing element in the street
- Vegetate and de-waterproof pavements to achieve a higher CBS equal to 0.4 (PLUM)
- Rediscover a water cycle for better management of rainwater and increase and reuse water resources.

4. Constraints and assets

After exploring the set of possible cooling solution for the public realm, it is important to anticipate the constraints and the assets before designing.

We identified three key attributes (Parking - localization of underground infrastructure - heritage) for the design stage of the street in which can present at the same time constraints and assets. (Figure 43)

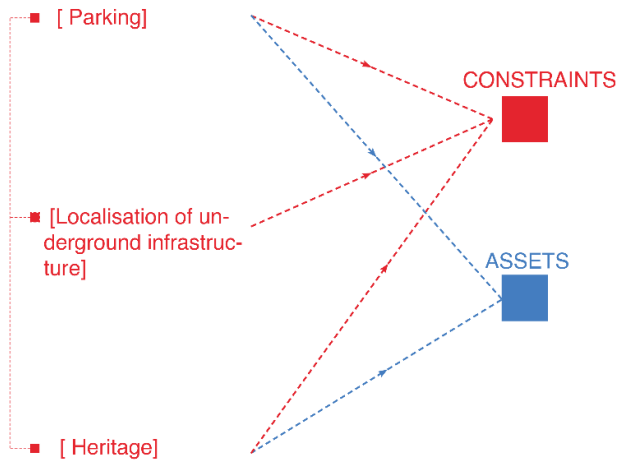


Figure 43: Diagram showing constraints and assets. Drawn by the author

a) **Parking:**

- **Constraints:** Following the parking occupancy statistics on rue Léon Jamin recorded during the red zone parking survey carried out in January 2019, we discovered that the street has:
 - 14 parking spaces
 - The occupancy rate of 9 am-7 pm: 92%
 - Congestion rate (legal and illegal parking) 9 a.m. - 7 p.m.: 94%
 - Turnover rate: 2.3 different vehicles per seat
 - 9h - 19h congestion rate
 - Typology of uses: (Residents: 24% - Cupping: 55% - Visitors: 8% - Pendular: 13%)

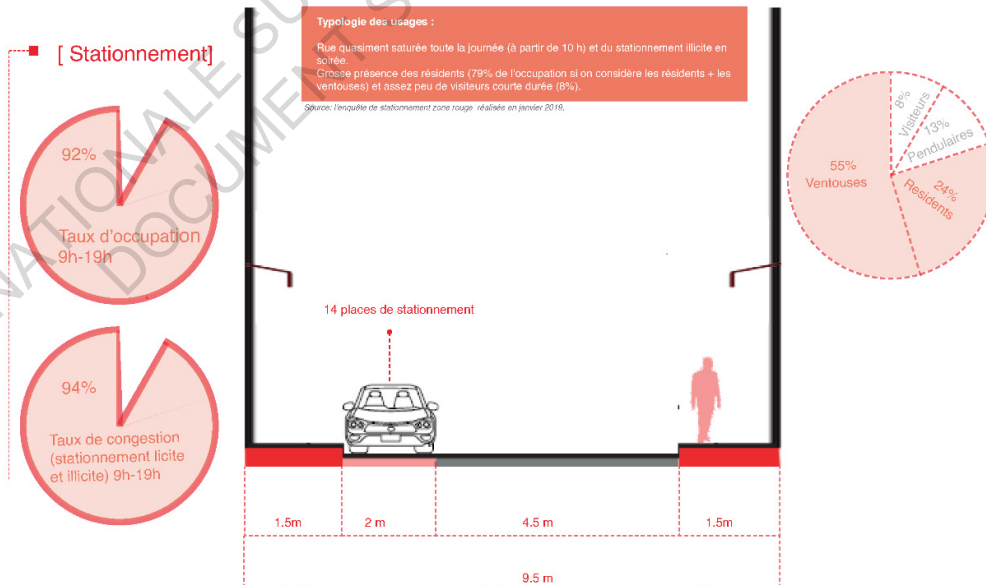


Figure 44: Parking assets. Drawn by the author

The Leon Jamin street is almost saturated all day (from 10 am) and illegal parking in the evening. There is a large presence of residents (79% of occupancy if we consider residents + suction cups) and relatively few short-term visitors (8%). (Figure 44)

However, this mobility and traffic investigation was conducted before trying the temporary car-free strategy on Leon Jamin st. Therefore, a further and updated investigation should take place to check the efficiency of this strategy. To turn this issue into an opportunity for the design proposal.

- **Assets:**

Knowing the importance of accessibility and traffic in the design process, it is vital to take into consideration the experience of a car-free and to check its efficiency and whether was accepted by the residents or not.

The pedestrianization of the Street has undergone three phases: the first one from June till August 2020, then the period was extended till September 2020 and later till December 2020.

Following the qualitative approach of the urban investigation in chapter 4

and based on the "Dialogue

citoyen" and the interviews conducted with the mobility actors at Nantes metropoles and Ville de Nantes, there was no negative feedback so far. Therefore, the possibility of intervention within the street as a car-free, parking-free zone is highly recommended, however, big attention should be taken on the negative acoustic environment such as noise and the quality of soundscape produced.

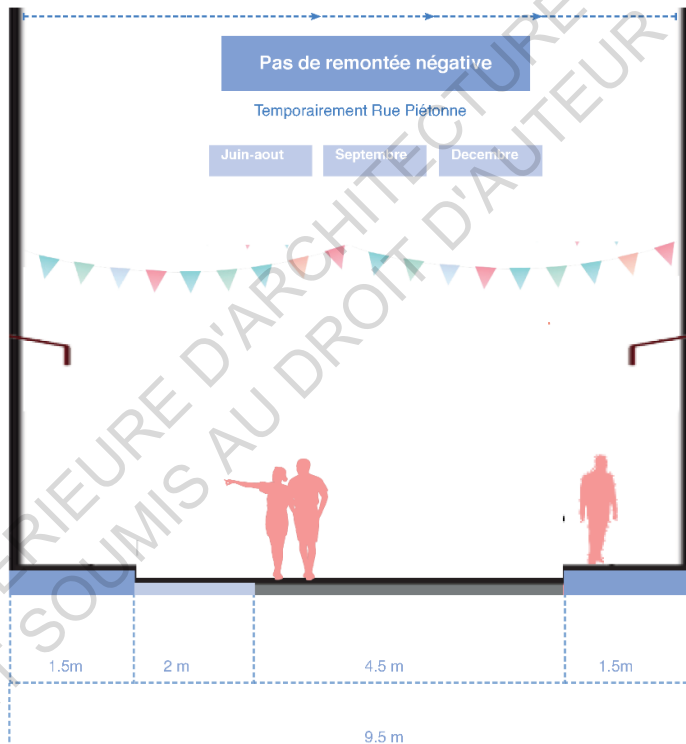


Figure 45: Parking constraint. Drawn by the author

b) localization of underground infrastructure:

- **Constraints**



Figure 46: Infrastructure delimitation. Drawn by the author

For any urban design projects in the public space, access to the locations of the underground infrastructure is important as it defines the possible solutions that could be incorporated into the design, such as the choice of trees and the integration of water bodies. During the internship, we discovered that access to the underground infrastructure maps is highly complex on one hand and the other hand is costly. For instance, the area requested is approximately 1048 m² which means around 5km of networks and costs around 1000 euros. (Figure 46) This constraint will imply other limitations such as Soil and Water Cycle, arboricultural constraints (Root protection perimeter), and funding constraints.

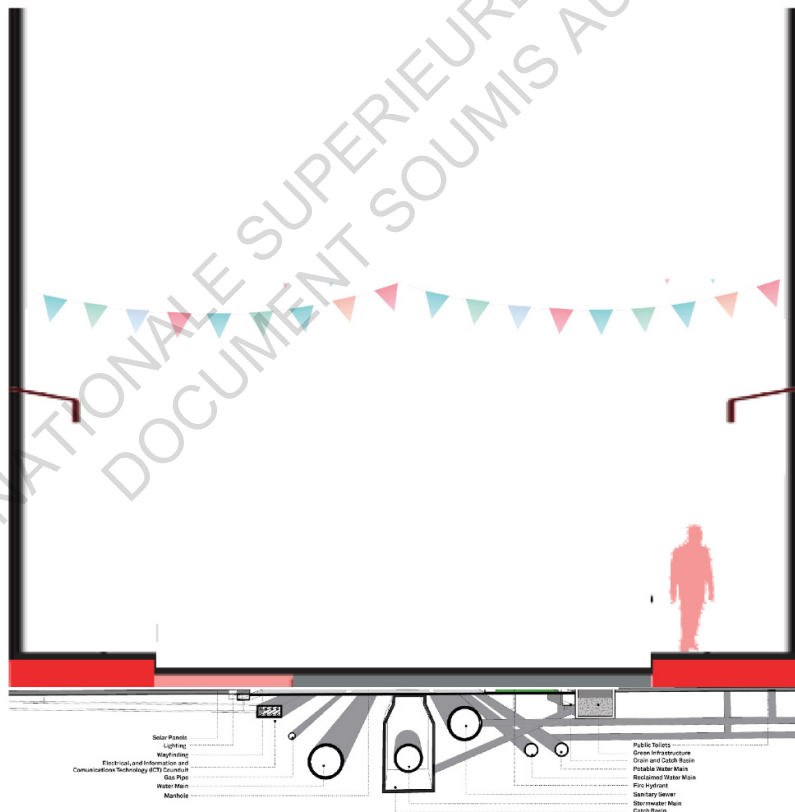


Figure 47: section showing the complexity of underground network. Drawn by the author

c) Heritage:

- **Constraints:**

The land is located in the UMa zone - Development sector of current or future centralities.

The street contains a built heritage: Building which is the Primary School Jean-Jaurès and it is considered in a preserved heritage perimeter since it has at its proximity the church of Saint Similien. The location of the street in a heritage preserved zone impose several regulations and recommendation such as the choice of building materials (light-colored stone) and also recommend from the stores on the ground floor to adopt a wooden panel for the storefront (Figure 48)



Figure 48: Photos taken from Leon Jamin street, Nantes (Saint-Similien church, Dans le noir restaurant). Photos taken by the author

- **Assets:**

As an opportunity, the presence of a façade of a public school that has no openings except the presence of an old heritage fountain that could be used for a possible return of a water feature in the design proposal.



Figure 49: Primary School Jean-Jaurès. New Photo taken by the author. Old photo taken from archives Nantes

5. Design intentions

As a result, we identify two main zones of intervention, the north and south edge of the street. These two zones could present future thermal discomfort on a pedestrian level when the temperature increases. The intervention within these two zones should focus on implementing cooling solutions for the summer heatwaves while respecting the constraints mentioned earlier. The third zone for intervention is the courtyard of the public school which is considered within the area of study and could hold potential for cooling solutions. However, the solutions and the scenarios for this latter are not going to be featured in this paper. (Figure 50)

To summarize spatially the urban investigation conducted on the street in chapter 4, we define, by a red tone on 3d visualization of the street, how and where to intervene. (Figure 51)

Therefore, we should consider intervening on:

- Sidewalks and street
- Buildings (West elevations, façade treatment,...)
- Zone 1 and zone 2

Besides their inclination and inaccessibility, the roof is being excluded from the spatial intervention in this paper due to the low impact on pedestrian comfort in an urban canyon.

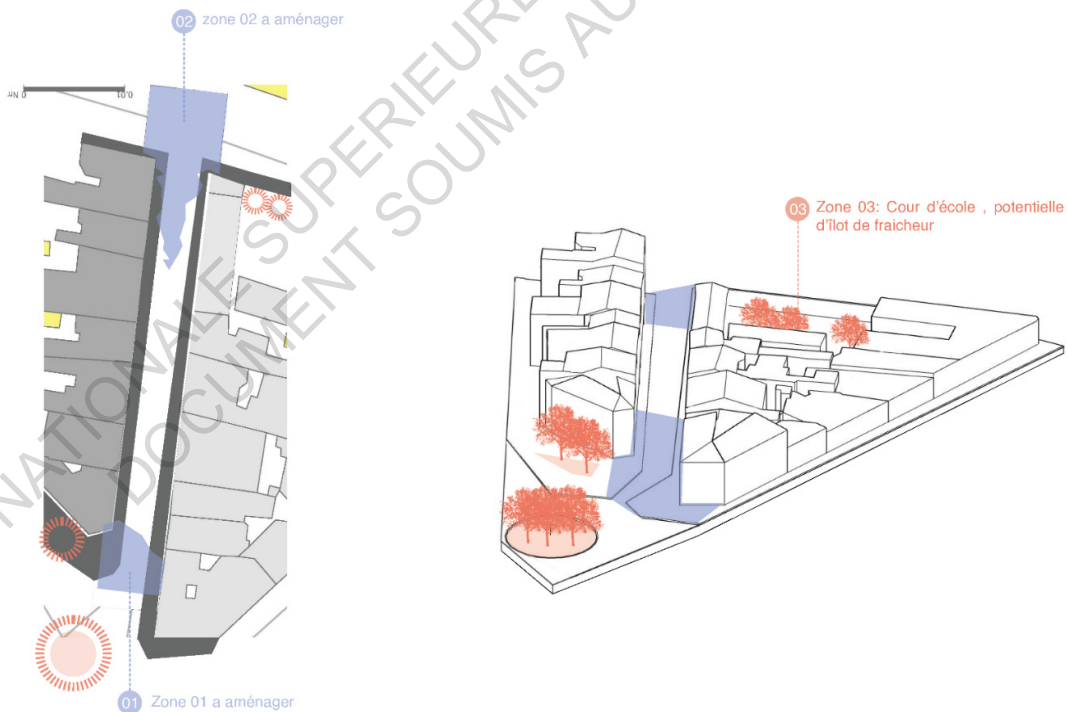


Figure 50: Plan and bird view of the study area highlighting the zone of intervention. Drawn by the author

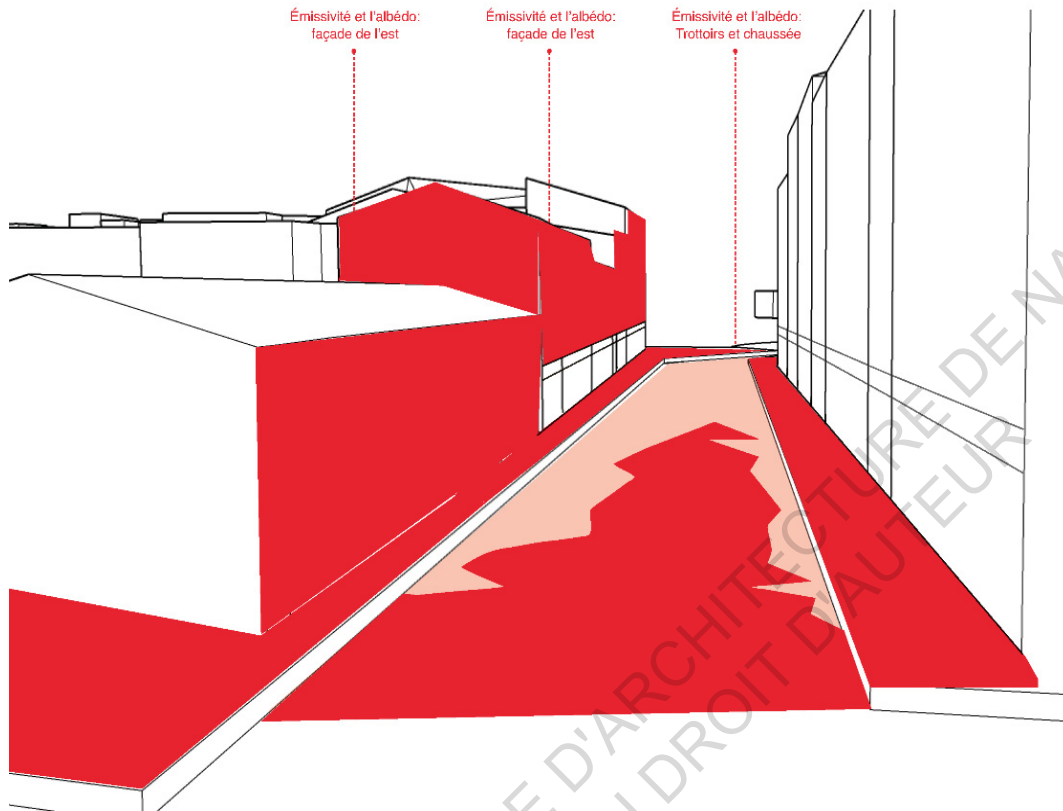


Figure 51: 3D Visualisation showing the possible spatial intervention. Drawn by the author

a) Grey solution

According to Musy, to reduce the heat storage, the materials used in the public space should undergo certain modifications in their properties: such as increasing the albedo and the porosity and reducing the emissivity of the materials. (Musy, 2016)

Since the street is situated in a protected heritage zone, so it is hard to intervene within the materials of the façade and the storefront. For instance, choosing white paint or finishing will decrease the heat stored by buildings, but increase the solar reflectivity towards the street in which the glare is a factor that should be taken into consideration especially when it is a car traffic street. However, as mentioned in the urban investigation chapter, the existing light-colored stone and the wooden storefront with high albedo don't have heat storage properties. Thus, the main intervention should be on the street and sidewalks. The removal of the upper impervious surface such as the experiment conducted in Paris by Apur could cool down the temperature as shown in the visualization of zone 01 (Figure 52) (review the albedo and emissivity in chapter 4.1). (Apur, 2017) Other alternatives consist of paving the street with low thermal storage and high albedo materials, such as bricks (especially light colors) which its porosity allows the water to enter the substrate. As for the sidewalks, the use of pervious materials such as open pavement filled with grass could contribute to the evapotranspiration. Moreover, in some cases where the asphalt is used for the street, the need for shading is

mandatory or to use these surfaces as solar energy collectors. Another consideration should be taken, the urban noise in which according to dialogue citoyen, the inhabitants were worried about the noise during summer night when the street is pedestrianized. Thus, choosing paving materials with a high sound absorption coefficient should be highly recommended.

b) Green/blue solutions

According to Musy (2016), the adaptation strategies of the urban fabric to reduce the temperature via the integration of the cooling solutions are achieved by introducing the vegetation or increase its density and volume in the urban space, adding the water bodies to bring freshness, and ameliorating the ventilation.

As treatment for the buildings, a green façade could not only provide a cooling aspect for the urban space but also reduce the sound level. However, that option is costly and needs a lot of maintenance. Another way to introduce vegetation easily and less costly in the buildings is to encourage the inhabitants to plant their balconies with flower beds.

In zone 02, we suggest removing the impervious surface of 103 m² on the edge of the street where it is more exposed to direct sunlight and vegetalize the soil while adding three trees. Here, we take advantage of the need to increase the coefficient of surface biotope CBS from 0.06 to 0.2. The choice of trees is still under investigation as it requires a specialist and access to underground infrastructure. (Figure 53)

In zone 01, the return of water could come with the old existing fountain. The cycle of water here is problematic as it is essential for the functioning of the water feature.

c) Soft solutions

The temporary experience of Leon Jamin street as a car-free and parking-free street pushed the idea of transforming it into a pedestrian street while cohabiting the bicycle lane. We should also mention the importance of developing the thermal renovation of buildings in the urban canyon. Nantes Metropoles provides digital tools to support residents in the thermal renovation. In particular, two internet platforms exist:

- InSunWeTrust[™]: a solar platform, allowing to estimate the investment and the future gains of the installation of solar panels.
- Mon Projet Renov[™]: aims to support individuals in the energy renovation of their homes.

Moreover, architects should treat the west facades by adding external blinds, adding vertical elements to reduce the use of buildings for air conditioning.

Zone 01

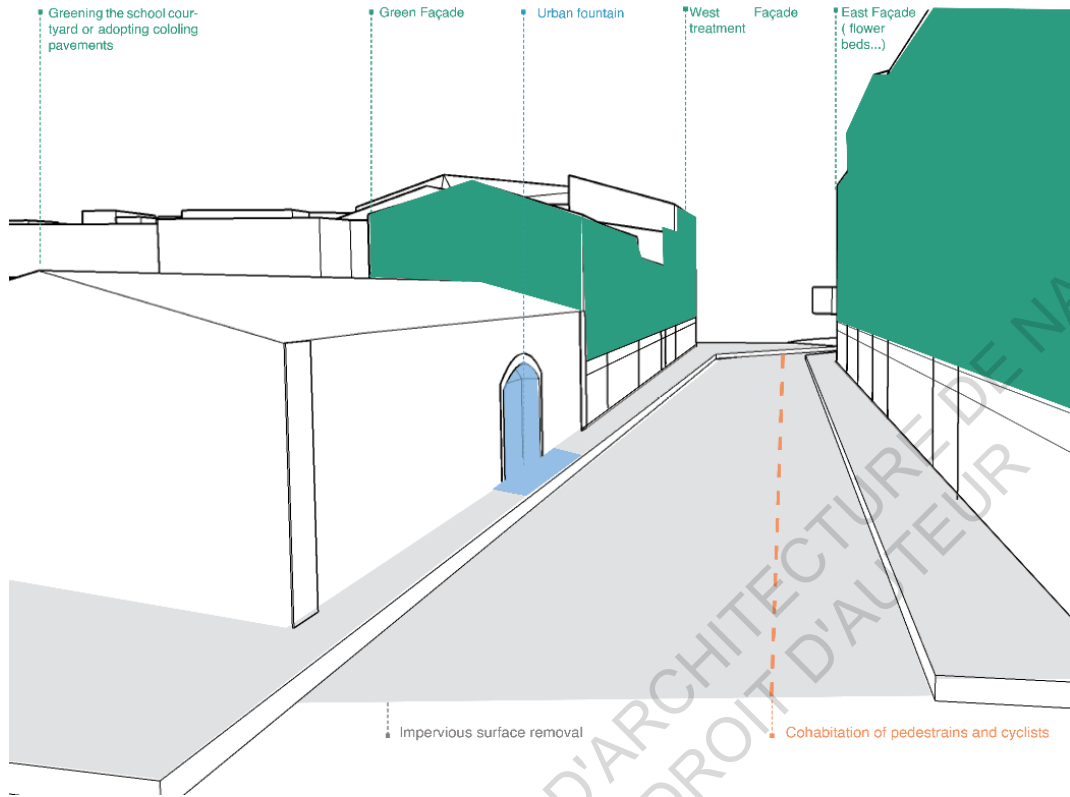


Figure 52: Visualisation of the intervention on the zone 01

Zone 02

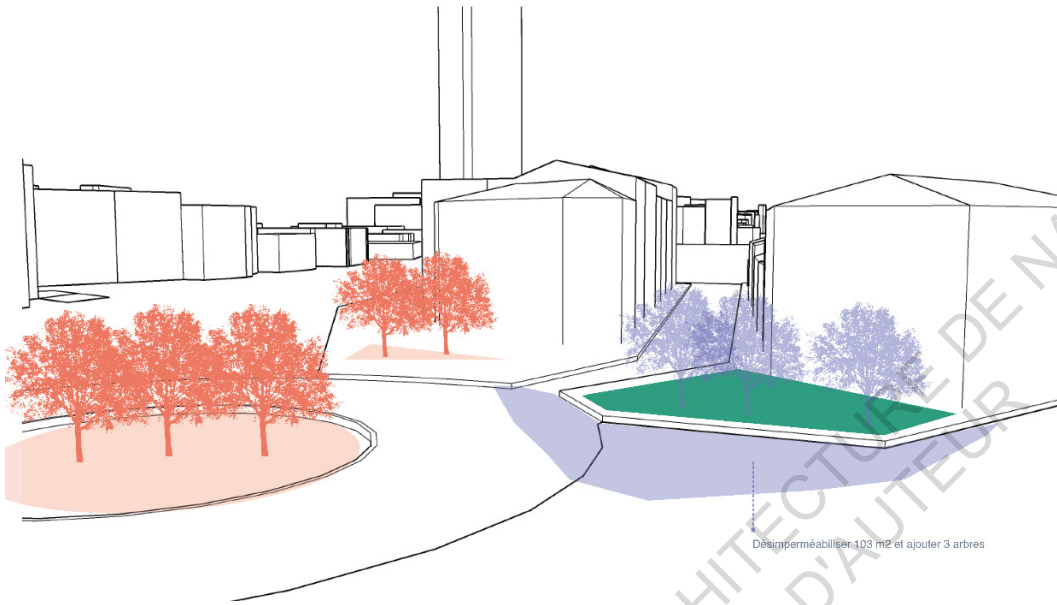


Figure 53: Visualisation of the intervention on the zone 02

6. Discussion and evaluation

	Limitations and observation
- Make the street car-free and no parking zone within	The area is well served by public transport and close to the center and underground parking lots. Positive feedback
- Promote the circulation of soft mobility	Proposition of a bicycle path instead of parking lot and make the street car-free throughout the year
- Return “ the water feature” as a refreshing element in the street	The return of water in the form of a fountain on the school of Jean-Jaures Rethinking the water cycle and infrastructure
- Vegetate and de-waterproof pavements to achieve a higher CBS equal to 0.4 (PLUM)	Difficulty in the access to the infrastructure maps Substantially involve a tree specialist upstream Difficulty in making a fine estimate of the CBS - CBS increases from 0.06 to 0.2. (De-waterproof 103 m2 and add 3 trees)
- Rediscover a water cycle for better management of rainwater and increase and reuse water resources.	Lack of skills and access to the infrastructure maps

ECOLE NATIONALE SUPERIEURE D'ARCHITECTURE DE NANTES
DOCUMENT SOUMIS AU DROIT D'AUTEUR

CHAPTER 6

KEY FINDINGS

ECOLE NATIONALE SUPERIEURE D'ARCHITECTURE DE NANTES
DOCUMENT SOUMIS AU DROIT D'AUTEUR

CHAPTER 6: Conclusion

The public space could be defined from two points of view:

- Quantitative (quantifiable)
- Qualitative (evaluation of the public space).

You must have a global understanding of the meaning of an open public place before intervening in it. The definition of the latter is therefore multiple and brings together:

- a space for movement, travel, irrigation flows, which can bring about many urban constraints (traffic, underground networks, access to shops, buildings);
- an area for residents, a place for meetings where the residents can find comfort and services (a bench, a fountain, a telephone, a basket, a kiosk, and a little nature, flowers, trees, water...):
- a space with a historical background behind its composition

At last, we want to portray in which ways the adaptation strategies to climate change in the preparatory planning phase can help the public spaces to be resilient, to adapt to global warming, and to fight against UHI. To achieve the satisfactory development of public space, it is essential to take into account the different criteria that make it up, build it, and allow it to evolve.

Throughout this thesis, we have been able to note that existing policies frame the issue of urban comfort in an urban public space. However, one of the main constraints of architects and town planners in taking the microclimate into account in urban design is the lack of knowledge about atmospheric and thermal phenomena. This problem should be resolved with the integration of multidisciplinary specialists into the work teams. This is a difficult shift in the development of urban projects and especially in developing cities. The perception and the preferences of residents on the temperature shall be considered in the proposed model and measured as a minimum condition to ensure their comfort.

It is, therefore, necessary to transmit this knowledge to architects and town planners in a simple way, in order to at least ensure that the microclimate and outdoor thermal comfort is correctly integrated into projects. The responsibility for providing information on urban microclimatic conditions lies with local authorities so designers can put it into practice.

6.1 Key findings

The responsibility of local authorities

Local authorities must make an effort to update the urban inventory, by area, with information on:

- The urban form and the criteria influencing the microclimate: sky view factor, the heights of buildings, the H/W ratios, the permeable and impermeable surface, by neighborhoods or urban fragments, the construction materials, the characteristics of the local vegetation.
- the microclimatic variables such as air temperature, wind speed, solar radiation, and minimum air humidity.
- The easy access to underground infrastructure and the flexibility of regulations regarding the heritage preserved area.
- The development of new mobility policies to ease down the traffic such as the “quarter-hour city” policy adopted by the Mayor in Paris.

The greatest responsibility of local authorities in Nantes Metropoles is to centralize, communicate, and facilitate access to this information. Often the information is created by subsidiary entities (meteorological or cartographic laboratories such as CEREMA, ADEME, CRENAU,...) and it is chargeable and expensive; this discourages and makes the process longer as it needs a lot of paperwork and funding. In all cases, this information will be necessary to integrate the policies into the technical memory of and justify the urban guidelines in terms of thermal comfort of outdoor spaces.

Finally, the climate and adaptation department within the local authorities must ensure that the urban projects are gathered in their file the microclimatic and bioclimatic studies present. This file must also contain the study of the urban form where the designer develops the analysis of his project with the environment. With this, the local authorities/adaptation department determine the degree of impact on the microclimate of the project and ensure to recommend microclimatic solutions et evaluate at the delivery phase.

The responsibility of designers: putting it into practice

The architect and the urban designer have a great responsibility in the face of climate issues, but mainly with the inhabitant. As expressed in speaking of the practice of urban space:

For example, societal involvement could facilitate the assimilation of valuable local information about comfort — which could help define more accurately the needs and conflicts — and could help legitimize, by consensus, decisions on controversial issues. We recognized, however, that societal involvement in thermal comfort has important limitations: some are related to the nature of participatory processes, and some are related to the participant's behaviors and backgrounds. There must exist epistemological tools broader than those provided by hard sciences.

Therefore, we consider that the adaptive urban design approach has much to offer as a complement to traditional urban design strategies because it allows taking into account not only the opinions and experiences of the users of the space but to cross-analysis the microclimate measurements and perceptions.

After bibliographical research and interviews with professionals, we realized that it doesn't exist a tailored procedural model for the development of adaptive public space projects. The final questioning being based on its accuracy, It is advisable to reorientate the problem and to define other specific objectives.

Finally, we recognize, indeed, the importance of integrating the quantitative analysis to the evaluation of public space (qualitative approach) in the pursuit of improving the thermal comfort of users. Therefore, the suggestion is to reconcile different rationalities and integrate them into one comprehensive approach for successful design. Despite the lack of a procedural model, the complexity of the development of public space project procedure requires setting up a specific organization and specific skills. Since there is no procedural model, methodological adaptation tools (examples: recommendations, intentions) specific to DEEC/ Climate, should be integrated upstream of the urban development procedure in order to maintain coherent management of the project.

To summarize, this thesis aims to examine existing practices of urban design management and explore paths to improve them. We speculate that by incorporating the adaptation theme in designing the public space, in particular the urban canyon. We could open new opportunities for urban management, including the incorporation of the perception of outdoor thermal comfort, that may lead to prepare cities for climate change and extreme temperature events.

6.2 Prospects for future research

The assessment of the quality of public life in cities starts by investigating ways to approach the multiple layers of outdoor thermal comfort. The urban microclimate at a pedestrian/ street level is the most crucial factor in influencing the perception of thermal comfort.

The assessments can be challenging because it can be defined as dynamic and subjective. On one hand, they are dynamic because the adaptation to ambient temperature in an urban space is gradual. On the other hand, the perception of thermal comfort depends on previous experiences therefore it is subjective.

We are aware that the model considered in this paper is ambitious and presents multiple challenges. Sophisticated techniques and methodologies are required to be integrated into urban planning and public space design. Despite this, we believe that the quantitative and qualitative analysis of urban public spaces is a worthy exercise that can guide us in identifying solutions for the future challenges of cities.

In relation to the challenges mentioned above, we present in the following section of this thesis a collection of tools, case studies, and research from climate adaptation practices

that are useful to move forward in the integration of thermal comfort of users into the design of adaptive public space. (see ANNEX)

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ANNEX

OPERATIVE INSTRUMENTS FOR PUBLIC SPACE

Following the previous findings and case studies, this chapter offers a collection of tools and methods from case studies, theories and practices.

//01 Methods for the assessment of outdoor thermal comfort

the methods are briefly described as:

- *Simulated/reproduced*

Laboratory experiments: This method is used in labs to simulate a thermal condition as a way to predict comfort and to test. the data collection is done usually by measurements or semantic scales.

- *In situ:*

Commented walk: is an empirical common method conducted in situ to collect data to evaluate and measure thermal comfort in an urban public space. It is aimed at inviting participants to walk at a given and to make their judgments and give their impressions afterward (Aletta 2016). Various aspects can affect the walk such as the questioning protocol, the diversity of the participants, and the duration of the experiment. Also, there are different tools to collect data from the participants:

Behavioral observations: The researchers conducting the commented walks can combine other methodology such as observing the participants and reviewing their behaviors.

Crowdsourcing: This method can be used by inviting people whether in a specific place through soundwalks or at anywhere, anytime through smartphone apps to register their sensations and to express their impressions (complaints, emotions). For example:

The tools available for these methods are:

Semantic scales: rating system used to measure the connotative meaning of outdoor thermal comfort.

Narrative interviews (through interview protocol): It is a tool in which the researchers leave the participants to narrate or write about actual (*in situ*) or prior experience.

Questionnaires: used by the researcher to collect data through open-ended questions.

According to (Chen, L , & Ng, E (2011)), they suggest in their paper a framework to study behavioral aspects of users in order to evaluate their perception of outdoor thermal comfort in space. The framework is based on four degrees: physical, physiological, psychological, and social/behavioral. (Figure 54)

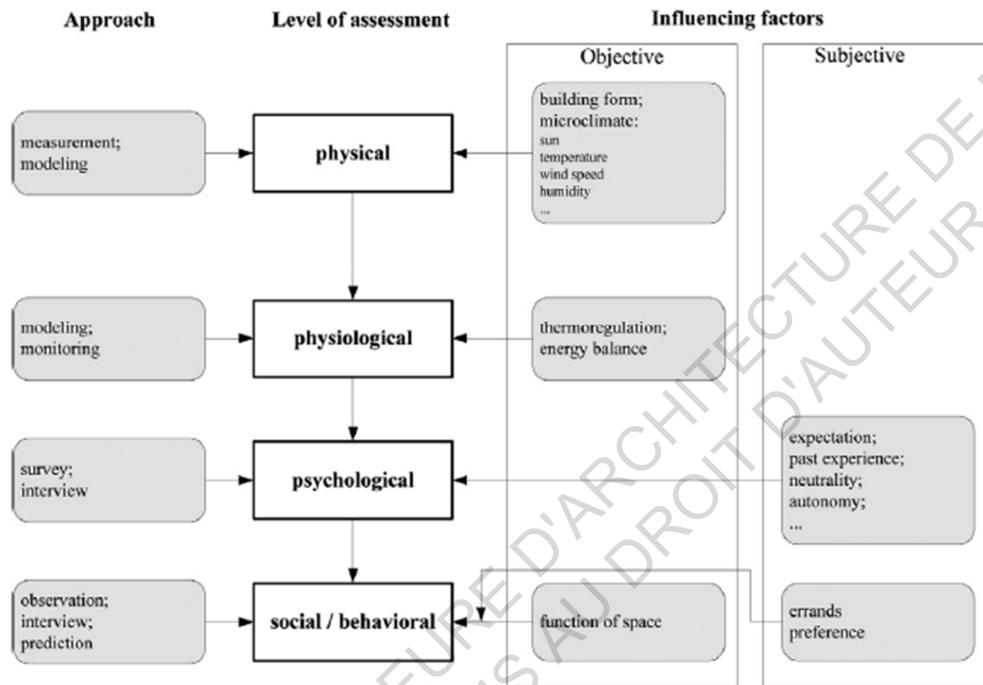


Figure 54: Diagram for outdoor thermal comfort assessment based on behavioral aspects. (Chen, L , & Ng, E, 2011)

//02 Adaptation projects in the world

Nom	Description	Lieu	Lien	
Urban Innovative Actions (2018-2021)	The aim of the IAU Initiative is to provide urban authorities across Europe with space and resources to test untested ideas aimed at addressing real-life issues.	Europe	https://www.iau-initiative.eu/en/iau-cities	
UIA (1/1/2018-31/10/2021)	RESILIO - Resilience network of Smart Innovative climate-adaptive rooftops	Amsterdam (Netherlands)	https://resilio.amsterdam/en/about-resilio/	
	GBG_AS2C - Blue, Green & Grey Adapting Schools to Climate Change	Barcelone (Spain)		
	IGNITION - Innovative Financing and delivery of Natural climate solutions in Greater Manchester	Greater Manchester (UK)		
	OASIS -	The OASIS project plans to transform 10 schoolyards into cool islands through innovative techniques, nature-based solutions, in an integrated approach.	Paris (France)	https://www.iau-initiative.eu/en/iau-cities/paris-call3
	GUARDIAN - Green Urban Actions for Resilient fire Defense of the Interface Area	is a pioneering model of sustainable, innovative management of the natural environment, which will ensure the safety of the citizens of Riba-Roja and contribute to the preservation of the Natural Park of Túrria and La Valles.	Riba-roja de Túrria (Spain)	https://www.iau-initiative.eu/en/iau-cities/ribaroja-de-turia
	CartujaQanat - Recovering the street life in an	CartujaQANAT will act as a catalyst for public-private urban transformation, facilitating Seville's	Sevilla (Spain)	https://www.iau-initiative.eu/en/iau-cities/sevilla

	acclimate-changing world	adaptation to future climate conditions, and will help Andalusia become an urban reference in adapting to climate change, facilitating replication in the Mediterranean environment and positioning local companies in the environmental industry.		https://cartujaqanat.com/eventos/
Climate Proof Zomerhofkwartier (2014-ongoing)		<ul style="list-style-type: none"> - Bentheplein water square already has become a renowned innovation that combines temporal water storage with the improvement of the quality of urban public space - Polder roof project proposes the transformation of the roof of the 'Katshoek' parking garage into an attractive green roof that stores and reuses rainwater from the nearby buildings in a controlled way for urban agriculture. - Katshoek Rain(a)way Garden is part of the new Heer Bokelweg street profile in which an abundance of hard surfaces is being decreased. In the context of a colorful linear garden, innovative Rain(a)way tiles by Fien Dekker will be integrated and tested. - ZoHo Rainbarel is a participative water storage system. - Greening Hofbogen aims at climate proofing the monumental structure of the 'Hofpleinlijn'. Analyses show, that there is a potential for a substantial greening of the facades and sidewalks. - ZoHo Raingarden turns an abundance of hard surface and underused parking spaces at the entry of the ZOHO district into an attractive welcome garden that collects rainwater from nearby buildings and public spaces. 	Rotterdam, (Netherlands)	https://hofbogenplannenarchief.wordpress.com/2015/05/15/de-urbanisten-climate-proof-zomerhofkwartier/ http://www.urbanisten.nl/wp/?portfolio=climate-proof-zomerhofkwartier
Amsterdam Rainproof		Amsterdam Rainproof wants to make the city more resilient to this type of weather.		
The Liverpool Air Project		artists and scientists work together to think about the air quality in cities.	Liverpool (UK)	https://thetownmovement.com
The Motown Movement		Three students from Delft moved to Detroit to inspire homeowners to sustainably renovate their homes and fight climate change. With one exemplary project, they aim to show the inhabitants the possibilities of new	(Netherlands)	

	technologies in the reconstruction of their homes.		
Adaptation of public spaces/ squares			
Hamburg - The new walk on the Elbe (2019)	The main objective of this achievement was to adapt to the potential danger caused by climate change and hydrogeological consequences. The new promenade is part of the reinforcement of the system of protection against floods and exceptional tides for the water districts.	Hamburg (Germany)	https://cittaclima.it/portfolio-items/amburgo-la-nuova-passeggiata-sullelba/
Copenhagen - Anti-flooding road surfacing	A new road paving system in Copenhagen aims to reduce flooding and at the same time create green spaces. The "climate tile" is punctuated with holes that allow water to be collected and managed, channeling it into spaces planted along the sidewalk, to help prevent roads from flooding. The slab has been in development since 2014 and was recently installed in the Nørrebro district of Copenhagen, over an area of 50 meters	Copenhagen	https://cittaclima.it/portfolio-items/copenhagen-la-pavimentazione-stradale-anti-allagamento/
Hamburg - A program for the spread of green roofs (2017)	To allow the increase of urban green spaces and especially for the construction of green roofs.	Hamburg (Germany)	https://cittaclima.it/portfolio-items/amburgo-un-programma-la-diffusione-dei-tetti-verdi/
Bratislava - The Climate Change Adaptation Strategy (2016)	The main actions undertaken concern the increase of green infrastructure, the greening of certain areas, the construction of green roofs, rainwater storage systems to reduce leaching and for irrigation purposes, new drainage systems. sustainable.	Bratislava (Slovakia)	https://cittaclima.it/portfolio-items/bratislava-la-strategia-ladattamento-ai-cambiamenti-climatici/
Los Angeles - The Whitewashed Streets Against the Islands of Heat (2018)	A special whitish emulsion is used called "CoolSeal" which instead of absorbing the rays of light reflects them, lowering the temperature of the asphalt by at least ten degrees. The record belongs to a road in Canoga Park, in the San Fernando Valley, which went from 33 degrees to 21 degrees thanks to the repaint.	Los Angeles (USA)	https://cittaclima.it/portfolio-items/los-angeles-le-strade-dipinte-bianco-le-isole-calore/
Milan - Piazza Gae Aulenti (18 jan 2015)	By water squares, we mean urban spaces designed as play or relaxation areas and characterized by a "variable" aspect or - to put it another way - elastic in relation to climatic conditions.	Milan (Italy)	https://cittaclima.it/portfolio-items/milano-gae-aulenti-piazza/

Madrid - Project Madrid Rio- From the highway to the park on the river (January 18, 2011)	The plan to restore the natural habitat surrounding the Manzanares River is a major redevelopment project for a public space, made possible under the MadridRio project launched in 2004 in which the M30 motorway was redirected underground.	Madrid (Spain)	https://cittaclima.it/portfolio-items/madrid-rio/
Modena - Piazza Roma (2016)	The original objective was to free the beautiful square on which the 17th century Palazzo Ducale emerged from a large parking lot with asphalt pavement. The intervention aimed to pedestrianize the area through the use of materials and a system of ponds and fountains, which has a positive effect towards the heat islands.	Modena (Italy)	https://cittaclima.it/portfolio-items/modena-piazzaroma/
Adaptation in the squares: BORDEAUX - PLACE DE LA BOURSE (2017)	"The water mirror" is in fact a 3 cm high water mirror suitable for cooling the air on summer days.	Bordeaux (France)	https://cittaclima.it/portfolio-items/bordeaux-place/
Rimini - Piazzale Kennedy (2018)	The intervention of Piazzale Kennedy, who will deliver to the city an important hydraulic garrison under the roadway and a completely redeveloped area with a belvedere overlooking the sea, goes a step further.	Rimini (Italy)	https://cittaclima.it/portfolio-items/rimini-piazzale-kennedy/
Adaptation strategies			
Malmö – port zone (2017)	The city of Malmö aims to implement climate adaptation measures by integrating them directly into the urban planning of areas destined to develop, such as that of the west port, thanks to a mix of public funding and private.	Malmö (Suède)	https://cittaclima.it/portfolio-items/malmo-area-portuale/
Competition			
Lille Bas Carbone		Lille-France	https://claas-architectes.com/lille-bas-carbone/

//03 Research and expertise related to adaptation

Projets de recherche			
Nom	Description	Lieu	Contact et partenaire
GROOF (2018-2021)	Un projet européen qui a pour objectif de faciliter et accompagner l'émergence de serres en toiture en milieu urbain, en vue de réduire les émissions de CO2.	Allemagne, Luxembourg, Belgique, Espagne, France	Construction : - Conseil de Développement Economique pour la Construction (Luxembourg) - Cluster Eco Construction (Belgique) - Institut de Formation Sectoriel du Bâtiment (Luxembourg)
GROOF	Adhoc habitat participatif	Kirchberg (Luxembourg)	Energie/Technique : - Centre Scientifique et Technique du Bâtiment (France) (Construction) - Hochschule Trier Institut für angewandtes Stoffstrommanagement (Allemand) (Agro-socio-éco) Agro-socio-éco : - Université de Liège, Gembloux Agro-Bio Tech (Belgique)
	Green(s)pot	Bruxelles (Belgique)	
	J'habite mon jardin	Tour (France)	- EBF GmbH (Allemand)
	ISA/Yncrea	Lille (France)	- ASTREDHOR: Institut Technique de
	Les Petits Poucets	Namur (Belgique)	
	Culina Hortus	Paris (France)	
	Novacitis	Liège (Belgique)	
	Symbiose	Nantes (France)	

	Pousses & Vous!	L'activité principale de ce toit, y compris une serre consiste en des visites scolaires tandis que les récoltes représentent les sous-produits valorisés socialement par le biais de dons à des organisations caritatives.	Bruxelles (Belgique)	l'Horticulture (France) - Groupe One (Belgique) - Les Jardins de Gally (France) (Energie/Technique)
	Toits Vivants	Le projet consiste à aménager une serre urbaine multifonctionnelle et un potager commun situé sur les toits des immeubles d'habitation mis à la disposition des résidents. *Toits Vivants est une association qui vise à développer des écosystèmes comestibles intégrés et participatifs.	Arcueil (France)	- Universitat Autònoma de Barcelona (Espagne) (Energie/Technique)
VegDUD (2010 - 2014)		Rôle du végétal dans le développement urbain durable ; une approche par les enjeux liés à la climatologie, l'hydrologie, la maîtrise de l'énergie et les ambiances	France	IRSTV
TVGEP (2013)		L'objectif du projet : évaluer l'intérêt des toitures terrasses végétalisées (TTV) pour la gestion quantitative et qualitative des eaux pluviales, en en identifiant leurs atouts et limites, tant à l'échelle de la parcelle qu'à l'échelle de la ville.	France	Bernard de Gouvello, chercheur CSTB localisé au LEESU
TERRACES (2012-2015)		L'objectif du projet : évaluer l'intérêt des toitures terrasses végétalisées (TTV) pour la gestion quantitative et qualitative des eaux pluviales, en en identifiant leurs atouts et limites, tant à l'échelle de la parcelle qu'à l'échelle de la ville.	France	Subventionné par l'ADEME
Thèse				
	Modélisation climatique de la végétation urbaine : évolution de l'impact de dispositifs végétaux architecturaux sur la consommation énergétique des bâtiments	Plusieurs scénarios de végétalisation du quartier de Pin sec de Nantes densifié ont ensuite été étudiés. Il a été montré que l'effet direct de la végétalisation des façades et des toits permettait de supprimer l'inconfort d'été à l'intérieur des bâtiments sans isolation thermique.	(Nantes) France	Laurent Malys - Thèse de doctorat soutenue en 2012- AAU ENSA Nantes
Expertise collectivités				

<p>Ville de Montréal Pierre Jutras Plan d'action canopée</p>	<p>Vise la plantation massive d'arbres dans les secteurs bâtis.</p> <p>Le projet de plan d'action canopée 2012-2021:</p> <ul style="list-style-type: none"> -concerter la canopée existante -plantation de 300000 arbres --> saisir nouvelles opportunités d'accroître le couvert végétal et la biodiversité en milieu bâti et peuplé : la mise en place d'espaces-relais (ilots de végétation, potagers, murs verts, toitures...) 	<p>Montréal</p>	<p>Direction des grands parcs et du verdissement</p>
<p>Expertise bureaux d'études</p>			
<p>Cool roof France</p>	<p>Le système ° CoolRoof est un revêtement de toiture conçu pour refroidir l'air intérieur des bâtiments et éviter la surchauffe du rayonnement solaire, en le bloquant avant qu'il n'entre dans le bâtiment.</p>	<p>France</p>	<p>Contact : Antoine Horellou, Directeur Général</p>
<p>Le Prieuré</p>	<p>Assistance pour l'évaluation de produits de toitures terrasses végétalisées (Le Prieuré, 2010-2012)</p> <p>*LE spécialiste de la végétalisation urbaine depuis 20 ans (toiture végétalisée, mur végétal et aménagement urbain paysager).</p>	<p>France</p>	
<p>Siplast</p>	<p>Évaluation d'une toiture terrasse végétalisée à zéro rejet. Un suivi de la qualité des eaux recueillies dans les alvéoles est également prévu.</p> <p>*Siplast : Le spécialiste des solutions d'étanchéité des toitures terrasses, des sous-toitures, des fondations et des ouvrages d'art.</p>	<p>France</p>	
<p>Nidaplast</p>	<p>Développement de connaissances sur des systèmes innovants</p>	<p>France</p>	

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GLOSSARY OF TERMS

Albedo

Is a non-dimensional, unitless quantity that indicates how well a surface reflects solar energy. *Albedo* varies between 0 and 1.

Anthropogenic heat

Heat release from human activities.

Anthropogenic flux

A surface through which water cannot penetrate.

AURAN

Agence d'Urbanisme de la Région Nantaise.

“Canyon effect” or *Radiation trapping*

The modification of the characteristics of the atmospheric boundary layer in a street flanked by buildings on both sides.

DEEC

Direction Environment Energy Climate.

Density (building)

Amount of the ground occupied by buildings.

DGTEESU

The general direction of the Ecological and Energy Transition and Urban Services.

Emissivity

The measure of an object's ability to emit infrared energy. Emitted energy indicates the temperature of the object. It can have a value from 0 (shiny mirror) to 1.0 (blackbody).

Evapotranspiration

Loss of water to the air due to combined evaporation and transpiration.

Fabrique de la ville

Une Fabrique de la Ville supports the Nantes Saint-Nazaire Metropolitan Center in the synthesis of strategic territorial issues and the definition of innovative implementation methods for territorial dynamics.

Heatwave

A period of abnormally and uncomfortably hot weather.

H/W Ratio

Is defined by the building's height to the street's width ratio.

Impervious surface

A surface through which water cannot penetrate.

La Ville Du Quart d'Heure (the quarter-hour city)

A new proposal by Mayor Hidalgo, who has been in office since 2014, consists of converting Paris into a city in which nobody takes longer than 15 minutes to get to work or take their children to school with the aim of decarbonizing the economy and make Paris a healthier city.

LCZ

Local Climate Zone: a *climate*-related classification of homogenous urban structure and land cover.

Microclimate simulation

Is the suite of climatic conditions measured in localized areas near the earth's surface, these include temperature, light, wind speed, and humidity.

Morphological indicators

Are signposts that allow measuring the livability in an urban environment; they can include density, rugosity, porosity, sinuosity, occlusivity, compacity, contiguity, solar admittance, and mineralization.

Microclimate indicators

Are the air temperature difference (ΔT), wind speed difference (ΔWS), and PMV (Predicted Mean Vote) difference (ΔPMV).

Permeable surfaces

Surfaces that allow water to percolate into the soil to filter out pollutants and recharge the water table.

Radiative cooling

is the process by which a surface loses heat by thermal radiation.

solar irradiance/exposure/insolation

the output of light energy from the sun as measured on earth.

Sky view factor (SVF)

Is a geometric concept that is used to quantify the proportion of the visible sky or open canyon space in urban street canyons.

Territorial Air Climate Plan (PCAET)

French national climate plan that is used as a tool for coordinating energy and economic policies and also for improving the quality of life by examining: reducing greenhouse gas, emissions, climate change adaptation, energy efficiency, air quality, and renewable energy development.

T4QG

A Quantum-GIS plugin was created at the CRENAU Laboratory.

Urban boundary layer

is the spatially integrated heat and moisture exchanges between the city and its overlying air.

Urban canopy layer

The atmospheric layer between the ground and rooftops.

Urban design

Part of urban planning focuses on the design of places, i.e. buildings and the three-dimensional space between them. It is often defined as an intermediate scale between architecture and urban planning.

Urban fabric

The physical structure of an urban area.

Urban form

The physical form of an urban area consisting of street patterns, building sizes and shapes, architecture, and density.

Urban heat island (UHI)

Urban areas being warmer than the surrounding rural areas. Primarily a nocturnal phenomenon.

Urban morphology

is the study of the built form of cities, towns, and villages, their spatial composition at different scales; and physical characteristics.

Urban street canyon

The space delimited by the street and the façades of the buildings along the street.

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