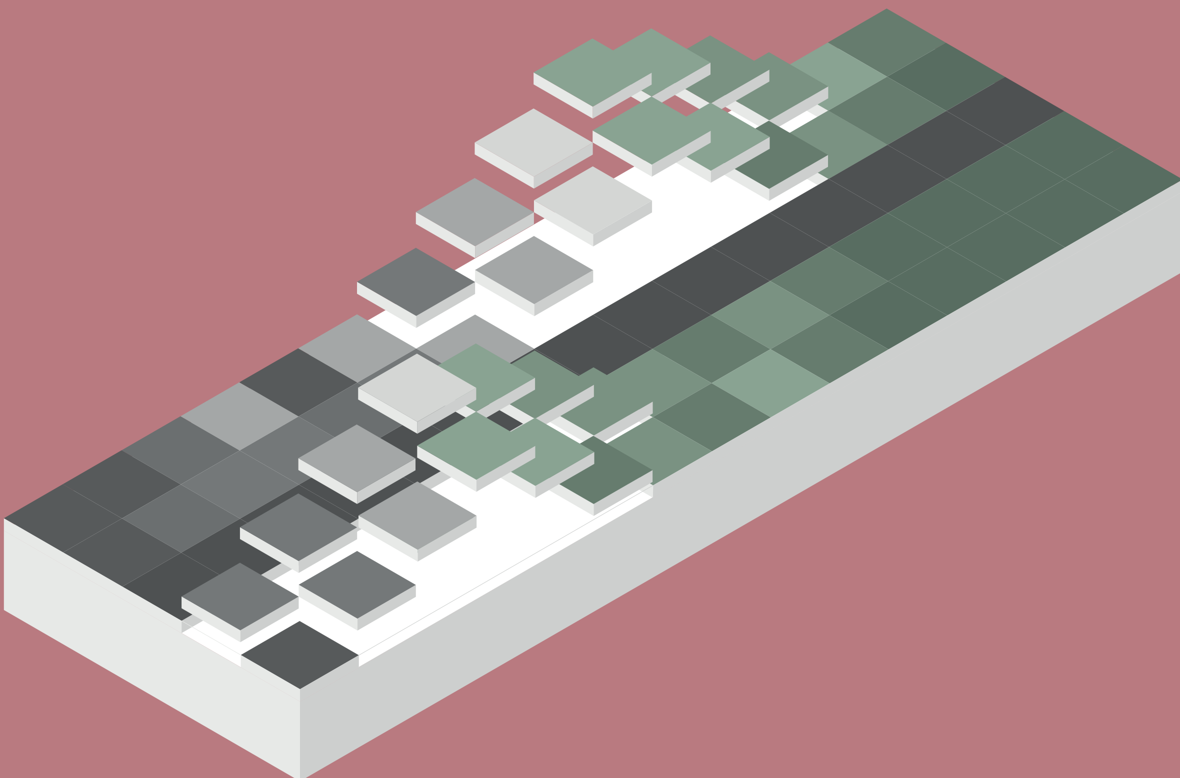
RIGHT TO A HEALTHY CITY

MITIGATION AND ADAPTATION STRATEGIES TO FACE URBAN AIR POLLUTION THROUGH PUBLIC SPACE DESIGN

SZYMON MICHALSKI



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SCHOOL OF ARCHITECTURE
URBAN PLANNING CONSTRUCTION ENGINEERING
MSC URBAN PLANNING AND POLICY DESIGN
MASTER OF SCIENCE THESIS
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TO FACE URBAN AIR POLLUTION
THROUGH PUBLIC SPACE DESIGN

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MASTER OF SCIENCE THESIS
Right to a healthy city: Mitigation and adaptation strategies
to face urban air pollution through public space design

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We will see each other again.

April, 2020

Szymon Michał Michalski

ABSTRACT

Climate change became one of the most discussed topics on both governmental and scientific levels. Air quality and its impacts on public health are a big part of that discussion. The official approach of every EU member bases on the implementation of big-scale energy transition strategies and green policies, but such a transition will take the next 30-50 years to be completed. There is a relatively long in-between period, which shapes challenges but also gives opportunities. The question emerges about what can be done now on the urban scale level.
This graduation project, by discovering the relationships between air pollution and public space design, tries to establish and propose new measures and solutions to mitigate air pollution in Warsaw, Poland. The multi-issues and inter-scalar approach tackle the public space design from the small scale of street design elements, to the big scale landscape system, following the grid of wide city streets. Design activity is focused on the proposed case study street in central Warsaw on which, with attention to improving urban air pollutions, the solutions are suggested to impact also urban green and soft mobility.
Overall, this graduation project attempts to underline the relevance of urban design in the process of mitigating air pollution in urban environments. It offers extensive, comprehensive, and alternative solution, which aim to support general air quality policies existing in modern cities.

KEY WORDS: Air pollution, Public space design, urban design, resilience, environmental planning

[IMG.0.01]
PEOPLE WEARING MASKS DANCE AMID HEAVY SMOG DURING A POLLUTED DAY AT A SQUARE IN FUYANG, ANHUI PROVINCE, CHINA JANUARY 3, 2017
source: REUTERS/File Photo

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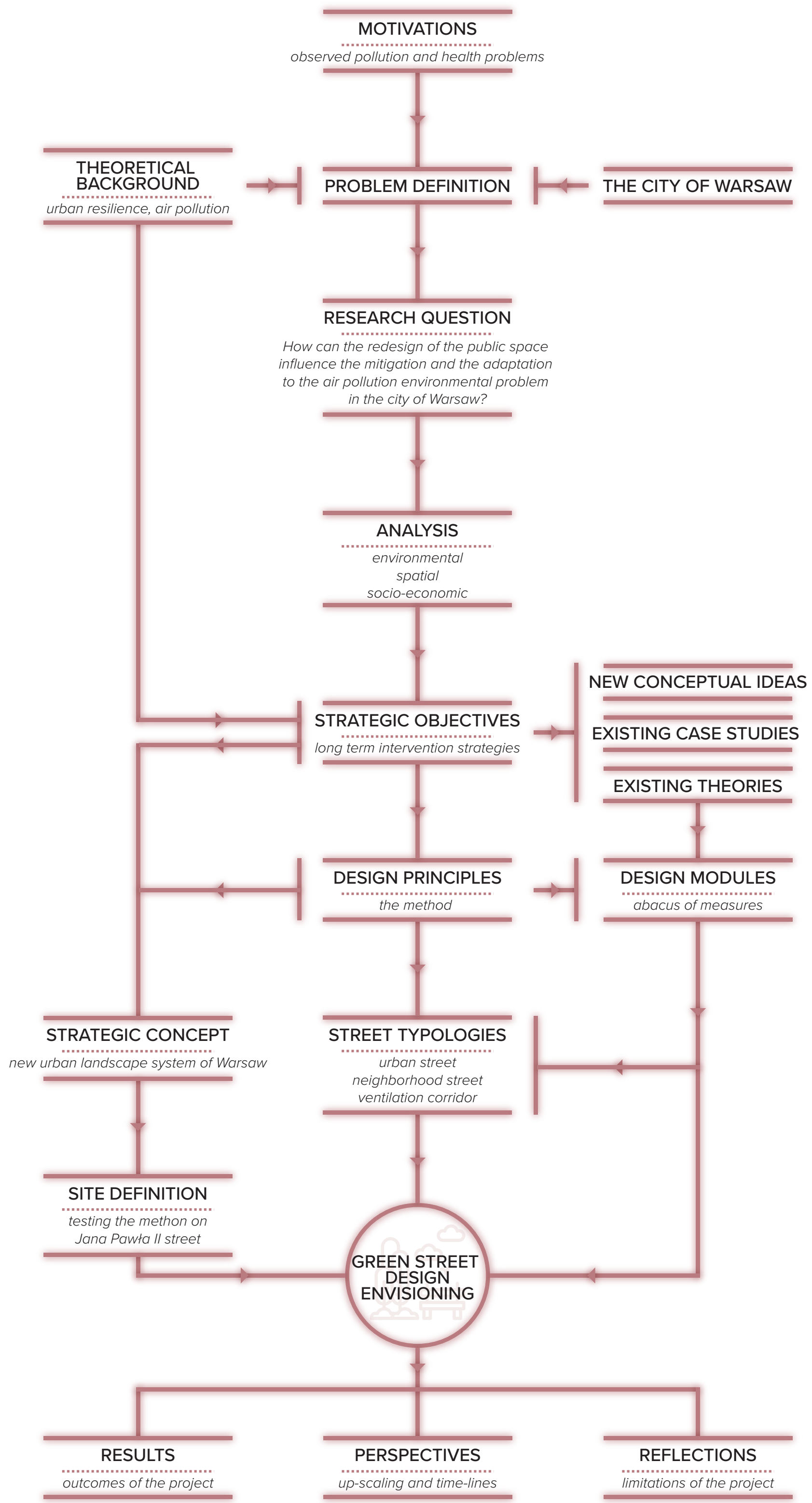


[FIG.0.01]
STRUCTURE OF THE WORK
source: by author

STRUCTURE OF THE WORK

The scheme presents how the working process has been conducted. Each of the steps brought significant progress to the overall work. From the first steps which had an **explorative** role, it was possible to understand and define the problem. Afterward, the **analytical** part helped to understand the intensity and spatial distribution of the phenomenon. This lead to the development of the **strategic** part, which set goals, defined the methodology, and big scale conceptual proposal to meet the goals. The **design** part was the response to the previously set goals. Afterward, the **empirical** part aimed to create a meeting point for strategy, planning, and design, in a specific context of a defined site to test the methodology and design. Finally, the **reflective** part allowed to describe the conclusions but also define the limitations that have been noticed during the project development. The full structure formed the complete working process during the development of this research.

On the design level, this research introduces an abacus of design solutions on a small scale, for the street design purpose. Later this abacus is developed into the form of a street typology. The repetitive typologies form a large scale landscape system using the structure of public space. The abacus is composed of around 40 design modules, prepared using the existing solutions from all around the world, which have been successfully implemented to mitigate urban air pollution. Overall, the work proposes inter-scalar and multi-issues solutions to face to urban air pollution within the public space design.

The comprehensive analytical part of the environmental and social conditions of the city of Warsaw, conducted using the GIS tools, give the definition of the most affected areas by the air pollution problem, and allow to create a big scale strategic response using the specific case study - Jana Pawła II street in central Warsaw, with corresponding public space design.

Finally, the last part, divided into results, perspectives, and reflections, aims to critically evaluate the entire process and give more objective conclusions about the programs and solutions proposed.

chapter 1

AIR POLLUTION

- MOTIVATIONS
- WHAT IS AIR POLLUTION
- TYPES OF POLLUTANTS
- TYPES OF SMOG
- POLLUTION NORMS
- SMOG AND THE IMPACT ON HEALTH
- SOCIETAL RELEVANCE
- PROBLEM DEFINITION

“AIR POLLUTION IS ONE OF THE MOST SERIOUS ENVIRONMENTAL RISKS”

- *ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)*

MOTIVATIONS

Air pollution is a visible cause of death on a global scale. Polish Ministry of Health has estimated that due to the smog-related diseases, the country has lost 67 000 inhabitants in 2017 (NFZ, 2017). Because of the relevance of the topic, this thesis will focus on air pollution and its relation to public space.

Warsaw, the capital of Poland, the city where I was born and raised, is facing intensive problems with the air quality. The city is taking steps in improving the situation, but they are limited to a narrow type of policies, tackling only the most substantial emissions related to burning fossil fuels. It is indeed the crucial step, but several alternatives could be taken into consideration, including rethinking the way we design our city and its public spaces, to transform them into the more pollution-resistant ones.

I believe that air pollution should be one of the crucial topics in the urban discussion, due to its large scale of exposure of the entire city population. There is a high necessity of understanding those topics and introducing them to the public in order to change the negative habits but also find the most effective design solutions.

The paraphrase of Lefebvrian ”Right to the city” is used in the title of this work. Lefebvre’s idea was to call for a radical restructuring of social, political, and economic relations, both in the city and beyond. (Purcell, 2002). Due to the high importance of the topic, and severity of the consequences, I believe that this call should be expanded to include also the environmental issues, which lack negatively affects the existence of social interactions that guarantee urban life.

[IMG.1.01]
SMOG EPISODE OVER PRAGA DISTRICT IN WARSAW
source: Mateusz Wlodarczyk/NurPhoto, via Getty Images

WHAT IS AIR POLLUTION

Air pollution is a harmful substance in the air (Cambridge Dicctionary, 2020). Smog is a mixture of smoke, gases, and chemicals, especially in cities, that makes the atmosphere challenging to breathe and harmful for health (ibid, 2020). The word smog derives from the combination of English words fog and smoke. While air pollution is a highly concentrated single hazardous substance in the air, the smog is being described as a combination of them.

While trying to understand air pollution, identifying the primary pollutants and the sources of their origins might become a significant difficulty. They are everywhere around us and come from a wide variety of sources. However, the first step to understanding the relationship between pollution, environment, health, and possible risks, is to summarize the main pollutants and their primary sources and effects.

In Poland, air pollution is measured by the Chief Inspectorate Of Environmental Protection (GIOŚ), according to the levels of seven chemical compounds in the air. The compounds are: Particulate matters (PM2.5 and PM10), Sulfur dioxide (SO2), Nitrogen dioxide (NO2), Carbon monoxide (CO), Benzene (C6H6) and Ozone (O3). Apart from those also the levels of Benzopyrene (C20H12) and Heavy Metals (Lead-Pb, Arsenic-As, Nickel-Ni, and Cadmium-Cd) in the PM10 are measured and defined. The result is presented on the 6-levels scale: Very Good, Good, Moderate, Sufficient, Poor, Very Poor.

European Air Quality Index, operated by the European Environment Agency, is based on the levels of 5 primary pollutants (PM2.5, PM10, SO2, NO2, O3). The result is presented on the 5-levels scale: Very Good, Good, Moderate, Poor, Very Poor (Directive on Ambient Air Quality, 2008). These differences already show contrasts in measuring the problem and presenting the data to the public.

[IMG.1.02]
SMOG EPISODE IN PARIS, FRANCE
source: Reuters/Philippe Wojazer

[IMG.1.03]
SMOG EPISODE IN SHANGHAI, CHINA
source: REUTERS/Aly Song

TYPES OF POLLUTANTS

PARTICULATE MATTER (PM10, PM2,5)

Particulate matters in the air are the mixture of organic and non-organic substances. The size might specify them – PM10 referring to particles less than 10 µm in diameter, and PM 2,5 referring to those smaller than 2,5 µm. They can be naturally generated like sea salt, but also combustion created smoke particles. They are released during the combustion of fossil fuels related to power generation, home heating, motor vehicles, and industrial activities, including waste incineration. Construction activities may be a significant source of dust the same as unsurfaced roads (Elsom, 1996). Particulate matters with a diameter of fewer than 10 µm are absorbed in the upper respiratory system and bronchi. When inhaled, they lead to various reactions like coughing, difficulty in breathing, and shortness of breath. Strong allergic reactions have been observed (WIOŚ Warszawa, 2018). Small dust fractions with a diameter of fewer than 2,5 µm can penetrate the bloodstream, and more prolonged exposure to high dust concentrations can have a significant impact on the course of heart disease (heart attack) or increase the risk of cancer, especially lung cancer. Dust with a diameter of fewer than 2.5 µm is absorbed in the upper and lower respiratory tracts and can also penetrate the bloodstream (WIOŚ Warszawa, 2018).

SULPHUR DIOXIDE (SO2)

Sulfur Dioxide is a gas coming mostly from the combustion of the sulfur-containing fossil fuels such as coal or heavy fuel oil (Elsom, 1996). The concentration of SO2 affects breathing and causes cardiovascular diseases (Scorecard, 2011). It is also the primary contributor to acid rain, which changes the environments of the lakes and rivers, with the ability to destroy trees and greenery. It is considered as an industrial pollutant.

CARBON MONOXIDE (CO)

Carbon monoxide is an odorless and colorless gas produced during the incomplete combustion of carbon-based fuels. The presence of the CO is strongly correlated with the heavy traffic, and its accumulation can be observed along the main roads within the urban environment. The areas along roadsides are especially exposed and can be vulnerable to the high CO concentrations. Carbon monoxide is a systemic poison, which affects health. It interferes with the absorption of oxygen by the blood. The presence of CO in the blood system reduces the oxygen-carrying capacity of the blood and has the potential to starve the brain (Elsom, 1996).

NITROGEN DIOXIDE (NO2)

Nitrogen Dioxide is another pollutant related to combustion, which makes it strongly related to traffic in the city. It is a reddish-brown gas that has a severe impact on health. It has been proven that bronchitic symptoms of asthmatic children increase in association with annual NO2 concentration (WHO, 2005). NO2 causes serious lung diseases and respiratory problems to people exposed in the urban environment. Nitrogen Dioxide is the gas responsible for the characteristic brownish color of the smog (Airly, 2019).

BENZOAPYRENE

Benzo(a)pyrene is an organic chemical compound that high chronic toxicity, which is associated with its accumulation capacity in the body. It is a highly carcinogenic compound that has mutagenic properties. Other side effects include irritation of the eyes, nose, throat, and bronchi. Benzo(a)pyrene is emitted during the combustion of wood, coal, and garbage (usually PET-type plastics) (WIOŚ Gdańsk, 2015).

OZONE

Ozone is a secondary pollutant, being crated during photochemical reactions between nitrogen oxides and volatile organic compounds in the sunlight. It is beneficial in the upper atmosphere because it protects the earth from ultraviolet radiation (Polski Alarm Smogowy, 2019). It is mostly present during summer, in sunny climates, and warmer days, in the urban environments with a high concentration of individual Diesel vehicles (ibid).

HEAVY METALS (PB, AS, CD, NI)

Heavy metals are present in the smog. They can form part of the Particulate matters. They are released from different types of industrial activity and are actively poisonous in high doses (Elsom, 1996).

TYPES OF SMOG

Due to different origin and composition we can define 3 different types of smog (Wallace, Hobbs, 2006)

SULFUROUS SMOG
(LONDON SMOG, CLASSICAL SMOG)

Sulfurous smog results from a high concentration of sulfur oxides being released into the air, because of burning fossil fuels (Healthfully, 2017). While the burning of coal is the primary reason why sulfur oxides are released into the air, the other causes stem from the production of crude oil and metallic ore. London-type smog is characteristic of the moderate climatic zone, with damp autumn and cold winter, due to the heating season lasting from November to February. It is composed mostly of PM2,5, PM10, SO_2, CO, and others (Elsom, 1996).

PHOTOCHEMICAL SMOG
(LOS ANGELES SMOG)

Photochemical smog is a type of air pollution caused by nitrogen oxide, hydrocarbons, and sunlight. (Healthfully, 2017). Nitrogen oxide is commonly produced from the internal combustion of engines and reacts in the atmosphere with the sunlight rays, which increases the levels of ozone and formaldehyde in the atmosphere. Photochemical smog occurs mainly in the subtropical zones in the summer months. It is composed mostly by O_3, NO_2, and others

VOLCANIC SMOG

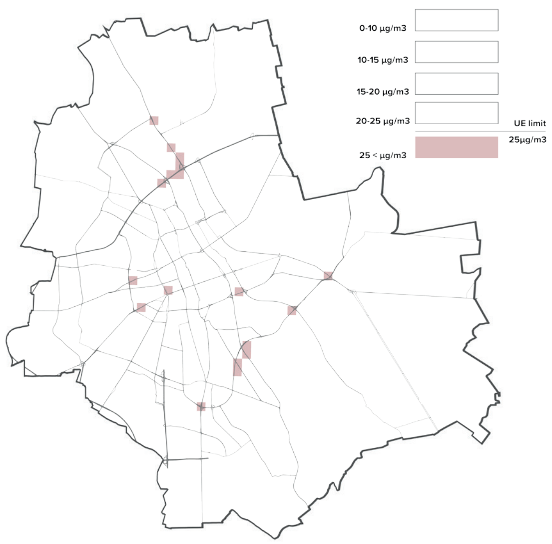
Volcanic smog is a type of smog that forms when gases and particles are released from an erupting volcano and mix with sunlight, oxygen and moisture. Some of the chemicals in volcanic smog can be damaging to the environment, including animals, plants and humans. This type of smog commonly takes place in the Hawaiian Islands, as the Kilauea volcano has been erupting everyday since 1983 (Healthfully, 2017). It is composed mostly by SO_2, NO_2, CO and dust of the natural origin.

[IMG.1.04]
SMOG EPISODE
IN LOS ANGELES, USA
source: Yenwen, Getty Images

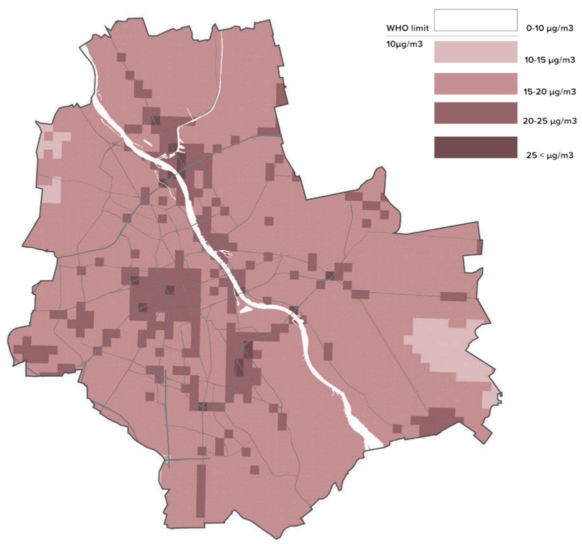
[IMG.1.05]
SMOG EPISODE
IN MILAN, ITALY
source: Claudio Furlan/LaPresse

POLLUTION NORMS – WHO, EU, POLAND

Several organizations have set the limits for measuring components of the air quality. Those limits differ from each other. We can also observe differences between amounts called as 'recommended' and 'required.' Those norms also vary due to the perspective and goals of each organization. The most important are the norms set by the World Health Organization and the European Union. The general EU norms are also recommended for each of the member states, however, we can observe some other norms on the national levels which are not coherent. In the table the norms of UE and Poland with the guidelines of WHO have been compared. The World Health Organization levels are visibly more restrict than the national levels. They have been set with an aim to create a harm-neutral environment, while the UE and national levels had to be a compromise between public health and possible economic problems in the industrial sector if the norms would have been set too strict. For the aim of this research, the WHO norms have been selected as goal conditions. The maps show the same data of the spatial distribution of the PM2.5 in the city of Warsaw, but separately for the EU and WHO norms.



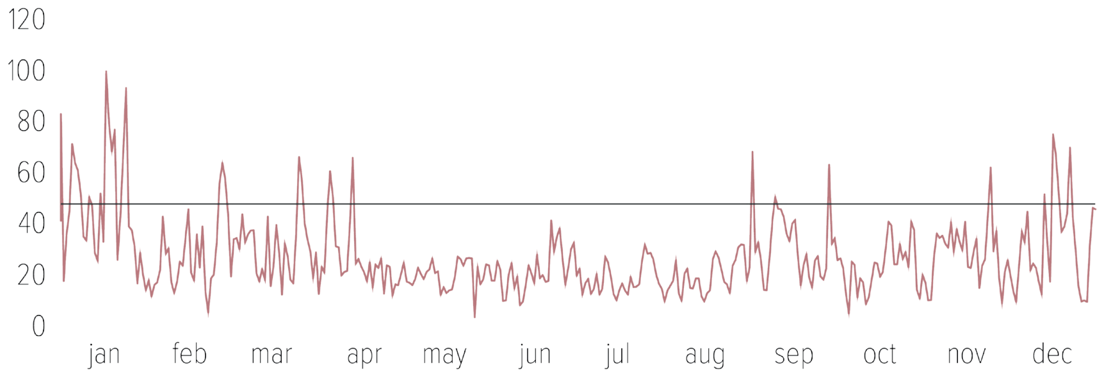
[FIG.1.01]
PM2.5 - UE NORMS (AV. ANNUAL)
source: Self-elaboration by author
data: WIOŚ MAZOWSZE
(National Environmental Agency for Masovian region) 2015



[FIG.1.02]
PM2.5 - WHO NORMS (AV. ANNUAL)
source: Self-elaboration by author
data: WIOŚ MAZOWSZE
(National Environmental Agency for Masovian region) 2015

[FIG.1.03]
NORMS - COMPARISION
source: Self-elaboration by author
data: European Commision - Air Quality Standards
WHO Guidelines for indoor air quality: household fuel combustion
Chief Inspectorate of Environmental Protection of Poland

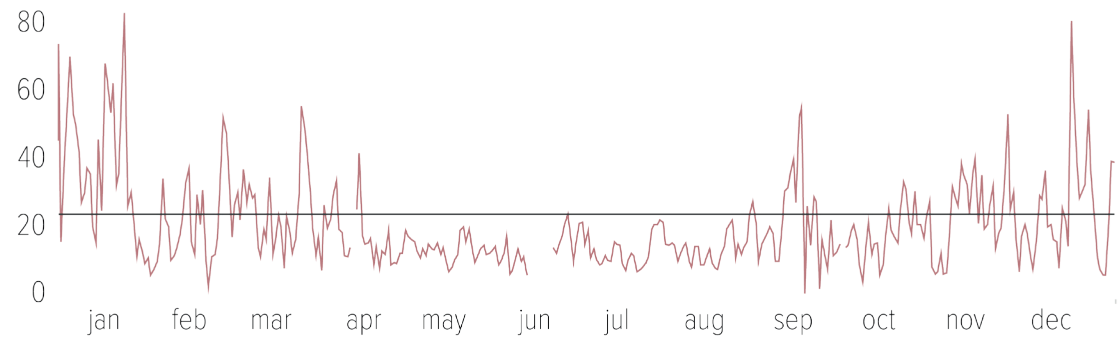
		WHO guidelines		EU norms		PL norms	
	averaging period	concentration	permitted exceedance each year	concentration	permitted exceedance each year	concentration	permitted exceedance each year
PM 2,5	1 year	10 $\mu g/m^3$	n/a	25 $\mu g/m^3$	n/a	20 $\mu g/m^3$ from 2020	n/a
	24 hours	25 $\mu g/m^3$	3	n/a	n/a	n/a	n/a
PM 10	1 year	20 $\mu g/m^3$	n/a	40 $\mu g/m^3$	n/a	40 $\mu g/m^3$	n/a
	24 hours	50 $\mu g/m^3$	n/a	50 $\mu g/m^3$	35	50 $\mu g/m^3$	35
SO_2	24 hours	20 $\mu g/m^3$	n/a	125 $\mu g/m^3$	3	125 $\mu g/m^3$	3
	1 hour	n/a	n/a	350 $\mu g/m^3$	24	350 $\mu g/m^3$	24
	10 minutes	500 $\mu g/m^3$	n/a	n/a	n/a	n/a	n/a
NO_2	1 year	40 $\mu g/m^3$	n/a	40 $\mu g/m^3$	n/a	40 $\mu g/m^3$	n/a
	1 hour	200 $\mu g/m^3$	n/a	200 $\mu g/m^3$	18	200 $\mu g/m^3$	18
CO	max. 8h/day	10 mg/m^3	n/a	10 mg/m^3	n/a	10 mg/m^3	n/a
O_3	max. 8h/day	100 $\mu g/m^3$	daily	120 $\mu g/m^3$	25 / 3 years	120 $\mu g/m^3$	25 / 3 years
C_6H_6	1 year	n/a	n/a	5 $\mu g/m^3$	n/a	5 $\mu g/m^3$	n/a
$C_{20}H_{12}$	1 year	n/a	n/a	1 ng/m^3	n/a	1 ng/m^3	n/a
Ni	1 year	n/a	n/a	20 ng/m^3	n/a	20 ng/m^3	n/a
Cd	1 year	n/a	n/a	5 ng/m^3	n/a	5 ng/m^3	n/a
As	1 year	n/a	n/a	6 ng/m^3	n/a	6 ng/m^3	n/a
Pb	1 year	n/a	n/a	0,6 $\mu g/m^3$	n/a	0,6 $\mu g/m^3$	n/a



[FIG.1.04]

DAILY PM10 LEVELS COMPARED WITH THE 24H UE/WHO NORM - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author
data: GIOŚ (General National Environmental Agency) 2016



[FIG.1.05]

DAILY PM2.5 LEVELS COMPARED WITH THE 24H WHO NORM - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author
data: GIOŚ (General National Environmental Agency) 2016

We can observe a drastic change in the intensity of the problem, with UE norms of the annual level being exceeded only in most crucial points of the city, and WHO guidelines being exceeded on the significant areas in and out of the city. Some limits, as NO2 or SO2, have been set on the same level for WHO, EU, and directly by Poland. It is important to remember that the annual levels are averaged and present a standardized situation. However, air pollution as a dynamic problem can occur only in several days per year, strongly affecting public health, and those phenomena can disappear while being presented in the aggregate annual averaged data. It is essential to compare it with 24h or 8h data. For each of the elements measured in the hourly time frame, there is permitted exceedance each year allowed, measured by the numbers of days in which the levels can be exceeded.

An example is presented with the case of PM 10. All the PM10 norms for the 24 hours have been set on the 50 µg/m3. EU and PL allow this limit to be reached 35 days per year. On the presented station (al. Niepodległości street), the limit of 50µg/m3 has been exceeded 29 times during 2016. That means that statistically, the situation fitted the norms. However, WHO guidelines do not allow to exceed that limit during any day of the year, which makes the existing conditions not coherent with WHO norms.

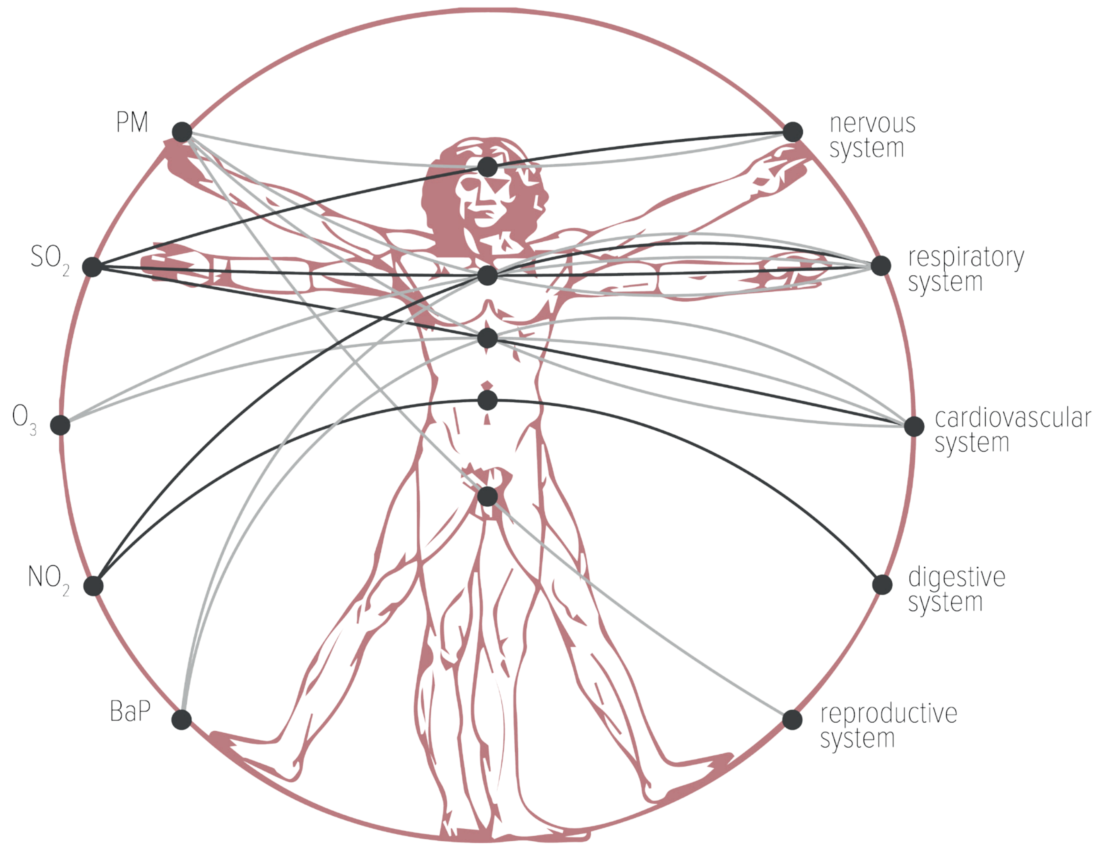
For the PM2.5, the 24h norms are set only by the WHO, and the level is 25 µg/m3, with permitted exceedance each year set on three days per year. That level has been exceeded 99 times during the entire 2016, which means that almost 1/3 of the entire year, the levels of PM2.5 were higher than WHO guidelines. The correct understanding of the differences in norms is crucial in order to accurately analyze and define the origins of the air pollution problem in Warsaw. The most detailed spatial analysis of the pollutants will be presented in the next chapters.

SMOG AND THE IMPACT ON HEALTH

The impact of smog on human health has been well measured and described in the literature. However, Yang, Hoffmann, and Scheffran discuss that the existing knowledge about the health impact is based on statistical records of mortalities, mostly from the Western World, and lacks more in-depth analysis of the local context (Yang and others, 2017). Recent extreme smog phenomenons in China and India have paradoxically increased the knowledge about those impacts. China, while being the most extreme case study for the smog environmental problem, is now facing the daily mortality of smog-related diseases around 4400 people (Rohde, Muller 2015). However, this problem is observed globally. It has been estimated that ninety-two percent of the world's population lives in places where air quality levels exceed the World Health Organization (WHO) limits set by WHO Ambient Air Quality Guidelines (WHO, 2016). It is not better in Europe, where 9 out of 10 European city-dwellers are exposed to pollution over WHO guidelines (The Economist, 2015).

Research conducted at the Medical Center of the University Medical Center - Universitätsmedizin Mainz in Germany declared that in 2015 air pollution contributed to 790 000 death in entire Europe (659 000 in the UE) (Lelieveld and others, 2019a). Of these deaths, between 40-80% were due to cardiovascular diseases (CVD), such as heart attacks and stroke. Air pollution caused twice as many deaths from CVD as from respiratory diseases (MedicalPress, 2019).
The observation of the individual countries showed that air pollution caused an excess death rate of 154 per 100,000 in Germany (a reduction of 2.4 years in life expectancy), 136 in Italy (reduction in life expectancy of 1.9 years), 150 in Poland (reduction of 2.8 years), 98 in the UK (reduction of 1.5 years), and 105 in France (reduction of 1.6 years). Excess death rates were particularly high in eastern European countries, such as Bulgaria, Croatia, Romania, and Ukraine, with over 200 each year per 100,000 of the population (Lelieveld and others, 2019b)

Warsaw Smog Alert, an environmental NGO, has used the data provided by the local authorities to calculate that an average citizen of Warsaw spending 4h outside absorbs as much Benzo(a)pyrene as if he smoked four cigarettes per day (1307 per year) (Omnicalculator, 2019). The same NGO estimated that



[FIG.1.06]

EFFECTS OF AIR POLLUTION ON HUMAN BODY

source: by author
idea: Marcello Felice Vietti

just in Warsaw, the costs of treating the health diseases related to smog exposure, have reached 6 billion PLN per year (1,4 billion Euro) (Polski Alarm Smogowy, 2019).

Some of the recent research showed that the minimal diameter of PM2.5 makes it staying inside the airborne for a longer time, carrying toxins through small passageways, penetrating buildings, and finally, to be inhaled easier by humans. Postmortem analysis detects that people living in more polluted areas for long periods tend to have elevated concentrations of PM2.5 in their brains, smaller brain volume, and higher rates of brain infarcts or areas of necrosis. (Chen, 2018)

Unfortunately individual residents who are affected by smog pollution can often do very little to prevent it. At the individual level, people can mostly diminish their exposure to it. Some options could be encouraging the change of household coal or gas cookstoves to electrical ones, adopting a flexible (home-based and office-based) work system when possible, and also raising public awareness about exposure reduction (Yang and others, 2017).

Clean air has been defined as one of the most basic, universal human health needs (Schandl and others, 2012). However, it has been estimated that in 2015, 47300 people died in Poland due to the exposure to PM2.5, NO2, and O3 (EEA, 2015). Increased mortality is associated with long-term exposure to pollutants, and affects shorter expected life length. The research showed that the increased exposure to PM2.5 by 10 µg/m3 in the long term decreases life expectancy of 0.61 years (Pope, 2002).

It is essential to mention that the costs of lost wealth caused by premature deaths due to air pollution in the OCED Europe area reached 730 billion USD in 2010 (OECD, 2016).

[FIG.1.07]

EU URBAN POPULATION EXPOSED TO AIR POLLUTANTS IN 2014-2016

source: self-elaboration of data provided by European Environmental Agency
data: EEA (European Environmental Agency) - "Air pollution still too high"

SOCIETAL RELEVANCE

As proven before, Poland has one of the highest shares in air pollution-related death in the EU. In the last years, we can observe an ongoing increase in awareness among citizens. A group of NGOs and city activists (Warszawa bez Smogu, Akcja Demokracja) are organizing peaceful protests to inform more inhabitants about the situation. Mass media has also recognized the problem. Gazeta Wyborcza (polish daily newspaper) has started a weekly series about climate change, including the air pollution problem, devoting their main page every Friday to tackle that issue. Several other newspapers regularly report about the difficult situation, especially during winter seasonal smog episodes. In 2018 group of polish actors and celebrities has sued the state, demanding compensation from the state for the lack of access to clean air. The case has been won, creating a precedent for future similar moves. In the justification, the court stated that there were undoubtedly very significant dust exceedances in Poland. In the court's assessment, the legislation on air quality clearly shows an obligation for EU member states to care for its condition. The international media have also recognized the situation in Poland:

The New York Times[1]:
"Warsaw Grapples With Gloomy, Gray Smog"
The Economist[2]:
"Why 33 of the 50 most-polluted towns in Europe are in Poland"
Associated Press[3]:
"Smog-plagued Warsaw to limit access by car, coal heating"

However, air pollution does not concern only Poland or Europe. As mentioned before, WHO has estimated that in 2012 around seven million people die globally as a result of air pollution exposure (WHO, 2016). Overall, well-being of societies is shaped by their health aspects, and air pollution, as described, has a crucial role and deserved our attention and concern.

Newspaper articles about smog in Warsaw:

1 - *https://www.nytimes.com/2017/01/14/world/europe/warsaw-air-pollution-smog.html*
2 - *https://www.economist.com/europe/2018/01/18/why-33-of-the-50-most-polluted-towns-in-europe-are-in-poland*
3 - *https://apnews.com/3590a79ad346408c853aac622ca0f2a5*

[IMG.1.06]
ANTI-SMOG DEMONSTRATION IN FRONT OF THE CITY HALL OF WARSAW
source: Akcja Demokracja/Warszawski Alarm Smogowy

[IMG.1.07]
SCHOOL STRIKE FOR CLIMATE IN POLAND, NOVEMBER 2019
source: naszemiasto.pl

PROBLEM DEFINITION

The first chapter of this work shows the relations between the health, cities, problems with understanding the core of air pollution, and the social awareness of the topic. Air is continuously moving, crossing significant areas of land, mixing, and its original composition is permanently changing. Processes related to the anthropological activities such as urbanization, the industrialization of the XIX century, popularization of combust engines and cars in the XX century, have been leading contributors to the air quality.

Nowadays, the topics related to air pollution are mostly associated with Asian countries, like China or India. Despite our collective beliefs, air pollution poses the single most considerable environmental health risk also in Europe today (EEA, 2015). The risk exists here and now, and it is real. In the last years, all EU countries have incorporated new measures, limits, and policies to tackle the pollution problem. However, a large part of the European population is still exposed to air pollution. The situation is even worst if we compare the existing situation with the values and recommendations of the World Health Organization, which restricts goals that have a bit set to obtain an utterly pollution-neutral environment for humans. Figure (FIG.1.07, page 31) shows that still more than 50% of the EU population is exposed to the risky concentration of 4 of 6 primary pollutants. That confirms that air pollution is still one of the most significant single environmental health risks in the EU and the world.

According to several researches Polish, Italian and Bulgarian are the populations that breathe the most polluted air. Among the continent's 100 worst cities for air quality, 29 are in Poland and 24 in Italy (IQAir, 2020). Italian town of Ceglie Messapica is the most polluted city in the entire EU (8th in Europe, including non-EU countries), followed directly by the polish town of Goczałkowice Zdrój. In the top 50 most polluted cities in Europe, we can also find Milan, Venice, Napoli and Modena in Italy, and Cracow and Katowice in Poland. In the same research, Warsaw has been called the 104th most polluted city in Europe. As a reflection, air pollution in those cities is a real emergency that needs to be tackled as soon as possible.

[IMG.1.08]
CLAUDE MONET'S PAINTING WHICH IS BELIEVED TO SHOW LONDON'S SMOG EPISODE OF VICTORIAN ERA
"Trouée de soleil dans le brouillard" (Sun Breaking Through the Fog) series: Houses of Parliament, 1904. London, Musée d'Orsay, Paris

chapter 2

THE CITY OF WARSAW

INTRODUCTION TO THE CITY

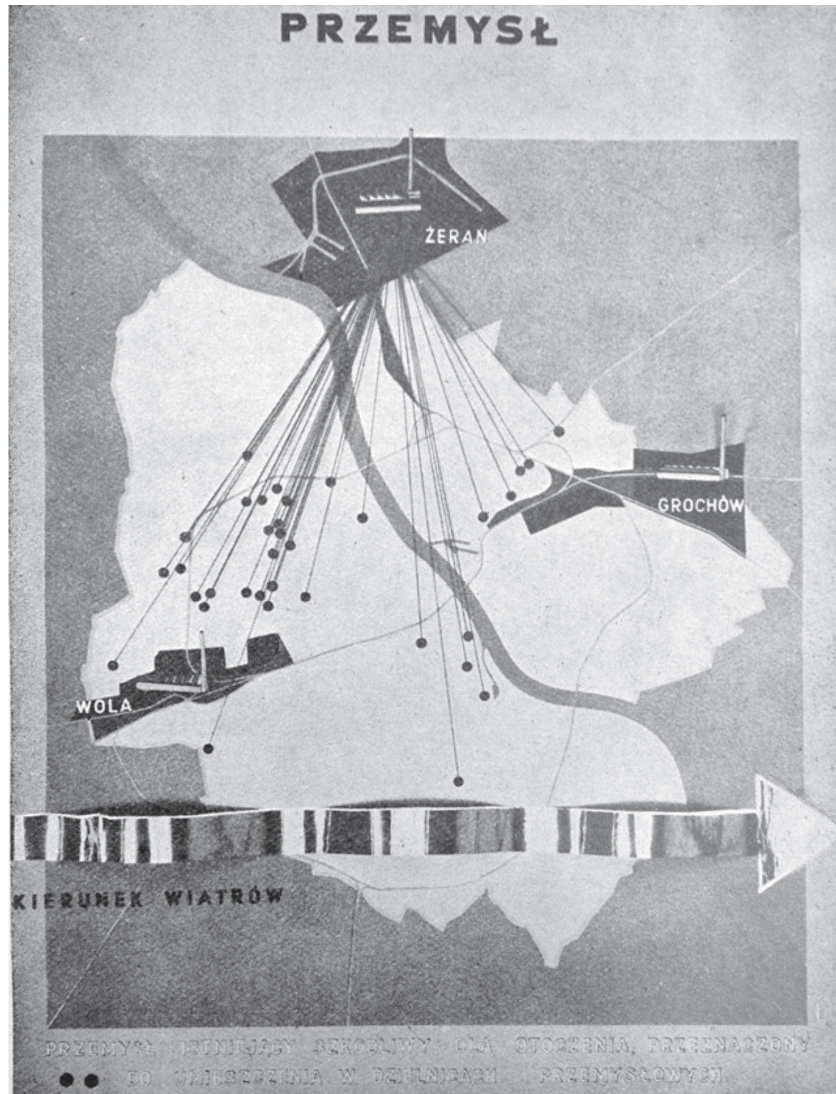
Warsaw, the capital of Poland, with 1 777 972 inhabitants (Local Data Bank, 2019), is the biggest city in the country. It has a surface area of 517,2 km^2. Comparing to 181,8 km^2 of Milan (comune), 105,4 km^2 of central Paris and 219,3 km^2 of Amsterdam, Warsaw is a big and spread city, with low-density level 3437 (ppl/km2) (Eurostat, 2019). Because of the incorporation of green areas and forests into the city, it is characterized nowadays by high amounts of green spaces - 40% of the city area is green (UM Warszawa, 2019). One of the main problems of the modern city is the urban sprawl and low levels of density in central, well-communicated parts of the city. The city is strongly car-oriented, which harms air quality. With fast-growing public transportation in the last 15 years, including a complete redesign of the bus transportation system and improvement of its quality, construction new metro line (M2), the extension of the old metro line (M1), active plans for another metro line (M3), growth of the suburban fast train system (SKM), there is a chance of redesigning the public space in the central areas of the city and limiting the accessibility of the car. This process has already started but is lacking a structured and systematic approach, which creation is one of the aims of this thesis.

URBAN GREEN AND AIR POLLUTION IN PRE-WAR PLANS

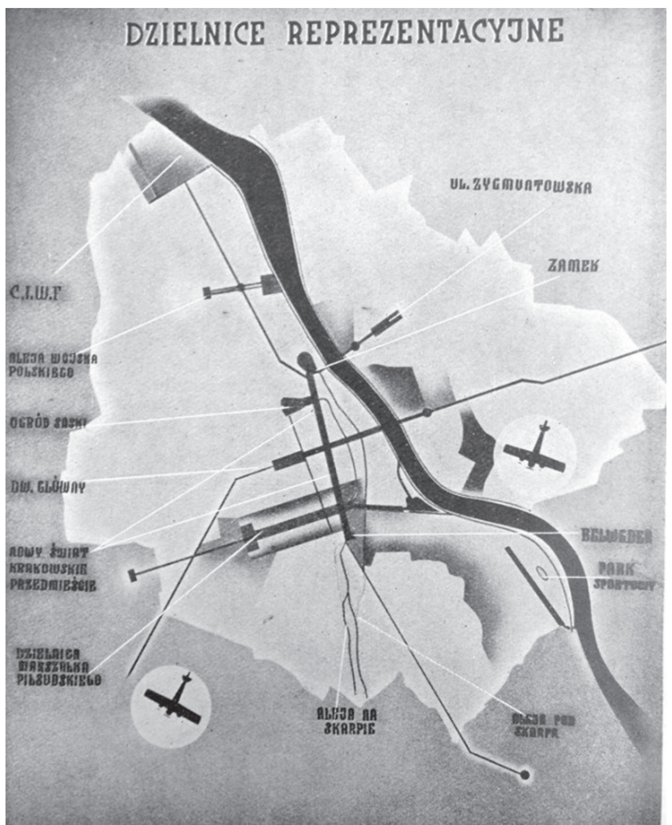
Warsaw Structure Plan, prepared in 1928 by city urbanists, under supervision of Stanisław Różański was a typical zoning plan, characteristic for that period in European urbanism. Together with the precise definition of residential, industrial, and office/services districts, it came with the definition of green areas that were supposed to penetrate the urban structure, bringing green from outside into the city's core. That was one of the first clear definition of what forms the modern ventilation system of the city. Just before the II World War, the city of Warsaw was facing dynamic growth. One of the plans from 1938, presented on the right page, has incorporated the wind analysis and proposed to relocate the industries to the north and east, due to the most common western wind direction, to avoid exposition of the central districts to the toxic elements coming from the industrial areas of Wola district. The pre-war ventilation corridors are present in the modern urban structure of the city, and are mapped in the further part of this research [Fig.4.20 and 4.21].

[IMG.2.01]
WARSAW STRUCTURE PLAN 1928, WITH DEFINITON OF GREEN VENTILATION CORRIDORS
source: Plan Ogólny Wielkiej Warszawy Stanisława Różańskiego

[IMG.2.02]
PLAN OF INDUSTRIAL RELOCATION 1936 (INCLUDING WIND ANALYSIS), DEFYING „WOLA" AS AN INDSTRIAL BUT EMISSIONS FREE ZONE
source: Warszawa przyszłości, 1936 Komitet Wystawy "Warszawa przyszłości"

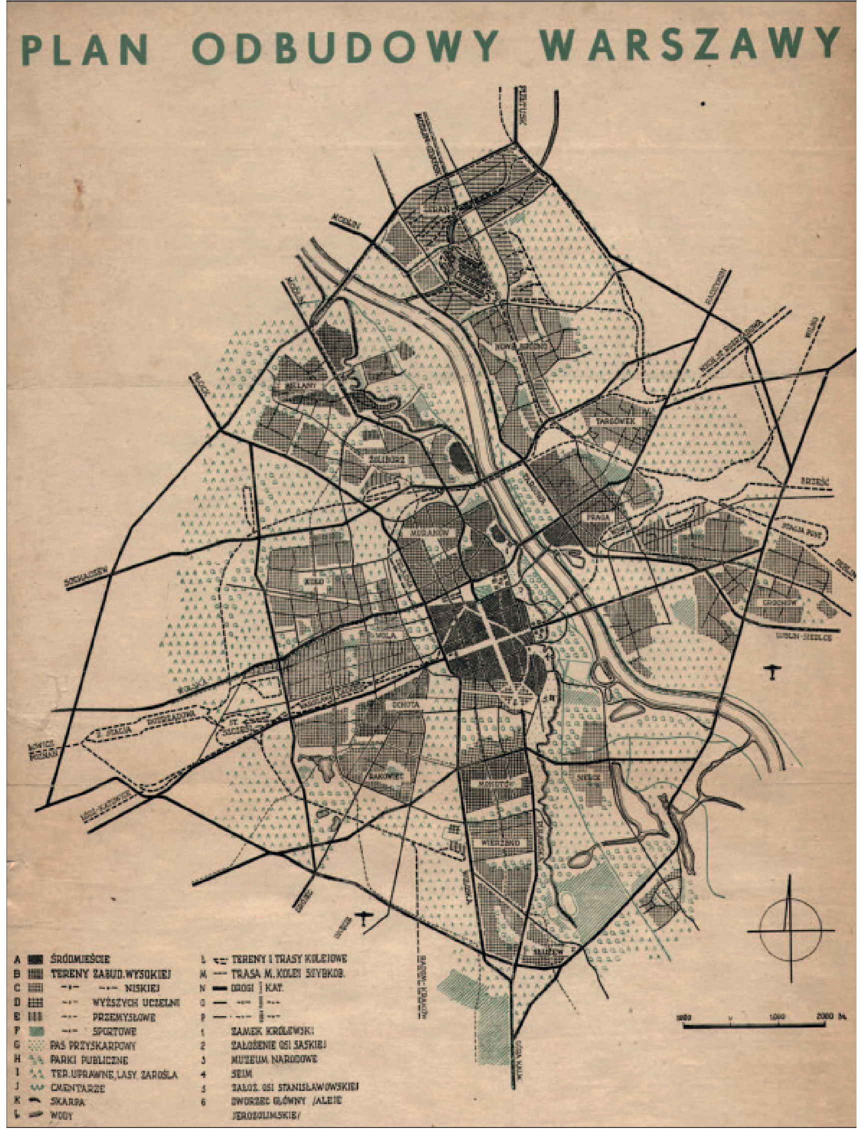


[IMG.2.03]
PLAN OF REPRESENTATIVE ZONES, 1936
source: Warszawa przyszłości, 1936 Komitet Wystawy "Warszawa przyszłości"



POST-WAR RECONSTRUCTION

During the II World War, Warsaw faced severe damage and has been one of the most destroyed cities in Europe. According to research done by Marek Gretter, Warsaw lost 100% of its bridges, 90% of industrial buildings, 90% of historical monuments (including churches), 95% of cultural buildings, 90% of health buildings, 70% of education buildings and 72% of residential buildings (Gretter, 2004). Massive and total destruction was, however, also a big chance for the post-war reconstruction and elimination of the pre-war problems. There were many concerns about the pre-war capital - it was over-populated, with an inefficient transportation system, it had too little greenery or public squares, and terrible housing conditions. After the war, the main focus was put on the city's urban reform. The creation of a clear communication system, improvement of the layout of streets that were too narrow and confusing before the war, became the priorities. The city has been given new, wide boulevards, buildings were dispersed, green areas were enlarged. Because of the destruction and the reconstruction, first in the social-realism style, and later on the soviet modernism, the city has reached the modern form with extremely low-density level, and low concentrations of the built environment, comparing to other European cities. A detailed analysis of those topics has been presented in the following chapters.

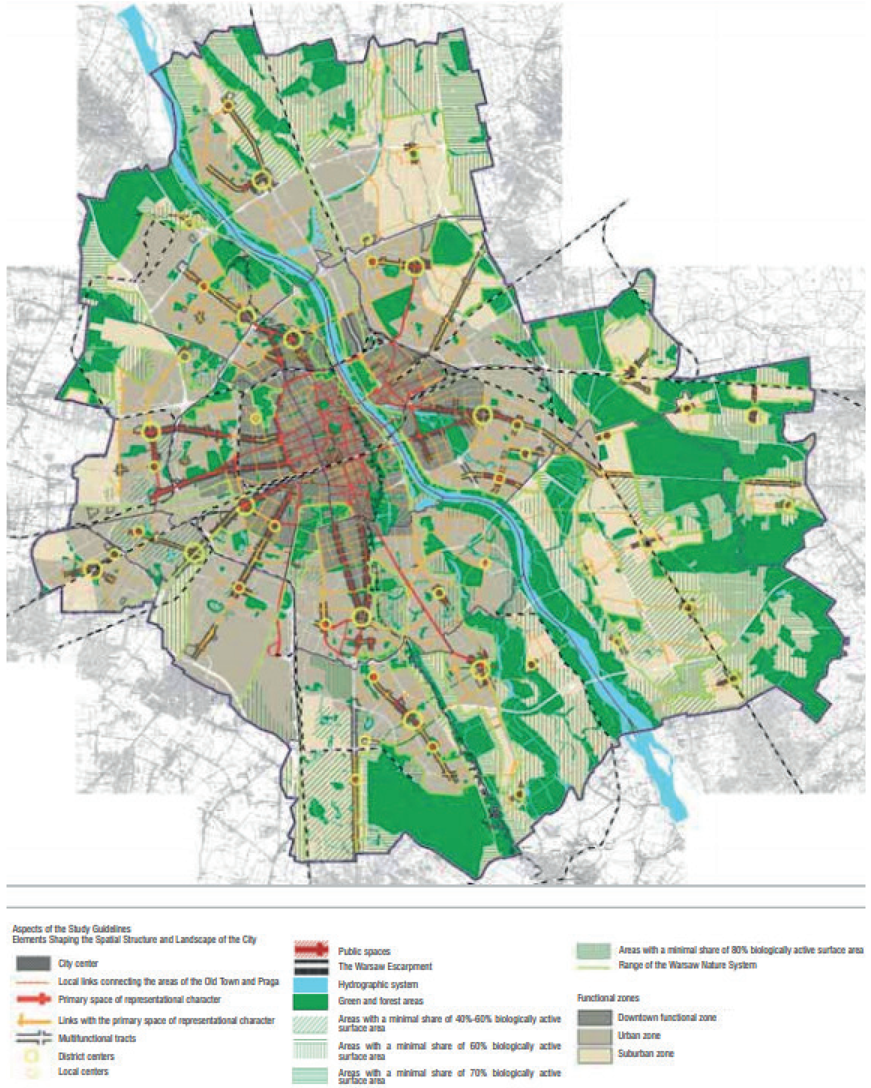


[IMG.2.04]
FIRST SKETCH OF THE WARSAW RECONSTRUCTION PLAN CREATED IN MARCH 1945 BY BUREAU OF CAPITAL'S RECONSTRUCTION
source: Historic Atlas of Warsaw, Capital city of Warsaw, 2004

[IMG.2.05]
DESTRUCTION OF THE JEWISH DISTRICT OF WARSAW, TODAY'S CENTRAL AND WOLA DISTRICTS
source: "Warszawa 1945-1970", Wydawnictwo Sport i Turystyka, Warszawa, 1970

THE ROLE OF URBAN GREEN IN THE MODERN SPATIAL DEVELOPMENT OF WARSAW

In modern times the city is facing a big problem with a lack of structure development plans for each district. Right now, only 39, 37% of the city is covered by the development plans (UM Warszawa, 2020). All the other areas lay under the general planning permission rule, and the developer has to apply for such a permit individually for each development project. The decision is given with the basic analysis of the most local context, and the decisions do not form or fit into the general strategy. The modern general structure plan of Warsaw does not have the status of a legal document, but a planning recommendation, due to the polish planning, legislative system. The plan recognizes the role of pre-war ventilation corridors. However, in last years, we could observe several development projects that have been constructed within those green corridors since their areas were not covered with a development plan. In those cases, developers applied for single permission, which has been given - for example, within the Mokotów ventilation corridor. The structure plan, however, has a firm definition of green areas, and the biggest challenge for the city is to guarantee the realization of the strategies, which goal is to protect the existing ventilation system of the city. However, the challenges are mostly located in the central, dense part of the city. Further analysis on this topics are presented in the chapter 4 of this research.



[IMG.2.06]
SPATIAL DEVELOPMENT PLAN OF WARSAW
source: Municipality of Warsaw

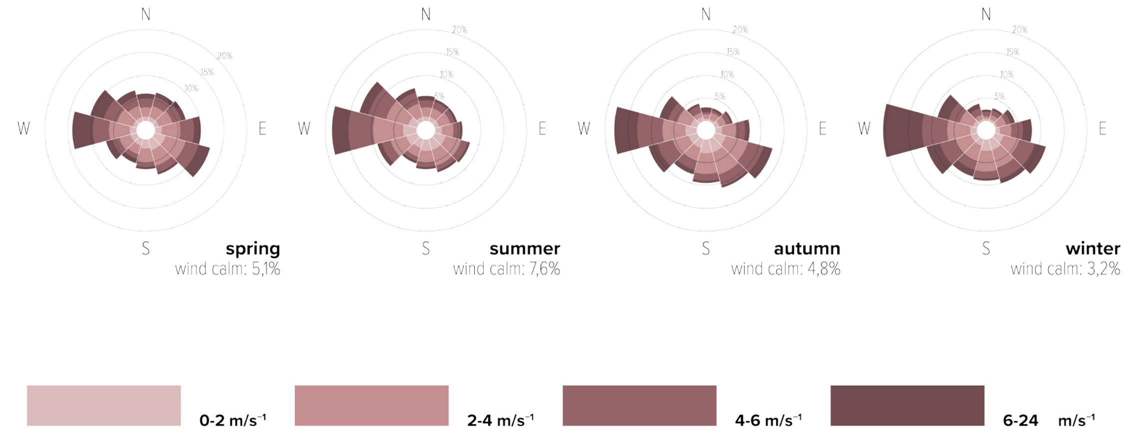
[IMG.2.07]
A PANORAMA OF THE CENTER OF WARSAW, SEEN FROM MARYMONT
author: Lomit, Hubert Sieminski

CLIMATE OF WARSAW

The city of Warsaw is located inside the Masovian-Podlasie climatic region, where the presence of air masses from humid continental climate (Dfb) and temperate oceanic climate (Cfb) often clash. (Pidwirny, 2014) That leads to significant differences in the local weather conditions during the year. During more than eight months of the year, maritime polar air masses dominate. Continental polar air mass shapes the local climate during episodes, which last around three months each year. Arctic air mass appears for around one month. Extremely rarely, Warsaw is under the influence of the dry and hot tropical air masses. The climatic curiosity of central Poland, so also Warsaw, is the relatively cold days during spring due to the arctic air masses, and warm, sunny autumn periods, provoked by the warm air masses from the south (Physiographic Study of Warsaw, 2006)

NATURAL VENTILATION AND THE ROLE OF WIND

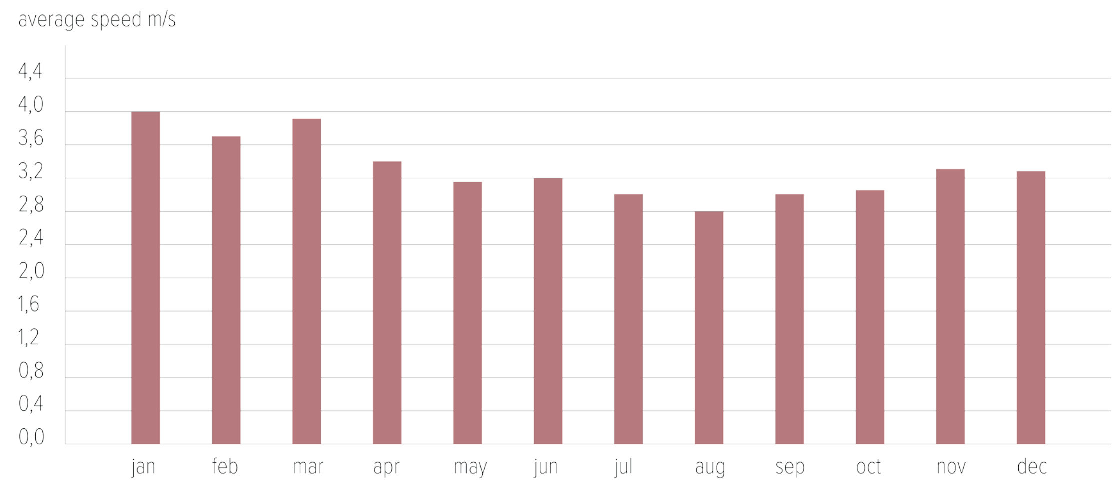
The ventilation system of Warsaw is composed of two elements: internal and external. The external system allows air to move zonally and depends on the overall air circulation. The internal system, related to local air movements in the densely built-up urban areas, depends on one the character of the build-up environment, the structure of roads, and the placement and size of the green areas. The speed of wind in the city center equals to just 42% of the wind speed on the open suburban areas. (Enviromental Impact Study, 2006) This phenomenon shows the big problem with the natural ventilation of the central districts. The main winds observed in Warsaw, measured in the last 50 years, origin from the west (24,7%). The second most observed are the winds coming from the North-West (10,7%) in the warm season, and the South-West (10,5%) in the cold season. The highest quality air comes to Warsaw from the direction of West and North-West, due to the location of the Kampinos National Park on the West-North borders of Warsaw. The most important for the natural ventilation system of Warsaw is the broad valley of the Vistula river. Natural ventilation is affected by the speed of the wind. Between 1971 and 2000, the average annual speed of wind measured in the Okęcie station (suburban area) reached 4,1 m/s, and 1,7 m/s at the University station (city center). The speed of the wind is 60% lower in the center than in the suburbs (ibid, 2006).



[FIG.2.01]

FREQUENCY OF THE WIND DIRECTIONS AND STRENGHTS IN 2016 (%)

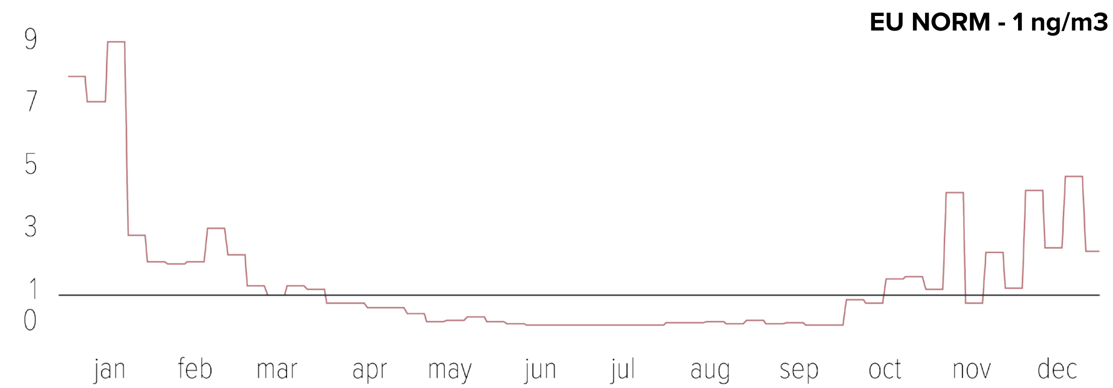
source: Re-elaboration of the data provided by the city of Warsaw
data: Municipality of Warsaw



[FIG.2.02]

MONTHLY AVERAGE WIND SPEED

source: Re-elaboration of schemes provided by Architecture and Spatial Planning Office
data: Municipality of Warsaw

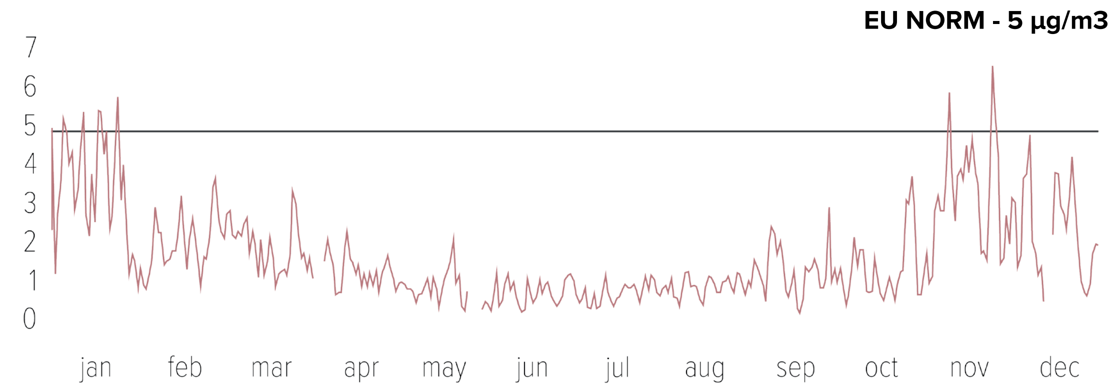


[FIG.2.03]

DAILY BENZO(A)PYRENE LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: ng/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016

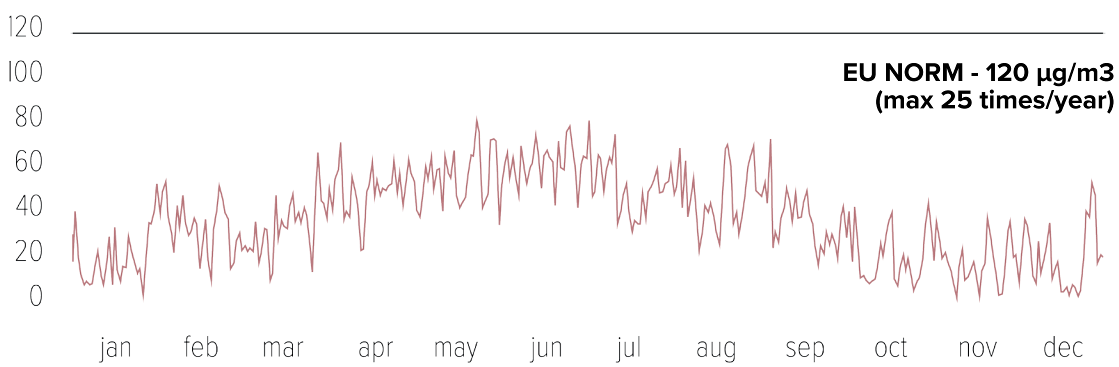


[FIG.2.04]

DAILY BENZENE LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016



[FIG.2.05]

DAILY OZONE LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016

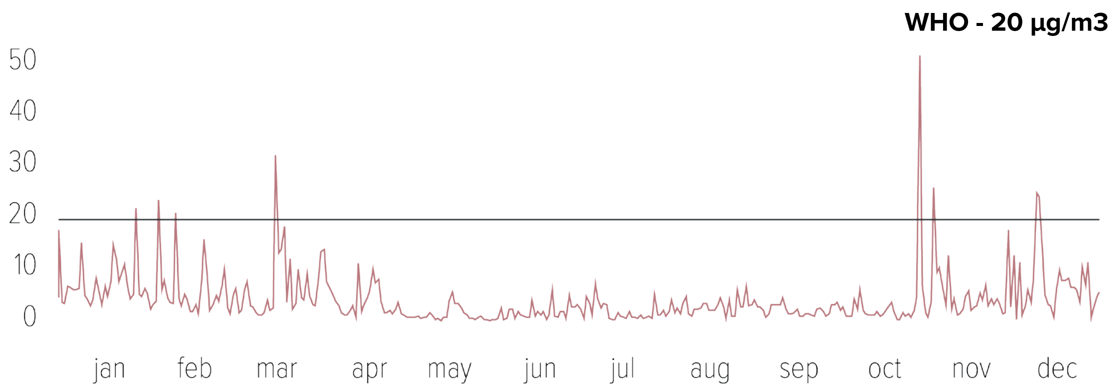
SMOG IN WARSAW

The following charts present the annual levels of air pollutants, according to the Polish Air Index system, in 2016. Data has been collected by the General National Environmental Agency. The analysis shows that Warsaw has a problem with the classical 'London' type smog, mostly during the winter periods. In January and December of 2016, the levels of PM2.5 have been exceeded more than 2 times over the norm. The level of Ozon, which is the main indicator of the Photochemical 'Los Angeles' Smog, has not exceeded the norms, however, we can observe a particular increase during the summer months. In summary, the situation is getting worst in the cold, winter months, and keeps being relatively fine during warmer months of summer. Warsaw is struggling also with the visible increase of all the elements usually related to burning fossil fuels, and slightly less to the ones related to the transport. The problem is typically episodic, happens only in certain moments of the year, and stays for several days, after which the situation normalizes. It gives a strong suggestion about the anthropogenic origin of smog, related to heating up houses.

The most dangerous is the situation with Benzoapyrene [FIG.2.03]. The levels in January were up to 9 times higher than the UE norm. The situation has stabilized during summer to increase again in the late autumn, exceeding the norms 5 times. Benzoapyrene is being created during the burning process, which explains the increase in the winter months.

Benze has been kept at a reasonable level during the entire year. [FIG.2.04]However it has been exceeded several times in winter and late autumn. With the EU norm being 5 µg/m3, the highest level recorded was 7 µg/m3 in 2016. During summer it dropped into marginal levels between 0 and 2 µg/m3. Again we observe here a situation in which heavy pollution is being created during the burning process, intensified in the cold winter months.

Ozone, the element typically related to photochemical smog, observed mostly during summer months is visibly being increased during that period [FIG.2.05]. However, the EU directive allowing the level to overpass 120 µg/m3 max 25 times per year has not been exceeded. It doesn't mean that Warsaw is not facing problems with ozone, because there is an episodic phenomenon happening, and the situation is getting worst in a certain part of the year, which included late spring and summer.

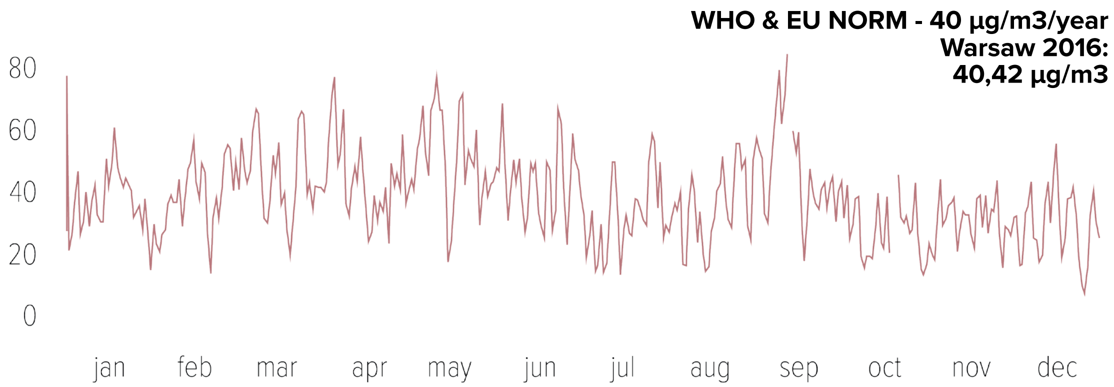


[FIG.2.06]

DAILY SULFUR DIOXIDE LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016

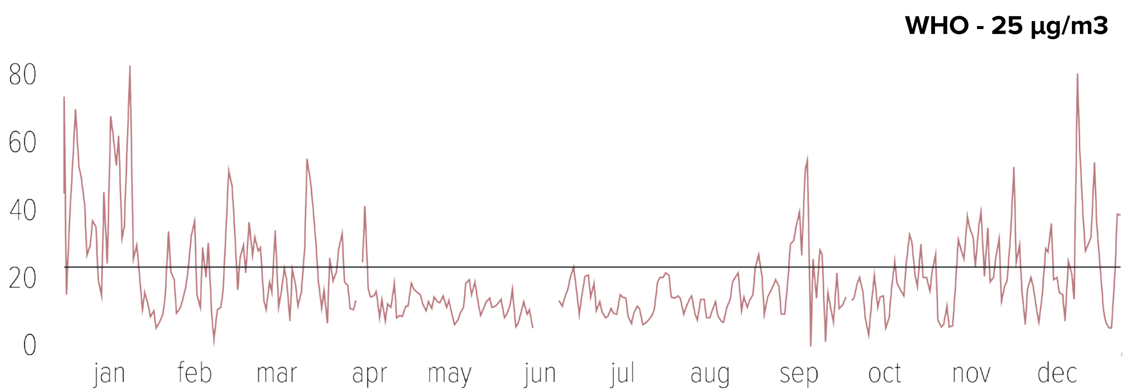


[FIG.2.07]

DAILY NITROGEN DIOXIDE LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016



[FIG.2.08]

DAILY PM2.5 LEVELS - WARSAW, AL. NIEPODLEGŁOŚCI - 2016 (unit: µg/m3)

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016

Sulpfur dioxide [FIG.2.06] in 2016 was under control during warm months of may, june, july, august and september, but has exceeded the WHO guideline several times duirng the winter period. The worst situation happened in late october, when the actual level was twice higher than the recommedned in the WHO guidelines.

Visibly worst situation happened with the levels of nitrogen dioxide [FIG.2.07] that has been high but stable through the entire year. This element typically related to heavy tranposrt concentration has been exceeded in the overal annual measurment. The yearly norm of 40 µg/m3 reached 40,42 µg/m3 in 2016. The situation is not dramatic, but the norms and recomendations have been overpassed, and the goal should be to keep those levels as low as possible, and not just lower than rocomendation. This tells us a lot about intensified transportation situation in Warsaw and amounts of private cars being used in daily commutng.

The worst situation in Warsaw is observed with the levels of Particulate matters [FIG.2.08 and FIG.1.04 on page 26]. The dusts exceeded the norms multiple times through the entire year, with the norms being overpassed almost everyday in the cold months of the winter. In January the levels of PM2.5 reached almost 4 times the WHO recommendations, and what is the worst, the levels were exceeded the norms for several consequentive days. Even in warmer months it happens that the levels almost overcrossed the recommendations, which keeps the air quality situation, with attention to the dusts, problematic also during the summer.

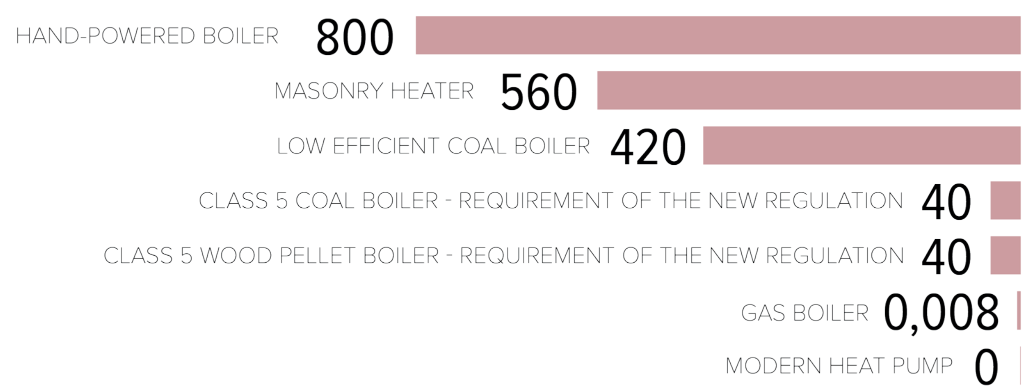
SOURCES OF POLLUTION IN WARSAW

One of the most controversial questions related to the smog in cities is its origin. Due to the different types of smog, weather conditions, geographical location but also the sources of the data, various cities can visibly differ in the origin of the primary pollutants. The available data for the city of Warsaw is not coherent, and different group of interests presents their own analysis, often with contrary conclusions. There is a big problem with data reliability. Summarizing, air pollutants are emitted from a range of both human-made and natural sources including:

• burning of fossil fuels in electricity generation, transport, industry, and households;
• industrial processes and solvent use, for example in the chemical and mining industries;
• agriculture;
• waste treatment;
• natural sources, including volcanic eruptions, windblown dust, sea-salt spray, and emissions of volatile organic compounds from plants.

In Warsaw, the primary sources are individual home heating systems, transport, and industry. However, the shares of those three elements differ in various sources. The official planning documents produced by the City Council state: "The main source of air pollution in Warsaw is transport." (The Spacial Policy of Warsaw, 2018). The study released by the City Office of Architecture and Urban Planning claimed that the chemical compound that mostly exceeds the norms in Warsaw is the PM10, and 61,8% of its production comes from the individual heating units at houses, making this one the primary sources of pollution in Warsaw (The physiographic study of Warsaw, 2006). Professor Artur Badyda from the Technical University of Warsaw, in his work, declares: "Transport is the main pollution emitter, however, the low emission (chimeneas, furnaces) is directly responsible for the smog episodes in various periods" (Badyda, 2006). The NGO "Polish Smog Alarm" has published the data together with The National Centre for Emissions Management, that defines levels of PM10 as the most exceeded in Poland, and defines that 52% of them comes from low emissions, 17% from industry, 10% from transport, 9% from Energetics, 8% from other sources and 4% from Agriculture (The National Centre for Emissions Management, 2016).

It is also important to mention the contribution of the "Rockwool" company, the biggest producer of the rock wool for house insolation, which has participated in the TV discussion about smog on 4th April 2018 in the TVN canal, where they declared „Smog does not come from cars, smog does not come from industrial activity. In Polish realities, smog comes from single-family homes that are not energetically sustainable" (Pawlak, 2018). This kind of statements have no scientific proof, but are actively shaping the public opinion due to the broad access in the mass media, and has to be considered as an element essential for the policymakers. It is crucial to mentions that the significant differences in data may come from different methodologies, but also particular interests of the data creators, so the high level of caution during the interpretation is required. For the aim of this work, the analysis of different pollutants in Warsaw has been prepared. It is essential to define the sources of smog in order to propose relevant solutions. In order to check the possibility of low emission being the primary pollutant, as suggested in many of the sources presented, the chemical compounds which levels have been mostly exceeded – PM2.5 and PM10 have been combined with the historical data of the average daily temperatures in Warsaw for the whole 2016. The thesis was: Low temperatures episodes lead to the increase in the usage of the single heating units, which are the primary sources of PM2.5 and PM10, and in consequence, increase the levels of those compounds in the air.



[FIG.2.09]
DUST EMISSIONS FROM THE PRIVATE HOME HEATING UNITS
source: Re-elaboration of the data provided by Polski Alarm Smogowy
data: dr. inż. Krystyna Kubica, dr. inż. Robert Kubica

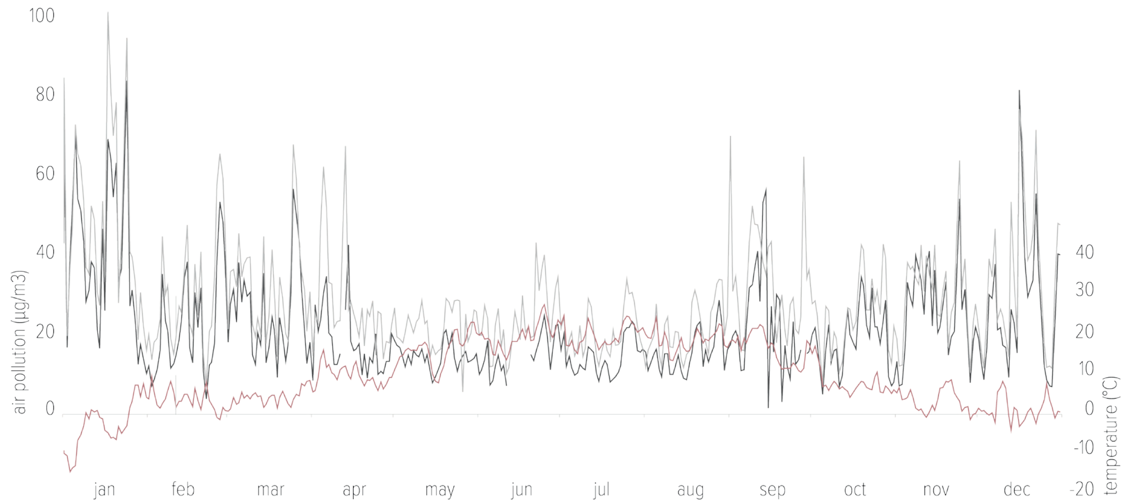
The correlation between temperature and the levels of PM2.5 and PM10 for each month [Fig 2.10], using statistical Pearson's method has been calculated following the formula:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

It has been observed [Fig 2.11] that the levels of PM2.5 and PM10 have been negatively correlated with the temperature (temperature decreases, pollution increases) in winter months and positively correlated (temperature increases, pollution increases) in summer months. The highest negative correlation was observed in January (PM2.5) and December (PM10), while the highest positive correlation was observed in July (PM2.5 and PM10). July was also the month with the lowest average level of PM2.5 (14,38) and also PM10 (20,64), both below the UE and WHO norms. Particular growth of PM levels up to hazardous levels is visible during the episodes of the shallow temperatures. The situation in the winter gives as a strong suggestion that there is a correlation between low temperatures and increse of dusts related to single house heating methods. We can observe several phenomena when drastic growth or declines of the PM levels do not correspond with the thermal situation of the city, which is related to other meteorological phenomena (wind, rain) that have not been an element of this analysis.

Due to the complexity of the natural and anthropogenic processes behind the creation of air pollution and its dynamic change, it is impossible to define the percentage shares of each cause precisely. The variety of sources and data for the city of Warsaw makes it essential to treat the air pollution causes in Warsaw with all its complexity and prepare the city to face any of the defined and mentioned reasons – low emission, transport, and industry.

In the "The Spacial Policy of Warsaw" the improvement of air quality has been presented as 4th out of 5 priorities that the city declares in the realm of protection of the environment and its resources.



[FIG.2.10]

DAILY PM2.5, PM10 LEVELS AND AVERAGE DAILY TEMPERATURES IN 2016

source: Self-elaboration by author

data: GIOŚ (General National Environmental Agency) 2016

IMGW (The Institute of Meteorology and Water Management)

PM2.5 PM10 (t)avg

MONTH	PEARSON PM2.5	PEARSON PM10	AV. TEMP.
JANUARY	-0.617	-0.448	-2.8 °C
FEBRUARY	-0.524	-0.582	3.6 °C
MARCH	-0.079	-0.001	4.3 °C
APRIL	0.465	0.715	9.7 °C
MAY	0.124	0.442	16.3 °C
JUNE	0.809	0.766	19.8 °C
JULY	0.857	0.824	20.1 °C
AUGUST	0.691	0.557	18.8 °C
SEPTEMBER	0.555	0.441	16.6 °C
OCTOBER	0.081	0.092	7.9 °C
NOVEMBER	-0.212	-0.143	3.3 °C
DECEMBER	-0.572	-0.658	1.3 °C

[FIG.2.11]

PEARSON METHOD

source: by author

ALTERNATIVE SOURCES OF POLLUTION

In recent years there have been numerous new voices and approaches in analyzing the pollution sources that had been ignored before. The research conducted by the Spanish scientists united around the "AIRUSE LIFE" project have estimated and pointed the most important ones are (Airuse, 2017) :

- emissions from construction and demolition works
- emissions from the industrial sector
- emissions from road dust resuspension
- emissions from biomass burning

In the case of the city of Warsaw, it is specifically essential to discuss the impact of construction/demolition works and the road dust resuspension, as those can participate in the overall air quality problem.

The Spanish scientist has estimated that in the city of Milan, local dust can contribute to 7% of the entire PM10 presence in the annual mean, and 5% of PM2.5. At the same time, road traffic generates 31% of the PM10 and 29% of PM2.5 in the city. Dust can be generated during the construction and demolition process. Those emissions are temporary, but they may have a significant impact on the situation, which makes it essential to implement policies in order to reduce those impacts. The most common construction activities that emit dust include the worksite preparation (demolition and excavation, soil and material stockpiles, loading and unloading of materials, vehicle transit areas) earth movements (preparation of the land by leveling and trench construction, soil compacting, material cutoff operations) road paving and the construction of building and structures (Airuse, 2017)

In order to minimalize those emissions, its crucial to include the analysis of the potential emissions into the planning process and implement more concrete solutions during the actual construction or demolition process. The developer has to be obliged by law to inform the workers of the risks and impacts they may face during the working process. The construction itself has to be conducted with strong attention to the wind movements, to minimalize the dust exposition of the surrounding neighborhoods. The same applies to the loading and unloading of materials, which should be done to the area against the wind. It should be forbidden to burn any materials within the site, reduce the need for transportation as much as possible, washing the streets next to the site, and to cover the materials or site while terraforming the site. Manufacturing the materials, including cutting the materials, should not be carried within site. Those steps would allow reducing the emissions and distribution of PM10 and PM2.5 during the construction process

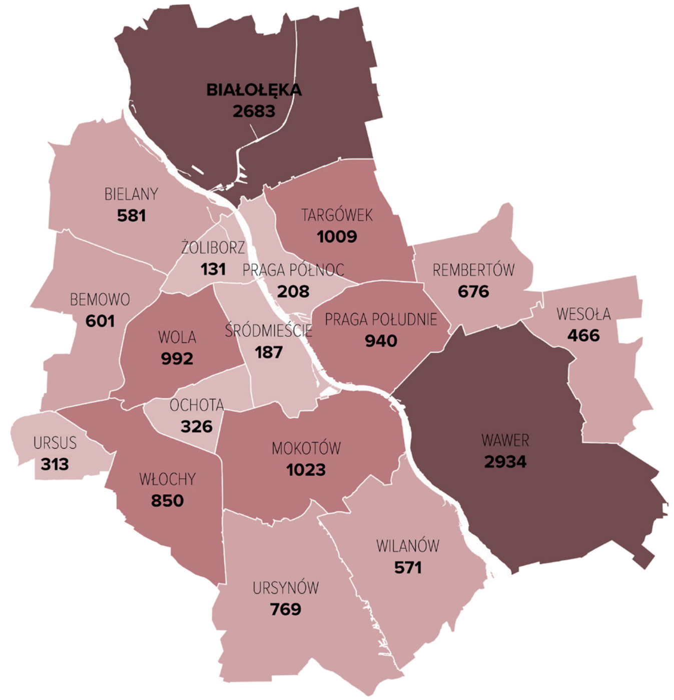
A second important source of pollution is the road dust from resuspension. When it comes to traffic pollution, we have to look not only at the pollutants that are directly produced by the vehicles. Also, the dust accumulated on the roadsides, raised while the vehicles move, has a significant impact on the air quality. Road dust can be a mixture of particles deposited on the surface of paved roads, and susceptible to be re-entrained into the atmosphere due to the vehicle-generated turbulence or wind. Moreover that type of dust contains heavy metals and organic components originated from the wear of breaks/tires. It has been estimated that, with the growth of electric vehicles, by 2030 in Europe, 90% of road traffic emissions will be from those non-exhaust sources (Rexeis and others, 2009). This problem is especially visible during hot days, without precipitation, and in southern European cities that face little amounts of rain. In order to minimalize those impacts, it is essential to develop an efficient system of sweeping and cleaning the streets. Vacuuming the busiest and exposed streets and cleaning them regularly with water allows us to keep the dust on the ground and utilize it later on. The same research showed that during the days with cleaning activities, the concentration of PM10 had been decreased by 18,5% (Airuse, 2017).

It is important to remember that the effectiveness of watering streets highly depends on climate and weather since the speed of water evaporation will differ. The researches about the full effects of those practices are still being conducted so that we can expect more detailed data about this topic soon. The most efficient way is still reducing the speed of the vehicles, which leads to fewer emissions from breaks/tires and lower levels of raising those that have already been emitted. Calming the traffic in the city centers, mixed with a sustainable way of cleaning the streets, could be a solution to this problem.

CURRENT ANTI-SMOG POLICIES IN WARSAW

The city of Warsaw has tried in the last couple of years to take the first steps in order to change and implement anti-smog policies. On 24 October 2017, the regional council has accepted the new official Anti-smog strategy for the entire region, which has started being implemented since 11 November 2017. The policy aimed to regulate the heating structure of private heating unites, and to forbid the highly polluted means of heating. Since 11.11.2017, only low emission heating units and boilers are allowed, which is coherent with the EU standards for single house emissions. The most important of the new decision is to eliminate the old, highly emitting boilers, using wood or coal, which are class 3,4 or 5 of the European norm PN-EN 303-5:2012 until the end of 2022. Until the end of 2027, all the boilers using wood or coal, of class 3 and 4 have to be replaced. Apart from that, all the private owners of house chimneys for recreational use are obliged to replace them into modern ones (that meet the standards described by the policy) or equip in dust absorbers, until the end of 2022 (Anti-smog policy of the region of Masovia, 2017).

From 1 July 2018, it has been forbidden to use the most dangerous sources of energy, such as lignite, coal slurry, or other residues in the hard coal production process. This was a necessary step taken by the regional council in order to limit the emissions of the most dangerous pollutants, such as Benzoapirens. The controversies were related to the high costs of the replacements of heating units by single families, especially in more deprived areas of the region. In order to prevent the creation of inefficient law, the city of Warsaw has implemented its own policy that subsides the replacement process. The inhabitants can ask for financial assistance if they decide to change their old heating unit into modern ones using renewable energy sources. Subsidies are also prepared if they would like to be connected to the city heating system, and if they do not have enough funds to pay for low emission energy sources such a gas, which is more expensive than previously used ones. The city hopes that this move will help to eliminate the most dangerous sources of emissions, mostly during the winter high smog period. This is an absolutely crucial move in order to start improving air quality. Without mitigation and elimination of emissions, any adaptive strategies would not be efficient. At the same time, the city has taken minimal steps to fight the transport based air-pollutants. There is no car-free zone in the central area of the city, so typical for Western European cities. The only step has been taken, was to increase prices for parking in the center by around 20 -25%. The new prices, together with new fines for illegal parking (500% higher –225PLN (approximately 50 euro) instead of actual 50 PLN (around 10 euro), are being discussed now, and are meant to be implemented by summer 2020. The city mayor has started the discussion recently about closing the city center for any combustion vehicles, but that idea will not be implemented in the next years. Both strategies presented, despite the level of implementation, base on the idea of eliminating the pollutants within the long term. The city is missing the supportive strategies, possible to implement immediately, or within a shorter term, that will allow minimalizing the negative consequences of exposure to the pollutants.



[FIG.2.12]

NUMBER OF HOUSEHOLDS NOT CONNECTED TO THE MUNICIPAL CENTRALIZED HEATING SYSTEM

source: Self-elaboration by author
data: Warszawa Bez Smogu (NGO)

chapter 3

SMOG AS A DISASTER: URBAN RESILIENCE

- URBAN RESILIENCE: THEORETICAL DEBATE
- MITIGATION AND ADAPTATION STRATEGIES
- RESILIENCE AND AIR QUALITY
- AIR POLLUTION: SOURCE, DISPERSION AND RECEPTION
- SCOPE OF THE PROJECT
- ROLE OF THE PUBLIC SPACE DESIGN
- RESEARCH QUESTION

URBAN RESILIENCE: THEORETICAL DEBATE

Urban Resilience is a fast attention-gaining topic across many studies on cities and climate change. Urban Resilience emphasizes the idea that cities, urban systems, and urban constituencies need to be able to bounce back from climate-related shocks and stresses quickly (Leichenko, 2011). Nowadays, resilience is also perceived as the capacity to absorb shocks while maintaining functions (Folke and others, 2002). However, the first definition was formed in 1973, and described resilience as ‘‘the persistence of relationships within a system’’ and ‘‘the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist’’ (Holling, 1973). Recently the complexity of the resilience topics is being underlined in modern literature, and various, multiple ways of interpretation have been introduced. Different modern approaches to resilient planning can be classified into three main categories (Colucci, 2012):

1) “Resilience and sustainability”: When the concept highlights the need to increase the levels of social-economical balanced coexistence

2) “Resilience and adaptation”: When the concept concentrates on the strategic adaptive adjustments, with regard to climate change

3) “Resilience and territorial risks”: When the concept underlines to problems related to the risk mitigation

For the aim of this research, the 2nd category appears to be the most suitable and relevant. Colucci collects and describes different literature that aims to focus on the development of cities, urban areas based on sustainable settlement models (Colucci, 2012). She points out that in the works related to transition cities, numerous concepts related to ecosystem resilience are mentioned, such as diversity and redundancy, modularity and hierarchies/organization, and feedback processes. These principles are the basis for constructing processes, strategies, and actions for resilient communities (ibid, 2012). Those principles have also been picked as the main methodological framework for the aim of the design activity within this research.

In a system designed concerning resilience strategies, change has the potential to create an opportunity for development, novelty, and innovation. Change can be perceived as a challenge but also a chance to grow. This approach is the primary design indication and the starting point for this research. It is interesting to mention that the resilience topic and the theoretical debate around it, has barely touched the air pollution environmental problem, and not many of the authors have examined the possibility to perceive the smog phenomenon as a temporary risk that city could be prepared for.

MITIGATION AND ADAPTATION STRATEGIES

In order to prevent society from the harmful effects of air pollution, specific measures need to be taken. These measures can range from installing filters on the primary sources of pollutants to increase the green profile of the streets with the most efficient planting in absorbing particular matters. These kinds of strategies can be classified into two categories: adaptation and mitigation strategies.
Adaptation strategies are those that incorporate the ideas of avoiding hazardous locations and taking measures to counteract or reduce the dangers of environmental phenomena (Dietz and others, 2008). The Intergovernmental Panel on Climate Change (IPCC) distinguishes adaptation in human systems from adaptation in natural systems. In a human system, adaptation strategies aim to moderate or avoid harm or exploit beneficial opportunities, while in natural systems, human intervention may facilitate to expect climate and its effects (IPCC, 2014). An example of an adaptation strategy is building dikes in order to prevent flooding in the Netherlands (Keessem and others, 2013). This adaptive solution reduces the chance of flooding, but the cause of the flooding is not tackled.

While adaptation strategies focus more on preventing or controlling the outcomes of environmental problems, mitigation strategies aim to focus more on combatting the causes of those problems (Dietz, 2008). It means that the mitigation strategies strive to tackle the source of the problem, instead of reducing its consequences (IPCC, 2014). Using sustainable energy sources instead of the non-sustainable energy sources are considered an excellent example of the mitigation strategies because these strategies reduce CO2 emissions by using energy sources such as hydrogen, which do require fossil fuels. Mitigation strategies tackle the source of the problem instead of reducing its consequences (Wang and others, 2014).

Instead of solely focus on one type of strategy, the future of climate policy will have to consider a combination of adaptation and mitigation strategies (Brasseur and Garnier, 2013). In their article, Brasseur and Garnier discuss that mitigation, as the approach which attempts to eliminate the problem, will always be the preferred one. A mitigation strategy is the first objective of the international agreements, but Brasseur and Garnier point that adaptation strategies are also extremely beneficial, especially in the short term, and they will become necessary. Although the adaptation strategies tend to be near-term, and mitigation strategies tend to be seen more as long-term solutions, there is a direct overlap between them. They both actively interact with each other in reality for the duration they are implemented, regardless level they are initiated (Moser, 2012)

RESILIENCE AND AIR QUALITY

There is not much of the literature that would attempt to merge the air pollution issues with the resilient strategies. However there are first attempts, to examine the relevance of connections between those topics. Interesting approach has been selected by Cariolet, Colombert, Vuillet and Diab on measuring the resilience to traffic-related air pollution in Greater Paris. In their study they defined resilience as the capacity of an urban area to tackle traffic-related air pollution issues through urban design (urban morphology, transport networks, services and land use), and they defined the term capacity as the potential of an area to improve a given situation (Cariolet, 2017). They also discuss that the concept of urban resilience may offer a new paradigm for tackling urban air pollution. They identified three capacities:

- capacity of an urban system to decrease air pollution emissions
- capacity to decrease concentrations
- capacity to decrease exposure

By introducing the GIS based model they proved that in case of the Greater Paris the capacity to decrease emissions needs to be improved in certain parts of the suburbs, and the capacity to decrease concentrations is low in Paris due to the high building density. They proved that the role of ventilation channels is crucial in tackling urban air pollution. The noted that ventilation channels may help to disperse pollutants (ibid, 2017). The most relevant ventilation corridors in Paris appeared to be located along the river Seine and along the existing rail. Similar observations have been made in the agglomeration of Wroclaw in Poland (Suder, 2013). Because of that the same approach will be taken into consideration while defying possible ventilation corridors for the city of

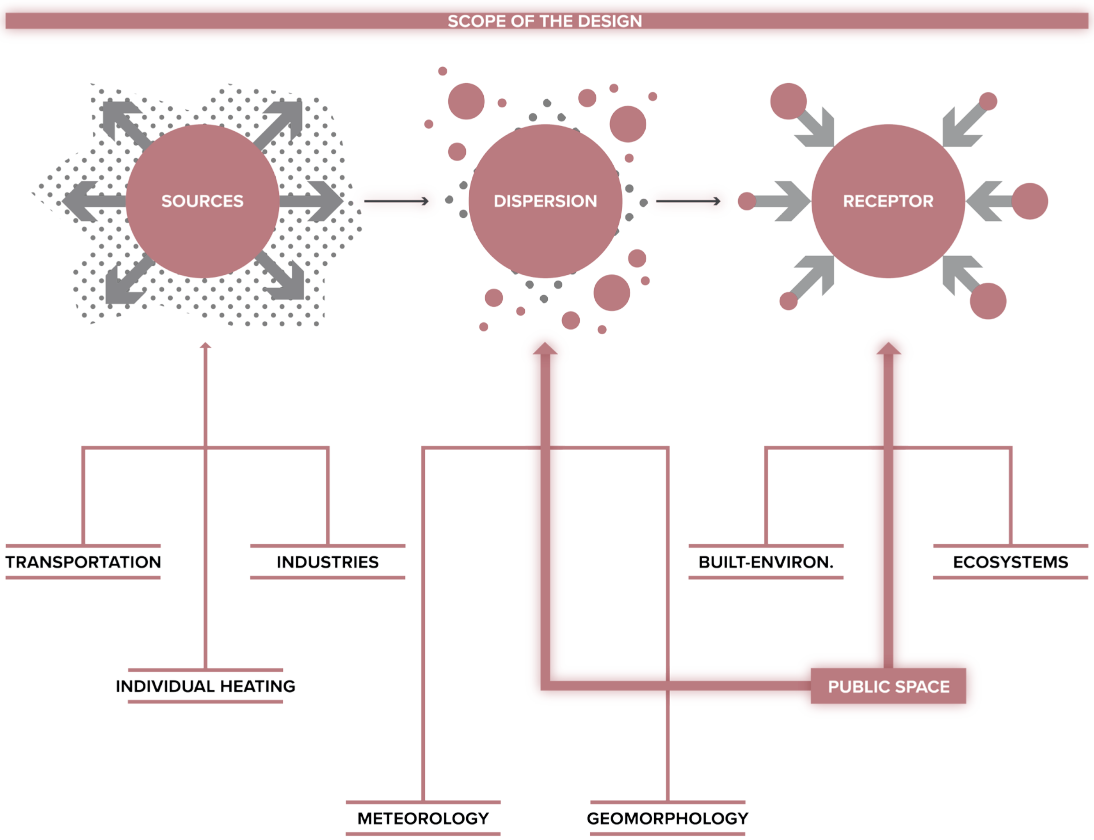
Warsaw within this research. The question emerges when we start to ask if air pollution can be considered as an issue open for resilience strategies application. Because of the impact that air pollution has on the health, it is not possible to fully adapt to it, in the same way in which we perceive the adaptation to the extreme water phenomenon in the city. However many of the key points and ideas behind the resilient planning are coherent and can be found in case of air pollution, such as its temporality, impact of cities life, and the fact that smog phenomenon should be considered as a disaster.

Our final and ultimate goal related to the air pollution is to completely eliminate any source of emitants, which will lead to the improvement of air quality, and finally to complete elimination of what we now call and understand as air pollution, following the mitigation strategies. The intermediate step is to limit those emissions as much as possible, however this is a challenging step in context of developing countries. Eliminating emissions requires a systematic change in the national or even global energy systems. On the city scale it requires a large scale change of the transportation system into completely non-emitting vehicles, big investments in improvement of the public transport, as well as changing the energetic profile of city buildings, and the entire energy supply. Those steps have to be put into long term strategies of cities, countries, and multinational organizations. However the construction of new ecological power plants, or efficient new mass-public underground transportation systems can take decades, and we are facing the air pollution problem right now. As it has been proven before, the mitigation cannot work successfully without adaptation. There is a need to find an intermediate strategies and solution that will allow the cities to minimalize the impacts of the air pollution at the short term. In European cities like Warsaw, what has been proven before, we observe the air pollution problems occurring only in certain periods of the year. Norms are being exceeded for several days, after which the period of relatively good air quality happens. This periodic and temporary nature of the air pollution problem in European cities leads to the idea of incorporating air pollution problem into the topic of urban resilience. As much as we can be prepared for the extreme rain, the attempt is needed to be prepared for an extreme low air quality period, before we will be able to completely neutralize that problem in the longer timeframe.

This matches for instance with the “City Model” by Coyle, presented also in the essay by Colucci. According to this idea, the model of the city (or urban system) consists of the built environment and supporting systems. The built environment consists of the physical structures and organisation patterns of buildings, blocks, neighbourhoods, villages, towns, cities and regions. The supporting systems are: Transportation, Energy, Water, Natural environment, Food production, Agriculture, Solid waste, Economics (Coyle, 2011). The role of air within such a concept is not yet developed, but the importance of it, and its impact is not less valuable than the other mentioned. It is important to bring the air as a one of the main topics in the urban discourse, and focusing more on it would be the first step in increasing the public awareness.

AIR POLLUTION: SOURCE, DISPERSION AND RECEPTION

In order to create a bridge between discussed topics it is cruacial to frame a methodological base for the design. The air pollution phenomenon can by described within three main categories: source, dispersion, and reception (Oke, 1987). Sources are items that emit air pollution, such as private heating units, industrial structures or transportation. Dispersion is the process of mixing, in which very small pieces of one substance are scattered within another substance. In this case, the dispersion happens between air pollution and the air, supported by the specific circumstances of the surrounding such as heavy wind, conditions of the terrain, or surface and porosity of the built environment. Atmospheric motions can serve both as a diffusor but also mean of transport for air pollutants. If the size of eddies is smaller than the pollutant cloud or plume they will diffuse it, if they are larger they will transport it (Oke, 1987). Reception is the group that contains all the possible vulnerable elements, especially sensitive to the problem of air pollution. In this group, we can mention the population, especially the most vulnerable groups such as kids and elderly people. Also generally speaking the city, and its architectural conditions can be perceived as a receptor. Source, dispersion, and receptor site are strongly interconnected, they can have the same or different scales of action, but they influence each other (Vietti, 2018). This division will be used in this project to structurize and categorize spaces, actors, and issues.



[FIG.3.01]

SCOPE OF THE PROJECT

source: by author

SCOPE OF THE PROJECT

The world is now on fight with the ongoing climate change. One of the crucial actions proposed is the global energy transition. This process, considering the time needed to create policies, to design ecologically friendly energy systems, and physically construct new sources of energy, will take decades. However, the problem is here now, and it is essential to talk about solutions that will help to adapt to the dynamically changing situation during this intermediate period. Air pollution affects regional, urban, and neighborhood scales, and the scope of this research is to focus on the intersection between those different scales. The aim is to understand what can be done within the region and the city to support the significant investments related to the energy and transportation transition processes.

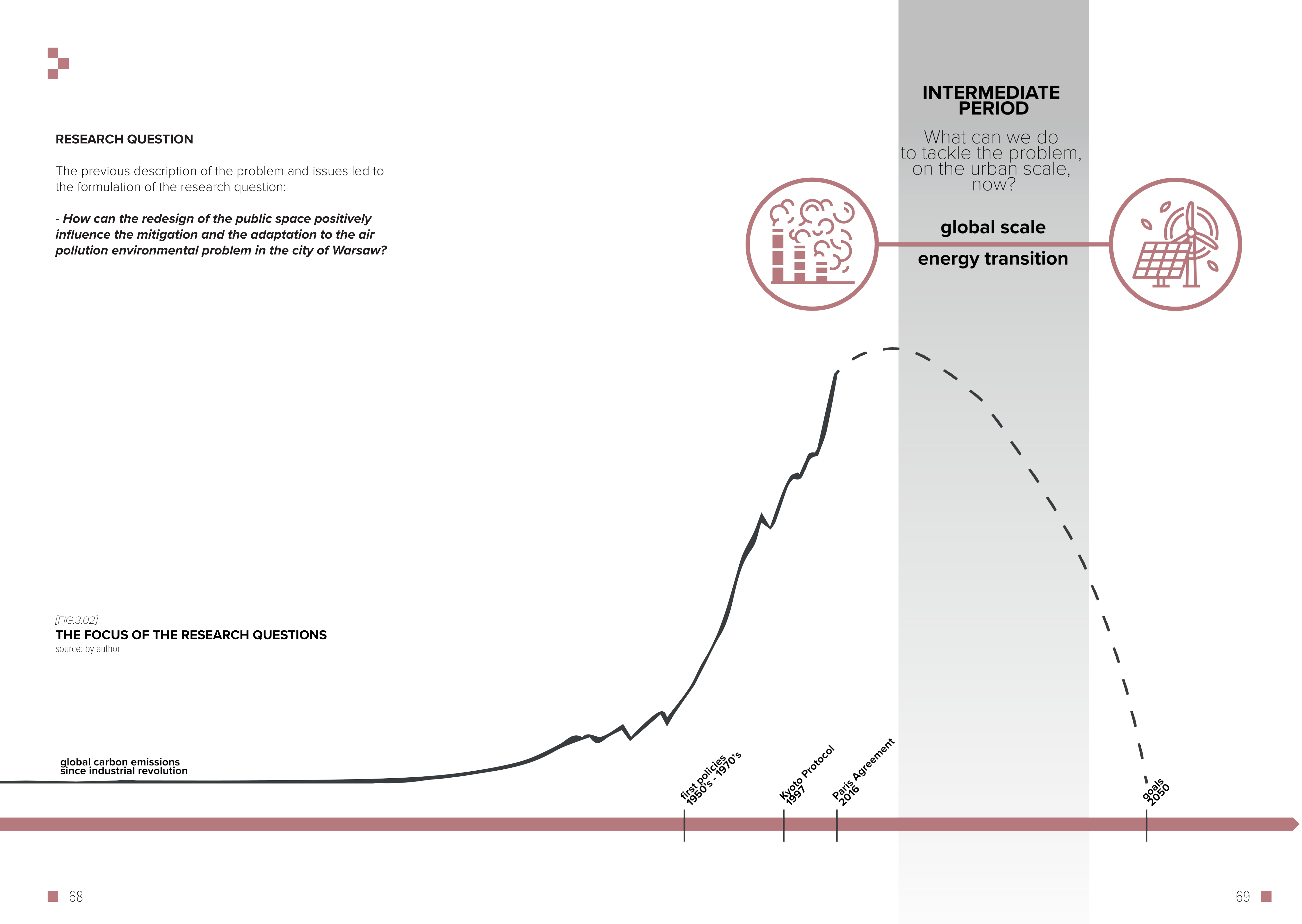
ROLE OF THE PUBLIC SPACE DESIGN

There has already been a lot said, in the polish scientific debate related to air quality, about limiting emissions, incorporating policies, and working within architectural conditions of single buildings, for instance, by decreasing energy consumption. Those are the main actions that need to be taken into consideration concerning the fight against the air pollution problem in the context of Warsaw and Poland. The idea of this project is to focus on supportive actions within the field of urban design, which could help improve air quality in the dense urban environment. The idea came out from the underestimated value of the public space in urban centers. Public space is the only space within the central parts of the cities that is flexible and relatively easy to redesign and improve. It is not possible, nor wanted, in the post-modernist and post-growth context to implement big-scale changes to the urban structure of entire districts. The chance is, however, hidden in rethinking the shape and role of public space, which due to its linearity and interscalarity, can be used and a method to create new landscape systems, affecting entire districts. Policies might be unstable, and peoples behavior is hard to affect, therefore there is a need for a more stable solution, dealing with the physical forms of the built environments, and in this particular case the focus will be given to incorporate public space as an essential element in dispersing air pollution and receiving it, to limit the reception in population.

RESEARCH QUESTION

The previous description of the problem and issues led to the formulation of the research question:

- How can the redesign of the public space positively influence the mitigation and the adaptation to the air pollution environmental problem in the city of Warsaw?



[FIG.3.02]
THE FOCUS OF THE RESEARCH QUESTIONS
source: by author

chapter 4

ANALYSIS

MATRIX OF ANALYSIS

Using the literature review (Oke, 1987), the matrix of analysis has been established with the most relevant topics tackled, aimed to define problems related to air pollution. The matrix contains several elements and tries to define the most crucial layers which can be responsible or affected by high concentrations of air pollution in Warsaw. The selection is also made using the features of the city of Warsaw, already mentioned in previous chapters, which aim is to put a more contextual look on the problem within the specific city, climate, and local history. The matrix is described in more detail way, with attention to each topic, in the following pages.

OBJECTIVES

The objectives of the matrix are to provide a detailed understanding of the spatial distribution of the problems. This is a crucial step in order to define a feasible and effective strategy in the following chapters. The examined topics in this chapter are land use, the traffic, air pollution, terrain, population, built environment (floor space index), and green. A big issue of multiscalarity has been observed while trying to set up this matrix. Sources of pollution are rather punctual or linear, but receptors such as neighborhoods or populations are measured instead in the zonal way. All of them exist within different scales, although they strongly overlap. The division in mesoscale, urban scale and local scale has been made to facilitate understanding of the spatial distribution of those phenomena. However, defying scales of actions of air pollution might not be that easy. One of the main goals of this analysis is to build a bridge between those different scales which are approachable by the further design interventions.

SOURCES, DISPERSION, RECEPTION

The analysis is proposed to be based on the previously described distinction into sources, dispersion, and reception, to understand the features of each layer. For instance, the population is a layer which can be considered as a source and as a receptor, since people at the same time can produce and receive pollution. This division allows us to understand the position on each layer in the process of air pollution creation, which will also require relative measures and responses later.

	source	dispersion	reception
mesoscale	**air pollution** *PM10 PM2.5 NO2 SO2 BaP*	**green system** *national and regional system* **wind** *direction and speed* **land use** *built environement* **terrain** *geomorphology*	**land use** *built environement*
urban scale	**urban traffic** *traffic flows* **land use** *main industrial sites* **air pollution** *PM10 PM2.5 NO2 SO2 BaP*	**density** *floor space index* **green system** *urban ventilation system* **terrain** *Warsaw Escarpment*	**land use** *residential commercial services industrial* **population** *density age* **green system** *urban green*
local scale	**urban traffic** *origin and destination map* **air pollution** *conclusion map*	**land use** *continuity* **green system** *urban green*	**population** *density age* **green system** *sport and recreation*

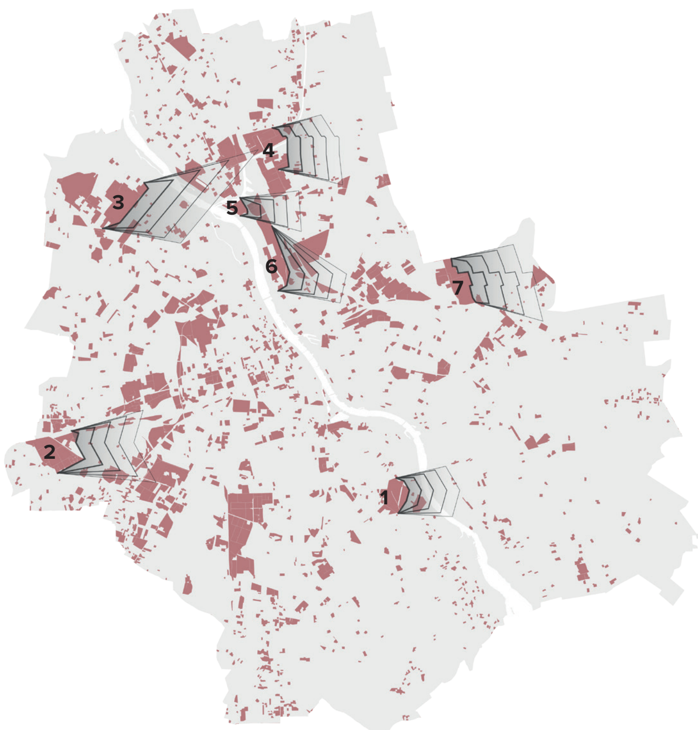
[FIG.4.01]
MATRIX OF ANALYSIS
source: self-elaboration by author

Continuous Dense Urban Fabric

Discontinuous Dense Urban Fabric

Discontinuous Low Density Urban Fabric

[FIG.4.02]
LAND USE - RESIDENTIAL
source: self-elaboration by author
data: Urban Atlas 2012: Copernicus Land Monitoring Service



1 - Siekierki Heat Plant

2 - Ursus industrial site

3 - Ironworks Warsaw

4 - Żerań industrial site

5 - Żerań Heat Plant

6 - FSO (Passenger Automobile Factory) industrial site

7 - Kawęczyn Heat Plant

pollution dispertion according to most common wind direction (W)

services and industries

[FIG.4.03]
LAND USE - SERVICES AND INDUSTRY
source: self-elaboration by author
data: Urban Atlas 2012: Copernicus Land Monitoring Service

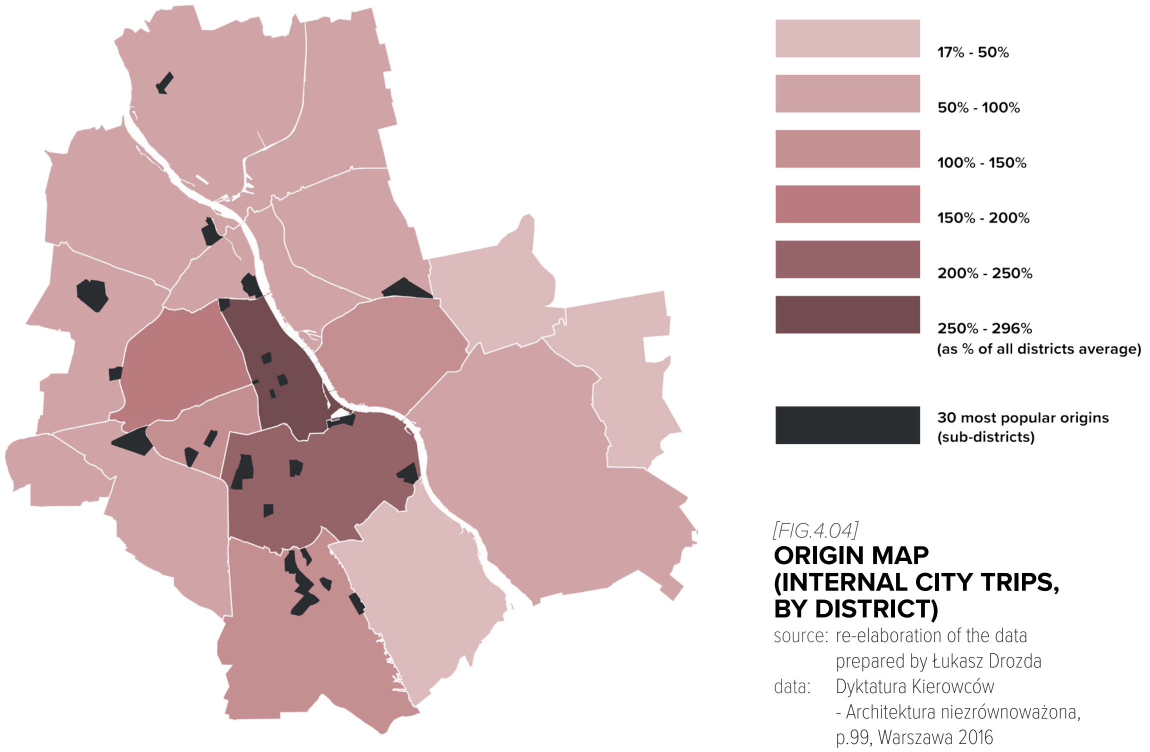
LAND USE

THEORY

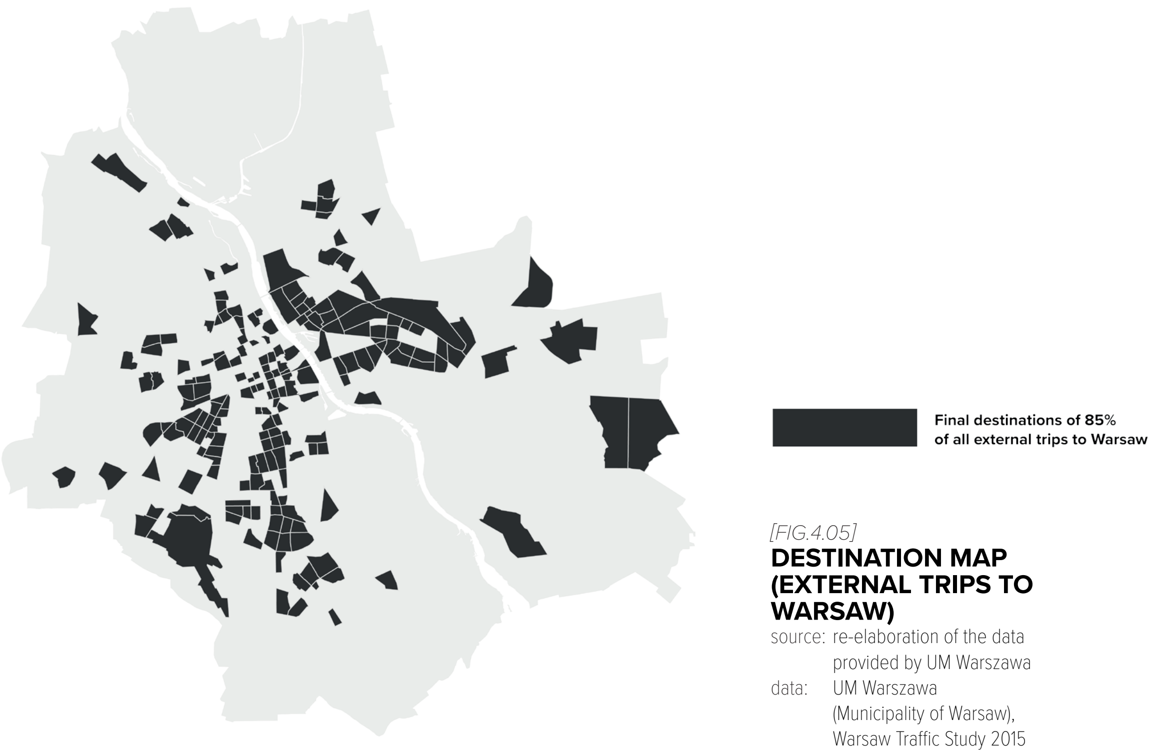
The analysis of land use in the context of air pollution and the definition of residential, industrial, services, and commercial areas can reveal the grade of integration of neighborhoods and possible need to travel by the private mean of transport (Vietti, 2017). Moreover, the vicinity of residential areas to productive and industrial sites should be taken into consideration in the air pollution exposure assessment (Oke, 1987)

ANALYSIS

The land use map shows the significant level of dispersion of different functions all around the city. Due to the massive destruction of Warsaw, and post-war reconstruction, the city is characterized by residential and industrial areas being spread, in the form of neighborhoods with various density. It gives a big chance for reducing the need to travel if densification will be made in an organized way, with the possibility to minimalize the use of private cars and limit the emissions of transport-related pollutants.
While overlapping the most significant industrial areas with the wind analysis presented in the previous chapter, the definition of possible areas affected by the dispersion of industrial pollution is possible. The precise estimation is challenging due to the fickle character of air pollution, so the map has to be treated as a possible simulation. However, knowing that the industrial area nr. 2 is being extinguished, it will leave most of the central densely populated areas of the city outside the furthest exposure zone.



[FIG.4.04]
ORIGIN MAP (INTERNAL CITY TRIPS, BY DISTRICT)
source: re-elaboration of the data prepared by Łukasz Drozda
data: Dyktatura Kierowców - Architektura niezrównoważona, p.99, Warszawa 2016



[FIG.4.05]
DESTINATION MAP (EXTERNAL TRIPS TO WARSAW)
source: re-elaboration of the data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw), Warsaw Traffic Study 2015

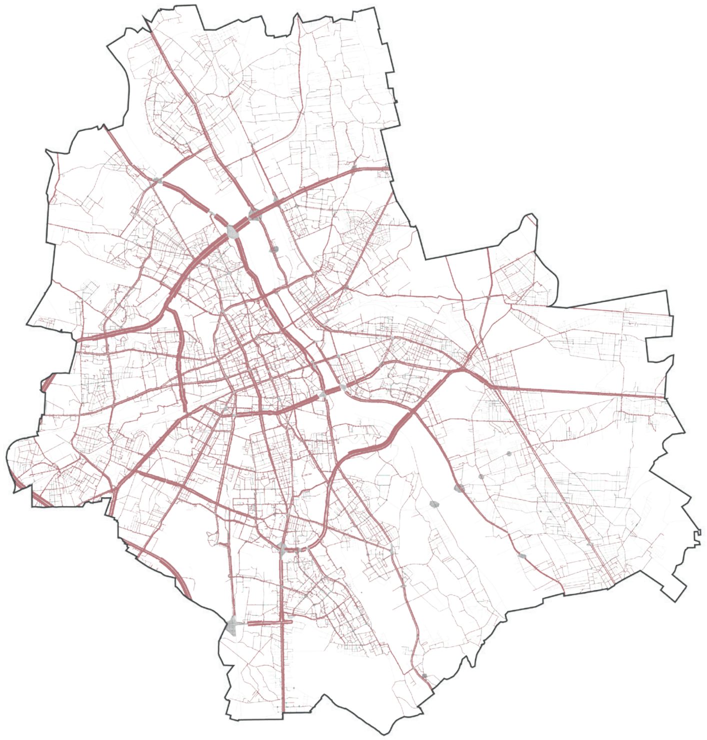
URBAN TRAFFIC

THEORY

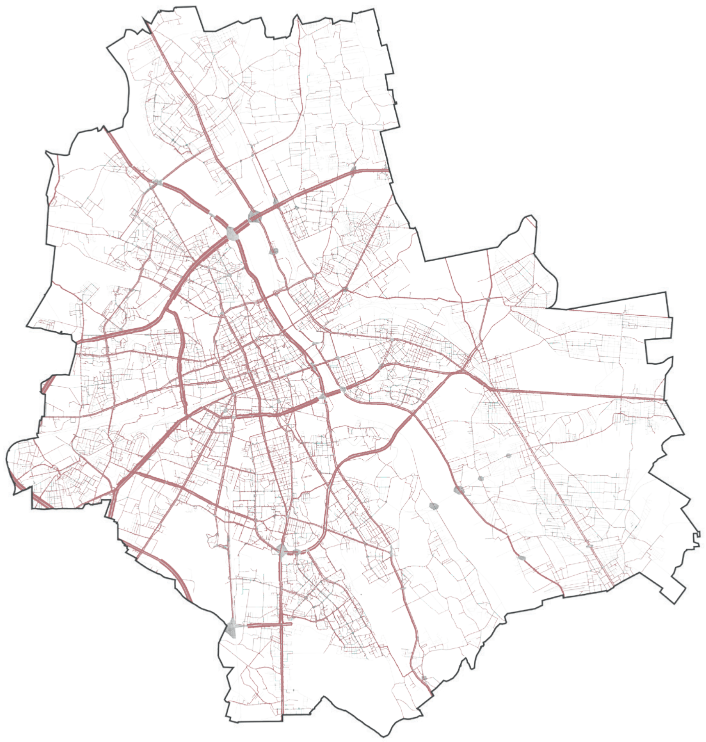
In previous chapters, it has been proven that traffic is one of the most important sources of pollution. Mapping the roads with great use of cars can help understanding where possible congestions are being created. The cars which are blocked in traffic congestion can emit higher levels of pollutants, although it is essential to define those areas.

ANALYSIS

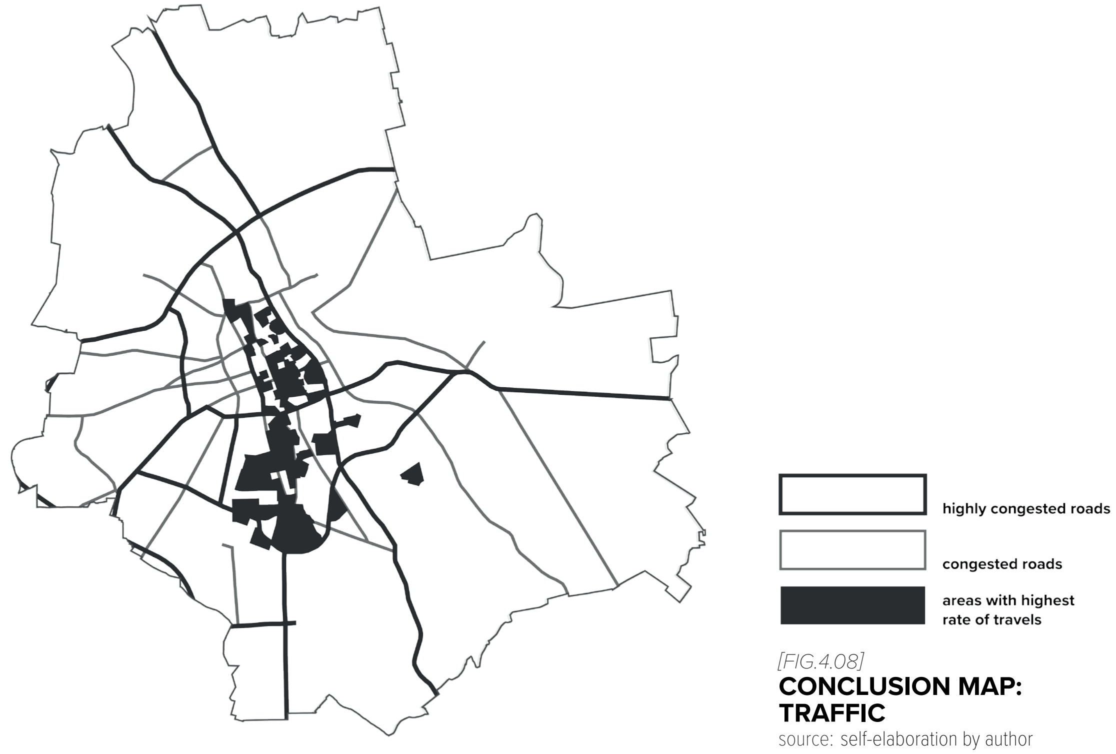
The origin map shows that the central district is the area that generates most of the travels within the city, reaching almost 300% of the average amount of travels by the district. The destination map showed that most of the external travels finish in the central and surrounding districts. It can be an estimator of how many citizens of the metropolitan region are working in the central parts of the city and need to travel. It is essential to mention that 31,7% of those travels are made by car (WBR, 2015), and the total number of vehicles entering Warsaw reached 480.000 each way in 2015 (WBR, 2015).



[FIG.4.06]
MORNING TRAFFIC FLOW
source: re-elaboration of the data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw), Warsaw Traffic Study 2015

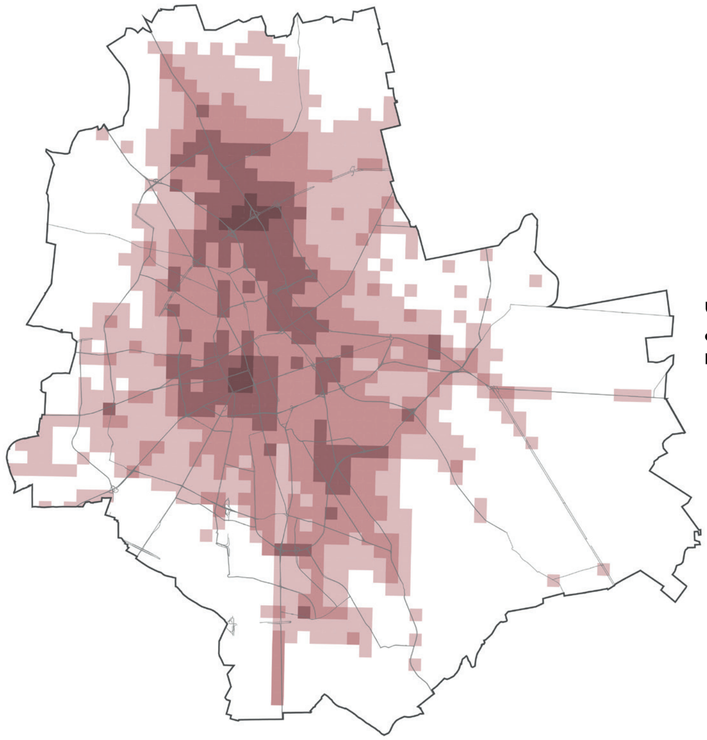


[FIG.4.07]
EVENING TRAFFIC FLOW
source: re-elaboration of the data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw), Warsaw Traffic Study 2015

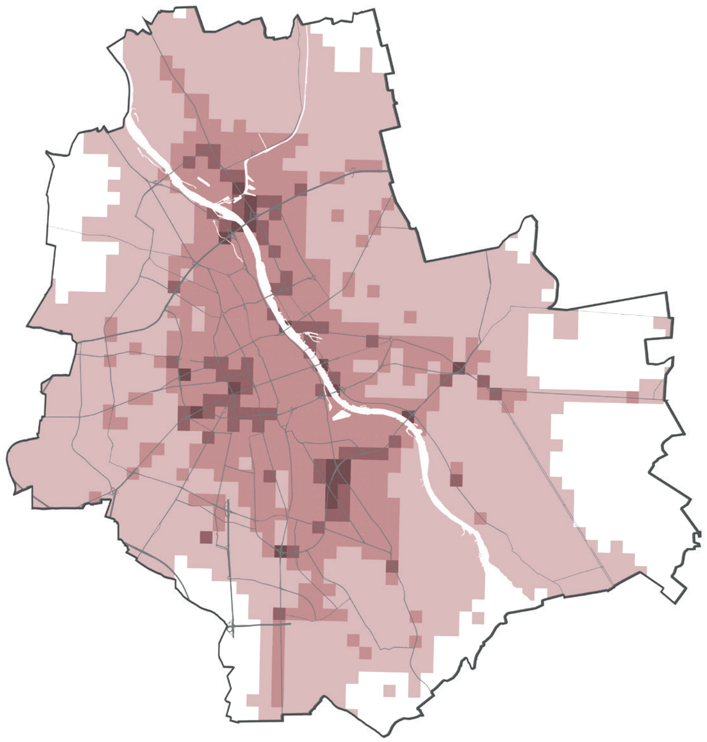


[FIG.4.08]
CONCLUSION MAP: TRAFFIC
source: self-elaboration by author

The flow maps show that the highest concentration of vehicle use is visible on the bypass roads of Warsaw and bypass roads of the central district, with exceptionally high use of the streets within the city center. It is essential to acknowledge that during the post-war reconstruction, many of the ruins in central Warsaw have been erased, to create space for wide 'city highways' that were corresponding to the vision of car-oriented cities in the '50 and '60. Those roads now give an extraordinary chance for a complete redefinition of the transport system, and placement of alternative green solutions.



[FIG.4.09]
PM10
AV. PERIOD: 24H
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model



[FIG.4.10]
PM10
AV. PERIOD: ANNUAL
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model

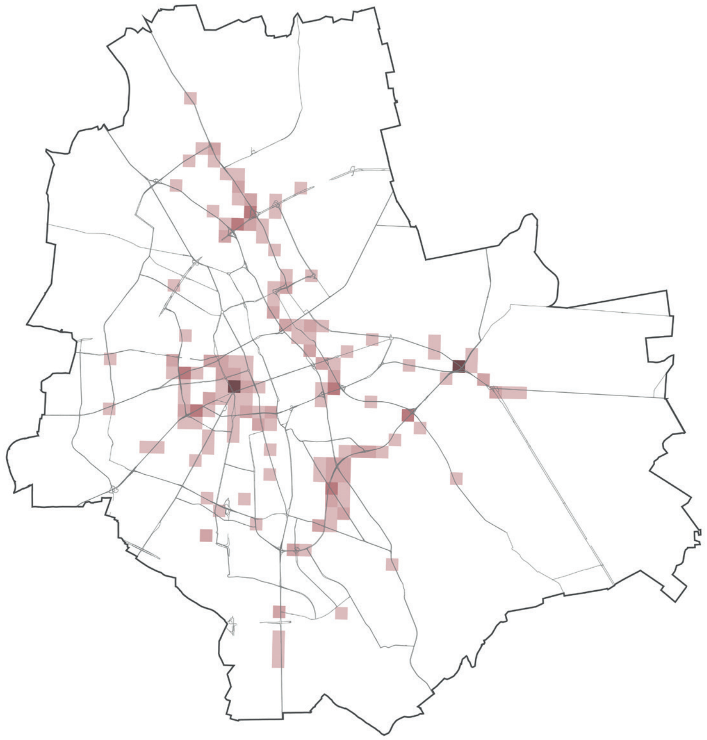
AIR POLLUTION

THEORY

The most relevant analysis for the aim of this thesis is the air pollution spatial distribution analysis. The aim is to try defining the most affected areas by the presence of different pollutants. This kind of data is very hard to obtain. Presented maps are an outcome of the mathematical Calpuff model prepared by the General National Environmental Agency. This method is used as a support to estimate the distribution of various pollutants. It is a multilayer, non-stationary model prepared for determining the spatial distribution of many substances, taking into account the topography and the impact of meteorological conditions changing in time and space. Data has been grided on squares 500x500 meters, using GIS software, and represented according to the strict WHO norms discussed in previous chapters, by author. The model was developed by the company ENVIRON International Corporation (USA).

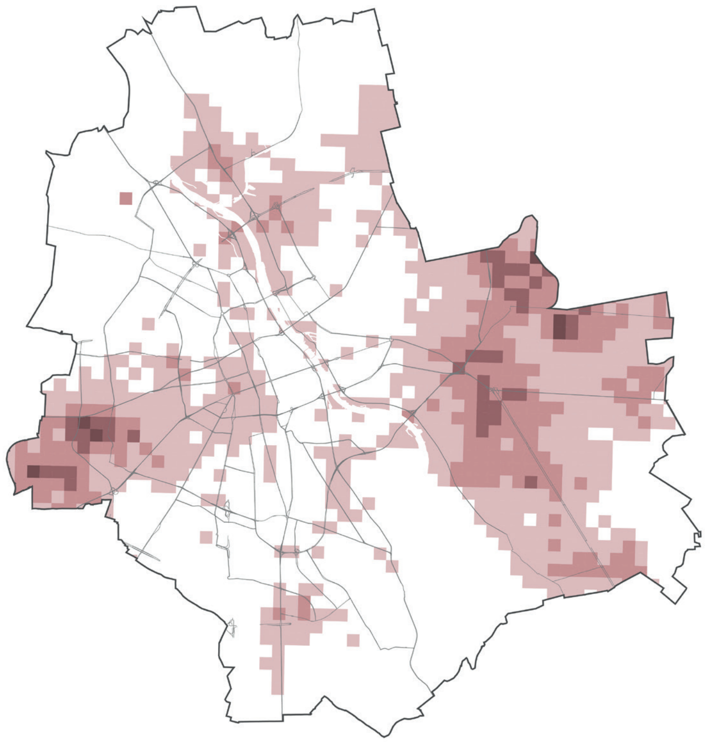
ANALYSIS

Figure 4.09 and 4.10 both represent the levels on PM10 but averaged in the daily and annual mean. The data has been overlapped with the existing car infrastructure of the city, tho we can observe the particular concentration of the PM10 on significant transportation nodes, where several streets cross. Almost every big crossing in the city overlaps with a grid representing high concentration. That gives a strong suggestion about the relationship between levels of PM10 and transportation within the city. Higher concentrations can also be observed in the central districts comparing to the suburbian areas of Warsaw, which can be related to both higher emissions in the center, but also problems related to the natural ventilation between suburbs and the core of the city.



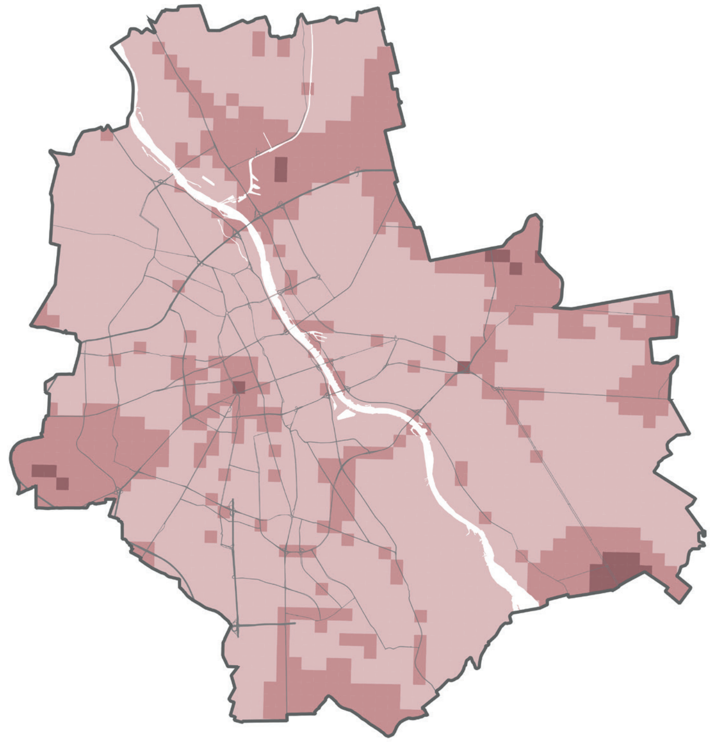
WHO limit
0-40 μg/m3
40-50 μg/m3
50-60 μg/m3
60-65 μg/m3
65< μg/m3

[FIG.4.11]
NO2
AV. PERIOD: ANNUAL
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model



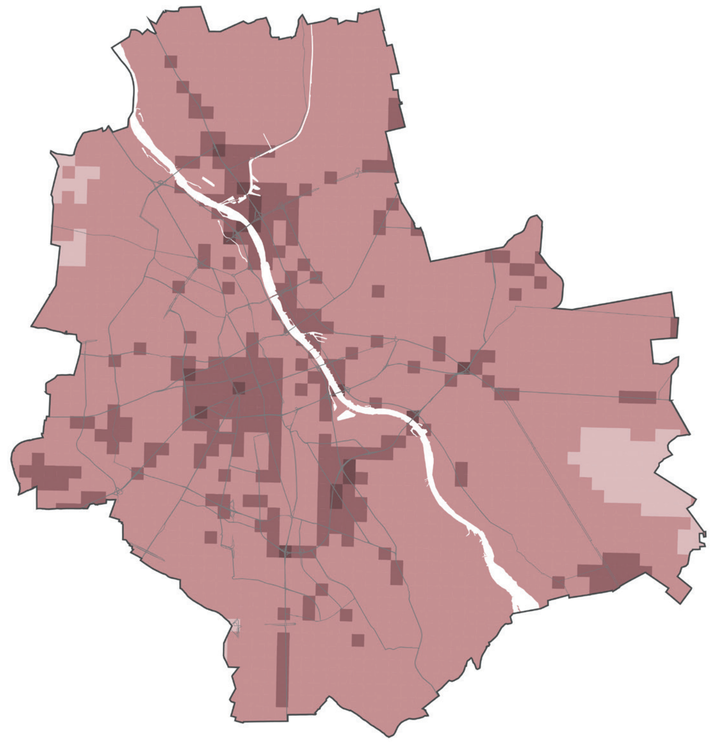
WHO limit
0-20 μg/m3
20-25 μg/m3
25-32,5 μg/m3
32,5-40 μg/m3
40< μg/m3

[FIG.4.12]
SO2
AV. PERIOD: 24H
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model



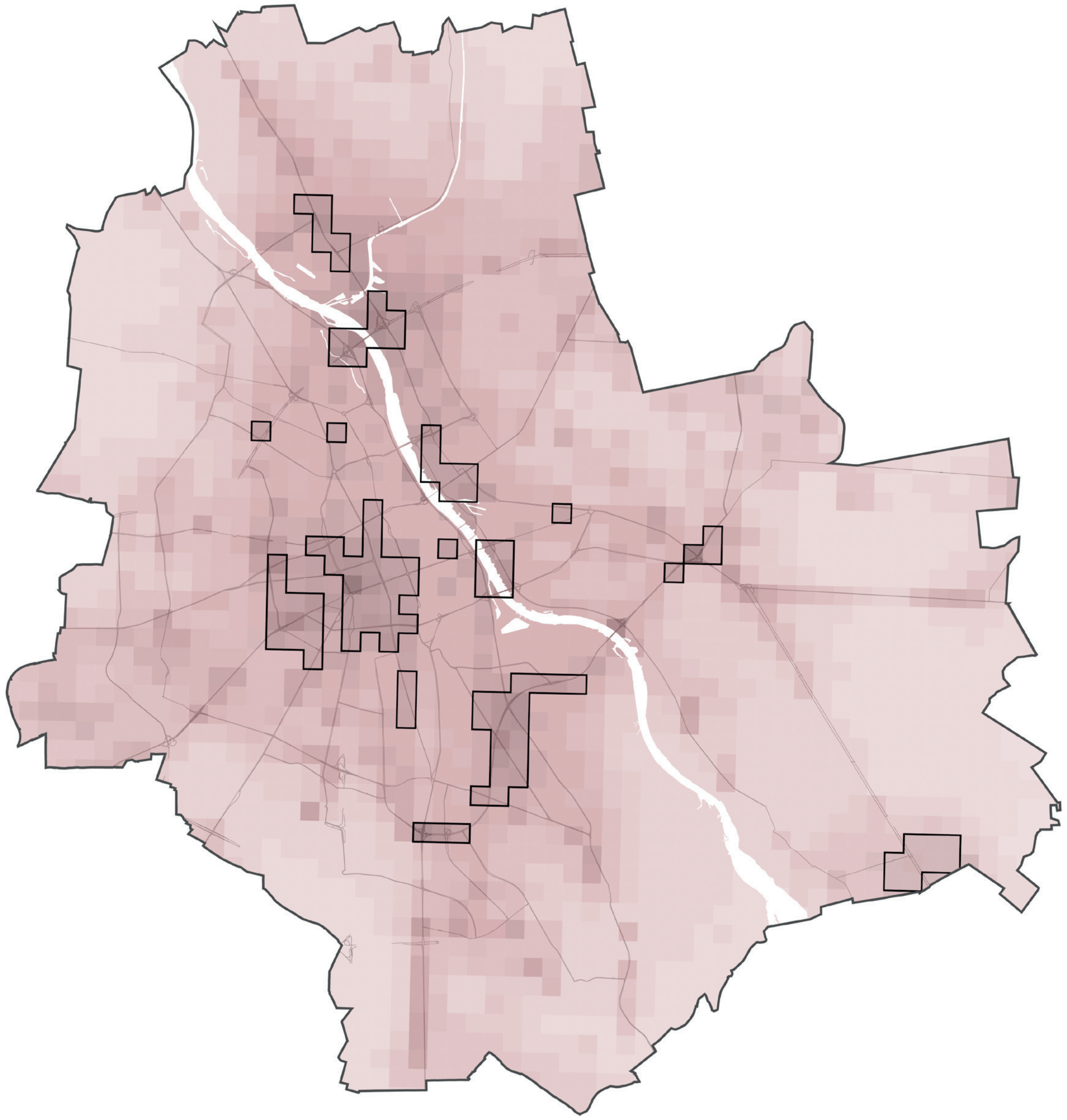
UE limit
0-1 ng/m3
1-1,5 ng/m3
1,5-2 ng/m3
2-3 ng/m3
3-5 ng/m3

[FIG.4.13]
BENZO[A]PYRENE
AV. PERIOD: ANNUAL
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model



WHO limit
0-10 μg/m3
10-15 μg/m3
30-40 μg/m3
40-50 μg/m3
50< μg/m3

[FIG.4.14]
PM2.5
AV. PERIOD: ANNUAL
source: Self-elaboration by author
data: GIOŚ - General National Environmental Agency - Calpuff Model



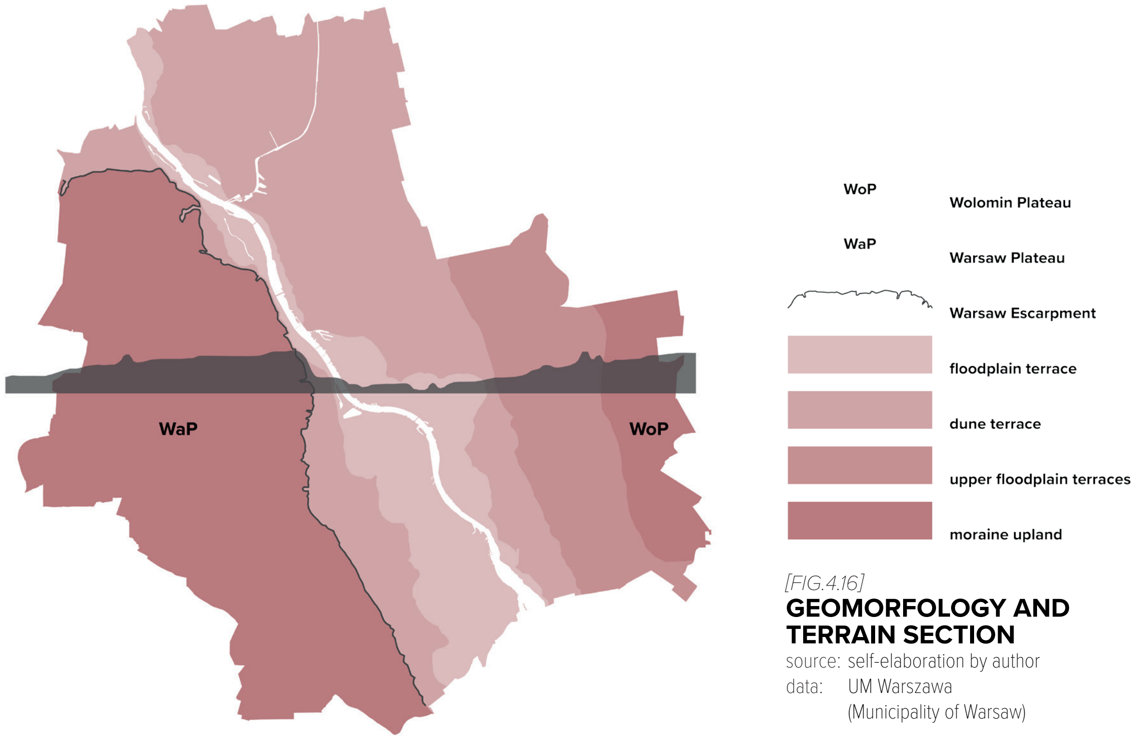
highly polluted areas

[FIG.4.15]
CONCLUSION MAP: AIR POLLUTION
source: Self-elaboration by author

On the previous page Fig.4.11 shows the spatial distribution of NO2, a typical pollutant related to intense transportation. The levels of NO2 in Warsaw are kept on similar levels throughout the year without the episodic character (see Fig.2.07). As expected, the concentration of NO2 is observed along the big streets and transportation nodes. However, a particular concentration is also noticeable in central Warsaw around Zawiszy square. This area appears to be hugely affected by the problem on every type of pollutants measured. A bit different is the spatial distribution of pollutants connected to burning fossil fuels. We can see the levels of SO2 (figure 4.12) or Benzoapyrene (4.13) higher in the areas further from the city center. These are mostly residential, single house neighborhoods where people have their own, single heating units. There are also higher levels of pollution for the same reason in towns around Warsaw, and this is partially visible on that map.

CONCLUSION

All the prepared maps have been overlapped in order to attempt the definition of areas with a particular intensity of pollution problem, visible on different levels (figure 4.15). Several significant transportation nodes and streets are visible, which confirms the idea of focus on public space redesign, presented in this thesis. The areas of City Center and close Wola district, especially around Zawiszy square, are also evident on the conclusion map. These are the areas with a lower possibility of natural ventilation, which is explained in further analysis, and focus on increasing the air ventilation should be considered there. We can also see the concentration around the Praga district on the east side of the river and some smaller concentration along the river. This outcome is a surprise since the river should work as an efficient natural ventilation corridor. The need for terrain analysis popes out in order to possibly explain this phenomenon.



[FIG.4.16]
GEOMORFOLOGY AND TERRAIN SECTION
source: self-elaboration by author
data: UM Warszawa (Municipality of Warsaw)

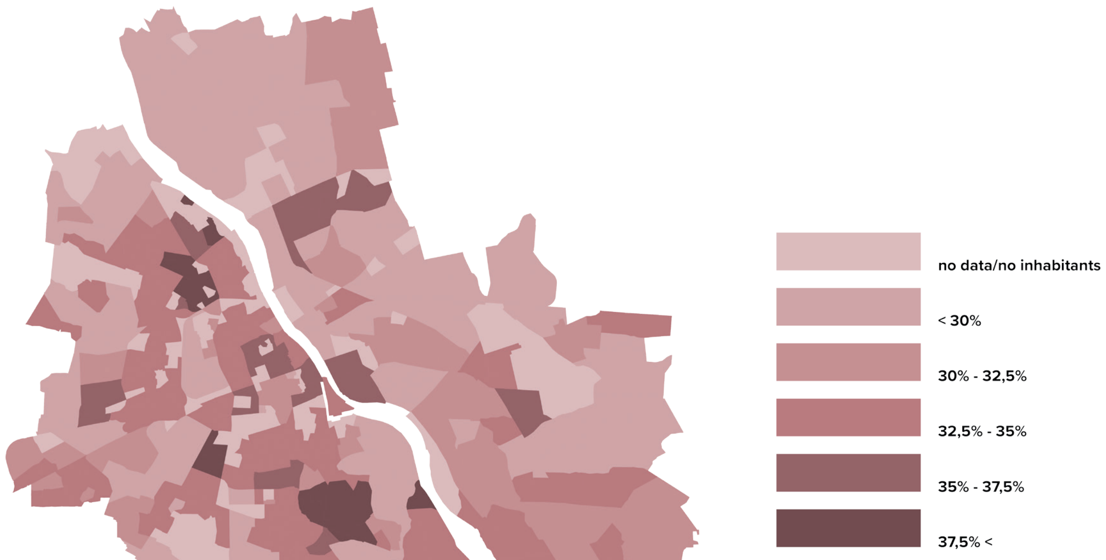
TERRAIN

THEORY

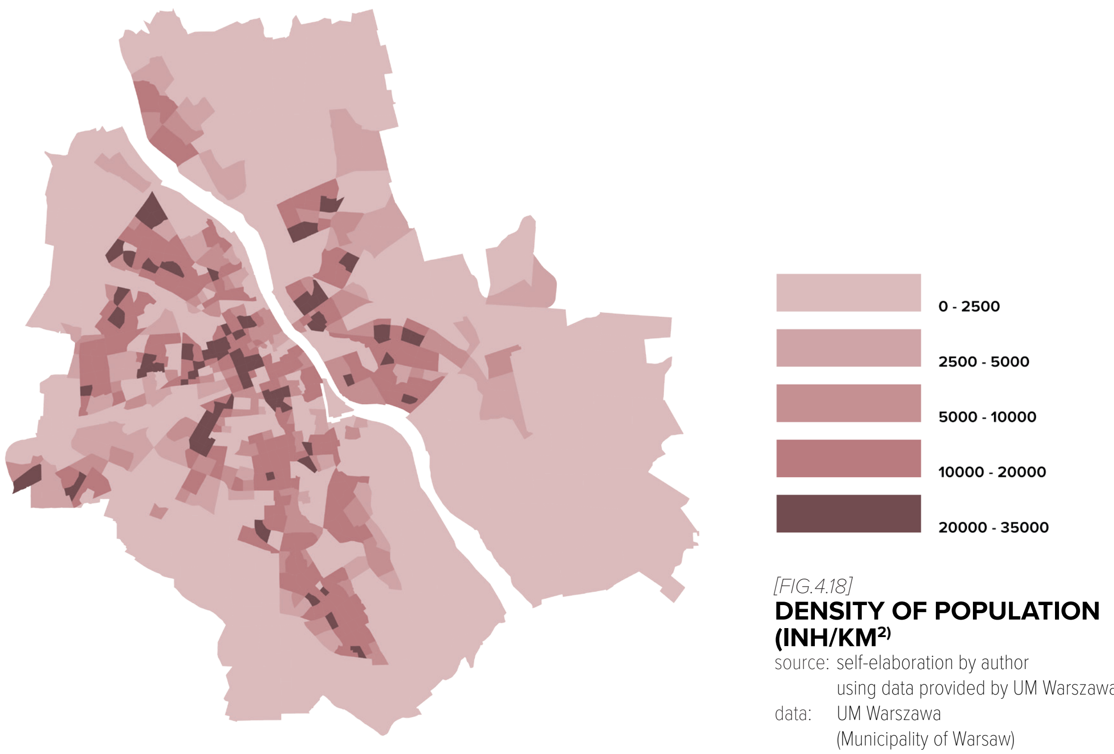
There is a strong correlation between the distribution of air pollution, wind flow patterns and geomorphology of the earth surface (van Esch, 2015). The creation of wind flows comes from differences in air pressure. Air pressure depends on the air density, which is affected by the temperature. The temperature is affiliated with specific features of the earth surfaces: their radiative, thermal, moisture and aerodynamic properties regulate their thermodynamic characteristics (Oke, 1987). Differences in height and diversified topography contribute to the climate response.

ANALYSIS

The city of Warsaw is located in the banks of the Vistula River, on the central Mazovian lowlands. The most characteristic geomorphological feature of the city is the presence of the Vistula river valley with typical terraces on both sides. On the western side of the city, the terraces are sharper and form the Warsaw Escarpment, while on the eastern side of the river, the terraces are more smooth. The Warsaw Escarpment creates up to 30 meters of differences in terrain profile between to top and bottom parts. Together with the presence of the river, this topographic feature may affect the temperature differences between the top and bottom parts fo the valley. The wind can be intensified or disrupted, which can potentially explain, or give a suggestion about the allocation of pollutants along the river in the air pollution analysis on previous pages.



[FIG.4.17]
PEOPLE UNDER 14 AND ABOVE 60 YEARS OLD
source: self-elaboration by author using data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw)



[FIG.4.18]
DENSITY OF POPULATION (INH/KM^2)
source: self-elaboration by author using data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw)

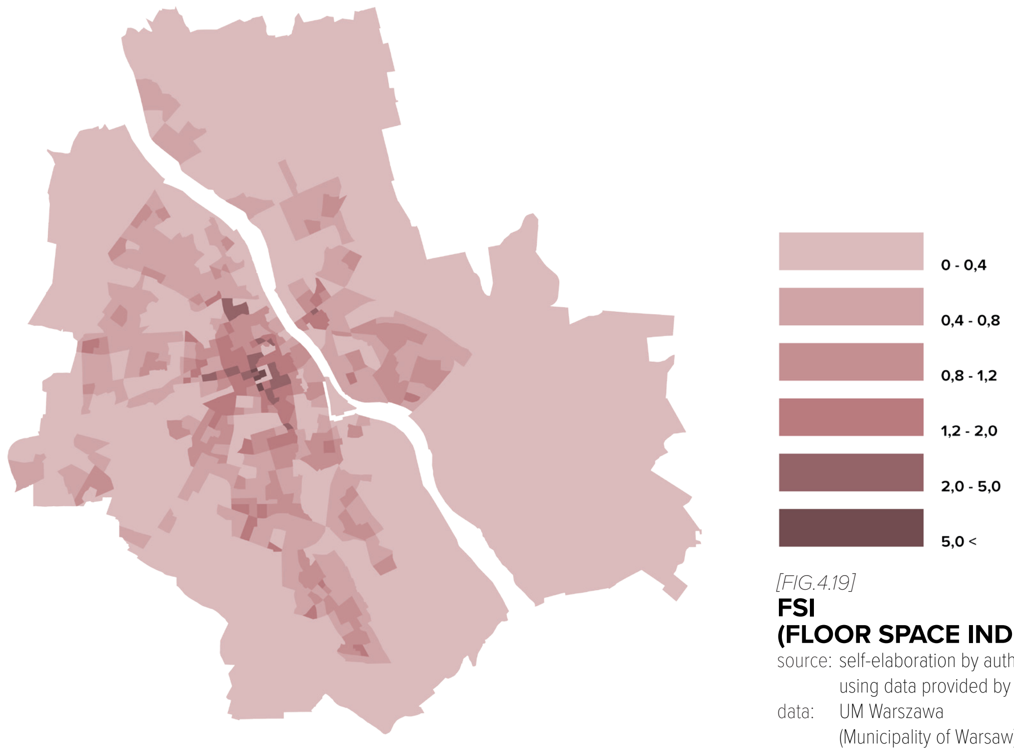
POPULATION

THEORY

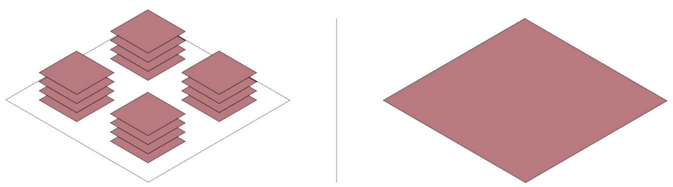
The inhabitants of the city create the receptor site. It is essential to define the most vulnerable people to the air pollution problem since this data is crucial for defying the impacts. For the aim of this research, it has been decided to show the spatial distribution of young kids under 14 years of age, and older adults, since their immune systems are the weakest and they can face the most severe consequences of pollution concentrations.

ANALYSIS

The data provided by the municipality of Warsaw is reduced to the areas defined for the transportation analysis done by the municipality, so the division of neighborhoods has been done for different reasons, and the data might not be exact for social analysis. However, it still gives us a strong suggestion, and while combined with other layers, can work for the aim of this research. We can observe concentrations of vulnerable people in the large post-war neighborhoods in the north and south of the city. Except for park areas, there is also visible concentration in the city center, also characterized by higher pollution levels. It is crucial to describe the density of the population map. Due to the post-war reconstruction, Warsaw has a low density, with 3500 people per m2 on average. It has to be noticed that contrary to other European cities, there is no densely populated core, but the density is higher in the modernist tower neighborhoods spread all over the city. That gives the first suggestion about the higher possibility of natural ventilation, but it needs to be confirmed with an analysis of the built environment.



[FIG.4.19]
FSI
(FLOOR SPACE INDEX)
source: self-elaboration by author using data provided by UM Warszawa
data: UM Warszawa (Municipality of Warsaw)



FLOOR SPACE INDEX (FSI)

$FSI_x = F_x / A_x$

F_x = gross floor area
A_x = area of aggregation
$_x$ = aggregation (here: subdistrict)

FLOOR SPACE INDEX

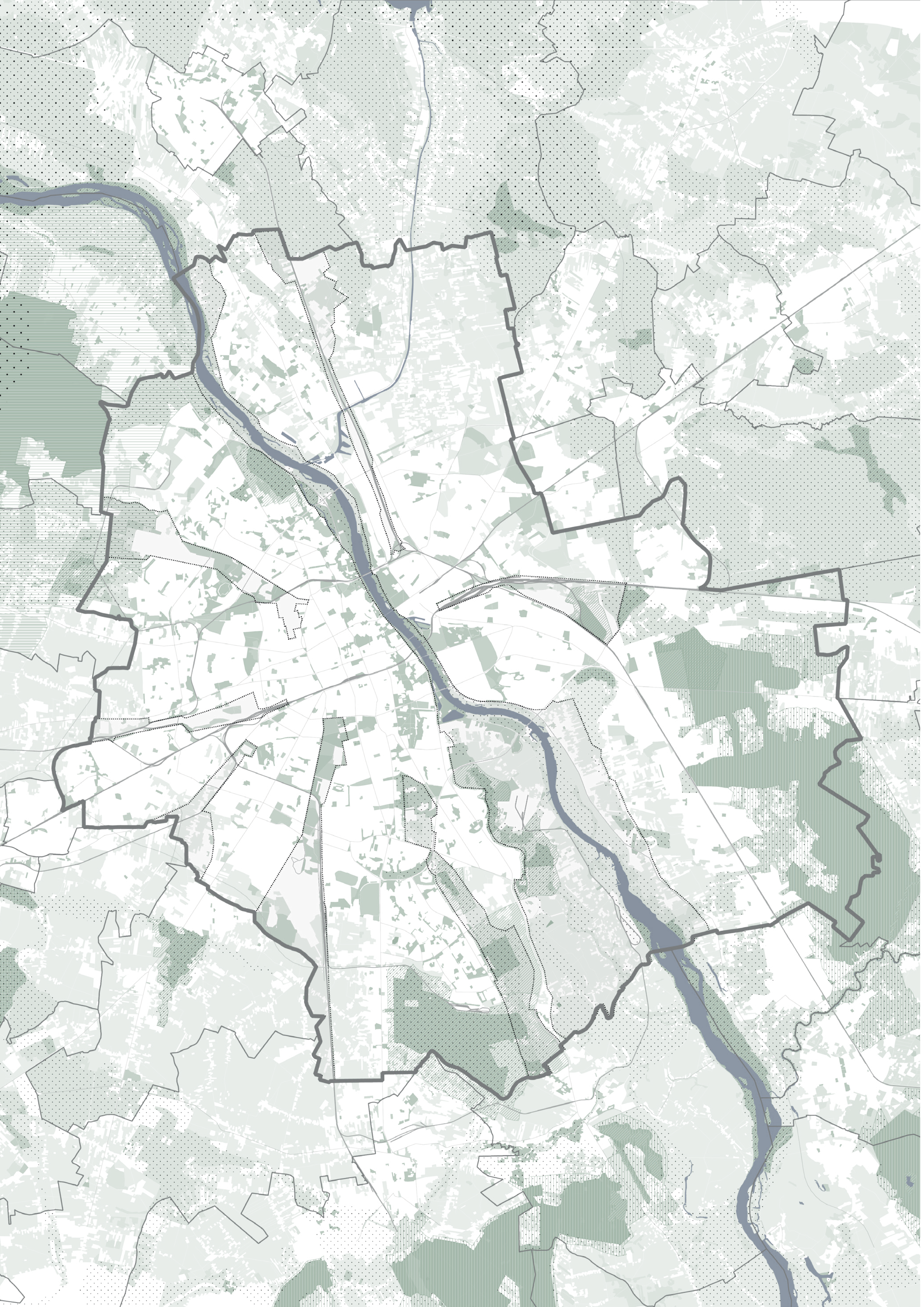
THEORY

As suggested in the previous analysis, the need to check the density of the built environment arose. The aim is to define how intense is the impact of buildings as natural obstacles on-air ventilations. The data collected is very limited, but it was enough to attempt to define levels of floor space index.
The floor space index (FSI) expresses the built intensity of an area. It shows how many square meters is built within a hectare of land. The higher the number is, the more intensely built up the area is. It would be beneficial to measure also Ground Space Index, which defines compactness of an area, but it was not possible due to the lack of relevant data.

ANALYSIS

The city is characterized by the very low intensity of the built environment. Naturally, there is higher intensity in the center where the big office towers are located and remain of the dense historic districts, but the rest of the city has a loose and permeable built environment. The intensity of 2-3 in Warsaw is defined as high, while similar research done on the city of Turin has defined high values on 9-11 (Vietti, 2018). Because visible part of the city has been constructed in the 70s, with the residential towers surrounded by parks, the possibility of natural ventilation in the city is considered high and should be used as a value in creating new ventilation systems.

GREEN SYSTEM AND VENTILATION SYSTEM



[FIG.4.20]
GREEN SYSTEM OF WARSAW AND SURROUNDINGS
source: GIS self-elaboration by author
data: UM Warszawa (Municipality of Warsaw)
WIOŚ MAZOWSZE,
(Masovian Environmental Protection Inspectorate)
GDOŚ
(The General Directorate for Environmental Protection)

THEORY

In many sources, the vegetation is described as the most effective measure to mitigate urban air pollution. This is, however, a very complex issue, and depends on the geographical location, types of vegetation, humidity, and several other factors. However, it is essential to understand the green pattern of the city, which can be used later in the definition of a more coherent ventilation system. To this extent, type, height, and disposition of vegetation are very relevant.

ANALYSIS

For the aim of this research data from several institutions has been collected to show the green system within the city, and on the biger scale. From the perspective of air pollution, it is not important what is the function of green, as long as the area is green, tho it has been decided to use very muted colors not to show differences but sizes and directions of different green structures. On the northwest side of the city, we have Kapinos National Park, a strictly preserved natural area, which location so close to the capital is unique on the European scale. An element that needs to be noted is the green ventilation corridors, created and defined by planners before the II world war. They still exist; however, there have been attempts to build over them. Especially the north-western corridor, connecting the city with the national park, has almost disappeared. The only chance to bring back those lost values is to use public space and street system to recreate those lost connections.

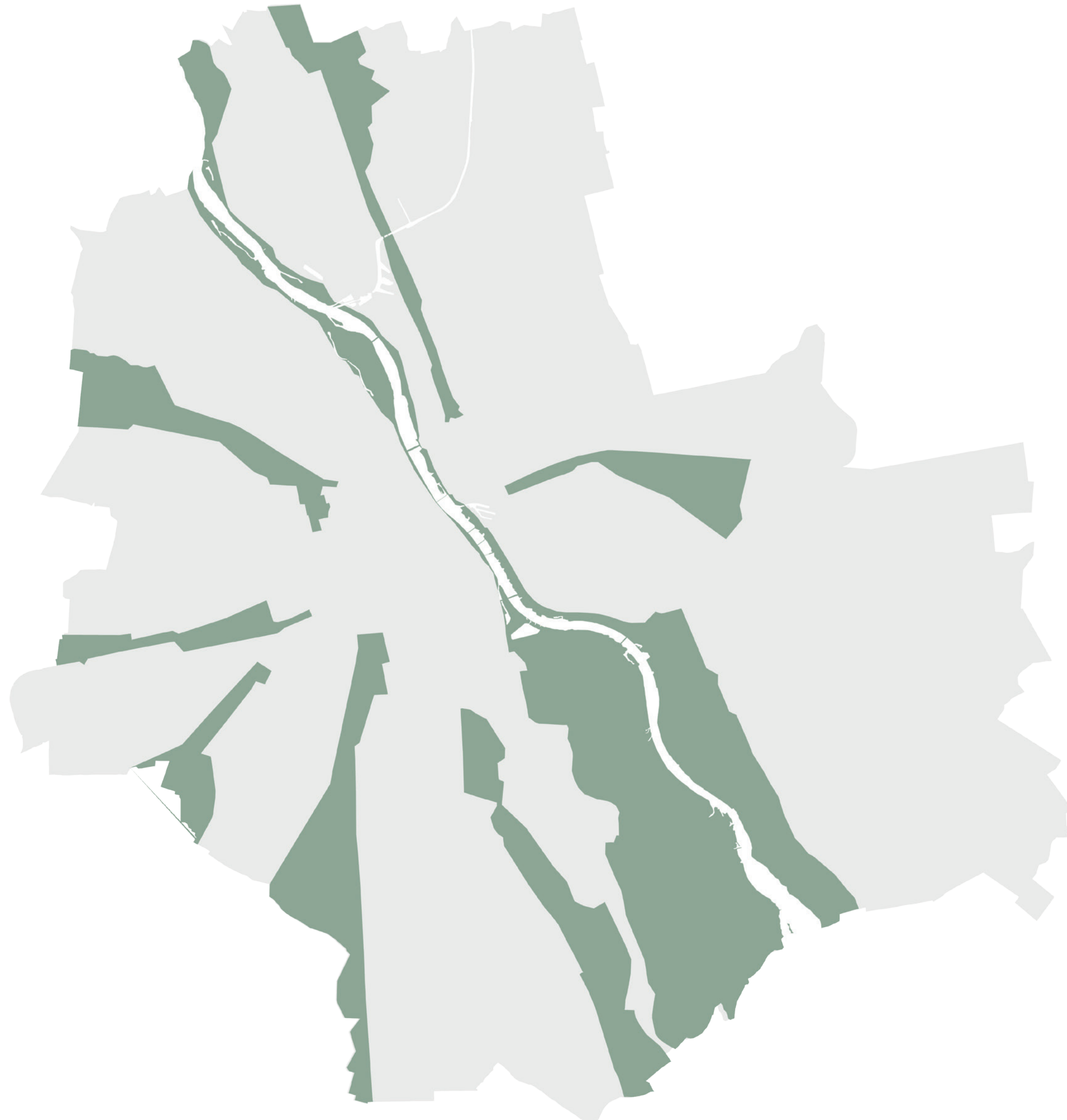
RESULTS

The analytical part of the research has shown several phenomena, and now some considerations can be made. In general, we can observe the highest concentration of pollutants, human activity, density of built environment, and traffic-related problems in the central part of the city, which could be expected. The crucial phenomenon is related to the density of the built environment, which is considered low in Warsaw. Apart from the central city, the FSI index gave low or meager results, due to the specific type of built environment in Warsaw. It suggests that the attempts in increasing ventilation have to be focused on the central part of the city, where historic and reconstructed dense built environment is an obstacle for a natural air movement. A big problem related to air pollution has been observed around most of the transportation nodes, where highways cross with big city streets. Those areas are the most vulnerable for the appearance of traffic congestion, and this is visible in the air pollution analysis.

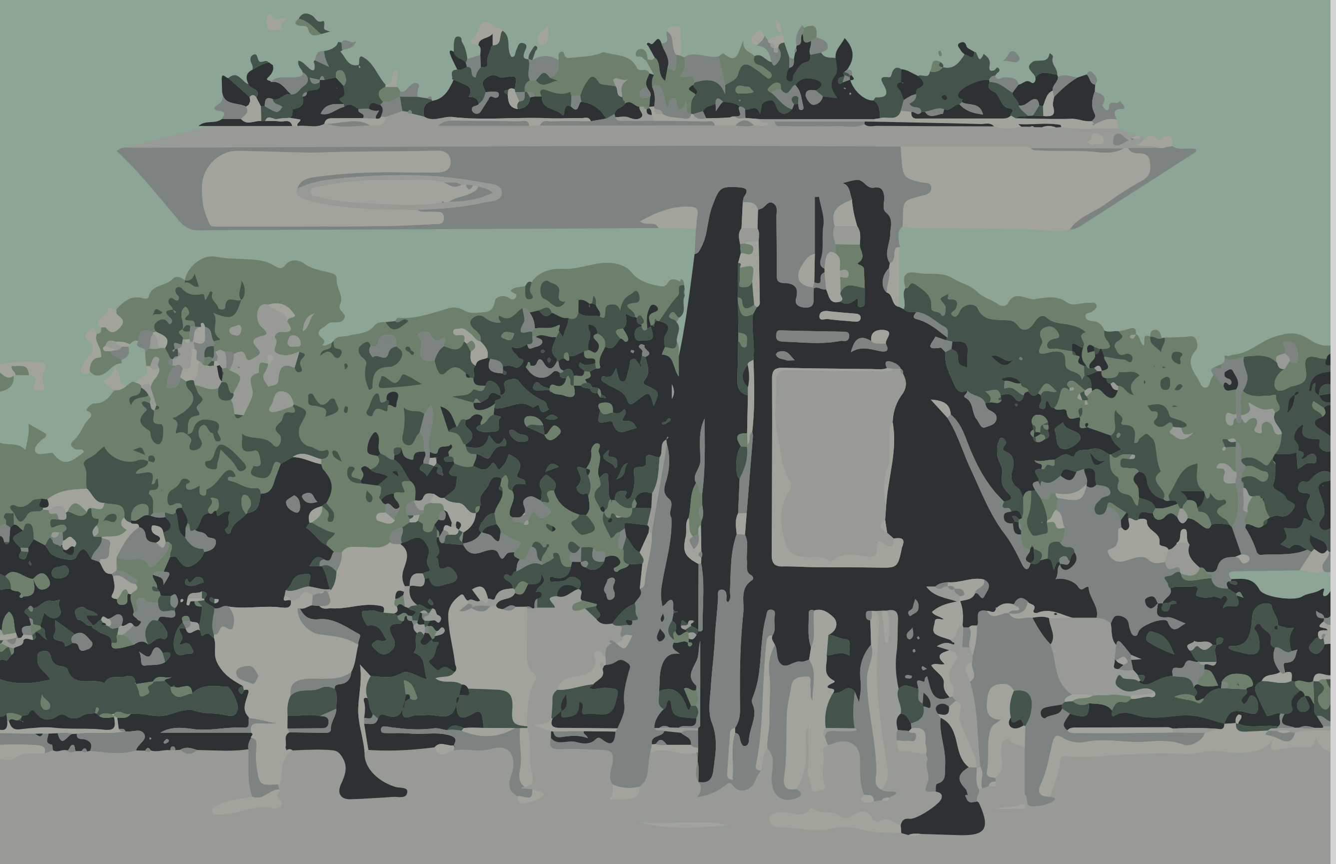
The geomorphology and terrain analysis gives some additional suggestions about the possibility of observed pollution concentration along the river, which was not expected to see. However, a combination of various factors, including congestion or density of development, also played a crucial role in the concentration of this phenomenon.

It has been observed that particularly tricky situations can be observed in the western sides of the central districts, where very high pollution levels met with a high density of development and population, transport issues, and lack of existing green. Those areas need particular attention during the conceptual and design processes.

During the air pollution analysis, the intercalary of the problem has been noticed. In the beginning, three scales have been defined - mesoscale, urban scale, and local scale. It is very challenging to define precise borders or exact concentration, and the analysis has to be taken suggestively rather than definitively, contrary to, for instance, density analysis, which gives more exact results. The analysis showed that there are several intermediate-scales within the extremes, and the possible visions and proposals have to tackle this intercalary of the problem actively.



[FIG.4.21]
AERATION CORRIDORS
source: Self-elaboration by author



chapter 5

DESIGN METHODOLOGY

STRATEGIC OBJECTIVES

The goal of the intervention is to define innovative steps the city should take to reduce the negative impacts of air pollution on environmental problems. The solutions aim to follow the strategic concept of adaptation and mitigation. The attempt is to define how public space could be transformed in order to create it more adaptive for the air pollution environmental problem, as a supportive strategy for the long term mitigation solutions to the air pollution problem. By increasing the level and capacity of public space to disperse pollutants, we can limit the levels of reception in the most vulnerable groups. The focus is on the city's perspective and involves both public, as well as public-private participation.

DESIGN PRINCIPLES

The design of the public space has been previously determined by the urban design around it. However, the new developments, increase in underground infrastructure, strong compaction, energy transition, air pollution problem, which is the crucial point of this research, but also other sustainability issues require the methodology to change. The public space has to co-determining how we arrange the build-up space around. Because of the complexity of those issues, the creation of the new efficient working method is needed.

DESIGN MODULES

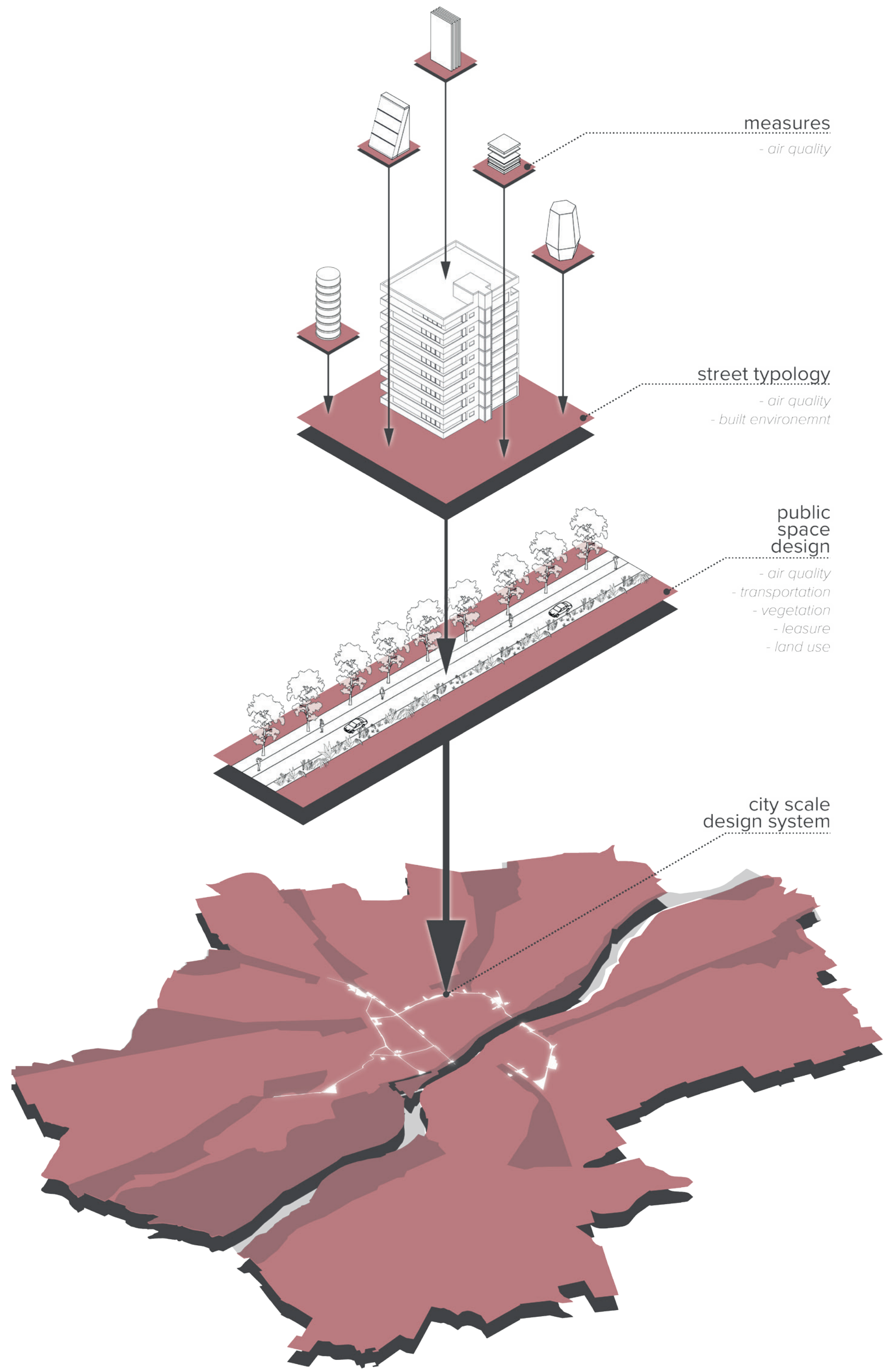
In order to find the most effective way to respond to climate change and environmental challenges, the meeting point between abstract mapping and time consuming and not flexible technical proposals has to be found. The methodology of performative design modules has been proposed—repetitive design solutions, easy to adapt, and illustrate, explicitly selected to each of the design challenges. The modules facilitate the design process with the perspective of the selected problem. In perfect situations, those modules are being prepared for several different topics, such as Water, Energy, Mobility, Flora, Fauna, Underground, and others. Each of the topics has to be mapped out, describing the existing situation and intended plans for which public space has to be designed. While having the existing situation and clear goals being established, the toolbox of design solutions allows us to respond to the defined challenges in a fast and flexible way. The combination of all of the topics, in an integrated way, guarantees the specific but flexible outcome. A similar approach has been proposed by the "Amsterdam Rainproof" with design solutions for the water problem. For the aim of this research, only the most relevant design modules from the perspective of Air quality have been prepared.

INTERSCALAR APPROACH

The use of the design modules allows introducing the design activity on different scales. The modules which are singular punctual interventions can work together on a bigger scale forming a systematic solution. Those solutions presented in the form of typologies affect the design of public space. Moreover, redesigned public space forms a new landscape system on the entire city scale. This approach creates an interscalarity of actions, from local, through urban, up to mesoscale.

MULTI-ISSUES SOLUTION

The interscalar approach also creates the possibility to tackle different issues. From air quality, being the main focus, through improved transportation, increased vegetation, boost leisure activities, expanded variety of functions, the interscalar approach allows us to propose more diverse solutions. The reached goal is not only to mitigate air pollution but also to add new values and qualities to the site of intervention.



[FIG.5.01]
INTERSCALAR APPROACH - MULTI-ISSUES SOLUTION
source: self-elaboration by author

INDEX OF MODULES

The proposed and researched measures, most efficient for air pollution absorption and mitigation, have been grouped in different categories. Green solutions are the category containing all the measures which use redesign of public space by an increase of share in vegetation. Those solutions have been divided into sub-groups, according to the type of solution and the placement. We have green roofs, walls, structures, infrastructures, and urban trees. The second category contains all the so-called urban furniture, independent elements able to be placed in public space that increases the presence of vegetation or absorbs air pollution. These measures are divided into urban furniture and smog-eating structures subgroups. The third category is an attempt to bring additional functions to air pollution mitigation. There are several measures that not only increase the presence of fo vegetation in public space but also allow water retention and increased infiltration. Those solutions have been placed in a category called water solutions.

Each solution has been given an individual code that allows faster recognition, but will also be used in the further chapters while describing the implementation of the modules in the specific context of the case study.

[FIG.5.02]
INDEX OF DESIGN MODULES
source: self-elaboration by author

issue	category of measures	design group	design module	code
air pollution	green solutions	green roofs	green roof extensive	GGR-1
			green roof semi-intensive	GGR-2
			green roof intensive	GGR-3
		green walls	elevation garden (1)	GGW-1
			elevation garden (2)	GGW-2
			elevation garden (3)	GGW-3
		green structures	standing garden	GGS-1
			façade garden	GGS-2
			green fence	GGS-3
		green infrastructures	green tram track	GGI-1
			green highway wall	GGI-2
			green noise barrier	GGI-3
			green parking lots	GGI-4
			green roadsides	GGI-5
			anti-smog meadows	GGI-6
			curbs extention	GGI-7
		trees	urban trees	
	urban furnitures	urban furnitures	smog free tower	FUF-1
			urban smog lamp (1)	FUF-2
			urban smog lamp (2)	FUF-3
			air purificator	FUF-4
			furniture with moss	FUF-5
			bus stop with moss	FUF-6
			green parklet	FUF-7
		smog eating structures	anti-smog pavement	FSE-1
			anti-smog tiles	FSE-2
			anti-smog façade	FSE-3
	water solutions	water structures	bio-retnetional swale	WWB-1
			bio-retentional planter	WWB-2
			hybrid bioswale	WWB-3

GREEN ROOFS

THE STRUCTURES

Green roofs compensate for interventions in the landscape and provide plans and animals with new habitat in an urban environment. They are an essential aspect of sustainable building planning. Compared with conventional roof constructions, they improve roof protection and building insulation. The developing area above other structures, such as terraces, inner courtyards, and roofs, creates usable open space. Green roofs absorb a significant amount of rainwater, decreasing runoff and reducing the amounts of debris and pollutants washed into lakes, streams, and rivers. 40-60% annual mean water retention is created by extensive green roofs, 60-90% for intensive green roofs. Consequently, the microclimate also improves, as the increase in water vapor balances extremes of temperature, and the vegetative surface filters fine dust and heavy metals out of the air.

AIR QUALITY

Research conducted by Jun Yang, Qian Yu and Peng Gong about the effectiveness of green roof systems installed in Chicago showed that a total of 1675 kg of air pollutants was removed by 19.8 ha of green roofs in one year with O3 accounting for 52% of the total, NO2 (27%), PM10 (14%), and SO2 (7%). The annual removal per hectare of the green roof was 85 kg. This research concluded that the green roof could be used to supplement the use of urban trees in air pollution control, especially in situations where land and public funds are not readily available.

Source:
Constructing Landscape - Materials, Techniques, Structural components. Astrid Zimmermann (ED.) Birkhauser Verlag AG, Berlin, 2009
Rowe, D.B., Green roofs as a means of pollution abatement, Environmental Pollution (2010)
Green Roofs and Rooftop Gardens, Brooklyn Botanic Garden

GREEN ROOF - extensive

GGR-1

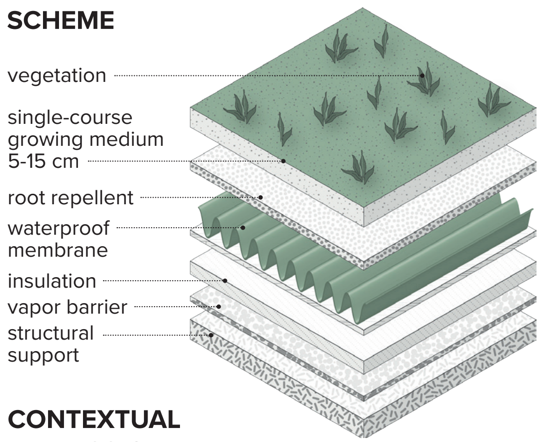
TECHNICAL QUALITATIVES

Source: Green Roofs and Rooftop Gardens, Brooklyn Botanic Garden

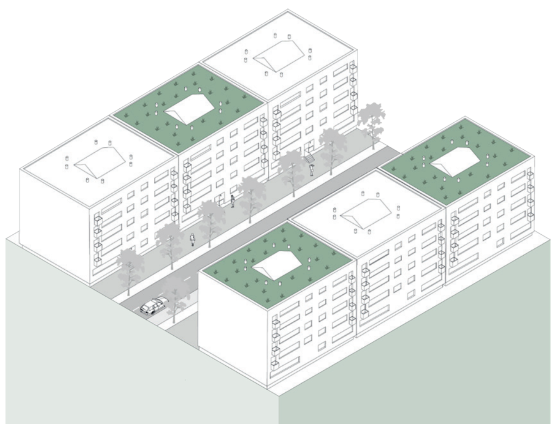
An extensive green roof type is recommended mostly when a roof will tolerate minimal superstructure and loads. This type of roof is not intended to be walked on. Creating and maintaining these is comparatively inexpensive. Except during the growing phase, maintenance is extensive.

An extensive green roof imposes functional loads on the roof construction of from 60 kg/m2 to approximately 250 kg/m2. Due to the minimal structure and extensive maintenance, only very robust and drought-resistant plants are used. Shrubs, grasses, lichens, and mosses or, more rarely, ground-covering woody plants are used. Many of these plants originate in high alpine locations.

SCHEME



CONTEXTUAL IMPRESSION



GREEN ROOF - semi-intensive

GGR-2

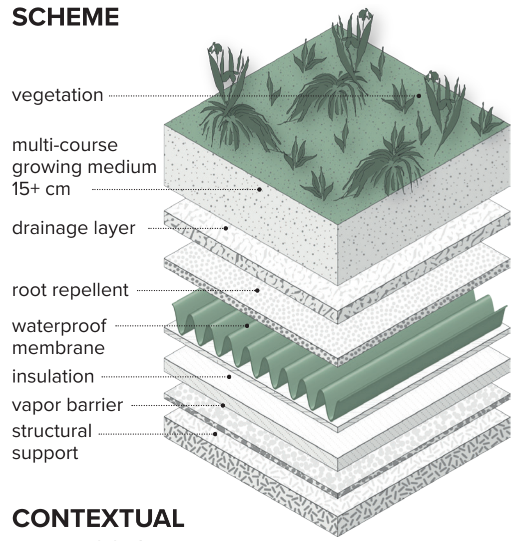
TECHNICAL QUALITATIVES

Source: Green Roofs and Rooftop Gardens, Brooklyn Botanic Garden

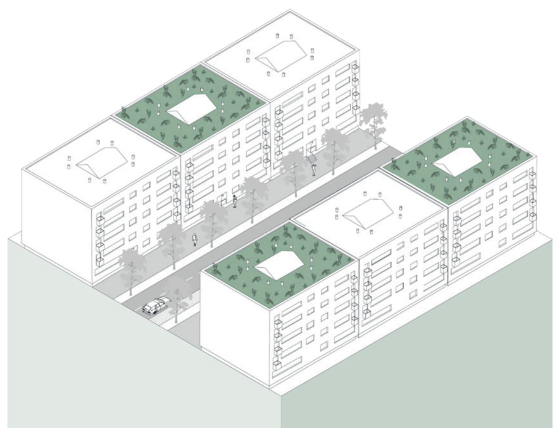
Semi-intensive green roof is an in-between form of extensive and intensive roofs. It can be used in all kinds of conditions when a havier roof load is possible, ranging from 180 to 300 kg/m2. It also allows having variety of plants, including bushes, low woody plants, and shrubs. The design process requires closer attention to watering and fertilizing issues.

> ***REMOVING THE AIR POLLUTION***
> *2000m² of uncut grass on a green roof can remove up to 4000kg of particular matter.*
> *Source: Rowe, D.B., Green roofs as a means of pollution abatement, Environmental Pollution (2010)*

SCHEME



CONTEXTUAL IMPRESSION



GREEN ROOF - intensive

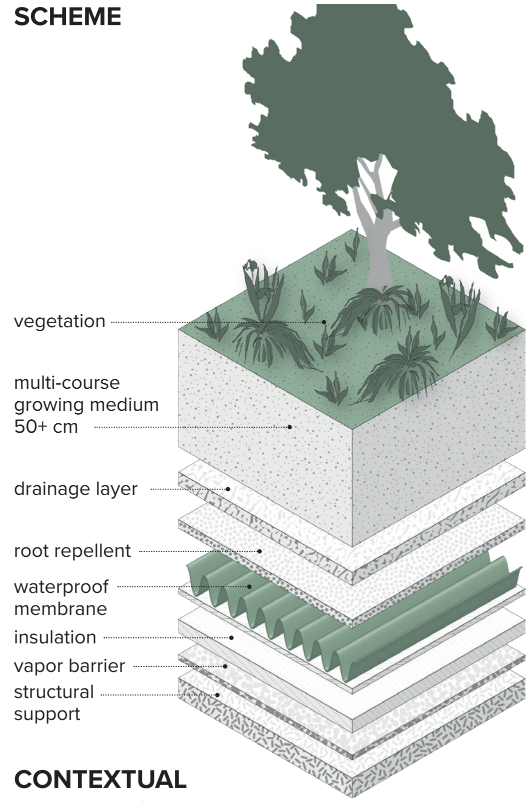
GGR-3

TECHNICAL QUALITATIVES

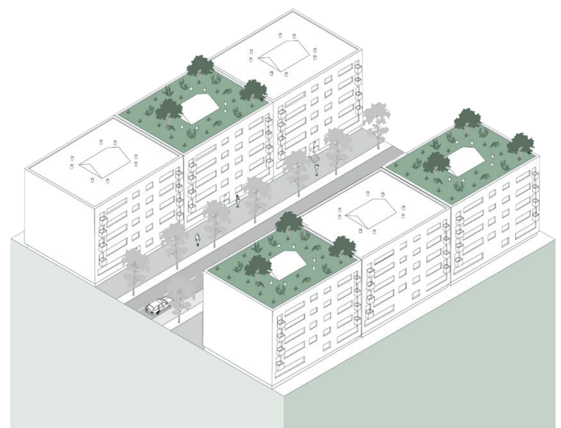
Source: Green Roofs and Rooftop Gardens, Brooklyn Botanic Garden

Intensive green roofs offer broader functionality and use of plants. This type of roof can sustain over 300 kg/m2 of a load. Bushes, small trees, and a variety of lawns can be present on that type of roof. It requires the durable construction and high loadbearing capacity of the host-building.

SCHEME



CONTEXTUAL IMPRESSION



GREEN WALLS

THE STRUCTURES

Green walls are an alternative way to introduce vegetation into the densely populated areas, with limited access to natural green systems. Plants bind dust and aerosols, such as the heavy metal lead and cadmium, from the air. The fabrics often settle on the leaves, are washed off by the rain, and then end up in the substrate. Another part of the substances is absorbed and stored by the plant. The uptake appears to be higher in the vicinity of busy traffic roads where, naturally, there is also more pollution in the air. The uptake depends on the leaf surface index (ratio between leaf surface and the façade surface occupied by the leaves) and the type of plant. Façade planting protects a building against global warming in the summer and keeps it cooler. In winter, the façade planting can limit the heat losses by limiting the wind and thus the convection losses along the façade and the stationary air cushion between plants and the building.

AIR QUALITY

Research conducted at the University of Birmingham showed that green walls placed in the dense streets could reduce levels of PM10 up to 23%, just by greening the walls across large areas of street canyons. In the zones with limited wind and natural ventilation access, these levels can reach even 60%. The same research also concluded that green walls could form a natural buffer against high-pollution episodes, being a useful tool in air pollution resilient planning, visibly more efficient that row of trees and green roofs

Source: Hermy M., Schauvliege M. & Tijskens G .; Groenbeheer - a story with a future; Velt in collaboration with the Bos & Groen department, Berchem, 2005
Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons, Thomas Pugh, Angus Mackenzie, J. Duncan Whyatt, C. Nicholas Hewitt, Environmental Science & Technology, 46 (14), 7692-7699. DOI: 10.1021/es300826w.

ELEVATION GARDEN - climbing plants

GGW-1

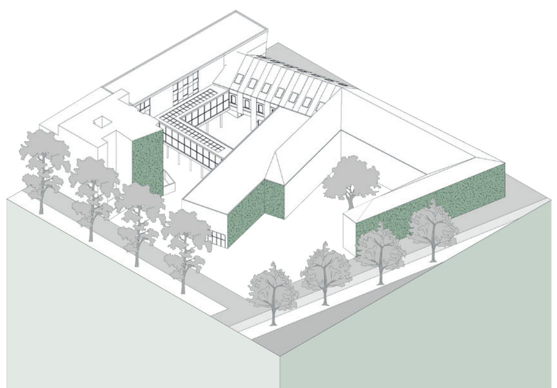
TECHNICAL QUALITATIVES

Source: Het klimaat past ook in uw straatje, Hogeschool van Amsterdam

There are two categories of climbing plants: self-climbing plants, which climb using tendrils, twining stems or suckers, and climbing plants that need a construction placed in front of the wall along which they can grow and climb. These types of green walls require direct access to the ground and soil, which is a base for the plant, but their maintainance costs are low.

SCHEME

CONTEXTUAL IMPRESSION



ELEVATION GARDEN - hanging plants

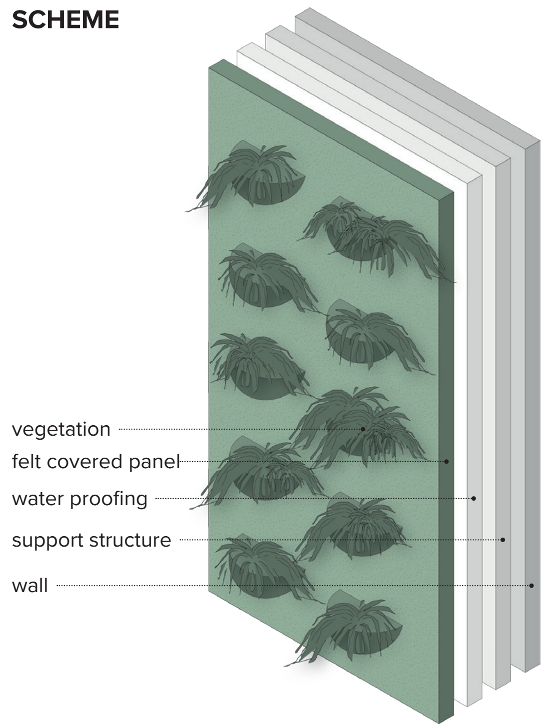
GGW-2

TECHNICAL QUALITATIVES

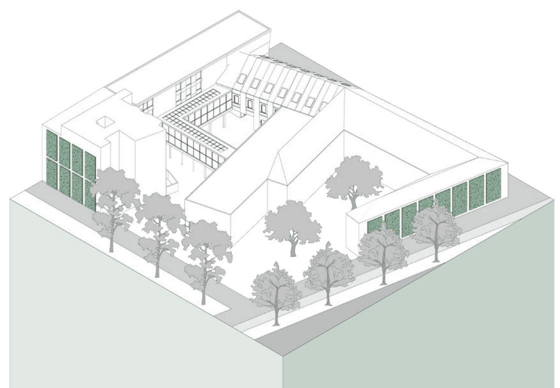
Source: Amsterdam Rainproof

In this technology, plants grow from trays on the facade, or on a substrate that is attached to the facade. These are generally costly solutions because they require intensive maintenance, watering, and fertilization, but they become fully active very soon after placing them. They should only be used when placing an elevation garden in the open ground is not possible.

SCHEME



CONTEXTUAL IMPRESSION



ELEVATION GARDEN - vertical garden

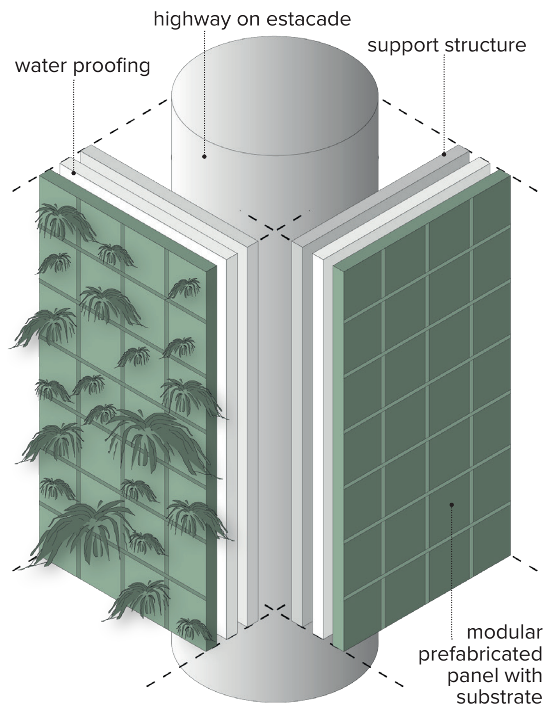
GGW-3

TECHNICAL QUALITATIVES

Source: Via Verde Mexico, Fernand Ortiz Monasterio

Vertical gardens in the form of prefabricated modular panels, allow the greenery to be placed in an unusual location, when the shape has to be actively controlled and limited, such as highway's pillars. Contaminated soil with street salt does not allow ground vegetation to be planted. Moss can perform high efficiency in absorbing particulate matters in those locations.

SCHEME



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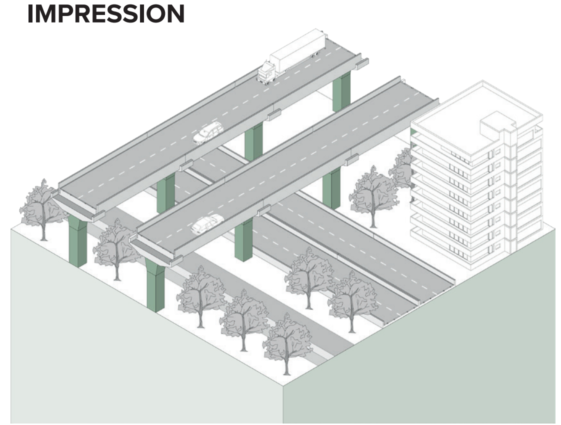

GREEN STRUCTURES

THE STRUCTURES

One of the most critical problems related to the regeneration design activities in modern cities is the lack of space. When changing the geometry of the street entirely is not possible, then green structures can help to introduce extra green. There have been several innovative measures developed in recent years, which aim to introduce extra green into spaces that cannot be eliminated from the public space. Those design elements are especially useful in the old towns and historic areas of the city since their presence does not affect the structure of historic buildings, potentially changing the high architectural values of those, which makes them an interesting choice for all kinds of the protected sites. They also work as a successful green substitute for urban elements that are required within the city, such as fencing. They also increase water retention, small scale biodiversity, decrease heat stress, and have a positive impact on the general beauty of the public space.

AIR QUALITY

The impact of that kind of structure differs from the size and design of each. The potentials of absorbing air pollutants also depend on the selection of plants. For instance, According to NASA's Clean Air Study, Common Ivy (Hedera helix) is especially useful in absorbing benzene and can be successfully planted as part of a facade garden. Selection of plants is crucial because vegetation with higher surface area, greater rates of transpiration, and longer in-leaf periods result in the most significant enhancements in dry deposition over that to bare surfaces.

Source: Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons, Thomas Pugh, Angus Mackenzie, J. Duncan Whyatt, C. Nicholas Hewitt,
Environmental Science & Technology, 46 (14),
Using green infrastructure to improve urban air quality (GI4AQ), C. Nick Hewitt, Kirsti Ashworth, A.Rob MacKenzie,

STANDING GARDEN

GGS-1

TECHNICAL QUALITATIVES

Source: NEXIT Architecten | Buro Poelmans Reesink Landschapsarchitectuur

Standing gardens solve the problems of old or weak buildings that cannot sustain extra weight on their roofs or walls.
The construction consists of steel base baskets filled with lava stone and sedum. The elements are stackable, and the low elements can be placed independently. As a result, the new construction does not constitute an extra load on the existing facade construction. The elliptical shape of the stackable elements ensures that the shadow effect is minimal, and the planting receives as much sunlight as possible.

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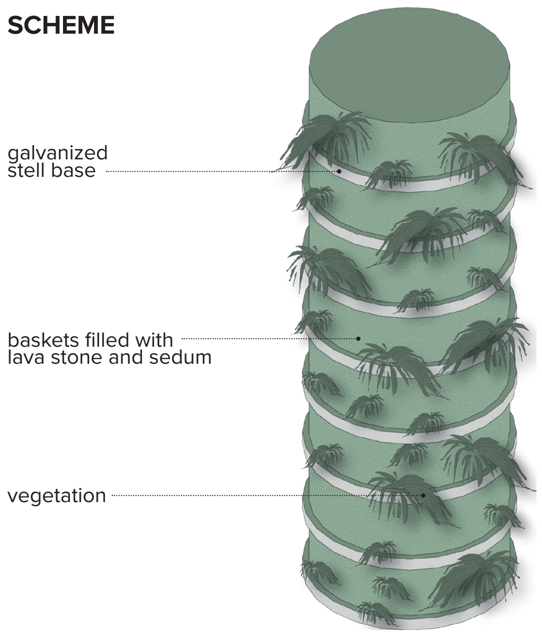

CONTEXTUAL IMPRESSION

FAÇADE GARDEN - geveltuin

GGS-2

TECHNICAL QUALITATIVES

Source: Amsterdam Rainproof

Façade garden consists of a narrow strip of the ground, located in front of the building, where the vegetation has been planted, with roots being located directly in the soil. Building a façade garden has several advantages. Plants in the open ground need less water than plants in a pot. By placing climbing plants in the façade garden, the façade remains cool in the summer. This kind of structure heavily increases the biodiversity in the area, rainwater infiltration, absorb particular matter from the surrounding street, and also is very easy to maintain.

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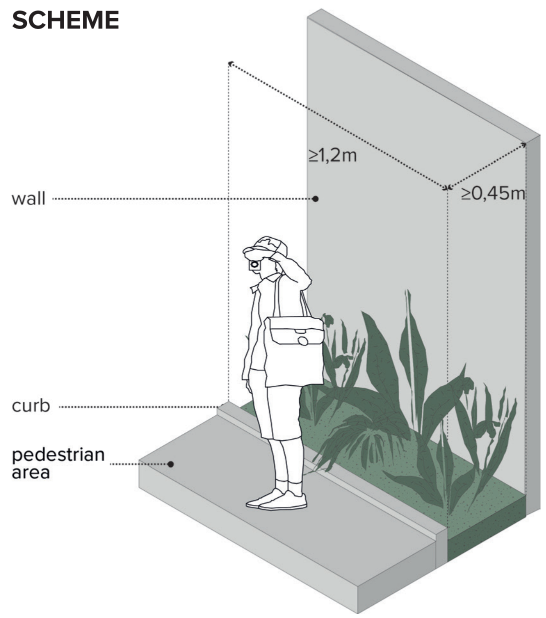

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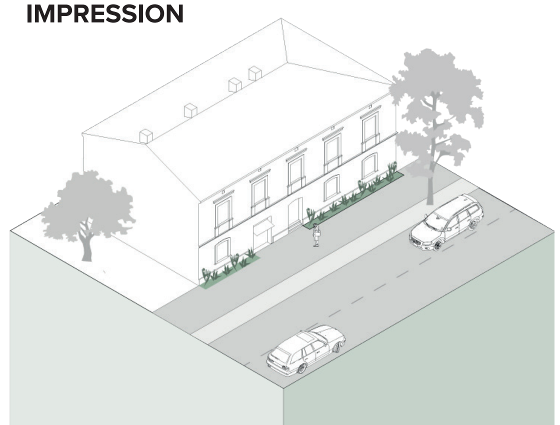

GREEN FENCE

GGS-3

TECHNICAL QUALITATIVES

Source: „Natuurinclusief bouwen en ontwerpen in twintig ideeen", Gemeente Amsterdam

Green fences allow implementing some extra greenery and vegetation into the urban area. In many places, mostly suburban, there is already a high number of different fences that separate parcels from each other. Turning them into green fences, build-out of a combination of such species as Hawthorn (Crataegus), Blackthorn (Prunus spinosa), and cut Field maple (Acer campestre), can absorb some other particular matters from the air. In general, linear green barriers help aid dispersion, and deposition from air pollution, and hedges (and fences) may, therefore, offer some protection to pedestrians.

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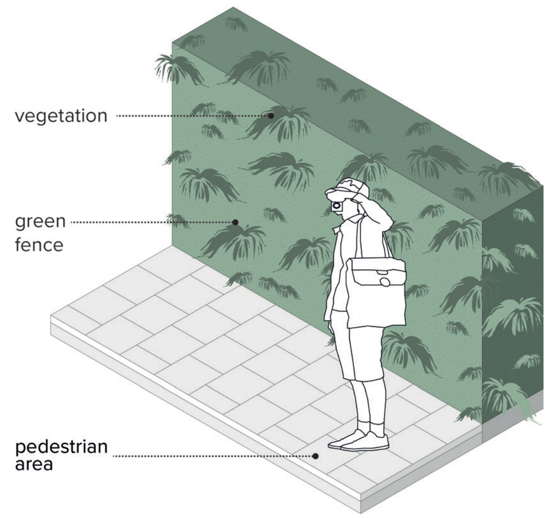

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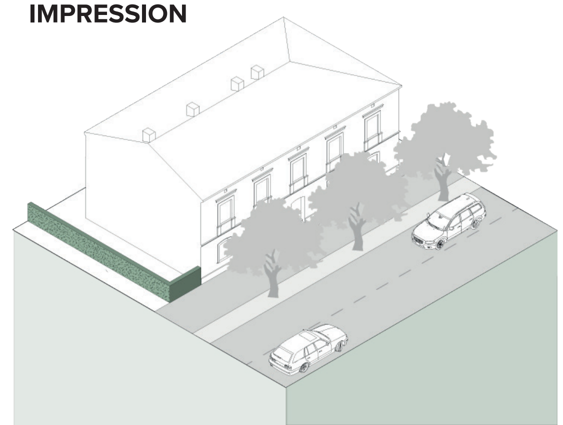

GREEN INFRASTRUCTURE

THE STRUCTURES

We can find multiple infrastructural elements in the public space, which presence is mandatory, but the function has been limited only to the transportation-related one. There is an attempt to give an extra ecological function to those infrastructural elements by turning them green. The methodology behind these actions is based on the idea that nature can be used to provide essential services for communities by helping to improve air, soil, and water quality. The linearity of infrastructure elements gives the potential to create a long and big scale green system, within densely build-up cities. Location of those elements directly close to transport corridors, which are one of the primary sources of emissions, helps to reduce the impacts directly where they are emitted. Implementation of those elements requires close cooperation between urban and traffic designers and is often characterized by the high costs in construction in maintenance.

AIR QUALITY

Green infrastructural elements have a high potential in improving air quality due to their linear character. They occupy large amounts of areas and are often located along or within transportation corridors, where the highest levels on NO2 and other transport-related pollutants are noted. Turning those linear elements green allows to create new ecological connections within the city, and helps to shape the ventilation corridors. The research conducted at the Humboldt-University in Berlin proved that sedum green tram tracks absorbed manganese, copperas, and polycyclic aromatic hydrocarbons, which were detected in the samples of plants taken from the site.

Source: Benedict, Mark A. & McMahon, Edward T. (2006). Green Infrastructure: linking landscapes and communities

Effect and Function of Green Tracks, GRÜNGLEISNETZWERK,

GREEN TRAM TRACK

GGI-1

TECHNICAL QUALITATIVES

Source: Effect and Function of Green Tracks, GRÜNGLEISNETZWERK,

Turning regular concrete tram tracks into green ones in another strategy to introduce more vegetation systems into densely built-up urban environments. Tramlines are often places along streets filled with vehicle traffic, which are one of the main pollution emitters in the cities. It gives a green tram tracks a great potential for dust and contamination deposition. The presence of big-scale green tram tracks also helps to decrease urban heat island effects and reintroduce more variety of temperatures in street canyons, which naturally enhances the movements of air and ventilation.

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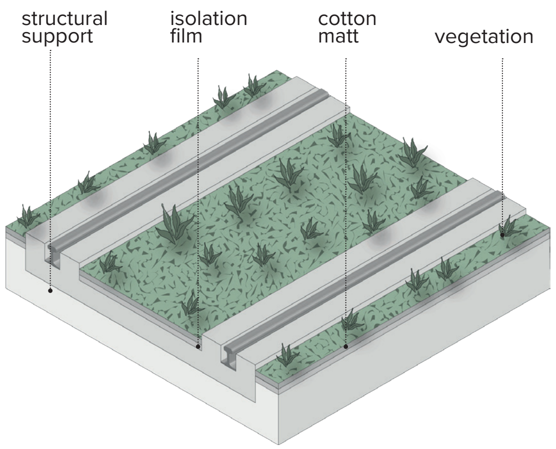

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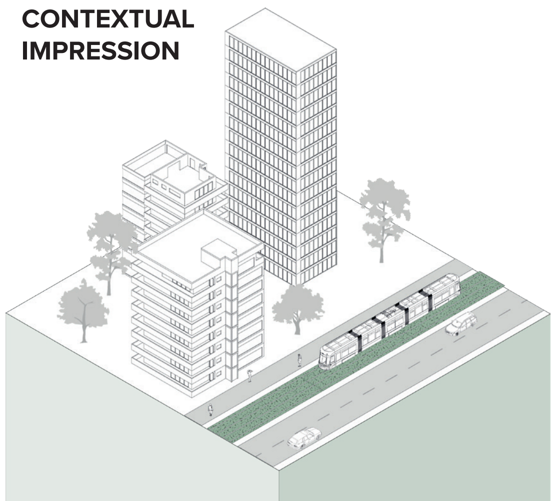

GREEN HIGHWAY WALL

GGI-2

TECHNICAL QUALITATIVES

Source: Birmingham Conservatives

Many pollutants produced by vehicles are often trapped in urban canyons, such as busy roads flanked by tall concrete walls. Lack of ventilation, strong separation from the surroundings, and intensive traffic responsible for producing car-oriented pollutants, makes it a problematic place to deal with air pollution. If the structures either side of the road were 'green walls' with plants growing on them, then many of these pollutants would be absorbed. The city council of Birmingham has estimated that the walls could remove 40% of nitrogen oxides and 60% of particulate matter from the surrounding air.

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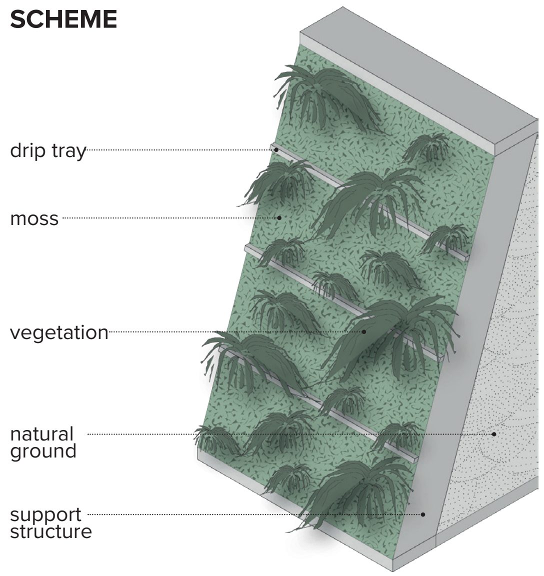

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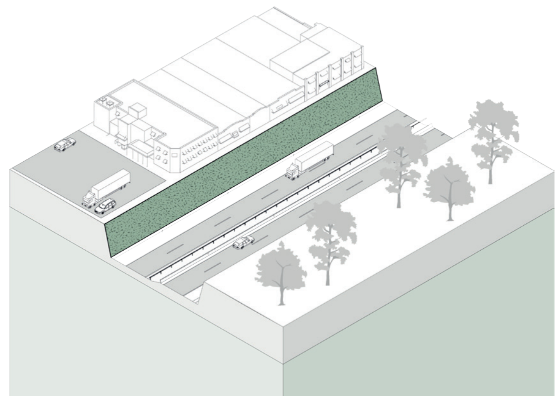

GREEN NOISE BARRIER

GGI-3

TECHNICAL QUALITATIVES

Source: Noise Barrier Design: Danish and European examples

The road can be given a new visual quality through planting. Planting can, among other things, soften the hard effect of new road construction. The vegetation is planted with little nutrient and water needs. Selected species are resistant to a local climate and are suitable for growing an inert substrate such as rock wool. Research carried under the EU-funded SILENTVEG project proved that the green wall planted with *Helichrysum thianschanicum*, reduced noise levels in the neighboring room by an average of 15 dB.

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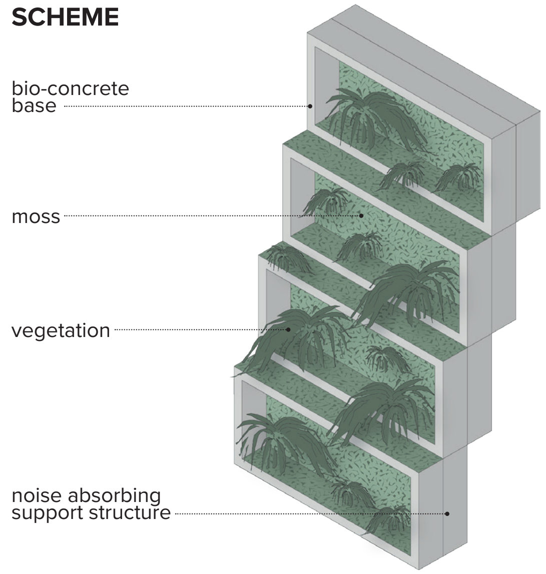

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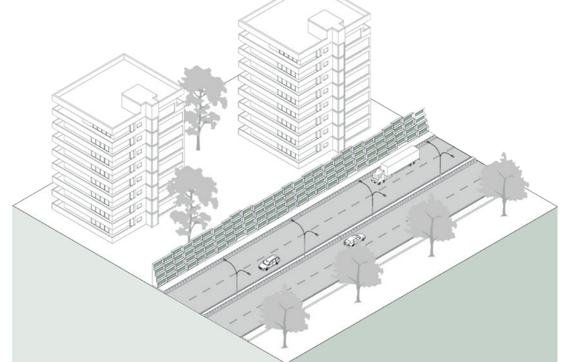

GREEN PARKING LOTS

GGI-4

TECHNICAL QUALITATIVES

Source: Hexapave Green Parking Lots, HEMSCO

The green parking lot can be used to reduce the environmental impacts of conventional asphalt parking lots. The system is a robust, ecological and economical pavement with a self-supporting foundation consisting of grass strewn or paved gratings. The 14 mm thick walls of the cavities allow the structure to handle the heavy loads and adequately protect the grass. Grass can quickly grow and requires minimal maintenance. The system is efficient even in bustling parking areas of the commercial centers, or along the streets.

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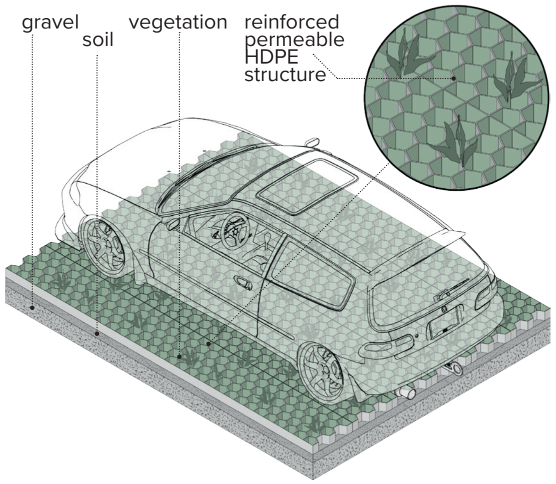

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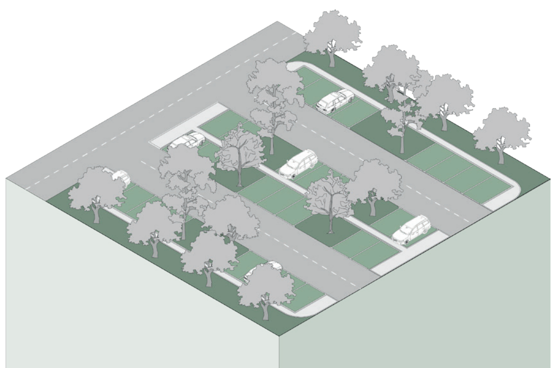

GREEN ROADSIDES

GGI-5

TECHNICAL QUALITATIVES

Source: by author

In the urban environment, the areas which do not need to are still often covered with concrete tiles. By opening up those areas for small scale urban green interventions, we can make a significant change in the street or even a city scale. It is an excellent chance for green solutions that directly absorb the pollution coming from the cars, and together with additional infiltration systems, and more resistant plant selection, it is a chance for the accumulation of runoff water directly from the street.

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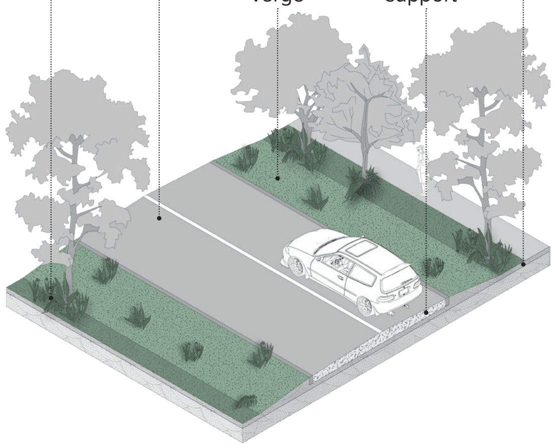


CONTEXTUAL IMPRESSION

ANTI-SMOG GREEN MEADOWS

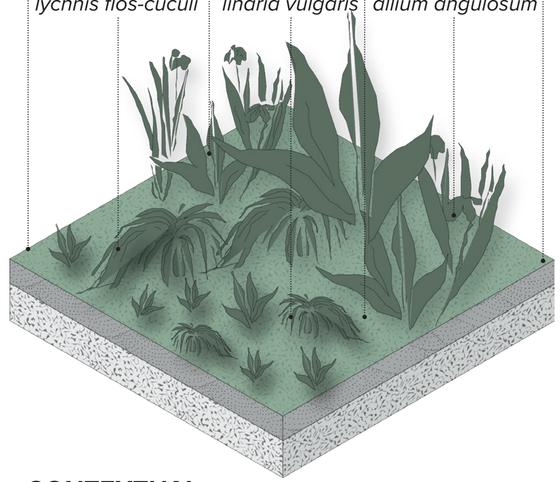
GGI-6

TECHNICAL QUALITATIVES

Source: Łąka Przeciwsmogowa - Smogówka - Łąka Fundation

Plants growing on meadows can catch dust from exhaust fumes and tire abrasion much better than grass. Common wild meadow species are able not only to accumulate heavy metals from the air but also to allow phytoremediation. They also reduce road maintenance costs. With flower meadows, the mowing is limited to two treatments a year, and hence significant savings. Meadows prove themselves as rainwater reservoirs. Thanks to this, they also can counteract local flooding of the roads.

SCHEME



CONTEXTUAL IMPRESSION

CURBS EXTENTIONS

GGI-7

TECHNICAL QUALITATIVES

Source: Urban Street Stormwater Guide, NACTO, 2017

Curb extension can visually and physically narrow the width of the street. It provides traffic calming uniquely on low-speed neighborhood streets. It helps optimizing parking problems on the street. The available space generated by curbs extensions can be used for bio-retention, planting, small scale meadows, or street trees, efficiently introducing additional green spaces in areas mostly devoted to transportation.

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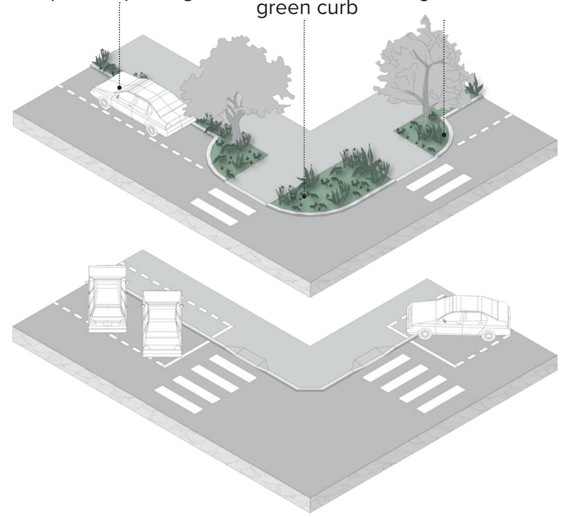

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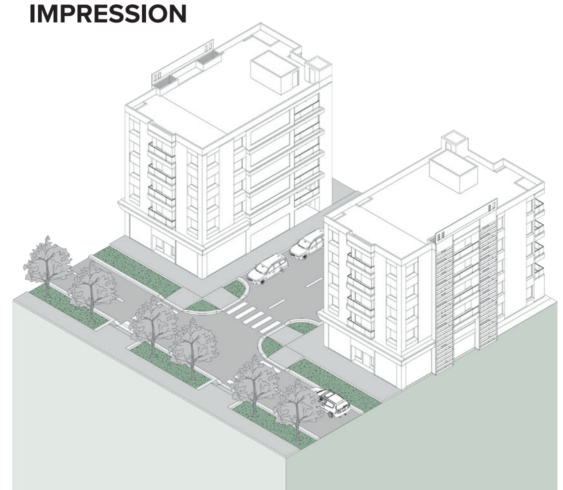
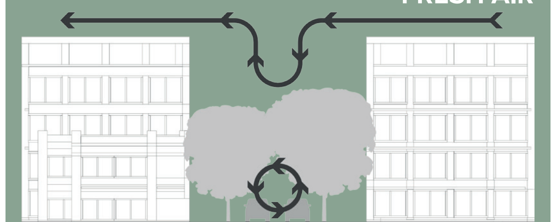
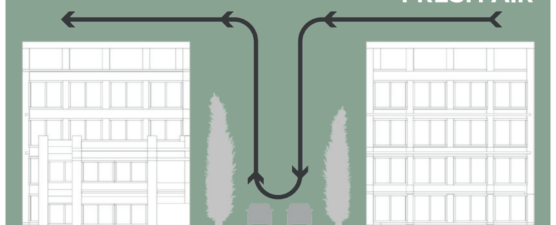


URBAN TREES

TUNNEL EFFECT

In some cases, vegetation may have a negative effect on air quality due to the phenomenon called the 'tunnel effect', which is negatively affecting the mixing of the air. If the trees are not placed correctly or are not maintained, they can create an uncontrolled dense canopy over the street, limiting the possibility to disperse the air and limiting the ventilation capacity of the street. The pollution produced by the car is concentrated under the canopy of the trees, and air quality can reach locally dangerous levels. It means that air quality can also deteriorate due to the presence of trees. It is essential to consider smart tree placement, giving the trees enough space to grow, select correct species according to the local conditions such a width of the street. It is also crucial to maintain them regularly and ensure that there is always enough space between rows of trees





Source: CROW (Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek); Solve - luchtkwaliteit en verkeer; 2011

URBAN TREES

TECHNICAL QUALITATIVES

It has been proven that trees are effective in reducing the concentration of particulate matter. Research conducted at Tsinghua University in Beijing has shown that cypress trees enhanced the PM2.5 removal rate by about 20%, making them one of the most useful trees in pollution absorption. Trees can absorb small gaseous air pollution primarily by uptake via leaf stomata, though the plant surface also removes some gases. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the leaf surface. In general, the rougher the surface and the larger the leaf surface area, the better the effectiveness. Analysis done by David J. Nowak from USDA Forest Service showed that In 1994, trees in New York City removed an estimated 1,821 metric tons of air pollution at an estimated value to society of $9.5 million. The mixing also causes some positive effects of urban trees on air quality in cleaner layers of air. Moreover, trees can also influence air pollution not directly by affecting other environmental issues, for instance, by lowering air temperature, which prevents inversion and can reduce smog.

> ***REMOVING THE AIR POLLUTION***
>
> *One hundred mature trees removes up to 460 kg of pollution per year, including 136 kg of suspended dust.*
>
> *Source: Rowe, D.B., Green roofs as a means of pollution abatement, Environmental Pollution (2010)*

ANTI-SMOG URBAN TREE - polish climate

TECHNICAL QUALITATIVES

Source: Związek Szkółkarzy Polskich

Due to the specifics of the Polish climate, characterized by long winter and short vegetation period it is proposed to consider the most effective deciduous tree for high absorption and dispersion during the summer season.

TILIA CORDATA

It can be found from Britain to the Caucasus. Popular as a shade tree with its dense canopy, an ornamental tree, and a street tree.

ACER PLATANOIDES

Species of Maple native to eastern and central Europe. It is favored due to its tall trunk and tolerance of poor soils and urban pollution.

FRAXINUS EXCELSIOR

It is native throughout mainland Europe. It is characterized by its resilience and rapid growth.

GLEDITSIA SPP.

Alternative proposal, native to central-east of North America. Defined as a tree with one of the highest relative effects on lowering ozone levels.

WINTER GREEN TREE - polish climate

TECHNICAL QUALITATIVES

Source: Związek Szkółkarzy Polskich

In order to provide efficiency with absorption during the whole year, but also create spaces that are visually attractive to the users during the entire year, several conifer trees more suitable for polish climate have been researched.

THUJA PLICATA

Native to North America, in eastern Europe, is used as a decorative winter-green plant, where does not reach its full, gigantic size, characteristic in America.

PINUS NIGRA

Native to Southern Europe, present in Poland since the XVIII century. Tolerates salinity, high air pollution, and heat.

TAXUS BACCATA

Native to western, central, and southern Europe. The plant is exceptionally efficient in absorbing and accumulating polluting metals and organic compounds.

JUNIPERUS CHINENSIS

Decorative plant for park and street design. One of the most resistant to harmful environmental and climatic factors.

URBAN FURNITURE

THE STRUCTURES

Apart from increasing the role and presence of green in the structure of the city, there are also other concepts developed in the last year by designers from all around the world, which tackle the air pollution problem in the urban environment. Those modules can be placed in public or semi-public spaces as urban furniture, replacing traditional elements with innovative solutions, or just adding another value to the existing structures. The solutions vary from smog absorbing complex technical devices to more traditional urban furniture with green moss or vegetation, which allows bringing additional greenery to the dense urban environment where it is not possible to place traditional vegetation or urban trees. They can be functional only in solving the issue of air pollution or provide additional functions related to biodiversity, water retention, or heat stress.

AIR QUALITY

Urban furniture is an attractive, alternative option to increase dispersion, decrease reception, and provide absorption of air pollutants. The efficiency is very diverse and depends on the particular module, the scale in which it is implemented, and the urban context. They can form linear, efficient structures that make an impact because of the number of implemented solutions. Moreover, due to its visibility in the public space, they also increase awareness of the inhabitants about the air pollution problem and can not-directly affect people's habits and choices, which leads to decrease emissions. However, those solutions have to be considered supportive of the main action, which is the creation of the main green structures of the city.

SMOG FREE TOWER

FUF-1

TECHNICAL QUALITATIVES

Source: Daan Roosegaarde, Studio Roosegaarde

Smog tower is a 7-meter tall aluminum construction using 1170 watts of green electricity and patented positive ionization technology to produce smog-free air in public spaces, allowing people to breathe and experience clean air for free. It is equipped with environment-friendly technology, capable of cleaning up to 30.000 m3 of air per hour. The Smog Tower provides a local solution for clean air, such as in parks.

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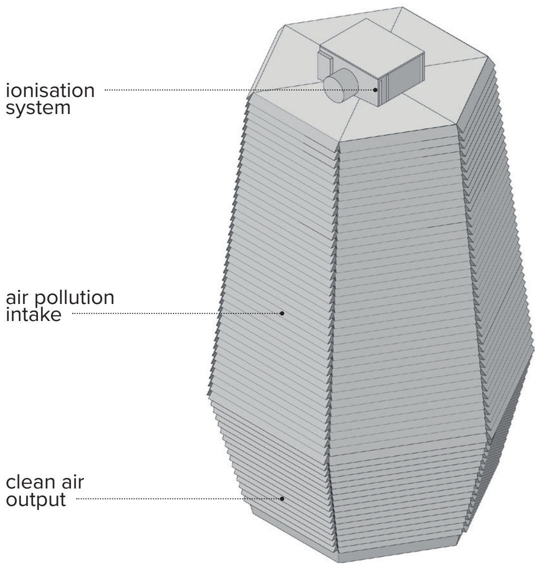

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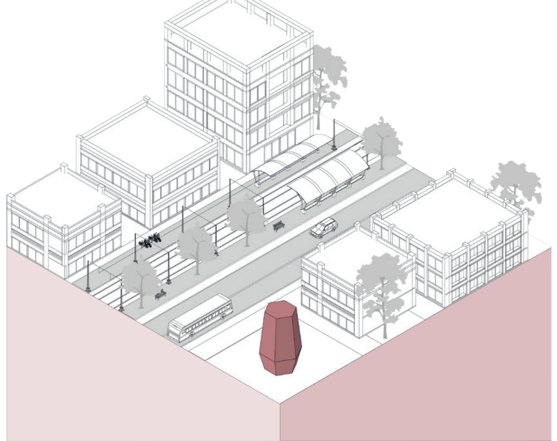

URBAN SMOG LAMPS -eco mushroom

FUF-2

TECHNICAL QUALITATIVES

Source: Tony Thomas Narikulam, RISEpad

The Eco-Mushroom specifically targets urban road networks that have become high-pollution areas. The compact LED streetlight is equipped with a scrubber, which can absorb CO2. Polluted air is pulled through four ducts, then passed through the central air purification system, and finally released as purified air through a vent positioned on the pole portion of the structure.

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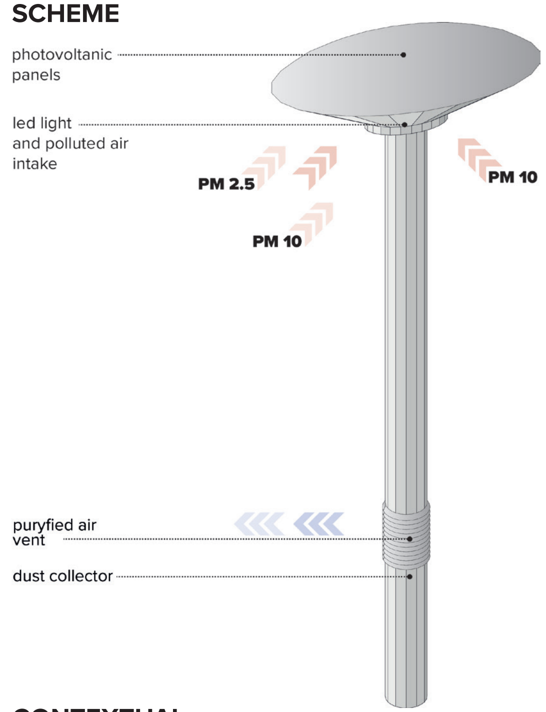

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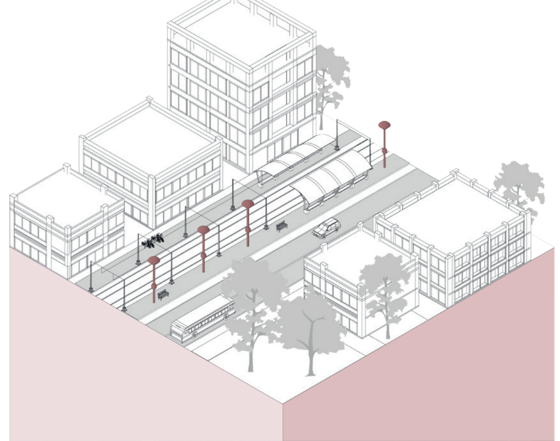


URBAN SMOG LAMPS - algae lamp

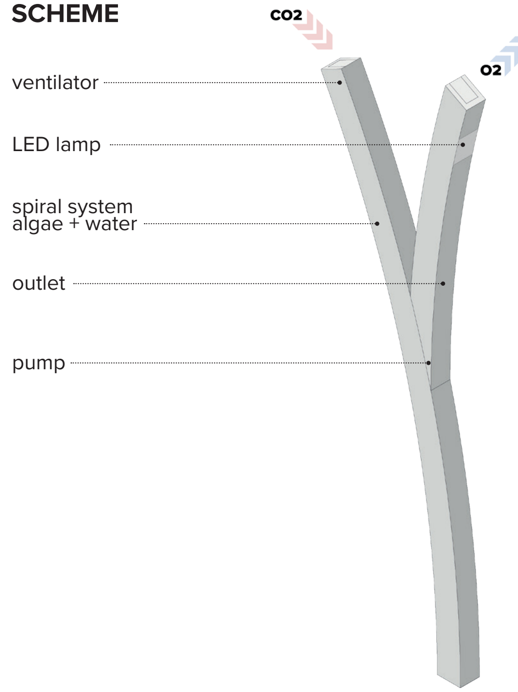
FUF-3

TECHNICAL QUALITATIVES

Source: Biolamp, Peter Horvath

Algae lamp is an innovative concept to purify the air using the natural process of photosynthesis. A ventilator is sucking the smog inside - which streams into the alga liquid. This liquid is being circulated in a spiral system thanks to a pump, which helps the alga absorbing the CO2 better. At the end of the process, the sunlight, CO2, and water transform the alga into biomass.

SCHEME



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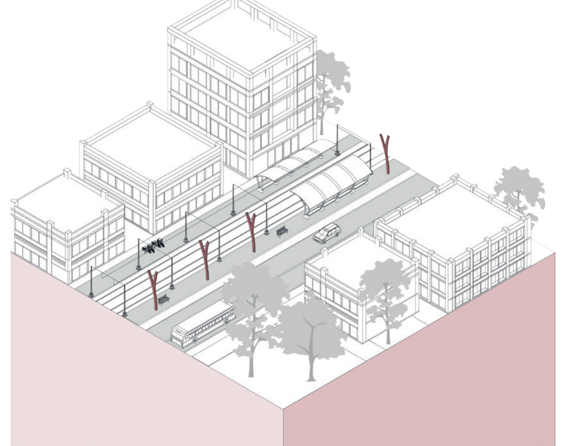

AIR PURIFICATOR

FUF-4

TECHNICAL QUALITATIVES

Source: "Lungs of the City" project,
Eindhoven University of Technology (TU/e)

The concept integrates air purification into the existing infrastructure at strategic places in an (inner) urban area, so that air quality at street level can be improved with physically invisible intervention. The technology can be built into traffic plazas, tunnels, overpasses, station buildings or, for example, street furniture. The idea consists of an electric powered device which captures fine dust and soot, and releases cleaned air back into the city.

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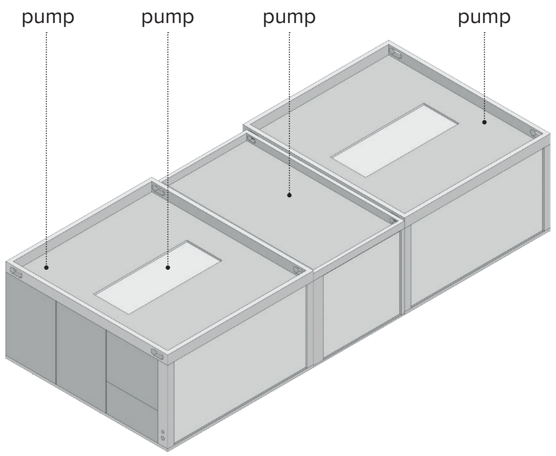

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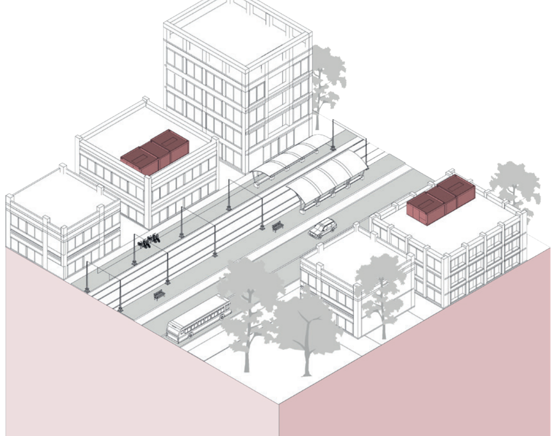

FURNITURE WITH MOSS

FUF-5

TECHNICAL QUALITATIVES

Source: GreenCity Solutions, The CityTree

The furniture covered with greenery combines specific moss cultures with a vascular plant that eats particulate matter (PM), nitrogen dioxide, and ozone – offsetting 240t of CO2/year in total. Annually the plant filter compensates pollution from up to 417 cars and can be adapted to any environment. The construction contains sensors collecting environmental data, to regulate, control the unit, and ensure that the plants survive.

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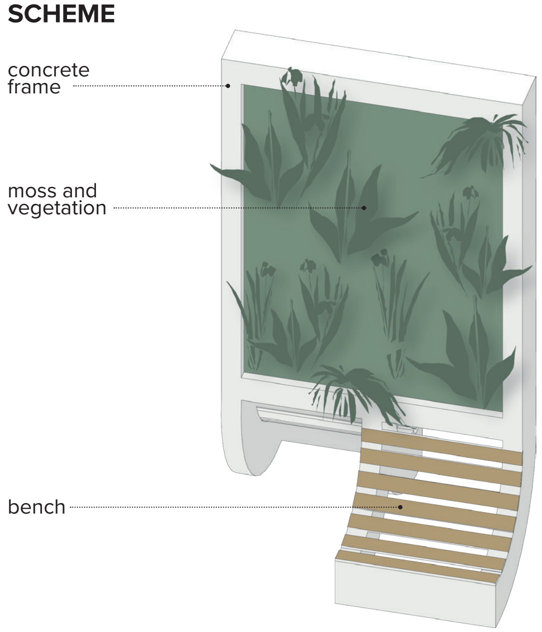

CONTEXTUAL IMPRESSION

BUS STOP WITH MOSS

FUF-6

TECHNICAL QUALITATIVES

Source: Gemeente Utrecht (Municipality of Utrecht)

This kind of bus stop has similar efficiency to the green roof and allows introducing additional green to usually impermeable, concrete areas. A mix of sedum helps with the capture of fine dust, the storage of rainwater, and provides cooling during hot days. Moreover, the herb covering the roof will attract bees during flowering,

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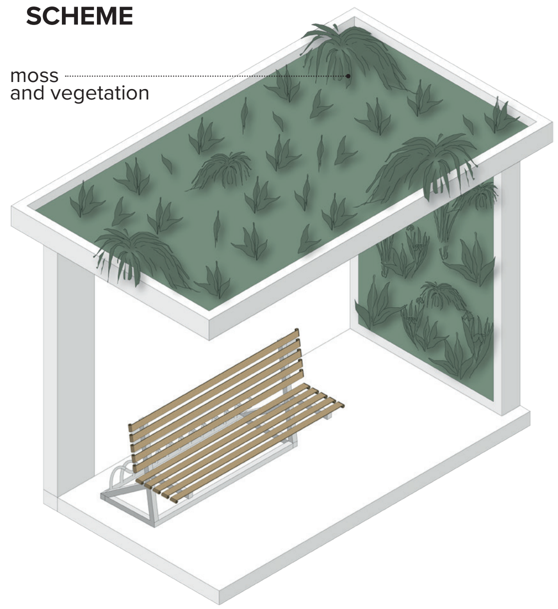


CONTEXTUAL IMPRESSION

GREEN PARKLETS

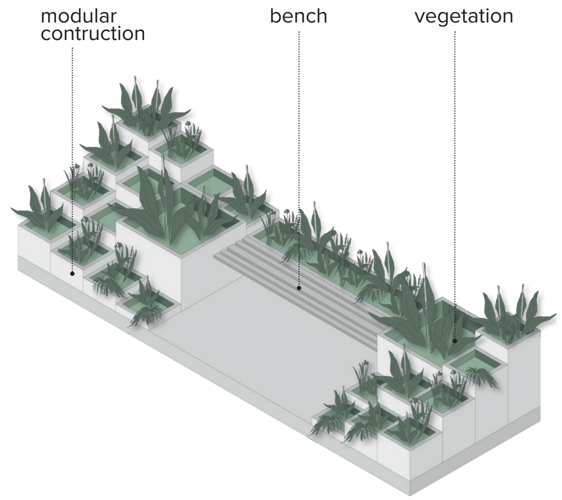
FUF-7

TECHNICAL QUALITATIVES

Source: STREETLIFE Europa, Parklet System

Parklet has a modular structure and creates pleasant resting areas on the street, adjacent to the sidewalk. The scarcity of public space is countered by removing existing parking spaces and turning them into 'green' zones. By combining trees and flower planters with wooden seating and cycle parking, the parklets are designed to make the area more pleasant for residents, shoppers, and businesses, while also encouraging cycling and improving air quality.

SCHEME



CONTEXTUAL IMPRESSION

SMOG EATING STRUCTURES

"Smog eating" technology is one of the most promising solutions that can affect the improvement of air quality within the public space. The engineers have combined graphene and titanium dioxide nanoparticles to create a new solar-powered catalyst that can pluck pollutants out of the air, much more efficiently than others. It is titanium dioxide that functions as a catalyst to the chemical reaction, which is activated by UV light. Not only does it filter the air, but the collected smog residue washes off with light rainfall. It is made up of inert salts that do not affect the surrounding environment. The catalyst could be incorporated onto building or street surfaces to improve air quality in cities.

AIR QUALITY

The technology is still under development but has already been introduced to some cities as a test example. The efficiency is very promising. It is calculated that with the average pollution levels of cities, the concrete has an efficiency of 60 mg per meter squared day. The study also notes that at lower humidity levels, the efficiency is not as high, with a slight drop at only 75% humidity, but only 2/3 efficiency at 25% humidity. It is especially suitable for use in confined areas prone to very high NO2 concentrations, such as tunnels or parking garages. The problem with this solution is still its price. The study from the Danish Technological Institute addresses this issue, as it states that titanium dioxide can drastically increase the cost of concrete, reaching up to a price four times that of regular concrete.

Source: "Smog-eating concrete": a new technology for better cities. Barcelo, Horgnies, Dubois-Brugger, Buffenbarger, Gartner 2014
"The concrete answer to pollution." J. Cartwright.
Horizon: The EU Research & Innovation Magazine. 12.18.2018

ANTI-SMOG PAVEMENT

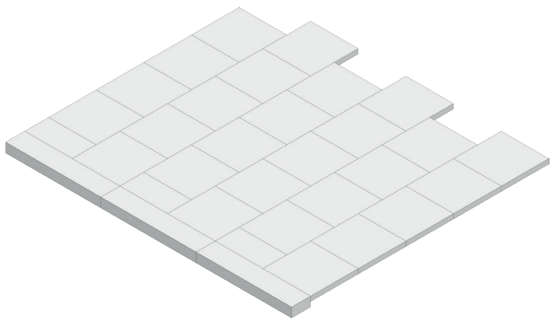
FSE-1

TECHNICAL QUALITATIVES

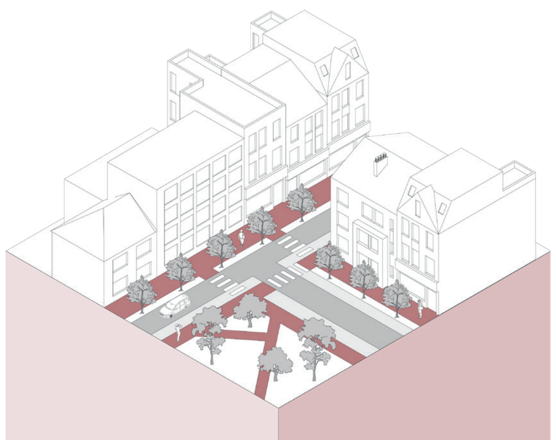
Source: TioCem® concrete, HeidelbergCement, Germany

One of the most efficient implementations of this technology is its incorporation into the concrete street tiles, which cover significant amounts of areas within the city. An experimental area has been recently constructed in the city of Warsaw. During tests in an area of 350 sq m of pavement was created, and data was obtained from special measuring stations. At the same time, air pollution was also tested in an area where there was no green concrete. Measurements have shown that the area where the green concrete was installed shows 30% a lower concentration of nitrogen dioxide compared to a standard section of the pavement.

SCHEME



CONTEXTUAL IMPRESSION



ANTI-SMOG TILES

FSE-2

TECHNICAL QUALITATIVES

Source: Smog-Eating Roofing Tiles - University of California

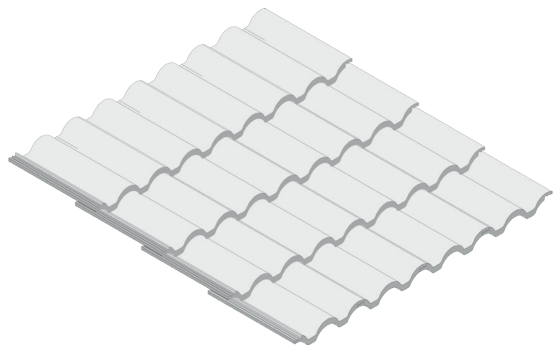
Another solution is related to the coverings of the roofs. Those spaces take tremendous amounts of space in the cities, and incorporating them into the anti-smog design systems would bring a great value. The technology is the same as in previously mentioned cases, but the materials are used for the production of roof tiles that capture NO2, decompose it and then with the rainwater bring to the ground.

REMOVING THE AIR POLLUTION

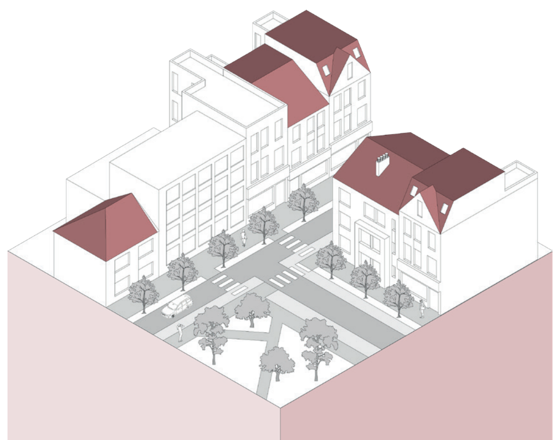
1 square meter of the material can remove up to 60mg of NO_2 per day

Source: The Ontario's Ministry of Transportation, „Ontario's Transportation Technology Transfer Digest."

SCHEME



CONTEXTUAL IMPRESSION



ANTI-SMOG FAÇADES

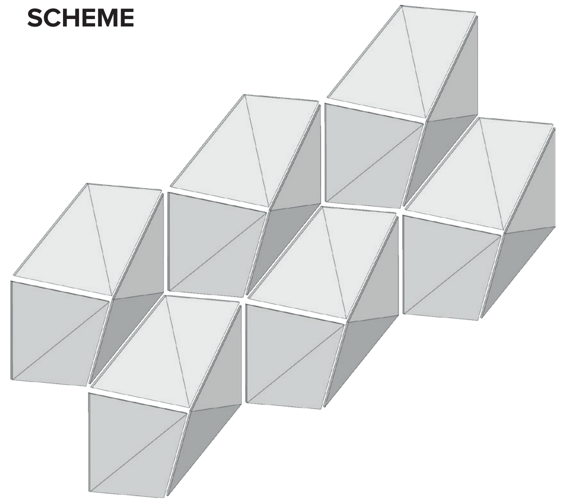
FSE-3

TECHNICAL QUALITATIVES

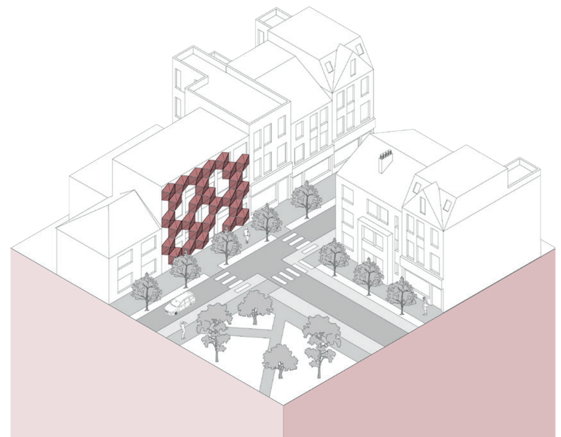
Source: Prosolve370e, Elegant Embellishments Limited, Germany

The same solution can also be incorporated into vertical panels placed on the facades or empty walls of the buildings. The design called pollution-eating prosolve370e facade module developed by Berlin-based company is a three-dimensional architectural module that eliminates NO2 from the air. The company describes the product as a first-of-its-kind thermoformed shells coated in photocatalytic titanium dioxide for facades.

SCHEME



CONTEXTUAL IMPRESSION



WATER STRUCTURES

THE STRUCTURES

Water structures are a resource to reintroduce valuable ecological water-related processes into the life of the urban street. Its a chance to bring additional green elements to the street profile, and give them an extra function related to water storage and infiltration. That kind of element serves then as a green area, biodiversity structure, beautification element, water retention site, and by being home for diverse species of vegetation, those structures also work as an additional catalyzer for air pollution dispersion. For long time streets have prevented stormwater from going back to the ground, managing all the rainwater into the inefficient sewage systems.
With the examples of those simple water management solutions, it is possible to increase infiltration, and introduce water retention to the public space of the cities. By increasing infiltration, those structures also affect the groundwater levels, which is one of the most efficient ways to tackle drought problems in the urban environment, which makes them complete multi-ussie solutions.

AIR QUALITY

The efficiency of those structures and their relation to air pollution strongly depends on the scale and particular location. In general, water structures can be fulfilled with vegetation, and the selection of planting has a crucial role in increasing efficiency. There is a possibility to merge those ideas with the concept of anti-smog meadows by selecting herbs that are more water-resistant and can grow in wet conditions. We can obtain an optimal solution serving both the water and pollution issues.

Source: Urban Street Stormwater Guide, National Association of City Transportation Officials, New York, 2017
Source: Amsterdam Rainproof 2020, Gemeente Amsterdam, www.rainproof.nl

BIO-RETENTIONAL SWALE

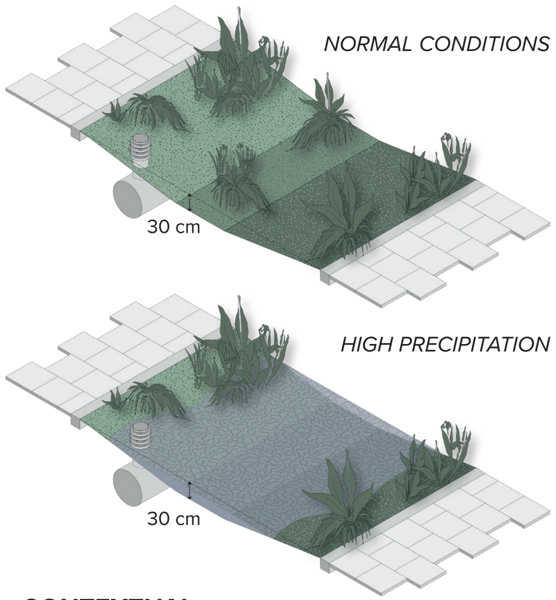
WWB-1

TECHNICAL QUALITATIVES

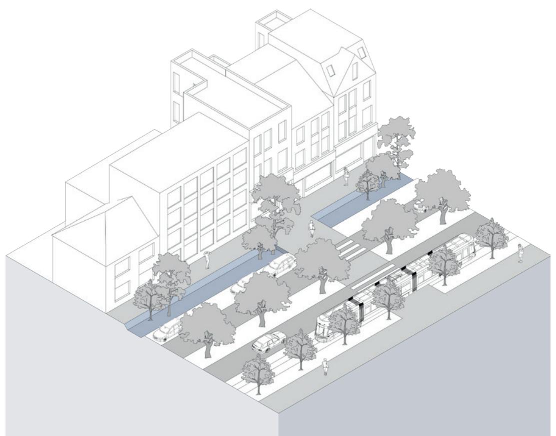
Source: Amsterdam Rainproof

This structure is a shallow, vegetated depression with sloped sides. They aim to capture, treat, and infiltrate the stormwater runoff. During heavy rain, the excessive amount of water goes to the sewer system, preventing local flooding. Swales can support a wide range of plantings to increase the beneficial habitat. They also provide high flexibility for planting, including the variety of street trees. They are designed to hold the rainwater for a maximum of 24 hours.

SCHEME



CONTEXTUAL IMPRESSION



BIO-RETENTIONAL PLANTER

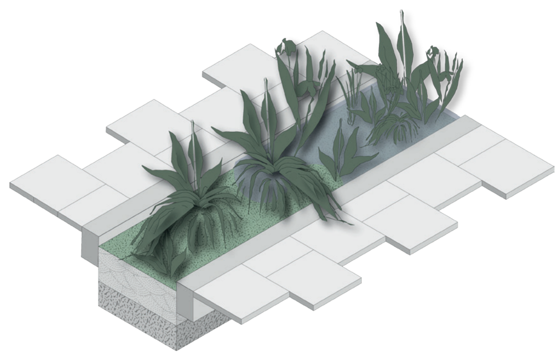
WWB-2

TECHNICAL QUALITATIVES

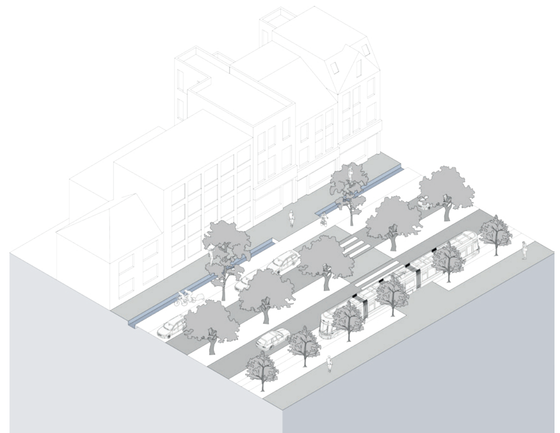
Source: Urban Street Stormwater Guide, NACTO, 2017

Planters are stormwater infiltration cells constructed with walled vertical sides, a flat bottom area, and a large surface capacity to capture, treat and manage stormwater runoff from the street. These structures are placed when there is no enough space for a bio-retentional swale with space demanding slopes. For safety reasons, their depth should not exceed 30cm (Gemeente Amsterdam). They work well as natural green linear fencing between pedestrian, car, and bicycle spaces, and are very easy to incorporate in the dense environment of central cities, with limited access to space.

SCHEME



CONTEXTUAL IMPRESSION



HYBRID BIOSWALES

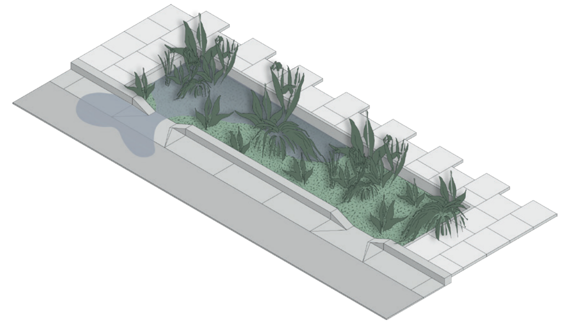
WWB-3

TECHNICAL QUALITATIVES

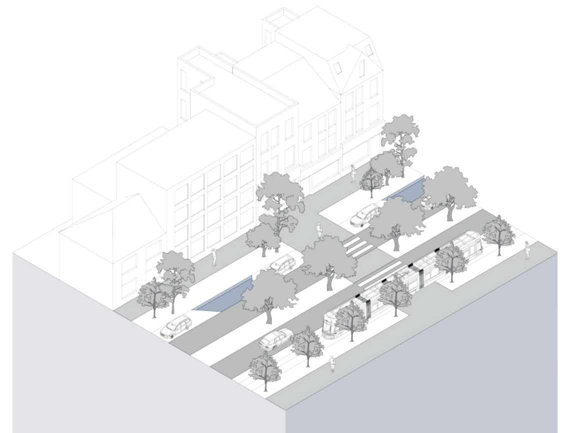
Source: Urban Street Stormwater Guide, NACTO, 2017

Hybrid bioswales combine elements of swales and planters to increase vegetated space and infiltrating areas while providing a softer streetscape for people walking. Walls can be configured adjacent to a street or sidewalk and can utilize a range of different materials, including concrete, rocks, or steel-faced curbs. Their aim is often to manage the flow of water directly from the street, which makes them efficient only in low to moderate traffic contexts. The selection of plants has to be done according to demanding conditions of direct proximity to heavy pollutants and salt coming from the street. They help introduce green elements in narrow areas where space is hardly limited.

SCHEME



CONTEXTUAL IMPRESSION



chapter 6

STREET TYPOLOGIES

URBAN TYPOLOGY - THEORY

The concept of typology has been widely incorporated into the urban design discourse. Lang describes it as “the study and theory of types and classification systems” (Lang 2005). It is particularly useful when visible similarities occur between researched phenomena, helping understand the common elements, as well as the differences between types. We could observe the usage of the typology system by Kevin Lynch in his The image of the city (Lynch 1960), where he introduced the examination of mental maps of the cities and people’s perception of the built environment. That was also developed further, for instance, by Bernardo Secchi in his structure plan for Antwerp, where different typologies – „cities” have been defined, such as water city, eco-city, port city, railway city or porous city. It has also been presented into the Italian context by Patrizia Gabellini in her work on the structural plan for Bologna and the idea of the “Seven Cities”. That kind of division helps to categorize the solutions, makes it easier to implement, and finally, because of its flexibility and repetitiveness, it is also cheaper to implement on a small scale. The definition of a typology can base on different measures, and those types may be universal or culturally defined. In the case of defying the most relevant typologies for tackling the air pollution problem in Warsaw, the typologies have been defined according to the spatial characteristics of the space, its scale or repetitiveness, however also the historic values related to the post-war reconstruction have played an essential role in the selection.

TYPOLOGY OF PUBLIC SPACE

The most common typologies we can observe in the urban literature, are usually related to the big scale development areas, concentrated around unique natural, or human-made core element, like Water city in structure plan Antwerp or Railways City in structure plan Bologna. For the aim of this project, the attempt to divide typologies within urban public space has been taken. The city of Warsaw, due to its destruction during II World War, and post-war reconstruction, first in the Socialist realism and later modernism styles, is now facing interesting challenges and opportunities in transforming car-oriented and over-scaled public space into nature-oriented and human-scale ones. I have defined three typologies, frequently characteristic in the central areas of the city, that show the most significant potential due to its linearity and size.

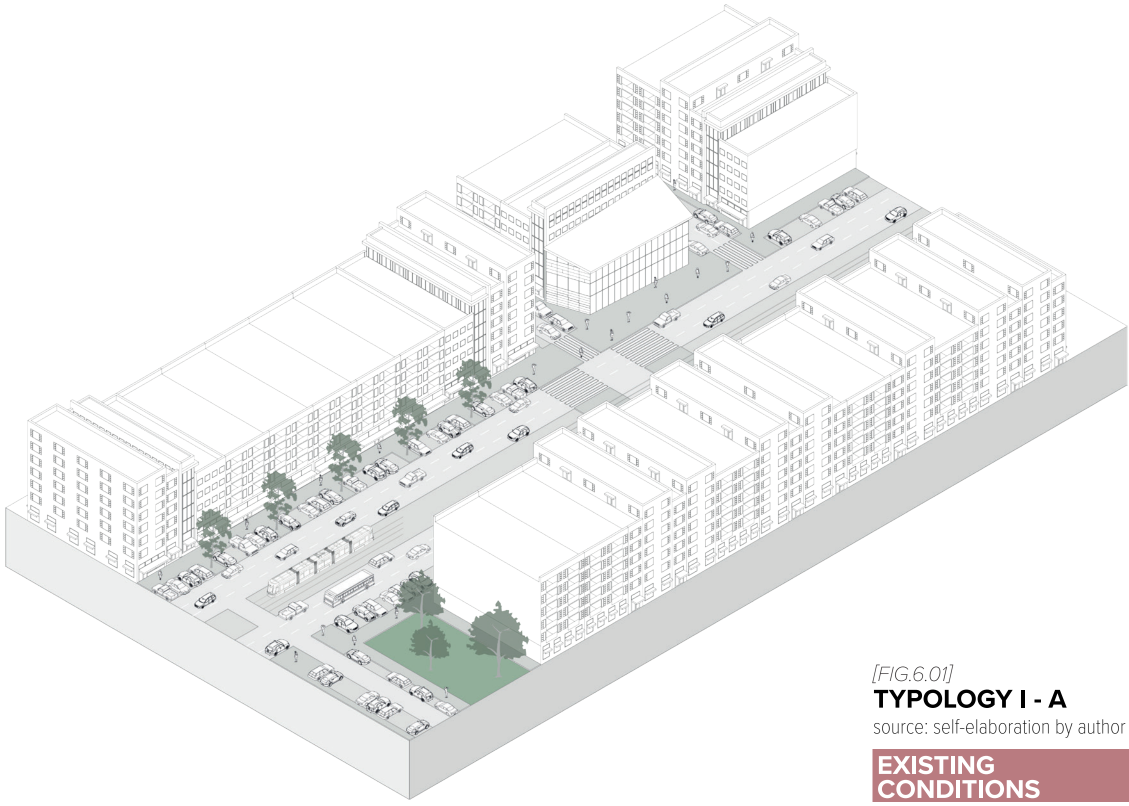
- *URBAN STREET*

- *NEIGBOURHOOD STREET*

- *VENTILATION CORRIDOR*

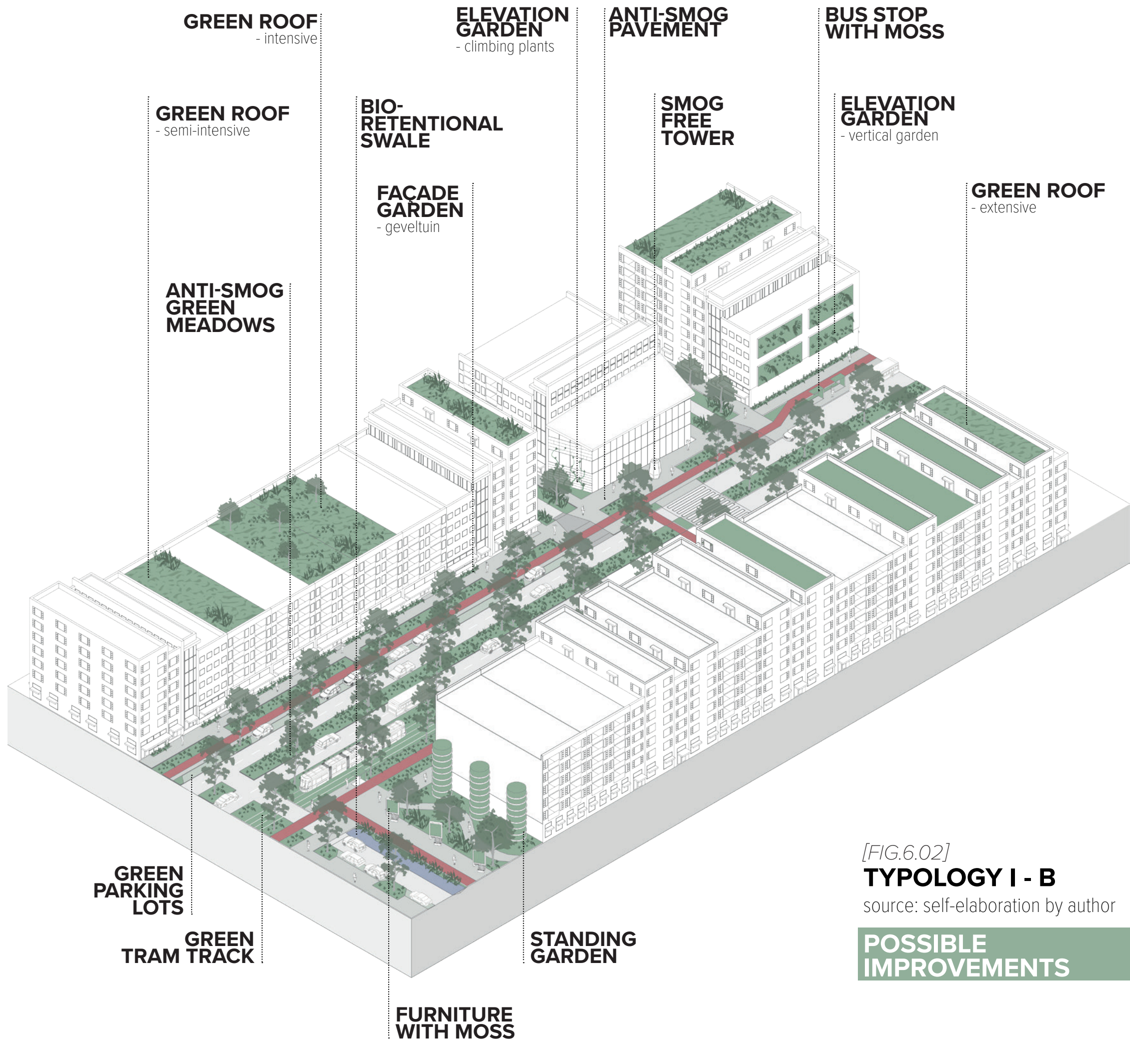
The idea of tackling the air pollution problem in Warsaw is based on the creation of linear interventions along those public space typologies. They differ in scale and functions they can welcome after transformation, but are all similar in the terms of visible potential in creating more ecological, and vibrant urban environments. The interventions on that scale are complementary to the general policies created by the city to mitigate and decrease emissions, and their goal is to add another level to the fight against air pollution by introducing adaptation strategies. Moreover, the new goals and visions for the public space in Warsaw also bring improvement in life quality and diversifies the urban functions those spaces offer.

TYPOLOGY I
- urban street



[FIG.6.01]
TYPOLOGY I - A
source: self-elaboration by author

EXISTING CONDITIONS



[FIG.6.02]
TYPOLOGY I - B
source: self-elaboration by author

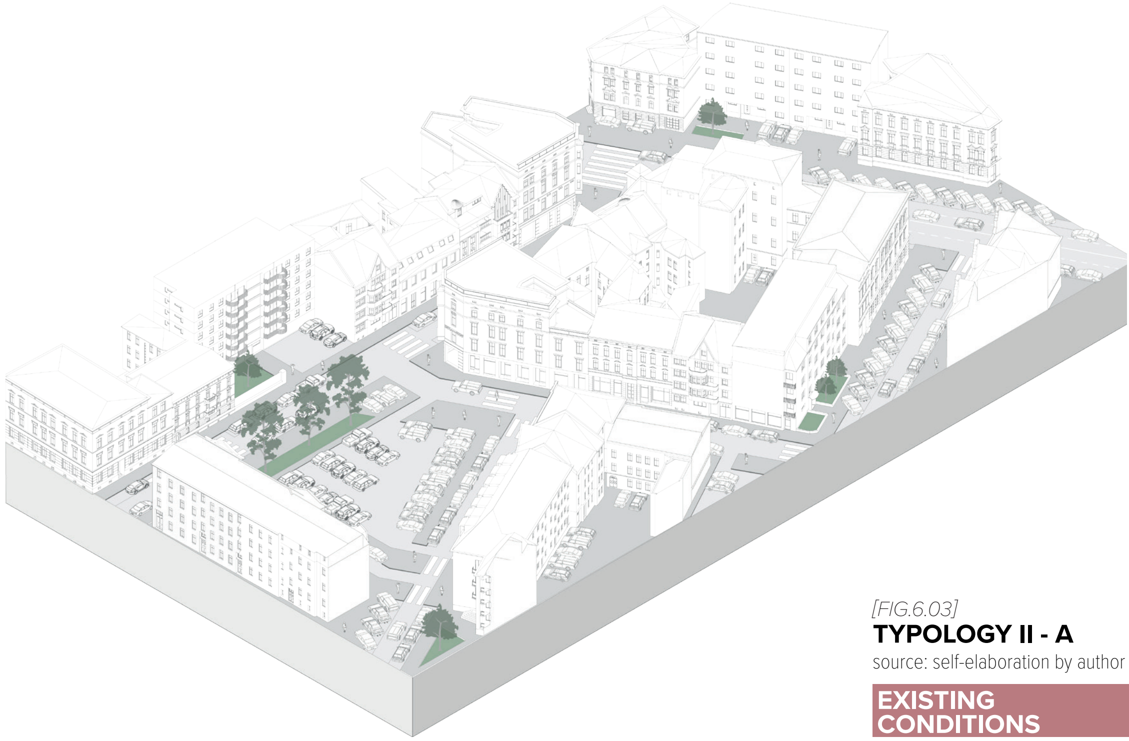
POSSIBLE IMPROVEMENTS

During the post-war reconstruction, many European cities have been given new street systems and transportation layouts, following the car-oriented and the modernist urban development ideas. The narrow streets of the XIX century centers have been widened and straightened, creating more space for the cars, but also increase the access to the sunlight of the adjacent plots. During the next decades, the increasing congestion and growing amounts of cars have enhanced the city governments to add new car lines to those wide urban streets, often at the price of surrounding green. It led to the creation of broad, multi-lane, and very long straight streets in the central urban districts. That was the case especially in the eastern cities which have been rebuilt according to the soviet urban ideas of the '50s, where that kind of street is called a Prospekt (rus. проспéкт)

ALEJA JANA PAWŁA II, WARSAW

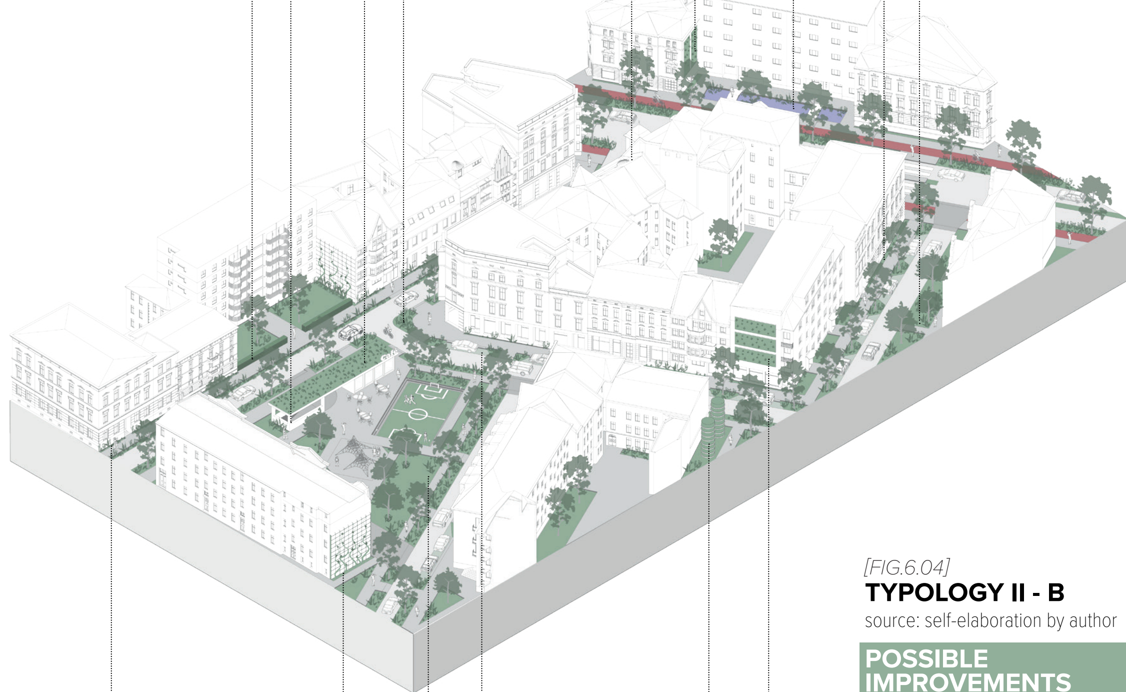
The negative elements of those urban streets also bring many possibilities for improvements. Their width and linear structure, together with the central location, can be used to create a big scale green system that connects the existing green structure of the city. After redesigning the high-capacity public transportation systems and banning the access of private cars into the central districts, there is no more need, nor the economic feasibility to maintain several car lines. The recovered space can be transformed and supported by the green roofs located on the adjacent buildings, which structure, coming from the 1950s, can allow such an intervention. Planting new trees on such a linear scale, together with the placement of supportive smaller plants and wide green urban meadows, will help to absorb the air pollution and create a more vibrant space for biodiversity and the inhabitants.

TYPOLOGY II
- neighborhood street



[FIG.6.03]
TYPOLOGY II - A
source: self-elaboration by author

EXISTING CONDITIONS



[FIG.6.04]
TYPOLOGY II - B
source: self-elaboration by author

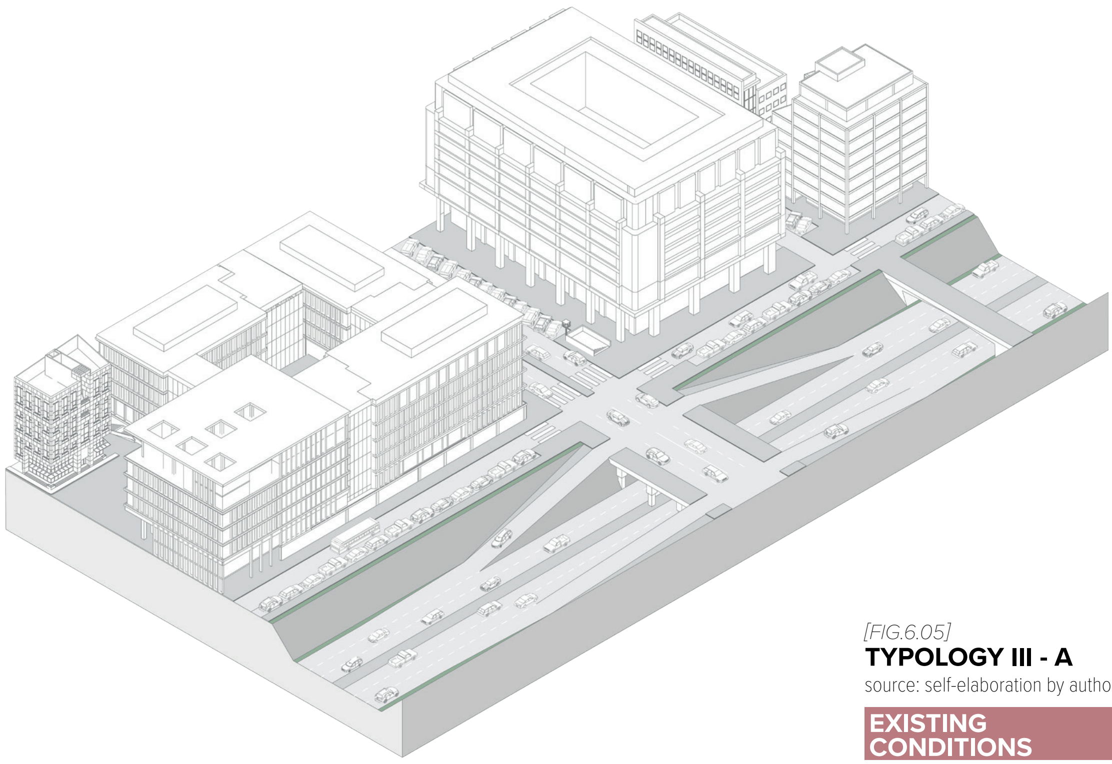
POSSIBLE IMPROVEMENTS

The post-war reconstruction also brought a change in the layout of the smaller neighborhood streets. The gaps created by partially destroyed built-environment has been filled up with high-rise apartment buildings, often not following the linear street frontage typical for historical European cities. The public space has been dedicated mostly to parking, transforming most of the public squares into areas for placing private cars. The amount of green and recreational areas has been limited to the minimum, due to the high demand for car possession. Those areas, mixing historical values with post-war modernist constructions, are lacking ventilation systems, green solutions that allow pollutants to be absorbed, and highly contribute to the increase of the heat island on the local scale.

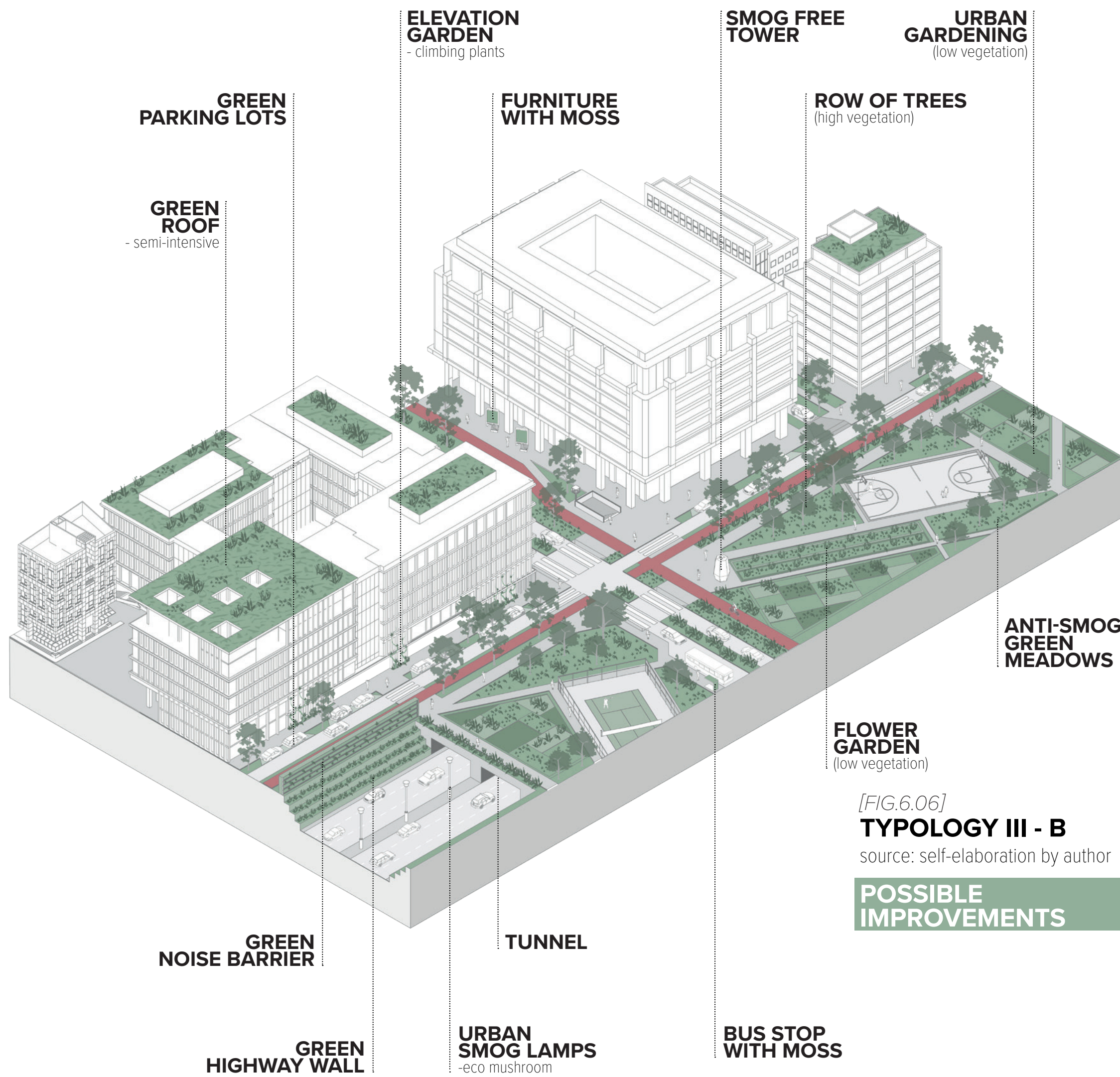
ULICA ZŁOTA, WARSAW

Re-thinking the transportation systems within neighborhood streets brings an excellent chance for improvement. Due to the limited space in those narrow streets, the presence of parked cars on the ground level has to be limited and preferably placed underground. The streets itself are turned into 'bicycle streets' (dutch. fietsstraat), which allows using extra space for green structures instead of a separated car and bike infrastructure. Due to the historical values of the buildings, it is usually not possible to introduce green roofs in those spaces. Narrow but continuous green stripes along streets, with planting efficient in pollution absorption, together with facade gardens, are the most efficient ways to reintroduce green.

TYPOLOGY III
- ventilation corridor



[FIG.6.05]
TYPOLOGY III - A
source: self-elaboration by author
EXISTING CONDITIONS

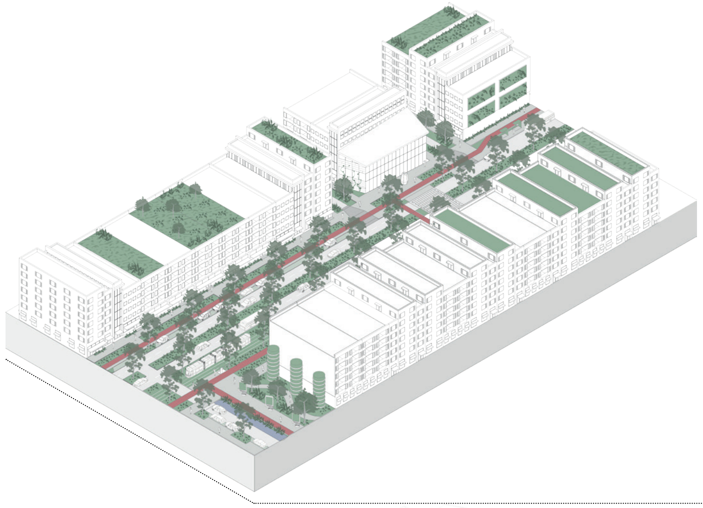


[FIG.6.06]
TYPOLOGY III - B
source: self-elaboration by author
POSSIBLE IMPROVEMENTS

Another unique type of post-war introduction of cars in the city centers was the attempt to enlarge high-speed car highways, and bring the traffic directly to the center, crossing the city in different directions. Due to the size of those interventions, the topography of the terrain, and financial shortages, the decision was made to locate thoroughfares in open tunnels. As the effect, highways with intense car-flows and high congestion have cut residential districts, creating impassable obstacles, increasing noise, and levels of pollution. The design choices to maximalize flow efficiency have been made at the cost of green structure and comfort of the inhabitants.

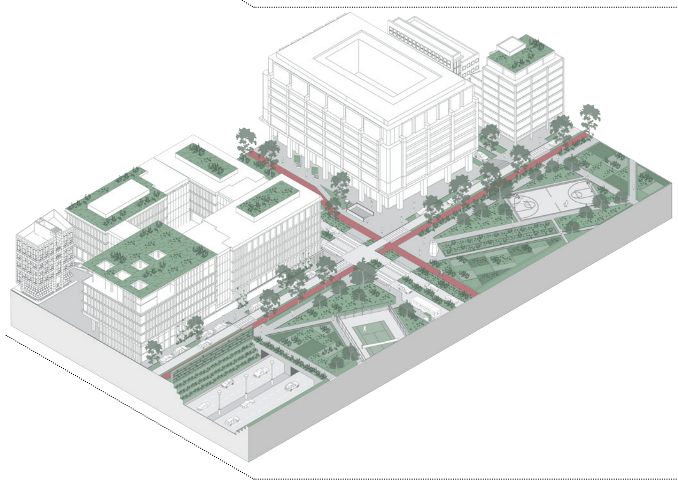
TRASA ŁAZIENKOWSKA, WARSAW

Due to the scale of those interventions and their construction, we can define big chances for improvement. The possibility to fully close the tunnels allows the creation of wide and long ventilation corridors between several districts of the city. The ground levels are proposed to be fulfilled with linear parks, sports infrastructure, and selected vegetation, efficient for the absorption of pollutants, planted in the way which does not block the ventilation. The principal thoroughfares for mobility are not limited but located underground.



urban street

neighborhood street



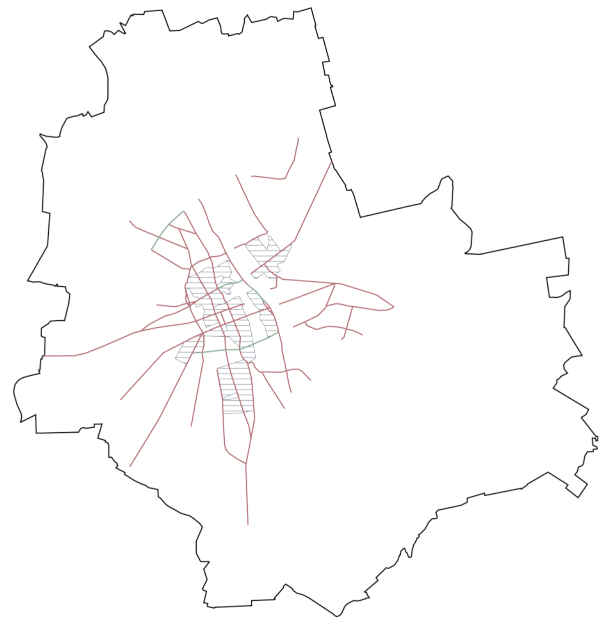
ventialtion corridor

CONCLUSIONS

Three presented street typologies correspond to the most characteristic types of streets observed in Warsaw. We can find those in several districts, and as described, they come from the historical reconstructions of the city. The repetitive pattern, together with the linearity of the described typologies, is a great chance for improvement and further redesign. The typologies are used as a starting point for the design activity, in order to define the large scale system in the city of Warsaw.

The typologies give us also an overview of the functional mechanism of the design modules in the physical context of the public space. It has been learned and showed which modules fit best in the spatial context of the surroundings.

Both of the experiences will be used in the following chapter during the design activity, and the typologies will be defined and placed in the physical context and used as a tool for the strategic design of the big scale system.



[FIG.6.07]
SPATIAL DISTRIBUTION OF DEFINED TYPOLOGIES
source: self-elaboration by author

ventilation corridor
urban street
zones of neighborhood streets

chapter 7

DESIGN ACTIVITY

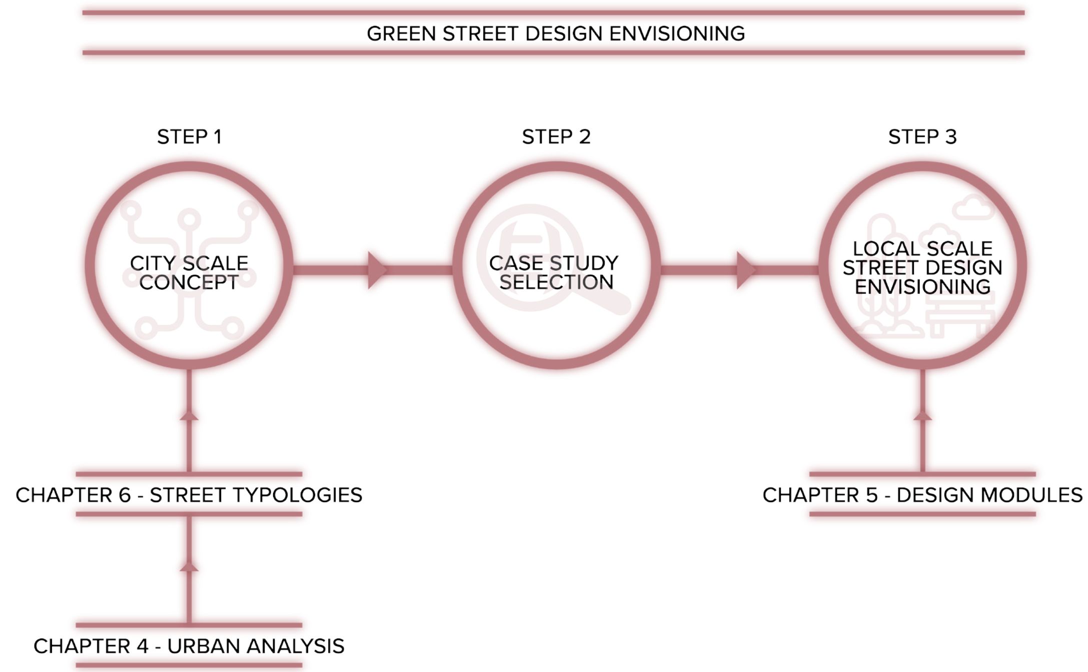
DESIGN APPROACH

The design activity has been divided into three main steps - strategic, selective, and visionary. During the strategic step, the proposal on the city scale has been created. This step is a bridge between two chapters and contains outcomes from the analytical part, and part describing street typologies. Big scale, city landscape system has been proposed using three different street typologies, and putting them in the most affected areas, and existing public spaces. The areas have been defined during the analytical part of the research.

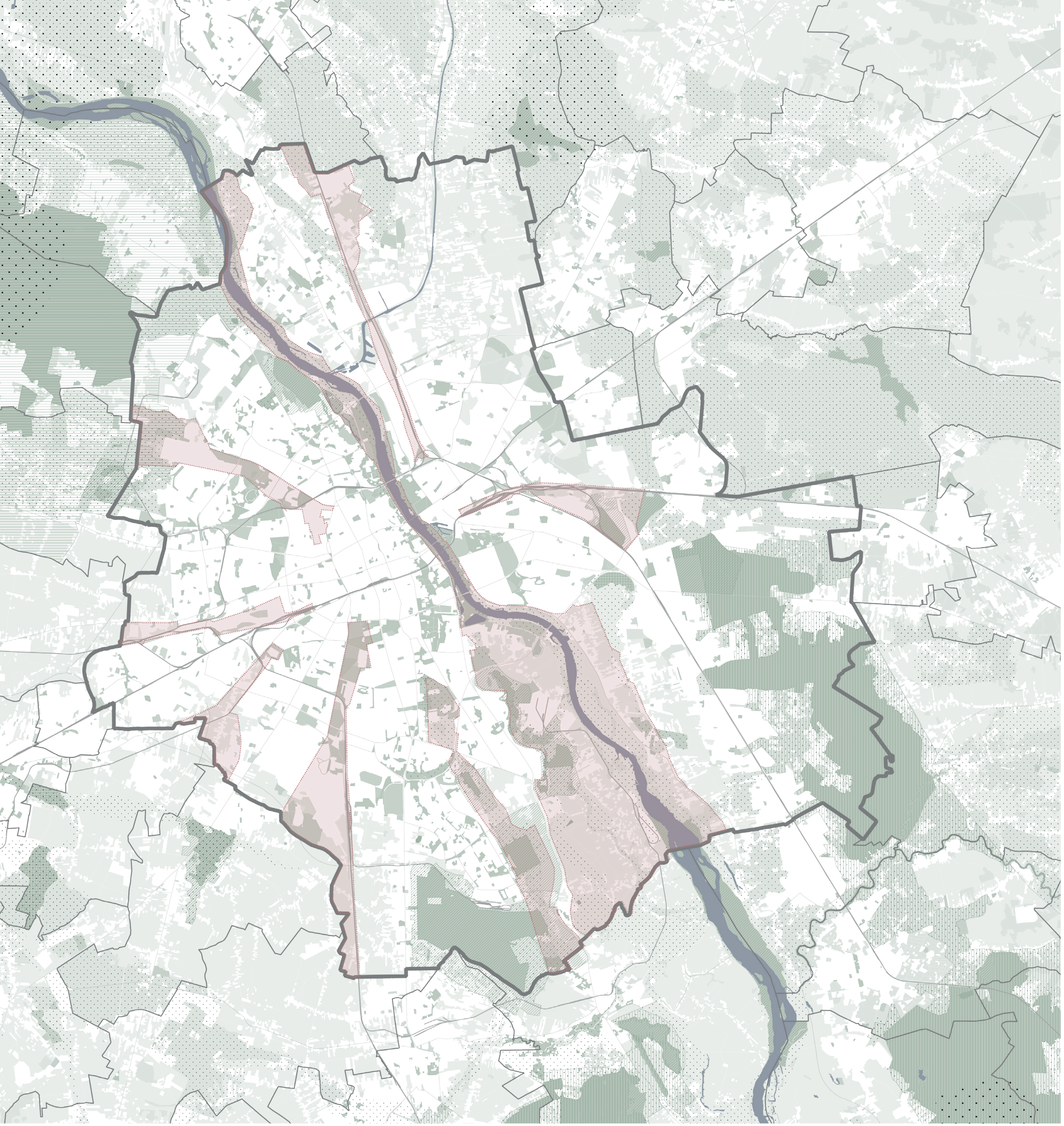
The second step is the selection of the case study to test the method. The selection has been made according to the possibilities of showing maximum issues and suggested solutions in one street. The selection could be repeated with any other case study, and the same air pollution measures would be proposed, but adjusted to the local context.

The third step consists of the visionary design proposal of one selected case study from the full big scale system proposed. The detailed spatial analysis of the local conditions has been conducted, and the division into different functional parts has been proposed, following the local characteristics. Under the primary strategy of air pollution, with attention to the local context, the selected case study street has been divided into different functional parts, with the corresponding visionary design proposed. The aim is to follow the general air pollution issue, tackled with the big scale strategy and design on a small scale using repetitive modules that mostly fit the local context. Thanks to that approach, the reached goal is not only to mitigate air pollution but also to add new values and qualities to the site of intervention.

Those three steps allow us to give an overview of air pollution environmental problems in different scales, going from the general strategy to the local implementation. Each step is strongly connected with others, and they work independently as a design proposal, and all together as a strategic concept. In this case, it is possible to merge the design approach with the interscalar concept of the project and to provide multi-issue solutions, but also tackling the quality of design or functions while proposing air pollution resistant public space.



[FIG.7.01]
DESIGN APPROACH
source: self-elaboration by author



STRATEGIC CONCEPT

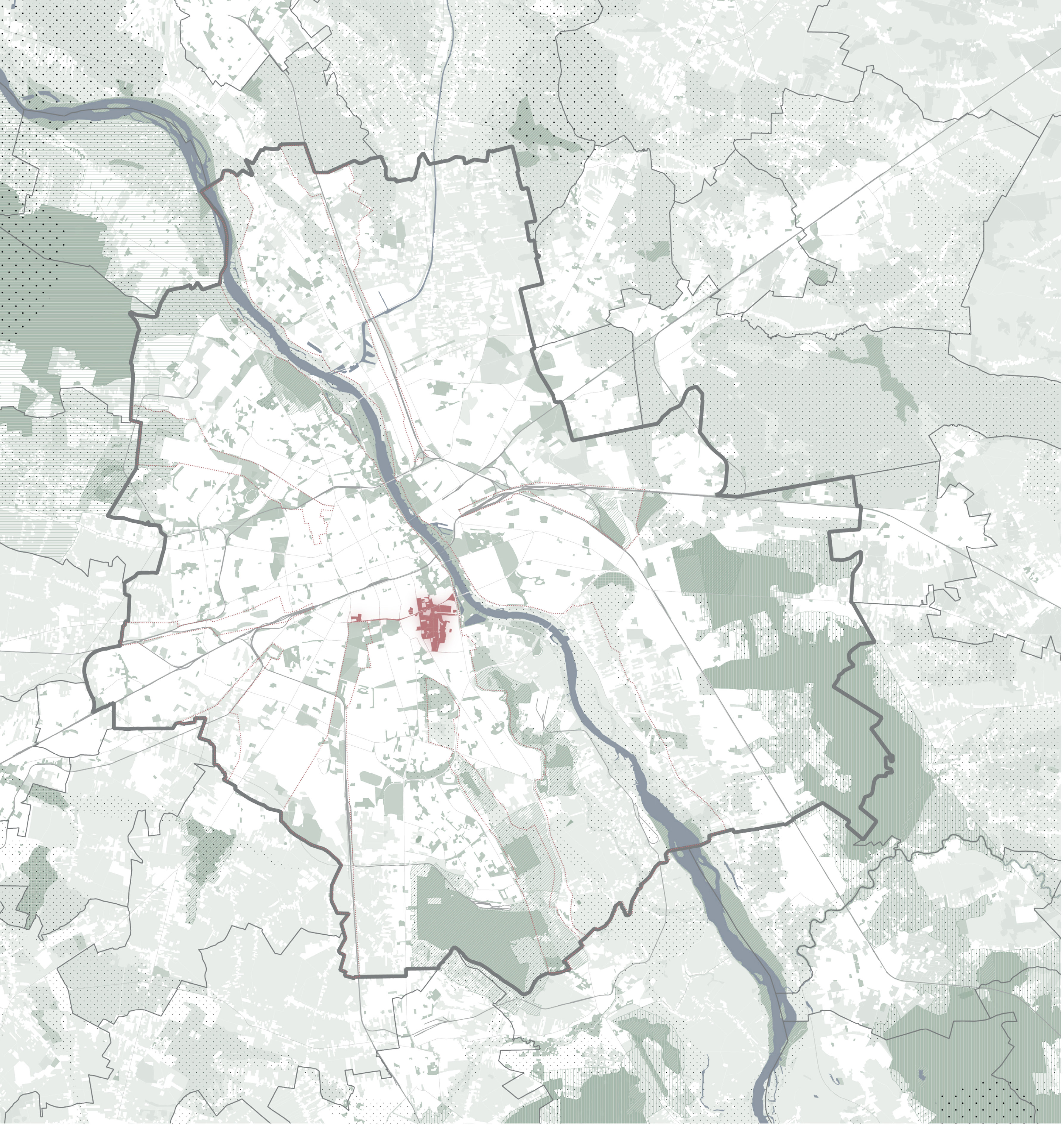
The existing ventilation system of Warsaw, consisting of green ventilation corridors, is a great value of the city's landscape system. It needs to be fully recognized, prioritized, and protected, preventing the attempts to build within the corridors, which has been observed in the last years. The concept of the project is built around its functionality.

From the analysis, we can observe that the most densely populated and densely build-up part of the city is located in the center, which is also not served by the green corridors system.

The idea is to create a new, supportive green system by connecting the corridors through the central part of the city, providing a new efficient system for urban ventilation. By doing so, we will introduce green into central Warsaw, but also brings additional functions and values to the inhabitants, creating inclusive places for leisure and recreation, for children to play, elderly people, to rest, and other users, accordingly the local characteristics of the space.

AS AN OUTCOME OF:

[FIG.7.02]
STRATEGIC CONCEPT
source: self-elaboration by author



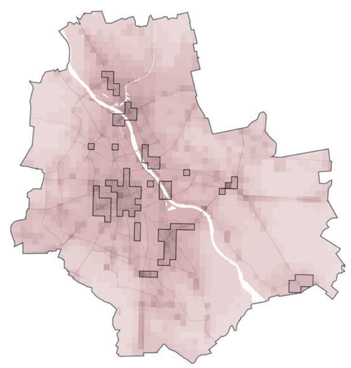
GREEN CORRIDOR - VENTILATION CORRIDOR

Translating one of the researched and presented before street typology of the „ventilation corridor" into the physical context, it is proposed to use one of the biggest highways placed in the open tunnel, crossing the city center, as a chance for placing green corridor.

The Łazienkowska street, with its width reaching 50-60 meters, placed 6 meters below the ground level, connects the Mokotów ventilation corridor with the Vistula river ventilation corridor, crossing through the dense neighborhood of „Śródmieście Południowe" and the „Łazienkowski Park" - the biggest and most beautiful historic park complex of the city. Increasing the connectivity and creating the green system between those crucial areas, would facilitate the exchange of the air between those two corridors, and create alternative dispersion area for the densely polluted neighborhoods.

The goal can be reached by covering and turning the existing half tunnel, into the full tunnel, with an underground highway, and green linear park placed on the ground level. The park should be characterized by diverse and intensive biodiverse vegetation, with attention to smart tree placing, to facilitate the flow of the air, and decrease the chance to block it.

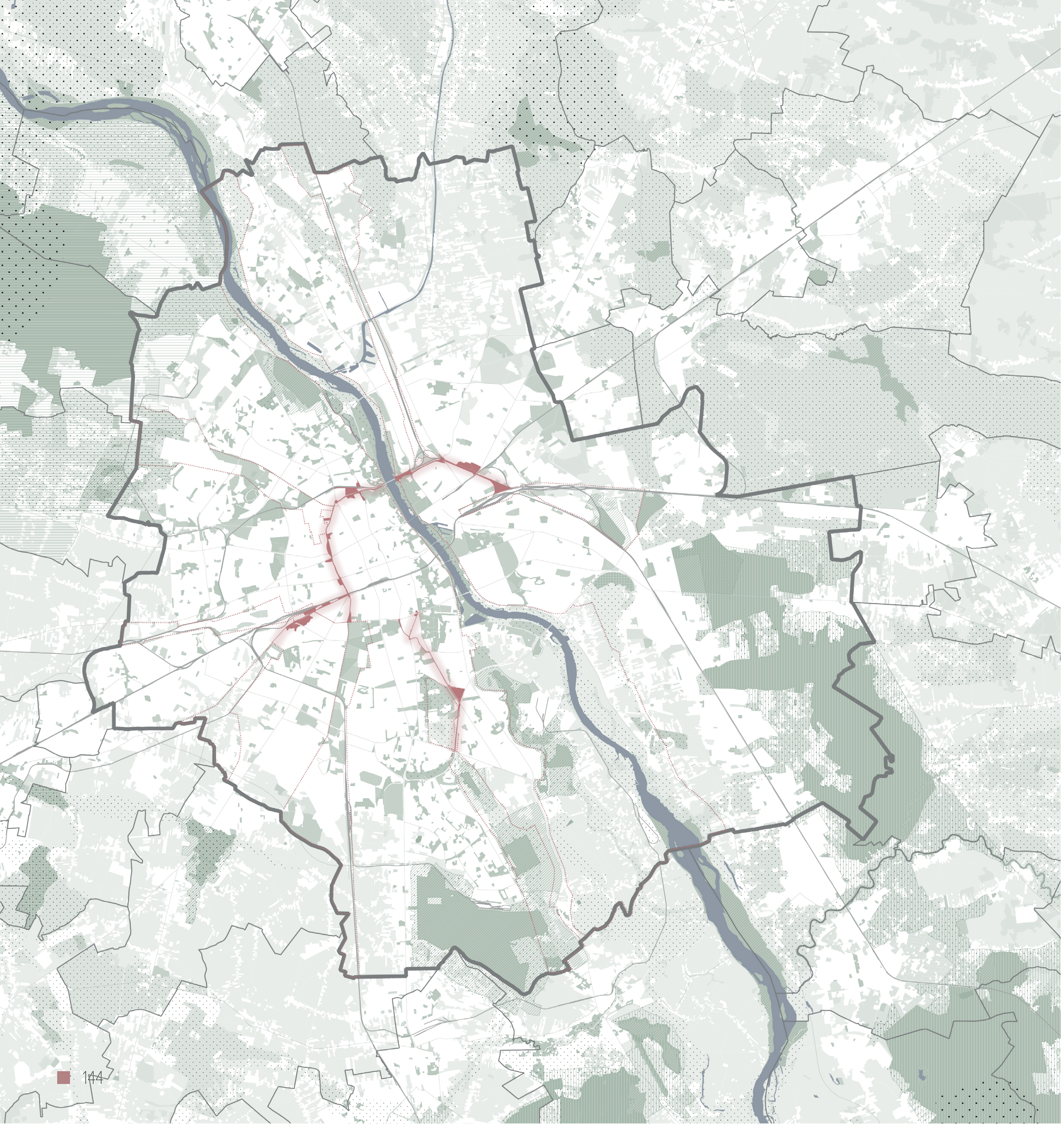
AS AN OUTCOME OF:



AIR POLLUTION

VENTILATION SYSTEM

[FIG.7.03]
GREEN CORRIDOR
source: self-elaboration by author



GREEN BYPASS - URBAN STREET

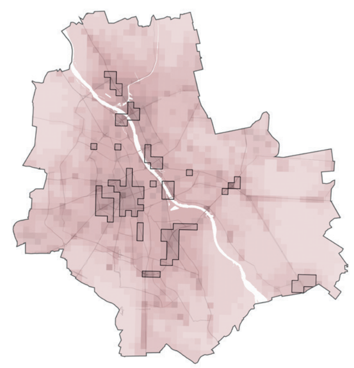
Continuing the same methodology, the spaces described previously as belonging to the typology of the "Urban Street" are taken into consideration. It is proposed to connect all the existing ventilation corridors, using existing streets pattern to form the Green Bypass of the city. By turning the public space on the edges of the ventilation corridors into a big scale green system, it is possible to improve the overall ventilation system and introduce another type of dispersion method for the air pollution produced locally.

Introducing more green solutions to the Towarowa street, currently under significant transformation into the new business center of the city, allows us to connect all the southern and northern corridors, through the most polluted areas of the city, according to the analysis presented previously.

Together with the corridor over the underground highway, proposed on the previous page, the system creates an almost complete loop around the most densely populated and built areas of the city, especially on the most problematic and affected the left side of the river.

It is essential to pay extra attention to the role of the streets in the transportation system, to find the optimal balance between green bypass and transportation bypass of the central city.

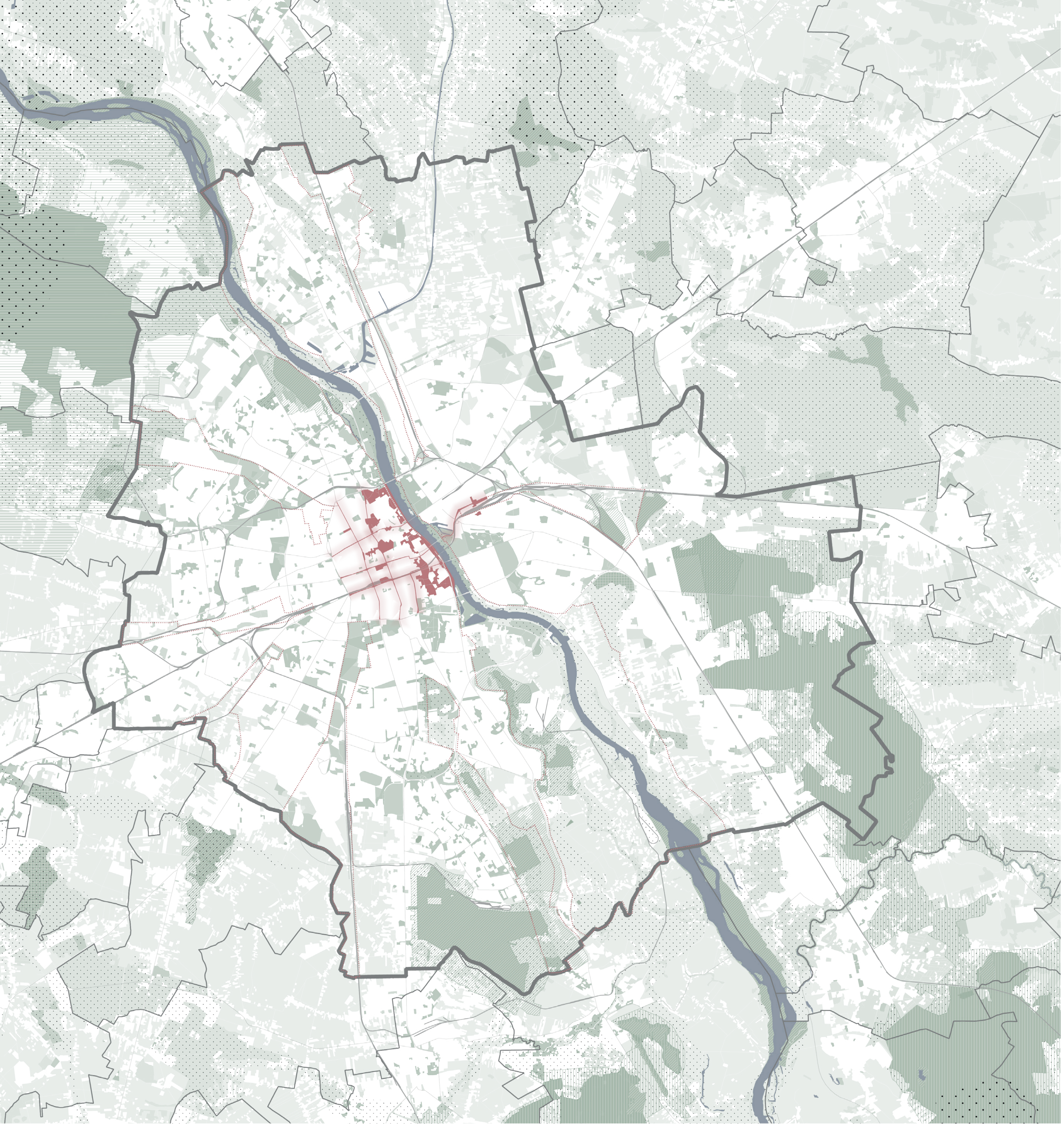
AS AN OUTCOME OF:



AIR POLLUTION

VENTILATION SYSTEM

[FIG.7.04]
GREEN BYPASS
source: self-elaboration by author

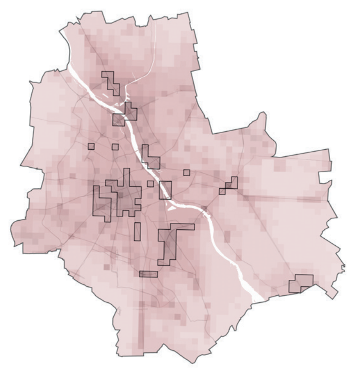


GREEN DOWNTOWN GRID - URBAN STREET

Next approach, but using the same street typology is proposed within the dense central part of the city. Using the network of the wide urban streets, constructed during the post-war reconstruction, it is proposed to create a new Green Downtown Grid. The grid connects the Green Bypass with the biggest Vistula River ventilation corridor, through several existing smaller and bigger parks in the central Warsaw. The street profiles can be turned from completely car-oriented, into more diverse, with particular attention paid to the role of green, biodiversity and air quality. The linearity of the system allows to create adequate support for the ventilation system, but also introduce new functions for the local inhabitants, and increase the general life quality.

Due to the growth of public transportation, including new metro lines, new tram lines, and redesigned bus system, it is now possible to enhance the decrease of private car transportation within the presented areas, to create healthy, diverse and sustainable neighborhoods.

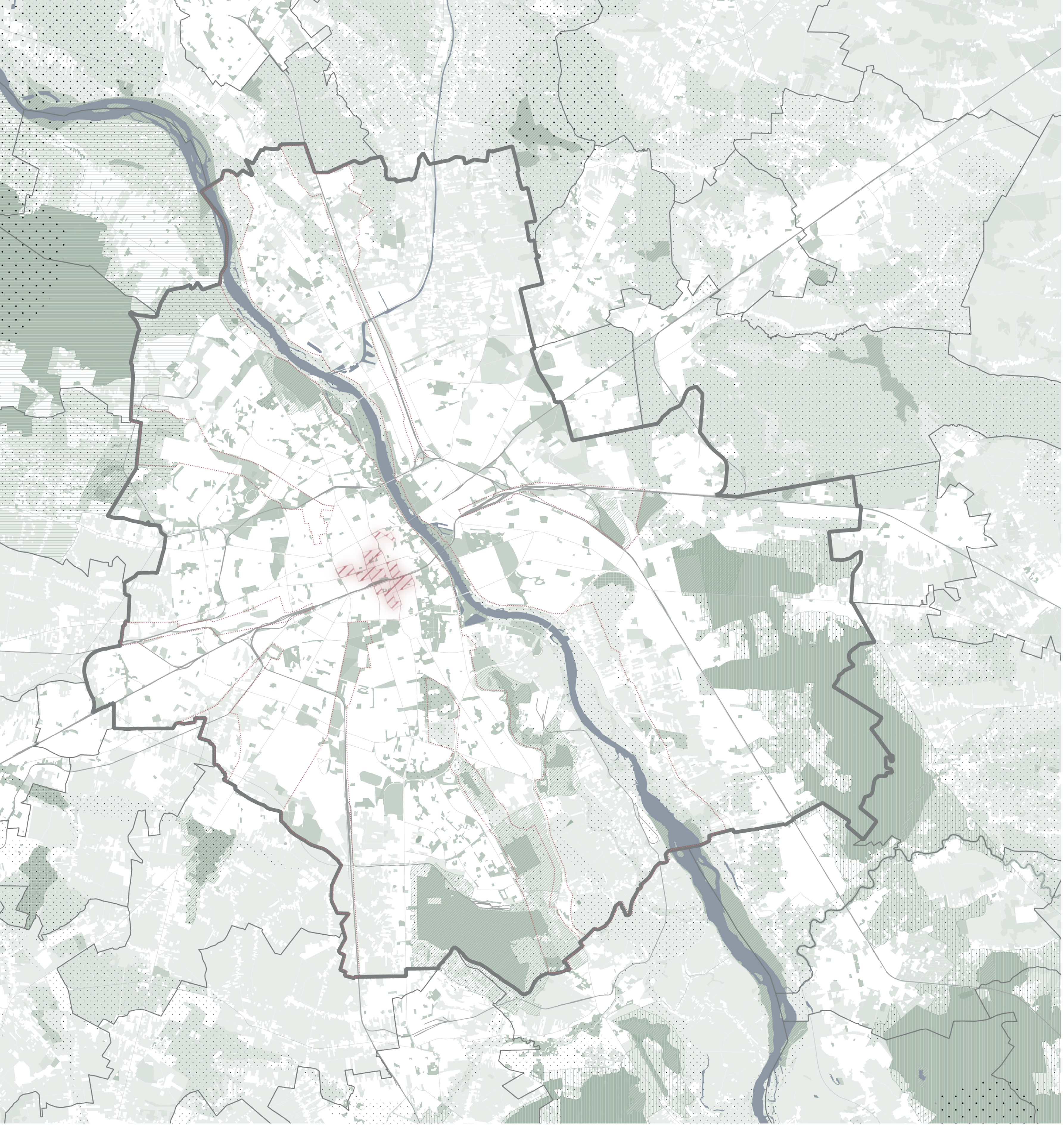
AS AN OUTCOME OF:



AIR POLLUTION

LAND USE

[FIG.7.05]
GREEN DOWNTOWN GRID
source: self-elaboration by author



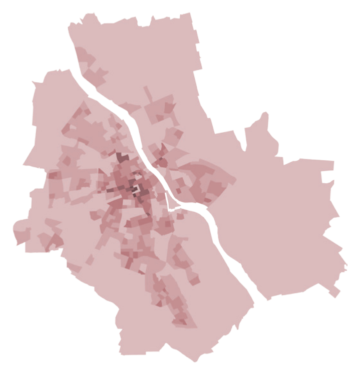
GREEN NEIGHBORHOODS - NEIGHBORHOOD STREETS

The last researched typology - the "neighborhood street" is proposed for implementation in the areas with the most limited possibilities for natural ventilation. Where the density of population and the density of build environment are the highest, it is suggested to focus on implementing green neighborhoods, to facilitate the flow of air by introducing green solutions, diversifying the ground temperatures, and enhancing higher infiltration and retention of the rainwater.

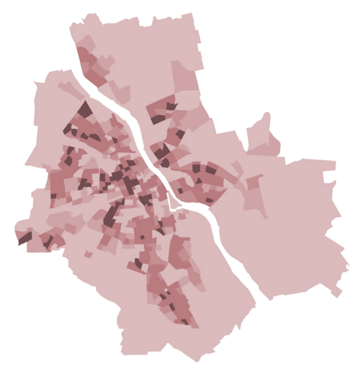
Areas located between Marszałkowska and Jana Pawła-Chałubińskiego streets have been defined as having the least capacity for ventilation and with the need for particular attention. The emissions should be eliminated there, and the dispersion increased to limit the access to the vulnerable reception groups, highly concentrated in those areas.

Improving the public space, and focusing on the role of green and biodiversity, gives a chance to pay extra attention to the quality of the space, and functionality, according to the needs of local inhabitants.

AS AN OUTCOME OF:

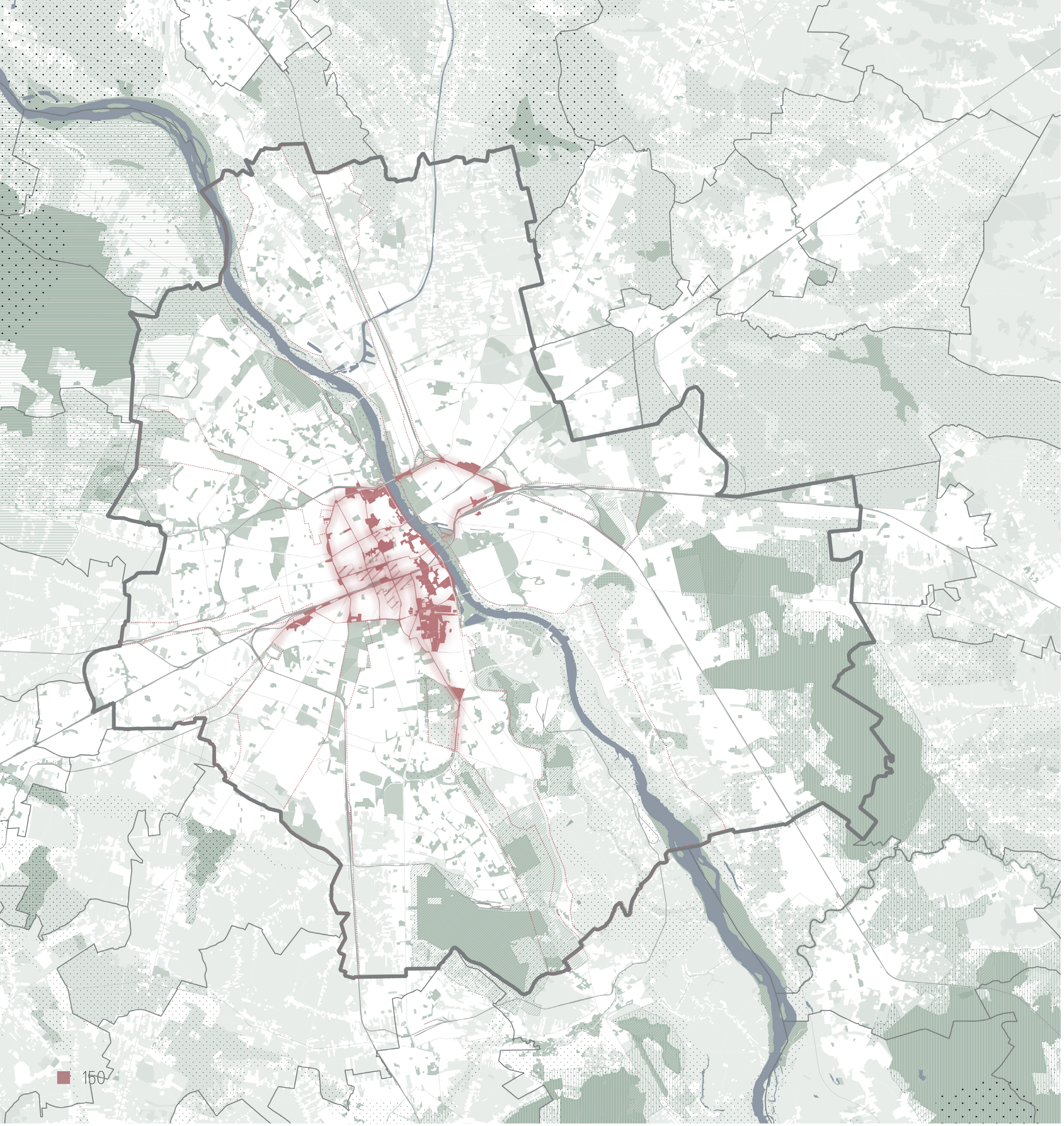


FLOOR SPACE INDEX



DENSITY

[FIG.7.06]
GREEN NEIGHBORHOODS
source: self-elaboration by author



NEW URBAN LANDSCAPE SYSTEM

By overlapping all the four presented actions, we can define the new urban landscape system of Warsaw. Summarizing, the system consists of:

- Green corridor
- Green bypass
- Green downtown grid
- Green neighborhoods

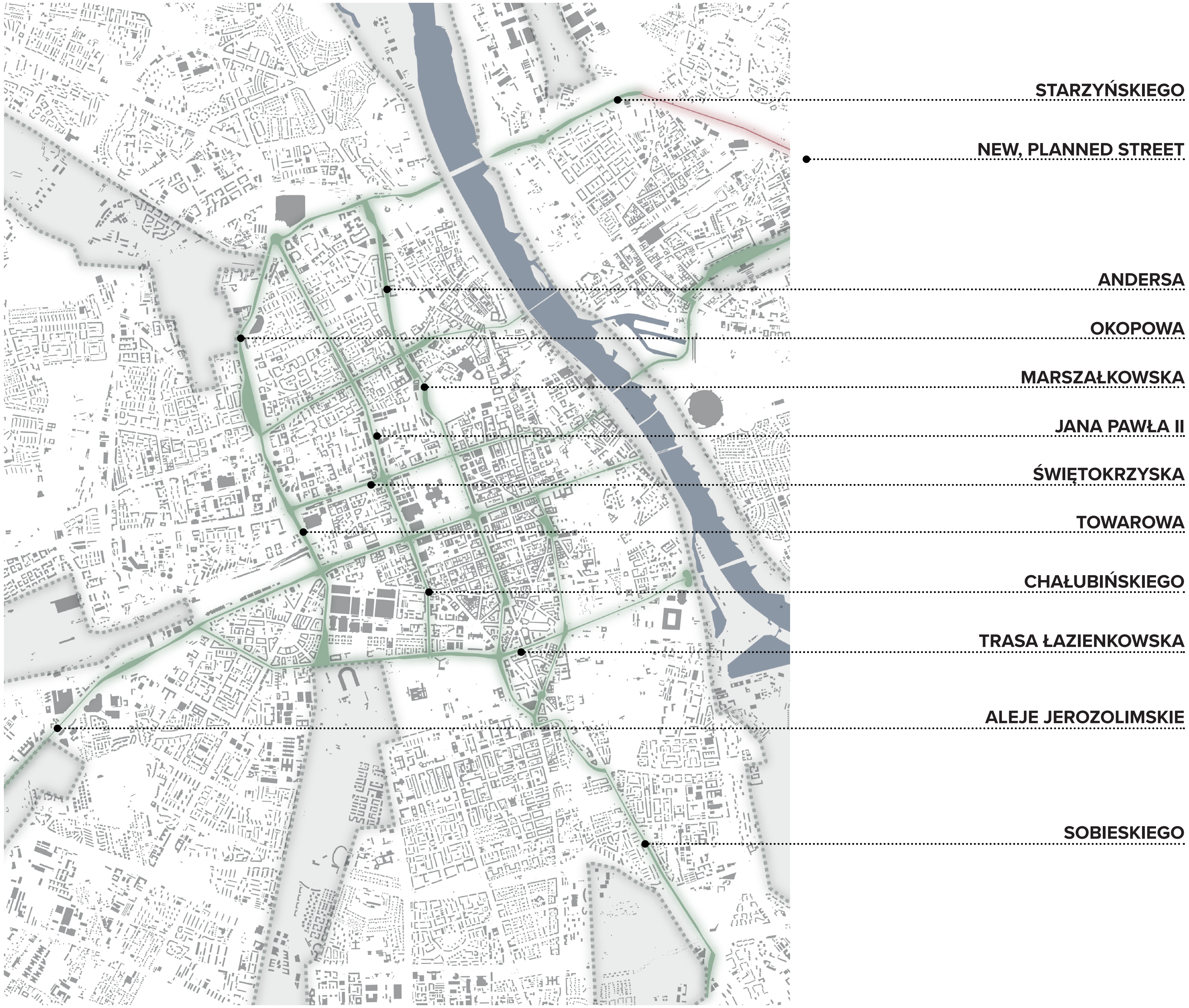
It incorporates all the existing green areas in the city, including existing ventilation corridors, parks, squares, city forests, natural meadows, and open areas. After the full implementation, it would be possible to cross the entire city from the north to the south using the only green urban infrastructure.

The air and natural wind flow would have an improved condition to freely infiltrate the build-up areas in the central part of Warsaw, increasing the role of wind in the pollution dispersion process. In the same areas the car traffic is limited, decrease the emissions. However, the system does not affect the main transportation structure of the city, nor the main bypass roads.

The biggest strengths are the big scale approach, and linearity of the solutions, which is a crucial point in increasing urban ventilation. Due to the composition of 4 independent elements, it is possible to form an efficient steps plan and invest separately in the solutions that all together create a large system, but are efficient also independently.

[FIG.7.07]
NEW URBAN LANDSCAPE SYSTEM
source: self-elaboration by author

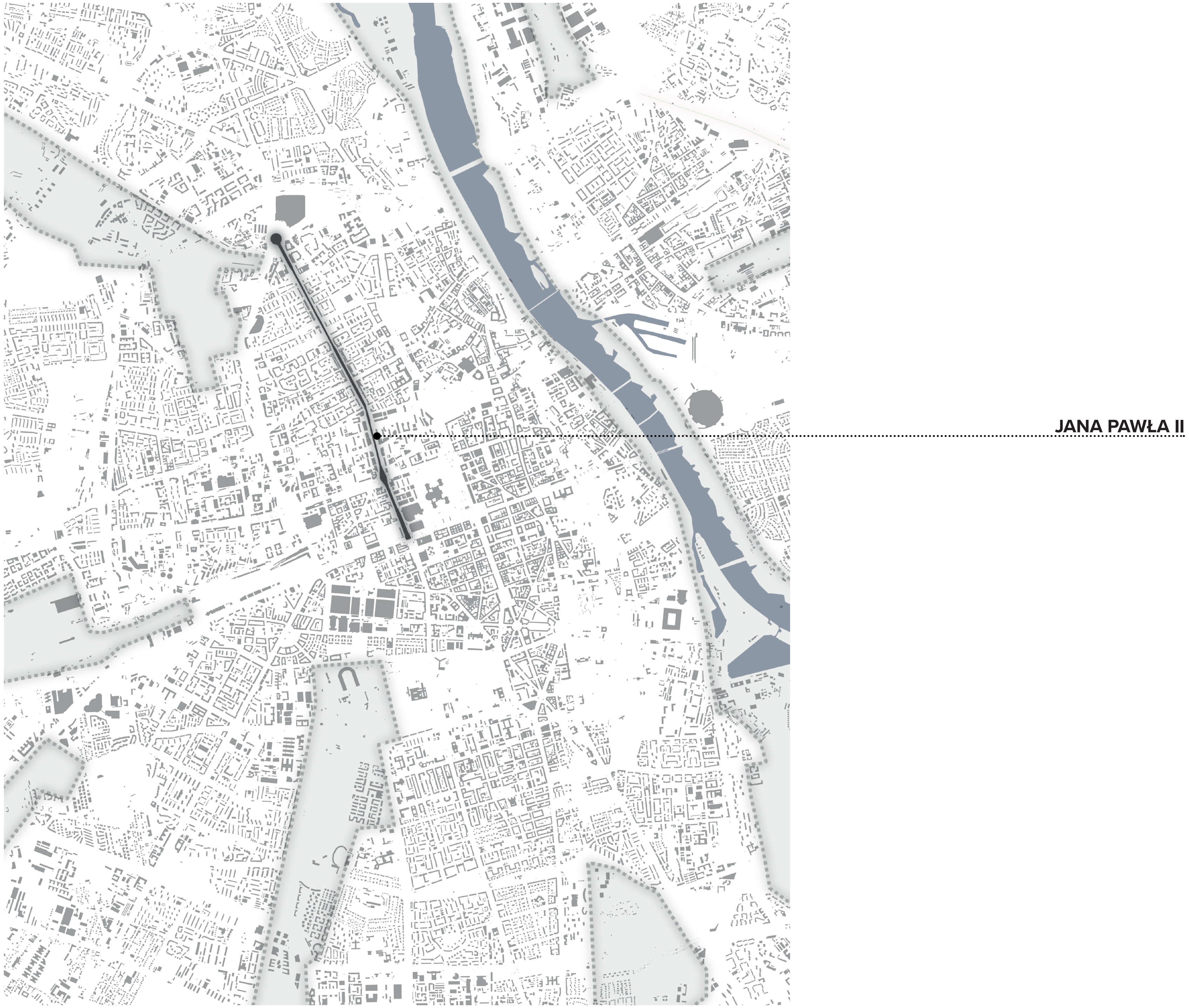
[FIG.7.08]
NEW URBAN LANDSCAPE - STREETS
source: self-elaboration by author



NEW URBAN LANDSCAPE SYSTEM

After zooming in, we can have a closer look at the particular context, street selection, and their characteristics. The selected streets for the grid, connect the city in the south-north and west-east directions. All the selected streets are characterized by a very high width of 50 up to 75 meters (in some parts, even more than 100m). The longest is the Aleje Jerozolimskie, which connects three different ventilation corridors with downtown Warsaw. The widest is Towarowa street, which several times exceeds the 75m, and also forms the new ax of the Warsaw business district.

[FIG.7.09]
NEW URBAN LANDSCAPE - JANA PAWŁA II
source: self-elaboration by author

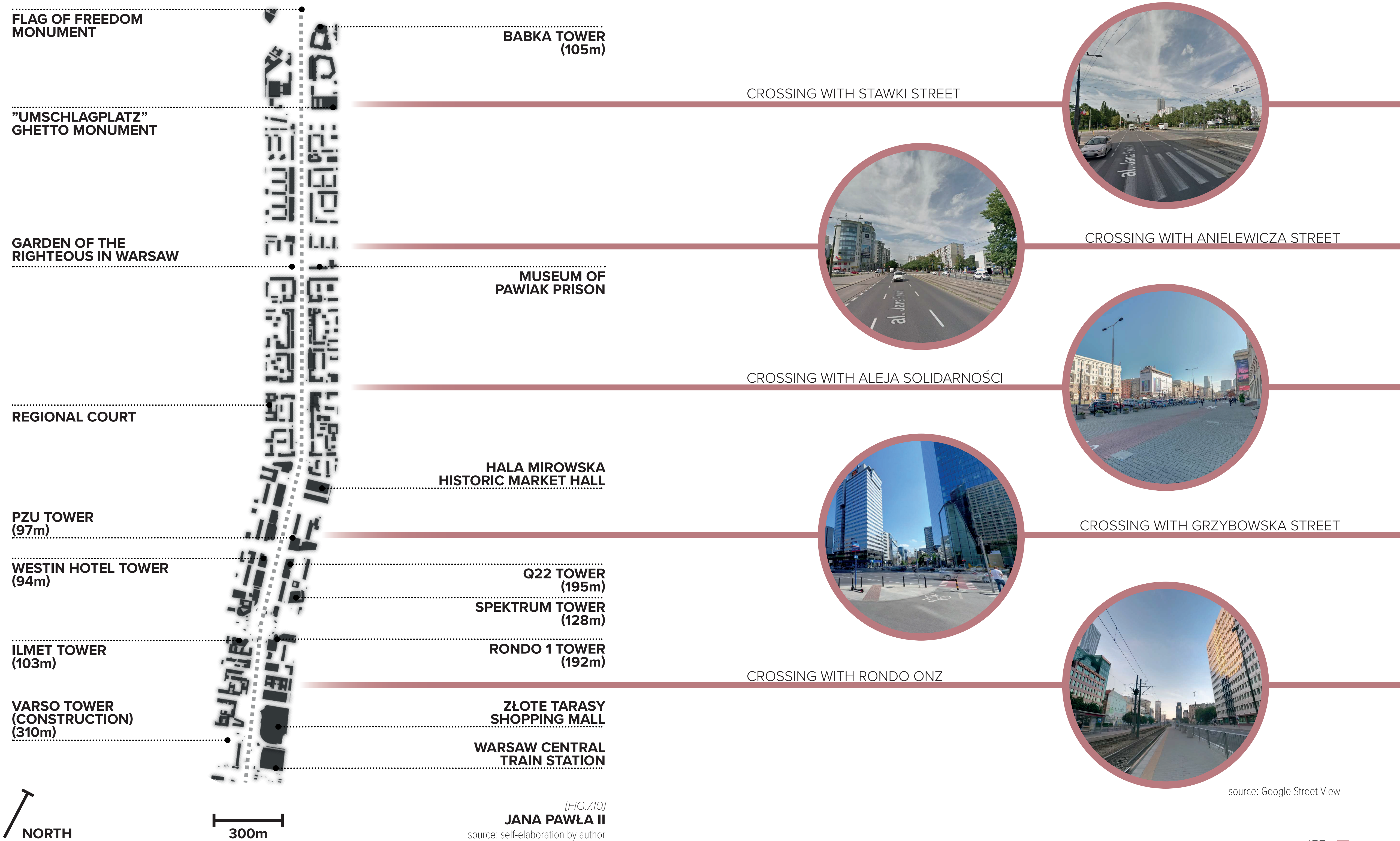


CASE STUDY - JANA PAWŁA II AVENUE

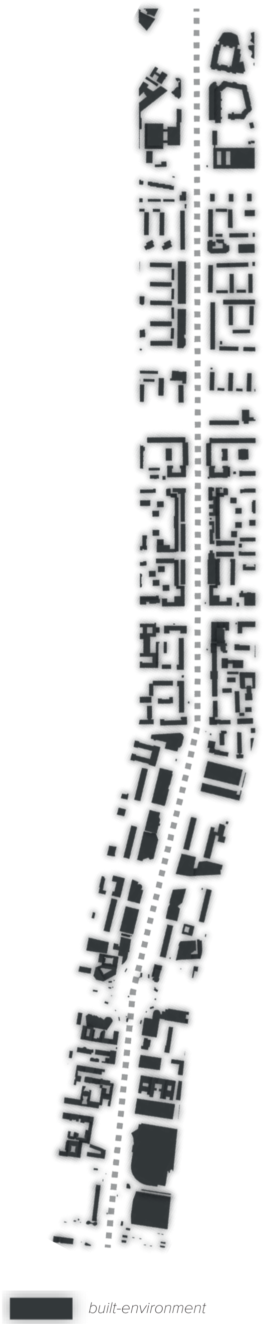
To test the method, and show the possible functionality of the public space, one street has been picked as a case study. The selection has been made on Jana Pawła II street due to its diverse character, which allows testing several solutions on a smaller scale.

The avenue has been primarily proposed before 1939, but work did not start before World War II, due to the high costs of land in one of the most densely built-up areas of pre-war Warsaw. The avenue was finally constructed between 1955–1959 as a fragment of the new North-South route. It was designed through damaged areas of the former Warsaw Ghetto. The street was designed as one of the significant post-war interventions and was given the typical form of the car-oriented designs of those times. The new built-up environment was very loose and spread, without coherent street facade, that has only been created partially in the next 50 years. Significant changes have arrived in the 90 when the street's facade has been completed with several new buildings.

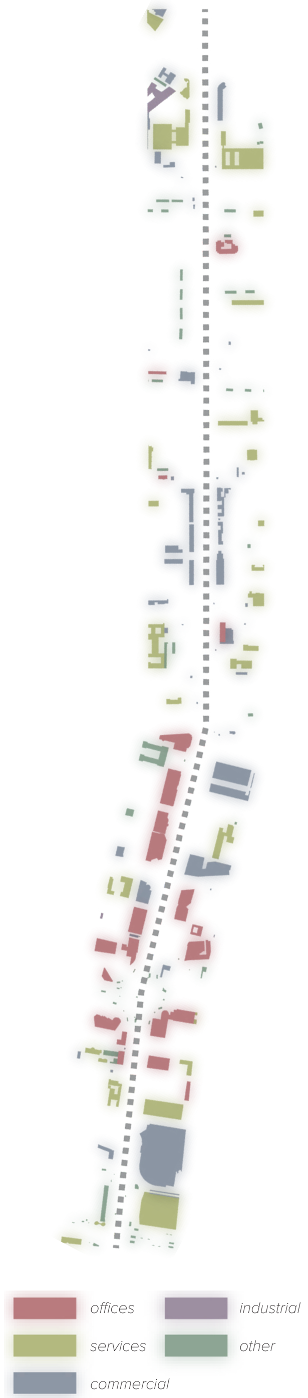
It is essential to define the role of Jana Pawla II street in the entire system of the new urban landscape. As a direct and linear connector between the northern ventilation corridors and the direct city center, this street is a primary green connector. The role of systematic green structure here is particularly important and has to be put as a priority over other topics and issues. The transformation of a very wide profile of this street can positively affect not only air quality and ventilation but also biodiversity, heat stress, water infiltration, and drought prevention in the central, most vulnerable areas, which this street crosses.



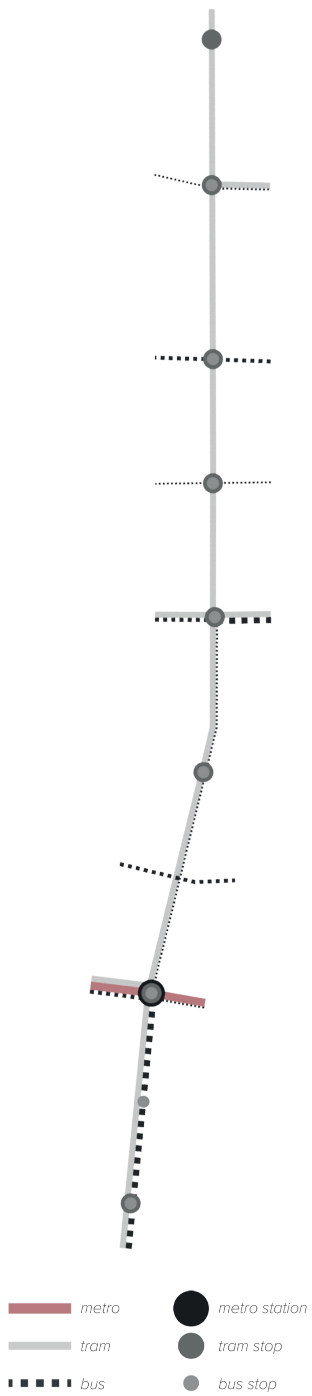
[FIG.7.10]
JANA PAWŁA II
source: self-elaboration by author



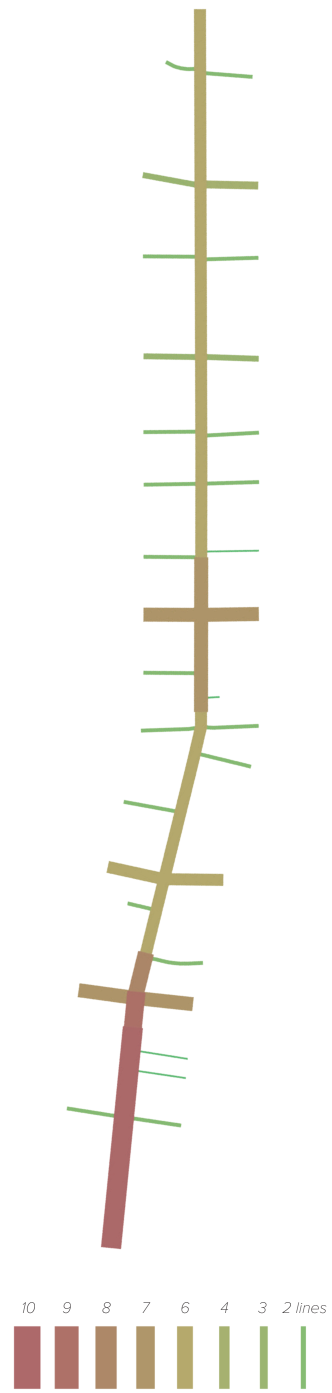
[FIG.7.11]
BUILT-ENVIRONMENT
source: self-elaboration by author



[FIG.7.12]
NON-RESIDENTIAL FUNCTIONS
source: self-elaboration by author



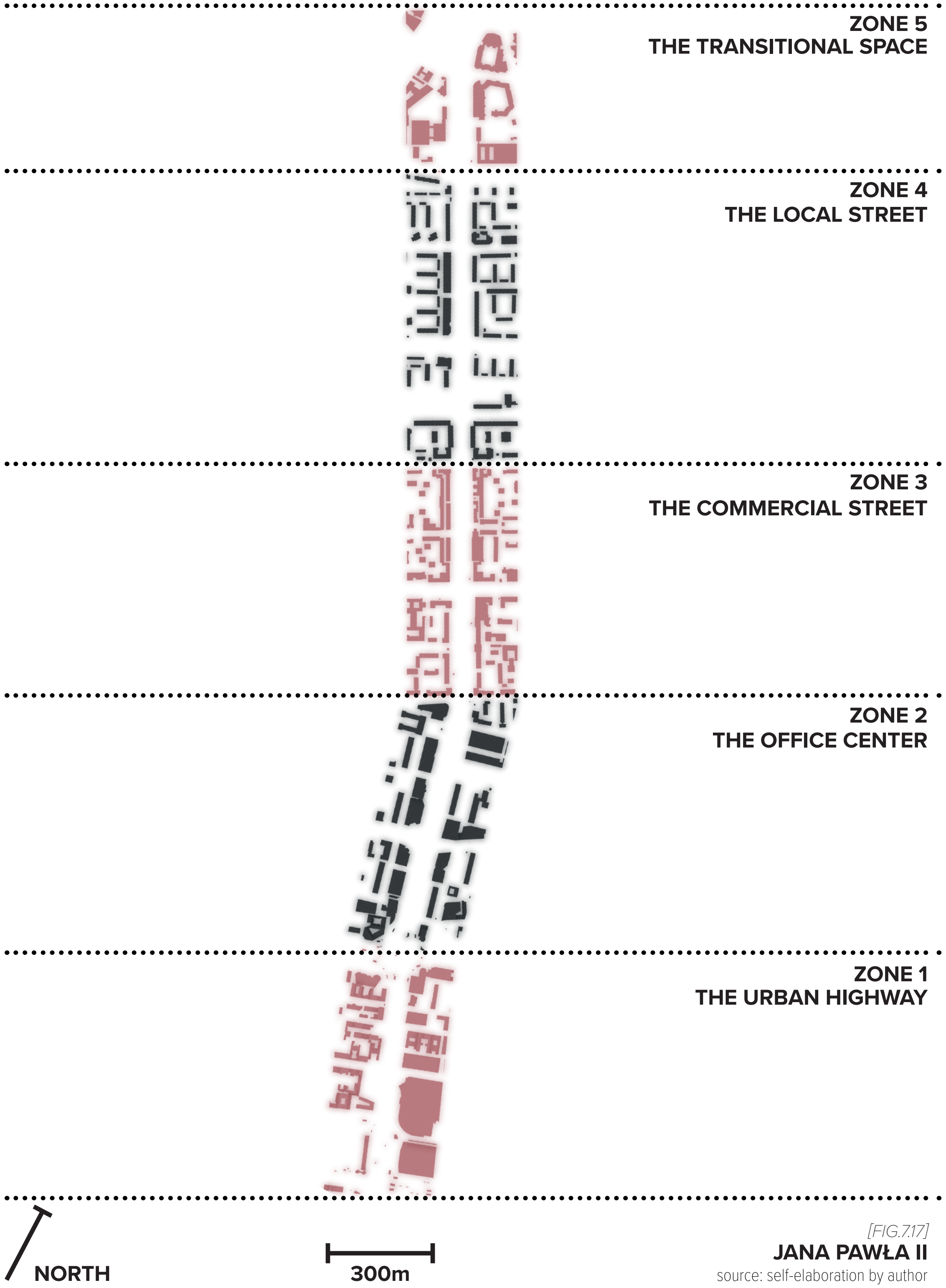
[FIG.7.13]
PUBLIC TRANSPORT
source: self-elaboration by author



[FIG.7.14]
CAR LINES
source: self-elaboration by author

[FIG.7.15]
EXISTING TREES
source: self-elaboration by author

[FIG.7.16]
FLAT ROOFS (POSSIBLE GREEN ROOFS)
source: self-elaboration by author



[FIG.7.17]
JANA PAWŁA II
source: self-elaboration by author

ZONE 5
THE TRANSITIONAL SPACE

Car oriented transitional area with a lack of defined character. We observe a scattered, built environment with low-quality green areas. This section is very unfriendly for pedestrians, has limited possibilities for crossing the street, and has no consistent urban structure.

ZONE 4
THE LOCAL STREET

Section of the street characterized by the high concentration of residential complexes. The entire urban structure has been built in the 1950s on the Jewish ghetto ruins, as West "Muranów" neighborhood. A small number of local services can be found within the area. The street separates the neighborhood into two, with a very limited possibility of crossing. We can find decent amount trees and urban greenery in this section. However, it is of low quality and does not form a system. Street partially has consistent urban façade.

ZONE 3
THE COMMERCIAL STREET

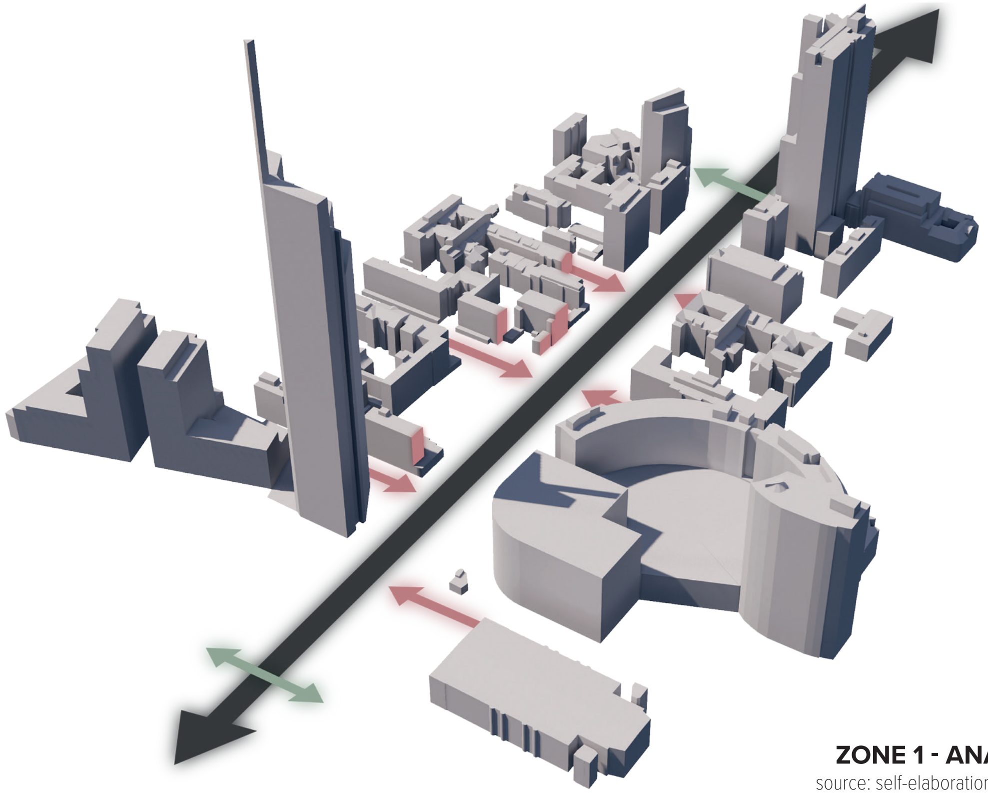
An area with a mix of functions but a highly predominant concentration of commercial activities. The one-floor pavilions for small scale trade located in the northern part, and commercial activities located on the ground level in the southern part, define the character of the entire area, on the city scale, attracting users from outside of the district. The street is a significant barrier but with several possibilities to cross.

ZONE 2
THE OFFICE CENTER

This section of the street is characterized by a high concentration of office activities, including several high rise towers. We can also observe some residential and commercial functions ("Za Zelazna Brama" residential neighborhood, historic "Mirowska" commercial hall), but space is functionally dominated by fast-growing office activity. It is one of the greenest parts of the existing street profile, with a concentration of existing trees, which needs to be preserved and enhanced.

ZONE 1
THE URBAN HIGHWAY

The most neglected section of the street. Space is wholly devoted to car transportation, with the street reaching up to 10 car lines. There is no possibility to cross the street, which makes it exceptionally not accessible for pedestrians. The low quality of public space does not attract users. It is the only part of the street with a lack of any bicycle infrastructure, and with minimal presence of urban greenery or trees.



[FIG.7.18]
ZONE 1 - ANALYSIS
source: self-elaboration by author

QUALITIES

the street profile is wide and offers space to various modalities

presence of several empty walls/sides of buildings facing the street

the architecture is diverse, from different periods, in various conditions

presence of Central Station and several office towers, services, and residential units

PROBLEMS/CHALLANGES

a street profile is car-oriented and overscaled, lacking green and pedestrian space

street lacks continuous facade due to the scattered post-war reconstruction

the styles of buildings do not form a clear picture and lack character

space is avoided by pedestrians, due to the barriers and low quality

OPPORTUNITIES

the wide profile gives a chance to allocate more green, and diversify the functions

chance to introduce green walls and green functions to the empty walls

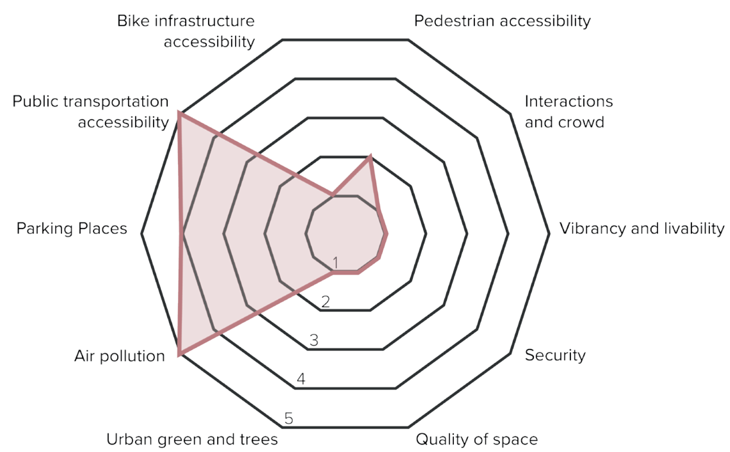
green elements as a definition of the space

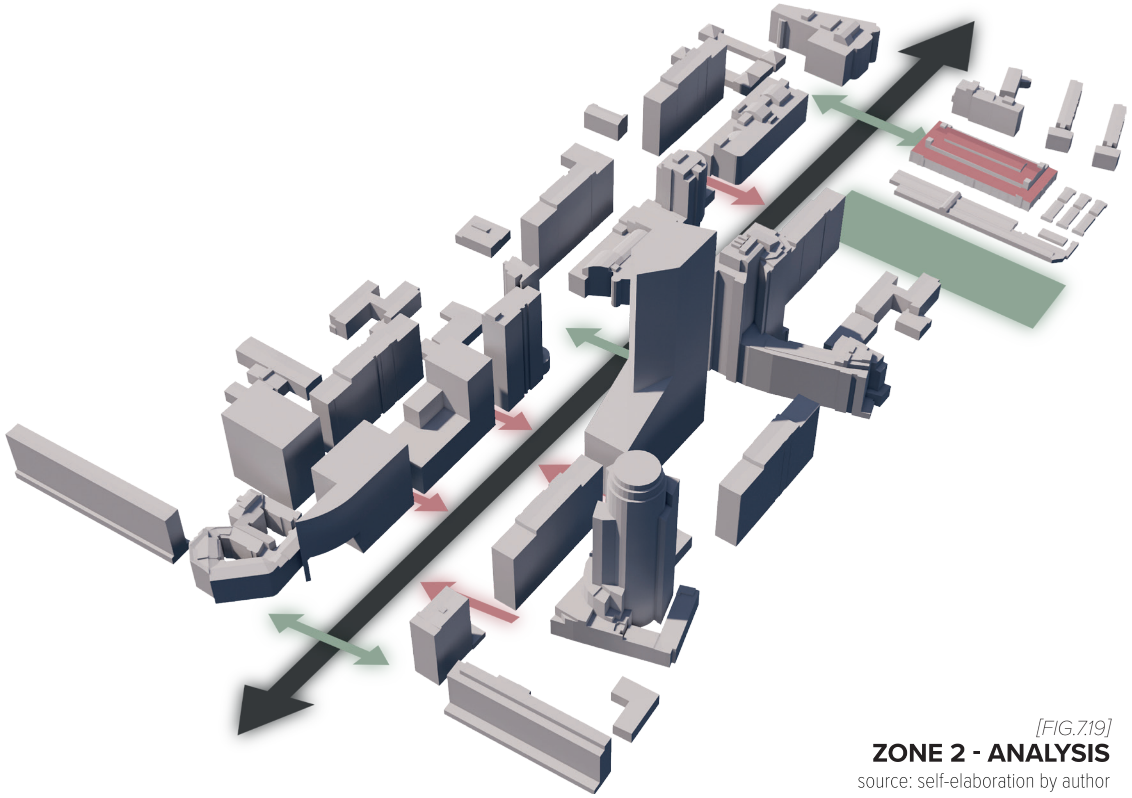
the train station and commercial center as a generator of potential users for the local context

ZONE 1
the urban highway

600 meters long section between Jerusalem Avenue and "ONZ" roundabout. Car corridor with 10 car lines, and 2 pedestrian crossings (2/600m). Several buildings are facing the street with empty walls (Sienna 45, Sienna 55, Zlota 58). No bicycle infrastructure, no trees, or urban green systems. Limited pedestrian accessibility. Residential, commercial, office, and service functions are present. 3 bus lines, 5 trams lines, metro stop, and proximity to local, national, and international train station. A massive amount of parking places along the street.

foto: UM Warszawa





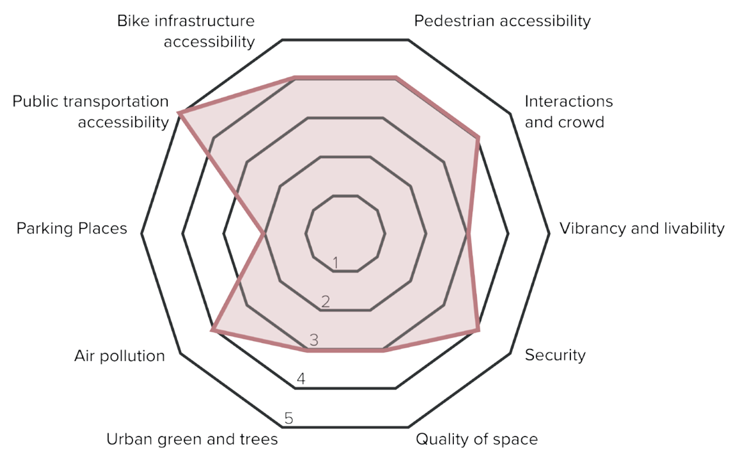
[FIG.7.19]
ZONE 2 - ANALYSIS
source: self-elaboration by author

QUALITIES	PROBLEMS/CHALLANGES	OPPORTUNITIES
a street profile is wide and offers space to various modalities	a street profile is a car-oriented barrier, with limited possibilities to cross	the profile gives a chance to allocate more green, and diversify the functions
a very high concentration of offices and towers with business functions	monofunctional space becomes an empty car corridor after the office hours	chance to bring new services that serve the workers and citizens
presence of the oldest still existing market hall in the city	big car traffic generator - users and deliveries	a chance for creating a new character for space
a high number of car lines, bike and tram infrastructure	transport oriented design with a lack of other functions	infrastructure as a catalyzation for improvement
proximity to the green Mirowski Park	lack of functional connection between street and park	presence of the recreational area for the neighborhood

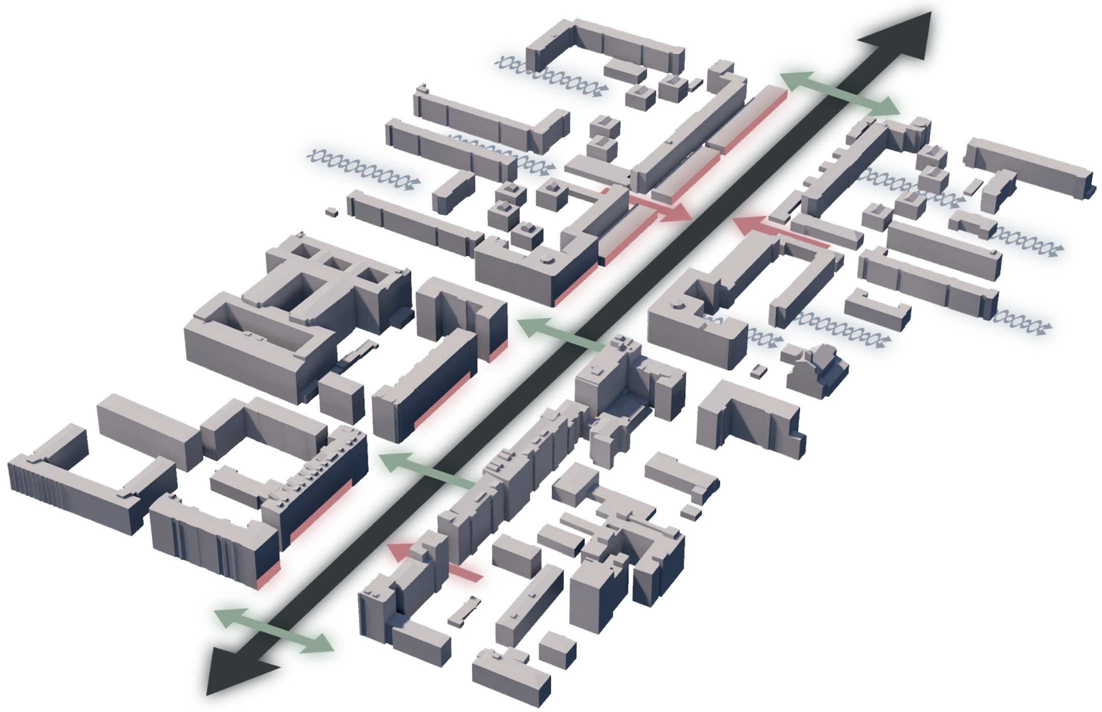
ZONE 2
the office center

700 meters long section between "ONZ" roundabout and Elektoralna street. Car oriented street with 6 to 8 car lanes and 3 pedestrian crossings (3/700m). Predominantly office functions, with the presence of residential and commercial activities. Bicycle infrastructure with 2-ways paths of both sides of the street, uncomplete on the east side of the street. The concentration of existing old trees in the northern part of the section and a small urban park. 1 bus line, 3 tram lines, metro stop in proximity of walking distance. Limited amount of parking places along the street.

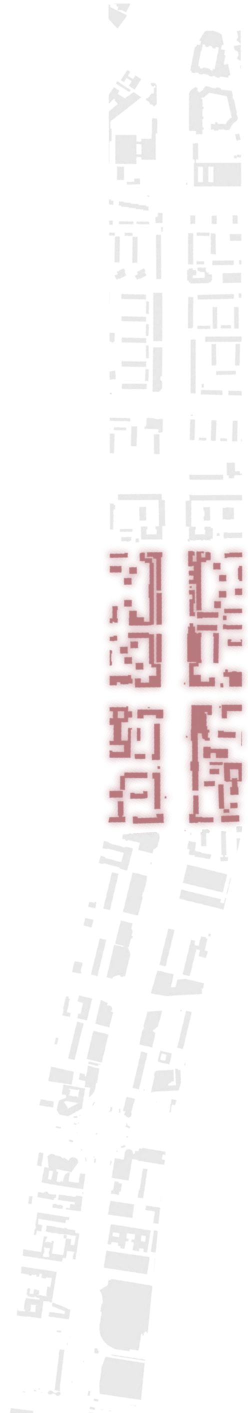
foto: Adrian Grycuk



ZONE 3
the commercial street

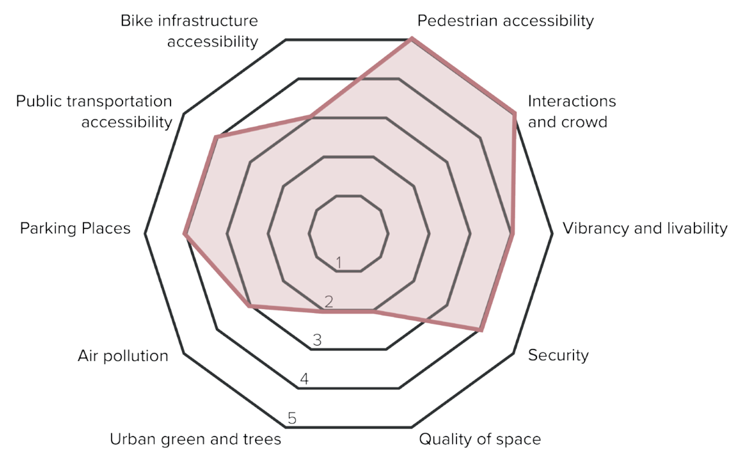


[FIG.7.20]
ZONE 3 - ANALYSIS
source: self-elaboration by author



650 meters long section between Elektoralna street and Nowolipki street. Car oriented street with 6 to 7 car lanes and 4 pedestrian crossings (4/650m). Predominantly commercial function, with the presence of offices and some residential buildings. Bicycle infrastructure on one side of the street – 2-ways narrow path. Very little trees but some open lawns. 1 bus line on the part of the street, 3 tram lines, and an important transportation hub on the crossing with Solidarnosci Avenue (2 more bus lines and 4 more tram lines). Several parking places along the street.

foto: warszawa.wikia.org



QUALITIES

a street profile is wide and offers space to various modalities

area vulnerable to flooding during heavy rain episodes

presence of monumental socialist-realist architectural style

a very high concentration of commercial activities on the ground levels and in separated pavilions

PROBLEMS/CHALLANGES

a street profile is a car-oriented barrier, with limited possibilities to cross

water is transported into the inefficient sewerage system

problems with the sustainability of architecture from that period

big car traffic generator - users and deliveries

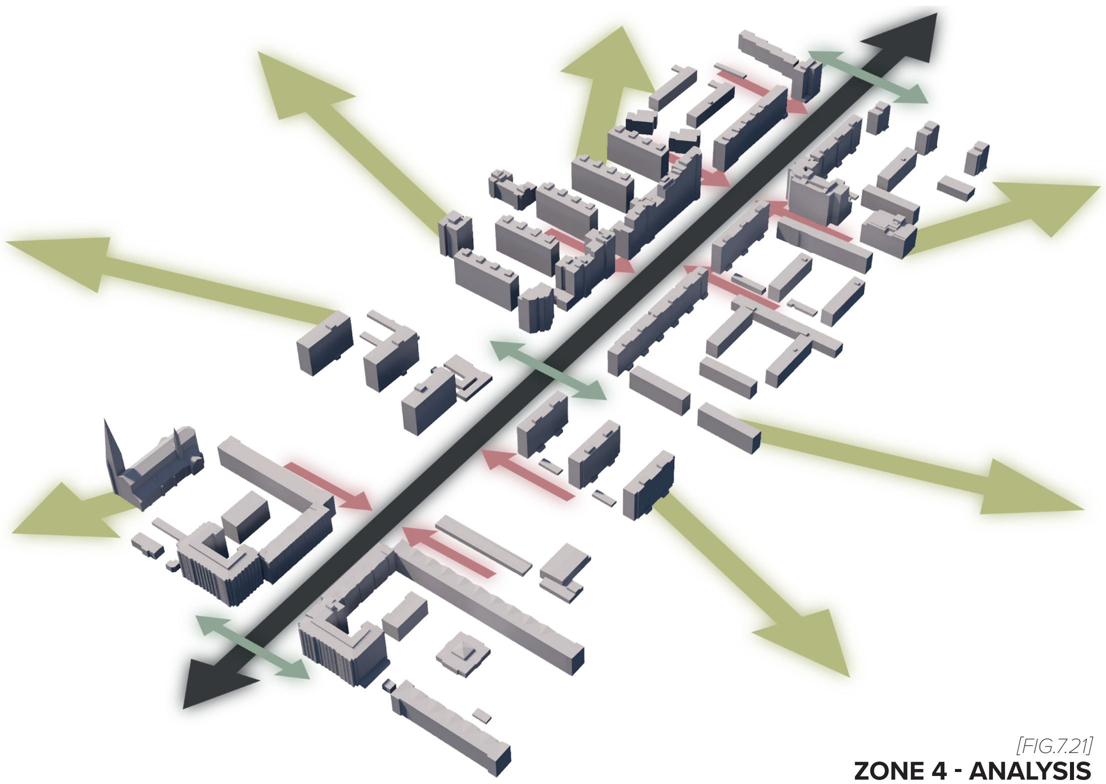
OPPORTUNITIES

the profile gives a chance to create more systemic green infrastructure

a chance to keep more water where it falls

chance to define the character of the space inspired by the architectural style

chance to create thermally friendly and sustainable space on the street level for the customers



[FIG.7.21]
ZONE 4 - ANALYSIS
source: self-elaboration by author

QUALITIES

a street profile is wide and offers space to various modalities

a high concentration of residential function without local center

big scale post-war modernist residential neighborhood

a low number of pedestrian crossings

PROBLEMS/CHALLANGES

an overscaled street profile is a car-oriented barrier for the local inhabitants

local inhabitants face the high need to travel, to fulfill the basic needs

scattered urban structure, with low quality but green public spaces

street as a local barrier creating two separated sub-neighborhoods

OPPORTUNITIES

the profile gives a chance to create more systemic green infrastructure

chance to create a sustainable local center with services and commerce

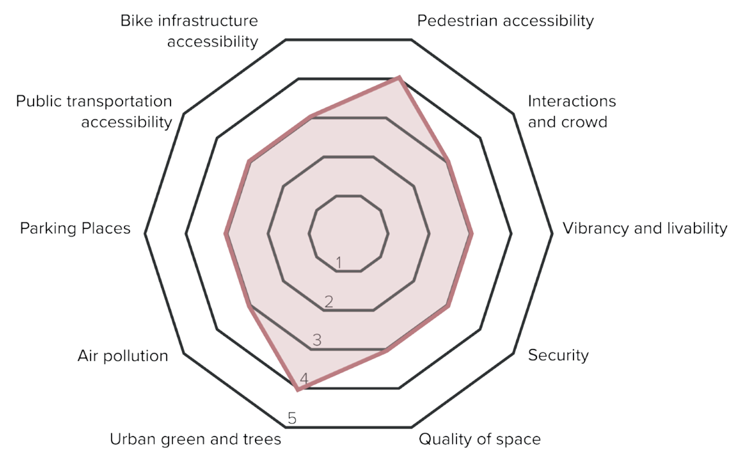
incorporation of the local green structures to big scale corridors for air-exchange

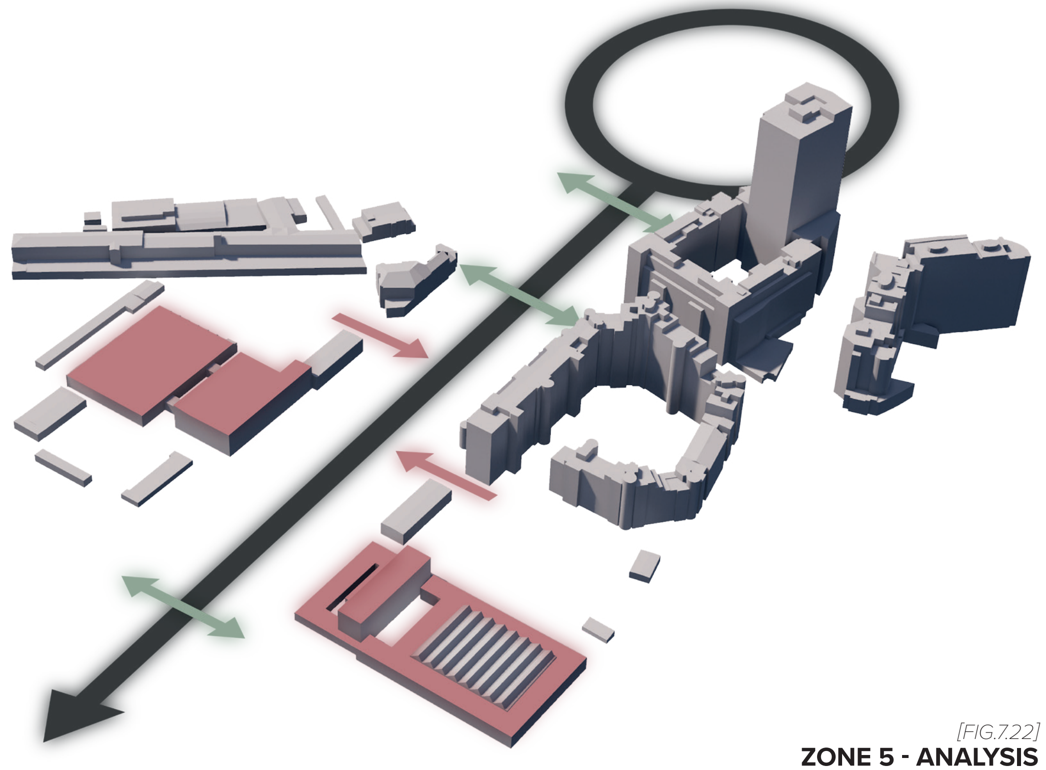
street becoming the central point of attraction for the local neighborhood

ZONE 4
the local street

800 meters long section between Nowolipki street and Stawki street. Car oriented street with 6 lines and 3 pedestrian crossings (3/800m). Predominantly residential function, with the presence of local services. Bicycle infrastructure on one side of the street – 2-ways narrow path. Rich green structure of old trees along the street and the presence of small urban parks. No bus lines along and 3 tram lines. Several parking places along the street.

foto: Agencja Gazeta





[FIG.7.22]

ZONE 5 - ANALYSIS

source: self-elaboration by author

QUALITIES

a street profile is wide and offers space to various modalities

presence of several buildings in different styles

a mix of residential, industrial and services from different periods

a little number of trees in the local urban context

presence of 2 big technical high schools

PROBLEMS/CHALLANGES

an overscaled street profile is a car-oriented barrier for the local inhabitants

space has no consequent urban structure

space does not have a functional definition of its surroundings

a higher level of air pollution in the area

users belonging to limited social and age group

OPPORTUNITIES

the profile gives a chance to create more systemic green infrastructure

plenty of space for possible green improvements

high possibility for a transformation and new definition

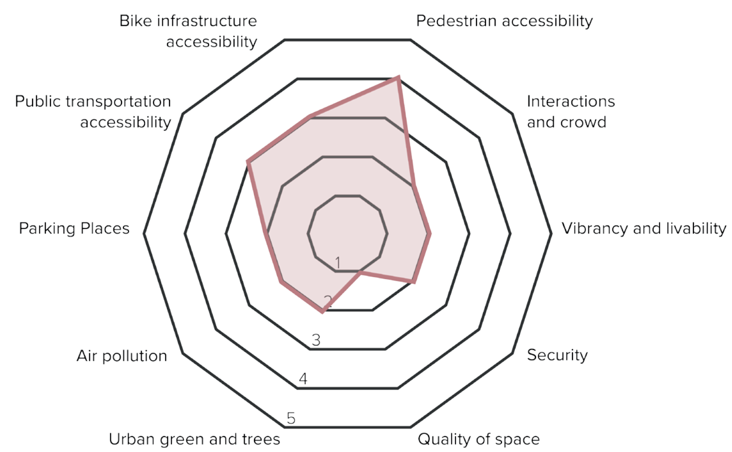
implementation of air pollution measures

creation of sustainable campus for education

ZONE 5
the transitional space

400 meters long section between Stawki street Radoslawa roundabout. Car oriented street with 6 lines and 3 pedestrian crossings (3/400m). Mixed function, including services, residential, and commerce. Two big vocational schools powerfully shape the type of local space users. Bicycle infrastructure on one side of the street – 2-ways narrow path. Scattered structure of existing trees and low quality of public space. No bus lines along, 3 tram lines, and important transportation hub on the Radoslawa roundabout (9 tram lines in total). Limited amount of parking places along the street.

foto: Agencja Gazeta



CONCLUSIONS

Jana Pawła II street is a diverse public space with various issues that require a broad spectrum of actions, tho it is a great example of a case study activity. It is linearity gives a great opportunity for incorporating big scale, long environmental interventions. A characteristic of this street is functional diversity in different profiles, from purely residential, through commercial up into a business and office center. From a perspective of testing the method, this makes it a great challenge but also allows us to show a variety of measures and design modules to be used, tho the selection of this street seems very reasonable.

The existing conditions of the street represent the rather low quality of space, with many issues related to the overscaled car transportation system, chaotic bicycle infrastructure, lack of green, problems with crossings, and large amount of parking places. Along the street, we observe a high concentration of air pollution, a problem more intensified here than in other areas of the city. The scale and width of the streets give, however, an excellent opportunity for improvement, and that is consistent along the entire street.

A fundamental goal of this thesis was to discover different scales on which urban design can tackle air pollution environmental problems. By selecting Jana Pawła II avenue and dividing it into smaller pieces, it was possible to give proposals on those diversified scales. This approach allows creating a healthy system able to affect air pollution on different levels and crossing different areas of effect despite the scale.

GENERAL DESIGN GOALS FOR THE STREET

It is necessary to define the general goals and strategies that will be implemented along the entire street.

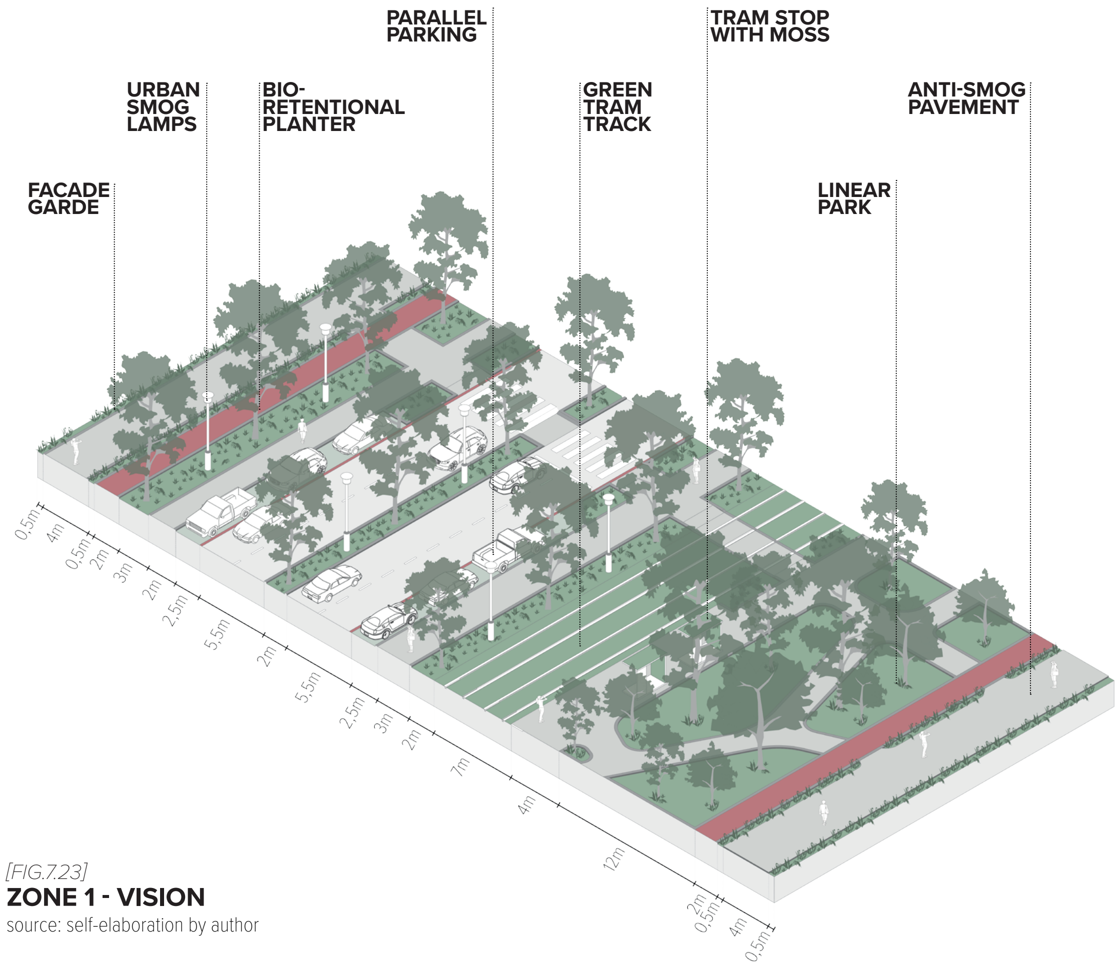
Jana Pawła II is an extensive street, and there is a possibility to optimize the functions to obtain as much space for improvement. For this reason, it is proposed to create an ungeometrical profile with street lines located on the western side of the profile. It leaves a wide stripe of land on the east side of the street, for green structures with various functions.

Some of the repetitive elements observed in every zone are the presence of tram infrastructure. It is proposed to turn it green along the entire street and locate it on the eastern side of the car lines. It allows us to obtain additional space and allocate trees between the car lines, previously occupied by the trams. Green tram tracks will increase water retention along the entire street and absorb significant amounts of dust and particulate matter (PM).

There is a large amount of space dedicated to pedestrian mobility. It is proposed to use the presented before smog easting structures technology in the form of concrete tiles on the walking areas. Due to the linearity and scale, this technology could have a significant impact on absorbing pollutants. This strategy is proposed to be implemented along with the entire street profile.

The bicycle infrastructure needs to be uniformed and structured. It is proposed to create a wide bicycle path of 2,5 meters of both sides of the street profile, which creates a network independent from the car mobility. The bike lines are separated from the pedestrian lines by small scale green structures, and it is assured that as much as possible, bike lines are planned together with rows of trees, which allows thermally comfortable travels during summer months.

Moreover, specific characteristics of each zone have been analyzed, and the proposal that takes into consideration the local context is being presented separately for each zone in the following pages.

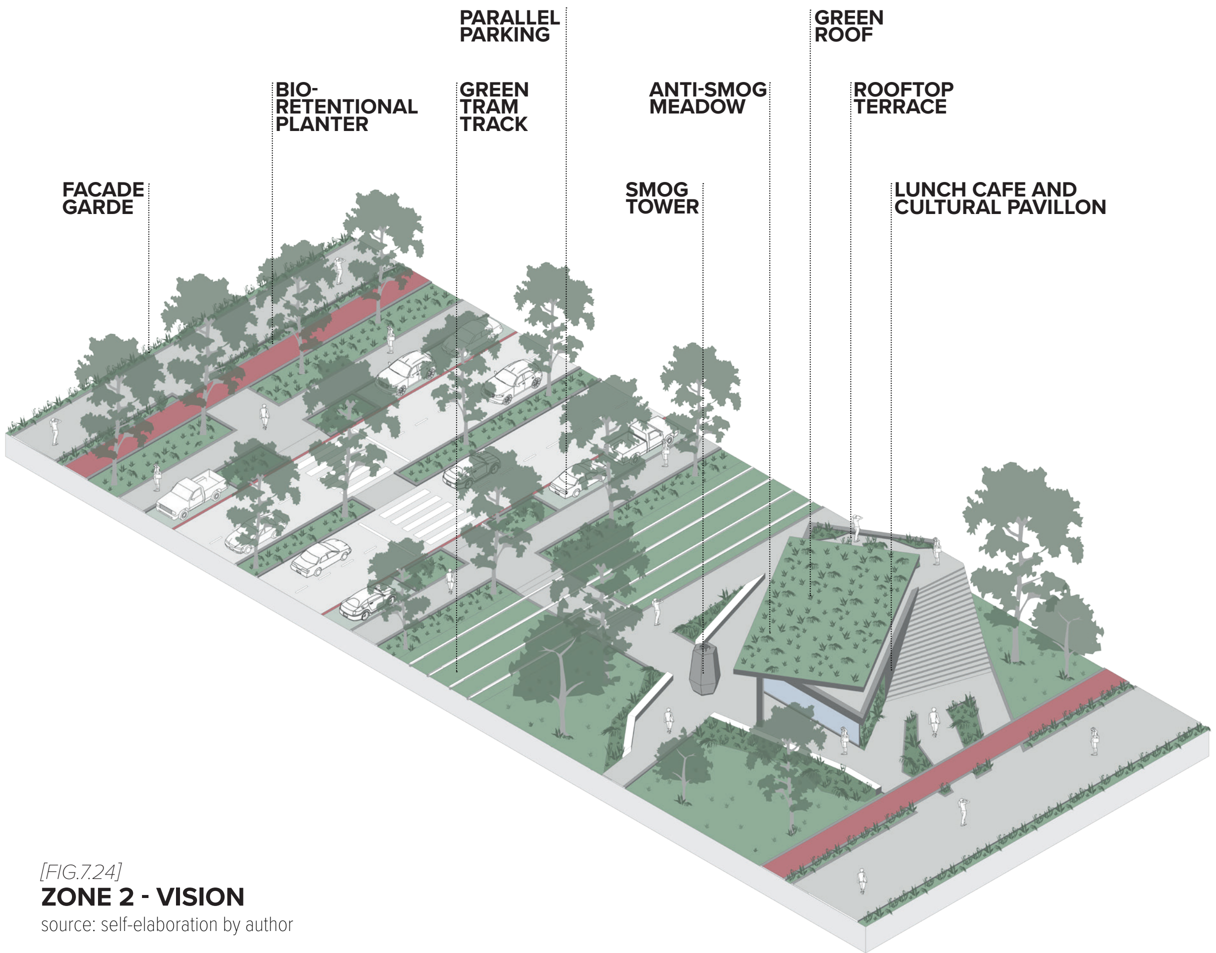


[FIG.7.23]
ZONE 1 - VISION
source: self-elaboration by author

ZONE 1
- urban highway into pollution resistant green city street

JANA PAWŁA II GREEN AVENUE

Optimizing the car mobility and reclaiming the public space for the green system is the main goal in this section. Depending on the further mobility analysis, it is recommended to reduce the 10 lines to 4 (2 lines each way with an additional line for turning). Due to the missing urban character of the existing profile, it is proposed to create new spatial recognition using the values of the new urban green. The goal can be achieved by implementing a linear park, especially an attractive solution due to the mix of functions in this section. Park would serve as a recreational area for the inhabitants, and resting space for the workers of surrounding and growing offices, but also helps to disperse the air pollution. Problematic but interesting value has been previously defined in the presence of empty walls facing the street from several pre-war buildings. It is proposed to use those spaces for the implementation of green walls in various technologies using design measures GGW-1, GGW-2, or GGW-3 (look chapter 5). Vertical gardens, together with liner park, will positively influence both the quality of the space, the biodiversity, and the ventilation and absorption capacities of the area. Rows of trees are proposed along the street, including the trees separating the car lines. The selection of trees and further maintenance is crucial to avoid the creation of a tunnel effect. Due to the limited commercial activity on the ground floor, caused by the structure of existing buildings, it is proposed to intensively implement the façade garden solutions, possibly with water infiltration – design modules or combinations of GGS-2 and WWB-2. To additionally decrease the impact of air pollution on the vulnerable group, it is possible to replace regular street lamps with pollution absorbing lamps – modules FUF-2 or FUF-3. In this vision the tram tracks are proposed to be placed asymmetrically, on the eastern side of the street, and to be constructed with a green track technology – design module GGI-1, together with green supporting infrastructure – green tram stops – FUF-6, all together forming the part of the green linear park. The pedestrian areas are covered with the smog absorbing concrete tiles to increase the air pollution dispersion – module FSE-1.

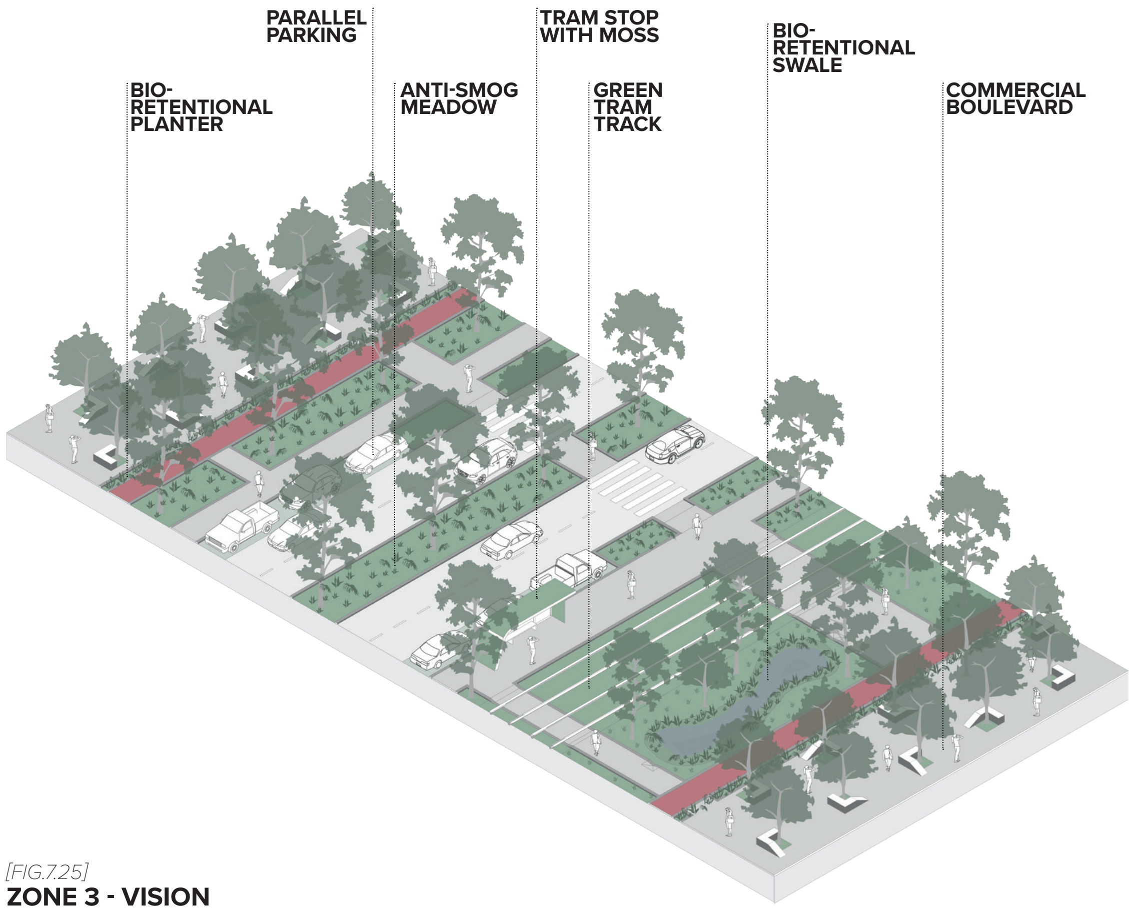


[FIG.7.24]
ZONE 2 - VISION
source: self-elaboration by author

ZONE 2
- the bio-diversified office center which does not sleep

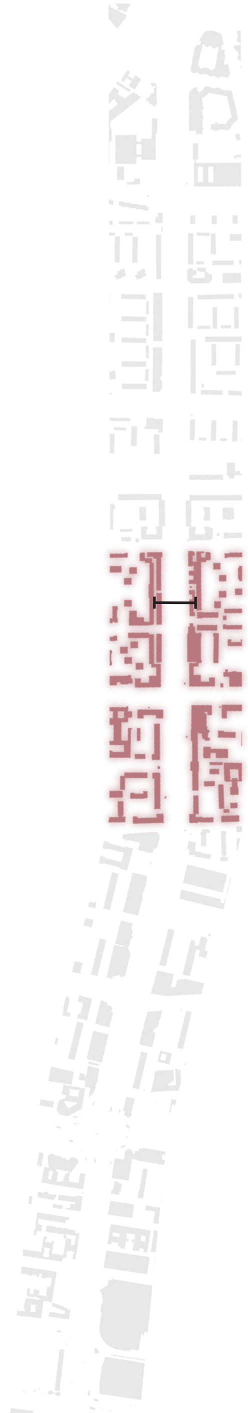
JANA PAWŁA II GREEN AVENUE

Providing a more diversified mix of functions is the most important goal for this section, in order to avoid the creation of the monofunctional business center. Narrowed street lines (2 lanes each way, with limited parallel parking places) located on the non-geometrical section allow reclaiming a significant amount of space. In this zone, we observe the widest street section, reaching 75 meters. It is suggested to use part of the public space to allocate a group of pavilions of various functions, hosting a cheap dining room with meals subsided by the municipality (a typical and historic polish concept of „Bar Mleczny"). In recent years many of the Bar Mleczny also became a local center for culture and entertainment, organizing book releases, premiers, art festivals. This concept is deeply rooted in the context of Warsaw, with the first Bar being opened in 1896 in Nowy Świat street. Location on such an activity, with a strong cultural background, would boost the local initiatives and create more vibrant space in the surroundings, at the same time providing affordable food for workers of local offices. The pavilions themselves should become a symbol of sustainable architecture built with strong attention to the concepts of a circular economy, to both contribute to creating a better environment and to increase awareness about circularity and sustainability (example - Circl building in Amsterdam). Green structures are recommended to be used in order to build the new character of the social space, including green roofs (module GGR-1/2/3). Together with the more significant intervention of the pavilion, it is possible to allocate, in areas with a higher concentration of pedestrians, the smog towers (module FUF-1). Similar to the previous zone, the tram tracks are turned green, and rows of trees along the street are proposed. Concerning the previous zone, the pedestrian areas are, again, covered with the smog absorbing concrete tiles – module FSE-1.



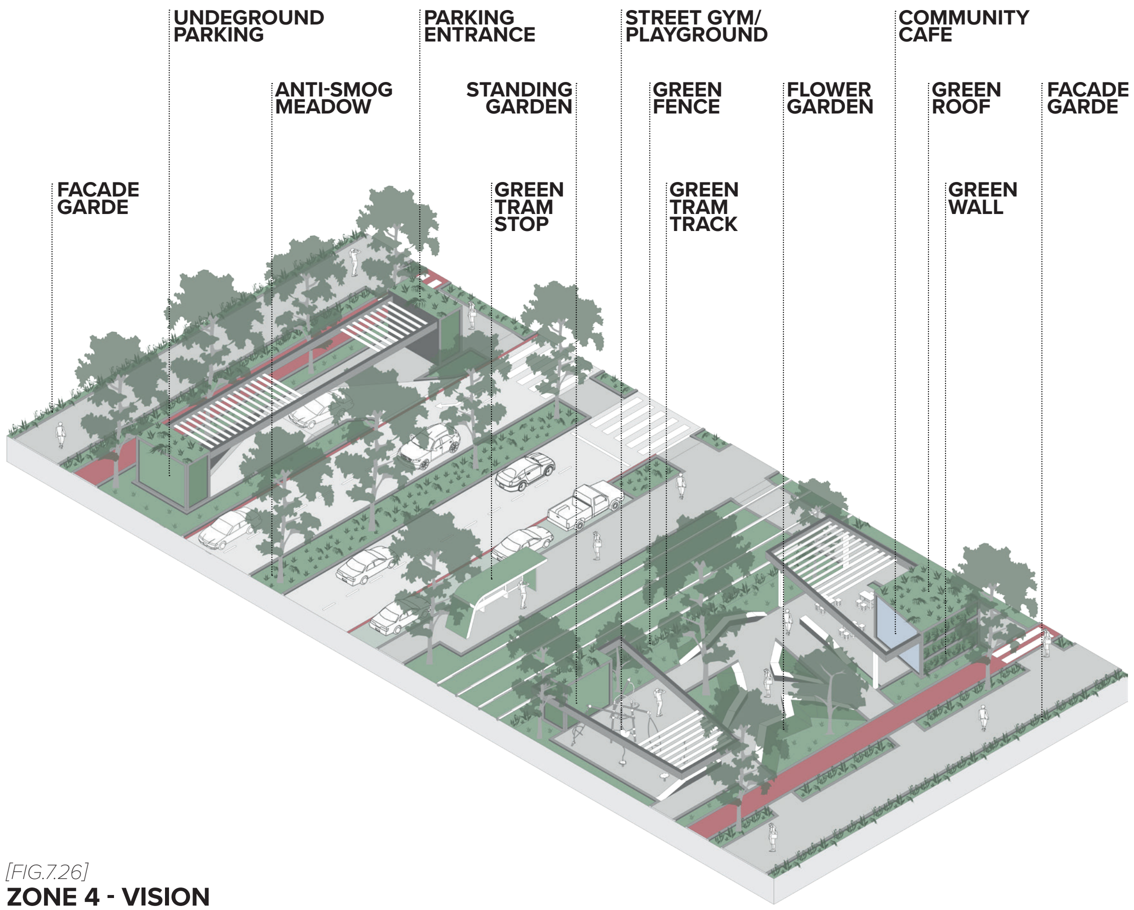
[FIG.7.25]
ZONE 3 - VISION
source: self-elaboration by author

ZONE 3
- the thermally comfortable and sustainable commercial street



JANA PAWŁA II GREEN AVENUE

This section, characterized by high commercial activity and a higher number of pedestrians, needs to be provided with a proposal that corresponds to the environmental issues and higher walking mobility. On both sides of the section, where shops and pavilions are located, it has been proposed to give wide and comfortable sidewalks, with direct access to facades of the building, in order not to cover the shop vitrines. At the same time, a dense pattern of trees is proposed, which creates a comfortable environment for pedestrians to walk during sunny or wet days. Wide walkable profile allows also to provide deliveries outside of the shopping hours, without blocking the pedestrian mobility. Because of intensified commercial and pedestrian activity, there is an increased number of resting places needed, represented on the drawing with white benches around the trees. Those conditions allow the customers to walk between different shops comfortably. Due to the problem with flooding in this area during heavy rains, it has been proposed to combine increased vegetation with the placement of bio-retentional swale (WWB-1), that can accumulate overflow of rainwater, and increase infiltration. At the same time, diversified the profile of plantings in the area but mixing it with anti-smog meadows (GGI-6). The continuous tram tracks are turned green (GGI-1) supported by the green stops (FUF-6) with green roofing (GGR-1/2/3). The wide pedestrian commercial boulevard is separated from the bicycle path by bio-retention planter (WWB-2) to increase even more the water infiltration capacity in the area. Due to the intensified pedestrian activity, it is crucial to provide numerous street crossing in the sections, to allow people to move between different shops comfortably. The entire boulevard can be covered with smog absorbing tiles (FSE-1), and additionally, due to the commercial activity of the buildings in this zone, the usage of smog absorbing panels covering facades can be reconsidered (FSE-3)



[FIG.7.26]
ZONE 4 - VISION
source: self-elaboration by author

ZONE 4
- the accesible and sustainable residencial street

JANA PAWŁA II AVENUE

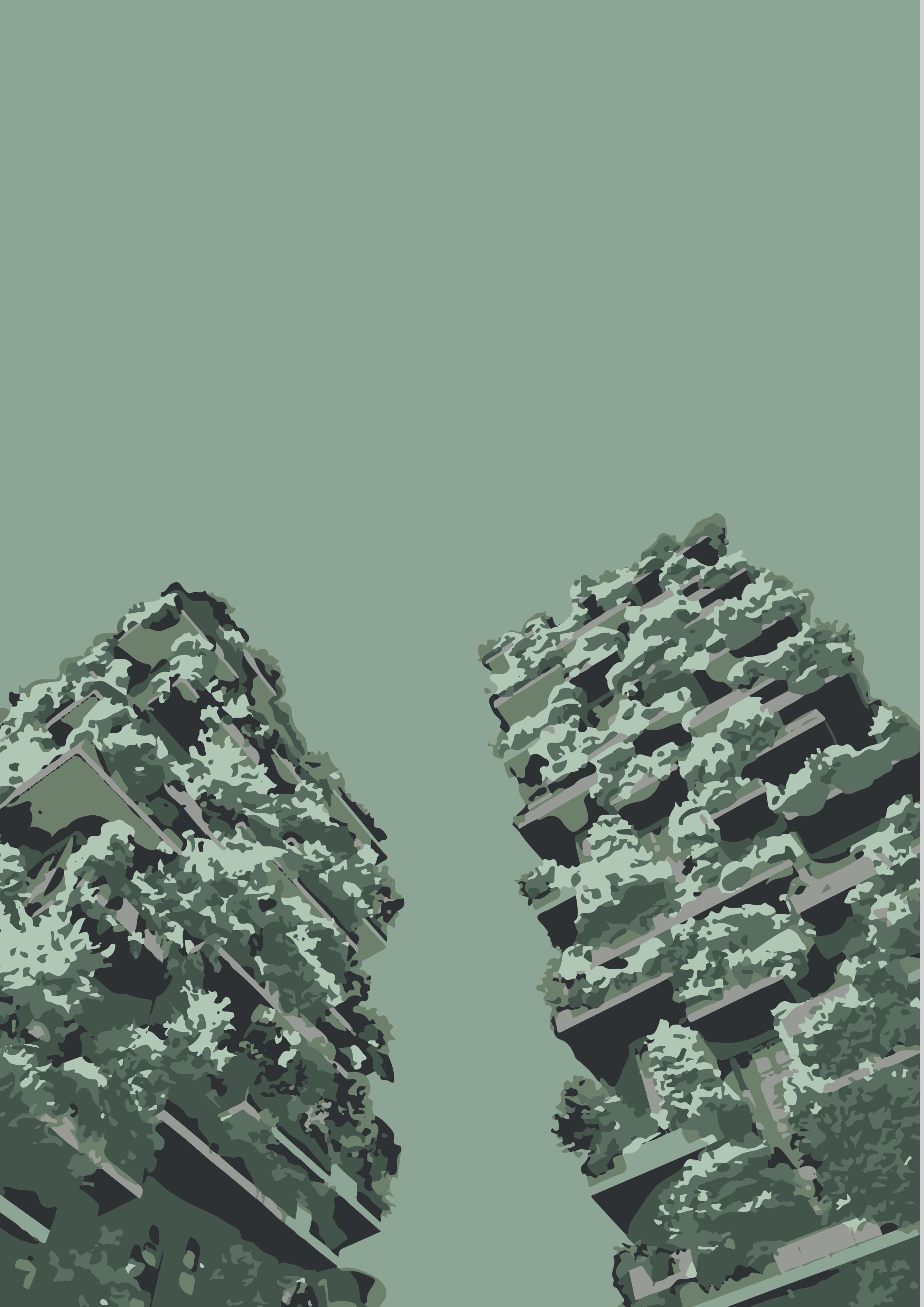
The residential section of the street needs a very local approach in dealing with environmental issues. It is proposed to create a high-quality public space that, in the long term, can attract a variety of functions in adjacent buildings and plots, partially decreasing the need to travel of local inhabitants in order to maintain basic needs. Despite the call to limit car mobility and car possession, there is still a big group of inhabitants that might need to use a car. It is proposed to allocate underground parking in the residential zone, to bring those necessary cars below the ground level, and to claim the space back on the street level for different activities. It is proposed to create an interesting and diverse offer of activities related to sport and leisure, that can be used by the inhabitants. High-quality public space with playgrounds, street public gyms, cafes, and small community centers allows creating more vibrance neighborhood.
The design can incorporate some of the researched and proposed modules, such as standing gardens (GGS-1). Big amounts of gathering places surrounded by green, including flower gardens, are proposed to create a local community by incorporating green structures. To increase the sense of belonging, it is proposed to incorporate facade gardens (GGS-2) on the facades of residential buildings financed by the city, but at the same, the inhabitants are enhanced to maintain them. It is a concept successfully working in many residential districts of Amsterdam. The area needs to be served by a comfortable system of bicycle paths, on both sides of the road, due to the wide profile od the street, separated from the pedestrian areas by bio-retention planters (WWB-2). The green space in between car lines is proposed to be filled with anti-smog meadows (GGI-6), and following the previous sections, the tram tracks are continuously being green (GGI-1).

[FIG.7.27]
ZONE 5 - VISION
source: self-elaboration by author

ZONE 5
- the diversified green transformation street

JANA PAWŁA II AVENUE

The final part of the street is proposed to be given an entirely new character, using the green system that may facilitate the transformations happening in the close neighborhood. The coherent and repetitive, tho attractive, and sustainable public space guarantees the attraction of investors into this problematic area. The most substantial existing element of the section - 2 technical schools, is proposed to be used as a trigger to bring more vitality to the area. Spaces for students dedicated to rest or lunch are being proposed. Increased amounts of sitting places, covered with green and flower gardens, with a focus on low-cost maintenance, is being proposed to allow more students to spend time on the street, and enhance the opening of new businesses serving them in the surrounding. The green system enriched by the anti-smog vegetation is filled with resting and leisure areas, represented on the drawing with white benches. Two lines car street has been supplied with parallel parking places and divided by a row of trees places in a loose form, allow the air ventilation. Because of the lack of coherent street facades in this section, there are no facade gardens placed in previous sections. The in-between spaces are filled with green, such as bio-retentional planters (WWB-2) or anti-smog meadows (GGI-6). Until the end of the street, the tram tracks are green (GGI-1), increasing the permeable surfaces on the street level. Intensified street crossings are necessary to boost pedestrian and public transportation accessibility and facilitate the creation of new development in this transformation area.



chapter 8

RESULTS AND REFLECTIONS

RESULTS

This graduation project aimed to research and understand the relationships between urban design narrowed to public space design, and the air quality in urban environments. The objectives such as ways to mitigate the pollution and the possibilities to enhance adaptation understood as responding to short term excessive increase of air pollution have been deeply examined. The idea was to provide alternative solutions to the already existing ones, tackled mostly in the form of policymaking.

GENERAL

Multiple researchers from various fields have so far tackled the topic of air pollution, but there is a significant gap in the field of urban design as a means of pollution mitigator. This work was meant to respond to some of the questions within this discourse. In the first chapter, the general introduction to the topic or urban air pollution has been set with a strong focus on the relation between heath and pollution. It was also researched how nowadays the topic is measured and described by official governmental bodies, with an outcome of defined differences between norms set on various levels. In the following chapter, the topic has been deeply set in the context of the case study city - Warsaw. The historical impacts on the modern urban structure of the city have been underlined, as well as the role of the climate and wind in the discussion of air pollution. The attempt to define to primary sources of pollution in Warsaw gave an outcome of the very diversified situation with several sources. However, underlined strong relation between high pollution episodes and the low temperature. That suggested that episodes are deeply rooted in the problems related to individual house heating and burning fossil fuels. In order to set this work in the scientific context, the following chapter examined the discussion around urban resilience, with the topics of mitigation and adaptation being highlighted. The attempt to build the correct understanding of adaptation in the context of air pollution showed that this approach is an intermediate step that helps to fill the gap between the ultimate goal of eliminating emission will be reached. As an outcome, the definition of three stages of pollution in an urban context has been set (sources, dispersion, and receptor site), and the role of public space design has been underlined. Chapter 4 attempted to scientifically measure the three layers in 3 different scales (mesoscale, urban scale, local scale), to create a bridge between the scientific approach of urban resilience and the more pragmatic and contextual approach, being an introduction to the design activity. As an outcome of the analytical chapter, the most affected areas in Warsaw have been described, and the most interesting anchor points that are a starting point for the design activity. In the next chapter, the design methodology has been described. An idea of interscalar and multi-issue approach, linking the research with design has been set. The selected form is the abacus of measures - the multi-issue list of the most efficient solution tackling air pollution in the context of public space. The explored design solutions have been collected, studied, and classified to apply them within design proposals. This section focused more on discovering existing design projects and principles which are part of urban air pollution discussion. Chapter 6 is an attempt to place those small scale design solutions in the bigger context of public space design. The definition of typology has been introduced, and three different typologies (Urban Street, Neighborhood Street, Ventilation Corridor) have been defined in the city of Warsaw. Each of the typologies have been filled with design modules showing their practical use in mitigating air pollution. The last chapter consists of the multiscalar proposal of the researched topics in the physical context of Warsaw. The big-scale proposal has been established, and a case study to test the method has been selected. The in-depth contextual analysis of the selected street (Jana Pawła II alley) showed the needs and different characters of specific sections of the street. The visionary proposal that combined the small scale design measures, methodological scientific approach of urban resilience, and big scale landscape idea for the city merged in order to show efficient and possible solutions to tackle urban air pollution within public space design.

APPLIED METHOD

During this work, the specific methodology has been selected, which based on the abacus of small scale modules. This methodology has turned to be very practical since small blocks are designed to maximalize the efficiency of mitigating air pollution, but at the same time, the scale of those modules keeps the flexibility and allows repetitiveness of the design, which is essential in case of street design. Such an approach allows creating an effective and consistent design on a big scale. The selection of modules was possible due to the detailed spatial analysis, leading to a comprehensive investigation of the issues. The attempt to use typologies helped to create a bridge between scientific design solutions and selected real case-study. The chosen methodology follows a linear and well-defined structure, which allows creating a cohesive design of the entire street structure in the city. The strong element of the presented methodology is its flexibility and repetitiveness, which makes it a starting point of turning the design proposal into a general design policy for public space in the entire city. A similar approach can be observed in the official policy of the city of Amsterdam, called 'Puccinimethode Rood - Standard for the Amsterdam street scene,' where several defined street typologies set the framework for any new design in the city. The approach has been accepted as an official city policy and urban planning document. Thanks to that approach, it is possible to minimalize the construction and maintenance costs, create a similar vibe, firmly rooted in the specific context of the city, and avoid minor design mistakes. In this thesis, the focus was only on air pollution. However, a similar approach could be incorporated into the general street design, with attention to other topics such as water, energy transition, circular economy, underground cables, and pipes or urban mobility.

MATRIX OF ANALYSIS

The matrix of analysis aimed to define the most vulnerable areas in the city of Warsaw and combine them with other spatial, economic, and social data in order to understand the problem entirely. The analytical model has been built concerning the primary scientific core base concept which this work rooted in - the urban resilience. Within this graduation project, the analytical approach is an outcome of theories and approaches, but it cannot be empirically measured. It has to be noted that collected data comes from the open sources tho the selection of problematic areas and conclusions base on a certain level of assumptions. However, still, the matrix was a successful method in showing sites of intervention and problematic aspects. When trying to define the impact rate and visualize conclusions from the analysis, some distinctions had to be made.

RESEARCH QUESTION

At the end of the theoretical part of this thesis a research question has been defined:

- How can the redesign of the public space positively influence the mitigation and the adaptation to the air pollution environmental problem in the city of Warsaw?

Several outcomes have appeared from work. A strong relationship between air pollution and urban design has been set. It has been discussed that roughness of the built environment influences the ability of natural ventilation. The analytical part showed that pollution levels are the highest, where the intensity of the built environment is also high (FSI). In this context, the role of public space as a robust linear connector has been pointed out. Concepts such as tunnel effect have been incorporated, which explained how tree placement could influence the ventilation. It has been proven that urban design can work as a feature that disperses but also receives air pollution. At the beginning of the design part, the selection of design measures showed that it is possible to mitigate air pollution within the urban design, in this specific case - public space design. Selected measures have various use and work in both mitigating, but also help to adapt to high-level air pollution episodes. From regreening, which leads to pollution absorption, to dispersing pollution by creating more significant systems, public space design can influence the concentrations of pollutants. The context of the city of Warsaw has been established in the analytical part and reviewed in the design activity part. The climate of the city facilitates and allows the big scale green interventions. The flexibility of the methodology allows repeating a similar approach in the case of other cities. However, the selection of modules has to be always adapted to the local context and climate.

PERSPECTIVES

It is interesting to discuss the perspective and the time-lines of the project. The selected approach of creating a big scale linear green system using public space requires a strong re-greeneration approach. The green has to be placed and located everywhere where the concrete is not required. This approach generates many opportunities but also several problems. It has to be acknowledged that maintaining the complex green system will always be more expensive than maintaining plane concrete and asphalt surfaces. Although it has been proven that re-greeneration is an efficient way to fight air pollution concentrations. It is not impossible to implement a design based on that kind of values, and examples can be widely seen in western European cities, for example, in Amsterdam (see: IMG.0.02 - page: 192). Green used as the primary tool during design and not as an additional layer considered at the very end of the design process can be successfully implemented. However, it requires a systemic change of thinking and approaching the role of public space in modern cities.

An important characteristic of the public space is the relative ease of changes, comparing to the enormous cost of changing the build-up environment, but at the same time long life-circle, due to the financial aspects and the fact that public space is designed and constructed using public funds. In this context, it has to be considered that in most of the cities, significant changes in the structure of street profiles happen only once in 30-40 years. That is why it is crucial to create a space that responds to the challenges of the generation. The circularity of the design encourages the use of systemic thinking to provide economic social and environmental benefits for its citizens, while also looking to improve nature and the quality of life.

As a final perspective, I personally believe that the challenge that our generation has to respond to is strongly related to climate issues, materialized in urban environments, also as air pollution environmental problems. It is required and desired to use reliable tools and brave decisions to tackle this problem, and the modern, nature-inclusive design of public space is one of the unique possibilities to face those challenges in the dense build-up environments of cities around the world.

REFLECTIONS AND LIMITATIONS

Urban air pollution, and the topics related to its emitions and receptions are a complex issues which depend on many fragile variables. They can be determined by the type of source, the local environment, physical features of the built environment and social factors. They can also change within short period of time due to, for instance, the local weather at particular moment. This wide selection of issues is analized with different importance by different experts. In planning the air pollution is mostly tackled from the persective of policy making and strategic planning. There is no much of examples where the air pollution is mitigated by the urban design, which was one of the core ideas of this thesis. Without merging the policy making with urban design, the fight against air pollution will be incomplete. However both of those topics greate immersly wide and deep spectrum of possibilities and variants to be analyzed. Within the graduation project this spectrum had to be narrowed only into the specifics of public space design. This is not a bad outcome, but it has to be recognized that it can be expected to recieve even more efficient solutions while working with built environment, which makes the redesign of public space crucial, but not ultimate response to that problem. This approach has to be also supported by compreensive policy making, which was also not a focus on this project.

It has to be recognized that some of the proposed sollutions have extremely possitive impact on air quality, but because of the holistic and complex reality of urban environments, those solutions may create other problems, and decrease the qualities of another focal points. Dense and intensified green system, proposed as an aternative to fight urban air pollution, will require big amounts of water, provided probably through artificial watering. This creates demand for complex system of underground pipes, and is expensive in mantaining. High demand for water can also locally lead to lowering underground water levels, which makes it more challanging for the local environment to deal with temporary droughts during warm months of the summer. This kind of relationships are infinite and it is always required to take into consideration several aspects. The aim of this work was to give the visions in one, very specific condition, which in real world would not exists alone, and which highlights the need of coprehensive and integrated approach in modern urban planning.

[IMG.0.02]
GREEN STREET IN AMSTERDAM - INSPIRATION
FREDERIKSPLEIN, AMSTERDAM, NETHERLANDS
source: by author

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