Geographical Information Management and Applications

MSc. Thesis

Greening the grey

A spatial multi-criteria analysis to identify and prioritize urban greening locations in Amsterdam - Zuid

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November 10, 2019

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Preface

This thesis is written in the fulfillment of the course requirements of the Geographical Information Management and Applications (GIMA) program. In February, I started the last part of my master's. In this thesis, I performed a spatial multi-criteria analysis to identify and prioritize urban green locations in Amsterdam Zuid.

The research topic intrigued me from a geographical point of view and my interest in sustainability. And some interest in urban geography as a remnant of my bachelor in Human Geography and Spatial Planning. During the courses of GIMA, my curiosity was aroused about modeling & visualization. This curiosity, in combination with my interest, has been the base for choosing my research topic.

After an intensive period of nine months, it is time to complete my thesis. Graduating was an educational process in which I learned a lot in the scientific field. I have been able to apply the knowledge and skills I have gained during previous courses and the internship in my master's thesis. I also learned new methods and software and developed more research and writing skills.

Writing my thesis and thereby completing my studies would not have been possible without the support of friends, family, and my supervisor. First of all, I want to thank my supervisor Corné Vreugdenhil for his guidance, useful advice, and feedback that he has always given me with great enthusiasm and expertise. His constructive criticism helped me to stay focused on the subject, and his subtle way of guiding also enabled me to structure the thesis. I also want to thank my family and friends for their support during all phases of my studies.

I wish you a pleasant reading.

Sara Franken

Breda, November 10, 2019

Abstract

Like many other European cities, Amsterdam continues to grow. Rapid growth results in the densification of the city, at the expense of green areas due to lack of space. Too little greenery results in various environmental and social problems. This research aims at making Amsterdam Zuid more sustainable by identifying possible locations for green parks that have the most impact on improving the immediate living environment and which are easily accessible for neighborhood residents.

The research is based on a combination of research methods, starting with a literature study to identify urban liveability issues. Potential urban park locations are identified by using location requirements, location size, and the perimeter-area ratio. The connection value is calculated using the space syntax method to determine the accessibility of each potential location. Finally, the connection values and urban liveability problems are classified and combined in a multi-criteria analysis.

Urban green spaces alleviate different urban liveability issues by reducing the risk of flooding, cooling during high temperatures, ensuring biodiversity, contributing to better health and well-being, and creating satisfaction with the living environment. By combining the five urban liveability issues with connectivity, the multi-criteria analysis is implemented, resulting in a map with the need for urban green space in the area. The values of this map are assigned to the potential urban park locations. The result is based on the average priority value of the multi-criteria analysis per potential urban park location.

99 potential urban park locations have been identified in the research area. The potential urban park locations are classified from low to high priority. Of the 10 parks with the highest score, 9 are in the stadium area. Therefore, the greatest profit can be achieved herewith regard to the reduction of problems in the urban climate and provides a more pleasant living environment for city dwellers.

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1. Introduction

The world is becoming more urban. Urban areas now host 72% of the EU population. Cities are economic powers, places of social interaction, and forums that enable us to exchange ideas. However, cities are also places where some of our most significant challenges manifest themselves (Nabielek, Hamers, & Evers, 2016). Urban areas can be places for innovation and production of knowledge and prosperity and offer broad access to employment, education, sanitation, and modern energy, but they can also have a high level of pollution, social exclusion, environmental degradation, and unintended consequences have outside of urban boundaries (Seto, Golden, Alberti, & Turner, 2017). Over the past 50 years, the urban population has continued to grow, with urban development taking place through the densification of the city (Roig-Ramos, & Pellerin-Carlin, 2019). The ongoing process transforms open areas within municipal boundaries into residential areas, while the development of green space is not considered.

In most cases, urbanization takes place at the expense of various types of urban landscaping (Łopucki & Kiersztyn, 2015). As a result, urbanization and interconnected densification processes around the world result in reduced access for residents to urban green areas and to the environmental and social benefits that such green spaces offer. Green spaces have ecological and health benefits, the most important of which is mitigating ecological impacts caused by urbanization and increasing the quality of life of citizens (Kabisch, Qureshi, & Haase, 2014; Lafortezza, Carrus, Sanesi, & Davies, 2009). Green spaces serve diversified goals, such as improving the urban environment, promoting human health and well-being, providing a social space for recreational activities of urban residents, improving aesthetics, increasing the value of properties, and the preservation of biodiversity (Neema & Ohgai, 2013). Integrated and accessible green areas will play a more central role in urbanism according to the theory of natural movement.

it is of great importance that the new parks are placed on a frequently traveled place for maximum usage to the residents of the neighborhood. Locations that are well connected will not only be visited and used more often, but they will reasonably also become better known because they are within the daily movement patterns of people (Abubakar & Aina, 2006). Space Syntax is a method based on topological-visual analysis of a built environment in an attempt to explain the movement of pedestrians in urban space (Hillier, 2007). Space syntax is a way to describe the spatial architecture of buildings and cities. In Space Syntax, streets, squares, and parks are perceived as empty spaces. These spaces are defined by obstacles that can restrict access or obstruct visibility, such as buildings, fences, and other barriers. The areas are connected to each other, and each space has at least one link to other spaces. The structural properties that make up these spaces and links can have an embedded social meaning that has consequences for the general behavior of the human habitat (Al Sayed, 2014).

Although the many benefits of urban greening are known, implementing green projects in urban requires accurate data about the benefits of green areas and the geographic accessibility of potential locations in order to make changes in a city where economic development, community revitalization, and job creation have priority (Drake, Ravit, J. Lawson, & Dikidjieva, 2015). Space Syntax is a useful tool that can help municipalities and other urban development agencies determine the optimum location for green facilities and infrastructure.

1.1. Problem statement

Like many other European cities, Amsterdam continues to grow. The urban expansion leads to the urbanization of areas that, until now, belonged to the outskirts of the town, but also to radical changes in the areas that already belonged to the urban area. The structural vision states that Amsterdam will build 70,000 homes by 2040, while also creating new facilities such as schools, shops, and sports facilities (Gemeente Amsterdam, 2010). Through the more intensive use of space, many more people and businesses can live and work in the city. Higher housing densities can be associated with relatively better efficiency, lower energy and gas use, and ensure a better introduction of sustainable technologies (Seto et al., 2017). Higher densities, however, also lead to fewer opportunities for sun and daylight penetration, there are more stress-related health problems and noise interference (Boyko & Cooper, 2011; Łopucki & Kiersztyn, 2015). Rapid growth in recent years, along with the transformation of green spaces to buildings in cities, has caused significant problems. Urban ecosystems are out of balance due to rapid urbanization because green areas are given little meaning in the grand plan. A balanced distribution of accessible green space within the city is of great importance to meet the needs of both recreational and essential contributions to the urban ecosystem (Cetin, 2015). Since climate has become an important political issue, more time and attention is now devoted to research for sustainable urban development. Cities are becoming increasingly aware of their responsibilities and capacities to play their role in creating a healthy living environment (Wolch, Byrne, & Newell, 2014). Amsterdam is also working on making all kinds of urban processes more sustainable, such as sustainable energy, improving air quality, the circular economy and a more climate-proof city (Gemeente Amsterdam, 2015). This research will contribute to making Amsterdam more sustainable by looking at possible locations for green parks while trying to make the most significant impact on the direct living environment.

1.2.De Gezonde Stad Amsterdam

This research is carried out to contribute to the "Park around the corner"-project of Healthy City Amsterdam. The foundation De Gezonde Stad is busy making Amsterdam a more sustainable and healthy city. They do this by starting projects and events together with the community and various investors from the city and supporting residents with sustainable initiatives. One of the initiatives is the creation of urban green spaces, also called pocket parks, as their size is usually relatively limited as a resutlt of the amount of available space. With the “Park around the corner”-project, they want to make Amsterdam more liveable by turning available petrified places in the city into green and cozy neighborhood parks. Together with residents of Amsterdam, they try to make the city greener. Because it requires quite a lot of work to check whether a particular location meets the requirements for a pocket park, this research can offer a solution to go faster through the planning and design process. With this thesis, useful information is calculated by combining the initiative of De Gezonde Stad with the space syntax method. This allows new valuable information to be released that can optimize the development processes within De Gezonde Stad.

1.3. Research objectives

This research contributes to making Amsterdam more sustainable by identifying possible locations for green parks that have the most impact on improving the immediate living environment and which are easily accessible for neighborhood residents. The main objective is to develop a method to identify potential locations and prioritize with information about urban liveability issues and the connectivity of the potential urban park location.

1.3.1. Research questions

The objective will be realized by answering the following questions:

1. How can parks and green spaces contribute to a healthy urban living environment?
2. Which locations in Amsterdam Zuid are suitable for potential urban parks in terms of location requirements?
3. How accessible are the potential urban park locations in Amsterdam Zuid?

To answer the main research question:

Given the accessibility and urban liveability issues, which potential urban park locations have the priority of turning into urban green space to make the most significant contribution to a healthy urban living environment?

1.3.2. Research limitations

This research focuses on the municipality of Amsterdam because the study is being conducted in response to the demand from De Gezonde Stad foundation. An overview will be made of all districts to be able to offer a comprehensive result. Within the municipality of Amsterdam, not all land is suitable for creating a park, such as private homes and plots. There are also a few location requirements that the location must meet to become a park. These conditions have been drawn up by De Gezonde Stad and are adopted for this research:

- *The location is in public space;*
- *The available space is between 100 and 700 m2;*
- *A location is a petrified place;*
- *The location is located in a residential or working area;*
- *The location is not a current development location.*

1.4. Relevance

1.4.1. Scientific relevance

Since decades of urbanization has led to the densification of many cities, much research is done into the benefits of green in the city. This research often concerns the comparison of a neighborhood in the vicinity of a park with a neighborhood that is characterized by little greenery. From this, conclusions are drawn about the benefits of greenery, such as better physical and mental health, more social cohesion, living pleasure, and an improved urban living environment with more biodiversity, better drainage, and temperature regulation. Since the importance of greenery has also been recognized by urban planners and area developers after recent years' investigations, in response to the ongoing densification of the city, petrified areas are increasingly being converted into small urban parks. To determine the locations of these new parks, the local government starts from the disadvantages that the absence of greenery has brought with it, such as neighborhoods with problems due to flooding or reduced social cohesion.

Several studies have shown that green results in moderate improvement for various urban issues, but is hardly useful to solve a specific problem. Creating green parks in the city is not a solution for a particular urban problem, such as flooding in the neighborhood, but makes a positive contribution to several different aspects of the urban living environment. To determine new locations for green parks, it is therefore essential to include as many of these aspects as possible in the study, and a multi-criteria analysis is a suitable method for this. To make it possible to improve the urban living environment, it is a condition that the green parks are accessible. This principle is considered to be the most crucial aspect for many public facilities when urban planners determine where facilities should be placed to maximize their usability. Urban planning is concerned with the best possible distribution of facilities in the living environment. Integrated and accessible spaces such as green areas will play a more central role in urbanism according to the theory of natural movement. These spaces are not only visited and used more often, but they are probably also better known because they are located in more accessible places and at the same time in people's daily movement patterns. One way in which the accessibility of the green areas can be measured is by using Space Syntax technology. In this study, the space syntax theory is used to improve multi-criteria analysis to prioritize potential parks. Current studies have not applied a combination of these methods before. This research will, therefore, take into account accessibility, as well as the improvements that a green park brings to the urban living environment.

1.4.2. Practical relevance

Originally green was only an aesthetic element in cities, but green has acquired a new value and function, the importance of which is generally praised within the field of sustainable development. Previous research shows that the presence of urban green spaces can significantly reduce social problems in the urban context and provide an attractive environment for residents by creating more green parks in the city. However, it is difficult for urban planners to conclude selecting the best site for public facilities in a city or neighborhood. Their main concern is that choosing the wrong location for a facility can make it less accessible and, therefore, potentially underused by the community. That is why researchers have developed different ways to distribute public facilities evenly so that the facilities bring benefits to the majority of people in society. One of these different techniques and tools is the use of the space syntax technique. Accessibility can be defined as the ease in which a citizen can reach a park. Space syntax studies local accessibility and investigates the association of the space with the surrounding pedestrian networks to see how the properties of the adjacent streets play a role in the use of the space. As a result, the number of streets and how space is linked are used to define the local accessibility to a park. This has added value for society because, in this way, the benefits of a pocket park connect with the environment.

1.5. Reading guide

Chapter 1 contains the introduction to the research with the research question, research questions, objectives, and relevance. Chapter 2 concerns the theoretical framework in which substantive theories, concepts, and developments are defined. The theoretical framework starts with the cause for the few urban green areas, associated urban environmental problems, and urban liveability issues that cities face. It includes concepts about how parks and green spaces can contribute to a healthy urban environment. Then the importance of accessibility of parks and the role of space syntax theory will be addressed. This broad focus provides a clear picture of the explanatory factors for the reduced amount of green space in the city and the areas in which the city and residents would benefit from creating new urban green spaces. Chapter 3 contains the methodology used to identify potential locations and prioritize information on urban liveability issues and the connectivity of potential city park locations. Chapter 4 includes the results of the research that has taken place. All potential locations and their prioritization based on the multi-criteria analysis are presented. Chapter 5 discusses the implications of the study with a critical note about various aspects of the research. Chapter 6 looks back on the research questions, draws conclusions about the study and the results, and discusses the research process. Finally, some suggestions are made for further research.

2. Theoretical framework

This chapter discusses information and findings from relevant literature studies. These findings together form the background of the research and the basis for the methodology. The literature study starts with the origin of the disappearance of greenery from cities, followed by the urban environmental problems that cities experience. Thereafter urban liveability issues are discussed, which are essential when it comes to outlining the need for urban green spaces. Finally, the concept of space syntax is deepened for the realization of a measurable method to analyze the connectivity and to provide a sound basis for methodology.

In urban areas, green spaces such as parks, public gardens, playgrounds, and green spaces are often a scarce resource. Green in the city is disappearing more and more, for example, by building new houses, widening roads, cycle paths and pavements, and tiled gardens. In recent years, the city has been aging more and more, which has put the city's ecosystem at risk. Green spaces are essential to the urban ecosystem. They contribute to the adaptation to the environmental problems caused by urbanization and climate change. The world is becoming more urban, and cities now house 72% of the population (Barbosa et al., 2007). A pleasant living environment is essential for the city because there are also many additional problems due to the crowds of the city. Green contributes to alleviating these problems (Boyko & Cooper, 2011). Urban green spaces are developing as essential sources of public health that can improve people's mental, physical, and social well-being. Urban green spaces can provide people with access to physical activities as well as relaxation and as safe, vibrant areas for the promotion of social connections. Various urban green spaces, including parks, gardens, urban forests, and community gardens, can all support people's health and well-being. So the need to ensure that cities are vibrant, sustainable, accessible, well planned, and designed is critical (Łopucki & Kiersztyn, 2015). This chapter first discusses the reasons why cities are becoming increasingly grey at the expense of green space, then explains the problems that exist in busy cities, and how green space can contribute to alleviating these problems. It also discusses that the accessibility of urban green areas is also important and how the space syntax theory can help in choosing easily accessible locations for new urban green spaces to be created.

2.1. Densification

Worldwide, the percentage of people living in urban areas will continue to increase (United Nations, 2013). This will lead to the expansion of urbanized areas, which are popular as places to live because of the many jobs, social contacts, and a wide variety of amenities. To manage urbanization in the Netherlands, the policy aimed at a more compact construction: the compact city. The compact urban approach has had a global impact as a planning approach for sustainable development in areas with an increasingly urban population (de Vries, Boone, de Rooij, & Keip, 2017).

The 'compact city' is characterized by highly dense urban development patterns, mixed-use, well-functioning public transport, accessibility of local services and jobs, and promotion of cycling and walking (Burton, 2002; Giezen, Balikci, & Arundel, 2018; Haaland & Konijnendijk van den Bosch, 2015). Through compaction and compact construction, the approach aims at counteracting the adverse effects of urban sprawl. Urban sprawl is urban development with low-density housing, both residential and commercial, separate land use, a high level of car use combined with a lack of public transport. Related problems are an inefficient use of resources, such as land and energy, resulting in a larger urban footprint, environmental issues and social inequalities, and loss of biodiversity (Haaland & Konijnendijk van den Bosch, 2015). By building smartly and compactly and using energy and fuels more efficiently, the impact on the environment will be reduced. In the context of sustainability and thus counteracting urban sprawl, a great deal of attention is being paid in urban development to compact construction, but this is a challenging goal to achieve together with the preservation and creation of more green space. Until now, the policy areas of urban development and green space are still often assessed separately from each other.

As a result, the unintended adverse effects that these areas can have on each other remain invisible. With research using satellite images and remote sensing technology, Giezen, Balikci, & Arundel (2015) show how the development of a compact city has influenced the public green space in the center of Amsterdam, see figure 1.

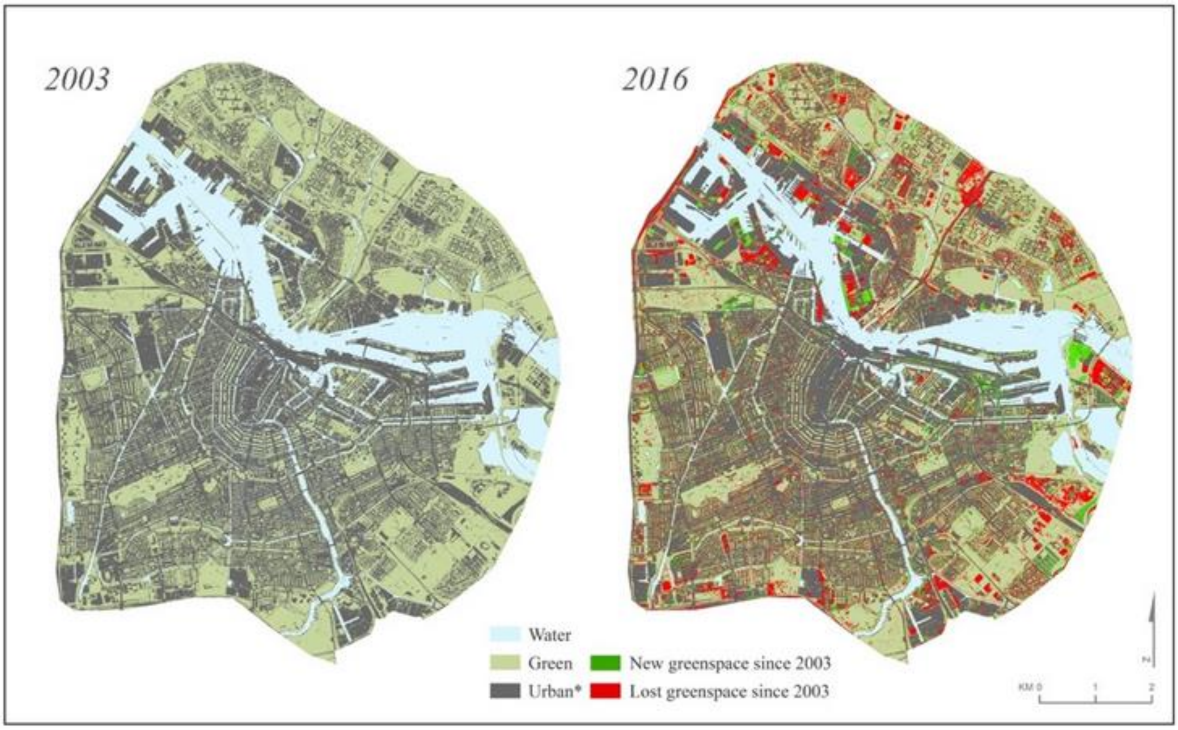

Figure 1: Change of public green space of the center of Amsterdam 2003 – 2016. Image from: Giezen et al. (2018).

The results show that the share of green space in land use decreased between 2003 and 2016 in favor of the built-up urban environment. The total area of all green space that disappeared was 3.07 square kilometers. This means that a full 11% of the existing green space within the inner ring road of Amsterdam has dissolved (Giezen et al., 2018). Moreover, a comparison of the satellite images shows a strong fragmentation of the green space into ever smaller parts. These results illustrate that Amsterdam's policy on urban green space does not suffice to offset the harmful effects of urban compaction. This makes it more challenging to achieve the goal of a sustainable city, despite the announced policy efforts in their program to increase the green space in the area.

How compact-city policy in the Netherlands is conducted has advantages and disadvantages in terms of urban issues relating to the themes of health, quality of life, climate resilience, and biodiversity (de Vries et al., 2017). Nevertheless, the adverse effects of certain aspects of densification are becoming increasingly apparent, such as a lower quality of life, and specific positive characteristics attributed to the densely populated city, such as less traffic and environmental problems, are being called into question. One of the reasons for this is the lack of urban green space in densely populated urban areas and the removal of green space when compacting urban areas (Haaland & Konijnendijk van den Bosch, 2015).

2.2. Urban Environmental Problems

In addition to the many social and economic benefits of urbanization, cities also face environmental problems. The effects of heatwaves, heavy rainfall, floods, droughts, and storm tides are increasingly felt in Europe. These extreme weather and climate-related events have a significant impact on human health, the economy, and ecosystems (Mell, 2009). Cities are an accumulation of people, traffic, industry, production, and the associated consumption of energy, materials, greenhouse gas production, waste, and emissions of pollutants into the environment. The world faces enormous environmental challenges in the areas of climate change, resource use, and protection of the natural environment. Substantial urban areas have a significant impact on the environment, whereby a difference is observed between economically developed countries and less developed countries. In cities of economically developed countries, environmental problems arise from large-scale industrial production and the generation of energy. In economically developed countries, urban issues are caused by a large amount of waste, intensified agriculture, and traffic emissions (Lele, Klousia-Marquis, & Goswami, 2013).

Cities consume existing natural resources, produce more waste and emissions, and all of this has an impact on the environment. The underlying causes of urban air pollution are the processes associated with burning fossil fuels, such as production and consumption of energy for heating buildings, industrial activities, and traffic (Zhou & Parves Rana, 2012). The deterioration of water quality in cities is mainly due to the water consumption of the population and industry. Industrial activities and waste disposal usually cause pollution. Densely populated urban areas are a significant cause of land degradation and deterioration of the ecosystem, as well as the environment in which the population lives (Borgogno-Mondino, Fabietti, & Ajmone-Marsan, 2015; Mell, 2009).

Urban buildings affect quantities such as temperature, wind, and precipitation. Cities are usually warmer than the surrounding countryside. They form a kind of heat island in the landscape. This phenomenon is called the urban heat island effect (UHI). This is caused by the absorption of sunlight by the dark materials in the city, the relatively low wind speeds and energy of all people, cars, buses, and trains (Oleson et al., 2015). The temperature differences between the city and the countryside are usually most considerable in the morning hours shortly before sunrise. In the suburbs, it is less warm than in the city center. The further away from the city center, the lower the temperature. The difference in temperature between the heart of the city and the surrounding area depends mainly on the size of the town, the time of day and the weather conditions (KNMI, 2017).

In cities, many places heat up during the day and do not cool down at night. These places are also known as the city's hotspots. If the temperature does not drop at all or hardly at all at night, this has an additional impact on health. Because of the high temperatures at night, sleep disorders occur, so people do not rest. Health effects due to high temperatures and fluid loss range from mild symptoms, such as fatigue and headaches, respiratory problems, to severe conditions such as heart failure, with potentially life-threatening consequences. These symptoms are referred to as heat stress because they appear after prolonged exposure to extreme temperatures, especially at night. Heat stress is a significant problem for cities because of the urban heat island effect (Oleson et al., 2015).

Knowing the problems of urbanization is not enough; it is necessary to understand their implications. The consequences and effects of urbanization depend on many other factors and operate in all segments of human activity and the environment. For example, environmental problems through production and consumption, such as increasing energy consumption, infrastructural issues, and excessive use of space. There are also pollution problems and emission problems caused by dispersed substances, such as pollution of water, air, soil by industry and agriculture by population concentration.

Also, there are social problems caused by urbanization, such as differences between population groups, stress, disease, and crime (Nieuwenhuijsen, Khreis, Triguero-Mas, Gascon, & Dadvand, 2017; Smith, Nelischer, & Perkins, 1997; Westphal, 2003). Urban environmental issues cannot be solved in their entirety, but several factors can contribute to reducing the problems, of which a greener environment is an essential factor.

2.3. Urban Liveability Issues

Green in the city is crucial for the climate resilience of the town and the quality of life for its inhabitants. Urban green spaces such as parks, landscaped gardens, street trees, city gardens, cemeteries, green roofs, and green facades increase sustainability in urban areas (Bowler, Buyung-Ali, Knight, & Pullin, 2010). Urban green spaces improve different urban liveability issues, by reducing high temperatures in cities, reduce noise, help to filter pollutants from the air and improve water flow in times of extreme precipitation events (Haase et al. 2014). In developing new green spaces to make cities more sustainable, an important part of urban planning is to consider the spatial location within the urban area, to maximize their potential role. Recently, interest in research has increased concerning the role of urban green spaces for helping to improve different urban liveability issues.

- *Green reduces the risk of flooding*

Urban green spaces are important elements of sustainable urban water storage systems. Ditches and unpaved areas can be used for water storage and biological filtration of runoff from surrounding roads and hard surfaces. The natural soil acts like a sponge. In green areas, precipitation can infiltrate freely into the ground, water plants, evaporate, and replenish the groundwater (Konijnendijk, Annerstedt, Nielsen, & Maruthaveeran, 2013). A green space holds rainwater where it falls. Because of all the hardening, the water hardly has the chance to sink into the soil. More greenery in gardens, on business premises, and in public spaces ensures that rainwater can be retained and stored where it falls (Dunnett, Swanwick, & Woolley, 2002). Using urban green spaces to manage water is one of the simplest ways to improve the environmental problems of urban areas.

- *Green cools the city in summer*

Urban greening is the best-known approach to mitigate the effects on human health of increased temperatures due to climate change. Trees, shrubs, grass, and other greenery can help lower the temperature in a city by evaporating water (Mell, 2009). Trees also provide shade. As a result, the air heats up less, and people experience the city as cooler. Most studies investigate the air temperature in parks and under trees and support in a broad sense that urban green spaces can be more refreshing than non-green locations. Research by Dunnett, Swanwick, & Woolley (2002) shows that a park was, on average, 0.94 ° C colder during the day.

- *Green ensures biodiversity*

Biodiversity in the city is under pressure due to the sober design of the outdoor space, efficient and traditional management, and petrified gardens, resulting in the loss of green space. In an environment with flowers and shrubs, you will find a variety of animals, such as insects, small mammals, and birds. Trees, bulbs, shrubs, and perennials that attract pollinating insects are particularly important for biodiversity (Aronson et al., 2017). These insects maintain the botanical richness. For endangered butterflies and wild bees, flowery urban verges can make the difference. Some green cities even have foxes, martens, and birds of prey. They are an essential link in the ecosystem. The plants and insects are in turn, a source of food for birds and other animals (Fischer et al., 2018).

- *Green contributes to better health and well-being*

Urban green space has been recognized for the social functions it performs, in terms of meeting places and areas for entertainment, recreation and leisure, and its recreational value including contribution to the quality of life, aesthetic enjoyment, a sense of security and freedom from urban noise and pollution (Marselle, Stadler, Korn, Irvine, & Bonn, 2019). There are strong links between poor environmental quality and health. Urban residents rely on green spaces, including parks and cities, forests, residential gardens, and other open areas for their daily recreational needs (Kabisch, Qureshi, & Haase, 2014). This includes whether urban green space can act as a health promoter by encouraging a more active lifestyle, or as disease prevention by reducing the impact of negative environmental conditions such as extreme weather conditions, air pollution, noise or heat (Kabisch et al. 2017).

- *Green contributes to satisfaction with the environment*

Urban green space can make a substantial contribution to making life in cities more pleasant. People living in more deprived areas reported poorer access to public open space and poorer safety. A study from Hodson & Sander (2017) shows that greenery in the neighborhood increases the satisfaction of the area. This means that residents are more satisfied if they have access to natural characteristics that directly surround their homes. Furthermore, the creation of green networks to encourage cycling and walking will benefit vulnerable road users.

As described, a green environment contributes to the reduction of problems in the urban climate. In addition, it also provides a more pleasant living environment for residents, not only in climatological terms but also in terms of quality of life such as satisfaction with the living environment, higher welfare and better health. To increase the positive effects of green space on these aspects of quality of life, it is very important that green space is accessible. The proximity and accessibility of green areas play a significant role in improving the quality of life in the city.

2.4. Accessibility

Accessibility or relative proximity of a place to another indicates convenience or reaching the destination from the origin. Accessibility can be defined as the simplicity with which activities in society can be achieved, such as the needs of citizens, commerce and industries, and public services (Gupta, Roy, Luthra, Maithani, & Mahavir, 2016). As a spatial analytical measure, it plays a crucial role for decision-makers in determining where to place public facilities or services to maximize their usability (Abubakar, 2006). More accessible public services such as parks and open spaces improve social cohesion and interaction. According to the theory of natural movement, integrated and accessible spaces will play a more central role in the urban character. Not only will these spaces be visited and used more often, they will probably also become better known because they are located in more convenient places and at the same time in people's daily movement patterns (Stahle, 2005). Distance measurements are simple accessibility measures, in which the distance from one location to all possible options is calculated. There are various ways to reduce all possibilities to a result, such as the average distance, weighted area distance, or smallest feasible distance to an option. These ways represent the accessibility that is related to the density of the destination. This density will be higher in cities than in rural areas (Abubakar & Aina, 2006; Makrí & Folkesson, 1969).

Because of the considerable health benefits of urban green space, access to green space has been a central issue in research into green spaces concerning human welfare (Barbosa et al., 2007; Haaland & Konijnendijk van den Bosch, 2015). Accessibility is one of the most important factors influencing the frequent use of urban green spaces and improving the well-being of users (Stahle, 2005).

It is, therefore, important that all residential areas have accessible urban green spaces to improve the quality of life in the city. The issue of accessibility to urban green spaces is one of the most discussed in sustainable urban planning, especially on issues such as environmental justice and public health. This is mainly due to the growing recognition of the health and well-being benefits of urban green spaces. Different people interpret accessibility according to their individual needs and priorities, but there is general agreement that facilitating access to urban green spaces can be particularly beneficial for people's health. To achieve this, it is essential to have well-designed green spaces within reach of the population, promoting a high level of walking and active use (Morar, Radoslav, Spiridon, & Pacurar, 2014). Equal distribution of distance and accessibility of green spaces in the city are closely linked to meeting needs and can be measured through accessibility measures.

2.5.Space syntax

The syntax of space measures two movements: it measures the accessibility, the potential of each street segment compared to all the others. And it measures the passage, the potential of each street segment relative to all the pairs of others (Van Nes & Yamu, 2018). Each of these two types of relational patterns can be weighted according to three different definitions of distance. The metric distance measures the city's street and road network as a system with shortest paths, while the topological distance measures the city's street and road network as a system with the least rotation paths. Finally, the geometric distance provides an image of the city's street and road network as a system with the least angular change paths (Hillier, Turner, Yang, & Park, 2007). Each type of relationship can be calculated at different locations of each street segment, redefining the radius in terms of shortest, least revolutions, or least corner paths (Hillier, 2007).

Spatial syntax made it possible to create a map of the space with all the streets in a large city. It can compare spatial configuration analyses about social activities such as the flow of pedestrian movements through streets, patterns of land use, or the spread of crime (Hillier, 2007a). The space syntax as a static street network model that indicates the dynamics are simple, enabling quick syntactic interpretation of a series of cases. Although the method can be used to explain the physical spatial planning of buildings and cities, the analysis of the results of the spatial studies must be done in combination with a good knowledge of social processes and human action. The space syntax method examines the structure of urban space and relates it to human use. It is assumed that the pattern of streets largely determines the course of traffic flows; this is called the theory of natural movement (Hillier, Penn, Hanson, Grajewski, & Xu, 1993). The space syntax method analyzes the metric, topological, and angular distances in the network of urban connections. It thus determines hierarchies in the system of streets and public spaces (Van Nes & Yamu, 2018). Space syntax calculates the accessibility of a place in the urban space mathematically, following modern network theories. However, the method also recognizes the importance of physical aspects such as sightlines (Hillier et al., 2007). The accessibility of a place can be calculated based on several variables. The calculation concerns the simplification of public space to the axial lines. These lines and their attributes, such as depth and connectivity, are depicted in a network. Depth is a topological concept and has no measurable geometric value (Al Sayed, 2014). Axial maps give a good representation of reality because they reflect many structural features of urban public space.

An example of how an urban area can be represented using the Space Syntax model is shown in Figure 2. The urban space (a) can be defined by the set of the axial lines (b) and the graph connectivity (c) (Al Sayed, 2014).

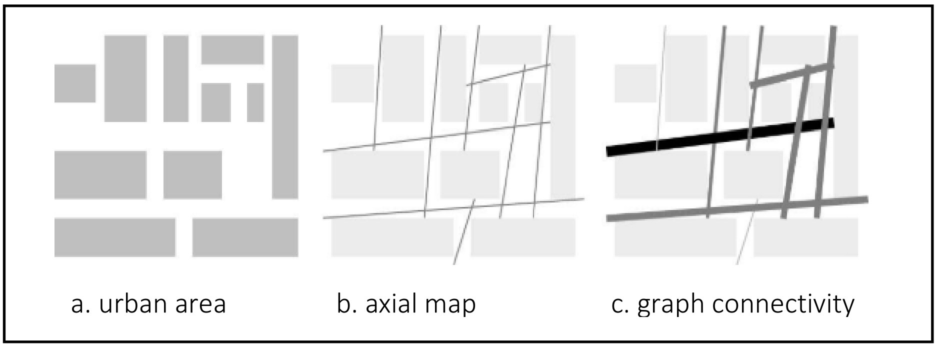

Figure 2: representation using Space Syntax (Al Sayed, 2014).

By depicting a road and street network using an axial map, the characteristics of cities can be determined. For cities, it identifies a low number of most extended lines and a very high number of rather short lines that form the road network (Van Nes & Yamu, 2018). People's behavior and choices create space and are the key to bottom-up, self-organizing processes that give cities their spatial form. It is closely linked with spatial transformation. Space syntax analysis can identify this spatial change as part of a city's self-organizing process (Hillier et al., 2007).

The central position of a street and an urban area can influence its economic attractiveness. The space syntax can quantify the spatial characteristics of a built environment in three ways: metric distance, topological distance, and geometric distance (Zacharias, 2001). Metric centrality means that something is in the middle of an area, with the shortest metric distance to all other points in that area. Sometimes temporary aspects, such as the time it takes to travel, are taken into account. Topological centrality deals with the spatial configuration of the street and road network in terms of the number of directional changes (Zacharias, 2001). The more fragmented a street network is, the weaker the spatial conditions become for a vital economic center. This concerns the degree of accessibility, in terms of the smallest directional changes. Geometric centrality deals with changes in angular directions when moving from one place to another.

The essential space measure for this research is the connectivity of a street. This measures how connected to other streets a spatial structure. It can also be related to the intensity of visitors: streets with a higher level of connectivity attract more people than lanes that score lower on these measures. According to space, the spatial structure then automatically ensures the natural movement. The physical connectivity studies the movement of people through the network of the space, and the visual connectivity looks at the visible aspects of an area, the extent to which a place is visible from other locations (Fathy Alagamy, Al-Hagla, Anany, & Raslan, 2019). A street has a higher connectivity value if it is highly connected to other streets. The connectivity value can easily be calculated by counting the number of directly connected streets (Hillier et al., 1993).

This involves identifying the primary route network that connects the edges of a city with its center (Van Nes & Yamu, 2018). A connectivity map will help to gain insight into the relationships between busy and quiet streets. This is important to be able to estimate the accessibility of new urban green spaces and thus to be able to choose the locations that are most likely to be used most often.

3. Methodology

This research is based on a literature study and quantitative research with data to answer the research question: ‘Given accessibility and urban liveability issues, which potential urban parks have the priority of turning into urban green space for making the largest contribution to a healthy urban living environment?’ In the course of this chapter choices in the field of the research design, data collection and data analysis explained. To maintain a clear structure, it was decided to treat the methods in the order of the research questions. Starting with the selection of the research area, then the collection of data about the urban liveability issues arising from literature. Next, the method for determining potential urban park locations is explained and then how the connectivity analysis is performed. Finally, the results of the research questions are brought together to prioritize the potential urban park locations by means of the multi-criteria analysis.

3.1. Research area

For this research, a district of Amsterdam was chosen instead of the whole of Amsterdam due to limited research time. Because the Healthy City requires that a new green park be located in a residential area, as residents must maintain it, the Westpoort district, being a port and business park, will be discarded. Also, the center will be excluded as this is too challenging for the given time because there is less space in the city center to transform potential locations, which complicates the process. Districts Noord, Nieuw West, and Zuidoost contain a relatively large amount of greenery, which makes it less critical for these districts to realize new urban greenery. As a result, the West and Zuid districts remain as useful research locations with the Zuid district being chosen. Its site contains both neighborhoods that are close to the center and more spaciously designed areas on the outskirts of the municipality, see Figure 3. This ensures more differentiation within the thematic layers on which the prioritization is based, namely the urban liveability issues.

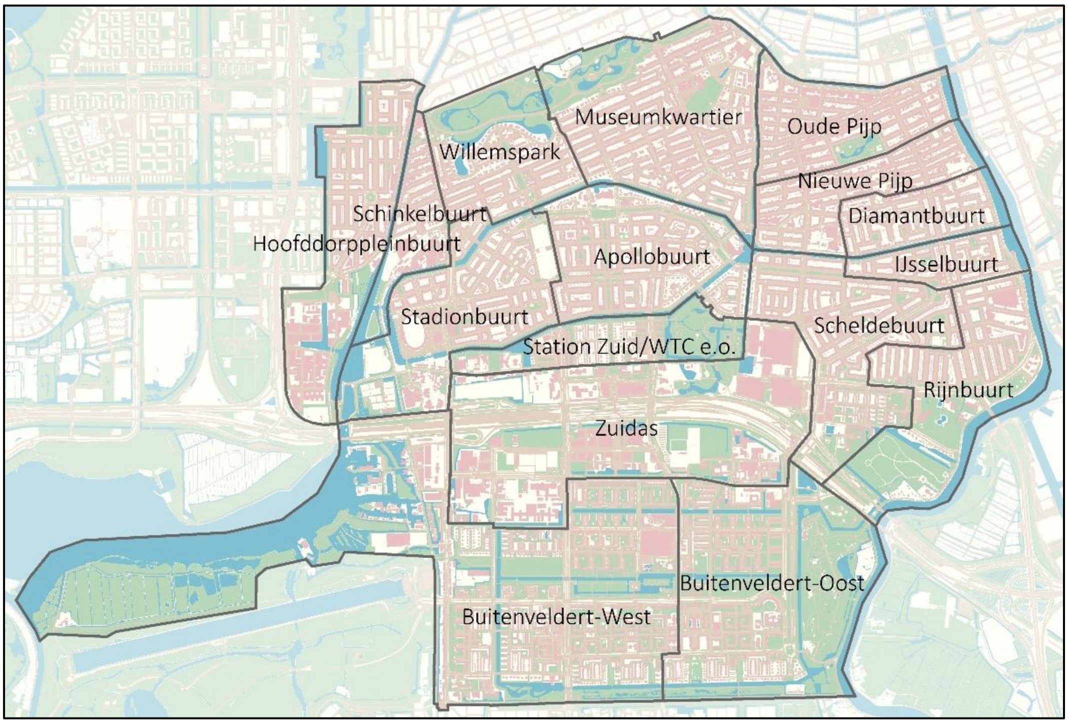

Figure 3: Neighborhoods in Amsterdam Zuid

3.2. Data on urban liveability issues

The first research question largely concerns a literature study on how parks and green spaces can contribute to a healthy urban living environment. This results in five urban liveability issues, which are used to prioritize the potential urban parks. For this reason, the data is discussed for every urban liveability issue.

3.2.1. Risk of flooding

The dataset on the risk of flooding indicates the maximum water depth that can occur in a location due to intense short-term rainfall. A temper of 70 mm in 2 hours was used for the modeling. Under the current climate, this shower occurs approximately once every 100 years. Heavy rainfall over a short period can cause local flooding. A large part of the Dutch streets and squares can be submerged in heavy showers. The most damage occurs when the water (over the pavements) enters buildings. Low-lying paved parts are particularly susceptible to flooding. Approximately ten percent of the buildings in the Netherlands have a risk of flooding in the event of very heavy rainfall. There are also health risks if contaminated water remains on the street: with mixed sewers, rainwater can mix with non-purified water. To gain a better insight into the risk of short-term flooding in the Netherlands, datasets were developed by Deltares in 2018 in the context of the preliminary flood risk assessment of the Floods Directive in the European Union.

3.2.2. UHI effect

The UHI effect is the average air temperature difference between the urban and surrounding rural areas. The urban heat island effect is strongest at night. Paved areas such as roads and houses heat up during the day and remain significantly warmer at night than rural areas. Hardening plays a dominant role in this because it ensures that the air temperature drops less at night so that sensitive population groups experience health effects. Green reduces the heat island effect. Green provides evaporative cooling and provides shade. The dataset for the UHI effect that is used as an input for the multi-criteria analysis shows a prediction of the urban heat island effect based on various underlying map data: the population density, wind speed, amount of green, waterbodies, and hardening. It is a raster dataset calculated and produced by the (partners of) the Klimaateffectatlas in 2018.

The Klimaateffectatlas was created in 2007 based on the need of various provinces and knowledge institutions to bring together national climate information in an easily accessible manner. The update of the Klimaateffectatlas in 2017 is funded by a subsidy from the Ministry of Infrastructure and the Environment. The maps from the atlas can be used to put the climate adaptation theme on the agenda and to get a feel for the order of magnitude of climate effects. The atlas is based on national data and indicates the order of magnitude of effects that may occur in an area.

3.2.3. Biodiversity

Biodiversity is represented by the location of hives of honey bees in Amsterdam. As there is no available dataset on biodiversity, honey beehives are used as they give a good indication of the presence of different types of flowers, plants, shrubs, and trees. Honey bee colonies increase the activity of pollinators in fragmented landscapes such as spatially separated city gardens, making a positive contribution to biodiversity (Snyder, McIvor, & Brown, 2016). Honey bees pollinate the plants in gardens and parks, especially fruit trees, raspberries, berry bushes, and rose hips. The allotment complexes cannot do without bees, and this also applies to the city gardens. The berries in the city are visited by many berries and seed-eating birds in autumn and winter; the vast majority of these berry bushes are due to the biodiversity in the city. The vector (point) dataset is released in 2017 by Onderzoek, Informatie en Statistiek.

The Onderzoek, Informatie en Statistiek (OIS) department collects data about Amsterdam and processes it into information. From topics such as the Amsterdam population, housing stock, employment, and activity in the city to topics such as security, elections, care, and education. Amsterdam City Data is the central data portal of the Municipality of Amsterdam, where data from OIS is open to the public.

3.2.4. Well-being & health

The well-being and health data are represented by looking at the perceived health of residents per neighborhood. Perceived health is also referred to as subjective health or health experience, and reflects the judgment about people's health. Perceived health is a summary health measure of all relevant health aspects for the person in question. Underlying health aspects can relate to both physical and mental health. Examples are illnesses, physical limitations and disabilities, fitness, fatigue, and depressive feelings. Lifestyle factors such as diet, smoking, and physical activity can also help to determine people's perceived health (Gezondheid in Beeld, 2019). Also, observed health is often more effective than clinical measures for predicting help-seeking behavior and use of health care. Observed health is a relative measure - there are indications that people assess their health in relation to their circumstances and expectations, and their peers. The data shows the percentage of residents aged 19 and over with good perceived health. The perceived health percentages for neighborhoods are based on survey data, demographics and neighborhood characteristics in 2016.

Gezondheid in Beeld (GiB) is an easily accessible and interactive website that provides insight into the health, well-being, lifestyle, and living environment of the people of Amsterdam. GiB is for everyone interested in the health and well-being of the people of Amsterdam. GiB contains data from the various monitoring studies that are taking place within the GGD Amsterdam.

3.2.5. Satisfaction with the living environment

This urban liveability issue of satisfaction is regarded as an intangible criterion. This criterion is complex and can be a challenge to define and measure. The main criterion is defined and divided by means of two sub-datasets to make the criterion more distinguishable, measurable, and understandable. The first dataset comes from Gezondheid in Beeld, where the satisfaction with the residential environment is considered. The second dataset comes from Onderzoek, Informatie en Statistiek and consists the perceived safety, nuisance and crime for every neighborhood. The weight assigned in the AHP will be divided into two, as both datasets are input data for the multi-criteria analysis.

The satisfaction with the residential environment dataset gives a percentage of residents aged 19 and over who give a sufficient grade for the living environment. This grade is based on satisfaction about the direct residential environment, greenery in the neighborhood, sports facilities, cycling, and walking possibilities and play areas for children. The municipality can protect and promote the health of residents by increasing the coherence between health, environment, safety, spatial planning, and living environment and taking this into account when planning. The dataset of the satisfaction with the residential environment is at district level.

The second dataset that has to do with the satisfaction of the living environment is safety. It is important to also include this dataset since the first only concerns the physical environment and safety also looks at the attractiveness of the environment and the social aspect. Safety is not solely dependent on crime. Nuisance from, for example, drunk people on the street or young people also has an impact. It is also essential how safe the residents feel in their neighborhood. The safety monitor is, therefore, composed of three aspects: crime, nuisance, and perception of insecurity. The scores range from 0 (unsafe) to 100 (safe). The safety score combines all three factors and uses the average score. The monitor provides insight into the social safety situation in a neighborhood over a period of 4 months and combines all relevant indicators of safety. The last monitoring moment was released in April 2019 by Onderzoek, Informatie en Statistiek.

3.3. Potential urban park locations

In order to be able to prioritize potential urban park locations, first, the locations that are suitable for being transformed into an urban green space have to be identified. Identification takes place on behalf of the location requirements given by De Gezonde Stad:

- *The location is in public space;*
- *The available space is between 100 and 700 m2;*
- *A location is a petrified place;*
- *The location is located in a residential or working area;*
- *The location is not a current development location.*

Potential urban park (PUP) locations are calculated using the Basic Registration of Large-Scale Topography (BGT) and OpenStreetMap (OSM). The layer of road sections contains all pavement and also gives a specification of the main use purpose of the road section. This can, therefore, be motorway, highway, regional road, railway lines, etc. Footpaths, in particular, are often classified more broadly than they should be, squares are often indicated as footpaths in their entirety, while part of that square could be a great urban park location. To distinguish the roads from the squares, OSM is used for a street centerline layer. OSM provides accurate data that is adjusted by volunteers. Because this data set consists of lines, a 5m buffer is used here. This margin is derived from the average lane width of 2.5 m, based on a double lane per street, or a combination of lane and bicycle lane. The 5-meter buffer around the OSM roads is then subtracted from the merged BGT pavement layer, leaving paved areas without road function, see Figure 4.

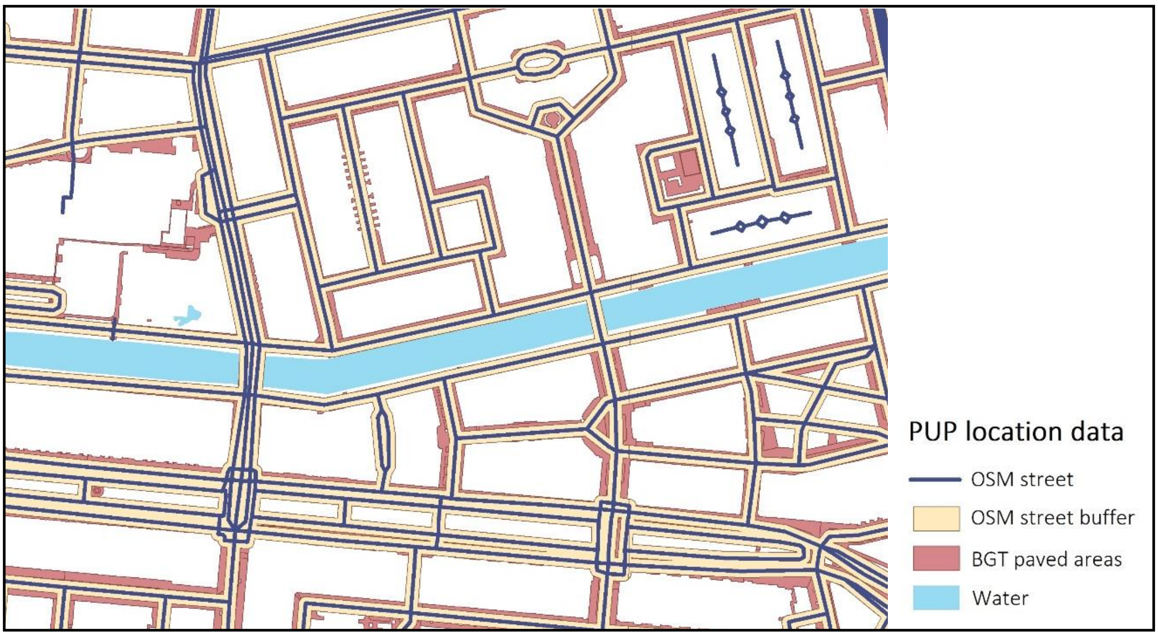

Figure 4: BGT + OSM roads and buffer in Nieuwe Pijp / IJsselbuurt

The remaining paved sections do not yet meet the requirements of the Healthy City; an urban green space must be at least 100m². The hardened pieces that are smaller than 100 m² will be removed from the data set. There is deliberately not filtered on the upper limit of 700 m² set by the Healthy City, because of areas that larger than the limit do not have to turn into urban green spaces for the entire area. As a result, areas with a surface area of more than 700 m² remain in the data set. What is an important aspect is the shape of the potential urban park location. Because many narrow strips will remain along blocks of houses, the Perimeter-Area Ratio is used to split off real squares from long strips parallel to the roadway. Perimeter-surface ratio is a simple measure of the complexity of the shape, but without standardization to a simple Euclidean shape, such as a square. Perimeter Area Ratio is equal to the ratio of the patch circumference (m) to the area (m²) (UMass Landscape Ecology Lab, 2019). This can easily be calculated for the remaining paving so that this can be selected for a good shape for a potential urban park location. In Figure 5, all remaining squares are represented based on the Perimeter-Area Ratio.

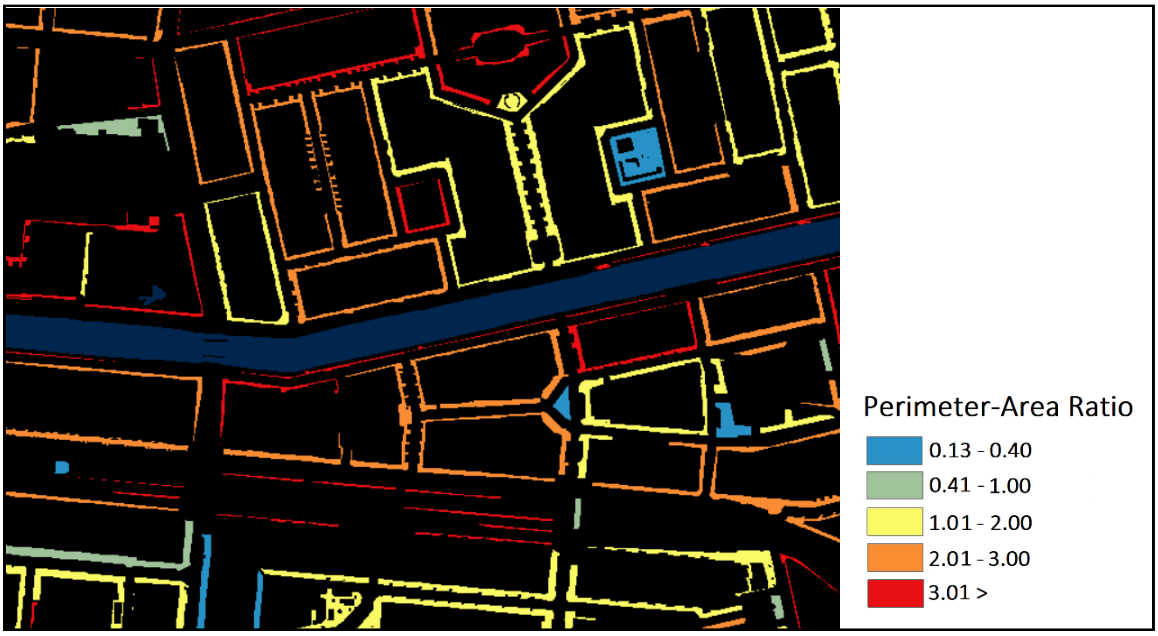

Figure 5: Perimeter-Area Ratio of squares in Nieuwe Pijp / IJsselbuurt

The map in Figure 5 shows the Perimeter-Area Ratio of all squares in the study area. By gauging different good potential urban park locations on their Perimeter-Area Ratio, it is possible to choose based on which threshold the remaining paving is selected to calculate the final potential urban park locations. In this study, it was decided by trial and error to include all locations with a Perimeter-Area Ratio ≤ 0.4 as a potential urban park location.

3.4. Connectivity analysis

This part of the methodology concerns the connectivity analysis to answer research question 3. The street network of Amsterdam Zuid is used to calculate the connectivity value for each street. Based on this value, a priority (low / high) can be assigned depending on accessibility. For the research it is important that potential urban parks are located in easily accessible locations in order to maximize the impact and effectiveness.

An important aspect of the location study is the connectivity analysis. The connectivity analysis is performed on the street network of Amsterdam Zuid, to identify how accessible and connected locations are. The method of space syntax is used by studying pedestrian movements. This methodology is based on topological-visual analysis of a built environment in an attempt to explain the movement of pedestrians in urban space (Hillier, 2007). The connectivity technique evaluates the spatial configuration of the urban areas. Connectivity is defined by Mohamad & Said (2014) as a direct connection of nodes (k) with every individual node in a connection graph. This research focuses on the identification of the locations of those green areas and analyzes their accessibility with the connectivity approach. These spaces will not only be visited and used more often, but they will probably also become better known because they are in more visible places and at the same time, in people's daily movement patterns.

Before the connectivity analysis can be performed, the input data must first be prepared. Usually, it is common for the constraints, such as water, buildings, and railway lines, to be used as input data while the remaining space used for the analysis. But there is a lot of water in Amsterdam that should not be treated as a constraint in its entirety, because there are also bridges that cannot be indicated. For that reason, the traditional method is not followed, and a choice has been made to use the BGT road sections as input for specifying the area that can be used for traveling. Highways and railroads are excluded from the analysis because the local network in the neighborhood is studied.

The software used for connectivity analysis is DepthMapX. DepthmapX is an open-source, multi-platform software platform for performing a series of spatial network analyzes that are designed to understand social processes within the built environment. It works on different scales, from building through small towns to entire cities or states.

The axial map is made in three phases. The pre-processing phase clears up any loose ends of lines in the card. The processing phase then traverses all pairs of invisible angles in space, according to the algorithm by Penn, Conroy, Dalton, Dekker, & Mottram (1997). The algorithm searches for the closest point on the surface of a building within the opposite quadrat for each convex vertex (Penn et al., 1997) If both angles are convex, a line is added between them, if there is one reflex or both are reflex, a line is only added if it can be extended beyond the reflex angles (Turner, Penn, & Hillier, 2005). The final phase of post-processing connects the lines in an axial map.

An example of possible types of axial lines, as defined by Penn et al. (1997) shown in Figure 6. The vertex can be a convex to convex vertex (a), a convex to reflex vertex, (b), or a reflex to reflex vertex (c).

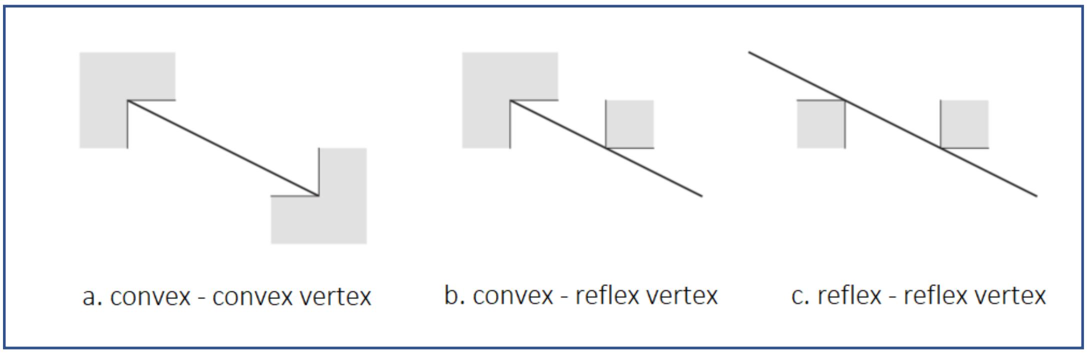

Figure 6: Possible types of axial lines (Penn et al., 1997)

3.5. Prioritizing the potential urban park locations

For the prioritization, the connectivity values and urban liveability issues are taken into account. The decision to select the potential urban park locations that make the most significant contribution to a healthy urban living environment, when replacing petrification with green space. The prioritization will be based on the multi-criteria analysis mean value per potential urban park location.

3.5.1. Multi-criteria analysis

The prioritization of potential city park locations depends on a number of criteria. The decision to prioritize the locations is carried out using a multi-criteria analysis. The definition of a multi-criteria analysis is explained by Dinçer (2011) as "an approach and a set of techniques, with the aim of providing an overall ordering of options, from the most preferred to the least preferred option." In this research, multi-criteria analysis is used as a priority tool but was initially developed to rank complex problems with multiple criteria. MCA fits well to address such complex decision problems by determining preferences between all possible options (Gül, Gezer, & Kane, 2006). MCA can also be used for data when criteria are not nominal, but rather have a relative degree of suitability (Baycan-Levent, Vreeker, & Nijkamp, 2009; Gül et al., 2006).

MCA is used to define the most suitable areas for creating a new city park. The implementation of the MCA is the operationalization or the definition and discussion of the criteria, weightings, scores, and alternatives. Here the scores are assigned and viewed with the weights. The criterion scores must be standardized on a common scale to allow comparisons. The Analytical Hierarchy Process (AHP) is used to determine the weights per criterion. This is a measurement method through pairwise comparisons. The method uses a scale of numbers to make comparisons. This scale varies from 1 to 9, where 1 represents the same interest, and 9 prefers a criterion that is very strong compared to another. Each criterion is given a value in comparison with another criterion, and subsequently priority per criterion can be obtained by dividing the sum of all values per criterion by the sum of all values of all criteria (Saaty, 2008).

It is clear that prioritizing potential city park locations does not lead to a determined outcome of the evaluation model; the result will differ per researcher based on the criteria used and the value assigned (Baycan-Levent et al., 2009). The output is a ranking of the alternatives and offers the most suitable locations for creating new green spaces in neighborhoods.

3.5.1.1. Criteria

After reviewing literature about healthy urban living environments, five main-criteria are defined for prioritizing urban park locations: risk of flooding, UHI effect, biodiversity, well-being and satisfaction (Aronson et al., 2017; Hodson & Sander, 2017; Kabisch et al., 2014; Konijnendijk et al., 2013; Mell, 2009). These thematic layers are combined with the connectivity analysis in the multi-criteria analysis and ultimately provide priority for every potential urban park location.

3.5.1.2. Scores

Scores are assigned to each urban liveability criteria. Locations with a high probability of flooding in heavy rain benefit more from an urban green space than locations that have a very low probability of flooding. That is why each criterion is subdivided into different classes, based on the value that it must receive for prioritizing PUP locations. The assigned scores range from 1 to 9. 1 is a low value where the location in that respect does not have a high need to create an urban green space, and 9 has the highest priority for creating an urban green space. For example, locations with a very low probability of flooding get assigned a value of 1, and locations with a high probability of flooding receive a value of 9. The result of assigning these scores is a grid file with a score of 1 to 9 for each grid cell. The grid cells with the highest values have the highest priority to be transformed into a park.

3.5.1.3. Weights

The main criteria are not equally imported into the decision-making process. Weights are assigned to each main criterion to determine the final ranking. The weights of each ULI criterion are assigned through the Analytic Hierarchy Process (AHP). Table 1 shows the weights per criterion. Two criteria are weighed against each other with the AHP method. In the second row of table 1, the connectivity (A) is weighted against all other criteria. A weight of 1 means that the criteria are the same. If the weighting is more than 1, this criterion has a greater influence than the criteria against which it is weighed. Connectivity, for example, has a greater influence than the UHI effect. The higher the weight, the more favorable the criteria. Biodiversity is moderately favorable compared to well-being, and connectivity, for example, is highly favorable compared to satisfaction. Which criteria are more important are based on the literature on the urban liveability issues that are positively influenced by greenery. The opinions of experts in the literature show that connectivity has a major impact on visiting city parks. In addition, the UHI effect and Risk of flooding are important risks arising from climate change that require extra attention in the city. The social aspects are difficult to concretize into data from the literature, so they are weighed less heavily in the AHP.

		A.	B.	C.	D.	E.	F.	Total score	Score in %
A.	*Connectivity*		2	2	2	3	3	0.302	30
B.	*Risk of flooding*	1/2		1	1	2	2	0.18	18
C.	*UHI effect*	1/2	1		1	2	2	0.18	18
D.	*Biodiversity*	1/2	1	1		2	2	0.144	14
E.	*Well-being*	1/3	1/2	1/2	1/2		1	0.097	10
F.	*Satisfaction*	1/3	1/2	1/2	1/2	1		0.097	10

Table 1: Analytic hierarchy process

3.5.2. Sensitivity analysis

Sensitivity analysis (SA) is the study of how the uncertainty in the result of the analysis can be attributed to different sources of uncertainty in the input of the analysis (Saltelli, 2002). The SA is, therefore, considered by some to be a condition for scientific research to make research results transparent about its reliability. Chen, Wood, Linstead, and Maltby (2011) claim that due to vague and unreliable data, analyses, and expert judgment, the concerns of SA are increasingly being recognized. Choosing a suitable and relevant set of criteria and weights is crucial for problem-solving and reliable and meaningful results and depends on the understanding and opinion of the user about the situation to be analyzed (Chen et al., 2011). For the multi-criteria analysis, scores and weights are assigned to the criteria to be analyzed. These scores and weights are based on scientific literature and expert judgment. Chen et al. (2011) discussed the uncertainty of the input values (scores and weights), and it cannot be assumed that these are naturally correct. The purpose of SA is to determine the likelihood of the outcomes and the effects of small changes in the input of a model (Chen et al., 2011). Uncertainty can be present in the input data and in the assigned scores and weights (Saltelli, 2002; Chen et al., 2011). Uncertainty in the input data, the measurement or estimation of environmental factors, and the selected range for including these criteria in the MCA can influence the general uncertainty of criteria (Chen et al., 2011).

The uncertainty of the scores and weights awarded lies in the scientific literature and the subjective judgment of experts about the relative importance of the different criteria, assigned by the range of their effects. In this study, the SA will be applied and performed on the uncertainty of the assigned scores and weights. The input data, which consist of the shapefiles for each environmental factor, is not measured by itself, but obtained by large Dutch organizations and institutions. The data has been carefully measured and obtained and will not be tested for uncertainties.

The uncertainties of the weights and scores have already been reduced by the AHP. The multi-criteria analysis correctly assesses the importance of the criteria and not the input data. It is not easy to establish a correct method for determining the weights and scores (Saltelli, 2002). Therefore, the sensitivity of the influence of each criterion is tested with the bootstrapping technique. The bootstrapping technique is a leave-one-out analysis that can be applied to overlay or suitability analyzes such as MCA (Heywood, Cornelius & Carver, 2002). One criterion is omitted, which shows the effect of the exclusion of the selected criteria. The weighting of the other criteria is recalculated without the value of the omitted criterion.

4. Results

This chapter presents the research results acquired from the performed analyses. Just like the methods, the results are treated in the order of the research questions. The first paragraph presents the classification of the data on urban liveability issues. Next, the results of potential city park locations are shown, and in the third section, the connectivity analysis as a whole and its direct influence on the potential city park locations. Finally, the result of the multi-criteria analysis is presented, and the results thereof are linked to the potential city park locations. This results in the prioritization of the potential city park locations.

4.1. Classified urban liveability issues

Classification is the process of classifying entities into groups and is used to generalize complexity in geographical phenomena and geospatial data and extract meaning. An equal interval is used for all urban liveability issues. Equal interval arranges a set of attribute values into groups that contain an equal range of values. This can help show different groups when they are close in size. Equal interval is best applied to familiar data ranges, such as percentages and temperature. This method emphasizes the amount of an attribute value relative to other values (Heywood et al., 2002). All criteria are scored from 1 (low priority) to 9 (high priority).

Criteria	*Classification*				*Score*
Risk of flooding	0	-	3.7	cm	1
	3.8	-	7.4	cm	2
	7.5	-	11.2	cm	3
	11.3	-	14.9	cm	4
	15	-	18.7	cm	5
	18.8	-	22.4	cm	6
	22.5	-	26.2	cm	7
	26.3	-	29.9	cm	8
	30	cm	>		9
UHI effect	0	-	0.29	° C	1
	0.3	-	0.59	° C	2
	0.6	-	0.89	° C	3
	0.9	-	1.19	° C	4
	1.2	-	1.49	° C	5
	1.5	-	1.79	° C	6
	1.8	-	2.09	° C	7
	2.1	-	2.39	° C	8
	2.4	° C	>		9

Table 2a: Classification of urban liveability issues

Criteria	*Classification*				*Score*
Biodiversity	0	-	133	m	1
	134	-	267	m	2
	267	-	400	m	3
	401	-	533	m	4
	534	-	667	m	5
	668	-	800	m	6
	801	-	934	m	7
	935	-	1067	m	8
	1068	-	1200	m	9
Well-being	83.4	-	85.1	%	1
	81.6	-	83.3	%	2
	79.8	-	81.5	%	3
	78	-	79.7	%	4
	76.2	-	77.9	%	5
	74.4	-	76.1	%	6
	72.6	-	74.3	%	7
	70.8	-	72.5	%	8
	69	-	70.7	%	9
Satisfaction	96.38			%	2
	93.04			%	5
	87.5			%	8
Safety	78.51	-	80.10	%	1
	77.01	-	78.50	%	2
	75.41	-	77.00	%	3
	73.81	-	75.40	%	4
	72.31	-	73.80	%	5
	70.61	-	72.30	%	6
	69.11	-	70.60	%	7
	67.51	-	69.10	%	8
	66.00	-	67.50	%	9

Table 2b: Classification of urban liveability issues

The classifications are used to create the input raster data for the multi-criteria analysis. A preview of the classified urban liveability issues is shown on the next page in Figure 7. Full-size maps of the urban liveability issues can be found in Appendix A.

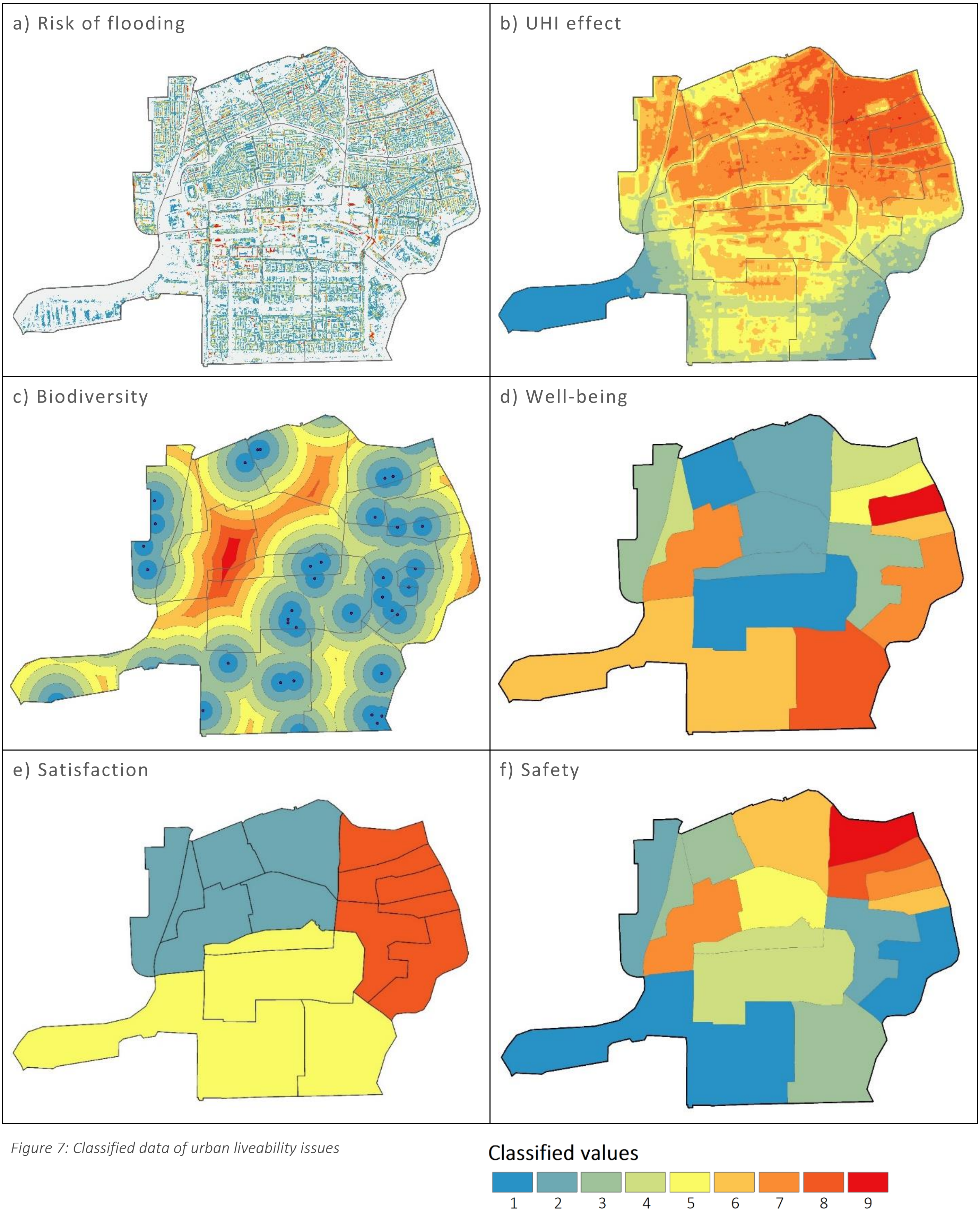

Figure 7: Classified data of urban liveability issues

4.1.1. Risk of flooding

Figure 7a shows the risk of flooding in Amsterdam Zuid. The risk of flooding classification is based on the water depth in mm, where each class represents an increase of 3.6 mm in water. The higher the water depth, the higher the need for an urban green space, because green areas can absorb large amounts of water and let it through to the subsurface. For paved areas is the processing of large quantities of rain has to be done by the sewer system, which is not able to perform under heavy circumstances. Every location which has too little water storage capacity is subject to the risk of flooding in the event of heavy rainfall. Locations where no chance of flooding has been identified, are classified as 0 in the multi-criteria analysis.

4.1.2. UHI effect

The temperature ranges are based on every tenth of degree the temperature is warmer than in the surrounding rural area of Amsterdam. The temperature difference between the city and surroundings can rise to 4 ° C and is highest at night. However, these are the biggest differences for cities, and such differences only occur during clear, windless nights. In practice, these circumstances do not occur very often (RIVM, 2017). The biggest difference in Amsterdam Zuid is + 2.6 ° C, which can be seen in Figure 7b. The temperature scores are divided into 9 classes, which display a proportional distribution of the UHI effect in Amsterdam Zuid, every class representing an increase of + 0.3 ° C.

4.1.3. Biodiversity

The classification of biodiversity is based on the foraging distance of bees from the hives. Literature shows that bees almost never go further than 1200m from their hives to forage, and thus will only positively influence biodiversity close to their hives. that most foraging from the urban bee colonies are at relatively short distances, up to 1.2 km from their hive, and thus within the surrounding urban area (Garbuzov & Schürch, 2014). 1200m was divided into nine equal classes for classification purposes, where areas close to the hive are mostly used as foraging areas and, therefore, highly susceptible to pollination and thus a diverse variety of plants, trees, and flowers. Locations further away from the hives are less likely to be pollinated by the honey bees and therefore could have less variety of plants. If urban green areas would also include the placement of a beehive, biodiversity will also flourish at those urban park environments. The beehives outside Amsterdam Zuid are also included, so as not to get a distorted image on the edge of the study area. Figure 7c shows that no beehive can be found in either the Apollo neighborhood or the Stadionbuurt.

4.1.4. Well-being & health

Figure 7d shows the classification of well-being and health. The classification for the perceived health, wellbeing, of residents will be based on an equal scale, where the neighborhood with the lowest percentage of residents with good perceived health will get a 9 as score, as this should be the priority location of this theme. Logically, the neighborhood with the highest percentage of residents with good perceived health will get scored 1. All percentages are equally divided over 9 classes, where each class represents a decrease of 1.7% in the number of residents with good perceived health.

4.1.5. Satisfaction with the living environment

Because the satisfaction of the living environment data is not at neighborhood level but at district level, it is less suitable to show differences at a small scale level. Also, due to the lack of more classes, this criterion cannot be classified in 9 categories, but in only 3, as shown in Figure 7e. Because the values are not far apart in percentage terms, it was decided to ignore the pronounced scores of 1 and 9 and instead use 2 and 8 as outer values, plus the average thereof.

The classified data about neighborhood safety is represented in Figure 7f. To classify the safety data to be used as multi-criteria analysis input, the neighborhood with the highest safety value is scored 1, and the neighborhood with the lowest safety value is scored 9. All other values are divided equally over the classes, which means an increase of 1,5% per class.

4.2. Potential urban park locations

The selection of potential urban park locations in Amsterdam Zuid results in the following 99 locations,see Figure 8. The size of the potential urban parks varies between 135 m² and 8332 m², but 70% of the locations are smaller than 1000 m². The potential urban park locations are dispersed throughout the Amsterdam Zuid, but around the Zuidas and the Olympic Stadium, there is a higher density of potential city park locations.

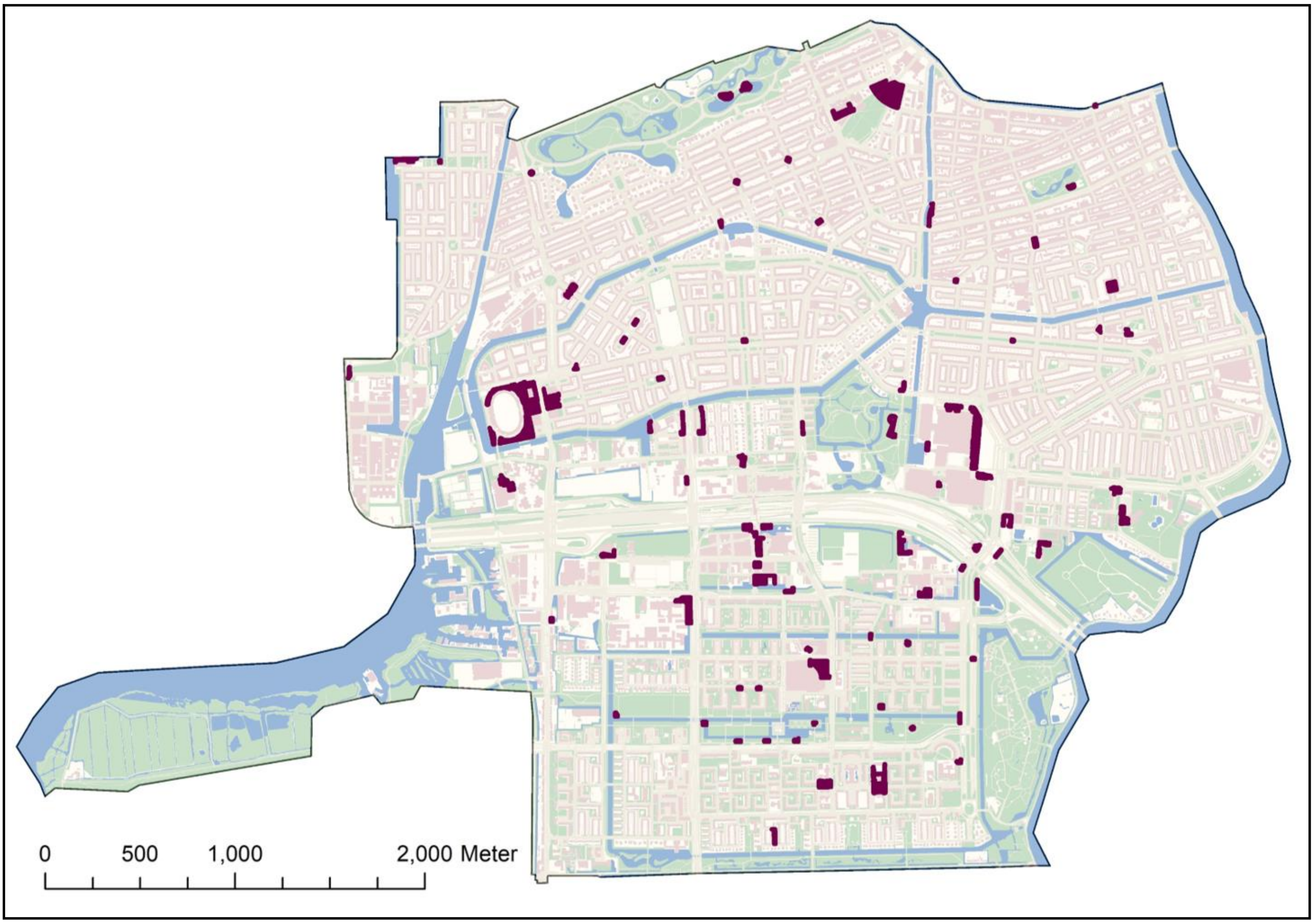

Figure 8: Selected potential urban parks

4.3. Connectivity analysis

The result of the axial map shows a wide range of connectivity values; the lowest connectivity is 11 while the highest connectivity is 2345. The connectivity value is classified according to a geometric interval. This classification method is useful for visualizing data that is not distributed normally or when the distribution is extremely skewed, which is the case, see Figure 9. Equal interval, as applied to most other MCA input criteria, is not appropriate here because the variation would disappear. But, differentiation in the variables is essential to be able to notice differences in the result of the multi-criteria analysis and the prioritization of potential urban park locations.

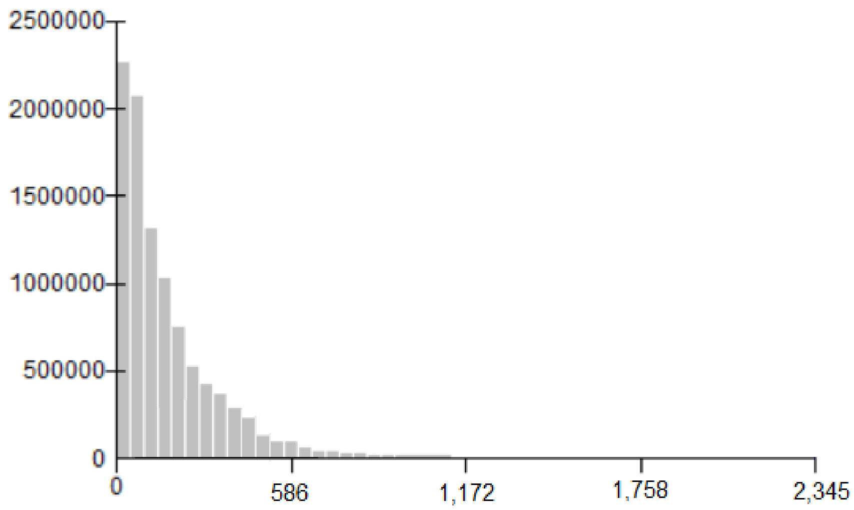

Figure 9: Skewed distribution of connectivity

From the geometric interval classification method, the classification values are displayed in Table 3: Classification of the connectivity value.

Criteria	*Classification*			*Score*
Connectivity	11	-	157	1
	158	-	278	2
	279	-	413	3
	414	-	482	4
	483	-	765	5
	766	-	987	6
	988	-	1292	7
	1293	-	1634	8
	1635	-	2345	9

Table 3: Classification of the connectivity value

The connectivity analysis classification results in Figure 10. For each street, the connectivity was calculated based on the number of connections to other streets. Streets with many nodes are seen as streets with high connectivity. Streets that have few intersections are less well connected to other streets. Most roads are classified as 1 or 2, as they are residential roads that are used for local traffic in the neighborhood. It is important for an urban green space that it is to be optimally used by the residents and for that it is desirable that an urban green space is located in an easily accessible and connected location.

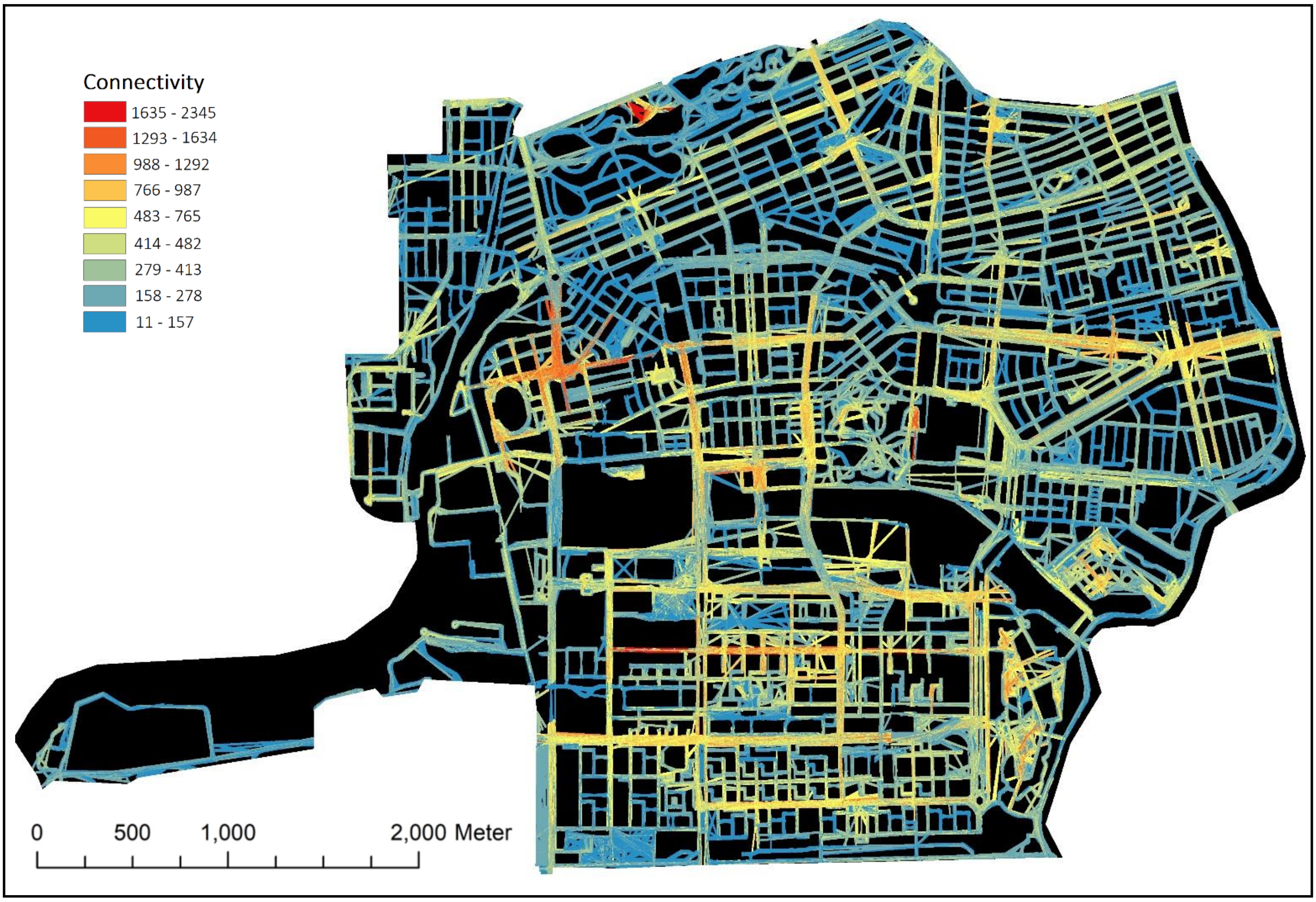

Figure 10: Classified connectivity

4.4. Prioritizing the potential urban park locations

Prioritizing the potential urban park locations is the final result of the research. First, the result of the multi-criteria analysis is discussed, then it is combined with the potential urban park locations for assigning the prioritization value.

4.4.1. Multi-criteria analysis

Combining the classified Urban Liveability Issues together with the classified connectivity analysis according to the weights calculated with the AHP method results in the multi-criteria analysis. The MCA result is displayed in Figure 11. The blue-colored areas have a low priority, and the red/orange colored areas have a high priority for creating an urban green space. The dense neighborhood De Pijp in the northeast part of Amsterdam Zuid and the Stadionbuurt, seem the most in need of urban green space. But, besides the need, there must also be an available square to be transformed into an urban park.

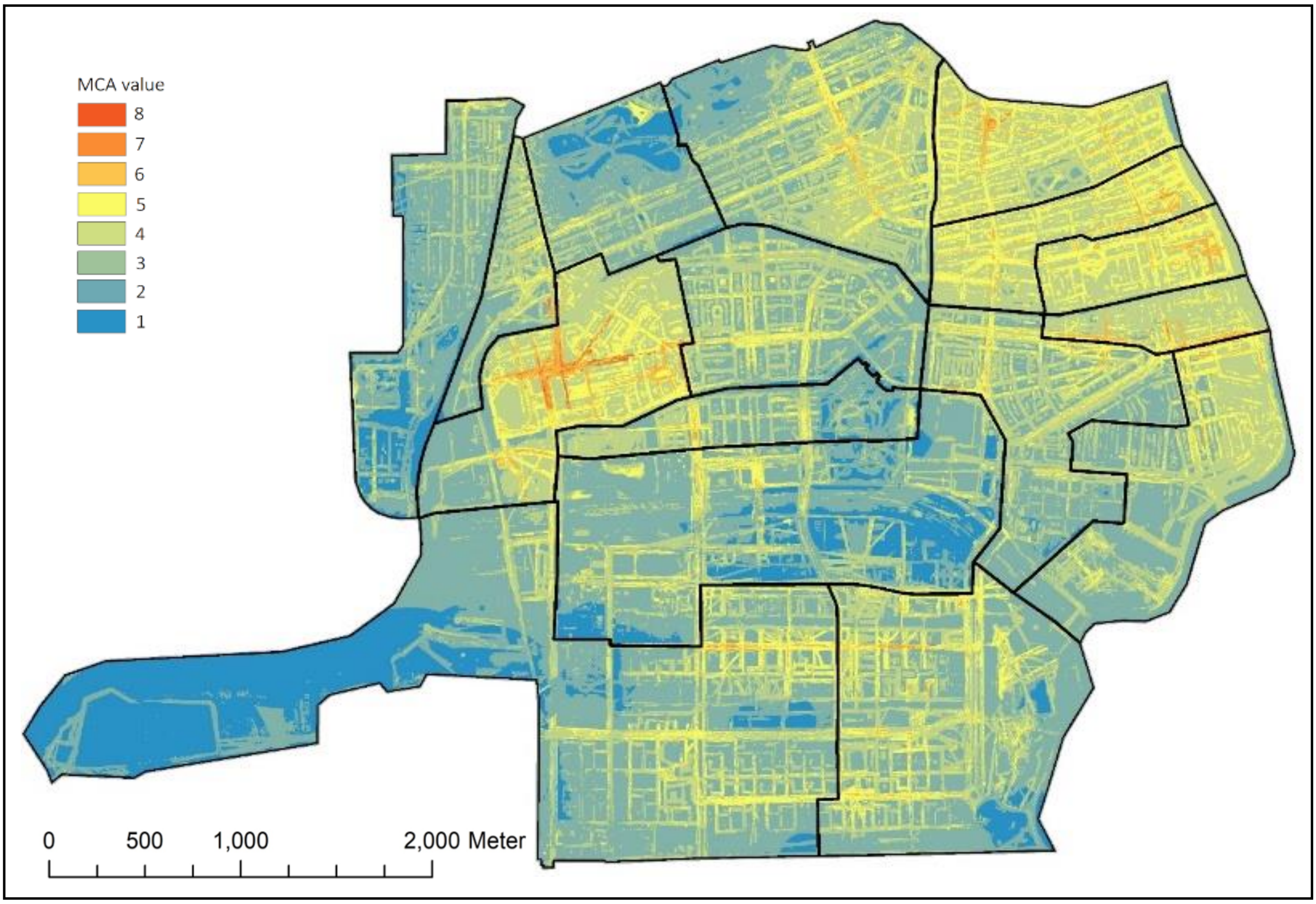

Figure 11: Multi-criteria analysis

For all 99 potential urban park locations, the average multi-criteria analysis value was calculated. This value will be called the prioritization score, as it is used to determine the highest need for an urban green space. Figure 12 shows all potential urban park locations and their score, numbered in order of their prioritization, where number 1 has the highest prioritization value. The highest prioritization scores were measured in Amsterdam Zuid around the Olympic Stadium. These are colored red, which means they are classified as potential locations with a high priority. The highest score is a 5,5, belonging to a small square of 256 m² on the intersection of the Stadionweg and the Olympiaweg.

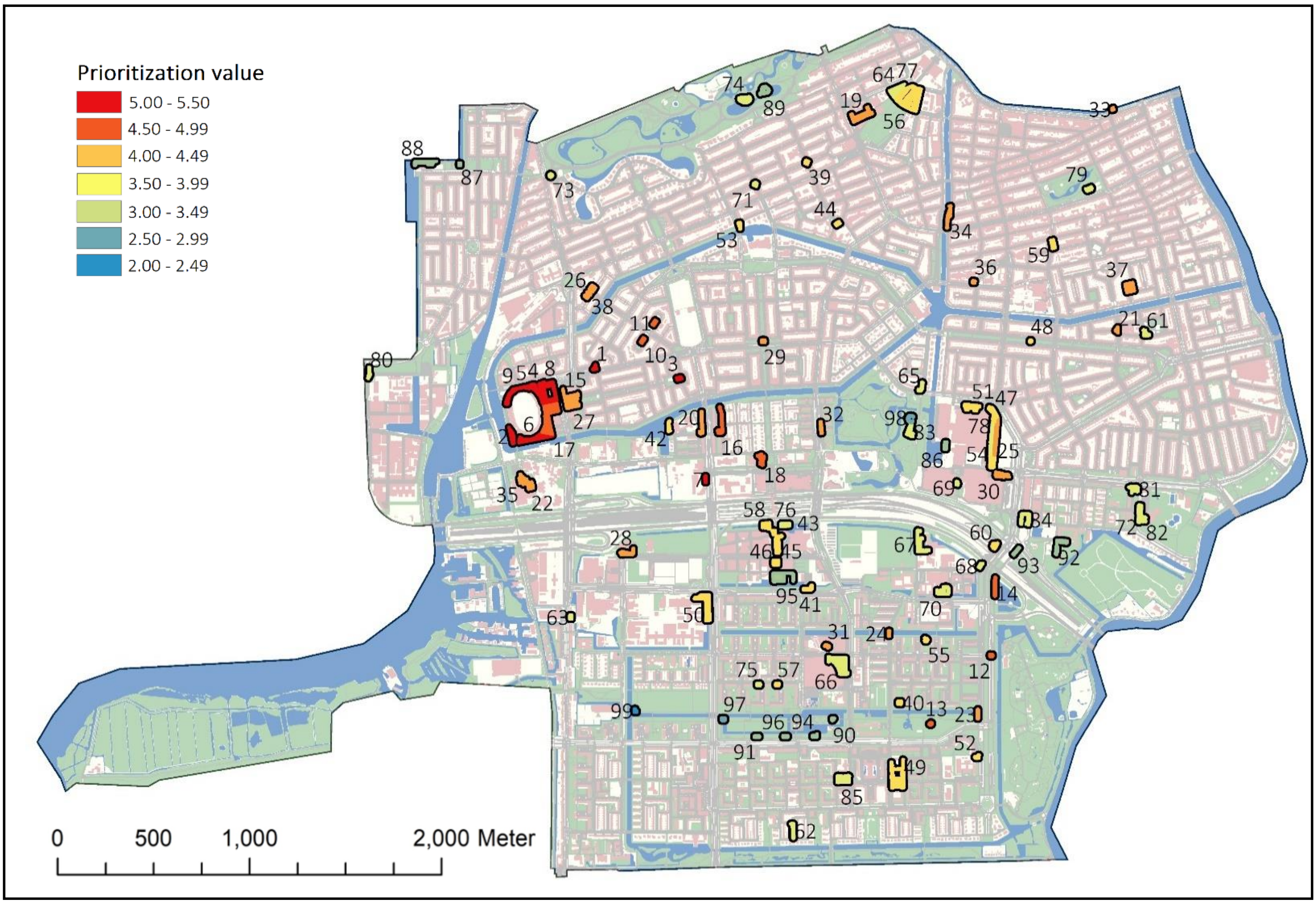

Figure 12: Prioritized potential urban park locations

Table 4 shows information about the multi-criteria analysis value, connectivity value, location size, Perimeter-Area Ratio, and neighborhood of the 10 highest prioritized locations. The full table consisting information about all 99 potential urban park locations can be found in Appendix B.

Prioritztion score	*MCA value*	*Connectivity value*	*Surface in square meters*	*Perimeter-Area Ratio*	*Neighborhood*
1	5.50	5.14	256	0.37	Stadionbuurt
2	5.37	6.59	755	0.37	Stadionbuurt
3	5.33	5.00	309	0.34	Stadionbuurt
4	5.26	4.64	1261	0.27	Stadionbuurt
5	5.18	4.55	765	0.31	Stadionbuurt
6	5.17	5.35	2208	0.31	Stadionbuurt
7	5.14	4.46	229	0.36	Zuidas
8	5.13	4.64	2042	0.40	Stadionbuurt
9	5.05	5.47	1274	0.36	Stadionbuurt
10	5.01	4.00	306	0.29	Stadionbuurt

Table 4: MCA values for the potential urban park locations

The histogram in Figure 13 shows the distribution of MCA values. From this histogram, it can be concluded that most potential urban park locations have a prioritization value between 3 and 4.5.

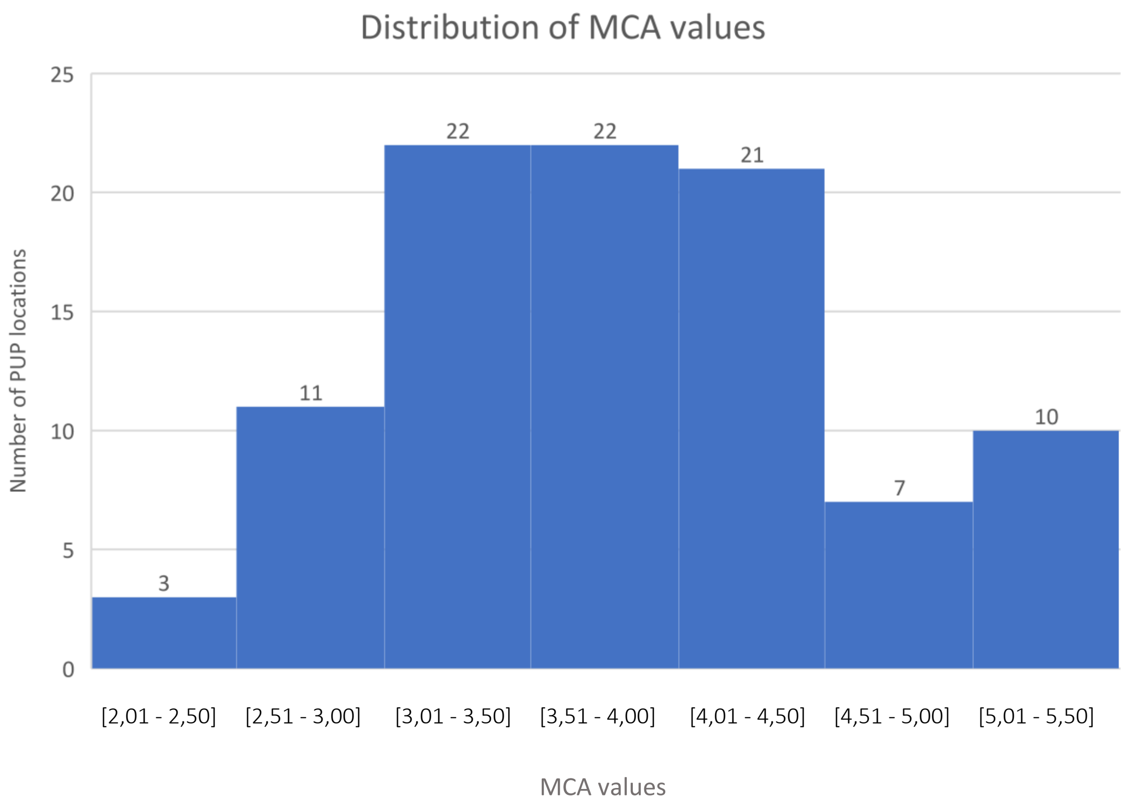

Figure 13: Distribution of MCA values

4.4.2. Sensitivity analysis

The bootstrapping technique is used to determine the sensitivity of the influence of each criterion. The multi-criteria analysis was performed with one criterion excluded each time. This results in five different output maps, which are shown in Figure 14. Differences are clearly visible in the export maps. Especially when connectivity, UHI effect, and risk of flooding are excluded from the analysis, the priority of some areas changes, in particular in the Stadionbuurt and the Oude and Nieuwe Pijp. These three criteria have the highest weights in the MCA, leading to a significant impact on output. Satisfaction and wellbeing have the least influence on the output, namely because of their lower weighting in the analysis.

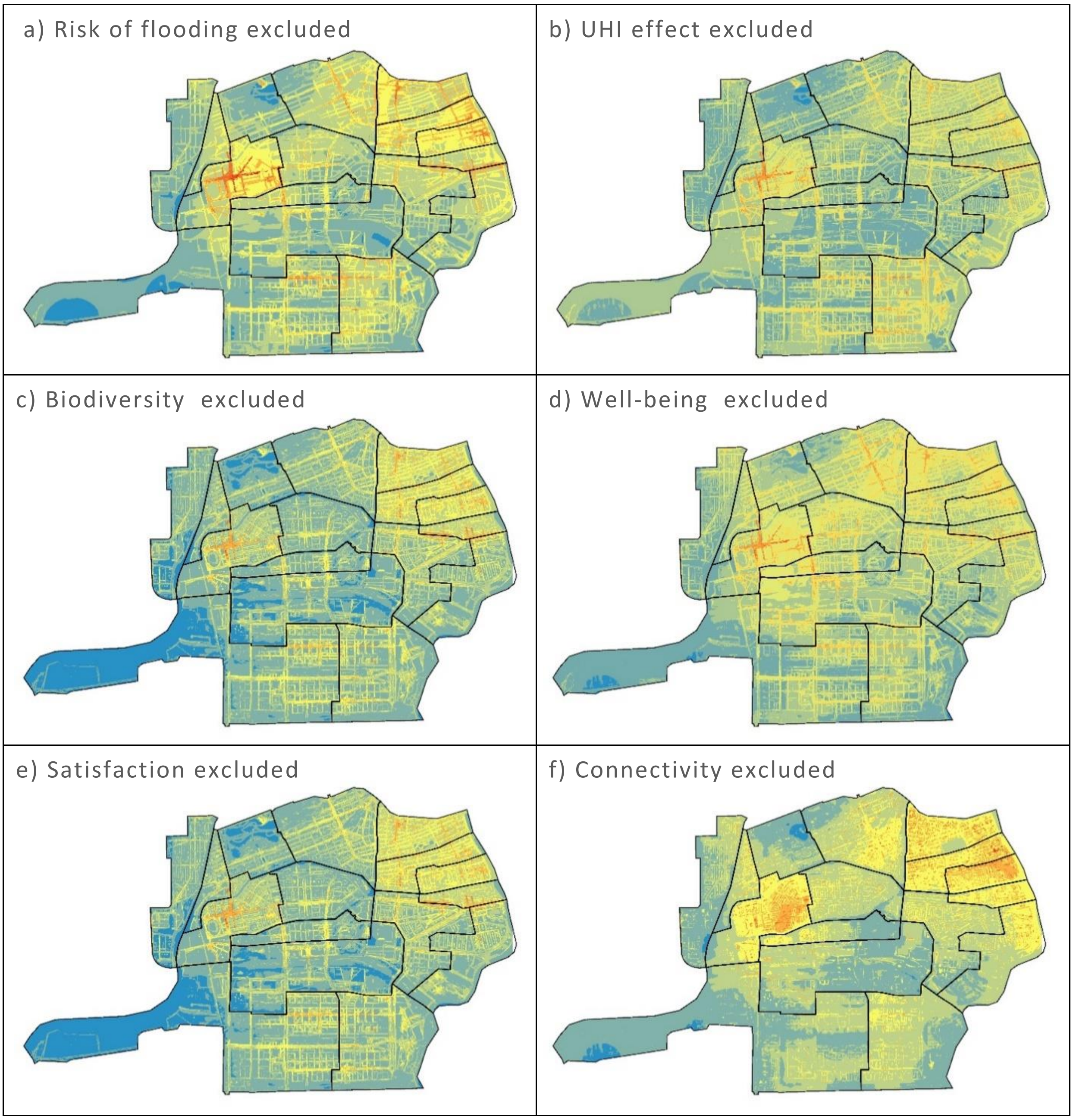

Figure 14: Bootstrapping analysis

5. Discussion

This chapter discusses the implications of this research according to its key outcomes. The study focused on the development of a method to identify potential locations and give priority to information on urban liveability issues and the connectivity of the potential city park location.

The results of this study indicate that there are enough potential locations for an urban green space. Ninety-nine locations are identified as suitable by taking into account a minimum size and the perimeter-area ratio. The most important finding is the prioritization of the 99 potential locations and in particular, the highest-scoring locations. The greatest need for urban green space is recognized for these locations.

Another remarkable result is that 6 out of 10 highest-scoring potential urban park locations are positioned around the Olympic Stadium. The area surrounding the stadium is paved due to regular sports competitions and other events for which it is used. Therefore, it can be questioned whether this is a practical location for an urban green space, given that the surroundings of the stadium must provide space for these events.

The data required to convert the urban liveability issues from the literature into measurable input for the multi-criteria analysis is not always available as expected. The replacement of data for criteria whose preferred data is not available is based on the researchers' assumption that the information is representative of the criteria In this study, this is the case for the urban liveability issue biodiversity, for which no dataset existed. For this reason, it has been decided to replace this for the locations of beehives, because the literature shows that beehives can give an indication of biodiversity.

In addition to the availability of the data, the quality also influences the research results. For privacy reasons, some data from OIS Amsterdam is presented on a larger scale than desirable for the study. The data of the urban liveability issues wellbeing and safety are at the neighborhood level, and the data of satisfaction with the residential environment is at a neighborhood-combination level. As a result, the results are less differentiated within a neighborhood itself because they have the same values for different criteria.

Analyzing the urban liveability issue about the UHI effect revealed that the closer the urban area, the higher the UHI effect. This is especially evident in the northeastern neighborhoods in Amsterdam South, Oude Pijp, Nieuwe Pijp, and Diamantbuurt. Nevertheless, only a handful of potential city park locations have been identified in these neighborhoods. This is due to the compact design of these neighborhoods. As a result, there is little room for improvement by placing urban green spaces.

The DepthMapX software was used to calculate accessibility, but lacked features required for more specific analysis. Although the result of the analysis of the axial lines resulted in the intended connectivity value, no other attributes were calculated due to the lack of specific capabilities of the software, algorithms used, and associated specifications.

The flexibility of application is an important advantage of multiple-criteria analysis. The criteria, scores, and weights are drawn up through various input sources, leading to solidity and reliability. Because an MCA always has to deal with preferred information, the methodology can be discussed, and the method used in that research is not immediately suitable for possible other research locations.

The power of this research method must be seen in the approach to identify locations and, using relevant criteria such as urban liveability issues and theories such as connectivity analysis, prioritize according to necessity.

6. Conclusion

The overall objective of this research is to develop a method to identify potential locations and prioritize with information about urban liveability issues and the connectivity of the potential urban park location. The main research question is: “Given the accessibility and urban liveability issues, which potential urban park locations have the priority of turning into urban green space to make the most significant contribution to a healthy urban living environment?” Several research activities have taken place in the search for identifying and prioritizing possible locations for urban green spaces. Accordingly, different conclusions can be drawn, which will be elaborated on according to the three research questions.

The first research question is: “How can parks and green spaces contribute to a healthy urban living environment?” Five urban liveability issues improve due to the presence of greenery that emerged as the most important from the literature. Greenery reduces the risk of flooding, due to all the paving, the water hardly has the chance to sink into the soil. Green ensures that not all precipitation has to be removed. Green cools the city in the summer because cities are usually warmer than the surrounding countryside. Trees, shrubs and other greenery can help lower the temperature in a city by evaporating water. Greenery ensures biodiversity, with the layout of the city determining the species that settle there. By replacing the stony urban landscape with lush greenery, a rich diversity of urban biodiversity with a variety of animals, birds, and insects is created. Green contributes to better health and well-being; many studies have shown that the presence of green reduces stress. Urban green space can act as a health promoter by encouraging a more active lifestyle. Greenery contributes to satisfaction with the living environment because inadequate access to public greenery is associated with more unsafe areas. Residents are more satisfied if they have access to natural features that immediately surround their homes. A green environment contributes to the reduction of problems in the urban climate and provides a more pleasant living environment for city dwellers.

The second research question is: “Which locations in Amsterdam Zuid are suitable for potential urban parks in terms of location requirements?” The locations are determined by mapping all paved areas, excluding roads, cycle paths, and footpaths, in the public space of Amsterdam Zuid. These locations were selected based on the Healthy City location requirements, location size, and Perimeter-Area Ratio, resulting in potential urban park locations. Ninety-nine potential urban park locations are identified in Amsterdam Zuid.

The third research question is: "How accessible are the possible urban park locations in Amsterdam Zuid? Accessibility or relative proximity or a place relative to another indicates convenience or reaching the destination from the origin. Accessibility is one of the most important factors that influence the frequent use of urban green spaces and improve social viability problems. The connectivity analysis is performed on the street network of Amsterdam Zuid to determine how accessible and connected locations are. Streets with many nodes, a lot of length and width, are seen as streets with high connectivity. Streets that are narrow and short and have few intersections less connected with other streets.

Finally, the main question is answered: "Given the accessibility and urban liveability issues, which potential urban park locations have the priority of turning into urban green space to make the most significant contribution to a healthy urban living environment?" The results of the three sub-questions come together in the multi-criteria analysis, where the potential urban park locations are prioritized based on the urban liveability issues and the connectivity value. All values are classified based on low to high priority, and assigned to the potential urban park locations. Of all 99 potential urban park locations, the highest score is 5.5, and the lowest is 2.01, and the average prioritization score is 3.79. 9 out of 10 are the highest priority locations in Stadionbuurt, and all have a prioritization score higher than 5.0. These are the potential urban park locations that will benefit most from the transformation into an urban green space.

6.1. Recommendations

Further research can be carried out into other areas in need of urban green spaces. An example of this is the inner city of Amsterdam, which contains little vegetation but needs it based on the urban liveability issues.

For further research, it is recommended to use different software to study the connectivity analysis better and in more detail. Other software for the calculation would be of great importance so that the algorithms can be better aligned with the goal.

It is necessary to conduct additional research that takes into account more possible urban liveability issues, which may play a smaller but important role in prioritizing locations. When examining other or multiple criteria, the alternatives, weights, and requirements must be adjusted.

Further research can be carried out to determine whether the data used, which does not always have the desired quality, is representative of the criteria. By investigating multiple locations and comparing the results, a clear statement can be made about the importance of solid data quality.

The outcome of the prioritization of potential urban park locations can be used for further research to model the effectiveness of the urban parks for the direct living environment.

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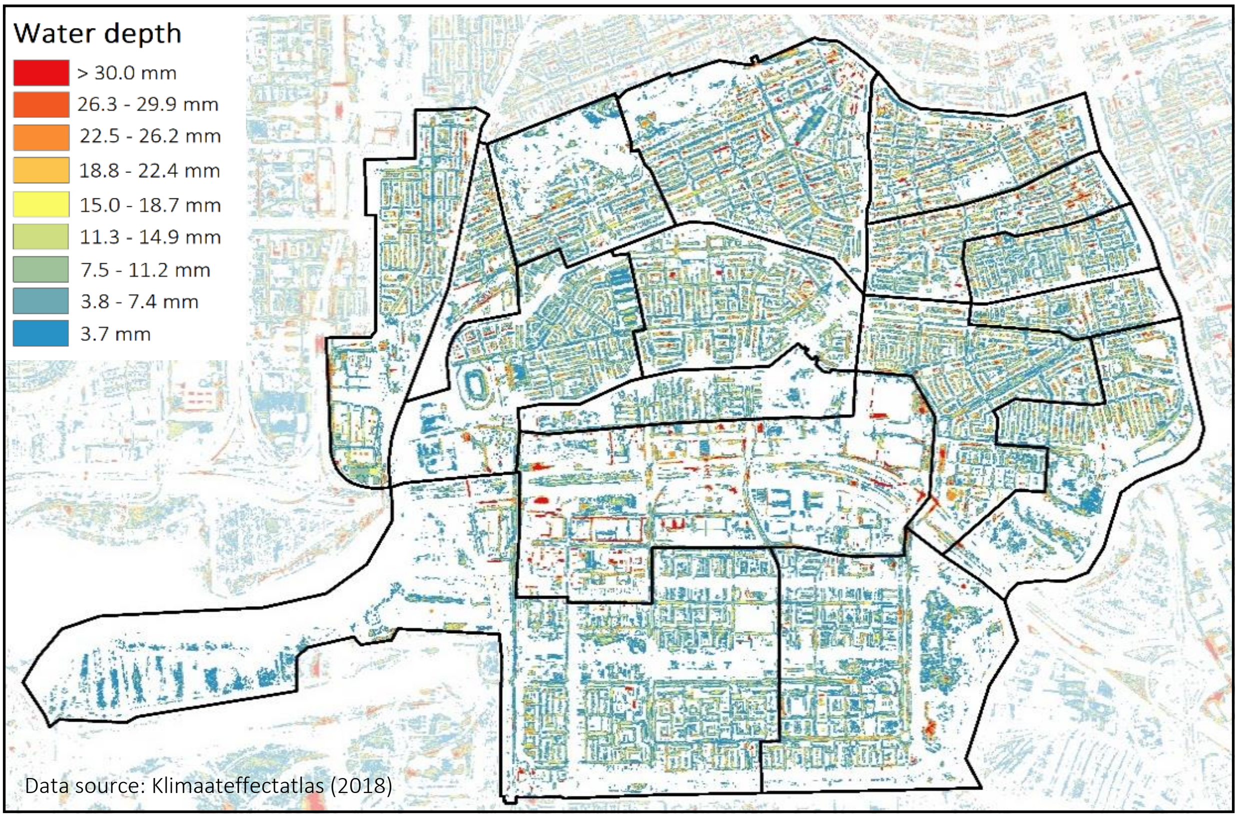
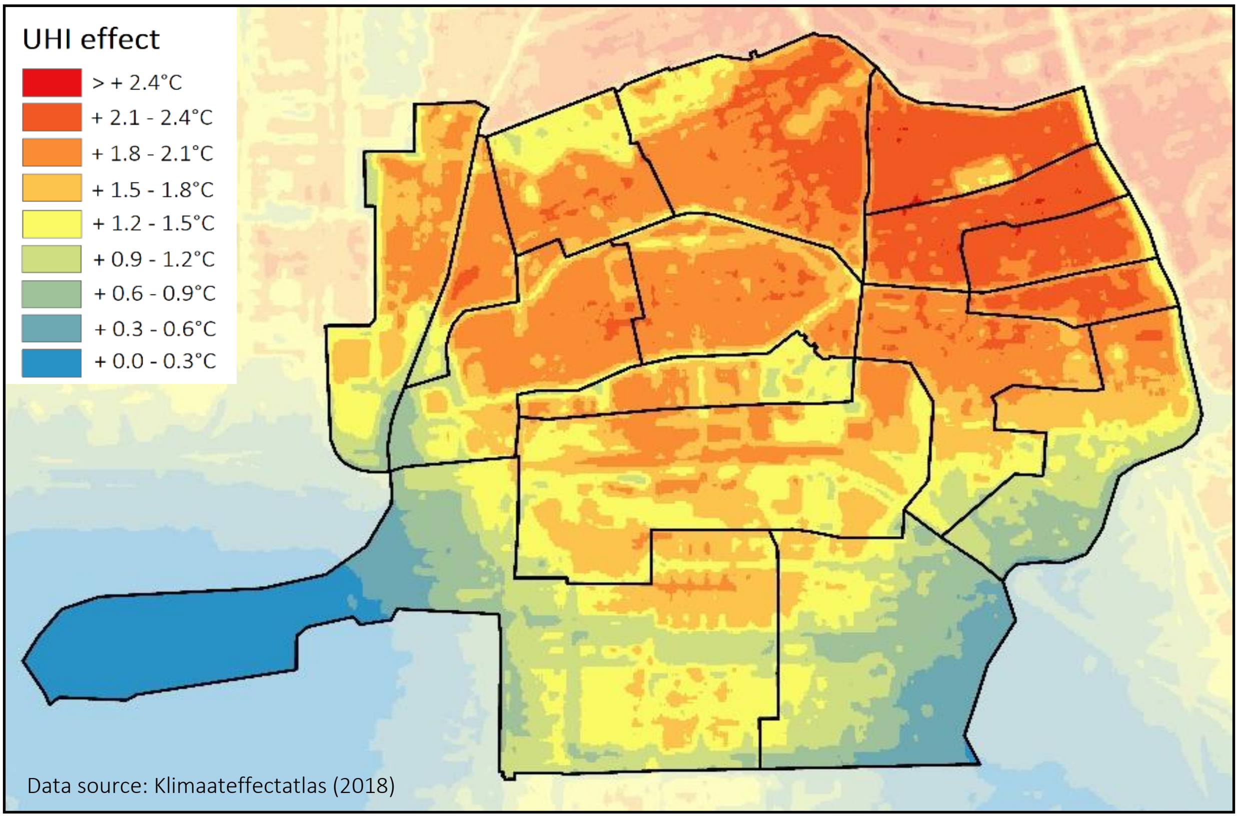
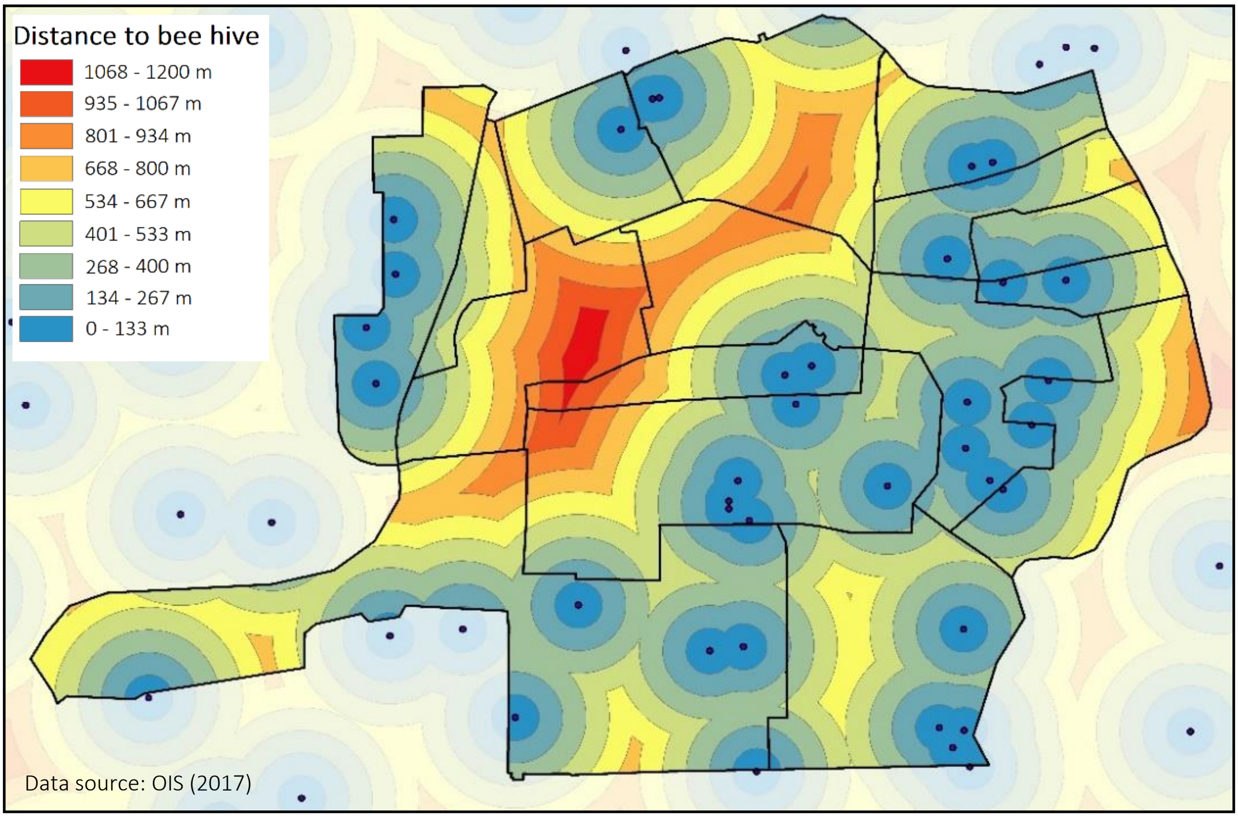
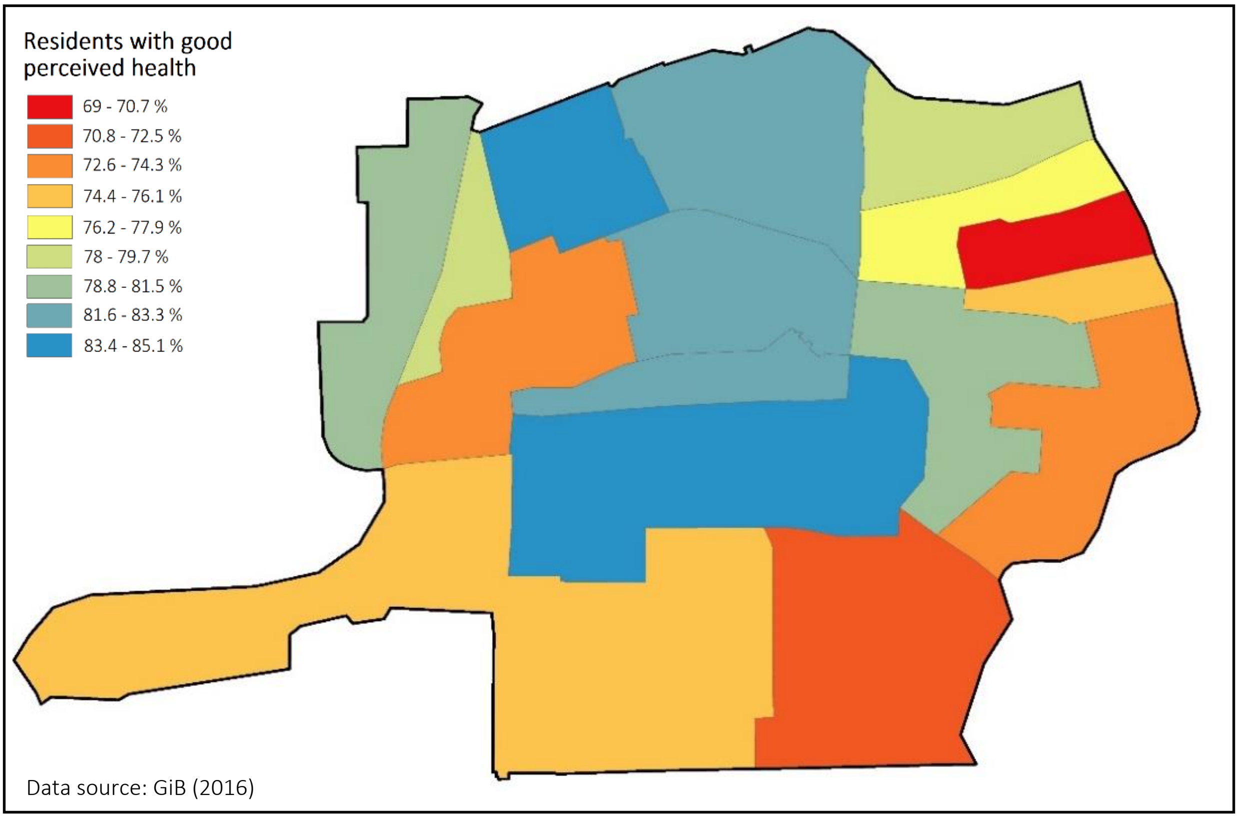
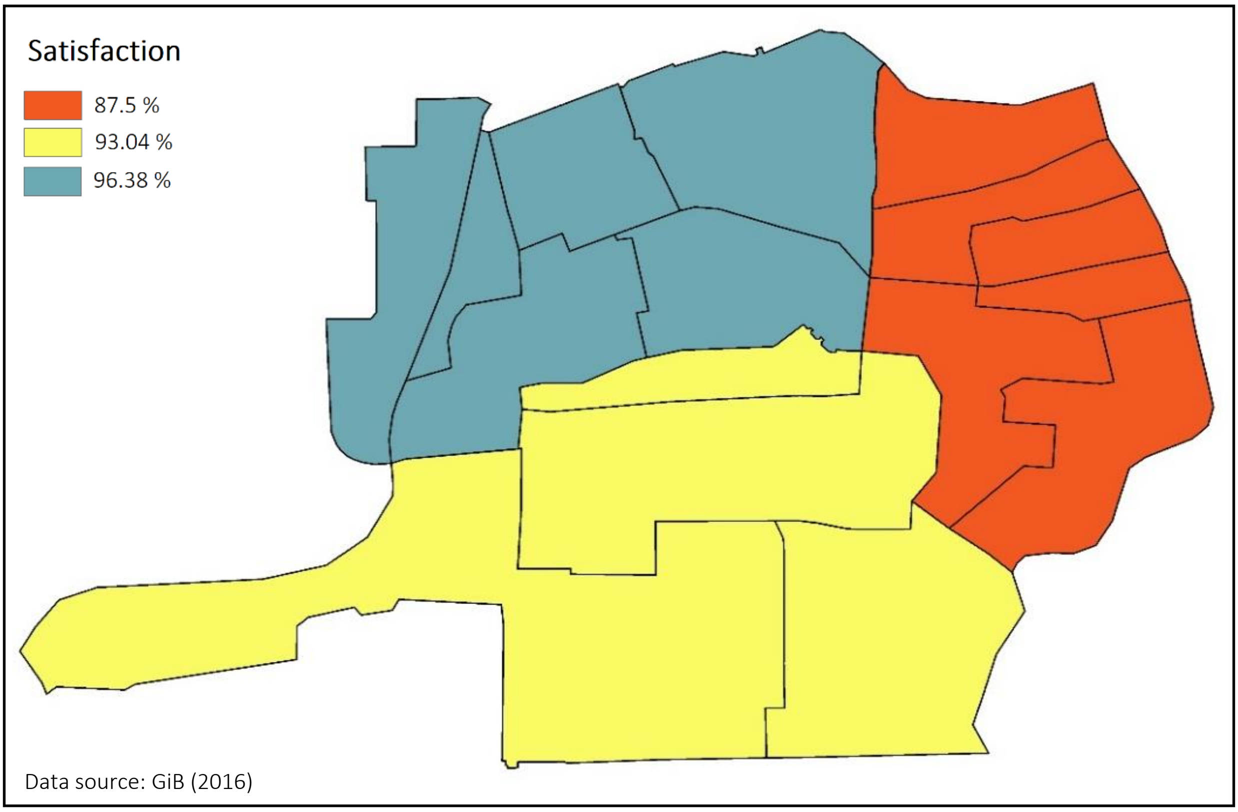
Appendix A: Classified urban liveability issues

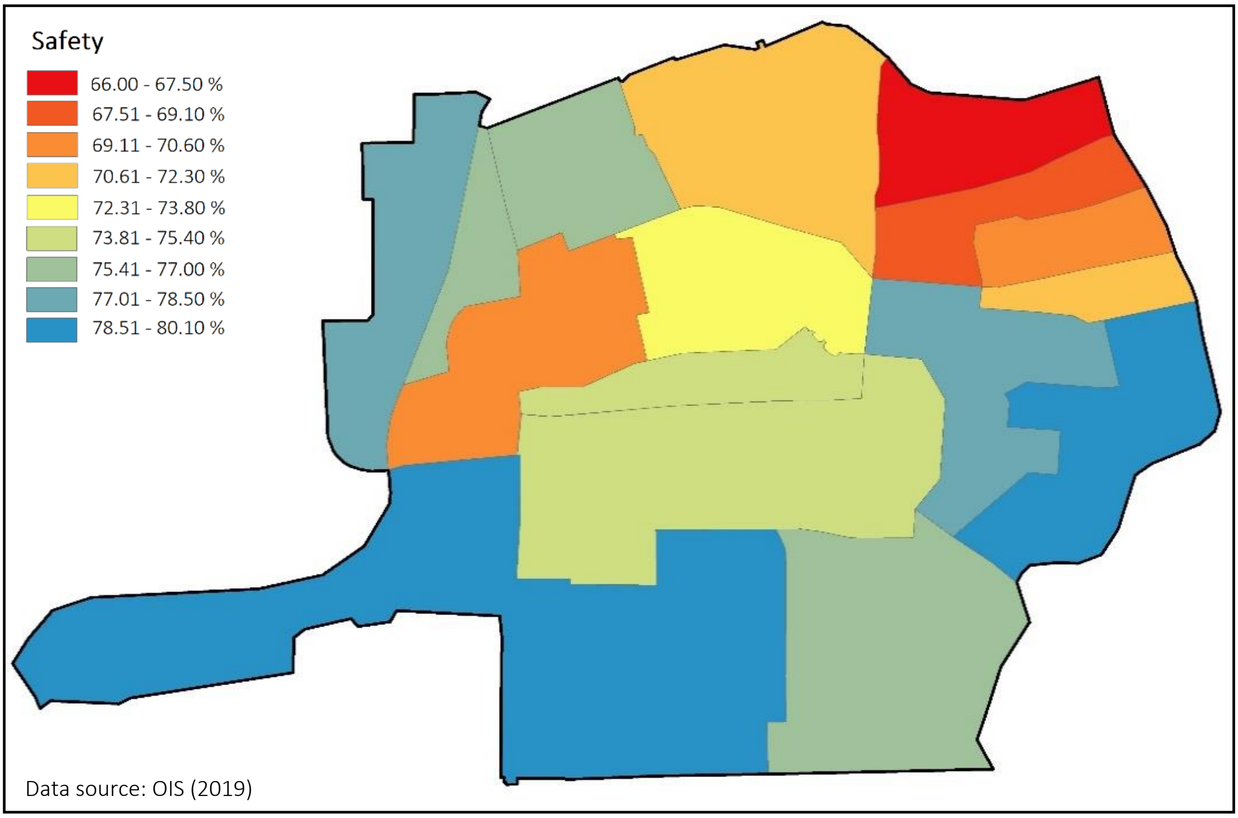





Distance to bee hive
1068 - 1200 m
935 - 1067 m
801 - 934 m
668 - 800 m
534 - 667 m
401 - 533 m
268 - 400 m
134 - 267 m
0 - 133 m
Data source: OIS (2017)


Residents with good perceived health
69 - 70.7 %
70.8 - 72.5 %
72.6 - 74.3 %
74.4 - 76.1 %
76.2 - 77.9 %
78 - 79.7 %
78.8 - 81.5 %
81.6 - 83.3 %
83.4 - 85.1 %
Data source: GiB (2016)


Satisfaction
87.5 %
93.04 %
96.38 %
Data source: GiB (2016)


Safety
66.00 - 67.50 %
67.51 - 69.10 %
69.11 - 70.60 %
70.61 - 72.30 %
72.31 - 73.80 %
73.81 - 75.40 %
75.41 - 77.00 %
77.01 - 78.50 %
78.51 - 80.10 %
Data source: OIS (2019)

Appendix B: Prioritization for all potential urban park locations

Prioritzation score	*MCA value*	*Connectivity value*	*Surface in square meters*	*Perimeter-Area Ratio*	*Neighborhood*
1	5.5	5.14	256	0.37	Stadionbuurt
2	5.37	6.59	755	0.37	Stadionbuurt
3	5.33	5	309	0.34	Stadionbuurt
4	5.26	4.64	1261	0.27	Stadionbuurt
5	5.18	4.55	765	0.31	Stadionbuurt
6	5.17	5.35	2208	0.31	Stadionbuurt
7	5.14	4.46	229	0.36	Zuidas
8	5.13	4.64	2042	0.4	Stadionbuurt
9	5.05	5.47	1274	0.36	Stadionbuurt
10	5.01	4	306	0.29	Stadionbuurt
11	5	3	305	0.29	Stadionbuurt
12	4.98	6.06	200	0.36	Buitenveldert-Oost
13	4.87	4.5	184	0.35	Buitenveldert-Oost
14	4.76	7	552	0.36	Buitenveldert-Oost
15	4.65	2.71	3205	0.17	Stadionbuurt
16	4.59	3.49	934	0.36	Stadion Zuid/WTC
17	4.51	2.36	2793	0.15	Stadionbuurt
18	4.5	4.75	816	0.33	Zuidas
19	4.46	2.78	2393	0.18	Museumkwartier
20	4.46	4.22	709	0.37	Stadion Zuid/WTC
21	4.4	4.57	255	0.33	Stadionbuurt
22	4.4	2.74	899	0.35	Ijsselbuurt
23	4.35	5.88	307	0.37	Buitenveldert-Oost
24	4.34	4.37	186	0.38	Buitenveldert-Oost
25	4.33	4.6	1648	0.22	Zuidas
26	4.33	2.08	556	0.31	Stadionbuurt
27	4.32	1.42	4978	0.29	Stadionbuurt
28	4.31	4.45	827	0.36	Zuidas
29	4.3	4.87	286	0.28	Apollobuurt
30	4.29	4.17	1109	0.26	Zuidas
31	4.21	4.83	259	0.36	Buitenveldert-West
32	4.2	6.29	368	0.36	Oude Pijp
33	4.2	4.33	202	0.35	Stadion Zuid/WTC

Prioritzation score	*MCA value*	*Connectivity value*	*Surface in square meters*	*Perimeter-Area Ratio*	*Neighborhood*
34	4.13	2.57	798	0.35	Oude Pijp
35	4.12	1.58	765	0.22	Stadionbuurt
36	4.08	2.92	182	0.35	Nieuwe Pijp
37	4.03	1.67	1528	0.38	Diamantbuurt
38	4.01	1.87	651	0.25	Stadionbuurt
39	3.98	2.94	292	0.27	Museumkwartier
40	3.93	1.57	329	0.35	Buitenveldert-Oost
41	3.88	4.94	501	0.37	Zuidas
42	3.87	3.05	438	0.31	Stadion Zuid/WTC
43	3.85	3.72	301	0.32	Zuidas
44	3.81	1.58	327	0.29	Museumkwartier
45	3.77	3.13	1699	0.19	Zuidas
46	3.77	4.22	674	0.39	Zuidas
47	3.75	3.87	1317	0.21	Zuidas
48	3.75	5.29	135	0.4	Scheldebuurt
49	3.73	2.12	3380	0.39	Buitenveldert-Oost
50	3.72	3.13	3474	0.24	Zuidas
51	3.68	2.86	1559	0.23	Zuidas
52	3.68	2.89	275	0.37	Buitenveldert-Oost
53	3.66	3.1	304	0.29	Museumkwartier
54	3.63	3.34	1454	0.15	Zuidas
55	3.62	2.26	284	0.34	Buitenveldert-Oost
56	3.61	1.91	8332	0.15	Museumkwartier
57	3.61	3.75	240	0.39	Buitenveldert-West
58	3.57	3.47	1085	0.16	Zuidas
59	3.54	1.88	681	0.36	Nieuwe Pijp
60	3.52	3.82	610	0.23	Zuidas
61	3.47	2.08	546	0.28	Ijsselbuurt
62	3.44	1.83	634	0.3	Buitenveldert-West
63	3.39	2.18	258	0.29	Zuidas
64	3.39	1.93	1396	0.22	Museumkwartier
65	3.38	2.88	400	0.37	Apollobuurt
66	3.37	2.55	4639	0.19	Buitenveldert-West

Prioritzation score	*MCA value*	*Connectivity value*	*Surface in square meters*	*Perimeter-Area Ratio*	*Neighborhood*
67	3.36	2.13	1675	0.36	Zuidas
68	3.32	3.13	281	0.35	Zuidas
69	3.27	1	203	0.33	Zuidas
70	3.24	2.33	1154	0.33	Zuidas
71	3.18	2.18	319	0.29	Museumkwartier
72	3.18	2.45	1229	0.25	Rijnbuurt
73	3.17	1.42	258	0.28	Willemspark
74	3.16	1.94	1521	0.14	Museumkwartier
75	3.15	2.85	242	0.39	Buitenveldert-West
76	3.15	2.28	795	0.21	Zuidas
77	3.12	2	332	0.36	Museumkwartier
78	3.11	1.59	2257	0.15	Zuidas
79	3.1	2.54	460	0.26	Oude Pijp
80	3.03	2.37	361	0.36	Hoofddorpplein
81	3.03	3.44	901	0.34	Scheldebuurt
82	3.02	1.5	451	0.28	Rijnbuurt
83	3.02	2.04	1013	0.26	Stadion Zuid/WTC
84	3.01	3.73	925	0.38	Buitenveldert-West
85	3.01	2.7	1339	0.39	Scheldebuurt
86	3	1	470	0.23	Hoofddorpplein
87	3	2.01	140	0.39	Hoofddorpplein
88	3	1.07	1114	0.38	Zuidas
89	3	1.05	822	0.35	Museumkwartier
90	2.98	2.24	182	0.37	Buitenveldert-West
91	2.95	3.47	260	0.38	Buitenveldert-West
92	2.84	2.91	1045	0.33	Scheldebuurt
93	2.81	1.95	360	0.37	Scheldebuurt
94	2.77	2.8	278	0.38	Buitenveldert-West
95	2.75	1.2	2740	0.19	Zuidas
96	2.75	2.67	268	0.36	Buitenveldert-West
97	2.49	2.47	330	0.27	Buitenveldert-West
98	2.22	1.33	523	0.4	Stadion Zuid/WTC
99	2.01	1.24	237	0.32	Buitenveldert-West