Thesis report

Urban Liveability:

The effects of the built environment on the attractiveness of an area for physical activity for different demographic groups

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Date: 28-02-2020

Abstract

Physical activity is becoming one of the major global health risks in today's society. Statistics show that more people are less physically active. This physical inactivity can lead to multiple serious health issues. Therefore, governments, organisations and institutions are developing different policies and measures in order to improve and stimulate physical activity. Most policies and measures are related to the built environment, because the built environment should provide people with comfortable, safe and attractive spaces to be physical active. However, what is considered as comfortable, safe and attractive spaces can differ per person and/or group. In addition, the available studies on this topic show that the built environment affects the physical activity of people significantly, but that these correlations are not statistically confirmable. These available studies make however no distinction between the effects of different built environment features on the attractiveness of an area for physical activity for different demographic groups.

Therefore, this research has the research objective; *Determine how the built environment affects the attractiveness of streets for physical activity for different demographic groups*. This research objective implies that this research first of all distinguishes the different relevant demographic groups in relation to physical activity and the built environment. Secondly, it studies which built environment features are relevant to include for what demographic group. This will result in a conceptual framework that shows how the attractiveness of an area for physical activity is affected by which built environment features for which demographic group. Finally, this research applies and demonstrates this framework in the case of Amsterdam. By doing so, per street of Amsterdam and per included demographic group an attractiveness score for physical activity is developed.

For five neighbourhoods of Amsterdam their streets and their corresponding attractiveness scores are analysed in detail. First of all, this analysis shows how the attractiveness scores are developed per demographic group. Secondly, it shows which built environment features are most determining the attractiveness score of an area for physical activity for which demographic group. Finally, this analysis provides insights in where the most determining features are and especially where they are not in a neighbourhood. With these insights of the construction of the attractiveness scores of streets and neighbourhoods, the attractiveness for physical activity of these streets and neighbourhoods can be improved. When it is known where specific built environment features are lacking in a street or area for a specific demographic group, these streets or areas and their built environment features can be specifically targeted so that the attractiveness for physical activity for a specific demographic group can be improved.

Preface & acknowledgements

This thesis report has been written as part of the MSc programme Geographic Information Management and Applications, commissioned by the University of Utrecht, University of Twente, Wageningen University and Research, and Delft University of Technology. From September 2019 till February 2020 this research for this thesis report took place under the supervision of Dr. Ir. Arend Ligtenberg.

At the beginning of my thesis I had some difficulties with deciding an interesting topic for my thesis research. After discussing different topics with different potential supervisors, I decide to focus my research on physical activity and the built environment. I choose this topic, because I noticed that I was enthusiastic and motivated when I told people about this research topic I was considering. Now that my thesis report is completed, I look back with a satisfied and content feeling on the whole process. I can reflect that I am more than happy that I decided to research this topic. I noticed that now my thesis is finished, I look differently to my surroundings and how these surroundings affect my interpretations and feelings of the area I am in. I now even go for a walk around my neighbourhood every now and then. Of course, I cannot claim that this is due to my thesis, but I am sure that it contributed. I believe that this shows, that I not only developed new technical skills during this research process, but that I also developed a new and/or different way of looking at my surroundings. Ultimately, I hope that through this thesis report and research I can change the way you look to your surroundings, and hopefully will even motivate you to be more physical active.

This thesis will not have succeeded without the supervision of Dr. Ir. Arend Ligtenberg. Therefore, I would like to thank him for his excellent supervision during the whole process. I must compliment him for his quick and adequate answers to my questions. Furthermore, he helped me with keeping a clear overview of what steps are needed to take. Also, He also supported me by looking at the bigger picture of my thesis whenever I was deeply focused on a minor technical aspect of this research. Besides Dr. Ir. Arend Ligtenberg, I would like to thank my friends and family for their support during the process.

Finally, with the completion of this thesis I can start with an internship which forms the final chapter of my student career.

With all that being sad, I hope that you enjoy reading this thesis report.

Bram de Rijk

Abbreviations

AHP	-	Analytical Hierarchy Approach
BAG	-	Basis Registration Addresses and Buildings / *Basisregistratie Adressen en Gebouwen*
FSI	-	Floor Space Index
GGD	-	Municipal Health Services / *Geneeskundige en Gezondheid Dienst*
GIS	-	Geographical Information System
MAUP	-	Modifiable Area Unit Problem
MCA	-	Multi Criteria Analysis
OIS	-	Research, Information and Statistics / *Onderzoek Informatie Statistiek*
OSM	-	Open Street Map
PBL	-	Netherlands Environmental Assessment Agency / *Planbureau voor de Leefomgeving*
WHO	-	World Health Organisation
WUR	-	Wageningen University and Research

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1.0 Introduction

1.1 Context

In today's society physical activity and especially physical inactivity is becoming a global concern. Studies show that currently more and more people are becoming less physical active, as one out of four adults and even three out of four adolescents (11-17 years old) fail to meet the World Health Organisation (WHO) recommendations on physical activity (Guthold et al., 2018). These are alarming numbers, since sufficient physical activity helps to prevent and treat a number of serious noncommunicable diseases such as heart diseases, strokes, diabetes and several forms of cancer (WHO, 2010). In addition, the WHO even identified physical inactivity as the fourth leading risk factor for global mortality (WHO, n.d.).

In order to promote physical activity the WHO launched the Global Action Plan on Physical Activity in 2018. The aim of this plan is a 15% relative reduction in the global prevalence of physical inactivity in adults and in adolescents by 2030 (WHO, 2018). However, improving physical activity is complex and difficult, due to the different forms of physical activity which are affected by different cultural, environmental and individual determinants. In general three forms of physical activity can be identified. First of all, there is casual physical activity, which includes the forms of physical activity such as walking, cycling, sport and other recreational forms (WHO, 2018). Secondly, there is the physical activity that is related to work, which includes forms of lifting, moving and other active tasks (WHO, 2018). Third and finally, there is domestic physical activity including physical activity forms such as cleaning (WHO, 2018).

These different forms of physical activity are affected by different individual, cultural and environmental features. For example, the amount of sport facilities in an area affects the participation in sports, and thus casual physical activity (Prins et al., 2010 & Eime et al., 2017). Therefore, the WHO aims to realise this reduction by making it easier for all people to be more active by addressing the cultural, environmental and individual determinants of physical (in)activity (WHO, 2018). Especially casual physical activity is important in the global action plan, because casual physical activity is, compared to the other forms of physical activity, a physical activity form that is not necessary. Where work or domestic physical activity are necessary and in some cases mandatory (work related physical activity), casual physical activity is done by choice and in people's free time. Because this casual physical activity is optional, it is the most decreasing form of physical activity. One of the explanations for this decrease is because casual physical activity used to be part of everyday life, but nowadays it is not (Winston et al., 2001).

One of the objective of the WHO global action plan is to create active environments. This objective addresses the need to create supportive spaces and places that promote and safeguard the rights of all people, of all ages and abilities, to have equitable access to safe places and spaces in their cities and communities in which they can engage in regular physical activity (WHO, 2018). In other words, this objective aims to create more inviting and attractive areas and spaces for physical activity. This objective highlights the importance of the built environment in the promoting and stimulating physical activity. That the built environment can affect physical activity is reflected by the study of Sallis et al. (2016). This study shows that differences in the attractiveness of the built environment for physical activity results in differences in physical activity; where physical activity levels range from 68 min/week in the least attractive neighbourhoods to 89 min/week in the most attractive neighbourhoods (Sallis et al., 2016).

That the built environment can affect physical activity is reflected by the example in Box 1.0, which shows the Porto Maravilha project in Rio de Janeiro. This project shows that a transformation of the built environment can affect the overall attractiveness of an area. As the example shows, the more attractive an area is the more inviting the area is for (casual) physical activity such as walking or cycling. Therefore, it is important to not underestimate the effects of the built environment on the attractiveness of an area or space for physical activity.

Box 1.0: Porto Maravilha project

(Photos by Companhia de Desenvolvimento Urbano da Região do Porto do Rio de Janeiro [Cdurp].)

Although the shown area in the pictures is only a small part of the whole transformation of the old harbour area, it already illustrates the impact a transformation of the built environment can have. The top picture shows the old situation, where an elevated highway limits the space and opportunities for pedestrians, cyclists and even for some forms of public transport (trams). The bottom picture shows the transformed situation, where the highway is removed and a tramrail is developed resulting in more space for pedestrians and cyclists. Next to that, more public and green space is realised to improve the overall attractiveness of the area. For many people the transformed area (bottom picture) is more attractive and more inviting for physical activity than the old situation (top picture). This example illustrates the influence a transformation of the built environment can have on the overall attractiveness, and on the attractiveness for physical activity of an area.

1.2 Problem statement

As stated, the built environment affects attractiveness for physical activity. However, the built environment is a broad concept and contains many different features. Some example of built environment features are the proximity to green and public spaces, the width of the pedestrian lanes and/or the amount of street lights. Therefore, different built environment features can affect the attractiveness of an area for physical activity. In the current literature different studies focus on different built environment features that affect physical activity. These studies focus on the built environment features that promote and attract 'general' physical activity. This implies that the built environment features that affect the attractiveness for physical activity have the same effects for everyone. However, different built environment features affect the attractiveness of an area for physical activity differently per person or group. For example, where the built environment feature; the amount and proximity of playgrounds, can be attractive for children and young families, it can be less attractive or even unattractive for students and/or elderly. Without acknowledging the effects of different built environment features on the attractiveness for physical activity for different demographic groups, policies and measures can lead to undesired effects on physical activity such as the exclusion of people and/or a decrease in physical activity.

1.3 Relevancy

1.3.1 Scientific Relevancy

The effects of the built environment on physical activity is a topic that is and has been studied extensively. Especially the effects of the built environment on travel behaviour of people is well researched. However, most of these studies on travel behaviour focus on car usage and the effects the built environment can have to reduce car usage. The studies that address the effects of the built environment on physical activity and especially on active travel (walking and cycling) is increasing rapidly. This is reflected by a timeline of published scientific literature on this topic; an online search for scientific literature related to the build environment and physical activity up to the year 2000 results in 17 relevant articles, while the same query used for the years 2001-2010 results in 570 articles, and the years 2011-2018 in 1286 articles (Nieuwenhuijsen and Khreis, 2018). Although this rapid increase of studies on this topic, only a few studies focus on the effects of the built environment on physical activity for different demographic groups. Most of the available studies research the effects of the built environment for one demographic group most of the times aged 18 to 65. For example, the aforementioned study by Sallis et al. (2016) uses data for people with the age 18 to 66 years.

The recently published study by Guthold et al. (2018) deviates from the standard 18 to 65+ age group and focuses on adolescents with an age of 11 to 17 years old. However, this study only analyses the amount of physical activity among the adolescents and does no analysis on the variables influencing their physical activity. Therefore, there exists a scientific gap in the understanding of the effects of the built environment on the attractiveness of an area for physical activity for different demographic groups. This research aims to fill this gap by researching how the built environment affects the attractiveness of an area for physical activity for different demographic groups.

1.3.2 Social relevancy

That physical activity and especially physical inactivity is an important topic in today's society is reflected by the identification of physical inactivity as the fourth leading risk factor for global mortality by the WHO (WHO, n.d.). Furthermore, the study by Ding et al. (2016) estimates that in 2013 the global direct health care costs of physical inactivity is around $54 billion. In addition, estimations are that physical inactivity accounts for 1 to 3 percent of the national health care expenses for both high-income as for low- and middle-income countries (Bull et al., 2017). These figures highlight the importance of physical activity and explains why the WHO has launched the Global Action Plan on Physical Activity. As stated, the effects of the built environment on physical activity must not be underestimated. Especially the effects on different demographic groups must be better understood. This research aims to improve the knowledge of the effects of the built environment on the attractiveness of an area for physical activity for different demographic groups. By doing so, it can contribute to both the WHO global action plan as to national, regional and even local policies to stimulate physical activity.

1.4 Research Objectives

As the previous paragraphs have indicated, there is little known about the effects of the built environment on the attractiveness of an area for physical activity for different demographic groups. Therefore, the goal of this research is to improve this understanding of these effects for different demographic groups. This goal can be transformed in the following main research objective:

- Determine how the built environment affects the attractiveness of streets for physical activity for different demographic groups.

In order to conduct this research in a structured manner the main research objective has been split up in the following sub research objectives:

- Determine which demographic groups are relevant to distinguish with respect to the relation between physical activity and built environment features.
- Determine which built environment features are relevant for which demographic groups.
- Develop a framework that combines built environment features as attractivity indicators that calculate and determine the attractiveness of an area for different demographic groups.
- Implement and demonstrate this framework in the case of Amsterdam.
- Validate the framework and test its plausibility.

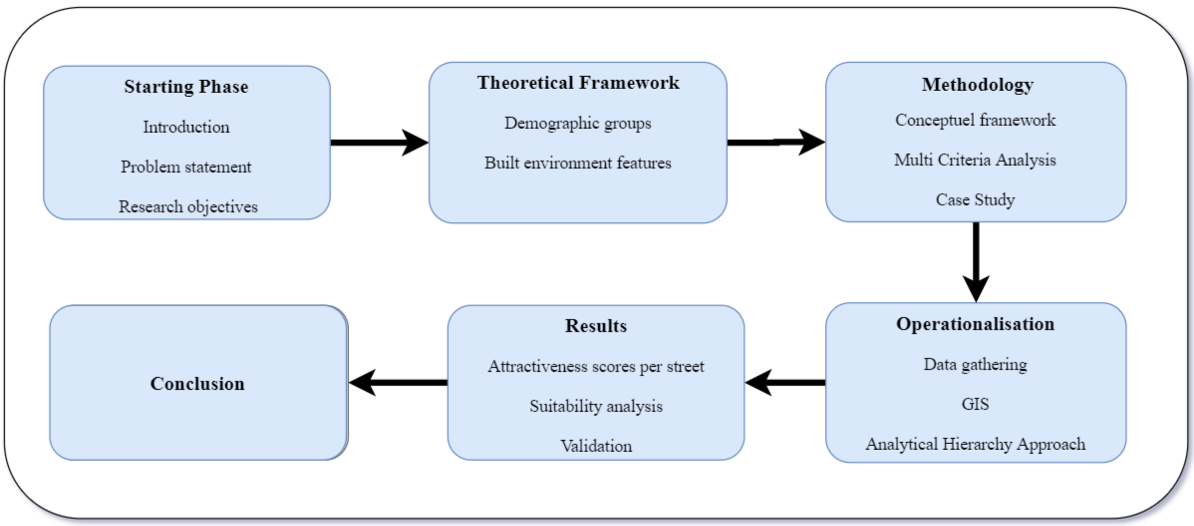
1.5 Research scope

Because this research has its time and budget constraints it is important to set a clear scope for this research. By doing so, an achievable research is set out that can contribute to the current research and literature on this topic. Since the association between both different demographic as socio-economic characteristics with physical activity is already well researched and established, they are not further analysed in this research. However, this research focuses on the effects of the built environment on the physical activity attractiveness of an area for different demographic groups. Therefore, the demographical characteristic of age is included in this research to distinguish the different demographic groups. Nevertheless, the main focus is on the built environment and their effects on the attractiveness of an area for physical activity. In other words, this research analyses the effects of the built environment on the attractiveness for physical activity and not on the quality of life. Finally, it is important to note that this research focuses solely on the casual physical activity form of walking. The other forms of physical activity (work or domestic physical activity) can be seen as necessary physical activities and are therefore less susceptible to the influence of the external factors such as the built environment.

1.6 Research set-up

In figure 1.6.1 the research set-up is shown. This figure can be used as a reading guide for this research. The overview shows that this research has several steps. With these steps each sub-objective of this research will be answered. Finally, based on the sub-objectives the main research objective will be answered.

Figure 1.6.1: Research set-up overview



Source: Author

As depicted in the 'Starting Phase' block, the first step is the set-up of this research. Here, the context, objectives, and methodology are formulated.

The second step of this research is the development of a theoretical framework. This theoretical framework forms the foundation of this research and is based on a critical literature review. The first thing that has to be determined are the different demographic groups that are taken into account in this research. The demographic groups will be categorized based on a critical literature review of researches that focus on physical activity of different demographic groups. By doing so, the first sub-objective will be answered.

As stated before, some built environment features may be more attractive for physical activity for one demographic group, while it can be less attractive or even unattractive for another demographic group. Therefore, the next step of this research is to analyse which built environment features are relevant for which demographic group. This will be partly based on a critical literature review and partly based on common sense. For example, it seems intuitive that playgrounds are more attractive for physical activity for children than for elderly. By determining the built environment features that are that are relevant per demographic group, the second sub-objective will be answered.

With the knowledge of the first two sub-objectives a conceptual framework can be developed that shows the built environment features that affect the attractiveness of an area for physical activity for different demographic groups. This framework will then be applied in the case of Amsterdam. In order to apply the framework, data on the relevant built environment features have to be collected. Most of the data will derive from the open data of the municipality of Amsterdam. However, some built environment features may have to be developed specifically for this research. In such cases, different Geographical Information System (GIS) methods, techniques and tools will be used. The data gathering will result in a database containing information on all the relevant built environment features of Amsterdam, that affect the attractiveness of an area for physical activity for different demographic groups.

With this database different Multi Criteria Analysis (MCA) can be performed. Based on the previously mentioned framework, the MCAs will use different built environment features with different weights depending on the demographic group. The MCAs will result in data that can be visualised in maps, which will show the attractiveness per street for physical activity for different demographic groups. With the knowledge of which streets (and therefore neighbourhoods) are most suitable for what demographic group, a suitability analysis can be done. By comparing the actual demographic composition of a neighbourhood with the attractiveness scores for physical activity of that neighbourhood, the suitability of that neighbourhood for the population living in that neighbourhood can be analysed. For example, a neighbourhood where many elderly live, but that has a low attractiveness score for physical activity for elderly can be considered as a poor or bad fit.

Finally, with these analysis and developed attractiveness scores this research con formulated a conclusion and discussion. In the conclusion the main research objective is answered, and in the discussion the strong and weak points of this research are discussed.

2.0 Theoretical framework

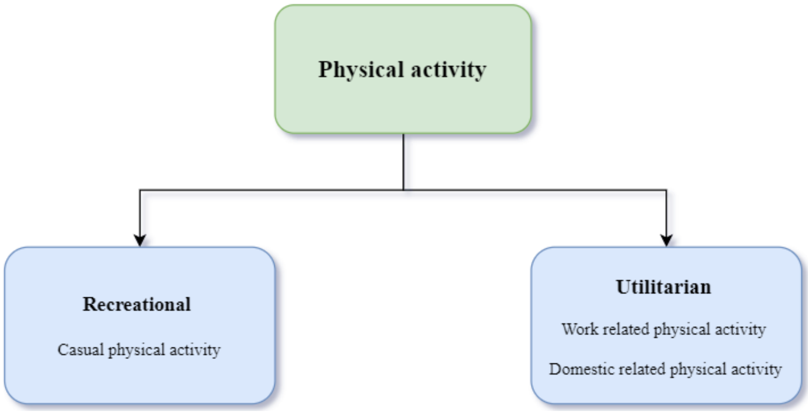
As stated, this research aims to fill the gap of the understanding on the effects of the built environment on the attractiveness of an area for physical activity for different demographic groups. In this chapter the theoretical foundation for this research is formed. This chapter starts by discussing the different forms of physical activity and which form of physical activity is addressed in this research. The second part of this chapter starts with a review of the existing literature on the relation between the built environment and physical activity, whereby the focus of the review is on what demographic groups were used in which studies. Doing so, provides insights in what the most common studied demographic groups are and which demographic groups are less or even not studied at all on this topic. Based on this knowledge the different demographic groups that are addressed in this research are determined and the first sub-objective will be answered.

The third and final part of this chapter focuses on which built environment features can affect physical activity. The focus here is, again, on the relation between the built environment features and its effects on the attractiveness of an area for physical activity for different demographic groups. In order to determine the relevant built environment features, a second literature review is conducted. The results of this literature review in combination with the different demographic groups will result in a conceptual framework showing the relation between different built environment features and the attractiveness for physical activity, which consequently answers the second sub-objective.

2.1 Types of physical activity

As stated, there are different forms and types of physical activity ranging from weightlifting and snowboarding to walking and cleaning. In general physical activity can be undertaken for two purposes, either recreational or utilitarian. Where the recreational forms of physical activity are done by choice and undertaken in people's free time, the utilitarian physical activities are done to accomplish other purposes (Lawrence et al., 2003). Although this distinction seems clear, there are some forms of physical activity that can be both utilitarian and recreational. For example, the physical activities forms of walking and/or cycling can be recreational in forms of jogging or mountain biking, or utilitarian when a person walks or cycles to school or work. The WHO also distinguishes these different forms of physical activity. They categorise physical activity in casual, work related and domestic related physical activities (WHO, 2018). Casual physical activity includes the forms of physical activity such as walking, cycling, sport and other recreational forms (WHO, 2018). The work related physical activity includes forms of lifting, moving and other active tasks, and the domestic related physical activity relates to forms such as cleaning (WHO, 2018). These three different forms distinguished by the WHO can be placed under either recreational or utilitarian physical activity as is shown in figure 2.1.1. However, as stated some forms of physical activity can be both forms such as walking and cycling.

Figure 2.1.1: Classification of physical activity



Source: Author

These different forms of physical activity are affected by different factors such as personal (age, sex, income) and environmental characteristics (weather, built environment). Some forms of physical activity are more affected by these characteristics than others. For example, the utilitarian forms of physical activity are necessary or even mandatory (work related physical activity) and are therefore less susceptible to the influencing effects of environmental characteristics such as the weather (WHO, 2018). Because casual physical activity is done by choice and undertaken in people's free time, it can be more affected by personal and environmental characteristics such as personal motivation, the weather and the attractiveness of the built environment (WHO, 2018).

Casual physical activity itself can also be in different forms such as walking, cycling, sport activities or other recreational forms (WHO, 2018). Because sport related or other recreational forms of physical activities are most of the times planned, structured, repetitive, and purposeful for improving or maintaining physical fitness (WHO, n.d.), they are less affected by personal and environmental characteristics than walking and/or cycling. One could even argue that walking and cycling are, compared to the other forms of physical activity, the most affected by personal and environmental characteristics. Furthermore, different studies have found that that walking is one of the easiest physical activities to undertake, because it can be done at any time and requires no special equipment or clothing. Therefore, it can easily be incorporated into the daily routine (Hamdorf et al., 2002; Tudor-Locke et al., 2002). However, some personal and built environment features can restrain people from incorporating walking and cycling in their daily routine. For example, the lack of decent quality sidewalks, no or limited number of cycling lanes and/or unsafe environments for walking and/or cycling.

As stated, this research focuses solely on the effects of the built environment on the attractiveness of streets for the casual physical activity form of walking. This research includes only the form of walking, because walking is considered as the easiest physical activity form to undertake. Although cycling is also considered as a relatively easy physical activity form to undertake, it is not included in this research. The reason to exclude cycling is because cycling allows cyclist to travel further distances. Therefore, one could argue that the close surroundings (built environment) has potentially less effects on the attractiveness of streets for cycling. Furthermore, walking is allocated to the sidewalks and/or pedestrian lanes, while cycling is allocated to cycling lanes or sharing the road with cars. This implies that for cycling other variables than the built environment features have a significant role in determining the attractiveness, while for walking the built environment has a significant effect on the attractiveness. Therefore, this research focuses on the effects on the built environment on casual physical activity in the form of walking.

2.2 Demographic groups

In this research it is important to distinguish different demographic groups. As stated, existing studies in this field focus solely on one demographic group or assume that the built environment has the same effects on the attractiveness of an area for all people. Therefore, this research distinguishes three different demographic groups as shown in table 2.2.1. These demographic groups are included based on age. The following paragraphs elaborate on the choice for these demographic groups.

Table 2.2.1: Overview of different demographic groups

Demographic group	Age
Children	0 to 18 years
Adults	18 to 65
Elderly	65 and older

2.2.1 Children & adolescents

The first demographic group included in this research are children. This demographic group is perhaps most affected by the built environment, since their environment is, compared to the other demographic groups, limited. Most children are reliant on their parents and/or caretakers for travelling long(er) distances. Therefore, most children are limited to the spaces and surroundings of their homes for physical activities. This implies that the attractiveness of the built environment features for physical activity of these spaces and surrounding, significantly affect the physical activity of children. Therefore, it is important to focus on this demographic group and to analyse what built environment features contribute to the attractiveness of an area for physical activity for children.

The study by Ding et al. (2011) shows that the demographic group of children is addressed in many studies. Their study reviews the available studies on the association between environmental features and physical activity among youth. Based on certain criteria such as, study population must be between 3-18 years old and the sample size must be larger than 50, they reviewed a total of 103 papers related to the association between environmental features and physical activity among youth (Ding et al., 2011). This extensive amount of studies highlights the importance of children in this research topic. Besides the confirmation of the importance of children in this field of research, the extensive amount of studies also shows that there are differences in terms of age in this demographic group. The study by Ding et al. (2011) analysed that from the 103 studies, 56 are related to children (aged 3 to 12 years old), 38 are related to adolescents (aged 13 to 18 years old) and that 9 studies are related to both age groups. This indicates that in the existing literature a distinction is made between children and adolescents.

The recent study by Guthold et al. (2018) reflects this distinction of age groups among youth as their study analyses the physical (in)activity among 1.6 million school-going adolescents aged 11–17 years. This distinction of age for youth is also representative for the case of Amsterdam. The study by the Steenkamer et al. (2017) reflects this as their study monitors the results of a policy implemented in Amsterdam in 2013 to improve the health among the youth. In this study the youth is categorized in three groups; 2 and 3 year olds, 5 and 10 year olds, and 14 and 16 year olds.

Although the work by Ding et al. (2011) is extensive and includes many studies, some remarks must be noted. First of all, because their study is conducted in 2011 and, as stated before, the attention for the relation between the built environment and physical activity is growing rapidly, the number of studies related to the youth have most likely increased. Furthermore, Ding et al. (2011) only used the Active Living Research (ALR) database for their search on publication on this topic. Therefore, their study potentially miss relevant studies. However, these remarks only further confirm the importance of children and adolescent on this topic as there are potentially even more studies available that focus on children and adolescent.

Although these studies indicate that there are differences in the demographic group of children based on their age, this research makes no distinction between the younger and older children. The main reason for this is that it is difficult and hard to assess and validate the different preferences of children and adolescents. Therefore, the age group of children is in this research 0 to 18 years old.

2.2.2 Adults

The third demographic group that is included in this research are adults aged 18 to 65 years old. This demographic group is most commonly used in studies on the relation between the built environment and physical activity. Although the literature review study by Badland and Schofield (2005) is not as extensive as the study by Ding et al. (2011), it indicates that the majority of studies on physical activity and built environment use adults as a demographic group. From the 24 studies analysed by Badland and Schofield (2005), only 2 studies include the demographic group of children. Furthermore, an online search for studies related to the built environment and physical activity confirms that the majority of studies use a demographic group aged 18 to 65 years old. The extensive amount of studies using adults as a demographic group can be explained by the way data on health, travel (behaviour) and physical activity is collected. Most data on health, travel (behaviour) and physical activity is collected through surveys. Since most surveys only include the adult population, the relevant health, travel (behaviour) and physical activity data is limited to this demographic group. In addition, compared to other demographic groups such as children and elderly, the demographic group of adults is the biggest in terms of absolute numbers. Therefore, many data on this demographic group is available. Therefore, this demographic group is included in this research.

2.2.3 Elderly

The final demographic group that this research takes into account are the elderly aged 65 years or older. This demographic group is included since this group is growing rapidly. Figures show that in the Netherlands the number of people older than 65 years old increased more than tenfold; in 1900 0.3 million people were 65 years or older and in 2018 3.2 million people were 65 years or older (Volksgezondheidenzorg.info, n.d.). In terms of percentages this demographic group increased from 6% of the total population of the Netherlands to 18% (Volksgezondheidenzorg.info, n.d.). This rapid growth implies that more care and attention is needed for this demographic group, especially in the field of physical activity. This rapid growth is therefore one of the main reasons for including the elderly as demographic group in this research.

A second reason is the susceptibility of elderly to the health implications of physical inactivity. Older adults who are physically active tend to have lower rates of all-cause mortality such as high blood pressure, heart disease and strokes, than older adults who are less physical active (WHO, n.d.). The importance of including elderly as a demographic group is also reflected by a study on the physical activity levels for different age groups in the United States, which shows that as the age increase the physical activity levels decrease (Frank et al., 2003).

Although elderly are less mobile and are less energetic than adults, they are also less limited by other activities such as work. Therefore, one could argue that they have more free time to undertake physical activity. Especially walking is a form of physical activity that is suitable for elderly as it one of the easiest physical activities to undertake, because it can be done at any time and requires no special equipment or clothing. Meaning that it can easily be incorporated into the daily routine (Hamdorf et al., 2002; Tudor-Locke et al., 2002). Therefore, the influence of the built environment can have significant effects in the physical activity levels among elderly. This makes the demographic group of the elderly, aged 65 years or older, an important demographic group in this research.

2.3 Built environment

Before the different built environment features that affect physical activity in the form of walking are discussed, it is important to establish what the built environment means and includes in this research. Different studies use different definitions of the built environment. For example, Cervero and Kockelman (p.200, 1997) define the built environment as: "*physical features of the urban landscape (i.e. alterations to the natural landscape) that collectively define the public realm, which might be as modest as a sidewalk or a neighbourhood retail shop or as large as a new town*". While Handy et al. (p.65, 2002) define the built environment as: "*The built environment comprises urban design, land use, and the transportation system, and encompasses patterns of human activity within the physical environment*". Although these definitions differ, they share common features. Based on these two definition of the built environment this research defines the built environment as: "*relating to the urban landscape that is constructed by humans in various forms ranging from small sidewalks to big building blocks*".

As the aforementioned figures of the published scientific studies illustrate, research on the effects of the built environment on physical activity is increasing rapidly (Nieuwenhuijsen and Khreis, 2019). Most of these studies are related to travel behaviour and what factors, such as the built environment, affect this behaviour. This travel behaviour relates to physical activity in the form of walking and cycling, because these forms can be seen as active travel. Active travel can be defined as traveling between locations using an active mode such as walking or cycling (Clark et al., 2014). Thus, most of the available studies analyse which built environment features affect (casual) physical activity in the forms of walking and cycling. In many of the existing studies different built environment features are included and analysed. This implies that there is a wide variety of built environment features available that affect casual physical activity. Although the wide variety of these features, it is possible to categorise the built environment features in the three or five D's using the study by Cervero and Kockelman (1997). The authors state that travel demand is based by the desire to reach places, and that the built environment features of these places can affect the amount of trips generated, the travel mode (car, bike, foot) and the route (Cervero & Kockelman, 1997). The authors first categorised these built environment features of places affecting the number of trips, the travel mode and the travel route in the three D's; Density, Diversity and Design. In 2001 they added the categories Destination accessibility and Distance to transit as the two other D's. The following paragraphs discuss the different D categories further.

2.3.1 Density

Density represents how compact the built environment is in various aspects (Cervero and Kockelman, 1997). For example, population density measures how many people are living per square meter or kilometre and household density measures how many households per square meter or kilometre there are. Other commonly used density aspects are; job density (number of jobs in an area divided by the population) (Cervero and Kockelman, 1997), building density (number of (residential) buildings per square meter or kilometre or per site) (Cervero and Kockelman, 1997). A more recent density feature is the Floor Space Index (FSI), which is the ratio between the floor space in a building and the size of the parcel on which the building sits (Handy et al., 2002 & Harbers et al., 2009).

From the five different categories density is regarded as the most important and is most commonly used in studies on physical activity and the built environment, because it is easy to implement and it directly affects walking (Lu et al., 2017; Handy et al., 2002). A reason why density directly affects walking is, because areas with higher neighbourhood densities have more nearby destinations such as parks, shops and jobs. These destinations contribute to the attractiveness of a space for walking (Forsyth et al., 2007; Lee and Moudon, 2006). Moreover, in areas with higher densities the distances to destinations are relatively short, which implies that it is more attractive to walk to these destinations (Gunn et al., 2017).

Higher density also contribute to demotivate motorized vehicle trips and promote other active forms of transportation such as walking and cycling, because in higher density areas less space is available for car parking and transit services are more accessible and often of higher quality (Cervero and Kockelman, 1997 & Moudon and Lee 2009). Therefore, density is seen as one of the most important built environment features that affect travel behaviour and therefore physical activity.

2.3.2 Diversity

Diversity accounts for the measurement of the different (mixed) land-uses in an area and the degree to which they represent that land area (Ewing & Cervero, 2010). Handy et al. (p.66, 2002) define land-use mix as: "*the relative proximity of different land uses within a given area*". Meaning that a mixed land-use area has multiple land-uses such as homes, stores, offices and parks. Cervero and Kockelman (1997) state that it is intuitive that the placement of supermarkets within neighbourhoods can produce walk and cycling trips that substitute car trips. Diversity further reduces the number of car trips, as restaurants, shops, and service outlets located in suburban office environments can induce workers to share rides by making midday destinations more conveniently reached, thus reducing the need to have a car (Cervero, 1989). Moreover, Tracy et al. (2011) argue that land-use mix is significant in explaining non-motorized and transit mode choice. In addition, the study by Ewing (1994) shows that more diversity stimulates (short) walking and cycling trips, since more and different destinations are reachable by active travel forms.

Ewing (1994) also argues that many of the previously mentioned density benefits may be related to mixed land-uses, because density and diversity usually co-exist and supplement each other. This co-existence and supplementation of diversity and design is further confirmed by the work of Frank and Pivo (1994), as their study shows that both mixed land-use and density influence the usage of single occupancy vehicles, public transport, and active modes of transport.

There are different methods to measure the diversity of an area. First of all, a simple form to calculate diversity is to measure the distance from a house to the nearest store or other form of land-use (Handy et al. 2002). A second method is to measure the shares (percentages or absolute numbers) of different land-use types present in an area (Handy et al., 2002). Another method to calculate land-use mix is the dissimilarity index which is considered more reliable.

This index is developed by Cervero and Kockleman (1997), it divides an area in grids cells and counts for each cell the number of neighbouring cells with a different type of land-use. Cervero and Kockelman (1997) also introduce and use the entropy index. This index is widely accepted and commonly used for representing the land-use mix by quantifying the homogeneity of land-use in a given area (Bordoloi et al., 2013). Although the dissimilarity and entropy index are the most commonly used methods to calculated diversity, Bordoloi et al. (2013) argue that these indexes have certain limitations. Therefore, they propose two new methods to measure diversity; Mix type index and Area index. Mix type index measures the allots points to each of the actively developed cells based on the mix of the land-uses in the surrounding cells (Bordoloi et al., 2013). The Area index is based on the land-use types linked with travel (mode). Here the assumption is that the mode choice differs for different work purposes inside a buffer zone of 500 meter, created around the trip origin (household in this case), and outside the buffer zone. Thereby it incorporates both land use spatial complementarity as functional complementarity (Bordoloi et al., 2013).

The diversity category must not be underestimated in analysing the effects of the built environment on the attractiveness of an area for physical activity. However, as Ewing (1994) argues density and diversity usually co-exist and supplement each other. This implies that both D's must be taken into account in any research on the built environment effects on physical activity.

2.3.3 Design

Design holds a wide variety of different built environment features. First of all, it contains different street network connectivity characteristics. Where connectivity can be defined as the directness and the availability of (alternative) routes from a certain point to another point within a street network (Handy et al., 2002). For example, design measures the connectivity of street through different network characteristics such as urban grids or more suburban networks formed out of curved streets with loops (Ewing and Cervero, 2010).

Street network connectivity can be measured in various ways. For example, the number of intersections per square kilometre indicates how well or poor an area is connected in regards to the street network. Another method to measure the street connectivity is to analyse the proportion of four- way intersections (Ewing and Cervero, 2010). The most commonly used connectivity measurement is the average block length (Handy et al., 2002). The longer a block length, the less connected the block is and the further the distance from one point to another point is, as is shown in figure 2.3.1. This figure shows that in an area with a block size of 150 by 150 meter a 700 meter as the crow flies distance results in a true distance of 1000 meters, while in an area with a block size of 500 by 500 meter it results in a true distance of 1400 meters.

Figure 2.3.1: Impact of different block lengths on street connectivity

Block size of 150 x 150 meters in Barcelona

Block size of 500 x 500 meters in Beijng

Source: Cervero et al., 2017

Besides the street connectivity, design also includes many different pedestrian orientated features such as sidewalk coverage, average building setbacks, street width, amount of pedestrian crossings, and/or street trees (Cervero and Kockelman, 1997; Ewing and Cervero, 2010). In some cases design even includes the aesthetics of an area that can contribute to the attractiveness of the area (Handy et al., 2002). However, as Handy et al. (2002) mention aesthetics is the most subjective feature of design. This subjectivity makes it difficult to include in research because it is hard to measure, since different people have different preferences in terms of attractive aesthetics. Some examples of these aesthetic features of an area are; the number and orientation of windows ("eyes" on the streets according to Jane Jacobs), street furniture, street lightning, street landscaping, art and building designs.

2.3.4 Destination accessibility

Destination accessibility measures the accessibility to trip attractions. It measures thereby not only the number of reachable trip attractions (destinations), but also the magnitude of activities of locations (Ewing and Cervero, 2010; Handy 1993). In other words, the level of accessibility of a place reflects the distribution of potential destinations around it (Handy, 1993). A simple example is the amount of attractions reachable in a certain (travel) time. This means that destination accessibility measures two things; the attractiveness of destinations and the cost of reaching them (Handy, 1993). This study by Handy (1993) further shows that this destination accessibility can either be on a regional or local scale. Handy (1993) defines local accessibility as nearby activities such as convenience stores, and regional accessibility as large shopping centres farther away. However, some studies use different regional accessibility definitions such as (simply) the distance to the central business district (Ewing and Cervero, 2010). Therefore, there exists a difference in which destinations are included on what scale and how well accessible they are. A way to measure destination accessibility is the gravity model of trip attraction (Ewing and Cervero, 2010).

2.3.5 Distance to transit

The final D category is distance to transit. This category includes, as the name implies, the average of the shortest routes from either residencies or from workplaces in an area to the nearest transit (Ewing and Cervero, 2020). An alternative way to measure the distance to transit is the transit route density. This method measures the distance between transit stops, or the number of stations per unit area, where it is measured by miles or kilometres of transit routes per square mile of land area.

Although transit use may not directly be related to physical activity it is still included as a D category, because it is almost always required to walk, and in some cases cycle, at one or both ends of a transit stop or trip (Ewing & Cervero, 2010).

2.4 Notes from previous research

A reoccurring issue in existing studies are the insignificant results of these studies. Many studies that analyse the effects of different built environment features conclude with the note that the analysed built environment features are influencing physical activity, but that it cannot be statistically confirmed due to the insignificancy of the results. One of the reason for these insignificant results is the influence of an intermediate variable that is often expressed by one of the other D's such as density. High density areas commonly have mixed uses, short blocks, and central locations, all of which shorten trips and encourage walking (Ewing and Cervero, 2010). Meaning that built environment features belonging to one D category also overlap and influence other D categories, which can result in insignificant results.

A second issue in previous research on physical activity and the built environment is related to self-selection. In the context of the built environment and physical activity self-selection relates to the tendency of people to choose locations based on their travel abilities, needs and preferences (Litman, 2011). In other words, people who are already physical active tend to live in areas that are more attractive for physical activity. Therefore, this self-selection aspect may result to biased results in research on the effects of the built environment on physical activity.

Finally, the issue of the geographical dimensions of an area that is considered in research on the built environment and physical activity needs to be mentioned. Different studies use different spatial sizes for different built environment features and physical activity analysis. This can lead to different outcomes for comparable analysis. For example, studies on the influence of the proximity and availability of green space on physical activity that use neighbourhoods of an European city can have different results than studies which use neighbourhoods of an American or Asian city. This is due to the differences in spatial size of European and American neighbourhoods. This spatial size issue occurs not only on global scale, but on all different scales. No clear rules or guidelines are available to measure neighbourhoods, since different people use different definitions of neighbourhoods (Spielman and Yoo, 2009). Openshaw and Taylor (1979) acknowledge this issue and define it as the Modifiable Areal Unit Problem (MAUP), which has the components scale and aggregation. An example of MAUP is given by Spielman and Yoo (p.1099, 2009); "*Imagine a map of a city; one could divide that map into 10, 20, 30, 100, or any number of subareas by drawing lines on the map. As one increases the number of subareas the scale of analysis is consequently deceased. Within a given scale, say the 10- zone scale, there are many, perhaps an infinite number, of ways to draw subareas. In the language of the MAUP this is known as zonation. Within a given scale there are many possible zonations*". Furthermore, the issue of MAUP implies that correlation and regression coefficients can unpredictably change when the scale and zonation change (Fotheringham and Wong, 1991).

Although these challenges of previous research, the categorisation of the five D's is still used to structurally list the different built environment features influencing physical activity. Nevertheless, these challenges from previous research have to be taken into account in this research.

3.0 Methodology

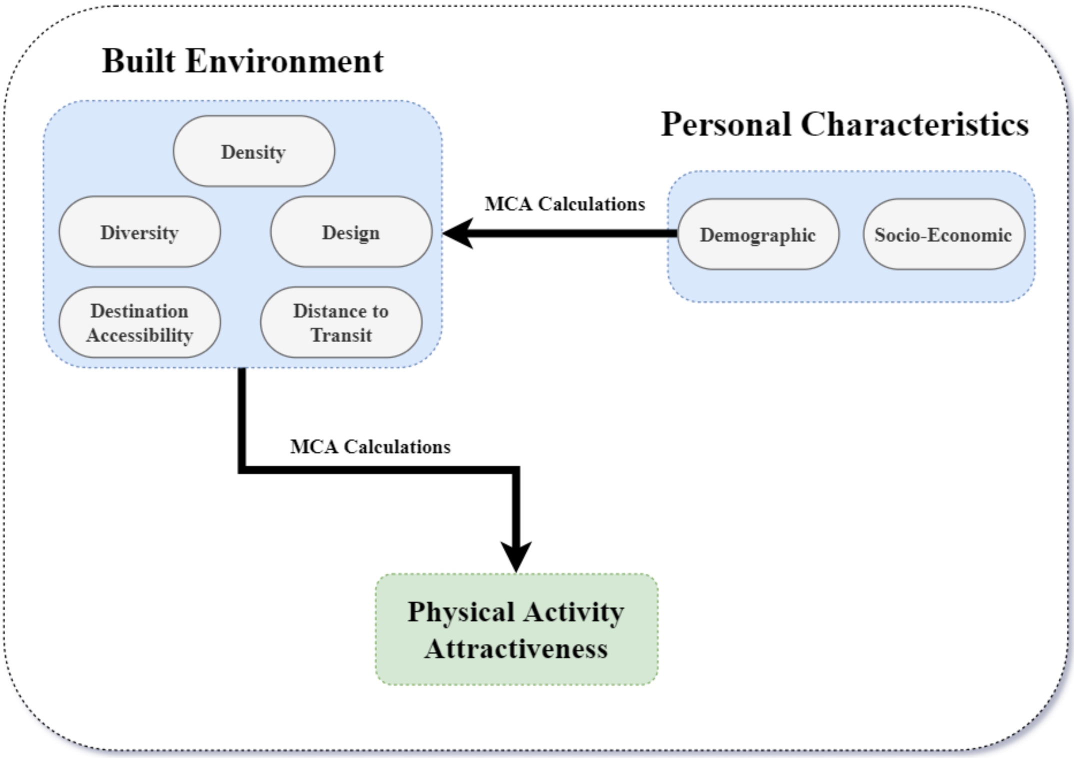
This chapter is split up in two sections. The first section presents and discusses the conceptual framework that is developed based on the literature review. This section also presents the case study of this research. Finally, the first section of this chapter discusses the use of the Multi Criteria Analysis (MCA) method and why this method is suitable for this research.

The second section addresses the used data. Based on the five D categories, determined in the theory chapter, different built environment features are included in this research. Per D category included built environment features are presented and their data source is mentioned.

3.1 Conceptual framework

The previous paragraphs have introduced and discussed different categories of the built environment features that affect travel behaviour and therefore physical activity in the form of walking. With the knowledge of the different built environment features that can affect physical activity of people and contribute to the attractiveness of an area for physical activity, the conceptual framework of figure 3.1.1 is developed.

Figure 3.1.1: Conceptual framework



Source: Author

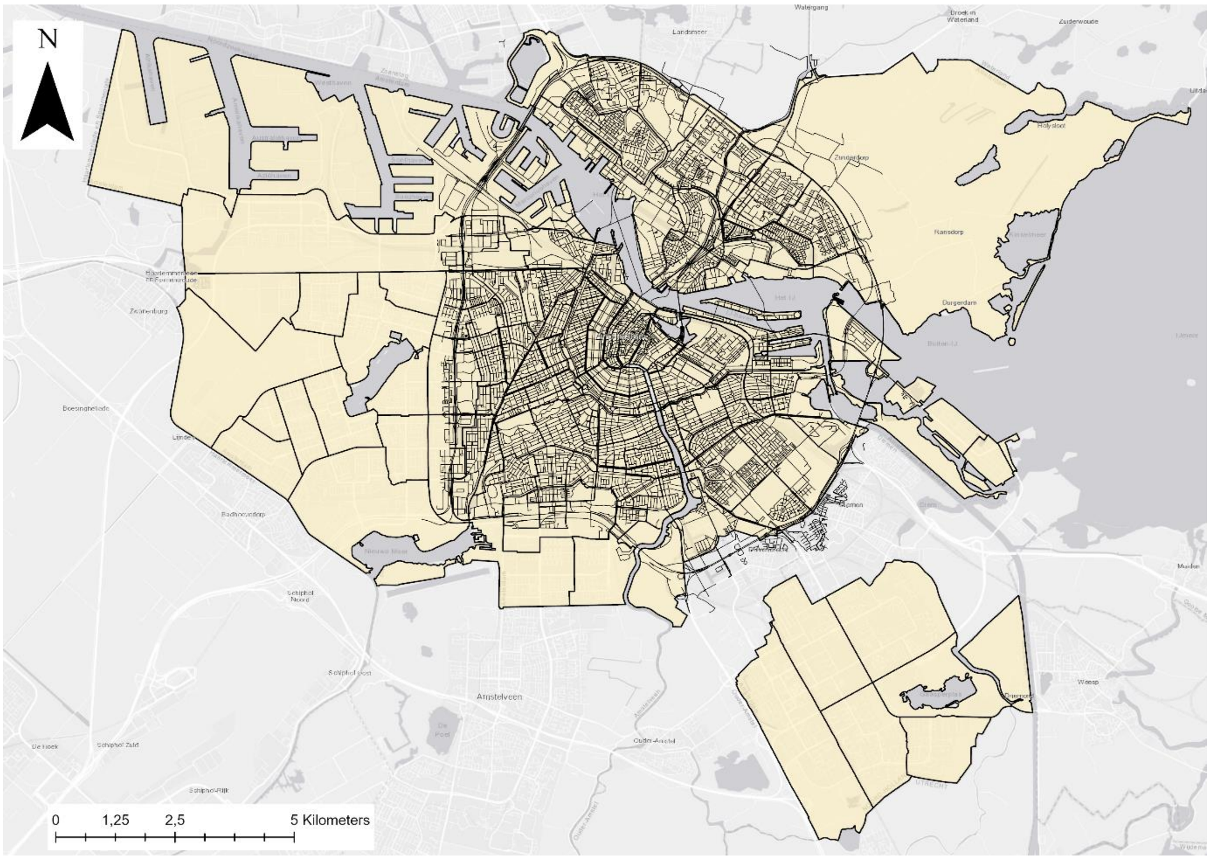
As stated, the attractiveness of the built environment for physical activity is determined by the different D categories in combination with the preferences of different demographic groups. In other words, different people find different built environment features attractive for physical activity. Therefore, the conceptual framework shows that the personal characteristics influence and determine the importance of different built environment features. Consequently, these features and their importance affect the attractiveness of an area for physical activity.

3.2 Case study: streets of Amsterdam

The above presented conceptual framework is applied and demonstrate in the case of the streets of Amsterdam, as shown in figure 3.2.1. This figure shows that not all streets of Amsterdam are included. Only the streets located in the inner city are analysed in this research. This is due to the used street network dataset. Therefore, only the streets shown in figure 3.2.1 are included.

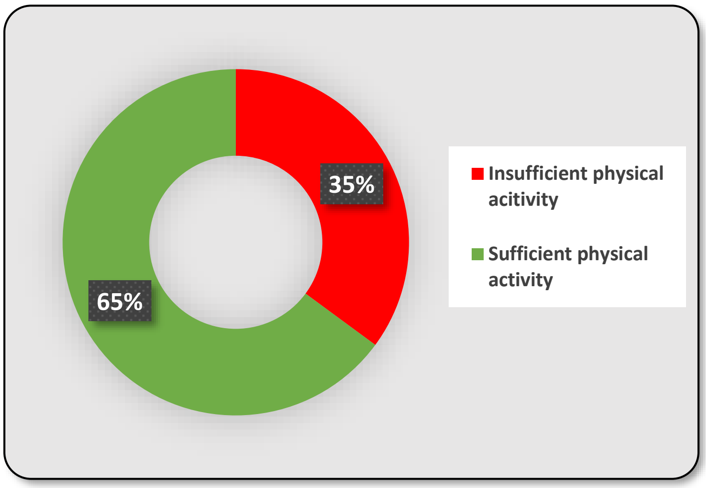
The city of Amsterdam is an interesting case for several reasons. First of all, figure 3.2.2 shows the percentage of people, aged 19 years or older, that meet the Dutch standard for physical activity (a minimum of 30 minutes of moderate physical activity on at least 5 days a week) in 2016. The figure shows that 35% of the adult population of Amsterdam does not meet the Dutch standard, and can therefore be seen as physical inactive (GGD, 2016). This is a growing concern for the Amsterdam municipality. In order to promote more physical activity the municipality is implementing different policies and measurements. One of these policies is called "*De Sportieve Stad*", roughly translated to the sportive city. This policy aims to increase the health of the Amsterdam citizens through promoting the participation in different kinds of sports and thus physical activity. The policy sets out nine different objectives, where the third objective is related to the realisation of attractive public spaces for physical activities (Gemeente Amsterdam, n.d.). By researching the built environment features that affect the physical activity attractiveness of streets for different demographic groups, this research can contribute to the aim of increasing the physical activity of Amsterdam citizens.

Figure 3.2.1: Overview of Amsterdam and included streets



Maker: Author, source: WUR & OIS

Figure 3.2.2: Physical activity of Amsterdam citizens 19 years and older in 2016



Source: GGD Amsterdam, 2016

Secondly, Amsterdam is selected as case because there is a lack of affordable houses in Amsterdam. In order to solve this the aim of the city council is to realise 52.500 new houses by 2025 (Gemeente Amsterdam, 2018). The development of these new houses also allows the municipality to construct the built environment around these new houses in such a way, so that it is attractive for physical activity. The results of this research may therefore contribute to the development of attractive built environment features that promote and stimulate physical activity.

Finally, the open data that is freely available for the city of Amsterdam is another reason to select Amsterdam as a case for this research. There is sufficient data available for a wide variety of themes including the built environment and different demographical and socio-economical features. By selecting Amsterdam as case, the city council of Amsterdam will be provided with the results that provide insights in the relation between the built environment and its effects on the attractiveness of streets for physical activity. These results can support the city council of Amsterdam in their plans for the future developments of an active and healthy Amsterdam.

3.3 Multi Criteria Analysis

In order to structurally analyse the importance of the built environment features on the attractiveness of streets for physical activity for different demographic groups, this research conducts Multi Criteria Analysis (MCA).

A MCA is a form of decision analysis which is a valuable tool in solving issues as characterized with multiple actors, criteria's, and objectives (Kumar et al., 2017). In general a MCA is a decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often conflicting, in order to guide the decision maker towards a judicious choice (Roy, 1996). In this research the form of a spatial MCA is used, which relates to the application of Multi Criteria Analysis in spatial context where alternatives, criteria and other elements of the decision problem have explicit spatial dimensions (Mousseau, 2008).

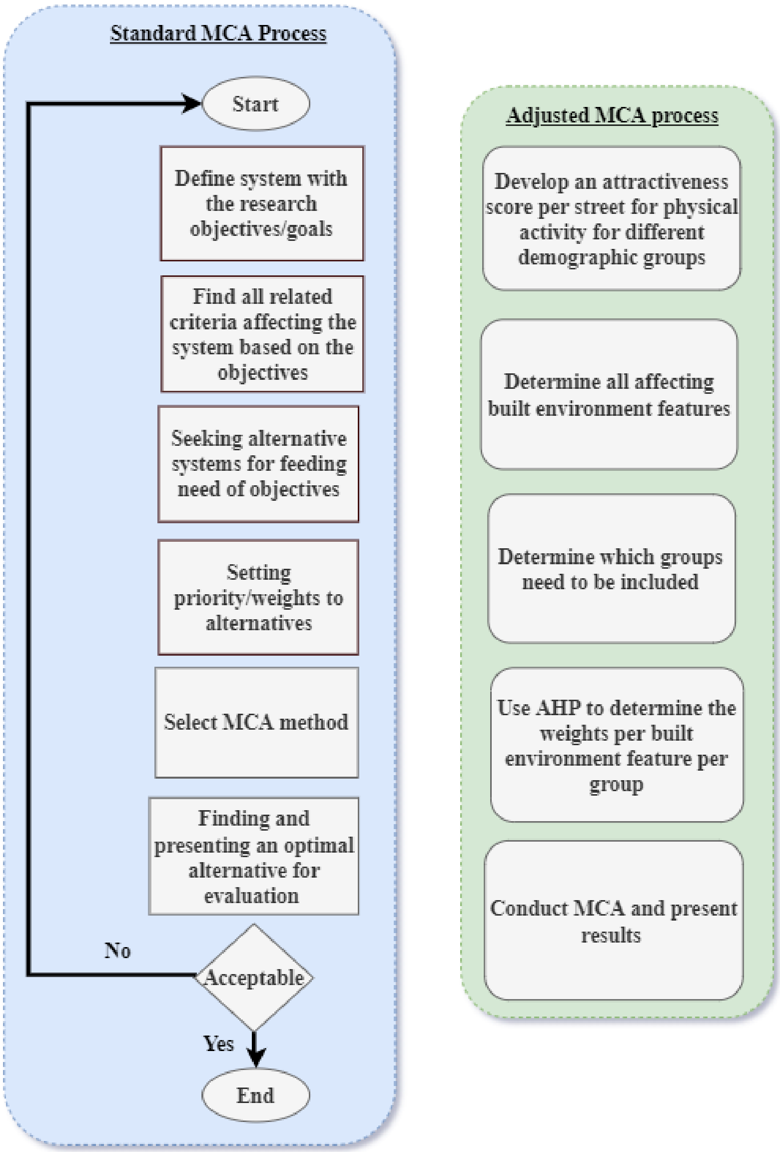
In figure 3.3.1 an overview of a standard MCA process is presented. The figure also shows an overview of an adjusted MCA process, this overview represents the MCA process that is used for this research. The adjustments are made to make the MCA fit the research objectives. The standard process shows that a MCA starts by defining a system with objectives that need to be met. In this research the objective is to develop per street an attractiveness score for physical activity. In the second step the different criteria that affect this objective need to be determined, which in this research are the different built environment features. Then, the different alternatives or scenarios need to be determined, which in this research are the different demographic groups. For each of these scenarios (demographic groups) the included criteria are given priorities or weights. These weights correspond to their importance or influence on the objective (Atici et al., 2015). Finally, with these different criteria weights it is possible to assess the different scenarios (Kumar et al., 2017).

In other words, per demographic group the importance of the included built environment features on the attractiveness score need to be determined. This importance of the built environment features are then transformed to certain weights, which are used in the final calculations to develop attractiveness scores per street for physical activity per demographic group. For example, for the demographic group elderly the walkability index is more important in the overall attractiveness of a street for physical activity than for children or adults. Therefore, the walkability will be given a higher weight for the elderly. This means that in the calculation of the attractiveness score per street for elderly, the walkability has a higher impact than in the calculation of the attractiveness score per street for adults. Thus, the walkability determines for elderly more the attractiveness of a street than for children or adults.

By conducting MCA this research supports policy and decision makers. Through these MCAs the development and calculations of the attractiveness scores are analysable. This implies that it is possible to analyse in which neighbourhoods and/or streets which built environments features are lacking and could use improvements to increase the attractiveness of that neighbourhood and/or street for physical activity for a certain demographic group.

There are different methods to determine the weights for the criteria and constrains such as the cardinal simple arrangement technique, the interactive estimation method, the indifference trade-offs technique or the Analytical Hierarchy Approach (AHP) (Moussea, 2008).

Figure 3.3.1: Standard MCA process



Source: Kumar et al., 2017, adjusted by Author

3.4 Validation of Multi Criteria Analysis

The validation of a MCA in general is regarded as a difficult task since a MCA involves many different parameters which affect the model's ability to simulate the outcome of policy options (Qureshi et al., 1999). An efficient method to evaluate a model or framework is to divide the evaluation process in the three components; verification, validation and sensitivity analysis (Qureshi et al., 1999). Here, verification refers to refers to building a model correctly, i.e. substantiating that a model properly implements its specifications (O'Keefe et al., 1991). Sensitivity analysis examines the extent of variation in predicted performance when parameters are systematically varied over some range of interest, either individually or in combination (Qureshi et al., 1999).

Validation accounts for building the `correct model', i.e. establishing that a model achieves an acceptable level of accuracy in its predictions (O'Keefe et al., 1991). The validation of a MCA includes checking if all the relevant and important criteria are included in the MCA.

Where in other models this validation could be performed by comparing the results of a model with data from real system. (Qureshi et al., 1999). This method is, however, only viable when there is real system data available. For many researches that use MCA's there is no real system data available, since a MCA analyse an optimal outcome such as a location or score which cannot be checked by real system data. Therefore, for MCA the methods to validate if the right criteria are included are surveys or face validity of experts in the field.

This research conducts MCAs so that for different demographic groups (scenario's) the attractiveness of the streets for physical activity (research objective) can be determined. This means that surveys are a suitable method to validate if the correct criteria are included and if these criteria are given the correct weights. However, due to time and budget constraints it is not possible for this research to conduct sufficient surveys per demographic group to validate the included criteria and weights.

The results of this research could be used to analyse potential correlations between the attractiveness of the streets for physical activity and actual health and/or physical activity statistics. However, a limitation is that sufficient health and physical activity data for different demographic groups per street is to date not existing. Such data is only available on neighbourhood scale or higher, whereby the data is scarce and limited. The health and physical activity data that is available, can be derived from the Municipal Health Services of Amsterdam (GGD). The GGD focuses on many different activities in the field of public health. Therefore, they have a wide range of available data related to the public health of Amsterdam. Some of this data is related to the physical activity levels per neighbourhood and per demographic group.

However, another limitation is that this physical activity data does not distinguish different forms of physical activity. This implies that a high rate of physical activity can relate to high levels of casual physical activity, work related, domestic related physical activities, or a combination of the three. Because this research focuses only on casual physical activity in the form of walking, it is difficult to analyse potential correlation between the results of this research and the available health and physical activity data. Furthermore, it must be noted that the physical activity is affected by not only the built environment but also by other criteria such as personal preferences and the weather. Therefore, the potential correlations are difficult and complex to understand and analyse.

Finally, because a model is a simplification and abstraction from the real system, the performance levels predicted by the model will differ from those of the real system (Qureshi et al., 1999). Therefore, subjective or statistical tests to validate a model can, even under the management policies and environments for which the real system has been observed, only in theory prove that a model is valid (Qureshi et al., 1999).

3.5 Analytical Hierarchy Approach

One of the most commonly used MCA methods is the Analytical Hierarchy Approach (AHP). The AHP is developed by Thomas Saaty in the 1970's and this approach allows users to assess the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner (Kasperczyk and Knickel, 2001). In order to determine the weights for the criteria the AHP uses pairwise comparisons (where X is more important than Y). These pairwise comparisons are then converted in a set of numbers representing the value priority of each of the criteria (Kasperczyk and Knickel, 2001). For determining the weights of the criteria the importance of a criterion relative to another criterion has to be considered. A tool to assess this relative importance and to assign weights to the criterion is the Saaty scale ranging from 1 (equal importance) to 9 (extreme importance), see table 3.5.1.

Table 3.5.1: Saaty Scale

Value	Meaning
1.00	Equal importance
2.00	Weak or slight
3.00	Moderate
4.00	Moderate plus
5.00	Strong importance
6.00	Strong plus
7.00	Very strong
8.00	Very very strong
9.00	Extreme importance

The AHP is a suitable method for this research, because it allows this research to assign different weights to different criteria (the built environment features) for different demographic groups based on literature and common sense. For example, the built environment feature of public sport facilities may have a higher importance for children than for adults. Meaning that the public sport facilities can be given a relative higher weight in the scenario of children than in the scenario of adults. The result is that in the attractiveness score per street for children the accessibility to public sport facilities has a higher impact on the attractiveness score than for adults.

As mentioned, this research develops attractiveness scores on street level for three different demographic groups. This means that per demographic group an AHP needs to be conducted, so that the weights of the built environment features per demographic group are determined. The set-up of the different AHPs in this research are discussed in the AHP set-up paragraphs.

3.6 Data & Software

This research uses the ESRI software ArcGIS Pro to extract and obtain the relevant built environment information of the streets of Amsterdam. Furthermore, this software is used to develop per demographic group the attractiveness scores for the streets of Amsterdam.

The main data source in this research is deriving from the department *"Onderzoek Informatie en Statistiek"* (OIS; Research, Information and Statistics) of the municipality of Amsterdam. This OIS department collects and processes data about Amsterdam. They collect data on a wide range of themes and topics such as the population of Amsterdam, the housing stock and business, but also on the (built) environment, health care and politics. Furthermore, OIS makes the collected and processed available to both the municipality itself as to the public. Therefore, the main data source in this research is the database of OIS.

In the next paragraphs, based on the five D categories, the different built environment features that are included in this research are presented and discussed. In most cases the data is derived from the OIS database. In order to enhance the readability of the paragraphs OIS is not consistently referred to as the data source. If the data is derived from a different data source than OIS, the data source will be mentioned.

3.7 Density data

In the theory chapter the importance of different density features are discussed. The chapter also presented different methods to measure these density features. Since this research focuses on streets, it is desirable to have data on the same scale. Although the OIS department has useable datasets such as the dataset *"Kerncijfers (Buurten)",* which contains data on the number of people, number of houses and the total size of the area (in hectares), these datasets are not used in this research due to limitations and inaccuracies as discussed below.

In (Dutch) spatial planning practices housing or building density is usually measured by the number of dwellings per hectare or other density features per hectare or other surface area indexes (Harbers et al., 2019). This means that in these density measurements the data only provides indications of the spatial density. For example, normally the housing density feature does not distinguish the size of houses, meaning that there is no difference between a very small or very large house. Also, these densities number exclude other buildings than houses (offices, schools shops and so on) from the calculations. Furthermore, these density features are not available on building block scale. Therefore, the traditional housing density feature is considered as less accurate and not useable for this research.

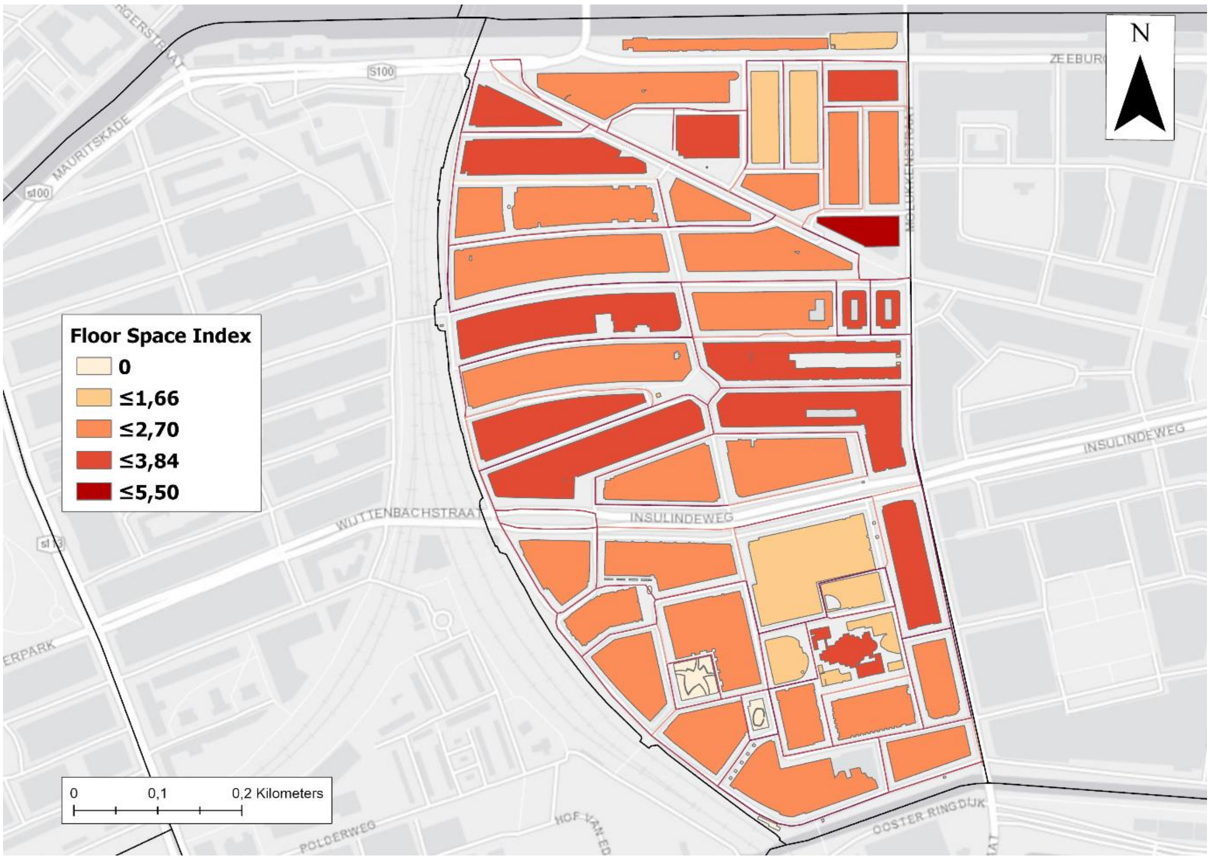
Population density is another frequently used density feature. This density feature measures the number of inhabitants per square kilometre of other surface area index. This population density represents the intensity of the use of an area (the crowdedness), but it is does not represent the physical indicator of the building density (Harbers et al., 2019). Thus, population density can reflect incorrect numbers and does not represent the rate of intensity of the population density of an area. Therefore, the population density is not used as a density indicator in this research.

The method that is used to measure density in this research is the Floor Space Index (FSI). By using the FSI to measure the density feature, the limitations of the 'traditional' density indexes are overcome. These limitations are overcome, because the FSI does justice to the physical-spatial appearance of an area (Harbers et al., 2019). The FSI shows how the floor area (the area of all floors combined) relates to the total area of the site, regardless of the function and the intensity of use. The FSI even includes underground floor surfaces and the floor surfaces on the upper floors (Harbers et al., 2019). Thus, one could argue that the FSI is a better and more accurate index for measuring the housing and population density of an area. Furthermore, because is calculated per site or building block it implies that the FSI is available on building block scale. Based on the more accurate measurement of density and the availability of the FSI on building block size, this research uses the FSI as an indicator for the density of an area.

The data of the FSI derives from the dataset "*RUDIFUN*" from the Netherlands Environmental Assessment Agency (PBL). This dataset contains information about the different function types of building and the total surface area of that area on different scales (building block, neighbourhood and municipality). Based on this data the PBL developed a method to automatically calculate, among other things, the FSI on building block, on neighbourhood and on municipality scale for the whole of the Netherlands. A visual representation of the FSI of building blocks for a neighbourhood in Amsterdam is presented in figure 3.7.1. The FSI numbers in the figure represent thus the density of the building blocks, where the higher the value the higher the density is of that building block.

This research uses this data of the FSI on building block size to represent the building density per street of Amsterdam. The exact steps and methods to add the FSI data to the streets of Amsterdam are presented and discussed in the operationalisation chapter.

Figure 3.7.1: Floor Space Index visualisation



Maker: Author, Source: PBL, 2019

3.8 Diversity data

As mentioned, diversity translates to land-use mix which as the name suggests represent the mix of different land-use or functions of an area. In order to include this diversity category in this research, the dataset "*Functiemix*" from OIS is used. This dataset contains the information on the percentage of function mix per building block in Amsterdam. This dataset is developed by the OIS department and is based on the function of a building and the surface area of that function. The OIS divided per building block the following three function types; Housing, Services and Working. This information of the function type per building block and the surface area of that building block is derived from the dataset "*Basisregistratie Adressen en Gebouwen*" (BAG). This dataset contains building information such as status, surface area, geometry, X and Y coordinates, year of construction and function for all buildings of the Netherlands (Kadaster, n.d.).

The OIS department calculated the percentage of the function mix per building block by adding per building block the surface area (in square meters) per category. With the sum of the surface area per function type, the function mix percentages are calculated.

In order to classify the different function mix types, the OIS department used the following classification rules;

- *If the surface area of a building block consists out of 70% or more out of a single function such as services, then the whole building block is labelled as Services.*
- *A building block has a two function mix if the two functions have less than 70% of the total surface area and the third function has less than 15% of the total surface area.*
- *Finally, a building block gets the label three function mix if none of the functions have more than 70% of the total surface area and not less than 15%.*

Based on these classification rules, the OIS department classified the different function mix types in the following categories;

- *Housing*
- *Services*
- *Working*
- *Housing-Working*
- *Housing-Services*
- *Working-Services*
- *Mixed*

This implies that, for example, the two function mix label Housing-Services is applied when the functions Housing and Services have a surface area percentage higher than 15% but lower than 70% and the third function Working has less than 15% of the surface area for the whole building block. In figure 3.8.1 an example is shown of the function mix for the city centre of Amsterdam.

Figure 3.8.1: Function mix visualisation for the city centre of Amsterdam in 2019.

Maker: Author, Source: OIS

It is common in Amsterdam that above services and/or (small) working buildings, houses are constructed. In other words, people tend to live above a shop or a small office. Therefore, it can occur that the function Housing has a surface area percentage of 70% or higher for almost every building block. With the used categorisation of the OIS it would imply that almost every building block in Amsterdam has a Housing function instead of a two or third function mix type, while a few shops and/or offices and/or workplaces in a street can already provide a function mix. Therefore, the OIS reduced the total surface area of the Housing function per building block by 50% before the percentages of surface area of the different functions are calculated, which results in more function mix per building block.

It must be noted that the OIS department classified residential care complexes such as care, nursing and reception centres are classified as residential functions and not as facilities. Also, addresses with parking and transport functions (e.g., garages and metro station entrances, often underground buildings for storing cars or moving people through) are difficult to qualify as living, working or services function types, and are therefore completely omitted by the OIS department. Finally, other user functions, utilities, storage and distribution smaller than 100 square meters are often unmanned and therefore not included by the OIS department as a function type.

Since this function mix dataset already calculates the function mix per building block in Amsterdam, it reflects the land-use mix and thus the density category. Therefore, it is incorporated in this research. The classification rules of the OIS department are also applied in this research. The used classes from the OIS department are reclassified for this research, because this research analyses mainly if there is function mix and not necessarily the type of the function mix. Therefore, the classification of the OIS department is reclassified into the following 5 classes, shown in table 3.8.1.

Table 3.8.1: Reclassification of the function mix dataset

OIS Label	Reclassification
Housing	Single Function
Working	Single Function
Services	Single Function
Housing-Working	Housing-Working
Housing-Services	Housing-Services
Working-Services	Working-Services
Mixed	Mixed Functions

The first class includes all the single functions types; Housing, Services and Working. Because these classes do not have a mixed function they are categorised into a single (no) function mix class. This is done because, as mentioned, there is no need to distinguish different single function types.

The second, third and fourth classes in this research, contain the different forms of the two function mix types; Housing-Working, Housing-Services and Working-Services. Each of these classes are a two function mix and can have different effects on the attractiveness of a street for physical activity per demographic group. Therefore, these different two function mix types are classified as individual classes. The fifth and final class that is included in this research contains the Mixed function. This class is made, since a complete mix of the three functions is considered as the optimal function mix and is therefore classified as a separate class.

3.9 Design data

The design category can contain a wide variety of built environment features. This wide variety can be split up in two components. First of all, it contains information of the street network connectivity. As stated in the theory chapter, a method to calculate the connectivity of a street network is through measuring the number of intersections of an area, where more intersections imply a better street network connectivity. This research uses the number of intersections a street has, but it uses these intersections to measure the street length. Here the street length is measured as the part of the street that is not intersected. Therefore, the intersections are needed to determine where the street is intersected and what length that part of the street has. The length of the street is used as an indicator for the street network connectivity. The street length reflects the street network, because the longer the streets is the greater the distances is to reach (or connect to) another street. In order to calculate these street lengths of the streets several steps are taken, which are explained in the operationalisation section.

The second component of design relates to the built environment features that are pedestrian orientated. The dataset that is used to obtain these built environment features in this research is the "*Walkability*" dataset from the OIS department. This dataset contains information about the effective street width of the streets of Amsterdam, the width of the streets minus all the obstacles in the street such as garbage bins, bicycle parking spots and so on. This effective street width is combined with the pedestrian demand, reflecting how crowded a street is and therefore how much space is needed to comfortably walk. This combination of the effective street width and pedestrian demand results in a walkability index on street scale. For example, a street has a good walkability score if the effective street width meets the pedestrian demand. In order to visualise and analyse this walkability index for Amsterdam, the OIS department reclassified the walkability index scores in the following 5 categories;

- *Very low*
- *Low*
- *Mediocre*
- *Good*
- *Excellent*

Because the OIS department already classified the values based on literature (Leidraad Voetganger, 2017) and explorative studies, this research uses the same classification for the walkability scores.

3.10 Destination accessibility data

Since destination accessibility measures both the number of reachable destinations and the magnitude of the attractiveness of these destinations, it is first of all important to define what destinations are included in this research. Secondly, the attractiveness (magnitude) of these destinations need to be determined for each demographic group, because some destinations are for one demographic group more attractive than for another demographic group. This determination of the attractiveness of different destinations for different demographic groups is done by the AHP. The exact steps and methods to determine and calculate the number of reachable destination are discussed in the operationalisation section.

The destinations that are included in this research are:

- *Green areas*
- *Public sport facilities*
- *Public playgrounds*
- *Public transportation stops*

This reachability of the destinations first have to be defined, so that it is clear what is considered as reachable and what not. The distance from one point (origin) to another point (destination) is thereby the main determent of reachability. There is a so-called acceptable travel distance, that differs per form of transportation, per destination and per person (CROW 2014). For example, a destination such as a museum where people spend more time, the acceptable travel distance is larger than when the destination is a park. However, this also differs per person for children the museum is perhaps less attractive than for elderly and therefore the acceptable travel distance may be less for children than for elderly.

This implies that many different factors need to be accounted for in the determination of acceptable travel distances. Therefore, it is difficult and complex to determine what acceptable walking distances are. As stated, this research develops and applies a conceptual framework in the case of Amsterdam. Therefore, acceptable walking distance for Dutch people need to be determined. Although different Dutch research is conducted on acceptable walking distances per destination, there is a lack of standard acceptable walking distances. For example, according to the ASVV (CROW, 2004 p.341) a general acceptable walking distance is 600 meter for all destinations. While other research state that the acceptable travel distance differs per destination and per person. Therefore, many different Dutch studies developed different acceptable walking distances per type of destination. An overview of these distances per destination type is given in table 3.10.1.

As the table shows for only a limited amount of destinations a proposed acceptable walking distance is available. Most of these destinations are car related trips, since they consider trips from a (car) parking lot to a destination. Because this research does not include parking lots as destinations, it is difficult to determine what acceptable walking distances are for the included destinations in this research.

Table 3.10.1: Overview of acceptable walking distances per destination

Destination	Acceptable walking distance according to literature
Housing	150 meter from parking lot (p) (CROW 2004)
Shopping	300 meter from p (CROW 2004); 400 meter (WCC 2011); 1000 meter (Carley and Donaldsons 1996 in TIHT 2000)
Working	500 meter from p (CROW 2004); 1000 meter (WCC 2011)
Recreational	300 meter from p (CROW 2004)
Health care facilties	150 meter from p (CROW 2004)
Education	300 meter from p (CROW 2004); 1000 meter (KPVV 2013)
Restaurants and bars	250 meter (Moudon et al. 2006)
Supermarkets	450 meter (Moudon et al. 2006); 15 minuten (Damen 2000) = circa 1200 m
Local bus stop	350 meter (CROW 2004); 250 (Pettinga 1985); 5 minutes (van der Blij et al. 2010) = circa 400 meter
Tram and regional bus stops	450 meter (CROW 2004)
Metro station	700 meter (CROW 2004)
Train station	1000 meter (CROW 2004); 10 minutes (Damen 2000) = circa 800 meter; 1,3 - 2,2 km (Keijer en Rietveld 2000); 12 minutes = circa 1000 m (RWS 2004-2009); 760 m (ITF 2012)
Parking ticket system	200 to 250 meter
Electric car charging system	250 to 300 meter
Garbage containers	125 meter
Bike parking lots	100 meter (Verkeersnet 2015)

Source: Molster, A. (2016)

Although table 3.10.1 presents acceptable walking distances based on Dutch research, international research on acceptable walking distances is also useful to include. The research by Ewin et al. (2015) and by Atash (1994) show that a general acceptable walking distance in the United Stated is 400 meters, since they show that after 400 meters the number of walking trips decline fast. The study by Moudon et al. (2006) found that acceptable walking distances for restaurants and cafes and supermarkets are considered respectively at 250 and 450 meters. Finally, Norwegian research shows that a distance longer than 900 meter is the threshold for walking, as distances longer than 900 meter are done by car (ITF, 2012). These different walking distances indicate that per country and per culture the acceptable walking distance differs. Therefore, it is difficult to implement international studies and their analysed acceptable walking distances in this research. The reason for this is because this research uses Amsterdam as a case study. Compared to other nationalities, the acceptable walking distance for Dutch people is less than for other nationalities, because many Dutch people are most likely to use bicycles for relatively longer distances (KiM, 2014).

Table 3.10.1 provides this research only with a suggestion for an acceptable walking distance of the public transportation services. The suggestion is that for tram stops the proposed distance is 450 meter and for metro stations it is 700 meters. Due to a lack of a standard acceptable walking distance for tram and metro stations, this research uses the acceptable walking distance of 700 meters. Meaning, that this research considers tram and metro stops reachable when they are within a 700 meter walk from a street.

For the other included destinations in this research, there is no literature based acceptable walking distance indication available. Therefore, this research uses the general acceptable walking distance of 600 meters from the ASVV as guideline for reachability of the destinations green areas, public sport facilities and public playgrounds.

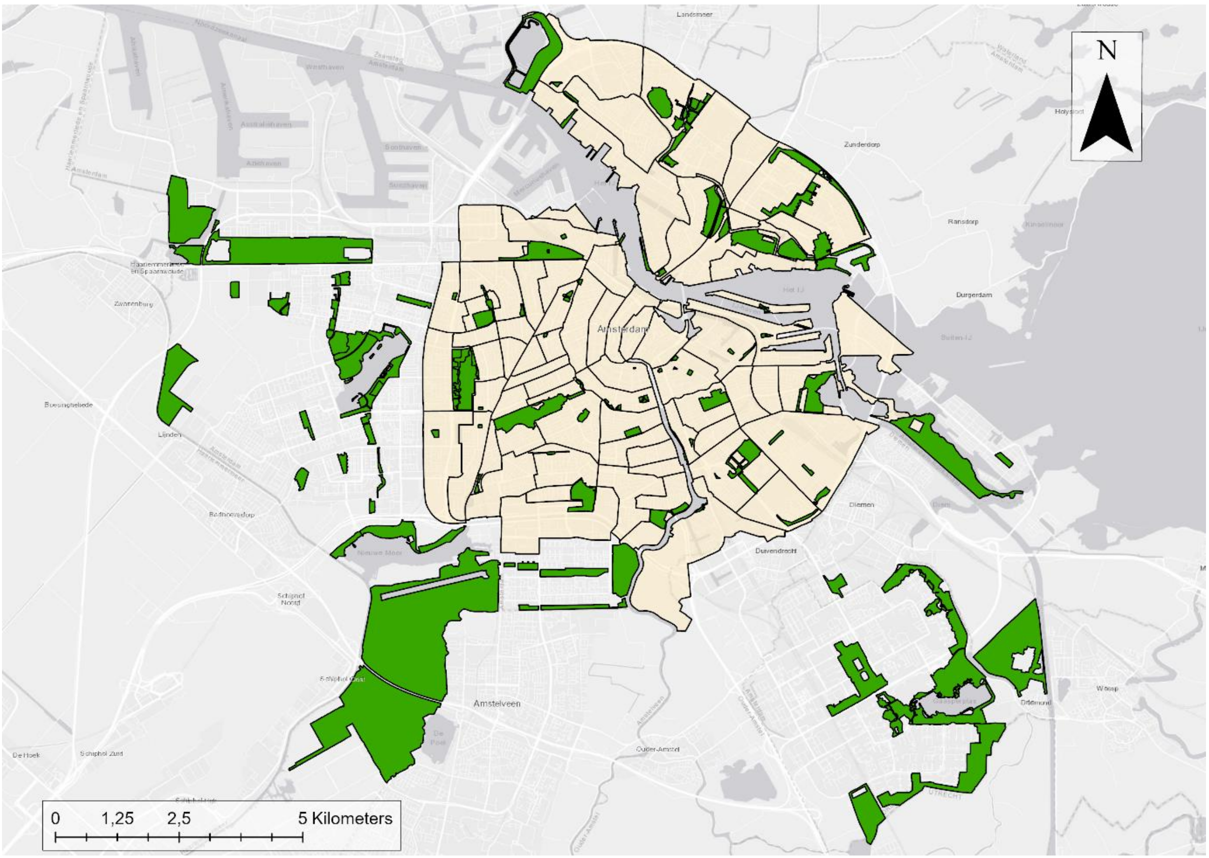
As stated, some destinations are more attractive than others for different people. This also affects the acceptable walking distances per destination. Some destinations can have a larger acceptable walking distances for some people than others. For example, the acceptable walking distance to a museum can be larger for elderly than for children. Although these differences in acceptable walking distances per destination per demographic group must not be underestimated, there are not included in this research for two main reasons. First of all, an acceptable walking distance differs per person and not only per demographic group. Therefore, it is difficult to implement and/or analyse these different acceptable walking distances for the destination accessibility category. Secondly, the MCA that is conducted in this research already distinguishes the importance of different destinations for different demographic groups by the different weights per built environment feature. Therefore, this MCA already considers the effects of the attractiveness of different destinations for different demographic groups.

The following paragraphs present and discuss the used data of the included destinations. Again, the exact methods and techniques to obtain and calculate the number of reachable destination is discussed in the operationalisation chapter.

3.10.1 Green areas

The first destination that is included in this research are the green areas of Amsterdam, shown in figure 3.10.1 The used dataset for this features is the *"Parken, plantsoenen en recreatief groen"* from the OIS department. This dataset contains the information about the name, type and location of the green areas in Amsterdam in 2014. The dataset included different types of green areas. The different green area types are city parks, recreative green and small green areas.

Figure 3.10.1: Locations of green areas in Amsterdam in 2014



Maker: Author, Source: OIS

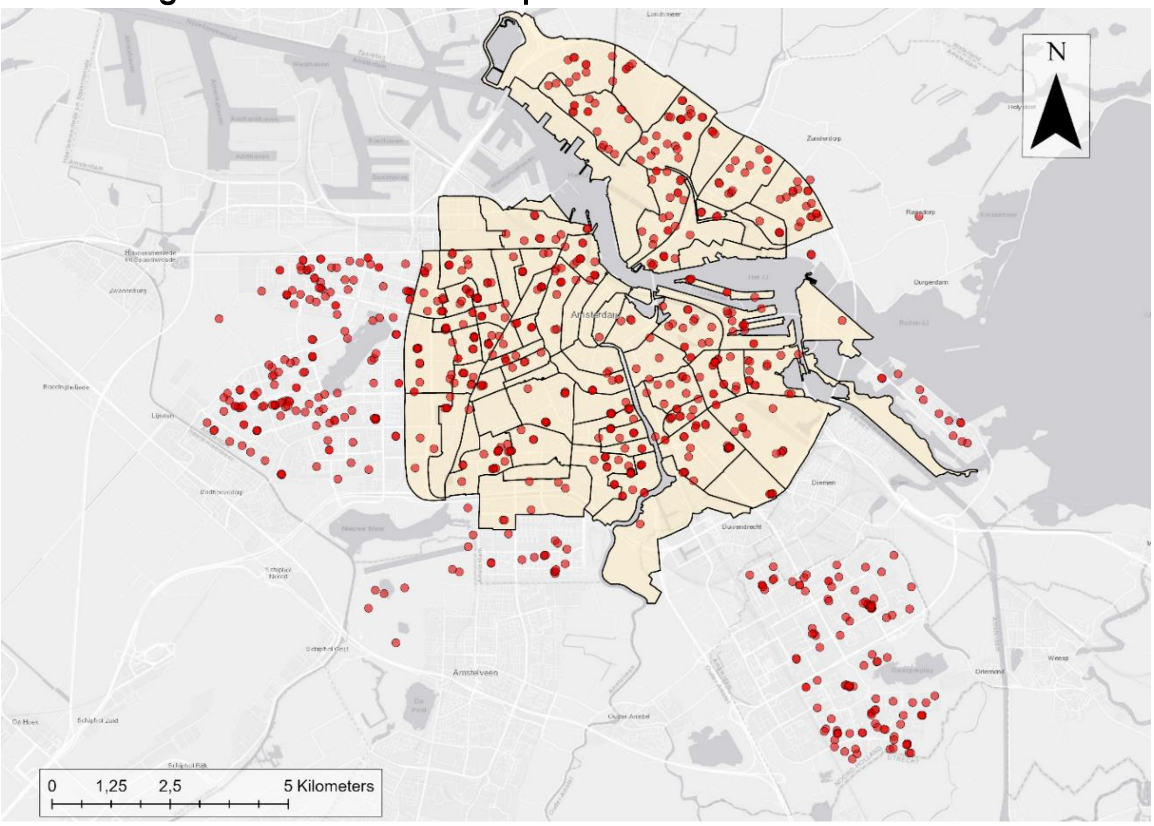
3.10.2 Public sport facilities

The next built environment feature related to the destination accessibility category are the public sport facility locations, shown in figure 3.10.2. The dataset that is used for this built environment features derives from the OIS department and is called: "*Openbare Sportplekken*". This dataset contains information on the name, type and location of different public sport facilities in Amsterdam in 2006. The different types of sport facilities that are included in this dataset are:

- *Skate*
- *Tennis*
- *Soccer*
- *Basketball*
- *Jeu de boules*
- *Fitness / Bootcamp*
- *(Beach) Volleyball*
- *Table Tennis*
- *Other*

It is important to note that In this research there is no distinction made between the attractiveness of different types of sport facilities. The reason for this is, because it is differs per person what type of sport facility is more attractive. Therefore, it is not possible to determine the attractiveness of different sport facilities in this research. This implies that for example a skate sport facility is equally attractive as a soccer sport facility. Finally, it must be noted that this dataset may not be up to date to the current number and locations of public sport facilities, since the dataset dates from 2006. Nevertheless, it is used in this research since no other datasets are available and this dataset gives a good indication of the number of reachable public sport facilities.

Figure 3.10.2: Locations of sport facilities in Amsterdam in 2006



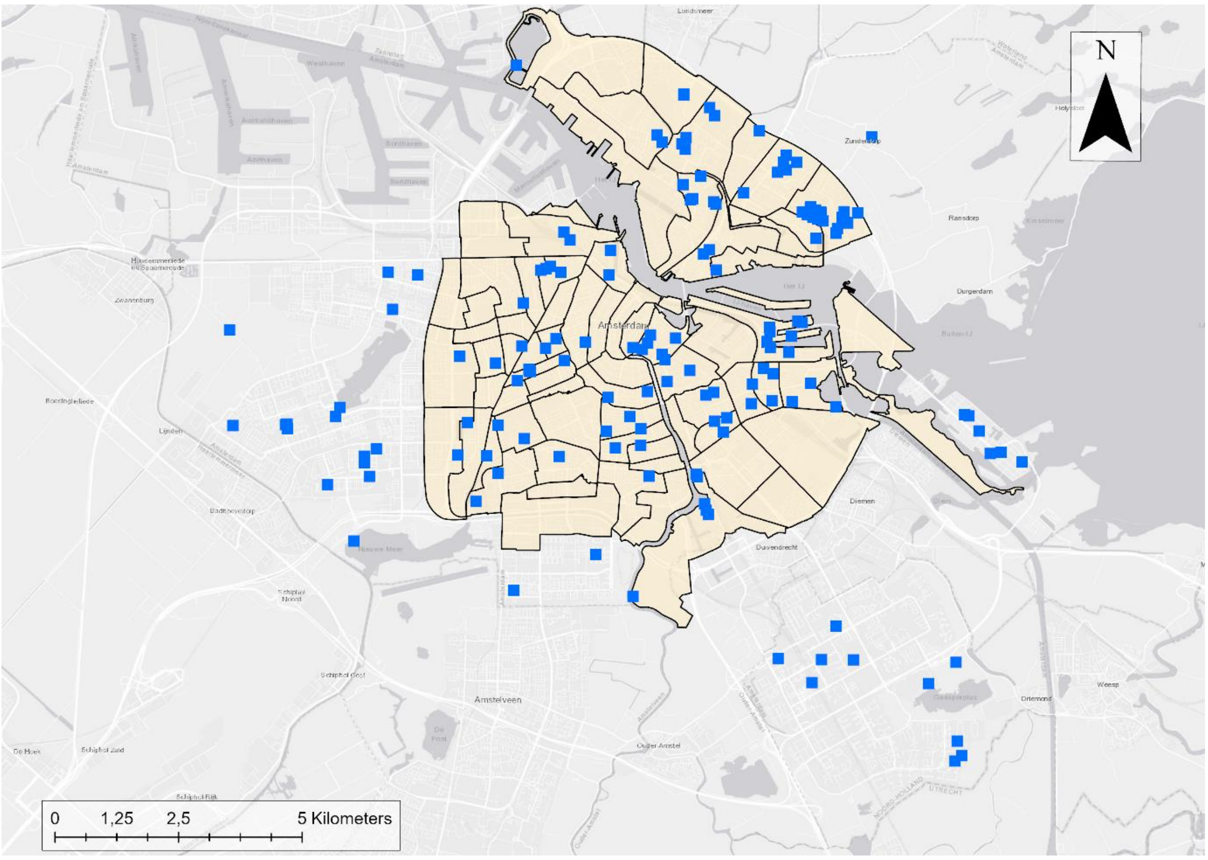
Maker: Author, Source: OIS

3.10.3 Public playgrounds

The third built environment feature that is included as destination, are the public playgrounds of Amsterdam, shown in figure 3.10.3. The data is derived from the platform Open Street Map (OSM). This platform is based on a community of volunteers that gathers and updates data to develop and publish maps and datasets for the whole world. Simply said, OSM is a world map that contains information on both street network characteristics such as highways, roads bicycle lanes, sidewalks and so on, and it contains information on different destinations such as restaurants, cinemas, transit services and so on (Open Street Map, 2018). Because the development of this world map is done by volunteers, it implies that the data of the world map is continuously updated with the use of local expertise. This OSM data is freely accessible and useable as long as the terms of the Open Street Map Licence is accepted and applied.

The OSM is used to obtain the information on the public playground in Amsterdam. Since it is continuously updated, it is important to note that the dataset from January 2020 is used in this research. As mentioned, the OSM dataset contains a wide variety of data. This wide variety includes among other things the location of public playgrounds.

Figure 3.10.3: Public playground locations in Amsterdam in 2020

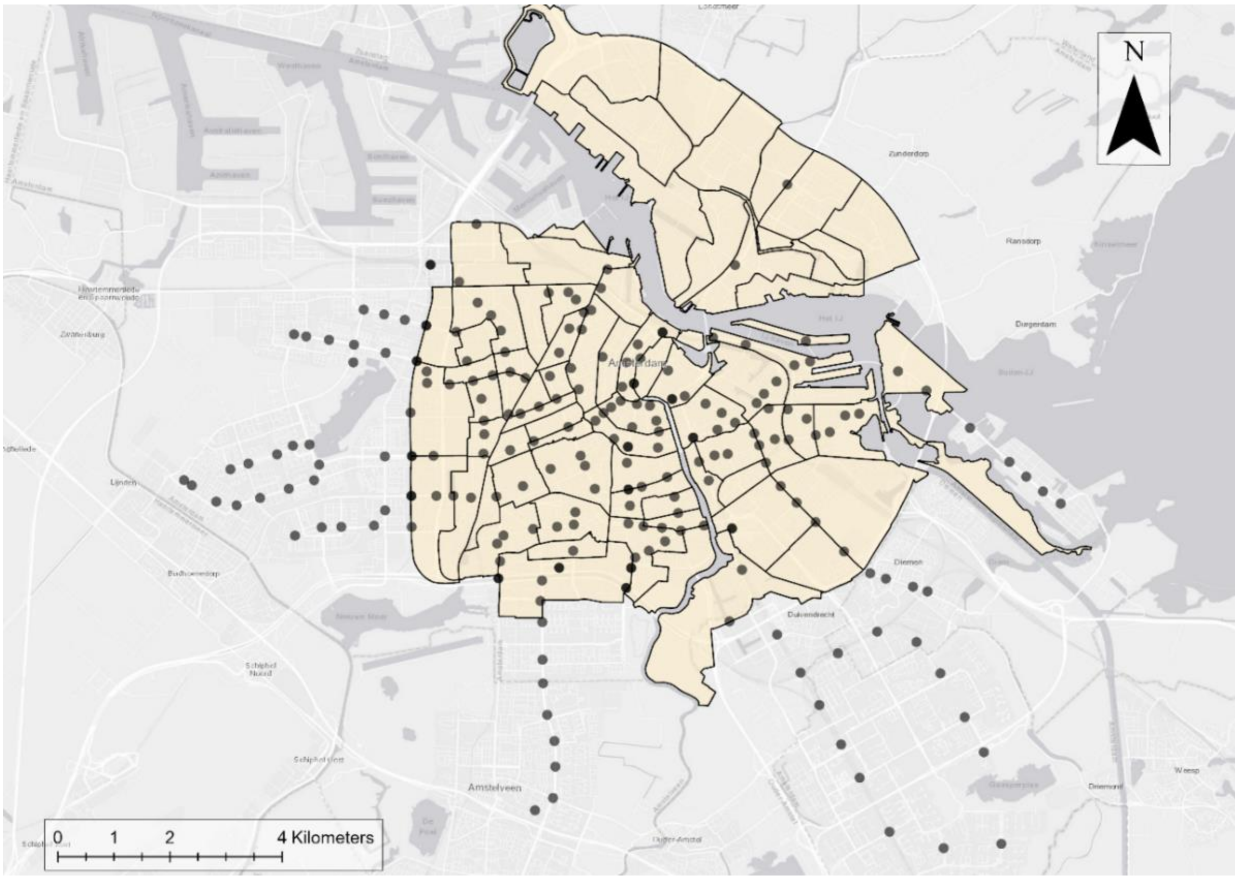


Maker: Author, Source: OIS

3.11 Distance to transit data

As the name suggest, for this last D category the distance to public transportation is measured. In the theory chapter is discussed that the average of the shortest route from either a residency or workplace to the nearest public transportation stop is calculated by this category. However, for this research the distances to the nearest public transportation stops are not measured or calculated. Instead a proxy is used that reflects the accessibility to public transportation stops. The dataset that is used to obtain the location of these public transportation stops is called "*Haltes van het Openbaar Vervoer in Amsterdam*". This dataset contains information on all tram and metro stops in Amsterdam in 2020, the locations of the tram and metro stops are shown in figure 3.10.4. Because this research analyses how many of these public transportations stops are reachable within 700 meter walking distance per street, this D category is added to the destination accessibility category. This means that in the destination accessibility category the number of reachable tram and metro stops serves as a proxy for the distance to transit category.

Figure 3.10.4: Location of tram and metro stops in Amsterdam in 2020



Maker: Author, Source: OIS

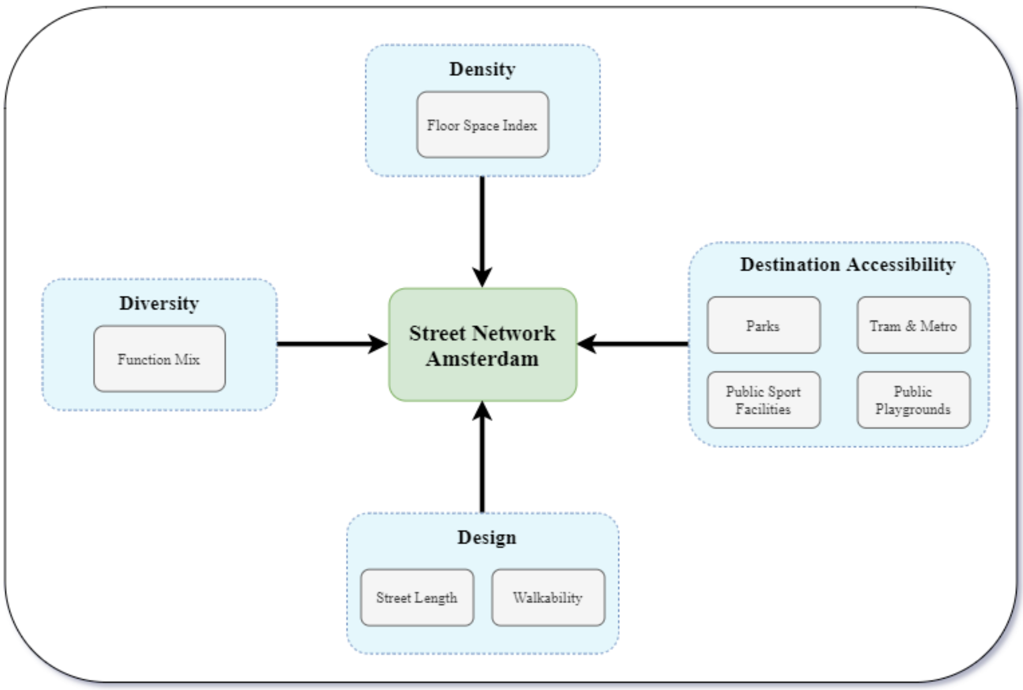
4.0 Operationalisation & implementation

This chapter is split in two sections. The first section discusses and present the operationalisation of the included built environment features. Furthermore, this section presents and discusses the workflow on how the conceptual framework is applied in the case of Amsterdam. Here, the different methods, tools and techniques that are used to prepare the data will be presented and explained. For this research multiple steps are taken in order to add the built environment features of the five D categories to the street network of Amsterdam.

In order to structurally discuss the different steps of the first section of this chapter, the overview in figure 4.0.1 is developed. The figure presents an overview of which built environment features are included per D category. Based on this overview the first section of this chapter discusses per D category how the data is added to the street network of Amsterdam. It must be noted that in the overview the category distance to transit is missing. As stated, this category is represented by the proxy of reachable tram and metro stops in the destination accessibility category. Therefore, the distance to transit category is excluded from the overview.

The second section of this chapter discusses the set-up of the AHP and how the weights of the included built environment features are determined and calculated.

Figure 4.0.1: Workflow overview



Source: Author

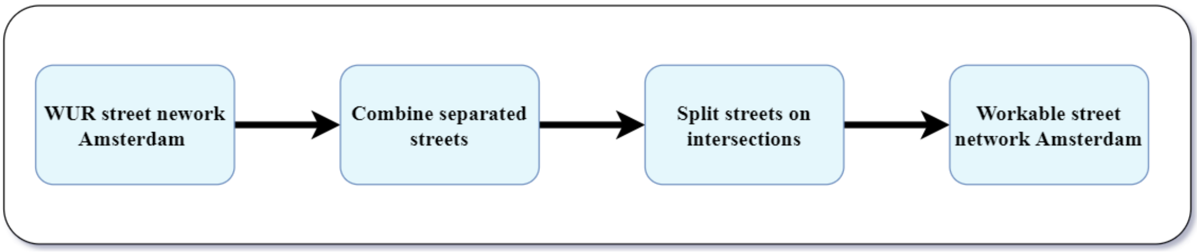
4.1 Design; Street Network Amsterdam

Since the goal of this research is to develop attractiveness scores per street of Amsterdam for different demographic groups, the first thing that has to be developed is a workable street network of Amsterdam. Therefore, this chapter starts off by explaining the workflow of how the street network of Amsterdam for this research is developed.

A first street network dataset for Amsterdam is derived from the Wageningen University & Research (WUR). This dataset from the WUR is a street network dataset that is based on Open Street Maps (OSM). The WUR researchers adjusted this street network for their own usage and purposes. Although this dataset is limited to the inner city of Amsterdam, see figure 3.2.1, it is still used for this research because the adjustments by the WUR researchers makes the dataset a quick and easy basis for this research. However, this also implies that only for the illustrated streets in figure 3.2.1 an attractiveness score for physical activity will be developed.

This street network dataset contains the information on the position of the streets and their names. Although the adjustments from the WUR makes the dataset a good basis for this research, there are still several steps needed in order to make the street network workable for this research. The different steps that are taken to develop a workable street network dataset are presented in figure 4.1.1.

Figure 4.1.1: Steps to prepare the street network dataset of Amsterdam



Source: Author

As figure 4.1.1 shows, the first step is to combine the separated streets of the dataset. In the dataset from the WUR the streets of Amsterdam are randomly split in several lines, while the lines contain the same street name. This results in a total of 14.963 different streets in the street network dataset of the WUR, while the actual number of streets for the used extent of Amsterdam is much lower. Therefore, these individual lines are combined to create a street network dataset of Amsterdam. In this street network dataset the different streets of Amsterdam form one line per street name. This results in a street network dataset containing 7.275 streets instead of 14.963 streets in the WUR street network dataset.

The second step is to split the streets again. This is necessary for two reasons. First of all, in the previous step all lines with the same street name are combined to a single line that represents the street. This implies that in the analysis the relatively longer streets will automatically be more attractive for physical activity than smaller streets. This is due to the fact that relatively longer streets potentially contain more (attractive) built environment features than small streets. In other words, how longer the street the more (attractive) built environment features it potentially has. This could lead to unrealistic attractiveness scores for streets since the attractiveness score accounts for the whole street, while in reality only a small part of the street is attractive for physical activity. For example, in a long street only the beginning of the street may be attractive for physical activity, while the rest of the street is less or even unattractive for physical activity. If this is not taken into account in the analysis, it means that longer streets are immediately more attractive for physical activity than smaller streets.

Secondly, the streets need to be split again in order to determine the block sizes, or in this research the street length. As stated in the theory chapter, the block size affects the attractiveness of an area (or in this research street) for physical activity. Therefore, the streets need to be split again when the building block is interrupted by a street. By structurally splitting the streets of Amsterdam when they intersect each other, the block size and therefore street lengths are determined. The visualisation of the workflow of splitting the combined streets of the first step is illustrated in figure 4.1.2.

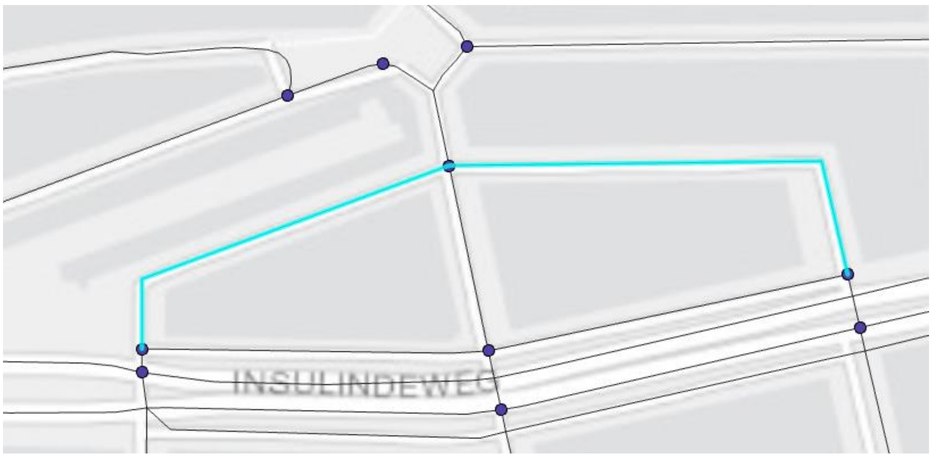
The lines in the figure represent the streets, and the points represent intersections. In the upper figure the street is shown as a whole. In the middle figure the street is split on the point (intersection) where the two streets intersect. However, as the lower figure illustrates, splitting the street based on the intersections with other streets can result in extremely small streets. These streets are unrealistic and must not be included in the further analysis. Therefore, these small streets are removed when the streets are smaller than 25 meters, so that only 'realistic' streets larger than 25 meters consist in the street network dataset.

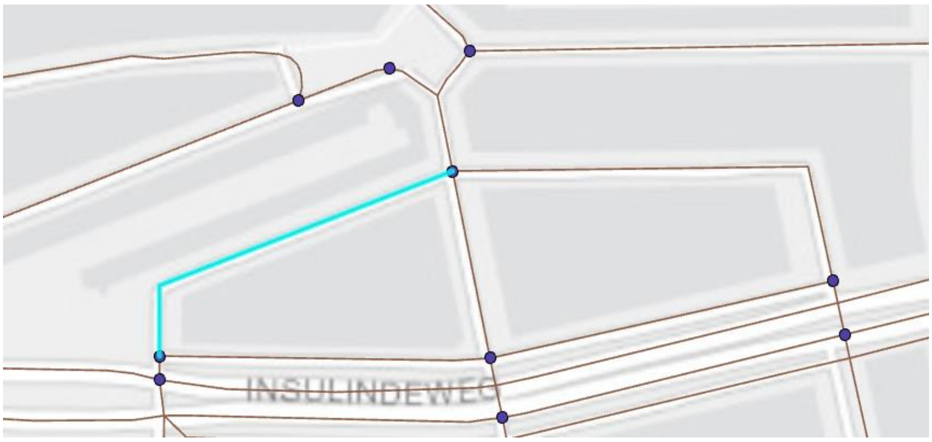
The final result of this step of splitting the street network is a street network dataset of Amsterdam that contains 12.559 separated streets based on the intersections the streets has. Furthermore, the street network dataset now contains the information on the street length that represent the block size and thus the street connectivity feature relating to the design category. The data shows that the shortest street in the dataset is 25.02 meter long and the longest street is 2268.3 meters long.

Before these street lengths can be used in the MCA. The different street lengths have to be classified. This is necessary, because this eliminates extreme low or high values in the final analysis. If this is not accounted for, it could lead to biased results. For example, when a street with a length of 30 meters and a street of 300 meter are compared, it would imply that the street of 30 meters can be ten times more attractive than the street of 300 meter. Although the shorter street is considered more attractive, it is not considered as ten times more attractive.

By classifying the streets in new classes these issues are prevented. Based on the range of the street lengths the classes and their values are determined, presented in table 4.1.1. The table shows that most streets in this research are categorised as very short and relatively a small number of streets are long or very long streets. Furthermore, the table shows that the very short streets are given a classification score of 5 and the very long streets a classification score of 1. This means that the very short streets are five times more attractive for physical activity than the very long streets. By giving each new class a classification score, the street lengths can be included in the MCA.

Figure 4.1.2: Visualisation of splitting streets





Source: Author

Table 3.9.1: Classification of street length

Street length in meters	Classification score	Frequencies
25-100 meters	Very short street (5)	6075
100 - 200 meter	Short street (4)	2469
200 – 300 meter	Normal street (3)	603
300 – 400 meter	Long street (2)	232
400 or more meter	Very long street (1)	283

4.2 Design: Walkability

Now that a workable street network dataset is created and the street lengths are reclassified, different built environment features can be linked to the street. The first built environment feature that is linked to the street network dataset is the "*Walkability*" dataset. The dataset is added to the streets based on the spatial relationship with the streets. Because the dataset is already on a street scale, the dataset can directly be linked to the developed street network dataset. Here, the data values of the "*Walkability*" dataset that are the geographically closest to the street network dataset are added to the street. The result is that the streets of the developed street network dataset now contain the data of the "*Walkability*" dataset, where the data from the "*Walkability*" dataset is added to the street network dataset based on the spatial relation between them.

As stated, the classification of the OIS department is copied and used in this research. However, these walkability classes need to be quantified so that they can be used as input in the MCA. This quantification of the walkability classes from OIS is shown in table 4.2.1. With these scores the final attractiveness scores per street per demographic groups can be calculated.

Table 4.2.1: Quantification of the walkability classes

OIS Class	Classification score
Very low	1
Low	2
Mediocre	3
Good	4
Excellent	5

4.3 Diversity; Function mix

Now that the streets of Amsterdam contain the needed design built environment features, the next category that is added to the streets is the diversity category. As stated, this category includes the land-use mix of an area. Therefore, the "*Function mix*" dataset is used in this research. Since this dataset is, just like the "*Walkability*" dataset, already on street scale, the data can directly be linked to the streets. This is, again, done by the spatial relationship between the two datasets, where the data values of the "*Function mix*" dataset that are the geographically closest to the street network dataset are added to the street. The result is that the streets of the developed street network dataset now contain the data of the "*Function mix*" dataset.

It is important to note that the type of function mix affects the attractiveness score differently per demographic group. Therefore, per demographic group the function mix type is given a score. These scores are needed to conduct the MCA and to develop the attractiveness score per street. Table 4.3.1 presents per demographic group which scores are given to which function mix type.

Table 4.3.1: Function mix reclassification per demographic group

Reclassification Category	Score for children & elderly	Score for adults
Single Function	1	1
Housing-Working	3	4
Housing-Services	4	2
Working-Services	2	3
Mixed Functions	5	5

Table 4.3.1 shows that for all demographic groups the single function types score the lowest (1) and the complete function mix the highest (5). It seems intuitive that a single function mix does not contribute to the attractiveness of a street for physical activity, and that a complete function mix has the highest contribution to this attractiveness. For the two function mix types there are differences between the demographic groups. First of all, the Housing-Working function mix type has only for adults the high score of 4. The reason for this is that the United Nations recommends the development of neighbourhoods where working and living are mixed, in order to improve, among other things, physical activity. However, this only applies for adults since children and elderly are not working (full-time). Therefore, the attractiveness of streets that have the Housing-Working function mix type is less attractive for elderly and children. Consequently, it implies that the Working-Services function mix type is more attractive for adults than for elderly and children.

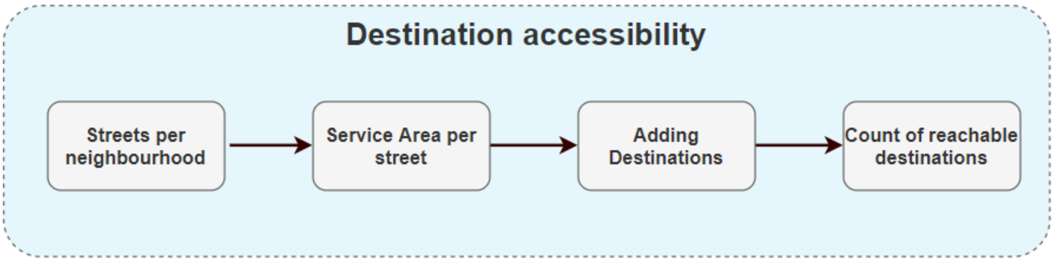
Finally, the attractiveness of streets for physical activity for the non-working demographic groups of elderly and children is higher when the function mix Housing-Services exists. More services in the streets around their homes will improve the attractiveness for physical activity for these demographic groups more than for adults.

4.4 Destination Accessibility

The street network dataset now contains information about the design category in the form of the street lengths and the walkability data, and it contains the information about the diversity category in the form of the function mix data. The next step is to add the built environment features related to the destination accessibility category.

As mentioned, the destination accessibility category measures the amount of reachable destinations given a certain travel time or distance, where in the MCA the different destinations will be given different weights according to their importance to the demographic group. Therefore, the number of reachable public playgrounds, public sport facilities, green areas and trams and metro stops need to be determined. This is done by conducting service area analysis, where per street is analysed which and how many destinations are reachable. The workflow of this service area analysis, is shown in figure 4.4.1.

Figure 4.4.1: Service area analysis workflow

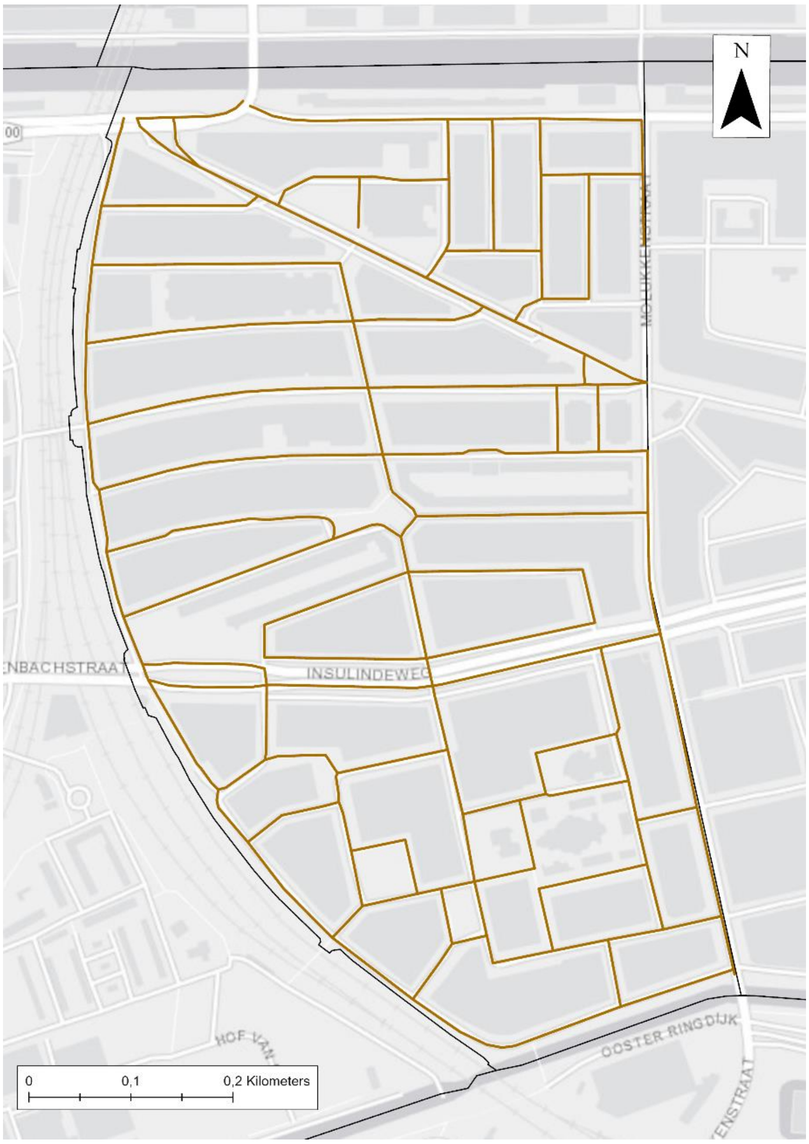


Source: Author

Figure 4.4.1 shows that the first step is to split the street network up per neighbourhood of Amsterdam. This is a necessary step because the street network dataset contains a total of 12.559 different streets, which implies that 12.559 service area analysis need to be conducted. However, because this research uses the ESRI software ArcGIS Pro, a maximum of 1000 service area analysis can be conducted. This means that for only 1000 streets of Amsterdam the destination accessibility category can be included in the development of the attractiveness scores for physical activity.

To avoid this software limitation of 1000 service area analysis, this research developed a method to conduct a service area analysis for every street of Amsterdam. Meaning that a total of 12.559 different service area analysis are conducted. The first step of this method is to split the street network up in smaller parts. In this research the street network of Amsterdam is split per neighbourhood. The result of splitting the street network per neighbourhood is that per neighbourhood a new dataset is created that represents a neighbourhood of Amsterdam, which contains the streets of that neighbourhood, as is shown in figure 4.4.2.

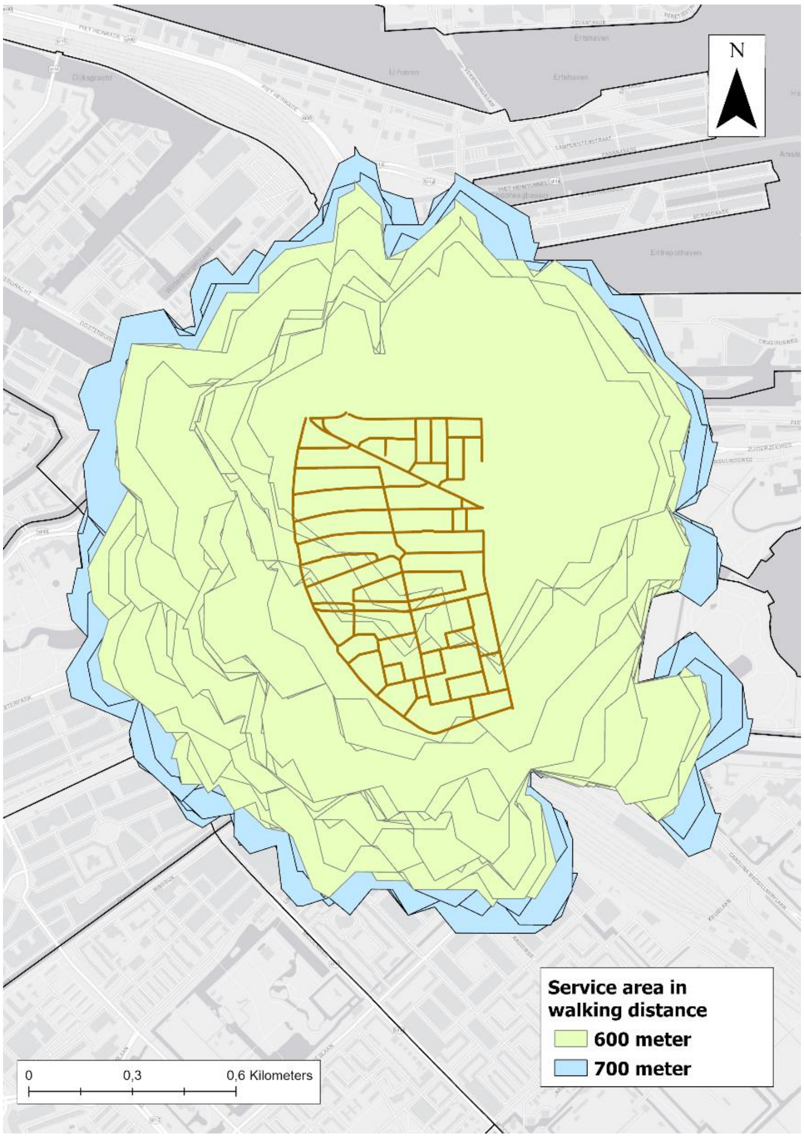
Figure 4.4.2: Visualisation of splitting the street network per neighbourhood of Amsterdam



Maker: Author, Source: WUR

Now that the street network dataset is split per neighbourhood, the next step is to conduct the service area analysis per neighbourhood dataset. As stated, there are two different cut off distances used in the service area analysis. The cut of distances are 600 meter and 700 meter. By doing so, per street a service area is created that represents the area that is reachable per street within 600 and 700 meters, as is shown in figure 4.4.3.

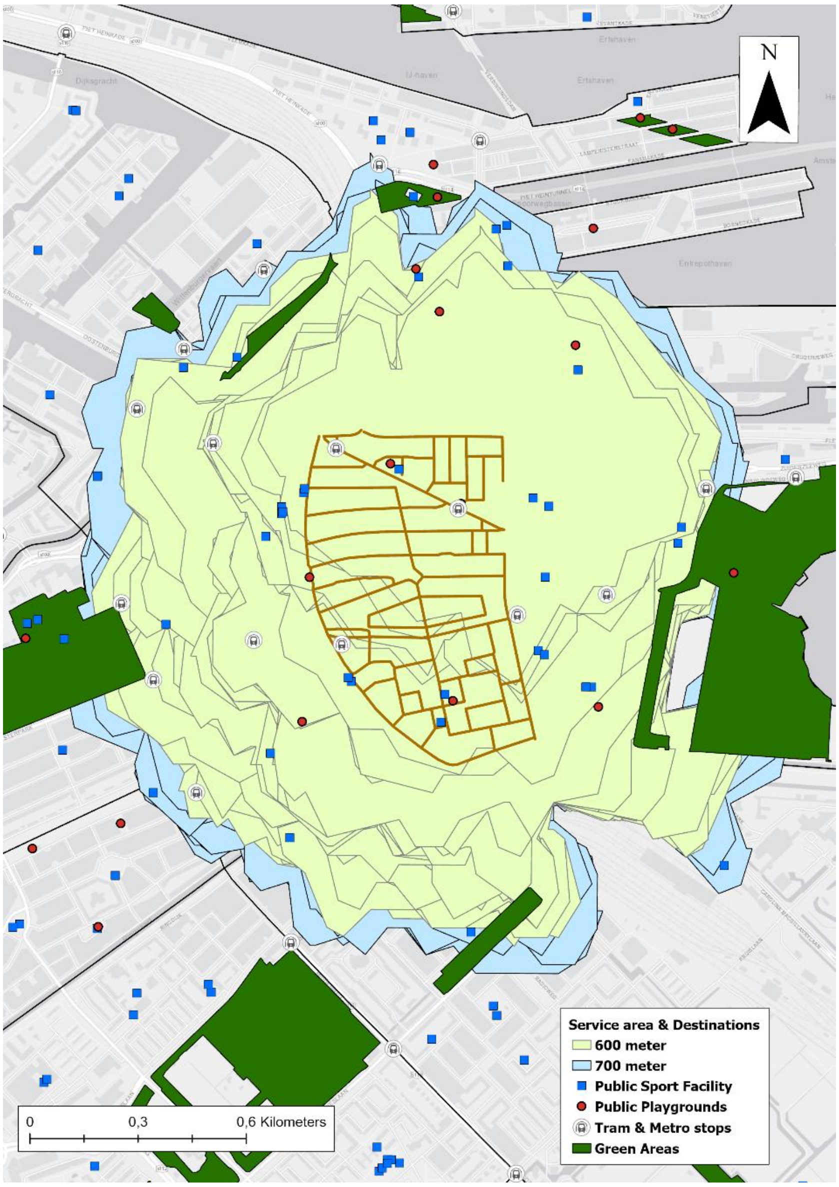
Figure 4.4.3: Visualisation of 600 and 700 meter service areas per street of a neighbourhood of Amsterdam



Maker: Author, Source: WUR

With the information of what area is reachable within 600 and 700 meters walking, the next step is to analyse which destinations lay within these areas. By adding the locations of the public playgrounds, public sport facilities, green areas and the tram and metro stops to the map of figure 4.4.3, it is possible to count the number of reachable destination per street. The result of a service area analysis for a neighbourhood is shown in figure 4.4.4. The final result of these steps is that for every street in Amsterdam the destination accessibility is included as variable.

Figure 4.4.4: Visualisation of a service area analysis for a neighbourhood in Amsterdam



Maker: Author, Source: WUR & OIS

4.4.1 Green areas

Before these locations of the green areas can be included in this research, a distinction between the different types of green areas is needed. It is necessary to distinguish the different green areas, because a city park is considered as a more attractive destination than a small green area such as recreative green areas. Therefore, the green areas that are labelled as official city parks are given a value of 5 while the other green areas are given a value of 1. This implies that a city park is five times more important in the development of an attractiveness score than the other green area types. When the number of reachable green areas per street are analysed it results in a score. This score represents the reachable green areas per street, where the higher the score the more green areas are reachable. For example, a green area score of 7 implies that there is one city park (5) and two other green areas (1) reachable.

The final step to include the green area destination as built environment feature in this research is to reclassify these green area scores. Just like the previous built environment features, the reachable green area scores are classified in five classes. So that streets where an extreme high number of reachable green areas are not automatically more attractive. This is done, since there exists a threshold where more reachable green areas will no longer contribute to a more attractive street. These reclassification scores are shown in table 4.4.1. This is table shows that a street gets the highest classification score of 5, when the streets have a reachable green area score of 11 or more. For example, if a street can reach two city parks and one other green area, or one city park and six other green areas (both a total score of 11), than that street is given a classification score of 5. By giving a classification score to each class, the destination feature of reachable green areas in Amsterdam can be included in the MCA.

Table 4.4.1: Classification of reachable green area scores

Reachable green area scores	Classification score
1 or less	1
2 to 4	2
5 to 7	3
8 to 10	4
11 or more	5

4.4.2 Public sport facilities

Just like the number of reachable green areas, the number of reachable sport facilities need to be classified before it can be included in the MCA. For the number of reachable public sport facilities there exists again a threshold, where more reachable public sport facilities will no longer contribute to a more attractive street. Therefore, the number of reachable public sport facilities is again classified in five classes and each class is given a score. The classification and their associated scores are presented in table 4.4.2. The classification of the number of reachable sport facilities is based on the range of the number of reachable sport facilities. The table shows that the highest classification score is given to a street when 20 or more public sport facilities can be reached. With these score the destination feature of reachable public sport facilities in Amsterdam can be included in the MCA.

Table 4.2.2: Classification of reachable public sport facilities

Reachable sport facilities	Classification score
4 or less	1
5 to 9	2
10 to 14	3
15 to 19	4
20 or more	5

4.4.3 Public playground

The third destination feature that has to be classified are the reachable public playgrounds. The classes and their associated score are shown in table 4.4.3. The table shows that streets will get the highest classification score when the streets can reach 11 or more public playgrounds. The classes of table 4.4.3 are, again, based on the range of the values of the reachable public playgrounds. By giving each class a classification score the destination feature reachable public playgrounds can be included in the MCA. .

Table 4.4.3: Classification of reachable public playgrounds

Reachable public playgrounds	Classification score
1 or less	1
2 to 4	2
5 to 7	3
8 to 10	4
11 or more	5

4.4.4 Tram and metro stops

The final destination accessibility that needs to be classified is are the reachable tram and metro stops. As stated, this built environment feature is a proxy for the distance to transit category, but since it measure the number of tram and metro stops that are reachable within 700 meter walking from a street it is included as a destination accessibility feature. Again, based on the range of values of the number of reachable tram and metro stops, the values are classified and given a classification score. The classes and their scores are shown in table 4.4.4. The table shows that streets are given the highest classification score (5) when they can reach 14 or more tram and/or metro stops. These classes and their scores enables this research to include this proxy for the distance to transit category in the MCA.

Table 4.4.4: Classification of reachable tram and metro stops

Reachable tram and metro stops	Classification score
1 or less	1
2 to 5	2
6 to 9	3
10 to 13	4
14 or more	5

4.5 Density: Floor Space Index

The last data that needs to be added to the street network to develop attractiveness score for physical activity per street of Amsterdam are the built environment features that are related to the density category. As mentioned, the data that is used to represent density in this research is the Floor Space Index (FSI) from the "*RUDIFUN*" dataset. Just like the "*Walkability*" and "*Function mix*" data, the FSI data is added based on the spatial relationship between the building blocks and the streets. Thus, the data of the FSI value of a building block that is geographically closest to a street is added to that street. By doing so the streets contain the data of the FSI of the closest building block with that FSI. When this is done for all streets of Amsterdam the final D category is added to the street network.

Based on the theory chapter density is considered as the most important built environment feature that affects physical activity. This implies that the higher the FSI value is, the more attractive that street is. The range of the FSI values shows that there are a few outliers that can cause biased attractiveness scores, when they are not accounted for. For example, if an extreme high FSI value is present in the street than that street will automatically get an extreme high attractiveness score. By classifying the FSI values in the classes shown in table 4.5.1 this is prevented. As the table shows the FSI values are classified in 6 classes whereby all FSI values higher than 5 are considered as the most attractive and thus given a classification score of 6. Finally, the table shows that most FSI values are 1 or less and only a few FSI values are higher than 4. The new classification classes and their scores enables this research to include the density category in the form of the FSI feature in the MCA.

Table 4.5.1: Floor Space Index classification

FSI values	Classification score	Frequencies
1 or less	1	4888
1 to 2	2	1687
2 to 3	3	1411
3 to 4	4	812
4 to 5	5	292
5 or higher	6	572

4.6 AHP set-up

Before the MCA can be conducted the weights per built environment feature need to be determined. As mentioned, the built environment features are compared to each other in respect to their underlying importance. Based on these comparisons the weight per built environment feature is determined. These comparisons are conducted using the Analytical Hierarchy Approach (AHP), where the Saaty scale is used to express the underlaying importance of the built environment features. In table 4.6.1 the AHP for the group of children is presented.

Figure 4.6.1: AHP Children

	FSI	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
FSI	1	6	6	6	6	6	6	6	**0.391**
Function mix	0.17	1	0.33	0.33	0.25	0.20	0.17	6	**0.042**
Walkability	0.17	3	1	2	0.33	0.20	0.20	7	0.069
Street Length	0.17	3	0.50	1	0.33	0.33	0.25	5	**0.057**
Green Areas	0.17	4	3	3	1	0.50	2	7	**0.126**
Public Sport Facilitie	0.17	5	5	3	2	1	0.50	6	**0.139**
Public Playgrounds	0.17	6	5.00	4	0.50	2	1	8	**0.156**
Tram & Metro stops	0.17	0.17	0.14	0.20	0.14	0.17	0.13	1	**0.020**
Sum	**2.17**	**28.17**	**20.98**	**19.53**	**10.56**	**10.40**	**10.24**	**46.00**	**1.00**

	FSI	Function mix	Walkability	Street length	Green areas	Public sport facilities	Public playgrounds	Tram & Metro stops	Total	Weights
FSI	0.462	0.213	0.286	0.307	0.568	0.577	0.586	0.130	**3.129**	**0.391**
Function mix	0.077	0.036	0.016	0.017	0.024	0.019	0.016	0.130	**0.335**	**0.042**
Walkability	0.077	0.107	0.048	0.102	0.032	0.019	0.020	0.152	**0.556**	0.069
Street Length	0.077	0.107	0.024	0.051	0.032	0.032	0.024	0.109	**0.455**	**0.057**
Green Areas	0.077	0.142	0.143	0.154	0.095	0.048	0.195	0.152	**1.006**	**0.126**
Public Sport Facilitie	0.077	0.178	0.238	0.154	0.189	0.096	0.049	0.130	**1.111**	**0.139**
Public Playgrounds	0.077	0.213	0.238	0.205	0.047	0.192	0.098	0.174	**1.244**	**0.156**
Tram & Metro stops	0.077	0.006	0.007	0.010	0.014	0.016	0.012	0.022	**0.163**	**0.020**

Source: Author

In the table is shown how the included built environment features in this research relate to each other in respect to their importance to the attractiveness scores of streets for physical activity for children. This is done by comparing the horizontal axis to the vertical axis. An example is given by the highlighted row of the walkability feature. It shows that the walkability is given a 7 when compared to tram and metro stops. Based on the Saaty scale, this means that walkability feature is very strongly more important for the attractiveness of streets than tram and metro stops. Consequently, this means that the tram and metro stops features get a 1/7 (0.14) value since the tram and metro stops are 1/7 as important as walkability.

In order to calculate the final weight of each built environment feature a few calculations are done. First of all, the sum of each column is calculated, then per built environment feature the given comparison value is divided by the sum of that column. For the example of the walkability feature, this implies that the score of 7 is divided by the total of that column (46) resulting in 0.152. The final step is to calculate the total of each row of the bottom table and divide it by the number of columns. For walkability this means a sum of 0.077 + 0.107 + 0.048 + 0.102 + 0.032 + 0.019 + 0.020 + 0.152 = 0.556. This total is then divide by the count of the rows (8) resulting in the weight of 0.069 for the walkability feature.

As stated in the theory chapter, the density category is the most important and determining built environment feature for the attractiveness of streets for physical activity. Therefore, the Floor Space Index (FSI) is given the Saaty scale value of 6 for all demographic groups. This results that for every demographic group the FSI feature has the highest weights and thus determines mostly the attractiveness score.

The aim of this research was to validate the criteria and their weights by consulting field experts. Therefore, different experts from the municipality of Amsterdam are contacted to discuss and validate the included criteria and their weights. Unfortunately, within the time frame of this research none of the contacted experts were able to confirm or deny the chosen criteria and their weights. Although the lack of expert validation, the included criteria in this research can be seen as valid since they are based on literature. The weights on the other hand are discussable. Therefore, the criteria weights may not reflect the reality. However, by conducting MCA it is simple and easy to adjust the weights according to other assumptions or opinions. Consequently, this will lead to different weights which will result in different attractiveness scores. Therefore, the MCA is suitable in this research since it allows different users to assess the included criteria differently in terms of their importance per demographic group. This means that through the use of MCA in this research, it enables this research to use chosen weights to develop the attractiveness scores and analyse the results

4.6.1 AHP Children

Figure 4.6.1 shows that for children the built environment features of the destination accessibility category; public playgrounds (0.156), public sport facilities (0.139 and green areas (0.126), are the most determining features in the attractiveness score besides the FSI feature.

As stated, children are limited to the surroundings of their homes and are dependent on their parents and/or caregivers to go to other places. This implies that it is highly important for children to have opportunities to be physical active close to their homes. Because the further away a destination is, the less likely it is that children will walk there, or are allowed to go these relative far destinations. Although all the destinations features are highly determining the attractiveness score for children, the tram and metro stops (0.020) is not and is even the least determining feature. This is due to the fact that children are often not allowed by their parents or caregivers to travel alone by public transport. Meaning that the number of reachable tram and metro stops are not affecting the attractiveness of streets for physical activity for children. The tram and metro stops can only contribute to the attractiveness of streets for physical activity for children when their parents and/or caregivers take the children with them on the tram and/or metro. Therefore, a street is attractive for physical activity for children when there are public playgrounds, public sport facilities and/or green areas reachable.

Figure 4.6.1 also shows that walkability (0.069), street length (0.057) and function mix (0.042) have intermediate to small effects on the attractiveness score. The walkability feature is thereby the most determining, since the quality and space on the street is important for children to be physical active on the streets. The more space there is on the streets the more opportunities children have to be physical active. Function mix provides children with potentially more opportunities for physical activity, because more function mix implies more (physical) activities that can be undertaken. For example, if a street has the function mix of housing and services it could be possible for children to walk to the bakery or supermarket.

The street length is not necessarily important for the attractiveness of the streets for physical activity for children themselves, but for parents and caregivers it is. In relatively short streets it is easier for children to walk around corners and to walk to other streets. This means that for parents and/or caregivers it is more difficult to maintain an overview and (social) control of the children. Therefore, in relatively short streets children are most of the time limited to a certain space to be physical active. While in relatively longer streets it is often easier for parents and adults to have an overview of the children to check where the children are and what they are doing. This can then result in a larger space for children to be physical active. This implies that for children the longer the street is, the more attractive the streets is for physical activity.

4.6.2 AHP Adults

The next AHP is conducted for the demographic group of adults. In table 4.6.2 the AHP for the adults is presented. The table shows that for adults the most determining features are function mix (0.182) and walkability (0.137). The function mix has the second highest weight in the attractiveness score for adults, because for adults it is more important to walk at or around street that have function mix. For adults this is considered as the most important, since a high function mix means that multiple activities such as shopping, working or living are close to each other. This implies that adults do not have to travel far for their daily activities such as grocery shopping. Therefore, it is more attractive to do these daily activities in a physical active way such as walking since the services are close. This is especially for adults more important, because many adults are working full-time and have less free time.

Besides the FSI and function mix features, the walkability feature strongly determines the attractiveness score too. Next to a high percentage of function mix, the space and quality of a street to walk around the different types of function mix is highly determining how pleasant and attractive a street is.

Table 4.6.2: AHP Adults

	FSI	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
FSI	1	6	6	6	6	6	6	6	**0.385**
Function mix	0.17	1	2	5	5	5	5	4	**0.182**
Walkability	0.17	0.50	1	5	4	3	5	3	**0.137**
Street Length	0.17	0.20	0.20	1	0.25	0.25	2	3	**0.047**
Green Areas	0.17	0.20	0.25	4	1	4	6	4	**0.112**
Public Sport Facilities	0.17	0.20	0.33	4	0.25	1	3	2	**0.066**
Public Playgrounds	0.17	0.20	0.20	0.50	0.17	0.333	1	0.25	**0.026**
Tram & Metro stops	0.17	0.25	0.33	0.33	0.25	0.50	4	1	**0.045**

Source: Author

Figure 4.6.2 furthermore shows that the green area feature has a relatively high weight (0.112). For many adults the proximity and availability of green areas is attractive, because as mentioned green areas provide the opportunities to relax, conduct sport activities and/or escape the city feeling. Since many adults have limited time, due to full-time work or other mandatory activities, it is important to have enough opportunities to be physical active close to their homes. When these opportunities are close to their homes and streets, the barrier of distance is kept to a minimum. This implies the more green areas are reachable, the more attractive the streets are for physically active. Since green areas provides the opportunities for physical activity, they are given a relatively high weight in the AHP for adults. This reasoning is also used for determining the weight of the built environment feature public sport facilities (0.060). The availability and proximity of public sport facilities affects the attractiveness of streets for physical activity. It affects the attractiveness scores, because the more opportunities for physical activity reachable within 600 meters, the more attractive it is to participate in physical activity.

The street length (0.047) and tram and metro stops (0.045) have almost similar effects on the attractiveness of a street for physical activity for adults. The street length is, compared to the elderly, less important for adults since adults are more mobile and can walk faster and longer distances. Therefore, a longer street is less affecting the attractiveness of streets for adults than for elderly. The same accounts for tram and metro stops, adults can walk further and faster to a tram and/or metro stops than elderly, and is therefore less important in the attractiveness of a street. Besides that, adults are mostly more comfortable in using bikes to travel the distance to and from tram and/or metro stops, further decreasing the importance of walkable tram and metro stops.

Finally, the least determining features for attractiveness for streets for adults is the public playground feature (0.026). Since public playgrounds are meant for children, it has the lowest priority for adults. However, for (young) families this feature can be important, because the parents may decide to walk to the public playgrounds. However, in this research the demographic group is adults and not young families. Therefore, the public playground features is given the lowest priority.

4.6.3 AHP Elderly

The final AHP is related to the demographic group of elderly. Table 4.6.3 shows that, just like for adults, the most determining built environment features for the attractiveness score for elderly are besides the FSI feature, the walkability (0.200) and the function mix features (0.138). However, where the function mix is the most determining for adults, the walkability is for elderly. The walkability feature is considered as the most determining feature, because elderly are compared to the other demographic groups less mobile. This implies that for elderly the quality and space on the streets is extremely important, so that they are not limited or hindered by bad quality of the streets or a limited amount of space on the streets. Since the walkability measures both the effective street width and the pedestrian demand, it reflects these needs of the elderly. Therefore, the walkability is given, besides the FSI feature, the highest importance in the AHP for the attractiveness score for the streets for physical activity.

Table 4.6.3: AHP Elderly

	FSI	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
FSI	1	6	6	6	6	6	6	6	**0.373**
Function mix	0.17	1	0.33	5	3	4	7	4	**0.138**
Walkability	0.17	3	1	5	4	6	8	6	**0.200**
Street Length	0.17	0.20	0.20	1	0.25	3	6	3	**0.068**
Green Areas	0.17	0.33	0.25	4	1	3	6	4	**0.099**
Public Sport Facilities	0.17	0.25	0.17	0.33	0.33	1	5	0.25	**0.039**
Public Playgrounds	0.17	0.14	0.13	0.17	0.17	0.20	1	0.17	**0.020**
Tram & Metro stops	0.17	0.25	0.17	0.33	0.25	4	6	1	**0.059**

Source: Author

The third most important feature is the function mix (0.138). This feature is regarded as important, because if a street has a variety of different functions than it is more attractive for elderly to go to the street and be physical active. In other words, the more function mix there is, the more activities there are to undertake. For example, a street with only houses and no other function types is less attractive for elderly to walk through than a street where services, houses and work are mixed.

The built environment features green areas (0.99), street length (0.068) and tram and metro stops (0.059) are more or less comparable to each other, in terms of their importance for the attractiveness of a street. The reachable green areas determines the attractiveness of the streets the most of these three features. This choice is made based on the attractiveness of green areas to walk around. Especially city parks are attractive because for many people a park is an opportunity to be physical active in various forms and to relax and/or escape the city. Therefore, the reachable green areas are given the highest weight after the FSI, the walkability and function mix feature. The availability and proximity of tram and metro stops are important for elderly, because most elderly do not have cars and may be using bikes less often. Therefore, the elderly rely more on public transportation to move to other places. Therefore, the availability and proximity of reachable tram and metro stops are relatively important for elderly.

As stated in the theory chapter, the length of streets determines how well connected a street is. Meaning that a relative short street is better connected, because more streets can be reached. Consequently, this implies that a shorter street is more attractive for elderly since it is easier and quicker to reach other streets and destinations. Furthermore, shorter streets allows elderly more to have a walk around a block than relatively longer streets.

Finally, the features with the lowest weights are the public sport facilities (0.039) and public playground (0.020). These features are given the lowest weights since the elderly are, as stated, less mobile. Therefore, they are less likely to participate in any of the public sport facilities such as basketball or fitness/bootcamp nor in the public playgrounds. Although these features may be attractive as destinations for the elderly to walk so they can watch others participate, the public playground and sport facilities are considered as less important as the other built environment features.

5.0 Results

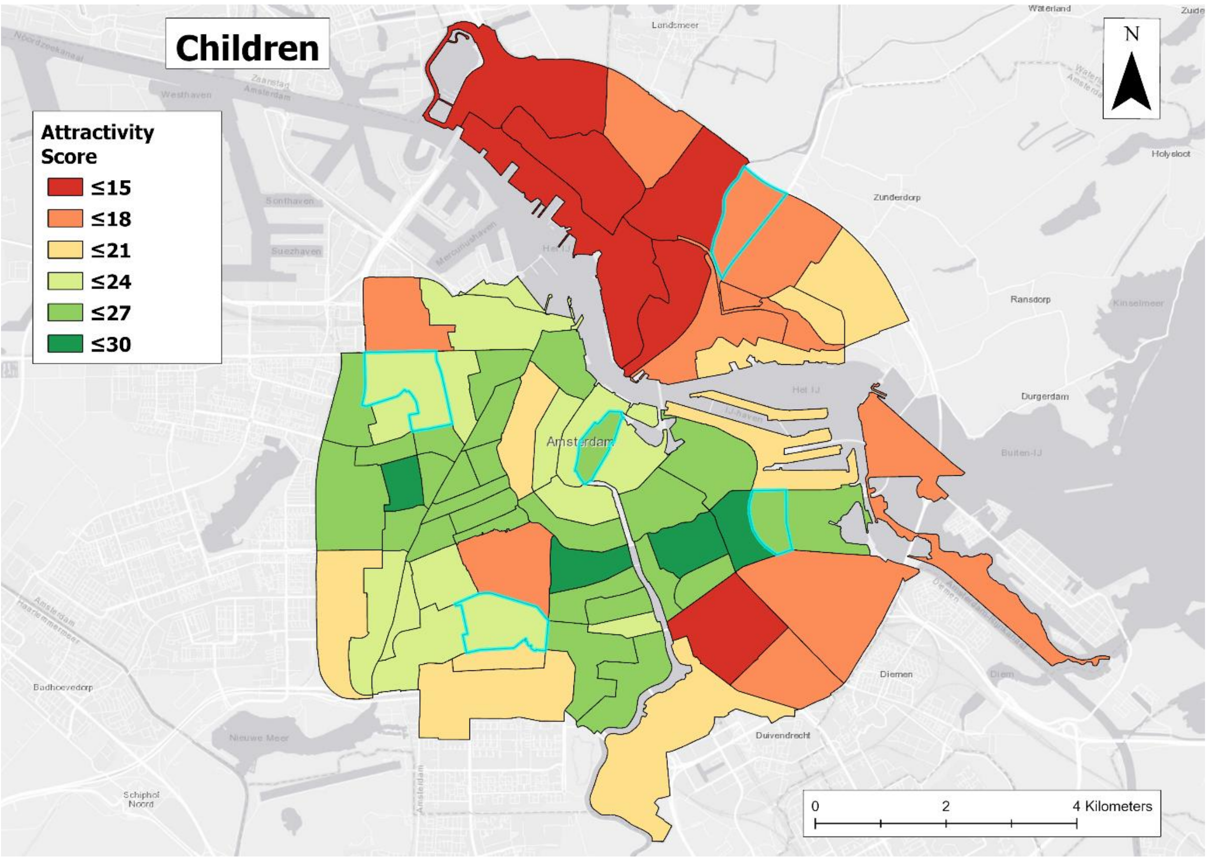
This chapter discusses and presents the results of the Multi Criteria Analysis. The first result of this research is presented in figure 5.0.1. This figure shows the average attractiveness score per demographic group per neighbourhood. This average attractiveness score is calculated by adding all the attractiveness scores per street per demographic group per neighbourhood, and then divide it by the total number of streets of that neighbourhood. These average attractiveness scores show that the Northern part (and especially the North Western part) of Amsterdam is the least attractive for physical activity for all demographic groups. Furthermore, the figures show that on average Amsterdam is, based on the included built environment features, considered as more attractive for physical activity for elderly than for adults and children.

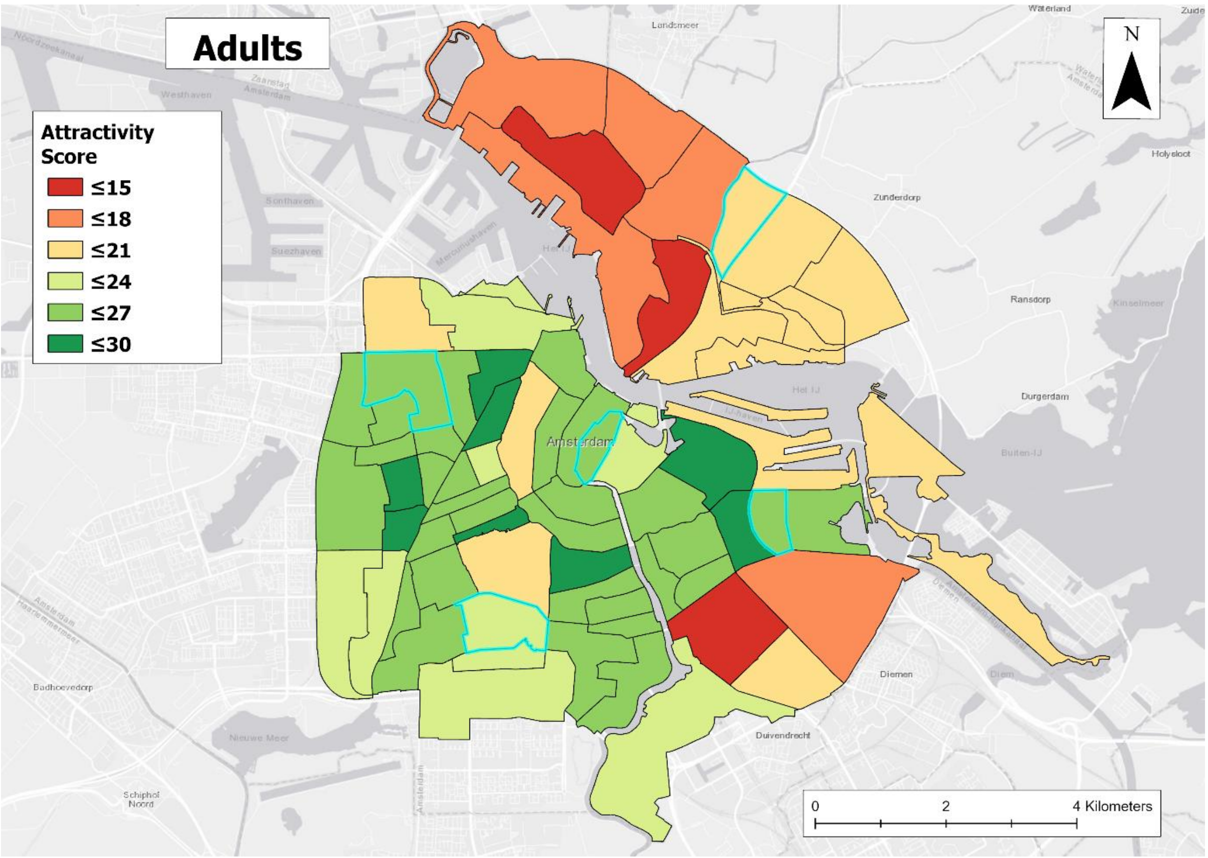
Although figure 5.0.1 presents an overview that provides a first impression of the different average attractiveness scores per neighbourhood for different demographic groups, it does not analyse the construction of the scores nor shows it the different scores on street level. As stated, this research develops attractiveness scores for all 12.559 included streets of Amsterdam. This means that it is difficult to analyse and visualise all these 12.559 different streets and their score in an understandable way. Therefore, in order to structurally analyse and visualise the results in a understandable way and to enhance the readability of this chapter, five neighbourhoods and their streets are selected to analyse. By selecting five neighbourhoods it is possible to analyse in depth per demographic group how the attractiveness scores are constructed and how these scores are spatially distributed in the neighbourhood.

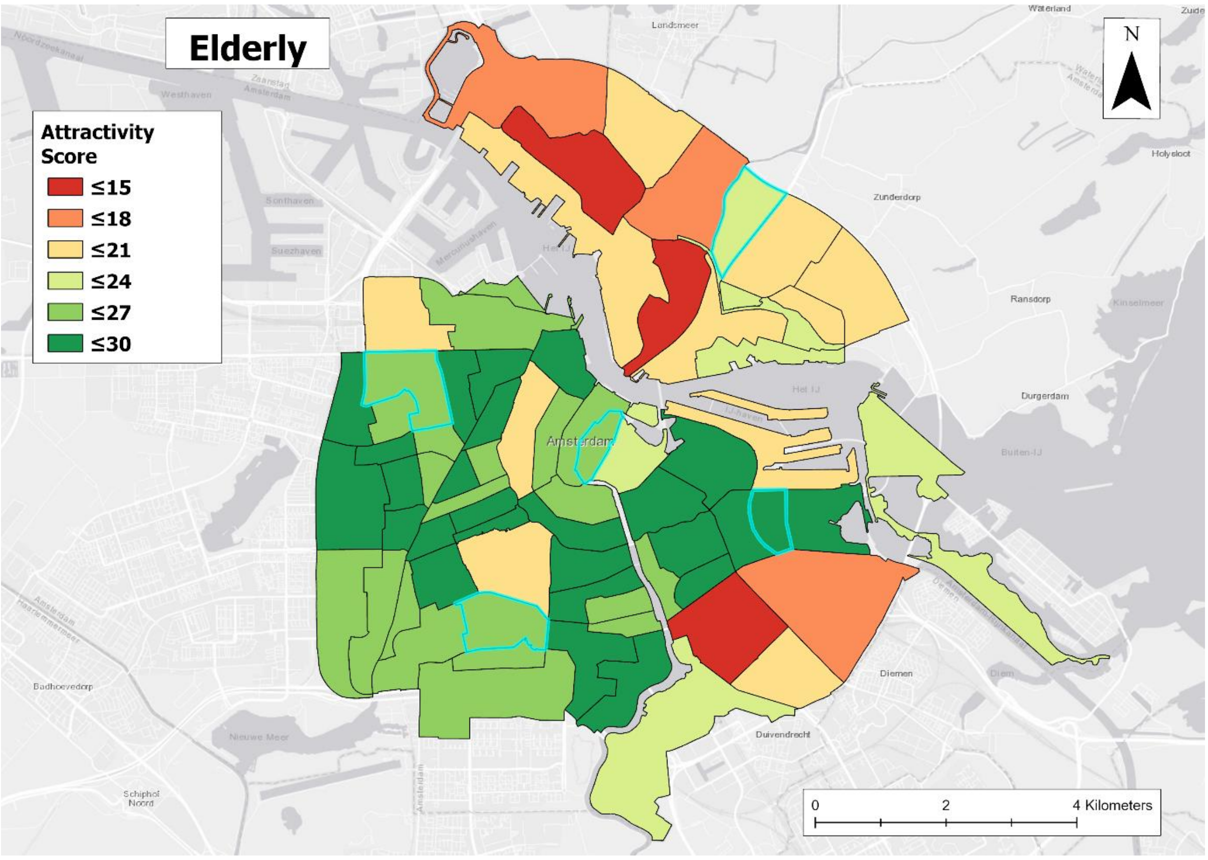
The five neighbourhoods that are selected to further analyse are the highlighted neighbourhoods in figure 5.0.1. The neighbourhoods are selected based on their location in Amsterdam. The selection is made so that each city district (Centre, North, East, South and West) is represented by a neighbourhood.

The following paragraphs will discuss per demographic group the attractiveness scores of the streets for the selected neighbourhoods. Because the attractiveness scores are developed by a MCA, it is possible to analyse per demographic group the most determining features of the attractiveness score. By doing so, an insight is given on the construction of the attractiveness score per demographic group. Furthermore, it provides an explanation why some neighbourhoods score relatively low or high for a demographic group. Finally, the paragraphs will analyse the suitability of the neighbourhoods by comparing the attractiveness score per demographic group with the actual age composition of the people living in the neighbourhood. This will show how (un)suitable a neighbourhood is for the people living in the neighbourhood.

Figure 5.0.1: Average attractiveness scores for physical activity per demographic group per included neighbourhood of Amsterdam







Maker: Author, Source: WUR & OIS

5.1 City Centre

The first neighbourhood that is analysed, is the neighbourhood in the city centre. Table 5.1.1 and figure 5.1.1 present the attractiveness scores per demographic group for the neighbourhood. Figure 5.1.2 shows the spatial distribution of the streets in the neighbourhood and their attractiveness scores

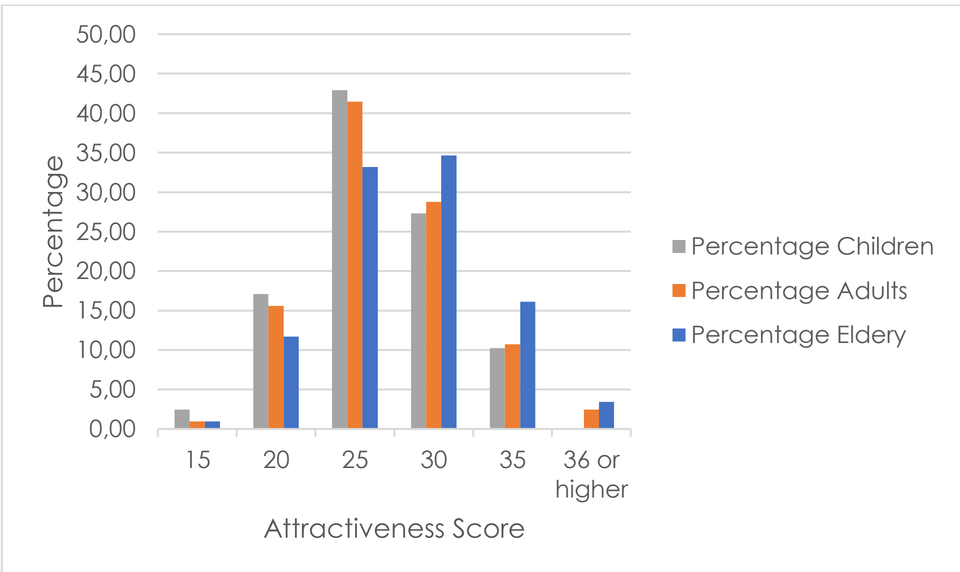
The first thing that table and figure 5.1.1 show is that the streets of the city centre neighbourhood are the most attractive for physical activity for adults and elderly and the least attractive for children. None of the streets have an attractiveness score of 36 or higher for children, while for adults and elderly respectively 2.44% and 3.41% of the streets score 36 or higher. Furthermore, for children a total of 19.51% of the streets have the lowest scores (20 or less), while for elderly this is only 12.69%.

Secondly, table and figure 5.1.1 show that most streets in this neighbourhood have an attractiveness score between 21 to 25 for children (42.93%) and for adults (41.46%), while for elderly most streets score between 26 to 35 (34.63%). Thirdly, figure 5.1.2 shows that in the South/Centre West part of this neighbourhood the most attractive streets are located for all demographic groups.

Table 5.1.1: Attractiveness scores in percentage per demographic group for the city centre neighbourhood

Attractiveness Scores	Children	Adults	Elderly
15 or less	2.44	0.98	0.98
16 to 20	17.07	15.61	11.71
21 to 25	42.93	41.46	33.17
26 to 30	27.32	28.78	34.63
31 to 35	10.24	10.73	16.10
36 or higher	0.00	2.44	3.41
Total	**100**	**100**	**100**

Figure 5.1.1: Distribution of the attractiveness scores per demographic group in percentage for the city centre neighbourhood



Source: Author

Figure 5.1.2: Visualisation of attractiveness scores per street per demographic group for the city centre neighbourhood

Maker: Author, Source: WUR & OIS

For the demographic groups children and elderly, an analysis of the construction of the attractiveness scores is done to provide insight why the streets of this neighbourhood are relatively (un)attractive for these demographic groups. Based on the AHP for children the most determining features for children are the FSI feature and the destination accessibility features. For elderly the most determining features are the FSI, the walkability and function mix features. For each of these built environment features an overview is made that shows the classification scores in percentage, presented in table 5.1.2.

It must be noted, that these classification scores are discussed in the operationalisation chapter and that per built environment feature the classification score can have a different meaning. For example, a classification score of 5 in table 5.1.2 means for the FSI feature a FSI value of 5 or higher, a walkability index of excellent, a complete function mix, 11 or more reachable public playgrounds, 20 or more reachable public sport facilities and 11 or more green area score. These different classification scores must be considered when analysing the different classification scores and their percentages.

Table 5.1.2: Classification scores in percentage for the most determining features for the city centre neighbourhood

Classification Score	FSI	Walkability	Function mix for adults	Public playgrounds	Public sport facilities	Green areas
1	1.46	47.80	54.63	23.90	99.51	100
2	2.44	17.56	1.95	72.68	0.49	0
3	38.54	16.59	6.34	3.41	0	0
4	31.71	17.56	32.68	0	0	0
5	25.85	0.49	4.39	0	0	0

First of all, the table shows that the streets have high classification scores for the FSI feature. Only 1.46% and 2.44% of the streets have a FSI classification score of respectively 1 and 2. This reflects that the city centre has a high building density, because as stated in the operationalisation chapter, a high classification score represent high FSI values. As stated in the theory chapter, a higher building density leads to a more attractive area or street for physical activity. And because the FSI feature is the most determining feature for all demographic groups, the city centre score has relatively high attractiveness scores for all demographic groups.

The table also shows that the streets of this neighbourhood score relatively high on the walkability and function mix features. The percentage of streets that have a classification score of 4 for walkability and function mix are respectively 17.56% and 32.68%. This means that, as one can expect, the city centre has a high function mix percentage. What is more surprising are the relatively high walkability scores for the city centre neighbourhood, meaning that the amount of space for the pedestrian demand is good to excellent. Since both the walkability and function mix features contribute significantly to the attractiveness scores for adults and elderly, these high walkability and function mix scores explain the high attractiveness scores for physical activity for adults and elderly.

In contrary, the destination accessibility features score low. For example, 99.51% and 100% of the streets have a classification score of 1 for respectively reachable public sport facilities and green areas. Furthermore, only 3.41% of the streets have a classification score of 3 for the reachable public playgrounds. This implies that a low number of destination are within a 600 meter distance of the streets of this neighbourhood. This consequently results in relatively low attractiveness scores for physical activity for children, because the destination accessibility features contribute, besides the FSI, the most to the attractiveness score for children.

Finally, the age composition of the neighbourhood is analysed to show the suitability of the demographic groups living in the neighbourhood and the attractiveness of the streets for physical activity for these demographic groups. Table 5.1.3 presents the age composition of the analysed neighbourhoods. The attractiveness scores of this neighbourhood indicate that the neighbourhood is in terms of the attractiveness for physical activity most suitable for adults and especially for elderly. Since the majority of people are adults (85.04%) and only a small percentage of the people in the neighbourhood are children (6.50%) or elderly (8.76%), the fit of this neighbourhood can be considered as good.

Thus, the demographic groups living in this neighbourhood are surrounded by streets that are attractive for physical activity for them. Only for children the attractiveness scores could be improved. However, only a small percentage of the people living in the neighbourhood are children. Therefore, the need of specific improvements for children is relatively low.

Table 5.1.3: Age composition in percentage of the analysed neighbourhoods in 2018

Neighbourhood	Children (0 to 18 years)	Adults (18 to 65 years)	Elderly (65 or older)
City centre	6.50	85.04	8.76
East	16.55	74.47	8.98
South	24.54	57.55	17.91
West	18.18	73.82	8.00
North	28.55	63.43	8.02

Source: OIS

5.2 East neighbourhood

The next neighbourhood is the neighbourhood in the East part of Amsterdam. The attractiveness scores of the streets of this neighbourhood for physical activity are presented in table and figure 5.2.1. In figure 5.2.2 the spatial distribution of the streets and their attractiveness scores are shown.

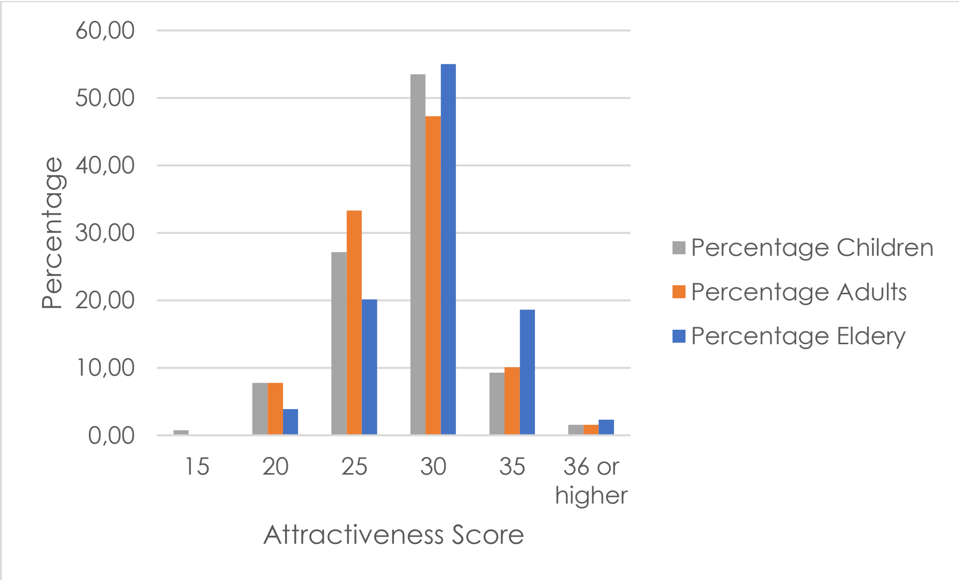
First of all, table and figure 5.2.1 show that the streets of this neighbourhood are comparable attractive for children and adults, while for elderly the streets are considered as more attractive. A total of 20.93% of the streets have an attractiveness score of 31 or higher, while for children (10.85%) and adults (11.63%) these percentages are significantly less. Furthermore, the table and figure show that for all demographic groups most streets have the relatively mediocre to high attractiveness scores of 26 to 30. It also shows that the percentage of streets with the highest attractiveness scores of 36 or higher, are for all demographic group comparable with 2.33% being the highest for elderly.

These relatively high attractiveness scores for all demographic groups are reflected in figure 5.2.2. The figure shows that only in the South part of the neighbourhood some streets have a relatively low attractiveness scores for all demographic groups and especially for children. Furthermore, the figure shows that the relative high attractiveness scores for all demographic groups are spread out over the whole neighbourhood.

Table 5.2.1: Attractiveness scores in percentage per demographic group for the East neighbourhood

Attractivity Scores	Children	Adults	Elderly
15 or less	0.78	0.00	0.00
16 to 20	7.75	7.75	3.88
21 to 25	27.13	33.33	20.16
26 to 30	53.49	47.29	55.04
31 to 35	9.30	10.08	18.60
36 or higher	1.55	1.55	2.33
Total	**100**	**100**	**100**

Figure 5.2.1: Distribution of the attractiveness scores per demographic group in percentage for the East neighbourhood



Source: Author

Figure 5.2.2: Visualisation of attractiveness scores per street per demographic group for the East neighbourhood

Maker: Author, Source: WUR & OIS

Table 5.2.2 presents the per most determining built environment feature the classification score in percentage for this neighbourhood.

Table 5.2.2: Classification scores in percentage for the most determining features for the East neighbourhood

Classification Score	FSI	Walkability	Function mix adults	Public playgrounds	Public sport facilities	Green areas
1	10.08	0.78	84.50	0.00	0.00	57.36
2	16.28	1.55	10.85	79.84	15.50	0.78
3	62.02	16.28	2.33	20.16	55.04	41.86
4	9.30	27.91	0.78	0.00	29.46	0.00
5	2.33	53.49	1.55	0.00	0.00	0.00

First of all, the table shows that the streets have relatively low classification scores for the FSI feature. Only 9.30% and 2.33% of the streets have a FSI classification score of respectively 4 and 5, and that the majority of the streets have a FSI score of 3 (62.02%). This reflects that the building density of this neighbourhood is relatively low. These relatively low FSI scores imply that the other built environment features of the streets of this neighbourhood score relatively high, since the overall attractiveness scores are relatively high for all demographic groups.

The table furthermore shows that the streets of this neighbourhood score relatively high on the walkability feature. More than 80% of the streets in this neighbourhood score on the walkability feature a 4 or 5, meaning that more than 80% of the streets have a good to excellent walkability index score. These high walkability scores contribute to the attractiveness for physical activity for adults and especially for elderly. In contrary, the function mix scores are relatively low. Most of the streets (84.50%) have no function mix (score 1). It is important to note that the classification function mix score 2 represents the function mix Housing-Services. This means that this type of function mix is less determining for the attractiveness score for adults than for children or elderly. This is an explanation for the difference in attractiveness scores between adults and elderly, because for adults 10.85% of the streets score relatively low while for elderly it scores relatively high.

The classification score percentages of the destination accessibility features show that a relatively high amount of destination are reachable within 600 meters. Especially the number of public sport facilities reachable is high, for 29.46% of the streets between 15 and 19 different sport facilities are reachable (classification score of 4). Furthermore, none of the streets of this neighbourhood have a classification score of 1 for reachable public playground and sport facilities. The high scores on both reachable public sport facilities as public playgrounds, explains the relatively high attractiveness scores for children.

The number of reachable green areas is mixed. In this neighbourhood the streets can either reach none or 1 green area (57.36%), or the streets (41.86%) can reach multiple green areas and a city park (classification score 3). Only a very small amount of streets (0.78%) can reach only multiple green areas but no city park. This is another reason for the differences between the attractiveness scores for adults and elderly. For elderly the reachable green areas is slightly more important than for adults. Therefore, the higher scores for reachable green areas results in higher attractiveness scores for elderly.

Finally, the age composition of the neighbourhood in table 5.1.3 shows that the suitability of this neighbourhood is only party sufficient. Most of the people are adults (74.47%), but a large number of children live in the neighbourhood (16.55%), while the streets of the neighbourhood are the least attractive for physical activity for children. Thus, the suitability can be considered as bad, but the attractiveness scores show that the streets are for all demographic groups relatively attractive for physical activity. Nevertheless, in order to improve the physical activity in this neighbourhood more attention and care is needed for the demands of children.

5.3 South neighbourhood

The third analysed neighbourhood is located in the South part of Amsterdam. The attractiveness scores of the streets for physical activity of this neighbourhood are presented in table and figure 5.3.1. In figure 5.3.2 the spatial distribution of the streets and their attractiveness scores are shown.

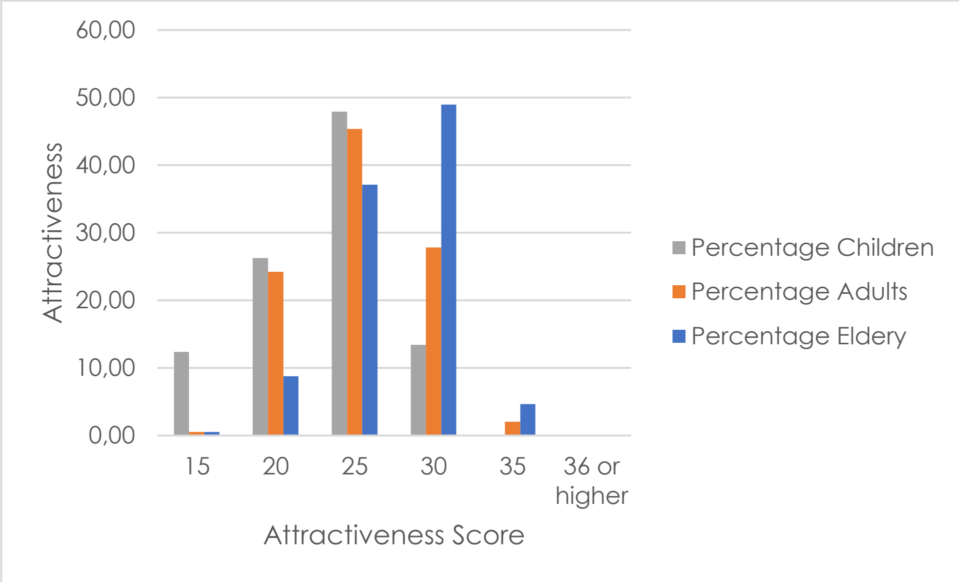
The streets of this neighbourhood are relatively unattractive for physical activity for all demographic groups. None of the streets have attractiveness scores of 36 or higher, and for only adults (2.06%) and elderly (4.64%) the streets have a score between 31 and 35. Moreover, table and figure 5.3.1 show that for adults (24.75%) and for children (38.66%) the streets have an attractiveness for of 20 or less. Especially for children the streets are unattractive with 12.37% of the streets scoring 15 or lower. For children (47.94%) and adults (45.63%) most streets score between 21 to 25, while for elderly (48.97%) most streets score 26 to 30. This indicates that the streets of this neighbourhood are most attractive for physical activity for elderly.

That the streets of this neighbourhood are relatively unattractive for physical activity for all demographic groups is also shown in figure 5.2.2. For children almost all streets are unattractive and for adults only a few streets are relatively attractive. Especially in the South Eastern part of this neighbourhood there are streets located that are relatively unattractive for physical activity.

Table 5.3.1: Attractiveness scores in percentage per demographic group for the South neighbourhood

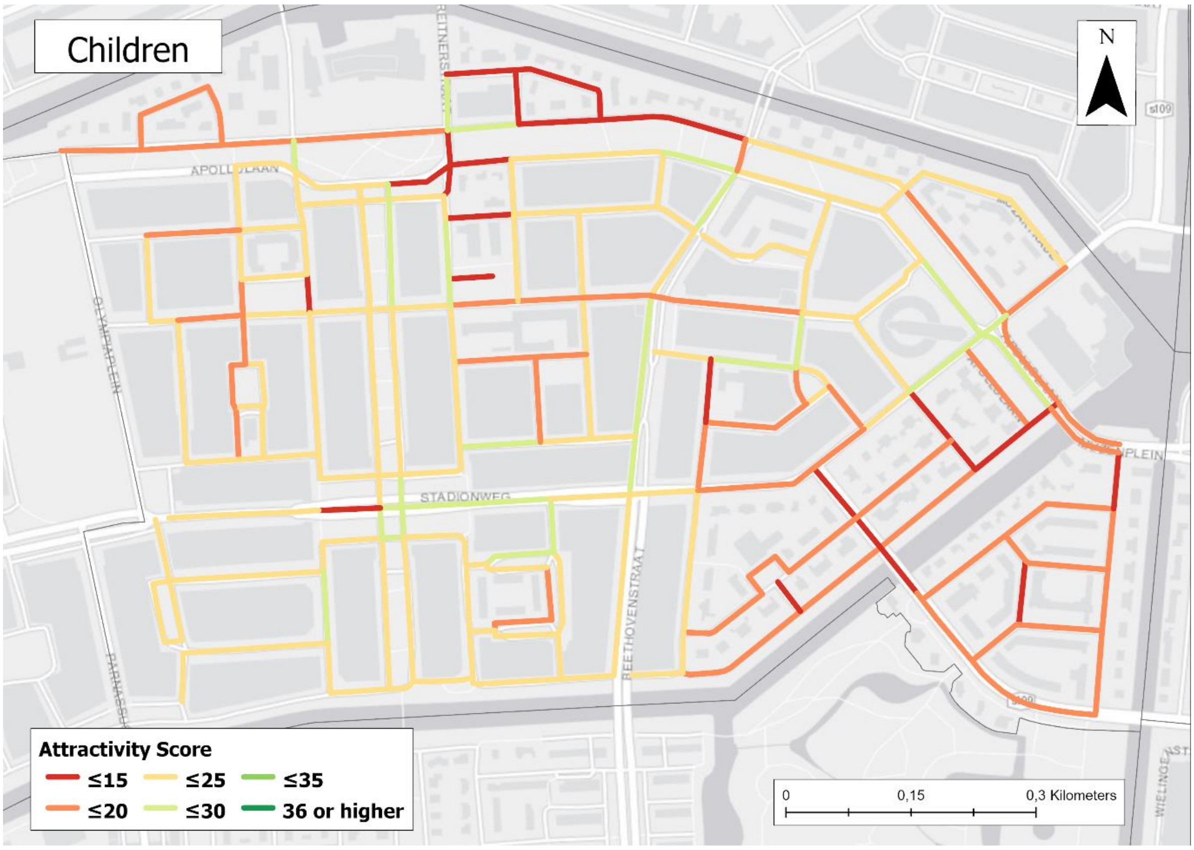
Attractiveness Scores	Children	Adults	Elderly
15 or less	12.37	0.52	0.52
16 to 20	26.29	24.23	8.76
21 to 25	47.94	45.36	37.11
26 to 30	13.40	27.84	48.97
31 to 35	0.00	2.06	4.64
36 or higher	0.00	0.00	0.00
Total	**100**	**100**	**100**

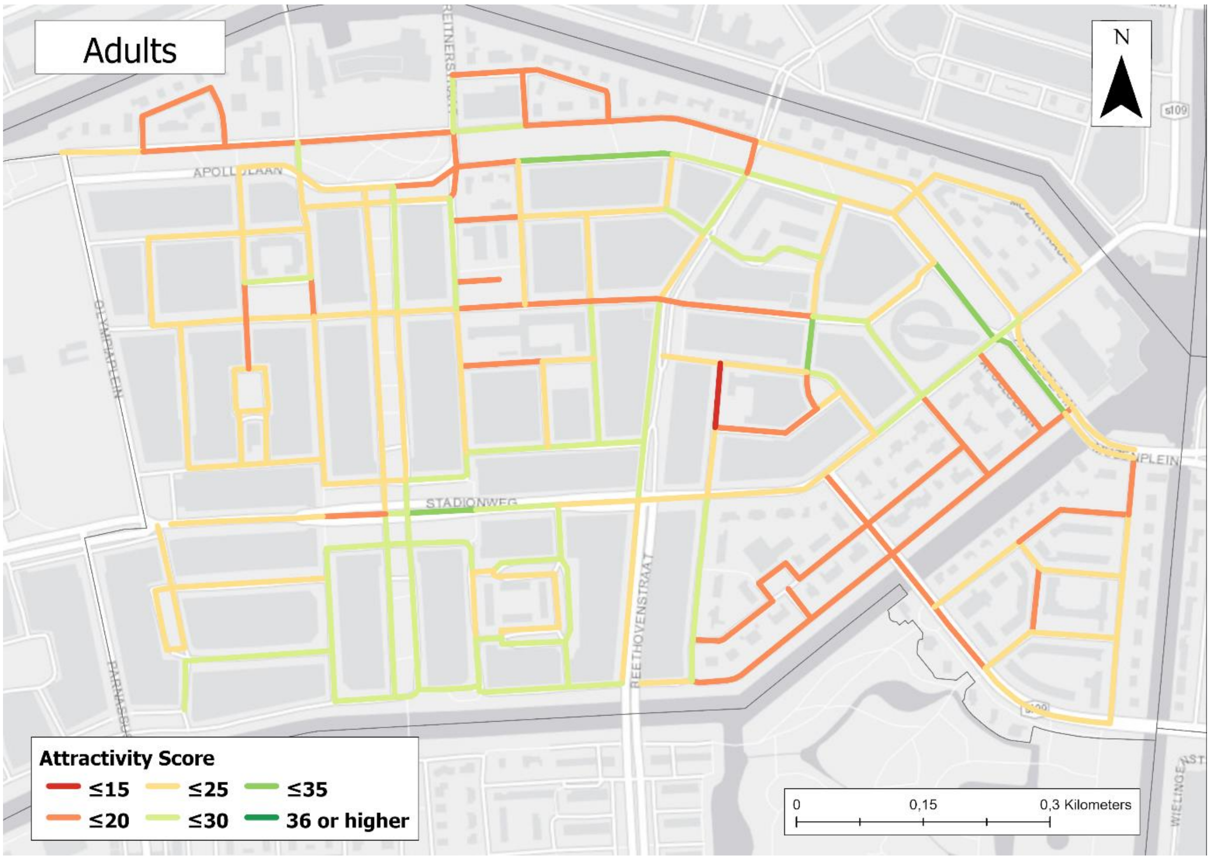
Figure 5.3.1: Distribution of the attractiveness scores per demographic group in percentage for the South neighbourhood



Source: Author

Figure 5.3.2: Visualisation of attractiveness scores per street per demographic group for the South neighbourhood





Maker: Author, Source: WUR & OIS

Table 5.3.2 shows first of all that the streets score relatively low on the FSI feature. None of the streets have a classification score of 5 and only 9.28% of the streets have a score of 4. In addition, a total of 45.36% of the streets have a FSI classification score of 2 or lower. These figures imply that in this neighbourhood the building density is relatively low. Consequently, this means that the attractiveness scores in this neighbourhood are lower than the other neighbourhoods due to the high importance of the FSI feature in the development of the attractiveness score for all demographic groups. The streets of this neighbourhood also score relatively low for the function mix feature. Almost all of the streets have no function mix (91.75%). This results in lower attractiveness scores for elderly and especially for adults, since for adults the function mix is, besides the FSI feature, the most determining built environment feature.

Table 5.3.2: Classification scores in percentage for the most determining features for the South neighbourhood

Classification Score	FSI	Walkability	Function mix adults	Public playgrounds	Public sport facilities	Green areas
1	23.20	1.03	91.75	92.27	34.54	42.78
2	22.16	1.03	5.15	7.73	50.00	0.00
3	45.36	1.03	0.00	0.00	14.95	57.22
4	9.28	9.79	2.58	0.00	0.52	0.00
5	0.00	87.11	0.52	0.00	0.00	0.00

The walkability classification scores are significantly high for the streets of this neighbourhood. Almost all streets have are labelled as good (9.28%) or excellent (87.11%) in terms of walkability. This results in high attractiveness scores for elderly, since the walkability is next to the FSI feature the most determining built environment feature.

The classification scores for the destination accessibility features explain the relatively low attractiveness score for children. Most streets (92.27%) can reach no or only 1 public playground and for none of the streets the public playground classification score is 3 or higher. The public sport facility classification scores are in the meanwhile relatively high, meaning that many public sport facilities are within 600 meter of the streets. Just like the East neighbourhood, the number of reachable green areas is mixed. In the South neighbourhood most streets (57.22%) can reach multiple green areas and a city park. The other streets (42.78%) in the neighbourhood reach no or 1 green area within 600 meter.

The figures of table 5.1.2 show that in the South neighbourhood the age composition, is compared to the other neighbourhoods, the most equally divided. Furthermore the table shows that in the South neighbourhood, relatively seen, most children are living (24.54%). However, the attractiveness scores for the streets of this neighbourhood show that the neighbourhood is the least attractive for physical activity for children. Therefore, the suitability of the neighbourhood is considered as low. More attention is needed to enhance the physical activity attractiveness of the streets for children. Based on the figures of table 5.3.2, the number of reachable public playground can especially be improved. On the other hand, the high percentage of elderly (17.91%) living in the neighbourhood may imply an acceptable suitability, since the streets are the most attractive for physical activity for elderly.

5.4 West neighbourhood

The attractiveness scores in percentage per demographic group for the neighbourhood in the West part of Amsterdam are presented in table and figure 5.4.1. In figure 5.4.2. the spatial distribution of the streets and their attractiveness scores are shown.

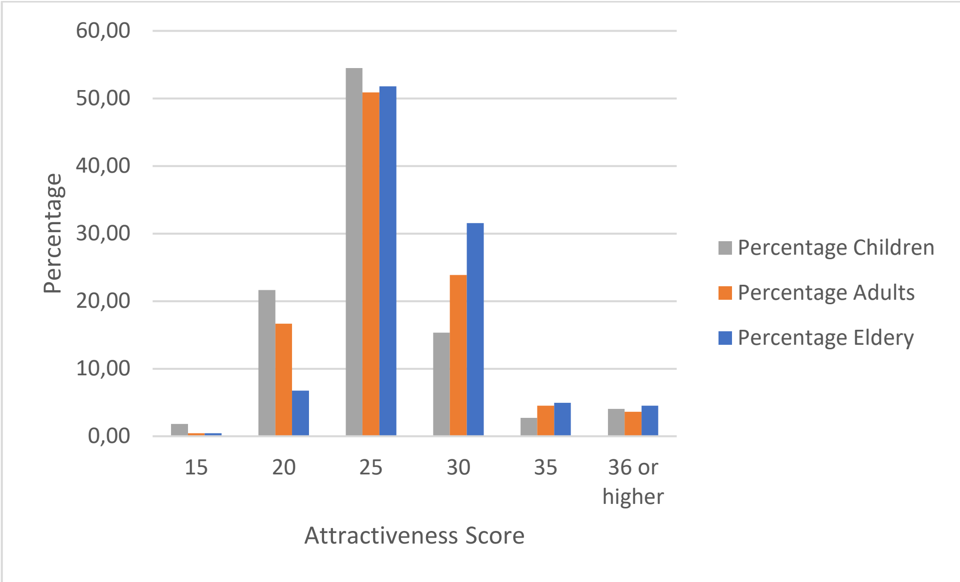
The first thing that table and figure 5.4.1 shows is that the attractiveness scores of the streets are close to equal for all demographic groups. For example, the highest attractiveness score of 36 or higher exists for all demographic groups and the percentage of streets that have these score is relatively high for all demographic groups, 3.60% (adults) to 4.50% (elderly). Furthermore, the most common attractiveness scores are for all demographic groups between 21 to 25. Nevertheless, there are some differences in the attractiveness scores. First of all, the streets can be considered less attractive for children since 21.62% of the streets have an attractiveness score between 16 and 20, while for adults and elderly respectively only 16.67% and 6.76% of the streets have these scores. In addition, the percentage of streets that have an attractiveness scores between 26 and 30 is for children (15.32%) the lowest and for elderly (31.53%) the highest. Therefore, the streets of this neighbourhood tend to be more attractive for adults and elderly than for children.

Figure 5.4.2 shows that the most attractive streets for all demographic groups are located in the Western part of the neighbourhood. It also shows, that for especially children the complete Eastern part is not or a little attractive for physical activity, while for elderly this part of the neighbourhood is considered as attractive.

Table 5.4.1: Attractiveness scores in percentage per demographic group for the West neighbourhood

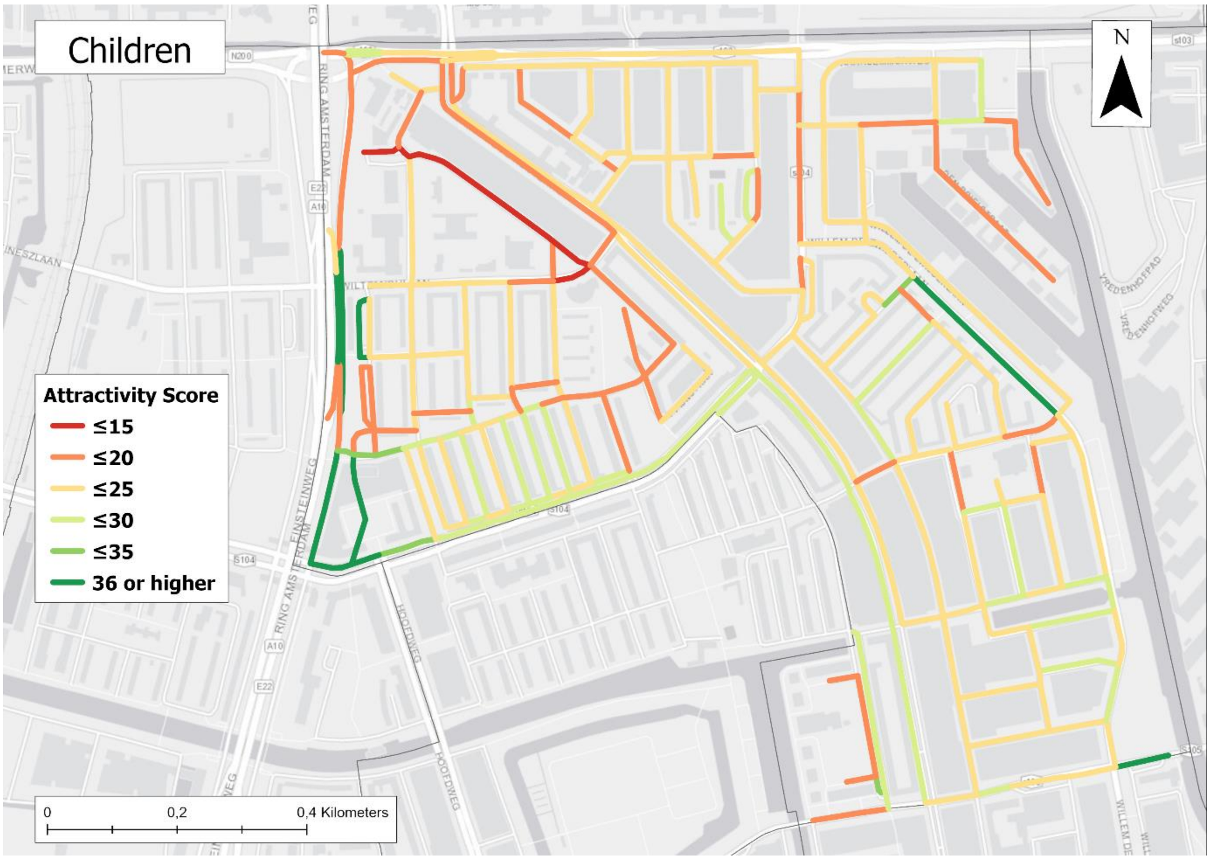
Attractiveness Scores	Children	Adults	Elderly
15 or less	1.80	0.45	0.45
16 to 20	21.62	16.67	6.76
21 to 25	54.50	50.90	51.80
26 to 30	15.32	23.87	31.53
31 to 35	2.70	4.50	4.95
36 or higher	4.05	3.60	4.50
Total	**100**	**100**	**100**

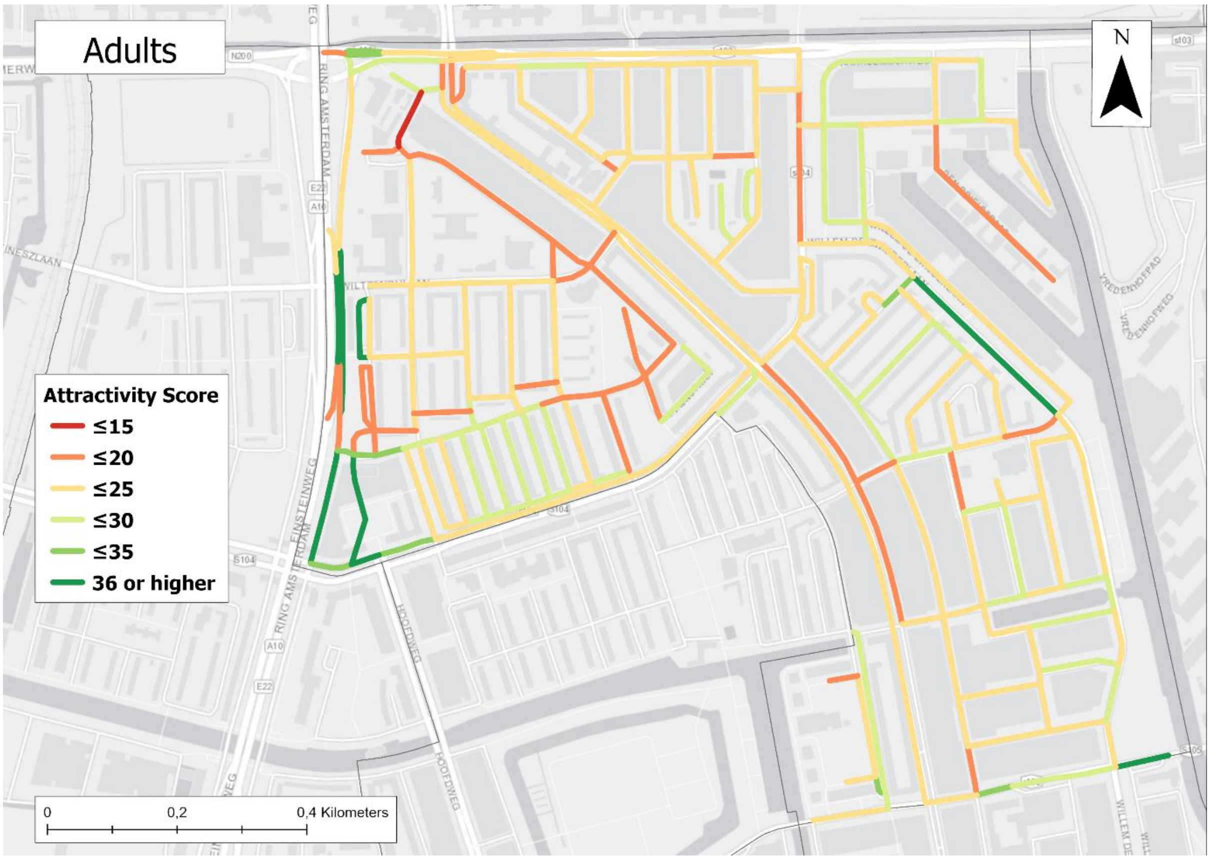
Figure 5.4.1: Distribution of the attractiveness scores per demographic group in percentage for the West neighbourhood

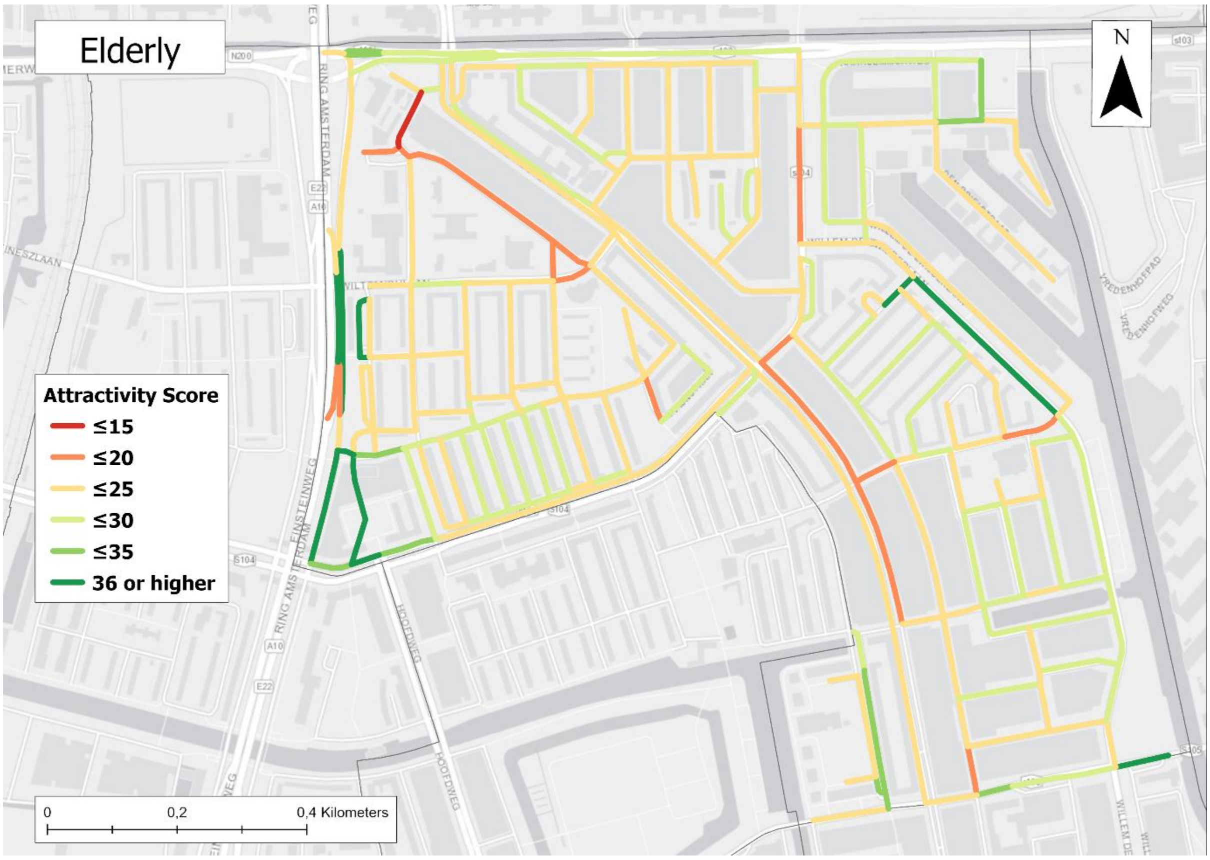


Source: Author

Figure 5.4.2: Visualisation of attractiveness scores per street per demographic group for the West neighbourhood







Maker: Author, Source: WUR & OIS

Table 5.4.2 presents per most determining built environment feature the classification score in percentage for this neighbourhood.

Table 5.4.2: Classification scores in percentage for the most determining features for the West neighbourhood

Classification Score	FSI	Walkability	Function mix adults	Public playgrounds	Public sport facilities	Green areas
1	12.61	4.50	87.39	100.00	8.56	10.36
2	52.25	3.60	8.11	0.00	36.04	10.36
3	25.68	5.86	0.90	0.00	44.59	77.03
4	3.15	17.57	3.60	0.00	10.81	0.00
5	6.30	68.47	0.00	0.00	0.00	2.25

The first thing that springs out is the building density of this neighbourhood. As the table shows the FSI classification scores of the streets are somewhat mixed, but on the low side. Most of the streets (52.25%) have a FSI classification score of 2, implying a low density. A total of 12.61% streets even have a very low density (classification score of 1). Although these low FSI and thus density scores, some streets (6.30%) have highest FSI scores. Therefore, there is a somewhat mixed density in this neighbourhood.

The second notable feature is the walkability. Just like the South neighbourhood, most the streets (68.47%) of the West neighbourhood have the highest walkability score. Only a small percentage of streets have a low (3.60%) to very low (4.50%) walkability score. This results in high attractiveness scores for elderly, because as stated for elderly the walkability is the most determining besides the FSI feature. Furthermore, there are no streets that have a complete function mix. Most streets (87.39%) even have a single function and thus no function mix at all. Only a small percentage of the streets have a Housing-Services (8.11%), or a Housing-Working (3.60%) function mix. These two function mix types explain again the differences between the attractiveness scores for adults and elderly. Because for elderly the Housing-Services function mix is more attractive than for adults, while for adults the Housing-Working function mix is more attractive.

Thirdly, the table shows that in this neighbourhood there are no streets that can reach more than 1 public playground within 600 meter. This can result in significantly lower attractiveness scores for children. However, the streets score better on the public sport facilities and green area features. Especially, the reachable green areas score relatively high; 77.03% of the streets can reach a city park and multiple green areas within 600 meter. Although the very low scores on reachable public playgrounds, the higher scores on the other two destination accessibility features result in more average to high attractiveness scores for children.

Based on the age composition of this neighbourhood (table 5.1.3), the suitability of this neighbourhood could be improved. The attractiveness scores are somewhat equal for all demographic groups with being most attractive for elderly, but only 8% of the population is elderly. Furthermore, more than 18% of the population are children, while the attractiveness scores are the lowest for children. Therefore, the suitability of the neighbourhood could be improved by improving the attractiveness of the streets for physical activity for adults and especially children.

5.5 North neighbourhood

The final neighbourhood that is analysed is the neighbourhood located in the North part of Amsterdam. Again the attractiveness scores of the streets in percentages for physical activity per demographic group are presented in table and figure 5.5.1.

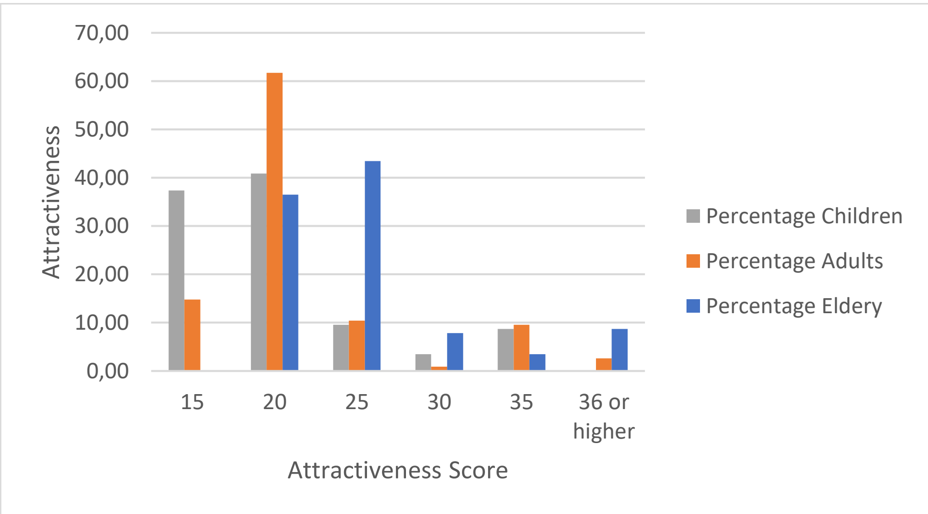
The streets of this neighbourhood are most attractive for elderly and the least attractive for children. This difference between the attractiveness of the streets for children and elderly is reflected by the percentage of streets that have an attractiveness score of 15 or less. For children 37.39% of the streets have an attractiveness score of 15 or less, while none of the streets have such scores for elderly. The same applies for the highest scores. None of the streets have attractiveness scores of 36 or higher for children, while 8.70% of the streets have these scores for elderly. The streets are also for adults less attractive, since the majority of the streets have an attractiveness score between 16 and 20 (61.74%) for adults.

Figure 5.5.2 shows that the streets with relatively high attractiveness scores for all demographic, are somewhat clustered in the centre of this neighbourhood. However, these high attractive streets are surrounded by very low attractive streets. Finally, figure 5.5.2 shows that especially the Western part of this neighbourhood is considered as unattractive for all demographic groups.

Table 5.5.1: Attractiveness scores in percentage per demographic group for the North neighbourhood

Attractiveness Scores	Children	Adults	Elderly
15 or less	37.39	14.78	0.00
16 to 20	40.87	61.74	36.52
21 to 25	9.57	10.43	43.48
26 to 30	3.48	0.87	7.83
31 to 35	8.70	9.57	3.48
36 or higher	0.00	2.61	8.70
Total	**100**	**100**	**100**

Figure 5.5.1: Distribution of the attractiveness scores per demographic group in percentage for the North neighbourhood



Source: Author

Figure 5.5.2: Visualisation of attractiveness scores per street per demographic group for the North neighbourhood

Maker: Author, Source: WUR & OIS

Table 5.2.2 presents the classification scores in percentage per built environment feature. As the table shows most of the streets score low on the FSI feature. Only 12.17% of the streets have the highest FSI classification score. The majority of the streets either have a FSI classification score of 2 (33.04%) or 1 (46.09%). This implies that the density of the streets and the neighbourhood is relatively low, which results in relatively low attractiveness scores for all demographic groups.

Table 5.5.2: Classification scores in percentage for the most determining for the North neighbourhood

Classification Score	FSI	Walkability	Function mix adults	Public playgrounds	Public sport facilities	Green areas
1	46.09	0.00	97.39	92.17	100.00	87.83
2	33.04	0.00	2.61	7.83	0.00	0.00
3	7.83	0.00	0.00	0.00	0.00	12.17
4	0.87	0.00	0.00	0.00	0.00	0.00
5	12.17	100.00	0.00	0.00	0.00	0.00

The walkability classification scores shows that all streets in this neighbourhood score the highest possible, meaning that there is no street where the walkability index is not excellent. This results in high attractiveness score for elderly, since the walkability index is highly determining the attractiveness score for this demographic group. In contrary to the walkability, the function mix scores are very low. Only 2.61% of the streets in the neighbourhood have a function mix. All the other streets have only one function and therefore no function mix. This results especially for adults in lower attractiveness scores, since the function mix index is highly determining the attractiveness score for adults.

Furthermore, the table shows that the destination accessibility features scores are also low. Especially the reachable public sport facilities is very low. There are no streets in the neighbourhood that can reach more than 4 public sport facilities (classification score 1), and only 7.83% of the streets can reach more than 1 public playground. In addition, only 12.17% of the streets can reach a city park and multiple green areas within 600 meters. All the other streets (87.83%) can reach no or only 1 green area. These very low destination accessibility scores explain the relatively low attractiveness scores for children. Furthermore, the low scores of the reachable green areas explain, combined with the low scores of function mix and high scores of walkability, the differences between the attractiveness scores for adults and elderly.

The attractiveness scores indicate that the streets of the neighbourhood are the least attractive for children followed by adults, and the most attractive for elderly. However, the age composition of this neighbourhood shows that the smallest population group of this neighbourhood are the elderly (8.02%). Furthermore, from the five analysed neighbourhoods the North neighbourhood has the highest percentage of children. Therefore, the streets should be most attractive for physical activity for children and the least for elderly. Thus, the suitability for this North neighbourhood is considered as very poor. The suitability could be improved by improving the attractiveness scores of the streets for physical activity for especially children.

6.0 Conclusion

This research aimed to improve the understanding of the different effects of the built environment on physical activity for different demographic groups. Therefore, the main research objective of this research is:

- Determine how the built environment affects the attractiveness of streets for physical activity for different demographic groups

In order to structurally answer the main research objective, sub-objectives are developed. These sub-objectives split the main research objective in multiple parts that enables this research to, step by step, answer the main research objective. Furthermore, the sub-objectives resulted in applying the conceptual framework of this research for the case of the streets of Amsterdam. The sub-objectives of this research are:

- Determine which demographic groups are relevant to distinguish with respect to the relation between physical activity and built environment features.
- Determine which built environment features are relevant for which demographic groups.
- Develop a framework that combines built environment features as attractivity indicators that calculate and determine the attractiveness of an area for different demographic groups.
- Implement and demonstrate this framework in the case of Amsterdam.
- Validate the framework and test its plausibility.

In the first sub-objective the different demographic groups that are relevant to distinguish with respect to the relation between physical activity and built environment features, are determined based on a literature review. This review showed that, in most studies in the field of the built environment and physical activity, there are mainly three demographic groups distinguished. These demographic groups are; children, adults and elderly. Therefore, this research has distinguished these three demographic groups with respect to the relation between physical activity and built environment features. With this the first sub-objective of this research is answered.

With the second sub-objective of this research the relevant built environment features per demographic group are determined. This determining of the built environment features is, again, done by a literature review. This literature review showed that almost all built environment features affecting physical activity and the attractiveness for physical activity, can be categorised in one of the five D categories. Based on these five D categories, different built environment features are included in this research.

However, as stated the effects of these different built environment features differs per demographic group. Therefore, in the third sub-objective of this research the different effects of these built environment features on the attractiveness of a street or area per demographic group is determined. In order to analyse these different effects on the different demographic groups, this research conducted Multi Criteria Analysis using the Analytical Hierarchy Approach method. This method enabled this research to assess the different built environment features differently per demographic group. This assessment of the built environment features resulted that for each demographic group, different weights are determined for different built environment features. These weights reflect the importance of the built environment in the development of the attractiveness score of a street or area In other words, the higher the weight of a built environment feature, the more determining that feature is for the attractiveness score for that demographic group.

The two literature reviews in combination with the Multi Criteria Analysis method resulted in a conceptual framework that showed how the built environment affects the attractiveness of a street or area for different demographic groups. Based on the different weights constructed by the Multi Criteria Analysis, this research applied and demonstrated the framework in the case of the streets of Amsterdam. This resulted that per demographic group and per street of Amsterdam an attractiveness score is developed. The use of Multi Criteria Analysis enabled this research to analyse in detail how the attractiveness scores per neighbourhood and per street are constructed. This analysis showed how a single or multiple built environment features can affect the attractiveness score of a street or area for physical activity for a demographic group.

The last sub-objective deals with the validation and plausibility of the developed framework. The aim of this research was to validate the included built environment features and their weights by field experts. Unfortunately, within the time frame of this research no field experts were able to validate the included built environment features of this research. This implies that the built environment features and weights are discussable. However, the included built environment features are based on a literature review. Therefore, the type of built environment features that are included are considered as correct. The associated weights on the other hand may differ from reality and are therefore discussable.

To conclude this research, the main research objective has to be answered. Based on both literature reviews, the developed conceptual framework and the implementation of this framework in the case of Amsterdam, this research has showed that the built environment has a significant effect on the attractiveness of an area for physical activity. Furthermore, this research showed that the impact of the built environment on the attractiveness score differs per demographic group and per built environment feature. Although the included built environment features are based on the literature review and their weights are partly based on literature and partly on common sense, they are not validated by an expert and therefore questionable. Nevertheless, this research developed a method whereby it is possible to measure and analyse the effects of the built environment on the attractiveness of a street or area for physical activity per demographic group. This method could even be used on an individual basis where per individual their preferences are used to develop the attractiveness scores for streets or areas.

7.0 Discussion

This final chapter discusses the different issues and challenges that this research encountered. Hereby, the strengths and weakness of this research are discussed and elaborated. Finally, this chapter will provide some suggestions for future research with this method and in this field of research.

First and foremost, the lack of validation of the criteria weights in this research must be noted. As stated, one of the best method to validate the criteria and their weights is by conducting surveys among the included demographic groups. However, due to a limited time frame and budget, this research was not able to conduct these surveys. A second method to validate the criteria weights is by consulting field experts. Although multiple potential field experts were contacted, they were either not able to validate the criteria weights, or had no time to discuss the criteria and their weights. This implies that the criteria and their weights are discussable. However, as stated the criteria are selected based on a literature review. Meaning that, the included criteria can be considered as correct and valid. The associated weights of the criteria may be seen as arbitrary, since the weights are partly determined by literature and partly by the assumptions and common sense of the author of this research.

Therefore, the use of Multi Criteria Analysis can, on the one hand, be seen as one of the major weaknesses of this research, and on the other hand the conducted MCA strengthens this research. Through the use of MCA, it is possible to quickly and easily adjust the weights according to the assumptions or opinions of others. This implies that for different persons, situations and/ or scenarios, different weights can be used to develop the attractiveness scores. Furthermore, the use of MCA enables this research to analyse in detail how the attractiveness scores are developed. These analysis show what built environment features are the most determining per demographic group for the attractiveness of an area for physical activity. It also shows which built environment features are lacking and where these built environment features are lacking. This can be useful information for policy and decision makers, so that they can take measures to improve the attractiveness of a street or area for physical activity for a specific demographic group. Therefore, the use of MCA is on the one hand suitable and even desirable in this research, and on the other hand it can result in difficulties in validating the results

The second notable and relatable issue of the MCA in this research, is that this research distinguished three demographic groups. These groups are distinguished based on a literature review. However, more and/or different demographic groups could be distinguished. For example, the literature review showed that the group of children could be split in children and adolescents. This could be considered in future research, since children and adolescents may have different preferences for different built environment features. However, it might be difficult to determine and validate the preferences of children and adolescents. Instead of using age to distinguish the demographic groups, other characteristics can be used. Some suggestions for other demographic groups are; men and women, students, young families and full-time employees.

This research showed that the built environment features that affect the attractiveness of an area can be categorised in the five D's. Based on these five D categories a total of eight different built environment features are included in this research. However, more built environment features could be included. Especially more destinations could be included to extend the variety of reachable destinations. Some suggestions for extra built environment features are; bus stops, street furniture such as benches and lights, aesthetics of a street and/or area, and museums. Although including more built environment features is relatively easy, it also implies that per demographic group and per extra built environment feature extra weights need to be determined and included. This means that the more criteria are included, the harder and more complex it is to determine and validate the weights of the criteria.

Related to adding more built environment features, is the issue of defining reachability. For the destination accessibility it is necessary to determine what is considered as reachable and what not. In order to determine this reachability, this research conducted a short literature review on both Dutch and international studies on reachability. This review showed that reachability is measured by acceptable walking distances. However, the review also showed that there are no standards or general guidelines for acceptable walking distances. There is no standard acceptable walking distance, because it differs per person and per destination what an acceptable walking distance is. Therefore, it is almost impossible to define the correct reachability. Especially in the context of the Netherlands it is difficult to define reachability, because in the Netherlands people use more often bicycles for walkable distances. Therefore, it is hard to estimate and determine what acceptable walking distances are. Nevertheless, the literature review provided this research with some suggestions for acceptable walking distances. Based on the literature review this research used a walking distance of 700 meter as an acceptable walking distance for tram and metro stops. For the other destinations the acceptable walking distance is set to 600 meters. Although these distances are based on a literature review, they may not represent the correct acceptable walking distance.

A third notable issue relates to the technical part of this research. The data of the Floor Space Index related to the density category, the data of the function mix related to diversity category and the data of the walkability index related to the design category, are added to the street network based on their spatial relation. This implies that the data of these built environment features are added to the streets that are the geographically closest to these built environment features. This may lead to results that differ from reality. For example, when the function mix of a building block is added to the geographically closest street, it may lead to a wrong impression of the total amount of the function mix in the street. In reality, one side of the street may have more function mix than the other side of the street. By adding the function mix only to the street that is geographically closest to this function mix, the total function mix of the whole street is not accounted for and can potentially lead to wrong results. To overcome this issue, it is recommended to develop a tool that measures the distances to all of the nearest different built environment features. These distances can then be used to calculate a rate that determines how much of a certain built environment feature should contribute to the value of that built environment for the street. In the case of function mix this would imply that for a street the distances to the nearest different building blocks and their function types are measured. Then per building block and its function type the distance to the streets determines how much of this function type should contribute to the function mix value of the street. By doing so, some sort of a weighted average rate can be used to determine the values of the built environment features of a streets. This may lead to more accurate results.

The quality of the used OpenStreetMap (OSM) data must be noted. As stated, the used street network in this research derives from the Wageningen University and Research (WUR). The WUR used the data from OSM and made adjustments to this data to develop the street network that is used in this research. Next to the street network dataset, this research used the data from OSM to include the public playgrounds as a destination. The usage of OSM data in research is discussable. The usage of OSM is discussable, because OSM is based on a community of volunteers who develop and publish the data. This implies that on the one hand the data is continuously improved based on local data and local knowledge. However, on the other hand this means that the developed and published data may be incorrect for different reasons. Therefore, the OSM data should always be checked and controlled for when it is used in research.

This research concludes with three recommendations for future research in the field of the built environment and its effects on (the attractiveness of a street or area for) physical activity. Firstly, as this research showed the effects of the built environment differs per demographic group and perhaps per person. In order to measure and analyse these different effects, it is recommended to conducted surveys among the included demographic groups of the research, so that the opinions of the demographic groups can be used to validate the criteria weights.

Secondly, when conducting these surveys it is recommended to include questions or statements about the attractiveness of destinations and acceptable (walking) distances for these destinations. Doing so, can result in walking distances that reflect per demographic group and per destination the acceptable walking distance. These walking distances can then be used to determine per street or area how many and which built environment features are reachable within the acceptable walking distance.

Third and finally, the use of physical activity data could be recommendable to use in this and/or other related types of research. With the use of this data, statistical analysis can be conducted to prove and/or demonstrate potential correlations between the attractiveness of a street or area for physical activity and the actual amount of physical activity of that street or area. This could, besides the surveys and expert consultations, be another method of validating the include criteria and their weights. However, as previous studies have indicated it is difficult and complex to prove and/or demonstrate these correlations between the built environment and physical activity, since there are many different overlapping factors affecting physical activity that differ per demographic group and even person. Therefore, the quality of the physical activity data should be checked and considered before such statistical analysis can be conducted.

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Appendix

AHP for children

	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
Function mix	1.00	0.33	0.33	0.25	0.20	0.17	6.00	**0.055**
Walkability	3.00	1.00	2.00	0.33	0.20	0.20	7.00	**0.099**
Street Length	3.00	0.50	1.00	0.33	0.33	0.25	5.00	**0.082**
Green Areas	4.00	3.00	3.00	1.00	0.50	2.00	7.00	**0.226**
Public Sport Facilitie	5.00	5.00	3.00	2.00	1.00	0.50	6.00	**0.245**
Public Playgrounds	6.00	5.00	4.00	0.50	2.00	1.00	8.00	**0.271**
Tram & Metro stops	0.17	0.14	0.20	0.14	0.17	0.13	1.00	**0.022**
Sum	22.17	14.98	13.53	4.56	4.40	4.24	40.00	**1**

	Function mix	Walkability	Street length	Green areas	Public sport facilities	Public playgrounds	Tram & Metro stops	Weights
Function mix	0.045112782	0.022257552	0.024630542	0.054830287	0.045454545	0.039292731	0.15	**0.054511206**
Walkability	0.135338346	0.066772655	0.147783251	0.07310705	0.045454545	0.047151277	0.175	**0.098658161**
Street Length	0.135338346	0.033386328	0.073891626	0.07310705	0.075757576	0.058939096	0.125	**0.08220286**
Green Areas	0.180451128	0.200317965	0.221674877	0.219321149	0.113636364	0.47151277	0.175	**0.22598775**
Public Sport Facilities	0.22556391	0.333863275	0.221674877	0.438642298	0.227272727	0.117878193	0.15	**0.24498504**
Public Playgrounds	0.270676692	0.333863275	0.295566502	0.109660574	0.454545455	0.235756385	0.2	**0.271438412**
Tram & Metro stops	0.007518797	0.009538951	0.014778325	0.031331593	0.037878788	0.029469548	0.025	**0.022216572**

AHP for adults

	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
Function mix	1.0000	2.0000	5.0000	5.0000	5.0000	5.0000	4.0000	**0.335**
Walkability	0.5000	1.0000	5.0000	4.0000	3.0000	5.0000	3.0000	**0.232**
Street Length	0.2000	0.2000	1.0000	0.2500	0.2500	2.0000	3.0000	**0.067**
Green Areas	0.2000	0.2500	4.0000	1.0000	4.0000	6.0000	4.0000	**0.168**
Public Sport Facilities	0.2000	0.3333	4.0000	0.2500	1.0000	3.0000	2.0000	**0.098**
Public Playgrounds	0.2000	0.2000	0.5000	0.1667	0.3333	1.0000	0.2500	**0.035**
Tram & Metro stops	0.2500	0.3333	0.3333	0.2500	0.5000	4.0000	1.0000	**0.066**
Sum	2.55	4.32	19.83	10.92	14.08	26.00	17.25	1

	Function mix	Walkability	Street length	Green areas	Public sport facilities	Public playgrounds	Tram & Metro stops	Weights
Function mix	0.392156863	0.463320463	0.25210084	0.458015267	0.355029586	0.192307692	0.231884058	**0.334973539**
Walkability	0.196078431	0.231660232	0.25210084	0.366412214	0.213017751	0.192307692	0.173913043	**0.232212886**
Street Length	0.078431373	0.046332046	0.050420168	0.022900763	0.017751479	0.076923077	0.173913043	**0.066667421**
Green Areas	0.078431373	0.057915058	0.201680672	0.091603053	0.284023669	0.230769231	0.231884058	**0.168043873**
Public Sport Facilities	0.078431373	0.077220077	0.201680672	0.022900763	0.071005917	0.115384615	0.115942029	**0.09750935**
Public Playgrounds	0.078431373	0.046332046	0.025210084	0.015267176	0.023668639	0.038461538	0.014492754	**0.034551944**
Tram & Metro stops	0.098039216	0.077220077	0.016806723	0.022900763	0.035502959	0.153846154	0.057971014	**0.066040987**

AHP for elderly

	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Weights
Function mix	1.00	0.33	5.00	3.00	4.00	7.00	4.00	**0.225**
Walkability	3.00	1.00	5.00	4.00	6.00	8.00	6.00	0.371
Street Length	0.20	0.20	1.00	0.25	3.00	6.00	3.00	**0.097**
Green Areas	0.33	0.25	4.00	1.00	3.00	6.00	4.00	**0.150**
Public Sport Facilities	0.25	0.17	0.33	0.33	1.00	5.00	0.25	**0.053**
Public Playgrounds	0.14	0.13	0.17	0.17	0.20	1.00	0.17	**0.022**
Tram & Metro stops	0.25	0.17	0.33	0.25	4.00	6.00	1.00	**0.081**
Total	**5.18**	**2.24**	**15.83**	**9.00**	**21.20**	**39.00**	**18.42**	**1.000**

	Function mix	Walkability	Street Length	Green Areas	Public Sport Facilities	Public Playgrounds	Tram & Metro stops	Total	Weights
Function mix	0.193	0.149	0.316	0.333	0.189	0.179	0.217	1.576	**0.225**
Walkability	0.580	0.446	0.316	0.444	0.283	0.205	0.326	2.600	0.371
Street Length	0.039	0.089	0.063	0.028	0.142	0.154	0.163	0.677	**0.097**
Green Areas	0.064	0.112	0.253	0.111	0.142	0.154	0.217	1.052	**0.150**
Public Sport Facilities	0.048	0.074	0.021	0.037	0.047	0.128	0.014	0.370	**0.053**
Public Playgrounds	0.028	0.056	0.011	0.019	0.009	0.026	0.009	0.157	**0.022**
Tram & Metro stops	0.048	0.074	0.021	0.028	0.189	0.154	0.054	0.568	**0.081**