The preferences and willingness to pay of urban residents in the Netherlands regarding Green-Based Solutions for heat adaptation

Graduation Thesis

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MSc. Construction Management and Engineering (CME)
2020-2021

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Eindhoven, 25th January 2021

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Preface

This thesis is the result of my graduation project for the Construction Management and Engineering (CME) masters at the Eindhoven University of Technology. The aim of the study was to get insight into the preferences and willingness to pay of Dutch citizens in Green-Based Solutions (GBS) for heat in urban areas. The study also focusses on the available information surrounding GBS, especially the advantages of different types of GBS. Additionally, the study looks closely at the opportunities for each type of GBS to be implemented more frequently in urban areas in the Netherlands. During this study, I worked closely together with employees of Arcadis NL, a built asset design consultancy firm focussing on sustainability.

Climate change is one of the most prominent topics in scientific research in recent years. One of the results of climate change is the increased temperature, and especially, the significant increase in temperature in urban areas. The use of GBS such as trees and green roofs have proven to reduce these effects. Therefore, the Dutch government is following in the footsteps of the European Union by promoting a higher percentage of GBS in urban areas. However, the implementation rate of GBS has been stagnating. Implementing GBS in (re)development projects provides additional cost for firms, and the current assumption is that these costs can not be transferred to the future residents, as they are unwilling to pay extra for a house with implemented GBS. On this basis, I saw an opportunity to dive into the subject of GBS, and see if a solution could be found for this problem. By finding the preferences of urban residents concerning GBS characteristics, the best GBS might be found for urban areas. The results of this study could help in increasing the implementation rate of GBS in the Netherlands. Which would be beneficial for the health and wellbeing of Dutch residents, and the environment.

The last five months have been an interesting new experience for me, not having done a thesis in my bachelors. Not to mention the presence of Covid-19 during the complete duration of this study, which made it significantly harder to meet with supervisors. So, first of all, I would like to thank dr. Ir. Peter van der Waerden, for thinking of new angles and possibilities and answering each of my questions quickly and thoroughly. Also, I would like to thank dr. Gamze Dane, who provided additional insight and suggestions on the preparation of the research approach. Next, I would like to thank Pascal Feller and his team at Arcadis NL. Even though Covid-19 prevented the collaboration from being on a daily basis in 's Hertogenbosch, you and everyone I have spoken to at Arcadis were always happy to help, and I appreciate that. Lastly, I would like to thank my family and friends for the support, and for being the first testers of the survey. Thanks to all these people for helping me finish this last part of my MSc degree. Looking forward to new opportunities, taking this experience with me.

Renée Verboven
Eindhoven, January 2021

Summary

One of the most covered subjects in research for the last century has been climate change. The average temperatures have been rising each year all over the world. In urban areas, the temperature rise gets enhanced by the number of stone buildings and pavement. The phenomenon of higher temperatures in urban areas is often referred to as the Urban Heat Island (UHI) effect. The UHI effect is well known in large cities around the globe and research shows cities in the Netherlands also deal with the effects of the heat island. The development of urban areas can be linked to the urbanization trend. An estimation is made by the United Nations that 66% of the world's population will be living in urban areas by the year 2050. Therefore, urban areas are expected to continue to grow in total area and built space to facilitate the increasing number of residents. As the built space continues to grow, the temperatures are expected to keep increasing as well.

The UHI effect has caused the European Union and the Dutch government to encourage the use of Green-Based Solutions (GBS) against heat. GBS can be defined as the use of natural and semi-natural green spaces to solve climate and environmental objectives. In recent years, research has been carried out to show the advantages of nature within urban areas for heat management and urban liveability, but the implementation of GBS has been stagnating. One of the most important problems in the case of GBS is the additional cost to implement GBS. In urban design and construction, the existing assumption is that urban residents are unwilling to maintain and, or pay for GBS in their neighbourhood, street, or house. This assumption leads to the decisions by non-governmental organisations not to implement GBS in urban design and construction projects. When the preferences of urban residents regarding GBS are known, the urban designs can be more based on residential preferences, and through the support of residents, organisations will have more confidence in the implementation of GBS. Previous studies have provided insight into the effectiveness of GBS types and characteristics, as well as preferences of urban residents regarding GBS for water nuisance. The objective of this study is to add to the available information regarding the preferences and willingness to pay of urban residents for GBS. The research question is formulated as follows:

What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?

The information needed to answer the research question is obtained by executing a Stated Choice experiment (SC). To conduct the SC experiment, the information needed for the experiment regarding available GBS and the stakeholders is found through a literature review. The SC experiment is carefully designed and distributed as an online survey. The data collection is done for two weeks in December 2020, resulting in 149 complete responses. The statistical analysis of the experiment was done through a Multinomial Logit Model analysis and the Latent Class model analysis.

The results of the Stated Choice experiment show that the urban residents in the Netherlands prefer GBS that have a high cooling characteristic and a large shaded area. Urban residents prefer the municipality to be responsible for the GBS. The Willingness to Pay shows urban residents are willing to pay more than €130, - extra for GBS with a high cooling characteristic, as opposed to €90, - for a large canopy volume. Two classes can be discerned with similar choice behaviour: GBS enthusiasts and GBS sceptics. The GBS enthusiasts hold considerably more people with younger age. The GBS enthusiasts are willing to pay more implementation costs for GBS with a high cooling characteristic compared to the GBS sceptics and are willing to give up 1.5 meters of private space for the GBS.

Samenvatting

Een van de meest behandelde onderwerpen in onderzoek van de afgelopen eeuw is klimaatverandering. De gemiddelde temperaturen stijgen elk jaar over de hele wereld. In stedelijke gebieden wordt de temperatuurstijging versterkt door het aantal stenen gebouwen en bestrating. Het fenomeen van hogere temperaturen in stedelijke gebieden wordt vaak het stedelijk hitte eiland effect (Urban Heat Island effect) genoemd. Het hitte eiland effect is bekend in grote steden over de hele wereld en uit onderzoek blijkt dat het ook te meten is in de steden van Nederland. De ontwikkeling van stedelijke gebieden kan worden gekoppeld aan de trend van urbanisatie. De Verenigde Naties schatten dat 66% van de wereldbevolking in 2050 in stedelijke gebieden zal wonen. Stedelijke gebieden zijn verwacht te blijven groeien in totale oppervlakte en bebouwd oppervlakte om het toenemende aantal inwoners te faciliteren. Naarmate de bebouwde ruimte blijft groeien, wordt verwacht dat de temperaturen ook blijven stijgen.

De Europese Unie en de Nederlandse overheid stimuleren het gebruik van groene oplossingen (Green-Based Solutions) tegen hitte. Groene oplossingen worden gedefinieerd als het gebruik van natuurlijke en halfnatuurlijke groene ruimtes om klimaat- en milieuproblemen op te lossen. De afgelopen jaren is er onderzoek gedaan naar de voordelen van groene oplossingen in stedelijk gebied voor warmtebeheer en stedelijke leefbaarheid, maar de implementatie van groene oplossingen stagneert. Een van de belangrijkste problemen bij groene oplossingen zijn de extra implementatie kosten. In het stedenbouwkundig ontwerp en de bouw is de bestaande aanname dat stadsbewoners niet bereid zijn om mee te betalen aan de groene oplossingen in hun buurt. Deze aanname leidt tot de beslissingen van organisaties om groene oplossingen niet te implementeren in projecten. Wanneer de voorkeuren van stadsbewoners naar groene oplossingen bekend zijn, kunnen de stedenbouwkundige ontwerpen meer gebaseerd zijn op de voorkeuren van bewoners en krijgen organisaties door de ondersteuning van bewoners meer vertrouwen in de implementatie van groene oplossingen. Eerdere studies hebben inzicht gegeven in de effectiviteit van groene oplossingen en de kenmerken, maar ook in voorkeuren van stadsbewoners ten aanzien van groene oplossingen voor wateroverlast. Het doel van deze studie is om de beschikbare informatie over de voorkeuren en betalingsbereidheid van stadsbewoners voor groene oplossingen aan te vullen. De onderzoeksvraag is als volgt geformuleerd:

Welke kenmerken van groene oplossingen hebben de voorkeur van stadsbewoners in Nederland voor warmteadaptatie, en hoeveel zijn stadsbewoners bereid te betalen?

Om deze onderzoeksvraag te beantwoorden, is een Stated Choice (SC) experiment uitgevoerd. Om het SC-experiment uit te voeren, wordt de benodigde informatie voor het experiment met betrekking tot beschikbare groene oplossingen en de belanghebbenden gevonden via een literatuuronderzoek. Het SC-experiment is zorgvuldig ontworpen en verspreid als een online enquête. Het experiment vond plaats gedurende twee weken in december 2020, resulterend in 149 volledige reacties. De statistische analyse van het experiment werd uitgevoerd door middel van een Multinomial Logit Model-analyse en de Latent Class-model-analyse.

De resultaten van het SC experiment laten zien dat de stadsbewoners in Nederland de voorkeur geven aan GBS met een hoge koelkarakteristiek en een groot luifelvolume. De betalingsbereidheid laat zien dat stadsbewoners bereid zijn om meer dan €130 extra te betalen voor groene oplossingen met een hoge koelkarakteristiek, en €90 voor een groot luifelvolume. Stadsbewoners hebben ook de voorkeur gedeeld om de gemeente verantwoordelijk te houden voor de groene oplossing. Twee klassen kunnen worden onderscheiden met vergelijkbaar keuzegedrag: groene oplossing-enthousiastelingen en groene oplossing-sceptici. Aanzienlijk meer jonge mensen vallen onder de groep enthousiastelingen De enthousiastelingen zijn bereid om meer implementatiekosten te betalen voor groene oplossingen met een hoge koelkarakteristiek vergeleken met de sceptici en zijn bereid 1,5 meter privéruimte op te geven voor de groene oplossingen.

Abstract

The combination of climate change and urbanisation have increased urban temperatures. The high percentage of impermeable surfaces in urban areas has shown to be a major factor for the increased temperatures. Green-Based Solutions (GBS) have been proposed to build the resilience of urban areas against heat. However, the implementation of GBS faces barriers, where the financial barrier most important. This study provides new information regarding the preferences and willingness to pay for GBS by urban residents of the Netherlands. A Stated Choice experiment is conducted to find the preferences of urban residents in the Netherlands regarding GBS as a heat adaptation method. The study presents respondents with several GBS characteristics for small scale implementation. The results of the Multinomial Logit model analysis of 148 responses show that GBS with high cooling characteristics and a large canopy volume are preferred. The willingness to pay of urban residents depends on the characteristics of the GBS, and the characteristics of the person. The results of the Latent Class model analysis show that residents of a younger age are more interested in GBS as a heat adaptation method and have a higher willingness to pay. Integrating the preferences and willingness to pay regarding GBS characteristics of urban residents in future urban development plans, combined with available municipal subsidies can reduce the financial barrier for the implementation of GBS.

Keywords: Green-Based Solutions, heat adaptation, urban resilience, willingness to pay

1 Introduction

This chapter introduces the topic of the study by defining the research problem, formulating the research questions, presenting the research model, explaining the scientific and societal relevance, and finally presenting the thesis outline.

1.1 Research Context

One of the most covered subjects in research for the last century has been climate change. The term climate change often refers to the increase of issues with water, wind and heat. This study will focus on the aspect of temperature within climate change and the effects it has on people's quality of life. In 2019, the Netherlands broke the national heat record by passing the 40 degrees Celsius in Gilze Rijen (KNMI, 2019). Even though the old record was from 1944, the average temperature has been rising significantly since that time (KNMI, 2016). This trend is also noticeable in other countries. Since the 1970s, studies have shown a significant increase in temperatures in urban areas relative to non-urban areas all over the world (Sarabi et al., 2019). In urban areas, the temperature rise gets enhanced by the number of stone buildings and pavement, also known as built space. The phenomenon of higher temperatures in urban areas compared to rural areas is referred to as the Urban Heat Island (UHI) effect (Döpp, 2011). The UHI effect is well known in large cities around the globe and research shows cities in the Netherlands also deal with the effects of urban heat island (Döpp, 2011).

Urban areas have a high percentage of built space, sometimes up to 70% of the surface is built space, in cities and business parks even 90%. The stone buildings and pavement absorb heat during hours of sun and release most of that heat once the sun has gone down, therefore preventing the surrounding area from cooling down during the hours of sundown (Döpp, 2011). The development of urban areas can be linked to the urbanization trend. Previous research shows that citizens of the Netherlands and citizens around the world are moving towards cities because of employment opportunities, educational institutions, or health care (Steeneveld et al., 2011). Between 1950 and 2005, the population in urban areas compared to the total population has increased from 29% to 49% in 2005 (Steeneveld et al., 2011) An estimation is made by the United Nations that 66% of the world's population will be living in urban areas by the year 2050 (United Nations, 2018). Therefore, urban areas are expected to continue to grow in total area and built space to facilitate the increasing number of residents. As the built space continues to grow, it is expected to have an enhancing effect on the differences in temperatures between urban and non-urban areas.

According to the World Health Organisation, the ideal temperature for people to live in is between 18 and 24 degrees Celsius. So, the human body needs to adapt to the heat from 25 degrees Celsius up (World Health Organization, 2016). Adapting to this heat is especially difficult for people with already weakened health like the elderly, very young, and people with pre-existing health problems. Extreme heat during the summer months can result in stress reactions, disturbed sleeping patterns, illness, and even death. Solutions to heat problems in urban areas come in many shapes and sizes, following the environmental goals set by the United Nations, researchers have been looking at Green-Based Solutions (GBS) that can create more sustainable environments for urban areas in the case of rising temperatures. The use of GBS like trees, green walls, or green roofs replacing manmade materials like steel and concrete has shown to have an enhancing effect on sustainability, general aesthetics, and residential wellbeing (Jamei et al., 2016).

Areas of grass, trees and other vegetation are known to have a cooling effect on the surrounding area. These areas absorb heat just like buildings and pavement. However, greenery processes the energy internally by evaporation of water, therefore reducing the effects of the sun instead of enhancing it like built space (Jamei et al., 2016). In the case of vegetation close to walls, it also provides an extra insulation layer between the heat and the walls (Döpp, 2011). Implementing green spaces in urban areas can therefore be a vital part of the solution for increased heat (Nastran et al., 2019). Increasing green spaces also has additional benefits as storing carbon, reducing air pollution, and providing additional recreational space (Jamei et al., 2016).

1.2 Problem Definition

In the last 10 years, extensive research has been carried out to show the advantages of nature within urban areas for heat management and urban liveability, but the implementation of GBS has been stagnating (Sarabi et al., 2019). Further research has been suggested to deduce what needs to change for GBS to be implemented at a higher rate in the future. Three main barriers have been identified for further implementation of GBS: inadequate financial resources, land scarcity, and uncertainty in decision making (Sarabi et al., 2019). These barriers need to be (partially) overcome to increase the implementation rate of GBS. Doing this requires support from the stakeholders. For GBS in small scale urban neighbourhood situations, three important stakeholders are the municipalities, non-governmental organisations working on urban development, and urban residents (Sarabi et al., 2019). The current situation is that municipalities are limited in the subsidies they can provide organisations and urban residents to support further implementation of GBS. Within the organisations, the current assumption is that the additional costs for implementing GBS will not be earned back by increased sales values. In turn, urban residents are generally unaware of the advantages of GBS and are therefore hesitant to pay the additional costs for GBS at their home (Williams et al., 2019).

As a first step to partially overcome the barriers of GBS, the suggestion is made to make the future urban designs of neighbourhoods including GBS more residential preference-based (Williams et al., 2019). The assumption is made that urban residents will be more willing to pay for GBS that have characteristics that they prefer. In combination with the subsidies provided by municipalities, the burden of the additional costs for the organisations will be reduced, which may help increase the implementation rate of GBS in the future.

Some previous studies have been conducted to evaluate the attitudes and preferences of urban residents regarding GBS. However, these studies often address GBS for water nuisance in urban areas. A study conducted by Derkzen et al. (2017) in Rotterdam assessed the preferences of Dutch urban areas concerning a wide range of GBS for heat and water nuisance. Though that study analysed many elements at once, the outcome provided a very general residential preference based on a wide range of problems and solutions. The studies that are only concerned with increased heat in urban areas often focus on the performance of the GBS. Therefore, the current study will evaluate the preferences of urban residents in the Netherlands. The choice is made to only look at GBS for heat. The area of interest for this study is GBS on a small scale such as streets and individual homes. Implementing water-based solutions requires much more available land than GBS, and as the available land for nature development in urban areas is scarce, GBS are better suitable. Another choice that is made is to present GBS characteristics to the urban residents, as opposed to GBS types. Doing this will test the preferences of urban residents for specific characteristics of GBS, which will result in more concise preferences that can apply to multiple GBS instead of just one type. Additionally, the willingness to pay of urban residents will be tested. The results will show how many urban residents are willing to pay for GBS as a heat adaptation method. Non-governmental organisations working on urban development can then base future choices regarding GBS on the outcome of this study.

1.3 Research Question

Green-Based Solutions provide many environmental opportunities and solutions for urban areas. As mentioned before, this study will only look into the solutions that GBS provide for heat in urban areas. The objective of this study is to add knowledge to the available information regarding the preferences of urban residents for GBS. The eventual goal is to raise the implementation rate in urban areas to a higher level. Therefore, the research question is formulated as follows:

What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?

The answer to the research question is found by answering the following three sub-questions shown in table 1.1. The second column of the table shows the method used to find answers to the sub-questions.

	Question	**Methodology**
SQ 1.	What types and characteristics of GBS are available to be implemented in urban neighbourhoods for heat adaptation?	Literature study
SQ 2.	Are the preferences of urban residents and the WTP for GBS characteristics influenced by the characteristics of the person or house?	Stated Choice Experiment

Table 1.1: List of sub-questions

1.4 Research Design

This study will be carried out in three phases. The literature review is the first phase and is divided into two directions. The types and heat-reducing characteristics of Green-Based Solutions are determined in the literature review. As well as the available information surrounding the stakeholders of Green-Based Solutions. The information gained in these two sections will be used in the next phase, Stated Choice Experiment. The Stated Choice Experiment phase consists of three sections. The design of the experiment, the data collection, and the statistical analysis of the experiment. The final phase of this study is where the conclusions and recommendations are made. To clarify, figure 1.1 below illustrates the research design once more.

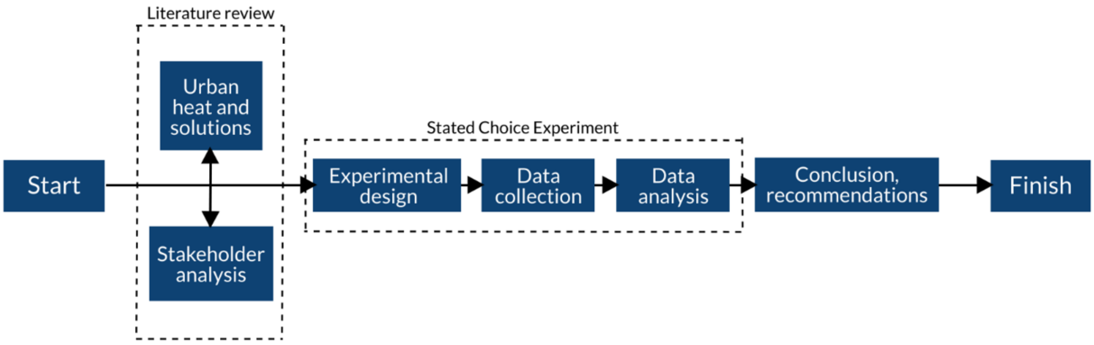


Figure 1.1: Graphical presentation of the research design

1.5 Research Relevance

As mentioned before, the environmental goals set by the United Nations and the European Union guide urban areas to implement more Green-Based Solutions. In the previous 10 years, many studies have been conducted to evaluate GBS as environmental solutions. New studies on this subject continue to appear, due to the promising possibilities and the stagnating implementation rate. Most of the studies in the past are conducted to evaluate the performance of GBS. Some studies can be found that evaluate the attitudes and preferences of stakeholders regarding GBS. Not many studies can be found to evaluate the preferences of urban residents for GBS. The ones that do evaluate the residents' preferences are mostly concerned with GBS for water nuisance. For this study, the choice is made to evaluate the preferences of urban residents of the Netherlands regarding GBS for heat. Additionally, the characteristics of the GBS are presented separately, to find out which characteristics residents prefer. By separating the characteristics from the GBS, the outcome will apply to several different types of GBS, instead of only the ones that are presented to the resident. The outcome of this study will therefore show more specific preferences, which can be translated to a wider range of GBS for heat. Additionally, the willingness to pay of urban residents for GBS will be tested. The information obtained by this study can be used in future urban (re)development plan based on residential preferences and willingness to pay regarding GBS. The outcome will provide more insight into the preferences and willingness to pay of urban residents regarding GBS and may help improve the implementation rate of GBS.

1.6 Thesis Outline

This thesis consists of six chapters. The first chapter involves the problem statement and research objectives, resulting in the main research question underlying this study. Furthermore, the chapter elaborates on the research design and relevance. The study then moves on to the second chapter, which covers the literature study regarding heat in urban areas and the possible solutions. The third chapter provides the stakeholder analysis and elaborates on the characteristics of the residents that are important for the experiment. The fourth chapter introduces the research approach for executing a Stated Choice experiment. Chapter five explains the output of the survey and elaborates on the results of the Multinomial Logit model and the Latent Class model, which estimate the choice behaviour of the respondents in the experiment. Finally, the conclusions and recommendations of this study are elaborated in chapter six.

2 Literature Review: Urban Heat and Solutions

This chapter aims to provide a foundation for this study by presenting a review of the available literature related to the subject. The chapter covers recent developments and solutions regarding heat in urban areas. Going into the details of the concept of Green-Based Solutions and the characteristics of the vegetation types. Furthermore, the involvement of municipalities, organisations and urban residents are described. Finally, the characteristics important for the current study are determined based on the literature. These characteristics will be included in the Stated Choice Experiment.

2.1 Increased Temperatures in Urban Areas

Global warming, climate change, and urban development have caused temperatures to rise significantly in the last 30 years. In 2015, the recorded overall average temperature in the Netherlands was 0.7 °C higher than in the years 1961 -1990 (KNMI, 2016). In 2019, the national heat record in the Netherlands was broken when the temperature passed forty °C in Gilze Rijen (KNMI, 2019). Since the 1970s, studies have shown a significant increase in temperatures in urban areas relative to non-urban areas all over the world (Sarabi et al., 2019). Several case studies in the period of 1990 to 2020 show a relation between the rising temperatures in urban areas and the amount and layout of the built area (Jamei et al., 2016; Li et al., 2011; Nastran et al., 2019; Ranagalage et al., 2020; Ward et al., 2016; Zoulia et al., 2009). Here, built space represents areas with a high percentage of buildings and pavement. Additionally, populations are moving towards cities because of employment opportunities, educational institutions, and/or health care. Between 1950 and 2005, the population in urban areas compared to the total population has increased from 29% to 49% (Steeneveld et al., 2011). An estimation is made by the United Nations that 66% of the world's population will be residents of urban areas by the year 2050 (United Nations, 2018). Therefore, urban areas are expected to continue to grow in total area and built space to facilitate the increasing number of residents. As the built space continues to grow, it is expected to have an enhancing effect on the differences in temperatures between urban and non-urban areas.

2.1.1 The Urban Heat Island Effect

The phenomenon of higher temperatures in urban areas is referred to as the Urban Heat Island (UHI) effect (Oke, 1982; Voogt & Oke, 2003). Simply put, it can be explained as the differences in temperatures between urban and non-urban areas (Oke, 1982). These differences in temperatures have been registered to be 5 to 15 °C and are at their highest point in the evening and night (Steeneveld et al., 2011). The study by Steeneveld et al. (2011) showed the UHI effect is also present in the Netherlands. The case study in the city of Rotterdam, Netherlands measured a maximum Urban Heat Island effect of 10C. Condensed areas such as cities show the most significant temperature difference compared to non-urban areas. As mentioned before, the increased heat in urban areas can be linked to the amount of built space as well as the area layout (Döpp, 2011). Built space represents areas of a high percentage of buildings and pavement. In cities and business parks the built space reaches up to 90 per cent. Outside the city boundaries, urban areas have up to 70 per cent built space. Outside of the urban area boundaries, in rural areas, the total area of built space is much lower, close to 40 per cent. The noted increase in temperature due to the built space is because of the properties of the materials used. Built space represents areas of a high percentage of buildings and pavement. Building elements such as pavement and stone are impermeable materials. Impermeable materials such as asphalt, concrete, or brick absorb solar heat. Once the air temperature has dropped below the surface temperature, the surfaces release the accumulated heat to the surrounding air (Döpp, 2011). Non-urban areas consist of less built spaces and more vegetation, which allows the area to cool down in the evening. In urban areas, the heat accumulated during the day lingers after sundown, making the difference in temperature between urban and non-urban areas highest during the night. The geometric characteristics of built areas can also have an enhancing effect on the temperature. The frequency and height of the buildings have the most impact (Voogt Oke, 2003). The local climate also plays an important role; the amount of solar radiation and wind has a significant effect on the UHI (Steeneveld et al., 2011). The increased heat in urban areas has a negative influence on the liveability of urban areas. The human body is ill-adapted to high temperatures. Heat can have a significant impact on people's health, especially those with pre-existing health problems. The impact of heat on the quality of life is further on discussed in more detail. It is important to keep in mind the UHI effect and the consequences when urban areas are further developed. Designing heat persistent urban areas becomes increasingly difficult as the urbanisation trend continues, and more buildings are added to keep up with the demand (Carter et al., 2015).

In recent years, several case studies have been conducted to determine the Urban Heat Island (UHI) effect (Marando et al., 2019; Ranagalage et al., 2020; Skelhorn et al., 2014; Stewart & Oke, 2012; Voogt & Oke, 2003). The study by Ranagalage et al. (2020) in Sri Lanka showed that the 5.5 °C increase in roughly 20 years has a positive correlation with the increase of impervious surfaces. Back in 2002, a study in London, UK has shown the temperature in urban areas are up to 7 °C higher than surrounding rural areas (Skelhorn et al., 2014). Whereas these studies analysed relatively small areas, other studies have combined large areas. For instance, the study by Ward (2016) analysed the influence of heatwaves on the UHI of multiple European cities. The results show that the UHI effect of cities within a colder climate is more affected by additional heat during heatwaves. Amongst the studies into UHI, some have been conducted in the Netherlands. The results of these studies show that cities also register the presence of the UHI effect (Golroudbary et al., 2018; Steeneveld et al., 2011; Wolters & Brandsma, 2012). The study by Golroudbary et al. (2018) used data from personal amateur weather stations (PWS) of five years observations across the Netherlands to analyse differences in temperature and precipitation. The study by (Wolters & Brandsma, 2012) also used amateur data from the Netherlands, for a year, comparing the data from 20 weather stations. The results from both studies show the UHI effect is present in all seasons in the Netherlands, although most prominent during the summer.

2.1.2 Surface Temperatures versus Air Temperatures

In the literature, two types of UHI's are mentioned: surface heat islands and atmospheric heat islands. It is therefore important to introduce the distinction between surface temperatures and air temperatures (Jamei et al., 2016). Surface temperatures can simply be defined as the measured temperatures of the surface. Surface temperatures are highly dependent on the amount of absorbed solar radiation. Air temperatures represent the air temperatures that are measured relatively close to the surface and represent the temperatures the residents' experience. The air temperatures are influenced by the surface temperatures as well as other heat sources such as vehicles. The relation between several types of heat can best be explained utilizing the Surface Energy Balance (SEB). As the name indicates, the heat held within by urban area is always in balance, no heat will be lost (Oke, 1982). This means that the total amount of heat in the system will remain the same. Meaning, if one of the values increases, another value needs to decrease to keep the balance within the system. The SEB describes the relationship between the net solar heat, the heat created by human activity, sensible heat, latent heat, and the heat absorbed by impermeable surfaces. Oke (1982) introduced the SEB with the following formula:

$$\mathrm{Q}^* + \mathrm{Q_F} = \mathrm{Q_H} + \mathrm{Q_E} + \Delta\mathrm{Q_s} \tag{2.1}$$

Where Q* is the net solar heat. Q_F is the heat created by human activity. Q_H is the sensible heat, experienced by residents. Q_E is the latent heat, which is the internal energy required by vegetation to undergo a phase transition. Q_S is the heat absorbed by impermeable surfaces. The latter heat source needs to be minimized to reduce the heat island effects. By increasing the amount of latent heat (Q_E) through the placement of vegetation, according to the formula, the heat absorbed by impermeable surface (Q_S) will be reduced. Therefore, the placement of green areas can potentially reduce the UHI effect (Kathrin Ward). For urban residents, the air temperature is most important, as it has a direct influence on the resident's wellbeing. However, the observation of temperature patterns in literature is mostly done for Land Surface Temperatures (LST). The presented reasoning is that the LST information is the only climate-relevant and spatially comprehensive information for comparative analysis. Whereas the analysis of air temperatures is highly dependent on testing circumstances such as weather conditions and the altitude (Jamei & Ossen, 2012). Most of the studies concerning heat in urban areas have therefore used the LST to determine the difference between temperatures in urban and non-urban areas (Voogt & Oke, 2003). The LST is indirectly, but significantly related to the air temperatures, as the LST releases excessive heat or cold to the surrounding air. The relationship between surface and air temperature is, however, not linear. The LST during the day versus during the night typically varies more than air temperatures (US Environmental Protection Agency, 2008). Additionally, the variation of the two temperature types is different for different land-use types. Dense, built spaces typically show higher air and surface temperatures than vegetated areas, which is in agreement with previously mentioned sources. Areas of water, such as ponds and city rivers, maintain a fairly constant temperature during the day and night. To show the variation, figure 2 is shown below. The temperatures shown in figure 2.1 are an indication. Actual temperature values fluctuate based on characteristics such as the season, sun intensity, or altitude. For the remainder of this study, the distinction between surface and air temperature will be noted.

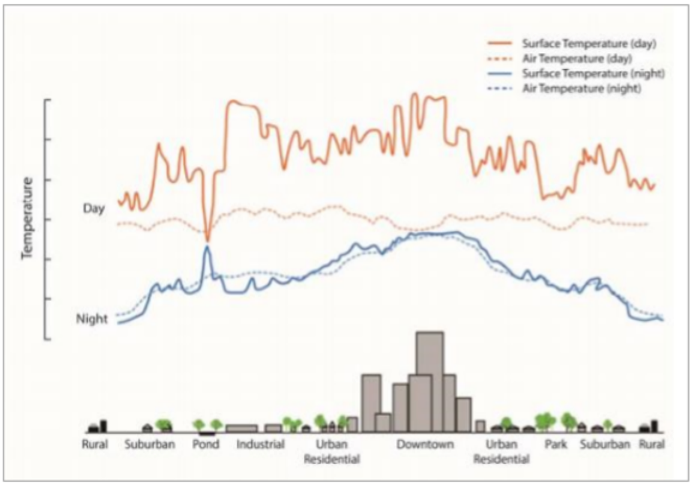


Figure 2.1: Urban Heat Island effect (US Environmental Protection Agency, 2008)

Also important to mention is the term thermal comfort. Recent studies have been conducted to evaluate changes in thermal comfort in outdoor settings due to rising temperatures (Jamei et al., 2016). Thermal comfort represents the heat that is experienced by people at a certain place and time (Nicol & Humphreys, 2002). It is therefore subjective and only partially influenced by the air and surface temperatures. Elements that have a big influence on thermal comfort are the amount of solar radiation and therefore shaded area, the presence of water and vegetation, and the presence of wind. These elements have a direct influence on the surface and air temperatures of the area; however, the perceived thermal comfort of residents is influenced even more than the temperature (Nicol & Humphreys, 2002). As this study deals with the preferences of people, it will be important to consider thermal comfort besides temperature. To clarify the influence of solar heat, figure 2.2 below shows the results of a test by (Middel et al., 2016) The test questioned people for their sensation vote, at the same situation and temperature, either in the sun or in the shade. The figure shows that almost 75% of the respondents voted for hot or very hot in a sunny situation. In contrast, only 40% voted for those two values in the shaded situation. Where the most selected value in the sun was 'very hot', in the shade people voted most for 'warm'. The perceived temperature is therefore much higher in sunny situations.

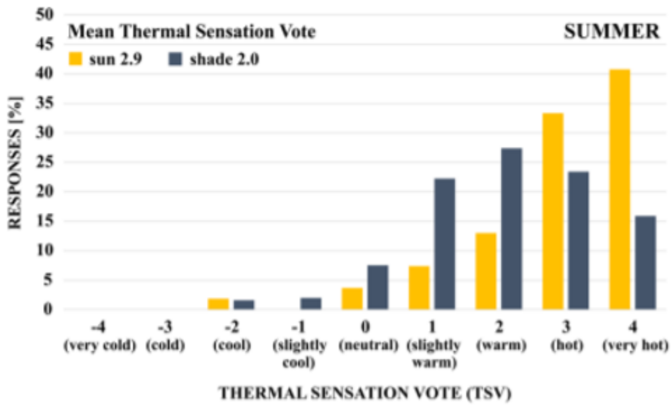


Figure 2.2: Thermal sensation vote (Middel et al., 2016)

2.1.3 Heat Impacts on Quality of Life

The urban quality of life is the measure of an individual's or group's experience of living, working, and recreating comfortably within an urban area (Serag El Din et al., 2013). The UHI effect has consequences for the urban environment as well as the urban quality of life (Feyisa et al., 2014; Marando et al., 2019; Ward et al., 2016). According to the World Health Organisation (WHO), the ideal temperature for people to live in is between 18 and 24 °C. The human body needs to adapt to temperatures starting at 25°C (World Health Organisation, 2018). The study by Tomlinson (2011) suggests the human body reaches a limit for heat adaptation. Once the temperature surpasses that limit, the human body starts to experience heat stress. This limit is different for every person and depends, amongst other things on the living climate, health, and age (Tomlinson et al., 2011). Those who are considered vulnerable to heat are suggested to have a lower heat adaptation limit. Mentioned vulnerable groups are the elderly, the very young, and people with pre-existing health problems such as cardio-vascular disease (Jamei et al., 2016). Extreme heat during the summer months can therefore result in more people experiencing stress reactions, disturbed sleeping patterns, illness, and even death. Through a case study in the Netherlands, Huynen et al (2001) concluded that the mortality rate increases by 12.1% during heatwaves. During the heatwave in 2003, 15,000 residents of France lost their lives due to the extreme heat (Jamei et al., 2016). Due to the increasing number of days with temperatures over 25°C, the temperatures inside resident's houses rise above 25°C as well. This means the human body also needs to adapt to the heat indoors. Respondents of a study in the Netherlands in 2013 indicate indoor temperatures above 25°C are indeed perceived as too warm (Helden, 2013). Increased indoor temperatures have a negative effect on people's sleeping patterns and work productivity. Insufficient quality of sleep can contribute to diseases such as heart failure or lung disease. The human body reduces the pace of movements and alertness to reduce the chance of internal overheating. This results in the work productivity to be significantly lower at an indoor temperature of 25°C or higher (Mairiaux & Malchaire, 1985).

2.2 Green-Based Solutions

As the temperatures continue to rise, and heatwaves become more frequent, the heat-related health problems are expected to cause more problems in the future (Huynen et al., 2001). As mentioned in section 1.1, temperatures in urban areas are significantly higher than temperatures in non-urban areas. Therefore, urban residents are more vulnerable to excessive heat and heatwaves (Lauwaet et al., 2018). In recent years, many studies have been conducted to find means to reduce the heat in urban areas. One of the most popular proposals is the concept of Green-Based Solutions GBS. GBS are a part of the larger concept of Nature-Based Solutions (NBS). Both of these concepts are relatively new, though especially the subject of NBS has been covered extensively in recent years. Because of the speed with which the concept of NBS has risen as a research topic, the description of NBS has become less explicit. It is therefore important to clarify what perspective of NBS this study will follow (Sarabi et al., 2019). The literature study by Sarabi et al showed most studies use the term NBS in one of two ways:

1. The implementation of natural elements to conserve and restore nature.
2. The implementation of natural elements to solve environmental and social objectives.

This study will address NBS as described in the latter definition. This definition of NBS combines the needs of nature and humans, with an emphasis on sustainable development (Sarabi et al., 2019). The natural elements mentioned in the description are usually water or vegetation, or a combination of those. Each of these elements has properties that can mitigate environmental, or human health risks (Marando et al., 2019). According to the literature, these properties include water retention, flood prevention, humidity control, wind patterns control, air quality increase, and temperature reduction (Jamei et al., 2016).

In recent years, researchers have attempted to quantify the added value of NBS. As a result, several case studies are conducted at locations where NBS have recently been implemented. To give an indication of some problems and provided NBS, three case studies are presented in Table 2.1. Figures 2.3 and 2.4 illustrate examples of NBS as drainage solutions.

Type of climate issue	Type of NBS	Location
Floods due to urban expansion	Charles River Basin. Natural valley storage areas of 33 km2.	Boston, USA
High urban temperatures	Implementation of green and blue infrastructure throughout the city.	Sheffield, UK
Reduced air quality due to urban expansion	The placement of trees alone in NYC has resulted in the removal of 0.4% of air pollutants	New York, USA

Table 2.1: Examples from (Depietri McPhearson, 2017).

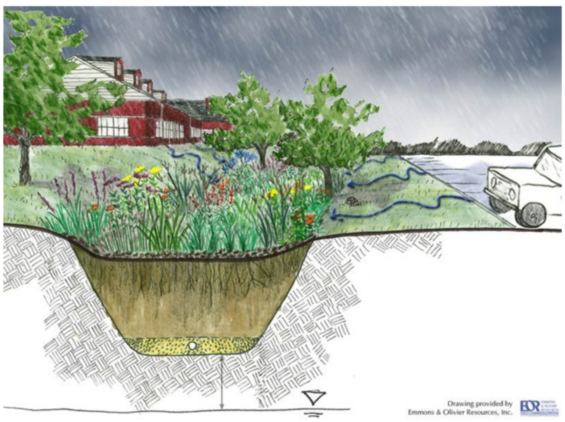


Figure 2.3: Rain garden during rainfall (Pinterest, 2020)

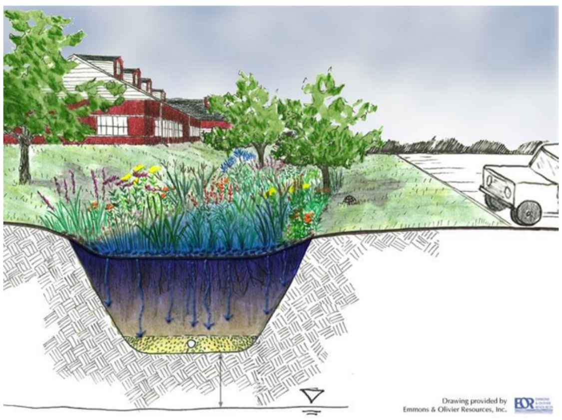


Figure 2.4: Rain garden after rainfall (Neponset, 2020)

The current study will focus on the use of NBS for rising temperatures in urban areas, the reasons supporting this decision will be elaborated below. Both water and vegetation have properties that mitigate temperatures in the surrounding area. Therefore, from this point on, the distinction will be made by introducing the term Green-Based Solutions (GBS). GBS can be defined as the use of natural and semi-natural green spaces to solve climate and environmental objectives (Jamei & Ossen, 2012). In urban areas, these include urban forests, lawns, and street trees (Ward et al., 2016). In recent years, GBS have been promoted as one of the most important solutions for climate change problems. Ward et al. (2016) proposed that green interventions are the fastest, easiest, and most effective way for the mitigation and adaptation of the city's temperature conditions and thermal environment. When comparing NBS to GBS, some advantages can be identified for GBS especially considering urban areas. The available space that can be used for nature purposes provides more possibilities for vegetation options, than water. Within urban neighbourhoods, the development objective is usually to fully utilize the area and provide the maximum number of residential houses. Therefore, there will not be much available space left for NBS. The placement of a water element requires a larger area to be available for development. For instance, a pond, or trench takes up more space than trees or bushes. It is possible to have NBS that combine the use of water and vegetation, though these combinations often face the same space constraints. Besides, vegetation elements can be placed onto the building, for instance through a green roof or wall. Finally, the implementation of a vegetation element is generally less expensive than the implementation of a water element (Depietri & McPhearson, 2017). Based on these advantages that are particularly relevant for urban areas, the choice is made to exclude the water element and continue this research with GBS only.

2.2.1 Conventional Grey Solutions

The alternatives for using green solutions are considered grey or hybrid solutions. Grey solutions can be viewed as conventional solutions that have been used for many years (Depietri & McPhearson, 2017). These structures are often physical structures made of concrete or other impermeable materials. Examples are locks and floodgates, shown in figures 2.5 and 2.6 below. Grey solutions usually ignore the potential benefits of vegetation for climatic problems (Depietri & McPhearson, 2017).

Figure 2.5: Lock in Finland
(Good free photos, 2020)

Figure 2.6: Flood gate in Buffalo
(The flood company, 2020)

Hybrid solutions are a combination of grey and green solutions aiming for optimal impact in social and climatic problems (Sarabi S et al.,2019). An example of a hybrid solution is the combination of plants and grasses with a dike structure for flood protection where both elements alleviate the water impact (Depietri & McPhearson, 2017). An example of a dike is shown in figure 2.7. Hybrid solutions exist in urban environments as well, such as the moss-covered structures shown in figure 2.8.

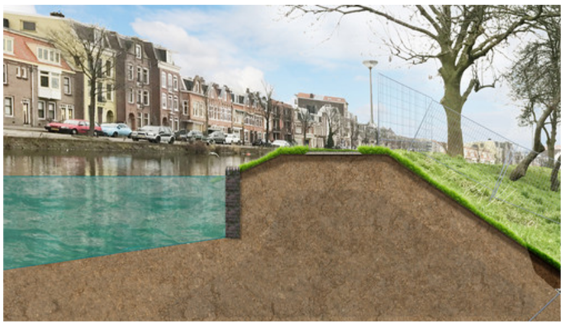


Figure 2.7: Hybrid flood protection (De Ingenieur, 2020)

Figure 2.8: Moss-covered CityTree (Dezeen, 2018)

2.2.2 Green-Based Solutions for Heat Reduction

Previous research shows Green-Based Solutions (GBS) are beneficial against heat due to specific properties of vegetation (Feyisa et al., 2014; Nastran et al., 2019). Two main advantages can be distinguished; intercepting incoming solar radiation, and the internal process of heat utilizing evapotranspiration (Derkzen et al., 2017; Marando et al., 2019). Intercepting incoming solar radiation is also known as the shading effect (Bowler et al., 2010). The temperature of the underlying surface will be significantly reduced by overhanging vegetation as it prevents the surface material to absorb solar energy (Marando et al., 2019). As mentioned in section 6.1.2, the absorption of solar energy by impermeable surfaces increases the temperature in urban areas. The shading effect is therefore an important cooling quality of vegetation. The second advantage of vegetation is evapotranspiration. Evapotranspiration is the process where solar energy is absorbed by vegetation and converted into latent energy. Latent energy is the internal energy required by vegetation to undergo a phase transition. By doing so, the leaf, as well as the surrounding area, notices a reduction in temperature. In Greece, a case study recorded a reduction in the air temperature of 3.1 °C by evapotranspiration alone (Jamei & Ossen, 2012). In addition to these two advantages, wind circulation is also mentioned in the literature as an advantage (Marando et al., 2019). The placement of trees can reduce the air temperature build-up, as the evapotranspiration lowers the surrounding air temperature. Figure 2.9 shows an urban situation without the tree, figure 2.10 including the tree. In the situation shown in figure 2.9, the air temperature between the two dwellings keeps building up as there is no cooling element. In the situation shown in figure 2.10, the tree has a cooling effect on the surrounding air temperature, therefore reducing the air temperature build-up in the area.

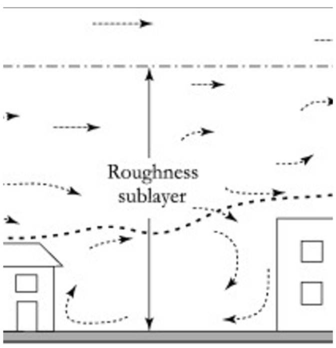


Figure 2.9: Urban area without a tree (K.R. Gunawardena, 2017)

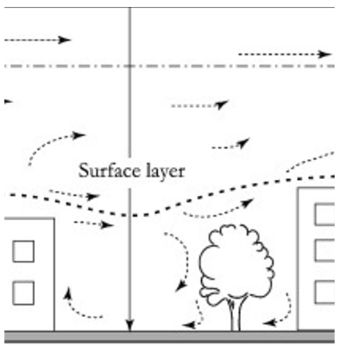


Figure 2.10: Urban area with a tree (K.R. Gunawardena, 2017)

However, discussions question the benefits of wind circulation. Trees can obstruct the airflow to and from the outer sky. This can increase the air temperatures in urban areas, as the lower air temperatures in the outer sky ensure a cooling breeze during the night. Where this may have little to no effect on the temperatures in normal situations, it may reduce the cooling effect of the wind during periods of high temperatures. A deciduous tree can reduce wind speeds by 30 to 40 % (Jamei & Ossen, 2012). During summer times, when wind speeds are generally lower, the placement of trees can therefore have a positive and negative effect on the temperature, depending on the urban layout.

The term GBS applies to many different green elements. These include but are not limited to urban and peri-urban forests, street-side trees, green roofs, and green walls. These mentioned elements have been subject to extensive research in recent years. Studies have tried to quantify the effects of GBS in relation to the UHI effect in cities and relative temperatures surrounding the green elements. A case study by (Marando et al., 2019) in Rome showed what amount of tree coverage has the largest reducing effect on the UHI (Urban Heat Island) effect. For the UHI effect, urban and peri-urban forests showed to be more beneficial than street-side trees. The study by Marando et al (2019) did not include green roofs and green walls. Many other case studies, evaluate the cooling capacity of larger green spaces like parks and urban forests (Feyisa et al., 2014; Jamei et al., 2016). The results from these studies show that these urban green areas effectively reduce the air temperatures within the green area, as well as reducing the UHI effect. Jamei et al. (2016) proposed the term "cool park" to illustrate the effect on the temperature in the overall urban area. Additionally, the results show that temperature reduction extends up to 400m outside the green space (Feyisa et al., 2014; Nastran et al., 2019). Therefore, research shows that the UHI reducing the effect of urban forests is more profound than the reducing effect of vegetation in neighbourhood areas (Nastran et al., 2019). However, vegetation in neighbourhood areas has the effect of prolonging the effects of a cool park. Huang et al. (1987) suggested that the combination of urban forests and vegetation at neighbourhood levels should be used to reduce air temperatures in the overall urban area (Huang et al., 1987). By increasing the total amount of vegetative cover, the UHI effect can be significantly reduced. Besides urban forests and street-side trees, the use of green walls and green roofs are highly encouraged in urban areas. The encouragement is based on the importance of land sparing in urban development areas. By using vertical vegetation and the readily available space on roofs, no additional space needs to be used. These types of GBS can increase the amount of vegetative cover without having to compromise in available development space (Galagoda et al., 2018; Manso & Castro-Gomes, 2015; Ranagalage et al., 2020). Recent studies have also shown the use of green roofs and green facades significantly reduce the indoor temperature during times of increased heat (Ranagalage et al., 2020). Additionally, green walls also reduce the temperature of the direct surrounding area (Ranagalage et al., 2020). Realistically, most urban areas already have some existing green areas in place. The results of case studies have shown that the effects of existing green areas do not mitigate the rising temperatures yet. Therefore, several studies have focused on the effects of placing additional vegetation in existing city plans (Nastran et al., 2019). A study by Kong et al. (2014) showed that an increase in vegetation rate by 10% can significantly reduce surface temperatures and the UHI effect. A study by Skelhorn et al (2014) showed that a 5% increase in mature trees would reduce the surface temperature by 1 °C (Skelhorn et al., 2014). This study tested seven GBS in a neighbourhood in England and the influence of each type on the microclimate. The modelled scenarios aimed to test the change in average temperature as well as the change in total leaf area for each green application. Additionally, one of the scenarios replaced the current vegetation with asphalt, to see what the results would be in the worst-case scenario. This worst-case scenario showed an increase in the surface temperature of 5 °C. The results show 5% additional mature trees have a higher temperature reducing factor than 5% additional hedges. The results of this study also show that the change in total leaf area cannot be directly linked to the change in surface temperature. Even though the difference between mature trees and hedges shows this result, the difference in surface temperature between new trees and hedges does not show the same relation for the change in leaf area. Table 2.11 below shows the results of the study. Note that by replacing the current vegetation with grass, average the temperature rises by 0.62 °C. Even though the experiment tested air temperatures as well, the table only shows values for surface temperatures. What the surface and air temperatures show, is that the surface temperature fluctuates more than the air temperature. This statement agrees with other studies mentioned in section 2.1.2.

Greenspace type	Average surface temperature change (°C)	Change in total leaf area (m^2)
+5% mature trees	−1.00	167,328
+5% new trees	−0.51	114,912
+5% Hedges	−0.46	38,304
Grass only, replacing current vegetation	0.62	−258,048
Asphalt only, replacing current vegetation	4.69	−322,560

Figure 2.11: Temperature change and total leaf area versus green space type, obtained from (Skelhorn et al., 2014)

The report by Skelhorn et al, (2014) also included a list of trees that were used in the model. For newly planted trees, the experiment used deciduous trees of a maximum height of 5 meters, with a rounded, or broadly rounded canopy shape. For medium trees, the experiment used deciduous trees of a height between 10 and 15 meters, with a narrow or conical canopy shape. For mature trees, the experiment used deciduous trees of over 20 meters maximum height, with rounded or broadly rounded canopy shapes. For hedges, the experiment used hedges with open spreading.

The information in table 2.12 shows that the cooling capacity of GBS is dependent on the characteristics of the green type. The example species used in this study are native to England, as the climate is similar to the Dutch climate, these sample species give a good indication of what trees may be useful in the Netherlands as well. In the experiment of this study, the actual types of GBS will not be used, but the characteristics of the GBS. The reasoning behind this choice is that the characteristics are relevant for multiple types of GBS. Therefore, the study will be more widely applicable. However, by studying the results for specific green types like the table above, important characteristics can be identified to be used in the experiment. Later, the characteristics that performed well in the test can be translated back to GBS types. As mentioned before, thermal comfort is also important in addition to the actual reduction of the temperature. The most important factor for increasing thermal comfort is the presence of a shaded area. Therefore, the final selection of the best GBS for heat depends on what characteristic of the green solution is valued most by residents. What the study by Skelhorn et al (2014) shows, is that it is important to present multiple green type characteristics to be evaluated by the respondents.

Greenspace type	Max height	Shape	Example species recently planted by red rose forest[a]	Example species from field surveys
Newly planted (small)trees – deciduous	5 m	Rounded/broadly rounded	*Prunus subhirtella* autumnalis (Autumn Cherry)	*Acer campestre* (Field Maple)
			Robinia pseudo umbracifulera (False Acacia)	*Aesculus hippocastanum* (Horse-chestnut)
			Tilia mongolica (Mongolian Lime)	*Tilia Mongolica* (Mongolian Lime)
Medium trees – deciduous	10–15 m	Narrow or conical	*Betula albosinensis* Fascination (Chinese Red Birch)	*Betula pendula* (Silver Birch)
			Sorbus aucuparia Cardinal Royal (Cardinal Royal/Rowan)	*Prunus padus* (Bird Cherry)
Mature trees (large) – deciduous	20 m+	Rounded/broadly rounded	*Acer campestre* (Field Maple)	*Acer campestre* (Field Maple)
			Acer platanoides Globosum (Norway Maple)	*Acer pseudoplatanus* (Sycamore)
				Quercus robur (English Oak)
Shrubs/hedges	15 m	Open spreading	*Crataegus monogyna* Stricta (Hawthorn)	*Crataegus monogyna* (Hawthorn)
			Crataegus laevigata Pauls Scarlet (Midland Hawthorn)	*Ligustrum japonicum* (Privet)
			Ligustrum japonicum (Privet)	

Figure 2.12: Greenspace type characteristics, obtained from (Skelhorn et al., 2014)

2.2.3 Analysis of Green-Based Solution Attributes

To gain insight into what GBS attributes are relevant to include in a user-based survey, the outcomes of other case studies need to be analysed.

Types of vegetation
Several case studies in recent years have compared the heat reduction results of different types of vegetation. Most studies have compared the cooling capacities of grass, hedges, and trees, with the base reference being the situation with no vegetation (Armson et al., 2012; Potchter et al., 2006; Skelhorn et al., 2014). A more recent study also included an analysis of green roofs and green walls (Galagoda et al., 2018). The next paragraphs cover the heat-reducing effects of different vegetation types and their characteristics found in previously conducted studies.

The placement of grass is an obvious choice when replacing "grey" infrastructure. Though, as mentioned before, the study by Skelhorn et al. (2014) showed that grass may increase the surface temperature instead of lower it. The case study by Armson et al. (2012) in Manchester, UK showed grass alone does not reduce the air and surface temperatures in a park. Additionally, the studies by Bowler et al. (2010) and Potchter et al. (2006) also came to this conclusion. Especially areas of grass and concrete placed in full sun register high increases in temperature whereas the studies show the placement of trees would register up to 8 °C reduction in temperatures (Armson et al., 2012). The local effect of tree shade is significant and noticeable in multiple case studies (Armson et al., 2012; Potchter et al., 2006). However, the study by Potcher et al. (2006) showed that parks dominated by grass areas showed slightly reduced temperatures during the night compared to parks dominated by trees. The explanation is that trees, unlike grass, take away the ability for the wind to displace the lingering heat. Results from other studies share this conclusion (Shashua-Bar et al., 2010).

Type of trees
Even with the possible wind reducing properties, trees are proposed as the best method for reducing heat in urban areas. Therefore, in recent years, several case studies have compared the results of different types of trees in high-temperature situations. It is important to find out what types of trees have the most cooling effect on temperatures, as these trees will be most effective in reducing the heat in urban areas. The case study by Shashua-Bar et al., (2010) emphasized the cooling effect of trees is influenced by three characteristics: Maximum height, foliage density, and canopy volume. Table 2.2 below shows the outcome of the study by Skelhorn et al. (2014) outlining those characteristics. The modelling test concluded that the large deciduous trees have the largest cooling effect, followed by medium deciduous trees. The difference in cooling effect by small deciduous trees, grass, and hedges is insignificant as each show low cooling effects.

Type of tree	Max height	Foliage density	Canopy volume	Cooling effect	Example tree
Small deciduous	5m	Dense	Small	Small	Field Maple
Medium deciduous	10m – 15m	Medium	Medium	Medium	Silver Birch
Large deciduous	20m +	Dense	Large	Large	Common Oak
Grass	0.01m	-	-	Small	Grass
Hedges	1m	-	-	Small	Hawthorn

Table 2.2: Type of tree characteristics (Skelhorn et al., 2014)

The cooling effect of trees was found to be dependent on the location characteristics as well as the characteristics of the tree. Of the tree-characteristics, the foliage density and canopy volume showed to have the most effect on the cooling capacity of the tree. However, the height of the buildings surrounding the area also has an impact on the cooling capacity of the tree. For instance, a tree with a small canopy size is beneficial in narrow streets with high flanking walls (Shashua-Bar et al., 2010). These trees will leave enough space for wind to blow away lingering heat. A tree with a large canopy size is more beneficial in open areas where the solar blocking capacity is at its full potential (Shashua-Bar et al., 2010). The combination of grass and trees has shown to have the most potential through the combined benefit of the two elements. Though as mentioned before, several studies point out that the benefits of grass are highly dependent on irrigation amenities (Jamei et al., 2016; Potchter et al., 2006; Ward et al., 2016). During heat waves and long periods of dry weather, areas of grass tend to dry out which stops or reverses the cooling effect of this green element (Nastran et al., 2019). Therefore, the geometry and environment of the area need to be analysed before the decision can be made for a certain type of GBS in an area.

Green roofs

Other green elements to be considered are green roofs and green facades. As the name implies, green roofs replace conventional grey roofs covered with a tarp by green types such as grass, plants, or moss. Several types of green roofs exist, two of which are shown in figures 2.13 and 2.14.

Figure 2.13: Example 1 (Groen dak aanleggen, 2020)

Figure 2.14: Example 2 (Garden Shed With Ornamental Grasses Green Roof, 2020)

Green roofs gained popularity in recent years (Langston, 2015). Most green roofs are implemented in public and commercial buildings. However, the placement of a green roof over residential housing has gained popularity as well (Tan et al., 2003). The main reason for this imbalance is that the investment for a green roof is greater than that for a conventional grey roof. For public and commercial buildings, the aesthetics and sustainability status of green roofs provide an additional appeal. Therefore, there are more advantages to invest in green roofs for commercial companies and the government as opposed to individual residents. However, the advantages of residential housing are substantial, and the implementation should be encouraged. For one, the durability of the roof-base is increased as it is no longer directly exposed to the weather. The water retention properties of green roofs ensure fewer drainage issues around the house. Additionally, considering the subject of this study, the placement of green roofs helps to reduce the Urban Heat Island (UHI) effect, as well as to control the inside temperature of the house. During the summer, a green roof absorbs the solar radiation that would otherwise have heated the inside temperature (Tan et al., 2003). During the winter, the green roof functions as an additional insulation layer, so preventing the inside temperature to drop. The placement of a green roof would therefore reduce the cooling costs during the summer, the heating costs during the winter, and increases the durability of the roof (Tan et al., 2003). Increased durability means that the resident will need to replace the roof less frequently, earning back the higher implementation cost of the green roof. To encourage the implementation of green roofs in residential areas, many municipalities in the Netherlands now offer subsidies to residents for replacing their conventional roofs with a green roof. A more detailed description of the efforts made by Dutch municipalities is discussed later.

Going further into the heat-reducing properties of green roofs, several studies have analysed the benefits of green roofs (Jamei et al., 2016; Langston, 2015; Tan et al., 2003). The study by Tan et al (2003) composed an experiment to test different types of green roofs. The experiment was conducted on the roof of a multi-story parking garage. The roof was divided into four parts, each planted with a different green roof type. The difference was measured between the surface temperature of using no vegetation, dense plants, sparse plants, and weeds. The surface temperatures were measured for each of the green types and compared to the solar radiation (see figure 2.16). As expected, the non-covered surface showed the highest temperature, closely related to solar radiation. The surface covered by weeds showed a significant reduction in temperature, sparse coverage showed an even greater reduction, and the largest reduction was shown by the roof-part covered by dense plants. Figure 2.15 shows the average result of each of the green roof types, as well as the correlating standard deviation of the test.

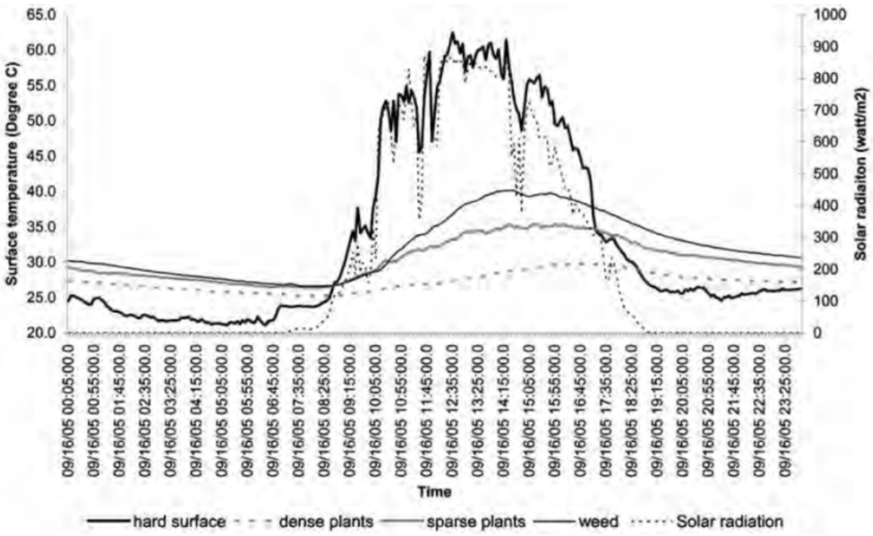
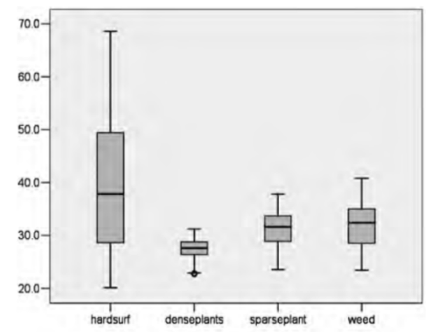


Figure 2.15: Comparison of surface temperatures (Tan et al., 2003)



	Hard surface	Dense plants	Sparse plants	Weed
Mean	39.6°C	27.5°C	31.2°C	32.0°C
Standard Deviation	11.9	1.6	3.1	4.0

Figure 2.16: Long-term analysis of the surface temperatures from 7.00 to 19:00 (Tan et al., 2003)

The main advantage of green roofs is the impact on the indoor temperature. The study by Tan et al. (2003) also tested the surface temperature difference between the surfaces above the slab to below the slab. The results show that the heat gain through the slab to the inside of the house is significantly reduced through the implementation of the green roof. The experiment shows a reduction of over 60 per cent. The results also show that exposed soil cover increases the temperature instead of reduces the temperature. This agrees with previously mentioned studies (Potchter et al., 2006). Additionally, the placement of green on rooftops may require structural alterations. Rooftops are structurally designed to hold the weight of water, snow, and the occasional maintenance worker. However, the consistent weight of weeds, plants, and the soil base will require additional structural planning. Therefore, the selection of the green roof type needs to balance the environmental, structural, and maintenance aspects (Tan et al., 2003). Several companies have sprung up in the Netherlands to provide reliable green roofs for residential houses. Although it is possible to place a green roof as the home-owner, residents should be aware of the possible structural consequences to retain residential safety.

Even though the implementation of green roofs has a smaller effect on the microclimate than trees, it does increase the total green area of a neighbourhood. According to Huang et al. (1987), the UHI can be significantly reduced when the total green area of a neighbourhood or city is increased. The total area of roof space that could be used for green roofs, could also be used for solar panels. However, the increasing popularity for solar panels could potentially reduce the interest in green roofs. The concept of green and solar roofs are already combined to create what is referred to as Biosolar roofs, illustrated in figure 2.17. This combination of smart and green technology has been implemented mostly in Switzerland, Germany and Austria (Renewable energy hub, 2020) The Biosolar roofs combine the individual benefits of solar panels and a green roof, as well as presenting additional benefits that are exclusively present in the Biosolar roofs. The largest benefit of a green roof is the green energy that is collected for the dwelling. The green roof, as explained before, reduces the energy usage within the dwelling, as well as reduce the UHI effect. Three of the additional benefits of Biosolar roofs are listed below, as provided by livingroofs.org.

1. Solar panels are more efficient when installed over a green roof system. A roof with solar panels alone builds up heat, which reduces efficiency. The green roof system has a cooling effect and helps keep the ambient temperature around the panels near 25°C. Which is the best temperature for solar panel efficiency.

2. The green roof system provides ballast to hold the frames and panels in place. Thus, there is no need to attach the solar panels to the waterproofing layer below, which would otherwise have damaged the integrity of the layer.

3. The solar panels can also provide a combination of damp and dry areas beneath the panels. This allows for a wider variety of vegetation to grow, attracting a wider range of fauna in return.

Figure 2.17: A Biosolar roof, photo obtained from (Renewable energy hub, 2020)

The introduction of the Biosolar roof shows that the interest in solar panels does not necessarily have a negative effect on the interest in green roofs. Important to note is that the implementation of green roofs provides only limited additional green area. Additionally, many row houses in the cities of the Netherlands have slanted roofs, which are less suitable for green coverage. Therefore, the dominant presence of high-rise buildings and row houses slightly constrict the implementation of green roofs in city centres. In highly built-up areas like city centres, another solution might be the implementation of green walls. Instead of using the limited available horizontal space, green walls are vertically arranged and can cover more exposed surfaces in dense urban areas.

Green walls
Green infrastructures such as green walls are suggested to implement more green in urban areas where the additional area for green is scarce. Green walls as part of a building can be divided

into three major categories: wall-climbing type, hanging-down type, and module type. The wall-climbing type (figure 2.18) is a very common vertical landscaping method. Climbing plants can cover the walls of buildings naturally, though the process can be time-consuming, or they can grow faster with the help of a trellis or other supporting systems. The hanging-down type is a popular vertical landscaping method, it is a quick way to green whole facades of buildings since plants can be planted at every story to make a complete green wall. Finally, the module type is a relatively new concept compared with the previous two types. The module type requires more complex designs and maintenance considerations. It is also likely to be the most expensive method of the three. The thermal performance is strongly influenced by the arrangement of vertical planting and the characteristics of the plants. Eastern and western orientations featuring solar protection through vegetation are preferred since those directions are most presented with solar radiation during the day. As green walls are best at absorbing solar radiation, the green wall will have the most effect on heat. Like in the case of green roofs, the structural integrity of the building needs to be considered. The load of the green wall is supported by the structural system. To ensure the safety of the building, stronger materials may need to be used to carry the additional load. However, the additional load of a green wall will be lower than that of a green roof, and therefore will not affect the structure as much. Also, the indoor air quality will be enhanced when the combination of vertical landscape and the fresh air inlet is placed on the vertical façade. A green wall contributes to indoor air quality by generating oxygen and filtering air pollutants around the fresh air inlet.

Figure 2.18: Wall climbing vegetation, Hanging-down vegetation, Module type vegetation (Tabassom Safikhani, 2014)

The case study by Galagoda et al. (2018) in Sri Lanka is one of the few studies that address the performance of vertical green facades for heat reducing properties. Galagoda et al. (2018) assessed the functionality of three types of vertical greenery: Living walls, indirect green facades, and direct green facades. In this context, living walls represent high hedges (see figure 2.19). What Galagoda et al. (2018) call indirect green facades is what is presented above as module type vegetation. The pieces of vegetation are connected to walls through supportive structures whereas the vegetation for direct green facades grew directly onto the surface.

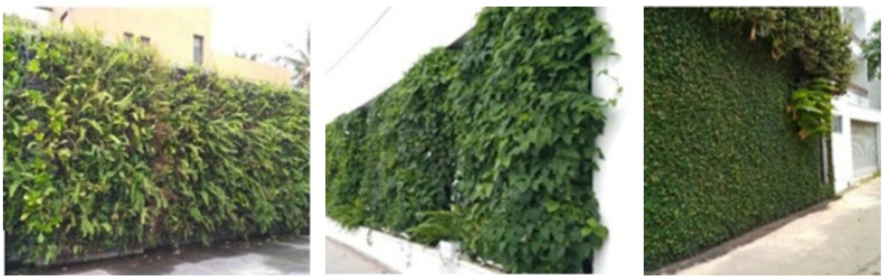


Figure 2.19: Living walls, indirect green facades,direct green facades (Galagoda et al., 2018)

Using these three types of vertical green elements, Galagoda et al. (2018) could assess the effect of distance between the vertical element and the exterior wall. The evapotranspiration property of the green wall ensures the direct air to be cooled. The space between the vegetation and the exterior wall ventilates the cool air to the surrounding area. The result of the study also shows that the green walls that have some ventilation space between the vegetation and the exterior walls produce better cooling results compared to green walls where the vegetation is placed directly onto the wall. Though, all three elements reduced the temperature up to 8°C in 24 hours. Other studies have conducted similar tests and showed the cooling capacity of vertical green elements is dependent on their size, vegetation cover, and location characteristics (Manso & Castro-Gomes, 2015). In these situations, increasing the size and vegetation cover has shown to have a direct increasing effect on the cooling capacity.

2.3 Conclusions

The literature review of Green-Based Solutions (GBS) provides an overview of the available GBS types for heat and the characteristics. The GBS types for heat are trees, grass, bushes, and the relatively new concepts of green roofs and green walls. The most important characteristics of GBS have been found are the cooling effect, shading effect, wind obstruction, maintenance, cost, responsibility, and necessary space for implementation. The types of GBS such as trees, grass, bushes green roofs, and green walls all have different benefits due to their characteristics. Grass has shown to have the least cooling effect during hot days, and may even have an enhancing effect on the air temperature during draughts. Bushes are slightly better regarding cooling effects, and the low implementation and maintenance cost provide an advantage. However, bushes provide little to no shaded area. Shaded areas have shown to have a positive effect on the thermal comfort of urban residents. Trees have shown to have the highest cooling effect. The shaded area due to the canopy volume ensures lower surface temperatures in addition to the evapotranspiration effects. Trees also affect the wind circulation, trees with a large canopy can obstruct the flow of the wind and reduce the cooling breeze during hot days. The amount of shaded area, wind obstruction and the cooling effect is dependent on the type and age of the tree. Green roofs and green walls have shown to be most effective in keeping the indoor temperatures low. Both these elements also help increase the total vegetative area in urban areas, which has shown to reduce the overall temperature in the urban areas.

In addition, this chapter looked into previously conducted studies regarding the preferences of urban residents for GBS. Not many studies have focussed on residential preferences and interest. Most studies analyse the effectiveness of GBS against heat. The next chapter will go further into detail of the studies that have considered the preferences and influences of stakeholders.

3 Stakeholder Analysis

In the previous chapter, the characteristics of Green-Based Solutions (GBS) and the benefits have been addressed. This chapter will address the stakeholders that are crucial for the further implementation of GBS. The three stakeholders discussed in this chapter are the municipalities, non-governmental organisations, and urban residents. Municipalities are considered meso-level actors, whereas non-governmental organisations and residents are micro-level actors. These two groups are typically viewed as the key actors for the implementation of NBS (Sarabi et al., 2019). The chapter aims to provide an overview of the influence and power that each of these stakeholders has concerning the implementation of GBS. Additionally, the chapter looks at previously conducted studies into the attitudes of the stakeholders towards GBS.

3.1 Implementation by Stakeholders

The stakeholder analysis by Sarabi et al. (2019) mentioned that the micro-level, and meso-level actors are the most influential in the implementation of GBS. Micro-level actors include urban residents, citizen initiatives, and non-governmental organisations (NGOs). Meso-level actors work at a municipal or city level and are mostly considered to be municipalities (Sarabi et al., 2019). Micro-level actors are the primary beneficiaries of GBS and are usually working with GBS on a street or neighbourhood scale, or even a single GBS element. The micro-level actors can be both the end-users and the initiators of the GBS. Municipalities are considered Meso-level actors and can have a great influence on the implementation of GBS within their municipal boundaries. The role of municipalities is usually considered critical due to the amount of power they have over development projects, as well as possible financial support. The interest for the municipalities lies in the possibilities of improvement of the area image and facilitation of increasing population numbers (Sarabi et al., 2019). Continuing in the current study, the micro-level actors will be split into urban residents and NGOs. For the meso-level actors, the municipalities will be mentioned to represent the local government.

Considering the limitations to successfully implement GBS, Sarabi et al (2019) mention the following three barriers to be of the most importance: Inadequate financial resources, land scarcity, and uncertainty in decision making. Financial resources are often mentioned as a barrier to innovation. GBS often provide additional costs in urban development projects, as GBS are generally more expensive than conventional solutions, or having no solution at all. Funding for GBS by governmental organisations is limited, and reliance on NGOs and residents to cover the additional cost places even more pressure on micro-level actors (Sarabi et al., 2019). The land scarcity limitation is mentioned in the previous chapter as well. Climate change adaptation is most needed in urban areas, which are also the areas with the highest scarcity of available space for GBS (Huynen et al., 2001). Therefore, the limited available space for GBS provides a considerable limitation on the implementation of GBS in urban areas. The uncertainty in decision making refers to NGOs and urban residents who base the decisions on past experiences and knowledge. The lack of knowledge regarding GBS implementation processes and benefits is an important limitation for the implementation of GBS (Jamei et al., 2016). A study by Watkin et al. (2019) aimed to assess the attitudes of certain stakeholders towards Nature-Based Solutions (NBS). The study by Watkin et al. (2019) showed that the stakeholders of development projects lack knowledge of the capabilities of NBS. This lack of knowledge leads stakeholders to choose grey methods that have little to no unknowns and therefore little to no risks. Watkin et al. (2019) proposed that when information is available about the advantages of NBS, the risk of implementation will be seemingly smaller, and the implementation will become mainstream. Even though the study by Watkin et al. (2019) is about the implementation of NBS instead of GBS, it can be assumed that the attitudes of stakeholders towards GBS will be similar. The reasoning behind this statement is that both cases are based on the confidence that stakeholders have in natural solutions instead of conventional grey solutions.

Though many studies in recent years have covered the subject and advantages of NBS, the knowledge regarding NBS has only spread to a portion of the residential community and NGOs (Sarabi et al., 2019). A study by Piacentini et al. (2020) aimed to find the attitude of local authorities and consultants in France and Italy concerning NBS. The experiment by Piacentini et al. (2020) provided the respondents with hypothetical questions about Water-related Green Infrastructures (WrGIs), also known as green-blue infrastructures, and Sustainable Drainage Systems (SuDSs). The residents were asked to share their preferences concerning the two NBS listed above, and the grey solution they currently have in place. The questions referred to previous choices for replacement options, as well as hypothetical replacement choices in the future. The results show that these stakeholders prefer familiar systems for implementation, where 10% said to prefer traditional systems purely because of previous experiences and proven reliability. However, the study also showed 35% of the stakeholders considered the importance and benefits of NBS, even though the construction and maintenance costs might be higher (Piacentini & Rossetto, 2020).

3.1.1 Non-Governmental Organisations

One group of the stakeholders for GBS are the non-governmental organisations (NGOs) that design, construct, or work on an advisory basis on (re)development projects. Arcadis is one of the leading global natural and built asset design & consultancy firm and specialises in sustainable and innovative assets. The employees of Arcadis work on assisting other companies in the design for new and redevelopment projects. Two of the key focusses of Arcadis are sustainability and residential wellbeing. The implementation of additional green in urban areas is therefore highly encouraged within the company. Even though the organisation promotes sustainable measures and the implementation of GBS, in the end, the cost of the project always has the leading hand. The clients of Arcadis are both private and governmental organisations. The client provides a case for which the Arcadis employees assist, keeping in mind the sustainability goals of the company. Arcadis employees can encourage the organisations to choose a more sustainable method, for instance constructing green roofs instead of conventional grey roofs. However, the solution always needs to fit in the project, and within the budget. The service provided by Arcadis employees is therefore always dependent on the preferences of the stakeholders, which are often the client, the current or future residents, and the municipality of the area of interest. The choice for implementing GBS in a project needs to be agreed upon by the stakeholders of the project. As previously mentioned, one of the most important limitations for the implementation of GBS is the additional cost in projects. Within the stakeholders of urban development projects, the assumption is that the additional cost needed for the implementation of GBS will not be earned back, for instance by means of a higher selling price. Currently, in the argument for or against GBS within urban development projects, the client most often chooses to save cost and not implement GBS. One of the goals of Arcadis is to use more sustainable methods in their projects. Therefore, the employees of Arcadis wish to implement more GBS in the projects but need to provide a solid argument to convince the other stakeholders. To have an overview of what GBS characteristics are appreciated by urban residents can make the designs more consumer-based. Besides, an analysis of the willingness to pay for GBS by urban residents can become the base of an argument for the implementation of GBS in a project.

To give an impression of the type of projects that are assisted by the employees of Arcadis, the project of park Vijfsluizen is elaborated in this section. Arcadis was assigned the task to assist in the design process. The stakeholders for this project were Heijmans NV (construction), Ruijzenaars landscapes (landscape architecture), KuiperCompagnons (architecture), and the municipality of Vlaardingen. Park Vijfsluizen used to be the sports accommodation for Shell employees and families in Vlaardingen, the Netherlands. Since 2012, the municipality of Vlaardingen wishes to repurpose the land, which led to the design for residential housing. The area is meant to combine the housing areas with recreational green areas. Each of the architectural aspects is therefore carefully designed. The houses are designed with light colours, which will be more resistant to heat during the summer. The park surrounding the houses will have a variety of trees, as well as a large pond. Both elements will ensure lower temperatures during the summer, as well as better water drainage of the area. The noise walls separating Park Vijfsluizen from the highway A2 will be covered in vegetation. The surface of the parking spaces will be permeable, aiming to keep the amount of asphalt and other impermeable surfaces low in the area. The park will hold a variety of housing types. Depending on the type, the roof will be green, or conventional grey, either with or without solar panels. The purpose of the park is to include nature in the residential area, providing a natural and healthy environment for its residents.

3.1.2 Municipalities

In (re)development projects, municipalities have multiple tools to influence the decision-making processes. The approval of spatial plans and design strategies is given by the municipalities. The integration of GBS into urban planning and design can contribute to the decrease in urban temperatures (Jamei et al., 2016). The municipalities have the power to suggest, encourage, or even obligate sustainable measures for (re)development projects within their area boundaries. The Dutch government and the European Union have set up environmental strategies that support the use of GBS (Research and Innovation, 2020). Municipalities, however, need to develop their strategies concerning GBS. The two most effective tools for supporting GBS are subsidies and (re)development regulations.

Subsidies

One of the most prominent reasons why the implementation of GBS is stagnating is because of the additional costs. These additional costs are the implementation cost and maintenance cost. The assumption of non-governmental organisations (NGOs) is that the burden of these costs currently falls on the NGOs working on urban development projects. These NGOs perceive two options, either to choose not to implement GBS to save costs, or to transition the costs to the future residents by raising the cost of the houses. To encourage the implementation of GBS, the municipalities can take some of the costs away for the organisations by providing funding. The ideal situation would be where the municipalities, NGOs working on urban development projects, and urban residents all take some responsibility for the costs, to choose for environmentally-friendly measures. However, currently, the expectations are that most municipalities and residents do not place a high value on GBS and do not wish to invest in the implementation. As a result, GBS are often not implemented in urban development projects. Municipalities in the Netherlands have the liberty to develop strategies for their area. The website groenesubsidiewijzer.nl provides a list of municipalities that support GBS utilizing subsidies. Subsidies can have a positive impact on the implementation of GBS because people are encouraged by positive stimulation. Positive stimulation means people receive a reward when they do something desirable. The opposite of positive stimulation is negative stimulation. An example of negative stimulation is giving people a fine if their garden consists of more than 80% impermeable surface. Both of these methods work well in stimulating people to change their behaviour. Although, the positive stimulation provides a positive attitude towards environmentally friendly measures, whereas the negatives stimulation invites negative attitudes towards those measures. It is therefore preferred to use positive stimulations and promote the use of subsidies in all municipalities in the Netherlands.

Subsidies are therefore a good method for stimulating residents to implement GBS. The specific details of these subsidies are highly dependent on the region and municipality. Table 3.1 represents some examples of regions and their subsidies for the implementation of GBS. The information presented in the table comes from an organisation called “Het Groene Loket”. Through their website, they promote the use of GBS for heat, and flood reduction, improving air quality, and more. The website also provides links to the website sections for environmental measures of different municipalities in the Netherlands. As this is an independent organisation, the table below may not include all Dutch municipalities that provide subsidies for GBS. However, it does indicate the existing interest within municipalities for the implementation of GBS. Noticeable is the size of the municipalities, smaller municipalities show less interest in the subsidies for GBS. A possible explanation might be that the larger municipalities are usually densely populated and notice the effect of the UHI, and therefore are more interested in solutions. The majority of municipalities that have subsidies for green solutions prefer the implementation of green roofs. Noticeable is the difference between the subsidies by municipalities and water authorities, relatively more water authorities promote the replacement of tiles by green elements, to support water drainage into the soil, instead of the sewage system.

Municipal Subsidies	
Green roofs	Groningen, Utrecht, Eindhoven, Den Haag, Amsterdam, Almelo, Arnhem, Breda, Den Bosch, Leeuwarden, Rotterdam, Tilburg
Green facade	Amsterdam, Breda, Leeuwarden, Tilburg
Replacement of tiles by green	Eindhoven, Breda, Leeuwarden, Rotterdam
Subsidies by Regional Water Authorities	
Green roofs	Hollandse Delta, Rivierenland, Aa en Maas, de Dommel, Hoogheemraadschap Van Delfland, Drents Overijsselse Delta, de Ronde Venen
Green facade	Hoogheemraadschap Van Delfland, Drents Overijsselse Delta, de Ronde Venen
Replacement of tiles by green	Hollandse Delta, Rivierenland, Hoogheemraadschap Van Delfland, Drents Overijsselse Delta

Table 3.1: List of municipal subsidies, provided by (Het Groene Loket, 2020)

The information provided by the municipalities concerning the conditions of the subsidies also differs. The amount of subsidy is highly dependent on the size of the project. Most municipalities have a minimum area that needs to be redeveloped to qualify for the subsidy. For instance, the municipality of Eindhoven requires a minimum roof area of $10m^2$ to qualify for a subsidy for a green roof, and a minimum of $20m^2$ replacement area of tiles to green space to qualify for subsidies ('t Groene Loket, 2020). Besides that, most municipalities also have a ceiling concerning the total amount of subsidies given during the year. Some municipalities have the condition that the design, construction, and maintenance of the green roof needs to be performed by a recognized specialist to receive the subsidy. Others require the house to be at least 5 years old. The amount of subsidy is also dependent on the municipality, though most municipalities reimburse 50 per cent of the construction price. This means that constructing a green roof, or other GBS, still requires an investment from the resident. Which emphasizes the importance of promoting GBS and its advantages for urban residents.

(Re)development regulations

Besides subsidies, the Dutch government or municipalities can provide regulations concerning green spaces in urban areas. As far as this study has looked, no clear regulations have been found, although two guidelines for urban areas are available. Since 2003, there is a guideline for public space around residential housing. The guideline states that within 500 meters of the house, more than 75 square meters of public green space needs to be available. In 2003, 15 out of 50 of the largest municipalities in the Netherlands could not reach 75 square meters. The municipalities of Utrecht and Amsterdam showed the lowest numbers, around 34 square meters (Indicator, 2008). Currently, there are no rules or explicit guidelines for the green in urban (re)development projects in the Netherlands. Though the government has provided documents guiding development organisations to use more sustainable measures in their projects. One of those documents is the GWW sustainable approach (Grond-, Weg-, en Waterbouw) which stands for the sustainable ground, road and water construction approach. Through this document, the government provides an instrument for organisations to help reach the sustainability goals set by the European Union for 2050. The document is created in 2013 and is still widely used by organisations, among which, Arcadis. The document stimulates organisations to use more sustainable methods. However, the focus of the document is on sustainable water management solutions, as well as the CO_2 reduction, and circularity. The document does not guide additional implementation of GBS and does not guide to reduce the heat in urban areas. Though, the knowledge that organisations use the document as a guideline shows that the creation of such a document by the government does help organisations to implement more sustainable measures in future projects. If the implementation and advantages of GBS would be elaborated in such a document, it could help the implementation rate of GBS to rise in the future.

3.1.3 Urban Residents

The perception of GBS by urban residents is important (Derkzen et al., 2017). The added value of houses with implemented GBS depends on the value residents place upon the element. However, studies have shown that the value residents place on GBS is highly dependent on their perception of heat and their concerns about climate change (Derkzen et al., 2017).

Perception of heat

Climate change and the rising temperatures in urban areas have resulted in an increase in heat-related health issues among residents of urban areas. However, these health issues are less noticeable for people outside of the vulnerable group. This vulnerable group includes the elderly, the extremely young, and people with pre-existing health issues. The perception of heat for people within this group is much higher than for people outside of the vulnerable group. People are less inclined to change current habits if the people in question do not feel the need first-hand. Studies looking into the implementation of GBS also notice this trend (Derkzen et al., 2017). The study by Derkzen et al. (2017) was conducted in Rotterdam, the Netherlands. The data was collected through surveys about the perception of heat and flooding because of climate change. Furthermore, the respondents were asked to give their opinion about the presented NBS for heat and flooding. The results show that the measure of which respondents feel the impact of heat and climate change has an impact on the willingness to implement NBS. More than half of the respondents expressed their concerns about high temperatures, where a third of the respondents already experienced stress reactions due to heat. Most of these residents expressed uncomfortableness, whereas a third confessed to having health or sleep-related problems due to heat. These results are shown in figure 3.1 below, as well as one of the choice options presented to the residents in the experiment. The study by Derkzen et al. (2017) is highly relevant for this study as the results show preferences from urban residents in the Netherlands.

Measures per scale level	Total (n=200) %	Those who did not receive climate information (n=100) %	Those who received climate information (n = 100)%
Home			
Front garden	48.0	54.5	41.4
Green roof	37.4	28.3	46.5
Green wall	14.6	17.2	12.1
Neighbourhood: street			
Shrubs	50.8	61.0	40.4
Trees	39.2	27.0	51.5
Grass	10.1	12.0	8.1
Neighbourhood: localsquare			
Small park	55.3	49.5	61.0
Playground	26.1	37.4	15.0
Water plaza	18.6	13.1	24.0
City: main road			
Canal	48.2	47.5	49.0
Trees	36.7	36.4	37.0
Grass	15.1	16.2	14.0
City: city park			
Wooded	46.0	36.0	56.0
Recreation	34.5	44.0	25.0
Water rich	19.5	20.0	19.0

Figure 3.1: Respondents for each area type and the choice options for the area type: street (Derkzen et al., 2017).

Attitudes of urban residents towards GBS

Besides the perception of heat, studies have also tested the attitudes of urban residents towards Nature-Based Solutions. Based on these results, an estimation can be made about the attitudes of urban residents towards Green-Based Solutions. To formulate the right questions, previous studies concerning the attitudes of urban residents towards GBS need to be assessed. In very recent years, multiple studies (Derkzen et al., 2017; Williams et al., 2019; Yu et al., 2019) have been trying to assess the attitudes of urban residents towards NBS, as urban residents can be considered one of the most important stakeholders. As mentioned before, the results from studies looking into the attitudes of residents towards NBS give a good indication of the attitudes towards GBS, because both are natural elements. Therefore, the knowledge gained by the above-mentioned studies is important to take into account for the current study.

Some of these studies performed revealed preference tests, such as the test in the UK by Williams et al. (2019). This study was conducted under residents living in an area consisting of Green-Based drainage systems. The residents expressed their positive opinion about the green space and the wildlife element that is added to the neighbourhood. However, the functionality of the GBS providing better drainage received little to no attention by the residents. The study shows that although the GBS provided excellent drainage results, most of the residents had little awareness of the function of the drainage system. As the drainage system was implemented at the development stage of the neighbourhood, the residents are unable to compare the current situation to a situation where the drainage system would not have been implemented. For the residents of this neighbourhood, the excellent drainage results are normal. Most residents expressed their concerns about the management fees and did not expect the house price would be increased due to the presence of the GBS (Williams et al., 2019). What this study shows, is that residents living in areas with implemented GBS may still be unaware of the advantages, and do not see the added value of the element because they have no comparison. Additionally, the real estate agents of the properties were presented with similar questions. The study shows the real estate agents did not see the added value of the GBS either. These studies show that the majority of the people are unaware of the advantages of GBS and are therefore inappreciable of its presence. A study by Baptiste (2014) mentioned that the advantages of NBS for flood protection would be more appreciated by residents who have experienced floods before. The areas where GBS are implemented as part of a new development plan are therefore at a disadvantage because the residents do not experience the difference between having and not having the GBS in the neighbourhood. Similar to this statement, the study by Yu et al. (2019) showed residents with a better perception of flood risk are more willing to participate in the implementation of NBS. Besides, the study by (Derkzen et al., 2017)showed a clear distinction between residents who were informed about the benefits of GBS, and those who were not. The knowledge of GBS has shown to be an important factor for the willingness to participate (Baptiste, 2014; Yu et al., 2019). A suggestion could be made for (re)development organisations to inform residents of the advantages of the implemented GBS.

Even though most of these studies are concerned with NBS for flood risk and other water-related problems, the results of these studies give an indication of the attitudes of urban residents towards GBS for heat. The reasoning behind that statement is that both question the confidence residents have in natural solutions instead of conventional grey solutions. In addition to that, they both assess whether residents believe the climate change issues are becoming a pressing problem.

The perceived benefits of GBS are also highly dependent on the type and characteristics of the GBS. Residents show a clear preference for attractive and familiar green areas over lesser-known options. The preferred option is, therefore, gardens over green-roofs, although green-roofs are more preferred than green facades. The introduction of green facades may also be too recent for residents to appreciate the element. Many residents express their concern over the cost and maintenance of green roofs and facades, which is likely to be an influencing factor (Galagoda et al., 2018). Highly educated respondents are more likely to implement a green roof, whereas residents with children prefer gardens (Derkzen et al., 2017). When residents are asked to list the advantages of GBS, the most mentioned advantages are perceived as higher attractiveness, temperature control, mental relaxation, and thermal comfort. Heat reduction and water control are rarely mentioned by uninformed residents (Galagoda et al., 2018). In a study about green facades for office buildings, 80% of the respondents showed their preference for the implementation of GBS at office buildings instead of their residences (Galagoda et al., 2018).

3.2 Conclusions

This chapter reviewed the available information about the influences and attitudes of stakeholders for Green-Based Solutions (GBS). For GBS on a neighbourhood and residential scale, the most important stakeholders are the municipality, non-governmental organisations and urban residents. The most crucial barriers regarding the further implementation of GBS have been identified as, inadequate financial resources, land scarcity, and uncertainty in decision making, in descending order of importance. Using GBS in urban projects raises the total costs for the project, as the implementation of GBS is more expensive than conventional solutions or having no solutions to heat at all. These additional costs lead to financial discussions within the stakeholders. Municipalities in the Netherlands can provide subsidies to residents and organisation for implementing GBS as a promotion tool. However, the available budget for such subsidies is limited, and the additional costs that come with implementing GBS are too large to be covered by municipalities alone. Non-governmental organisations are often most concerned with the profit of a project and are therefore hesitant to implement GBS with higher costs. The current assumption within organisations is that the additional costs as a result of implementing GBS in urban neighbourhoods will not be earned back by higher sales prices because residents are unwilling to pay for the GBS. Previously conducted studies into the preferences and willingness to pay of urban residents show that residents that have experienced the advantages of GBS are more willing to pay for GBS. Unfortunately, previous studies have also concluded that urban residents are generally unaware of the advantages of GBS for heat. Combining the attitudes of these three stakeholders concludes that the additional costs of GBS provide a considerable barrier to the implementation. However, the further implementation of GBS is important to reduce the heat in urban areas. Therefore, this study's objective is to gain new insight into the preferences of urban residents regarding GBS. If the preferences regarding specific GBS characteristics can be determined, non-governmental organisations can provide urban preference-based designs regarding GBS. The willingness to pay by residents and available municipal subsidies for GBS will reduce the burden of the additional costs for non-governmental organisations and may have a positive effect on the implementation rate of GBS in the future.

Another barrier to the further implementation of GBS in urban areas is the uncertainty in decision making. The concept of GBS is still relatively new. Stakeholders generally are uneducated in the advantages that GBS have to offer for heat in urban areas. Uncertainties regarding the subject are especially crucial for non-governmental organisations and residents. Organisations are often confined to making decisions based on previous experiences. New products are therefore difficult to introduce. Urban residents often make decisions according to similar methods. This encourages the necessity to spread knowledge about GBS further. The final barrier is the scarcity of available space. Especially in urban areas, space that is not being used by buildings, roads and other urban elements is scarce. This leaves very little available space for GBS. Therefore, in the considerations regarding the choice of GBS, the necessary space for the implementation needs to be an important aspect.

Based on the combined knowledge gained by this chapter and chapter two, conclusions can be made regarding the characteristics that will be interested to include in the Stated Choice Experiment. The available GBS for heat in urban areas are grass, bushes, trees, green roofs and green walls. Each of these GBS have different characteristics. Each of these GBS also has different types, for instance, trees can have a large canopy or a small canopy. These types also have different characteristics. The important GBS characteristics determined by the literature study are cooling effect, shading effect, wind obstruction, maintenance, cost, responsibility, and necessary space for implementation. Based on the information combined in these two chapters, the conclusion can be made that the Stated Choice experiment should test urban preferences for specific GBS characteristics and not types. The characteristics can later be combined to represent actual GBS types to be implemented in urban areas.

The characteristics that have been determined by previous studies to have an influence on urban preferences regarding the implementation of GBS are as follows. For the characteristics of the person, the gender, age, heat perception, climate change awareness and the knowledge of GBS. Regarding the house of the resident, the type of house is expected to have an influence, as well as the proximity to green space and the presence of a front or back garden. Lastly, the characteristics of GBS that are expected have an influence on the preferences and willingness to pay are the canopy volume, cooling effect, aesthetics, maintenance, responsibility and cost.

The next chapter will introduce the methodology of this study to obtain information regarding urban preferences and the willingness to pay for GBS characteristics.

4 Methodology

This chapter describes the research approach and the theory regarding Stated Choice Experiments. The chapter aims to clarify the steps in the experiment. It will start by introducing the relevance of the study, by explaining the research gap and the conceptual model. The chapter then moves on to provide the reasoning for choosing a Stated Choice experiment. Then, the chapter will continue with the structure of the survey and the distribution method. The chapter finishes with the method of analysis, introducing the statistical models that will be used to analyse the data retrieved by the experiment.

4.1 The Relevance of the Study

Global warming and urbanisation lead to increasing temperatures in urban areas all over the world. Green-Based Solutions (GBS) have been proposed as one of the best solutions for increased heat in urban areas. However, as studies like the one by Sarabi et al. (2019) have concluded, the implementation of GBS is lower than preferred. One of the problems is the additional cost to implement GBS. In urban design and planning, the existing assumption is that the implementation of GBS in urban (re)development projects is financially unbeneficial for the organisations as residents are unwilling to maintain and/or pay for GBS in their neighbourhood. If studies can show in what situations residents are interested in GBS, the urban designs can be more based on the preferences of urban residents, and organisations will be more confident that the investment in GBS will be earned back by higher rent/sales prices. No such studies have yet been found, resulting in a research gap. The next paragraph will explain why the current study will provide new information to fill this research gap.

The literature study in the previous two chapters provided an overview of the available information on Green-Based Solutions (GBS) and the associated stakeholders. The literature study shows that most previous studies have been conducted on the concept of Nature-Based Solutions (NBS). The concept of NBS includes water solutions, also known as blue solutions, in addition to the GBS. By including water solutions, the subject of the studies is often related to coastal areas or water nuisance. In addition, Derkzen et al. (2017) point out that most studies address a single aspect of the elements surrounding the implementation of NBS. To be more specific, studies often only analyse the effect of trees on urban heat, or the placement of a pond to reduce water nuisance. The results of those studies provide a solution for a very specific situation. The studies that have focussed on GBS only, are most often concerned with water nuisance in urban areas. Some studies provide GBS for water nuisance and heat issues in urban areas. Very few studies can be found that focus purely on GBS for heat in urban areas. Derkzen et al. (2017) also point out that only a few studies include residential preferences in the selection of NBS. The study was conducted in Rotterdam, the Netherlands. Derkzen et al. (2017) assessed the preferences of residents of Rotterdam regarding a wide range of NBS, including water sources, as a solution for water nuisance and heat. Though the study in Rotterdam analysed several elements at once, the outcome provides a very general residential preference based on a wide range of problems and solutions. Therefore, the choice has been made for this study to aim for a more specific resident related preference. The choice is made to exclude blue solutions, and to focus only on solutions for heat. Additionally, the characteristics of the GBS are presented separately, to find out which characteristic residents prefer. By separating the characteristics from the GBS, the outcome will apply to many different types of GBS, instead of only the ones that are presented to the resident. The outcome of this study will therefore show more specific preferences, which can be translated to a wider range of GBS for heat. The information obtained by this study can be translated into an urban (re)development plan based on residential preferences regarding GBS. The outcome will provide more insight into the preferences of urban residents regarding GBS and may help improve the implementation rate of GBS.

Conceptual model
In the conceptual model, the expected relationship between the independent and dependent variables will be elaborated. For this study, the conceptual model comprises of two flows. The first flow is the relationship between the preferences of urban residents concerning GBS and the characteristics of the person, house, or GBS. The second flow is the relationship between these preferences and the resident's willingness to pay for GBS. The characteristics of the person, house, or GBS are considered as the independent variables, whereas the preferences of urban areas and their willingness to pay are the dependent variables. These two flows combine to provide the conceptual model for the study and will provide the answer to the research question: "What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?

To start, it is important to go back to the literature and see what characteristics have been pointed out by previous studies that are expected to have an impact on the dependent variables. Table 4.1 lists the characteristics of the GBS, person, house, and neighbourhood that have shown to be of importance.

Characteristics of the Green-Based Solution	**Characteristics of the person**	**Characteristics of the house**	**Characteristics of the neighbourhood**
Canopy volume	Gender	Type house	Proximity to green space
Cooling effect	Age	Front garden	Street layout
Aesthetics	Income	Back garden	
Maintenance	Heat perception		
Responsibility	Knowledge of GBS		
Cost	Climate concern		
Location			
Required space			

Table 4.1: List of important characteristics

Figure 4.1 shows the conceptual model to illustrate the relationships between the characteristics and the preferences and willingness to pay of urban residents. On the right side of the figure, the characteristics of the GBS are listed. The preferences of urban residents will be tested for these characteristics of GBS. The characteristics on the left side of the figure will be used to test if these characteristics will have an influence on the preferences for the characteristics of the GBS. Finally, the preferences of urban residents will be used to test the willingness to pay for GBS.

Based on the conceptual model, the Stated Choice experiment is designed. The next section will explain the method of the Stated Choice experiment.

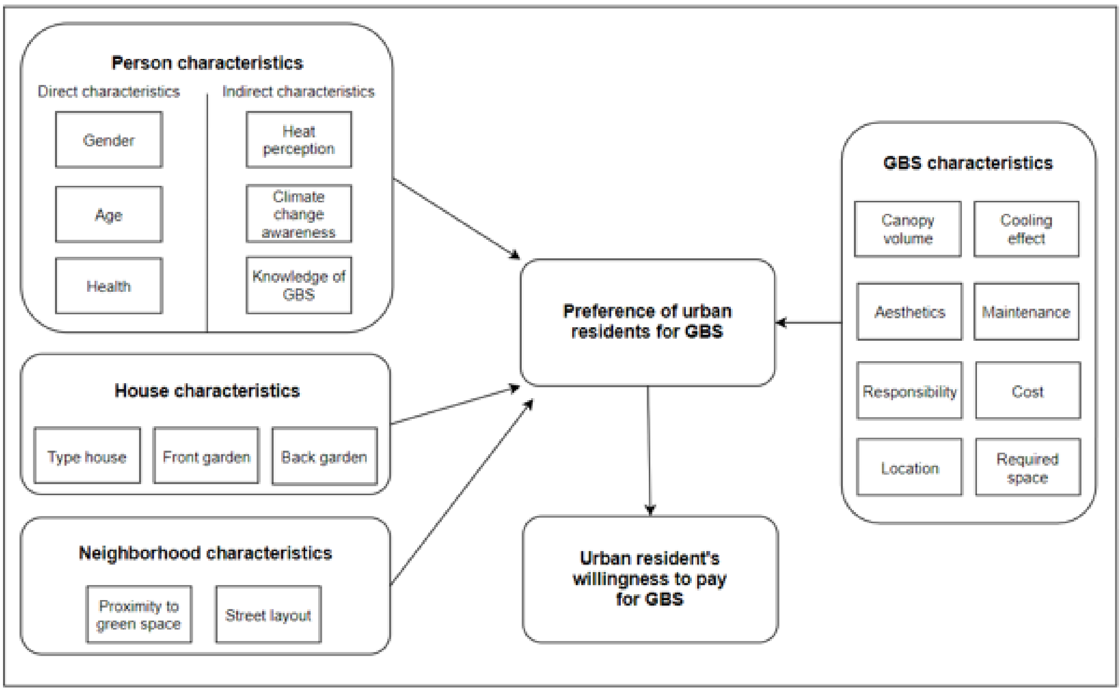


Figure 4.1: Conceptual Model

4.2 Stated Choice Experiment

In this study, the goal is to gain insight into the preferences of urban residents in the Netherlands concerning Green-Based Solutions (GBS). Finding the preferences of people is a complex objective, and it is therefore important to find a research approach that will provide a reliable outcome. Fortunately, the choice experiment approach has been put forward as a well-established multivariate technique for measuring people's preferences and choice behaviour (Hensher et al., 2015). Two main choice experiment approaches exist. The Stated Choice (SC) approach and the Revealed Choice (RC) approach. According to Hensher et al. (2015), the RC approach is used in real market situations. As the RC approach tests real market situations, the possibilities and control over the experiment by the researcher are small. The SC approach is used in hypothetical situations. Therefore, the control over the experiment by the researcher is large, only the elements that the researcher wants to be tested will be included. The advantage of the SC approach is that the subject can be tested and improved before going to the market. Additionally, the Stated Choice approach can be used when a subject is new and barely applied. This is the case for the implementation of GBS, therefore it is best to present the GBS as a hypothetical situation. The disadvantage of SC experiments is that people tend to answer in the way they should act, instead of the way they would act. According to Hensher et al. (2015), the best way to minimize this effect is by keeping hypothetical situations as realistic as possible. This can be realized by using actual or realistic life situations. The execution of the SC experiment is done by presenting individuals with choice sets consisting of hypothetical situations. The individual will then show their preference by choosing one of the scenarios.

A thorough explanation of the theory of a SC experiment is presented by Hensher et al (2015). This study will use this presentation as a guide through the steps. As is mentioned in the book, many other studies have focused on the theoretical aspect of the experimental design, whereas the book by Hensher et al. (2015) provides actual guidelines for performing a choice experiment. An experimental design is explained as the observation of the effect on one variable by changing the levels of another variable. In the case of a SC experiment, the observed effect is the change in preference of the individual. The levels describe the different options of each attribute. In turn, the multiple attribute combinations describe the alternatives within the choice set.

The SC experiment is further explained by the presentation of the experimental design process scheme shown in figure 4.2. The next paragraphs will follow this scheme to define the research approach for the current study. The first stage of the scheme is the refinement of the problem, starting with the clarification of the research problem and the objectives. This study aims to answer the research question: "What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?". The objective of the SC experiment is to extend the findings of the literature review.

Stage two in the experimental design process is stimuli refinement. This stage provides the platform to identify the alternatives, attributes, and attribute levels that will be used in the experiment. Hensher et al. (2015) proposed to first list all feasible alternatives, then exclude the alternatives that are outside the boundaries of this study. The result is a list of alternatives that is "universal" but "finite". By reducing the size of the list, the analysis focuses on practical, as opposed to theoretical situations. In stage two, the attributes and the corresponding attribute levels are defined. Each alternative is described by the defined attributes. The attribute levels of each attribute provide the options within the attribute. The attributes need to be carefully determined to prevent "inter-attribute correlation". This means that the content of one attribute has to be separated from the content of another attribute. For the attribute levels, the first step is to decide how many attribute levels need to be assigned to each attribute. Each attribute can have a different amount of levels. To start, the extreme ranges of the attribute need to be determined and based on those ranges, the necessary number of extra attribute levels need to be selected. The attribute level extremes and midpoints need to be decided based on the literature review.

Once the stimuli refinement is done, the next stage is stage three: the experimental design considerations. Here, the details of the experimental design are further defined. A SC experiment can be small or quite large depending on the number of attributes, and attribute levels. Based on the size, a choice is made between a full factorial and a fractional factorial design. A full factorial design tests all possible combinations whereas a fractional factorial only tests a subset of these combinations. The fractional factorial design is used when the experiment is considered large and is carefully constructed to include all relevant combinations. The fourth and fifth stages occur simultaneously. Here, the experimental design is constructed. This step involves adopting the design strategy and generating alternatives. Generating alternatives includes the selection of attributes and attribute levels. The attributes are assigned to a column in the design. Once the attribute levels are in place, and the design is checked for unrealistic combinations, the random choice sets can be generated. This is stage six in the design process. Choice sets are defined by Hensher et al. (2015) as "a mechanism of conveying information to decision-makers about the alternatives, attributes and attribute levels that exist within the hypothetical scenarios of a study". Two of the alternatives are randomly combined to become the options for respondents to choose from in the experiment.

In the second-last stage, the selection of the choice sets presented to each respondent is randomised. A choice set is a set of two alternatives that will be presented to the respondent as one choice question. Randomising is necessary to present the six choice sets to the respondent in a random order to prevent order bias. After that, the last stage can start; constructing the survey. The survey represents the platform for respondents to express their preferences for each choice set combination. For the experiment to provide a valuable outcome, the method and expectations need to be carefully explained to the respondent. Once the survey is constructed and tested, the survey can be distributed. The experimental design process scheme shown in figure 4.2 illustrates the eight stages presented by Hensher et al. (2015) that have been elaborated above.

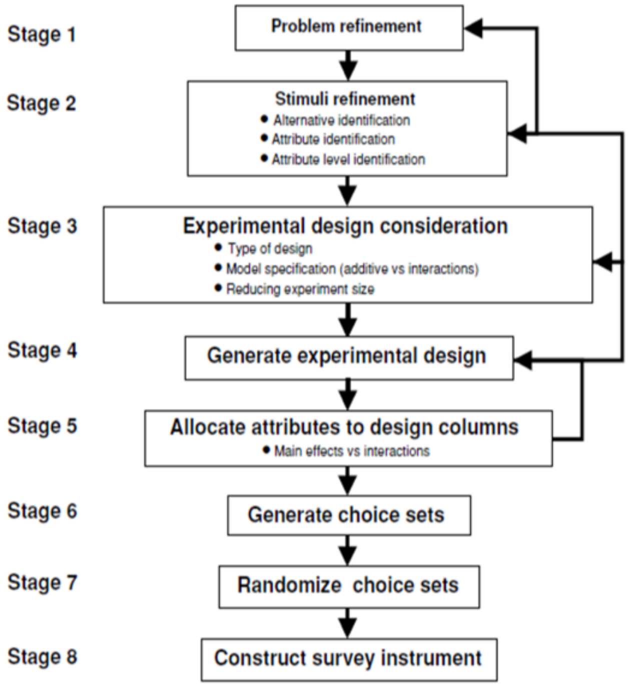


Figure 4.2: Experimental design process (Hensher et al., 2015).

The next sections will dive further into the stages detailed in this section and elaborate on the choices that have been made for the current study.

4.2.1 The goal of the SC Experiment

The goal of the Stated Choice experiment is to find the preferences of urban residents in the Netherlands concerning Green-Based Solutions (GBS) attributes. Additionally, the willingness to pay for GBS by urban residents will be determined. The preferences of urban residents can be used in the designs of future urban (re)development projects, as the result will show which attributes of GBS will be of added value to the current or future residents. To achieve this goal, the alternatives are decided for the experiment. The alternatives for this experiment will be sets of GBS attributes. Each alternative will be unique of GBS attributes and a unique combination of GBS attribute levels. The next section will cover these attributes in more detail.

4.2.2 Stage 2: Stimuli Refinement

This section will continue with the introduction of the variables used in the Stated Choice experiment. Up to this point, the word 'characteristics' has been used to describe a person or element. To clarify the difference between characteristics and variables, an example: The variable of a person is 'age', and the characteristic of a person is '36 years old'. The starting point of creating a Stated Choice experiment is to choose the independent and dependent variables. The value of independent variables will not change when the value of another variable change. In contrast, the value of a dependent variable might change when other independent variables change. However, a relationship needs to be present between the dependent and independent variables to see if a change occurs. The expected relationships between dependent and independent variables have been discussed in the previous chapters. In this study, the dependent variable is the preferred GBS of an urban resident. The literature study provided a list of independent variables that have been shown to influence the dependent variable of this study.

To start, the independent variables are split up into categories. These categories are the characteristics of the person, the house, the neighbourhood, and the GBS. Only the category: characteristics of the GBS will be included in the experiment. The other categories are not a part of the experiment but will be used to go into more detail when looking at the results of the experiment. The categories: characteristics of the person, house and neighbourhood will be obtained by presenting the respondent with predefined multiple answer questions. Each category comprises several specific variables. These independent variables are based on findings from previous studies discussed in the previous chapters. For the characteristics of the person, the variables gender and age of a person have been shown to influence the resident's choices. Additionally, women have shown to have more interest in GBS than men. Residents between the ages of 25 and 45 years are most willing to invest and place GBS in and around their homes. Another personal characteristic that influences the dependent variable is the monthly net income. The income of a person is related to their purchasing power, which is the amount of money that person can spend on goods and services. Therefore, a higher income leaves the person with more money to invest in GBS. This is explained as the most likely reason for the relationship between the independent variable net monthly income and the preferences of urban residents for GBS (CBS, 2018). Another variable is a person's health status. People that have chronic diseases and other serious health problems are more likely to be affected by their living environment. They are therefore expected to place a higher value on the amount of green space around their home and are expected to be more willing to implement and pay for GBS. The perception of heat is also an important variable, people that are more affected by heat are more likely to want a solution to the problem. They are thus expected to be more interested in GBS than people that have very little heat perception. People that have no problems with working, sleeping, or relaxing in an area of high temperature are likely to place less value on the benefits GBS will provide for this problem. Another variable is the knowledge people have about GBS and the qualities of vegetation. Research has shown that still, only a small number of people is aware of the heat reducing properties of vegetation, so most people are unaware of the solution the GBS could bring. People who are aware of the advantages of GBS are more likely to implement GBS. The last interesting personal characteristic is climate change awareness. People that have high concerns about climate change and global warming have shown to have a high interest in environmental solutions. People that have little to no concerns about these aspects are therefore less likely to be willing to implement and pay for the GBS around their homes.

The next category includes house characteristics. The first independent variable of this category is the type of house. People living in different types of houses are expected to have different preferences concerning green solutions. For instance, people living in a terraced house may prefer a green roof over street-side trees to save private space. No previous studies have been found that tested the relationship between house type and GBS preference. The same can be said about the relationship between people's preferences and whether their house has a front and/or back garden. Expected is that people living in a house with a garden feel less of a need to implement more greenery around their house than people living in a house without a garden.

The next category consists of neighbourhood characteristics. Similar to the house characteristics, one of the independent variables for this category is the location of the house. The location of the house has been shown to influence the preference of residents. Residents of city centres are expected to be more interested in the implementation of GBS than residents of suburban areas. One of the reasons may be the proximity to green space. Suburban areas usually have a higher presence of parks and other greenspaces than city centres. The preference of residents to implement more vegetation is expected to be higher if the distances to greenspaces are larger. Another neighbourhood variable is the street layout. Residents of narrow streets may have different preferences concerning GBS. Examples of a narrow and wider urban street are shown in figure 4.3. The last interesting variable in this category is the lost private space. As the total area of a neighbourhood is unchangeable, the placement of some GBS such as large trees is directly linked with a loss of private space for residents. By placing GBS that need space, the total area needed for public use becomes larger, therefore reducing the available space for private use.

Figure 4.3: Narrow urban street versus wider urban street (Google Maps, 2020)

The last category covers several GBS characteristics. The experiment will identify what characteristics of GBS are important for urban residents, and in what way the characteristics can best be implemented according to the preference of the residents. The first independent variable is the shaded area. A shaded area helps to reduce the surface temperature but also has a positive effect on the thermal comfort for people. The canopy volume is directly related to the shaded area that the GBS provides. As many people know the benefit of shade, the expected result is that people prefer GBS with a high amount of shaded area. The second independent variable is the cooling effect. As the cooling ratio certainly has a positive effect on residents' preferences, the expected result is that people prefer a GBS with a high cooling effect. Similar to the shaded area, the independent variable wind influences the thermal comfort as well as the surface temperature. The wind has the highest potential to reduce the temperature once the sun has gone down. During the day, the wind may not reduce the surface temperature, but the breeze is known to increase thermal comfort considerably. Some GBS, such as large trees, can obstruct the flow of the wind through an area. It is therefore important to address this variable. The next independent variable of the GBS is aesthetics. Previous studies have shown that people value greenery most because of their aesthetic value, it is expected therefore that GBS with a higher aesthetic value will be preferred over GBS with lower aesthetic values. Another independent variable for this category is the location of the GBS. As discussed in previous sections, many GBS are available, with different placement relative to the house. Whereas trees are likely to be placed on the street-side or in the garden, a green roof needs to be connected to the house. Residents are expected to have a preference concerning multiple options for GBS placements. The next variable is the responsibility, which represents who is responsible for the GBS. As GBS are living elements, maintenance is required, and this study will provide information as to whether residents prefer one responsibility option over another. The variable cost is very often used in choice experiments, as people usually prefer low costs over high costs for a product or service. The last independent variable concerns maintenance. A previous study in England among people living in a neighbourhood with implemented GBS showed issues with the maintenance costs. The expected relationship for this study is therefore that people would prefer little maintenance costs. However, people usually prefer to spend less money, so to test another aspect of maintenance, this study included the description of maintenance as work. Instead of paying for maintenance, people have to invest time to maintain the GBS themselves.

Even though the expected relationships between several independent variables and the dependent variable are elaborated above, the SC experiment aims to combine these variables. The experiment will allow respondents to make trade-offs between included variables. Thus, the experiment will not only test the direct influence of the independent variables on the dependent variable, but it will show in what situations people will want to pay more for a product or service. The conceptual model shows which relationships exist between independent and dependent variables.

To provide an overview, table 4.2 below shows the distinguished categories and the corresponding independent variables.

Category	**Independent variables**
Personal characteristics	Gender Age Monthly net income Health Heat perception Knowledge of GBS Climate change awareness
House characteristics	House type (terraced house, semi-detached house) Front garden Back garden (grass, tiles, tree)
Neighbourhood characteristics	Proximity to green space Street layout Amount of lost private space
GBS characteristics	Canopy volume (thermal comfort) Cooling effect Let-through wind Aesthetics Location Responsibility Costs Maintenance

Table 4.2: Distinguished categories and corresponding independent variables

Attributes and attribute levels
The independent variables listed above are all expected to influence the dependent variable this experiment aims to study. The results of the SC experiment will show the relationships between the independent variables and the dependent variables. Not all relationships can be determined using the stated choice questions, some relationships will be found using multiple-choice questions. Only the variables listed will be included in the survey, although other variables may also influence the choice behaviour. To keep the experiment doable, choices have been made. From this moment on, the variables that are used in the experiment are considered attributes. The stated choice questions present the participant with alternatives to choose from. These alternatives consist of a combination of attributes and attribute levels. The GBS is unravelled into separate elements, referred to as attributes of GBS. The attributes represent the independent variables discussed in the previous section and the attribute levels can be seen as the available values for each attribute. To elaborate, the next paragraphs will explain each GBS attribute and the corresponding attribute levels.

Temperature reduction
The first attribute is the temperature reduction, corresponding to the independent variable 'cooling effect' mentioned above. The term change is chosen to connect better to the mindset of the respondents. As one of the main subjects of this study, heat and cooling methods are crucial to mention. The results will show if the temperature reduction characteristic of the GBS is important to the resident. This attribute has three attribute levels: Little change in heat, medium heat reduction, and maximum heat reduction. The little change in heat refers to a minimum heat reduction. Figure 4.4 below shows the illustrations of each attribute level that is used in the

survey. These attribute levels are selected because they represent the most likely scenarios.

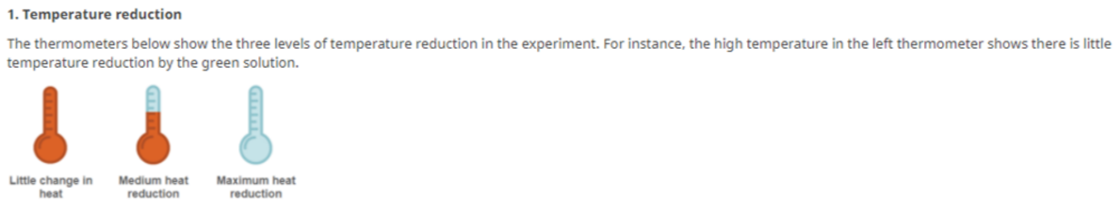


Figure 4.4: Explanation and representation of the temperature reduction attribute in the survey

Amount of let-through wind

The presence of wind during hot times can be perceived as pleasurable. Wind also ensures less lingering hot air in neighbourhoods during the night. There are three levels to this attribute: Little, moderate, and maximum. Figure 4.5 below shows the illustrations presented for this attribute in the survey.

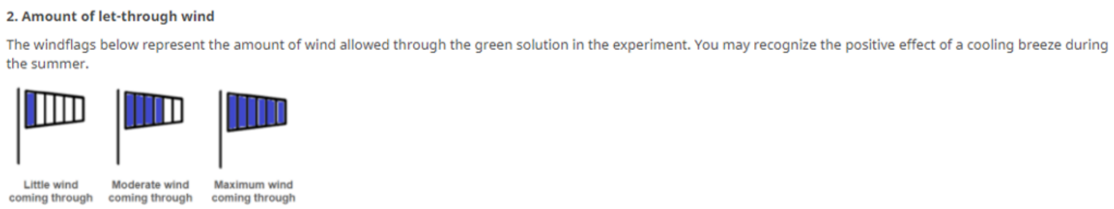


Figure 4.5: Explanation and representation of the wind attribute in the survey

Shaded area

The attribute of the shaded area is chosen because shade reduces the surface temperature by reducing the amount of solar energy that can be absorbed by the surface. To indicate the different levels of the shaded area, different types of green elements are used. Figure 4.6 shows the three levels: Large tree (indicating a large shaded area), small tree, and low vegetation. These three illustrations are chosen because they represent the difference between the levels of the shaded area, and these elements are familiar to the target audience.

Figure 4.6: Explanation and representation of the shaded area attribute in the survey

Location

The next chosen attribute is the location. This attribute represents the location where the GBS will be placed. The locations that have been chosen to represent the levels are: in the front garden, connected to the house, and on the street-side. Previous studies have shown that those locations represent all relevant options for GBS to be implemented in urban streets. The other available options would require larger areas of green such as neighbourhood recreational spaces. This study focuses on GBS in the surrounding of residential housing, therefore the choice has been made for these three levels. Figure 4.7 below shows the illustrations that are used in the experiment.

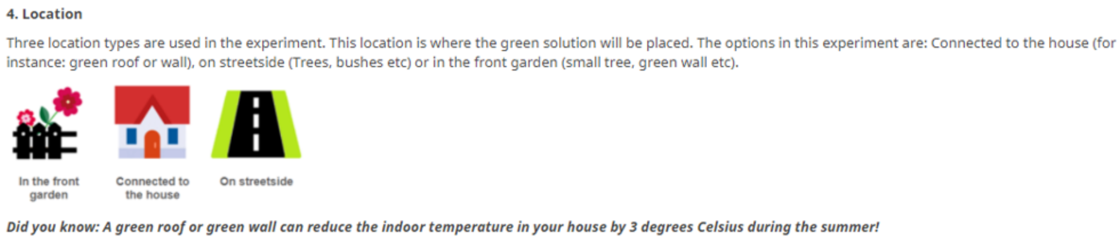


Figure 4.7: Explanation and representation of the location attribute in the survey

Implementation cost
An important attribute in most stated choice experiments is cost. The results of the experiment will show what price residents are willing to pay for GBS. The levels of this attribute have been determined in collaboration with some employees of Arcadis. The field experience from their projects has given them a good impression of different costs for GBS. The distinction is made between three reasonable levels. The first, no costs, is chosen because it gives the resident the possibility to show their preference for not investing anything at all. The highest level was chosen to be €250, - corresponding to the average cost for the placement of a green roof. The middle level was chosen to be €80, - corresponding to the average cost for the placement of a tree. Even though these values are chosen based on the placement of specific GBS, the stated choice experiment will only test how much residents are willing to invest in GBS in certain situations.

Maintenance
Maintenance costs can reduce the amount of implementation cost, though some people may prefer to pay only once instead of monthly. Choosing to show the implementation cost separately from the maintenance cost creates the possibility to include manual labour by the measure of time, in addition to the monetary value. The labour level is included because some people may prefer to do gardening, where others may prefer to pay for the maintenance service. It is therefore interesting to include this attribute with these levels in the test. The selected levels of the maintenance attribute are no contribution to the maintenance, €10, - per month, or 10 hours per month. Similar to the implementation cost, the values for cost and labour an estimation are based on the experience of employees of Arcadis.

Lost private space
The next attribute concerns the amount of lost private space. This attribute is included because the placement of a green border in an urban street can force the street architects to reduce the size or remove front gardens. By placing GBS that require space, the total area needed for public use becomes larger. The resident needs to choose whether they find it more important to for example have more private space, parking space, or a green border. The levels of this attribute have been determined in collaboration with Arcadis employees. The value represents the meters of length the resident will miss. Usually, the front of an urban house is 10 meters wide. By multiplying the lost private space by 10 meters, one could determine the number of square meters lost for each resident in that street. The selected attribute levels are 0 meters, 2 meters, and 5 meters. The attribute 0 meters of lost private space is included to allow the respondent to show that they are unwilling to give up any private space for GBS.

Responsibility
The last attribute is responsibility. Previous research has shown that there are three major stakeholders for the implementation of GBS. For future (re)development projects, it is interesting to see if residents have a preference concerning responsibility for the GBS. The levels of this attribute have become: the municipality, the individual resident, and the neighbourhood. These levels have been chosen because the municipality is highly influential in neighbourhood planning. In many neighbourhoods and streets, the municipality is often responsible for the placement, funding, and maintenance of trees. Even though this leaves the residents with no pressure to deal with the GBS, they are also not allowed to make changes. It is therefore interesting to see what preference urban residents have concerning responsibility. Would the residents rather be responsible, or place the responsibility at the municipality? A third option is to place the responsibility in the hands of a neighbourhood initiative. In this case, the municipality is not responsible anymore, and the residents of a neighbourhood can decide on the GBS as a group. They bear the responsibility of the costs and maintenance, but the responsibility and therefore cost and effort are shared over more people. The reasoning behind leaving the organisations from the responsibility options is because they are not likely to be responsible for the GBS. Organisations may get hired for maintenance work, but the responsibility of the GBS in those cases stays with the party that hired the organisation.

Figure 4.8 below shows an example of an alternative including each of the above attributes. This illustration is one of the alternatives that might be shown to the resident in the experiment. In this alternative, the temperature reduction is low, and the amount of let-through wind is also low. The shaded area is large, and the location of the GBS is in the garden. The implementation cost for the GBS is €80,- and no maintenance contribution is needed. Lastly, the lost private space for this alternative is 2.5 meters, and the responsibility lies with a neighbourhood initiative. One version of the survey can be found in Appendix I: Survey.

Attributes	
Climate adaptation	
Temperature reduction	
Amount of let-through wind	
Greenery specifics	
Shaded area	
Location	
Value	
Implementation cost	€80,-
Maintenance	€0,-/month
Other	
Lost private space	2.5 meter
Responsibility	Neighborhood

Figure 4.8: Example of an alternative in the SC experiment.

4.2.3 Stage 3 - 7: Experimental Design

Now that the alternatives, attributes, and attribute levels are determined, the next step is to select the experimental design. In this study, the total number of attributes that are included in the survey is 8 and each attribute has 3 levels. In total, this results in 3^8 (6,561) possible alternatives. The full factorial design would be able to determine all possible main and interaction effects, but the design would become far too large to make sense (Hensher et al., 2015). Therefore, a fractional factorial design is preferred. The total amount of alternatives to 6,561 can be reduced to 27. This reduction removes the possibility to analyse the interaction effects between attributes. However, as the attributes are chosen without existing correlations, it would not necessarily be beneficial to analyse the whole system. To keep the survey reasonable and interesting for the respondent, the choice is made to present each respondent with 6 randomly selected choice sets. Each choice set consists of two alternatives and a "neither" option. The "neither" alternative is added to leave the possibility for respondents not to choose. If the respondent needs to choose between two options but does not prefer either, they will choose the "least worst" option (Hensher et al., 2015). As this study aims to find the preference, the choice is made to include the "neither" alternative. To distribute the 27 choice sets over groups of 6 choice sets per respondent, the system is multiplied, and 54 combinations are created. The result is 9 groups consisting of 6 choice sets. Each respondent is randomly presented with one of these 9 groups and will present their preference for each of the 6 choice sets.

4.2.4 Stage 8: Construct a Survey Instrument

To conduct the choice experiment, a survey is created to be distributed amongst urban residents. Students of the Eindhoven University of Technology are provided with the platform "Limesurvey" to create a survey. The survey for this study consists of three parts: subject introducing questions, the choice experiment, and socio-demographic characteristics questions. Urban areas in the Netherlands and specific cities have a rising number of English residents (CBS, 2019). Therefore, the survey is provided in Dutch and English. One of the nine versions of the survey can be found in Appendix I: Survey.

As mentioned before, the survey consists of three parts. The first part of the survey introduces the subject of GBS using some subject related questions. According to (Fouyn, 2018), correctly set up surveys aim to keep the respondent interested throughout the survey. The first element of a survey should therefore be the introduction of the subject and questions that get the respondent thinking about their current knowledge of the subject. The questions that are asked in this section are therefore questions about their knowledge of climate change, vegetation properties, and their heat perception. The following questions are presented to the respondents.

The placement of trees and other vegetation types ensures lower surface temperatures in the surrounding area. Are you aware of these advantages of vegetation?
This question aims to introduce the topic of the survey and invite the respondent to think about their current knowledge. Studies have shown that knowledge of the advantages of vegetation has a positive effect on the attitude of people towards the implementation.

What advantages of vegetation do you value the most?
This question is included because some of the options below could not be included in the Stated Choice experiment. However, it would be interesting to see what advantage the respondent value most. The respondent is allowed to select three of the following options. Additionally, by displaying the advantages as options, the respondent is provided with more information.

- Aesthetics
- Cooling
- Water drainage

- Better air quality
- Noise reduction
- Increased neighbourhood value

Have you ever been encouraged to increase the amount of vegetation in your garden/house by a third party? If yes, please name the third party.
This question is based on the knowledge that most people are unaware of the advantages of GBS. Additionally, even though the municipalities provide subsidies to promote the implementation of more green in neighbourhoods and gardens, not many people are aware of these actions. However, it will be interesting to see if respondents have been encouraged in the past, and by what kind of the third party.

Imagine a situation where your home/room/living space has a temperature of 25 degrees Celsius for a longer period. In this space, you have to work, sleep, and/or relax. What best describes your reaction in this situation?

This question aims to find the heat perception of the respondent. The respondent needs to choose between four possible reactions related to heat stress. These four options are the following.

- Physical complaints (exhaustion and fainting, loss of concentration, insomnia, severe headache)
- Slight physical complaints (fatigue, headache, concentration problems, sleeping problems)
- Slight irritation from the temperature, difficulty falling asleep
- No problems with the temperature

Do you worry about the effects of climate change?
Previous studies have shown that people tend to be more interested in GBS if their concerns on climate change and global warming are greater (Derkzen et al., 2017). It is therefore interesting to see if the same result will present itself in this study. The respondents can choose between three answer options: Yes frequently, yes occasionally, and no not really.

Would you like to see more environmentally friendly measures in your neighbourhood?
This question is included to test the respondent's interest in environmentally friendly measures. If the respondent answers positively, it is more likely they will be interested in the implementation of GBS. It will be interesting to see the percentage of Dutch residents that shows a positive attitude towards environmentally friendly measures.

The second part of the survey includes the stated choice experiment. Stated Choice Experiments (SCE) require information to be given in advance. The respondent needs to understand the task they need to perform, as well as each of the attributes and attribute levels that will be used in the SCE. This section gives a detailed description of the attributes used in the SCE, as well as the attribute levels which are shown through their illustrations and values. Figure 4.9 below shows the information page of the online survey.

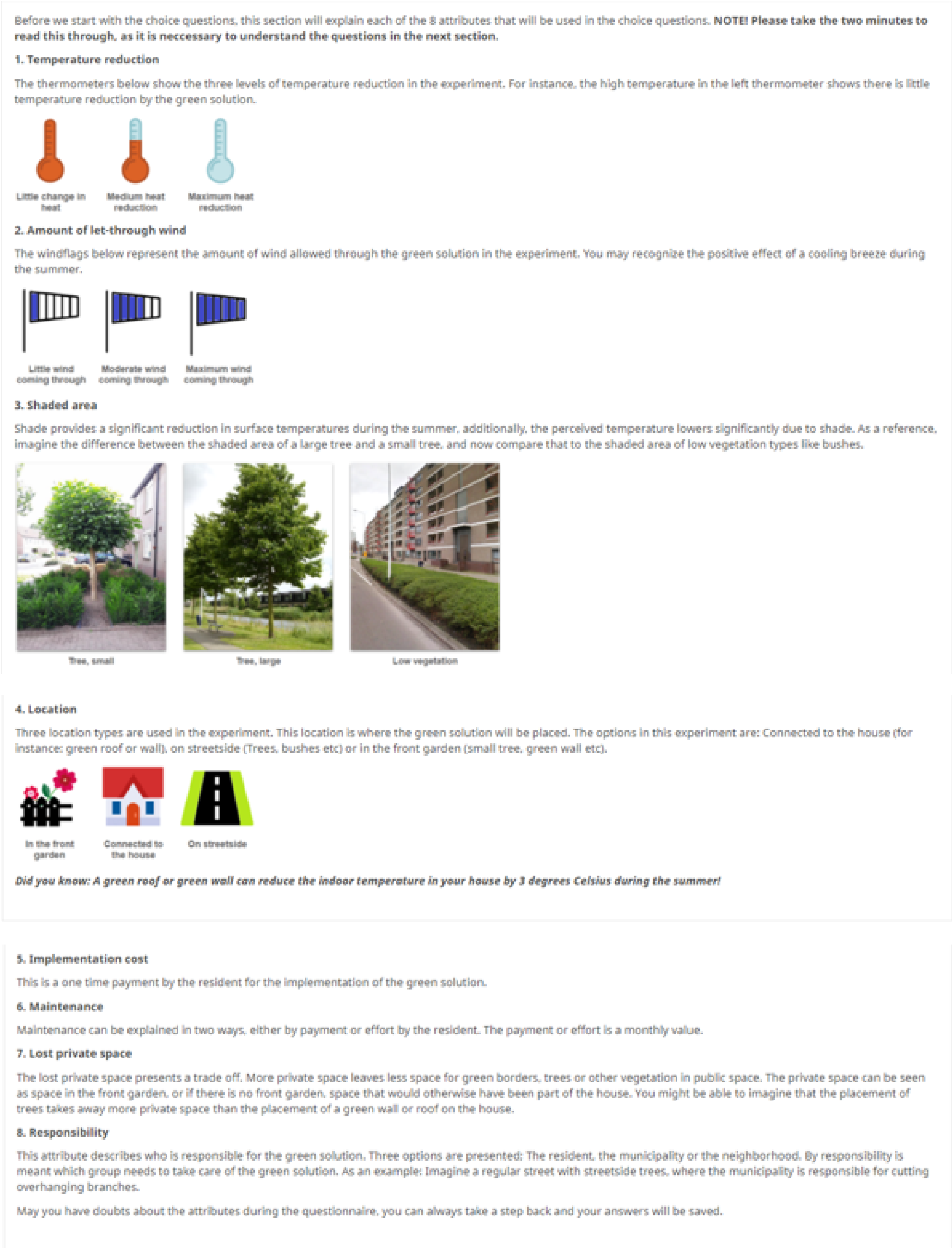


Figure 4.9: Attribute and attribute level information page from the online survey

Previous research shows respondents tend to quit the survey when the questions are too complex, when the survey is too long, or when the survey requires too much reading (Fouyn, 2018). It is therefore a complicated task to find the right balance for the SCE, as it requires explanations to get reliable results. The choice was made to not include an example of the choice set in this survey. For SCE, it is usual to show an example to make sure the resident understands the task. However, keeping in mind the lengthiness of the survey, the choice has been made not to include an example. Therefore, the next page in the survey presents the respondent with the 6 choice sets. Here, the respondent gives her/his preference 6 times between three alternatives, two alternatives consisting of different attributes, and the alternative of choosing "neither". When the respondent has selected the preferred alternative for each of the six choice sets, this section is finished.

The next section in the survey consists of the socio-demographic characteristics questions. The socio-demographic questions focus on people's gender, age, health, income, type of dwelling, and the 4 digits of the respondent's postal code. According to the literature provided in section X, these characteristics are likely to have a relationship with the preference concerning GBS. It is therefore important to collect these personal characteristics. Additionally, the data collected through these questions will show what the population is represented by the sample. Additionally, according to (Fouyn, 2018), the last page of the survey can be used to pique the interest of the respondents by including a footnote. By providing the direction for residents of the Netherlands to implement their own GBS, the implementation can be promoted.

The survey was first tested amongst fellow students and close relatives. Once those suggestions had been processed, the survey was tested by the first and second supervisor. Finally, the survey had to be checked by the TU/e ethical committee. This latter step is necessary to ensure the survey does not break any ethical rights. As of January 2020, the collection of personal data needs to be controlled. Once the ethical committee approved the survey, the survey could be shared. The online survey would be shared through communication channels and online survey sharing channels. However, to ensure the spatial distribution of the survey, a flyer has been distributed in the city of Eindhoven, Rotterdam, and 's Hertogenbosch. In each of the cities, 100 flyers have been distributed to random houses within the urban areas. The flyer can be seen in Appendix II: Flyer.

4.3 Method of Analysis

Once the data is collected, the data needs to be analysed. To do that, the correct method of analysis needs to be selected for this study. The most frequently used methods of analysis are Logit models. The Multinomial Logit (MNL) model and the Latent Class Model (LCM) are used in this experiment. The MNL model analyses the overall preference of an individual to a choice option, resulting in the average values for the total sample. The MNL model assumes homogeneity between individuals within the sample. The MNL model can only be used in experiments where no correlation exists between alternatives and choices. In this experiment, it can be assumed to not have such correlations, therefore the MNL will be suitable for the experiment. The LCM is used to find groups of individuals that have similar choice behaviour. These results will help form the relations between preferences and personal characteristics. The next two sections will elaborate on the MNL and LCM methods.

4.3.1 Multinomial Logit Model (MNL)

The Multinomial Logit Model (MNL) can predict an individual's overall preference concerning a choice option. It provides an analysis of multi-attribute experiments, measuring the choice behaviour of individuals (Kjaer, 2005). Although, the MNL model can only be used in experiments that assume no correlations between alternatives and choices. As the SC experiment of this study contains no complex relationships, the MNL is shown to be the best method of analysis. Additionally, the MNL can predict the probability of an alternative for an individual. This prediction is made based on the individual's expressed preference towards that alternative, and an unobserved random component. This random component refers to the uncertainty that belongs to predicting human behaviour. Each respondent's profile is represented by a single utility number to give the respondent an overall value. This is done by assigning weights to each of the attributes, which are then used to derive a linear combination. The weights in a main-effects additive utility model show the importance assigned to values on each of the attributes. The sum of the part-worth utilities equals the utility of the alternative. When the Vi is treated as a conditional indirect utility function, the observable utility function becomes

$$U_i = V_i + \varepsilon_i \quad \rightarrow \quad V_i = \beta x_i \tag{4.1}$$

Where $x_i = (x_{1i}, x_{2i}, ..., x_{pi})$ is the vector of the attributes for alternative i, β is the weight of the attributes, and ϵ_i the random component (Kjaer, 2005).

To estimate the probability of choosing alternative i out of the set of J alternatives, equation (4.2) can be used. This equation states that the probability of an alternative is equal to the ratio of the exponential of the utility for alternative i to the sum of the exponentials of the utilities for all J alternatives (Hensher et al., 2015).

$$P_i = \frac{expV_i}{\sum_{j=1}^{J} \exp v_j}; \quad j = 1, \ldots, \ldots \tag{4.2}$$

Goodness of fit
When the log-likelihood function is determined for the estimated parameters and the null model, the goodness-of-fit can be calculated. To determine the goodness of fit of the estimated model, McFadden's Rho-Square can be used for fitting the overall model. McFadden suggests p^2 values of between 0.2 and 0.4 should represent an excellent fit of the model (McFadden, 1974).

$$p^2 = 1.0 - [LL(\beta)/LL(0)] \tag{4.3}$$

In this formula, the LL(β) is the log-likelihood function using the estimated parameters and LL(0) is the log-likelihood function using the null-model (all β's being equal to 0) (Hensher et al., 2015).

The Log-Likelihood ratio test
Standard t-statistics are often used to test hypotheses in discrete choice models. A likelihood ratio test, also referred to as the LL-test can be used for more complex hypotheses. The LL-test can be used as a model selection criteria. The LL test statistic goes as follows.

$$LL - \text{ test } = 2 * (LL(0) - \mathrm{LL}(\beta)) \tag{4.4}$$

In this formula, the LL(β) is the log-likelihood function using the estimated parameters and LL(0) is the log-likelihood function using the null-model. If the value of the LL-test exceeds the critical chi-squared value for the associated degrees of freedom, then the null hypothesis is rejected (Kjaer, 2005). This indicates that the new model outperforms the null model.

4.3.2 Latent Class Model (LCM)

A Latent Class Model (LCM) is suggested to see if there is an improvement possible by separating the total sample into groups of respondents. The LCM also estimates the parameters for a given number of classes (or clusters) of respondents which are determined by the model. By executing a latent class model analysis, clusters of individuals are obtained. The individuals within the clusters have a similar choice of behaviour. For each cluster, a set of parameters is estimated. After executing the LC model, the results of the clusters can be compared to the socio-demographic and environmental answers of the individuals. Doing this will provide the characteristics of each group. Therefore, the result shows whether the respondents belonging to one cluster also share similar socio-demographic characteristics or have the same environmental conscious attitude. This information can later be used to form conclusions about what characteristics of the GBS are more preferred by the clusters of people with certain personal characteristics.

The underlying theory of the LCM says that the individual behaviour of respondents depends on observable attributes and on latent heterogeneity which varies with unobservable factors for the researcher. In the LCM, assumed is that individuals are sorted into a set of Q classes, which classes contain any particular individual. The central behavioural model is given in equation 4.5 (Hensher et al., 2015):

$$P_{it|q}(j) = \frac{\exp\left({x'}_{it,j}\beta_q\right)}{\sum_{j-1}^{J_i} \exp\left(x'_{it,j}\beta_q\right)} \tag{4.5}$$

Where $P_{it|q}(j)$ is the probability of choice j, by individual i, in the choice situation t, in class q.

The contribution of individual i in the likelihood is the joint probability of $y_i = y_{i1}, y_{i2}, ...,$ y_{iT}. Assuming that in the class assignment, the choice situations T_i are independent. Which gives equation 4.6 (Hensher et al., 2015):

$$P_{i|q} = \prod_{t=1}^{T_i} P_{it|q} \tag{4.6}$$

H_{iq} provides the prior probability for a class q for individual i, shown in equation 4.7 (Hensher et al., 2015):

$$H_{iq} = \frac{\exp\left({z'}_i\theta_q\right)}{\sum_{q=1}^{Q} \exp\left({z'}_i\theta_q\right)}, q = 1, \ldots, Q \quad \emptyset_Q = 0 \tag{4.7}$$

The probability for individual i is the sum of the expected class-specific contributions, as shown in equation 4.8 (Hensher et al., 2015):

$$P_i = \sum_{q=1}^{Q} H_{iq} P_{i|q} \tag{4.8}$$

Similar to the analysis of the MNL model, the log-likelihood ratio test shows if the LC model outperforms the MNL and the null model. Additionally, the goodness of fit can also be determined using the McFadden's rho square for the LC model.

4.3.3 Willingness to Pay (WTP)

A Stated Choice experiment is highly suitable to estimate the Willingness to Pay (WTP). The combination of the cost variable and other variables of interest provide a trade-off to the respondent. By doing this, the preferences of the respondents can be expressed in monetary values, therefore the results are easily applicable in real life. So, the WTP describes the cost an individual is willing to pay for the benefits of a service, or goods, or to prevent certain actions or circumstances. The marginal WTP describes how much the cost is required to change to keep the utility value the same. For this study, it is possible to estimate the respondents' WTP for the investigated GBS attributes. According to (Hensher et al., 2015), the Willingness to Pay for attribute j can be calculated as follows.

$$WTP_j = \frac{\beta_j}{\beta_c} \tag{4.9}$$

Where, WTP_j = the willingness to pay for attribute j, and β_j and β_c are the marginal utilities for the attribute of interest and cost, respectively.

4.4 Conclusions

In this chapter, the methodology of this study is explained. The chapter starts by elaborating on the relevance of the study. It then moves to explain the steps made to perform a Stated Choice (SC) experiment. A SC experiment is used to find the preferences of individuals in hypothetical situations. The purpose of executing the Stated Choice experiment is to answer the research question: "What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?". This chapter explained the stages for constructing an SC experiment following the theory of Hensher et al. (2015). The eight stages that were followed in this study are: problem refinement, stimuli refinement, experimental design considerations, generate experimental design, allocate attributes to the design column, generate choice sets, randomize choice sets, and construct the survey instrument.

The process starts with defining the alternatives, attributes, and attribute levels for this study. The alternatives within this study are a combined representation of different GBS characteristics. The alternatives are described using the following attributes: Temperature reduction, amount of let through the wind, shaded area, location, maintenance, implementation cost, lost private space, and responsibility. Each attribute is assigned three attribute levels. The full factorial design would therefore hold 6,561 combinations. To keep the experiment feasible, that amount can be reduced to 27 combinations. Each respondent will be presented with 6 randomly selected choice set combinations. Therefore, a total of 9 different versions of the survey are created. The survey is created in Limesurvey and includes 4 main elements: introduction questions, the introduction of the attributes, the Stated Choice experiment, and socio-demographic characteristic questions. The section introduction of the attributes requires a trade-off. A SC experiment requires a certain amount of explanation to be provided to the respondents. At the same time, respondents have known to lose interest when text portions of a survey become too lengthy. The choice has been made for this experiment to reduce the amount of explanation. This may have resulted in some misunderstandings by respondents, but by encouraging more respondents to finish the survey in its entirety, these misunderstandings will likely be of no influence. An example of an assumption is that the respondents understand that a medium shaded area is larger than a small shaded area and smaller than a large shaded area.

The last two sections of this chapter introduced the methods of analysis used in this study. The Multinomial Logit Model (MNL) is used to analyse the respondent's overall preference for the presented alternatives. The Latent Class Model (LCM) is used to find out if there are groups of residents with similar characteristics that have shown similar preferences.

The previous chapters have covered the preparation of the survey and the SC experiment. The distribution of the online survey has been done for two weeks in December 2020. A total of 148 respondents have completed the survey. The logit models mentioned in the previous chapter have been applied to analyse the responses. The next chapter will provide an elaborate on the results of the online survey and the SC experiment.

5 Results

This chapter analyses the output of the survey according to the statistical approaches introduced in chapter 8. The chapter starts by comparing the population sample of the experiment to the distribution of the Dutch population. The chapter then moves to present the results of the Multinomial Logit Model. The results show the choice behaviour data based on the Stated Choice experiment. Finally, the classes found by the Latent Class Model are explained. The creation of these classes is based on similar choice behaviour.

5.1 Data Collection

The data collection took place between December 7th and December 21st, 2020. The distribution of the invitations of the survey was done through online media channels. Through the email channels of Arcadis, the survey was shared with several advisory groups consisting of approximately 50 Arcadis employees each. Additionally, the survey was shared with the individuals who have provided their insight and experience for this research. Another online channel that has been used is my network. The survey has been shared through LinkedIn and Facebook, as well as family and friends. They, in turn, have shared the survey with other family members, friends or colleagues. To ensure spatial distribution, the survey was also shared by the distribution of flyers in the area of Rotterdam, Utrecht and Eindhoven. The flyer included a QR code and website URL to the online survey. Due to the presence of Covid-19 during the distribution of the survey, further personal distribution of the flyer and survey was constricted. A copy of the flyer can be seen in Appendix II: Flyer. After two weeks of data collection, the online survey had been opened 196 times. 148 of the 196 people completed in the survey, including the choice experiment.

5.2 Socio-Demographic Sample Distribution

In the survey, the last section provided respondents with social-demographic questions to deduce the characteristics of the person. The characteristics of all the respondents combined show the sample distribution of the retrieved data. Table 5.1 shows the comparison between the distribution of the experiment and the distribution of the Dutch population. The chi-square test is performed to test the representativeness of each characteristic. The chi-square test shows a significant difference when $p<0.05$. If the $p>0.05$, the retrieved sample can be seen as representative of the Dutch population for that specific characteristic as the difference between the sample and the Dutch population is small enough.

Characteristic	Level	% Experiment	% of the Netherlands	Observed N	Expected N
Gender	Male	58.8%	49.7%	87	74
Chi-square: 6.09	Female	39.2%	50.3%	58	74
Chi-square p: 0.014	Other	0.7%		1	0
	Rather not say	1.4%		2	0
Age*	15-25	17.6%	14.5%	26	21
Chi-square: 59.76	26-35	31.8%	15.3%	47	23
Chi-square p: 0.000	36-45	20.3%	14.1%	30	21
	46-55	14.2%	16.8%	21	25
	56-65	12.8%	16.1%	19	24
	66+	2.7%	23.2%	4	34
	Rather not say	0.7%		1	0
Health**	Chronic health problems	3.4%	20.3%	5	41
Chi-square: 40.97	Physical/Psychological complaints	15.6%	21.4%	23	43
Chi-square p: 0.000	Generally healthy	81.1%	58.4%	120	118
Residence	Terraced house	27.7%	41.5%	41	61
Chi-square: 40.11	Semi-detached house	18.9%	19.6%	28	29
Chi-square p: 0.000	Detached house	18.9%	23.0%	28	34
	Apartment/studio/flat	34.5%	15.9%	51	24
Income	Less than €1.000,-	18.9%	14.9%	28	22
Chi-square: 26.19	€1.000,- to €2.500,-	35.8%	43.1%	53	64
Chi-square p: 0.000	€2.500,- to €5.000,-	40.5%	26.3%	60	39
	€5.000,- or more	4.7%	15.7%	7	23

* *The percentages of the Netherlands have been adjusted to exclude the population with an age of 14 and younger.*
** *does not make the distinction between regular and occasional complaints; the two levels have therefore been combined for the comparison.*

Table 5.1: Sample distribution compared to sample distribution Dutch population received from Opendata.cbs.nl (October 2020)

The first row of table 9, shows that there is a higher participation rate for males than females in the collected sample. The percentage of the Dutch population also shows a slightly higher male rate. However, the Chi-square test shows a p-value of 0.014, which shows the gender characteristic is not representative of the Dutch population, as the chi-square value needs to be greater than 0.05. According to the distribution of the Dutch population, the largest age group should be the age group of 66+. In the collected sample, the largest age group is between 26 and 35 years. Even when the age group 66+ is excluded from the sample, the chi-square value shows a p-value of 0.0006. Though the sample then represents a better fit then when the age group 66+ is included, the sample still is not representative of the Dutch population. The distribution of the health characteristics may be related to the age characteristics. The collected sample has considerably more people in the 'generally healthy' level. This could be attributed to the small number of respondents in the 66+ level, as older people generally have more health problems. The age characteristic nor the health characteristic shows a representative chi-square p-value. Neither does the residence characteristic, the majority of the Dutch population lives in a terraced house, whereas in the collected sample that is the second-highest percentage. The collected sample also shows the higher percentage of people living in apartments, studios of flats, which according to the Dutch distribution should be the least occupied residence. Finally, the characteristic income also shows a deviation from the Dutch distribution. The collected sample reached mostly people within the income of €1.000,- and €5.000,- per month. This is in accordance with the Dutch distribution, though the chi-square test shows the characteristic is not representative for the Dutch population. A possible reason for this focus income is because of the large proportion of Arcadis employees that have responded to the survey.

Furthermore, the location distribution of the respondents in the Netherlands can be seen in figure 5.1. The figure shows an unequal distribution across several provinces, which can be attributed to the data distribution methods. As the personal connections and the Arcadis office that is collaborating most with this research are in the region of Noord-Brabant, the number of 62 respondents in that location was to be expected.

Based on the results of the socio-demographic responses, a couple of conclusions can be made. The obtained sample does not represent the Dutch population distribution. The obtained sample holds considerably more people with the ages of 25 to 45 than the Dutch population, and much fewer people with older age. However, the information that will be obtained by this study will be most relevant for generations that are likely to move to a different house in the future. It is, therefore, more relevant to emphasise on the preferences of younger residents, and not a problem that the sample is not representative of the Dutch population.

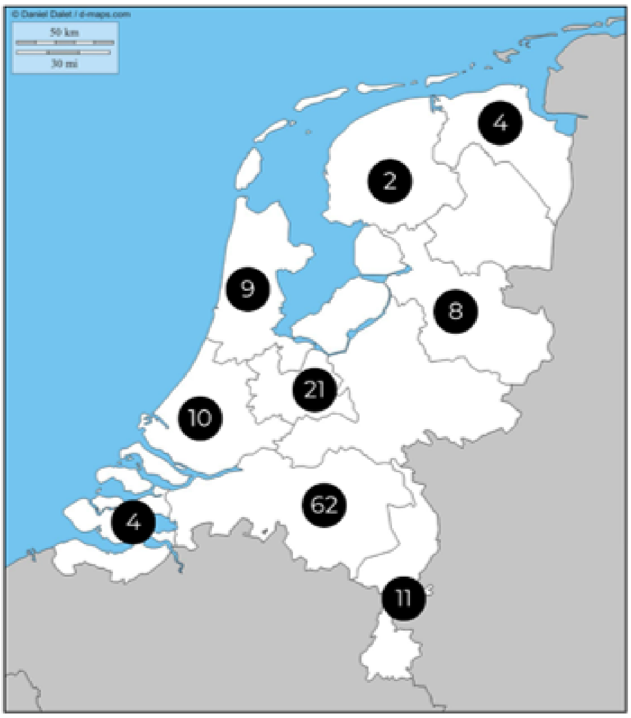


Figure 5.1: Distribution respondents over the Netherlands

5.3 Environmental Characteristics of the Respondents

In this section, the environmental characteristics of the respondent sample are analysed. This section provides insight into the overall attitude of the respondents towards elements concerned with Green-Based Solutions. To gain a better perspective of the results, the answers for each question are compared to the socio-demographic characteristics of the respondents. The characteristics that are used are gender, age, income, and residence.

Cooling property awareness
Right before the first question, respondents were introduced with the cooling properties of vegetation. The question followed if they were aware of these advantages of vegetation. The results can be seen in figure 5.2. 95% of the respondents were aware of the advantages, 5% was not aware of

these advantages. From this result can be concluded that most people are aware of the advantages of vegetation.

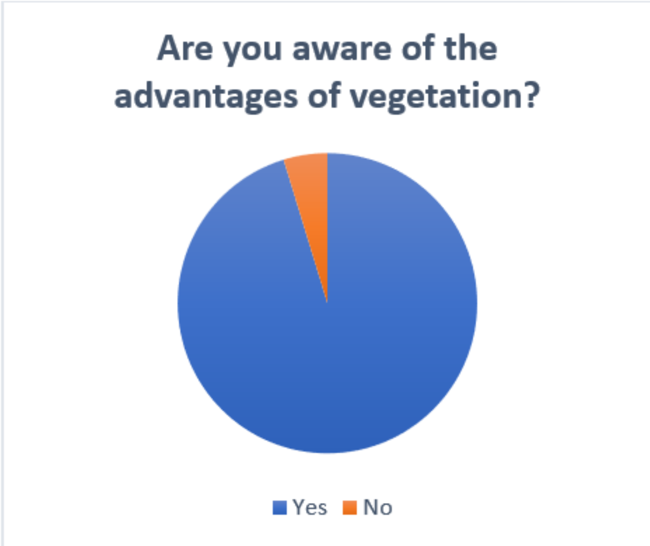


Figure 5.2: Reaction of respondents to vegetation awareness question

Green-Based Solution advantages
The second question moved the respondents to select three advantages of vegetation that they appreciate the most. The presented choice options were: Noise reduction, water drainage, increased neighbourhood value, aesthetics, cooling and better air quality. The results of this question show that the advantage that is most appreciated is better air quality, indicated by 73% of the respondents. Following are the almost equally appreciated cooling property and aesthetics. Noticeable is that water drainage is only appreciated by 28%. Figure 5.3 illustrates these results.

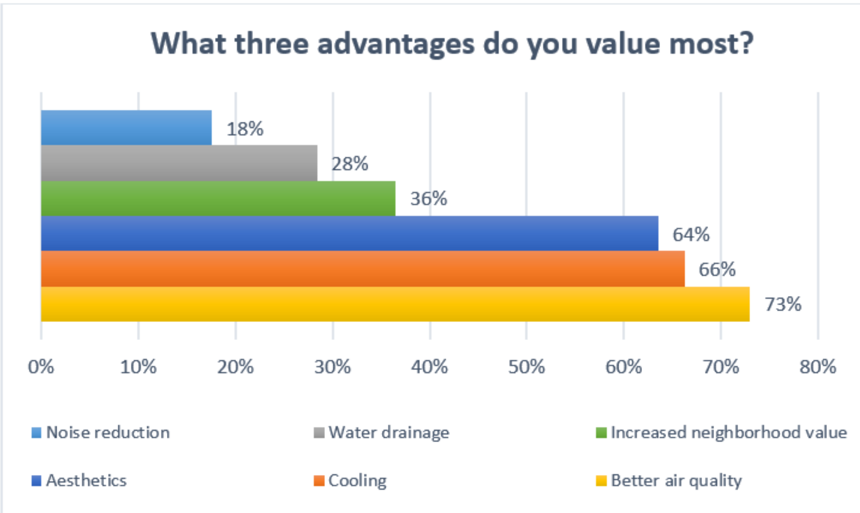


Figure 5.3: Reaction of respondents to vegetation advantage question

Vegetation encouragement
The results of question 3 show that most respondents have never been encouraged to implement more vegetation around their home. 81% of the respondents answered this question by selecting the answer option 'No'. Only 19% of the respondents have been encouraged to implement more vegetation. The respondents were free to add the source of encouragement in an open text box. Frequently mentioned sources are the municipalities, neighbourhood initiatives, or natural interest in vegetation. Figure 5.4 illustrates the results.

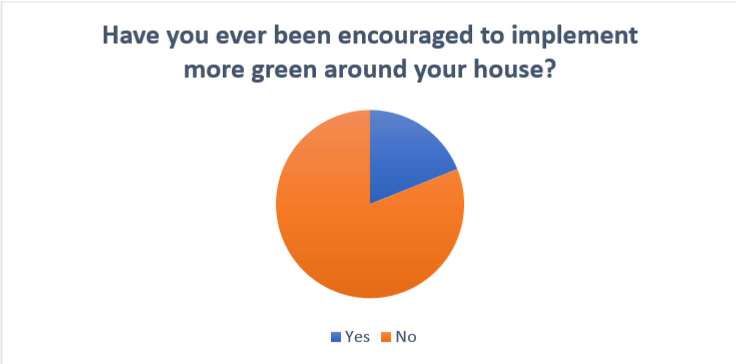


Figure 5.4: Reaction of respondents to vegetation implementation question

Heat perception
Before question 4 was presented to the respondent, the following situation was sketched.

"Imagine a situation where your home/room/living space has a temperature of 25 degrees Celsius or higher for a longer period of time. In this space, you have to work, sleep and/or relax. What best describes your reaction in this situation?"

Almost half of the respondents answered with slight irritation, followed closely by slight physical complaints. Only 13% of the respondents expected not to have any complaints, and 5% expected to have more serious physical complaints. It can be concluded that most people are uncomfortable to relax, work or sleep at a steady temperature of 26 ° C or higher. Figure 5.5 illustrates the results of question 4.

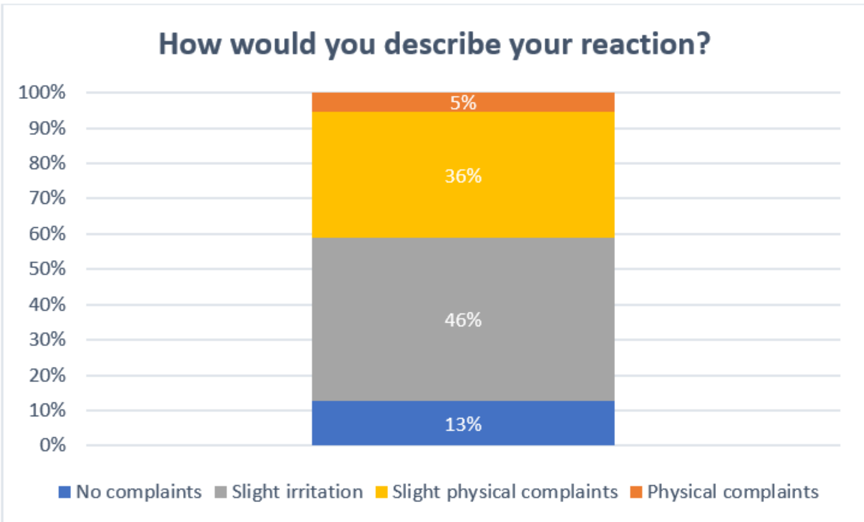


Figure 5.5: Reaction of respondents to heat

According to the literature, the human body needs to adapt to temperatures of 25 degrees Celsius and higher. The reactions of the respondents show that only 13% of the respondents do not notice any physical or mental disturbance by the increased temperature. It can be concluded, that it is necessary to keep the temperature of residential homes low in order to maintain good personal wellbeing.

Climate change concerns

The 5^{th} question concerned a general climate change concern statement. The results show that only 9% of the respondents are not worried about climate change. Therefore, 91% of the respondents are concerned about climate change. More than half of the respondents admit worrying about climate change only sometimes, whereas 31% is frequently concerned. Climate change reactions are also compared to the socio-demographic characteristics age by creating crosstabs. This choice is based on the assumption that younger people are more concerned with climate change. The results of the crosstab show that the younger the collective group is, the more concern they have for climate change. Therefore, the results are in line with the assumption. Based on this assumption, it can be assumed that future homeowners place a higher value on climate change adaptation measures, and therefore might be more willing to pay extra for those measures. Only the age group 66 years or older shows inconsistent results, as this group shows also to be concerned about climate change. However, this might be the result of the small sample of respondents with an age of 66 years or older. The results of the crosstabs between the climate change results and the socio-demographic characteristics age are shown in figure 5.6 below.

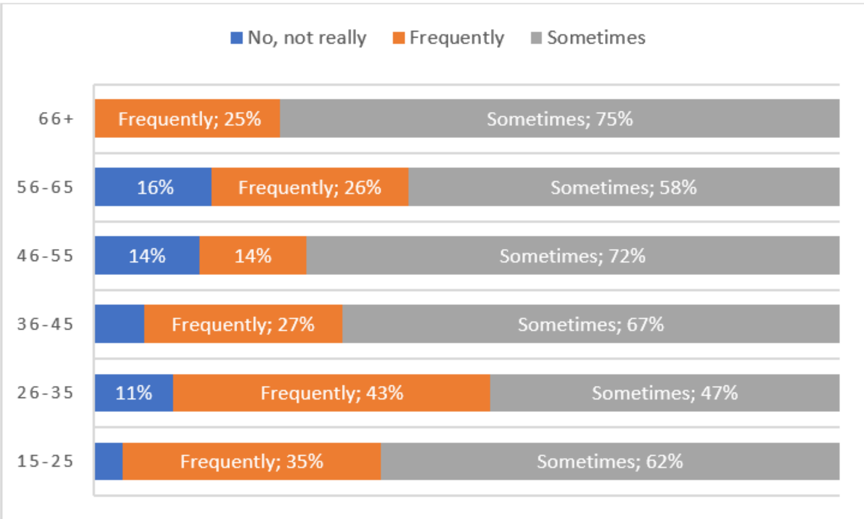


Figure 5.6: Age versus climate concern

As a result of the subject related questions, it can be concluded that the sample reacted similarly as expected according to the literature review. Only the awareness of vegetation cooling properties was considerably higher than expected. Noticeable is also the low percentage of respondents that has ever been encouraged to implement more vegetation around their home. As an addition to these results, the Stated Choice experiment will show under what circumstances respondents would and would not like to see more vegetation. The trade-offs of cost, maintenance, private space and other attributes that have not been included in the questions above, will most likely influence people's choices.

5.4 Multinomial Logit Model Analysis

In this section, the results of the Multinomial Logit (MNL) model are discussed. Table 10 shows the results of the analysis. The table shows the MNL coefficients as well as the corresponding significance levels. The results are visualized more clearly in figure 5.7, emphasising on the positive and negative MNL coefficients. The Log-Likelihood of the MNL model equals -731.41 and the Log-Likelihood value of the null model equals -851.54. The Log-Likelihood Ratio Statistics test gives a value of 240.26. This is greater than the critical Chi-square value with 17 degrees of freedom of 27.59, hence the MNL model significantly outperforms the null model. The original results of the NLogit MNL analysis can be found in Appendix III: Stated Choice analysis.

5.4.1 MNL Results

Table 5.2 shows the results obtained by the MNL model. The coefficient of the constant shows that respondents more often chose the presented combination of attributes, than they chose to select neither of the combination options. The column on the right shows the significance of the coefficient values. The significance shows whether the preference for an attribute level is small or large.

Attribute	Attribute level	Coefficient MNL	Significance
Constant		**1.349**	*******
Implementation cost	€0, -	0.241	***
	€80, -	0.267	***
	€250, -	-0.508	
Maintenance	€0, -/month	0.373	***
	€10, -/month	-0.217	***
	10 hrs/month	-0.156	
Responsibility	Municipality	0.380	***
	Resident	-0.354	***
	Neighbourhood	-0.026	
Temperature reduction	Low cooling	-0.795	***
	Medium cooling	0.294	***
	High cooling	0.501	
Wind amount	Low wind	-0.143	**
	Medium wind	0.179	**
	High wind	-0.036	
Shaded area	Little canopy	-0.328	***
	Medium canopy	0.043	
	Large canopy	0.285	
Location	Front garden	0.076	
	House	-0.019	
	Street	-0.057	
Lost private space	0 meter	0.281	***
	1.5 meter	-0.048	
	2.5 meter	-0.233	

Table 5.2: Results of the MNL model analysis

The ranges of the attributes show the differences between the highest and the lowest part-worth utility of each attribute. Table 5.3 shows each attribute and its range, ordered from the highest range to the lowest. A high range of utility shows that the attribute has a high influence on the respondents' choice behaviour. Therefore, the higher the range, the more influence the attribute has on the choice behaviour in this experiment. The results show that the attribute with the most influence is the temperature. The range of this attribute is much larger than the second-highest range for implementation, which is closely followed by the responsibility. Noticeable is that the implementation costs do not show to be the most influential attribute.

Attribute	**Range (β_{xi})**
Temperature reduction	1.296
Implementation cost	0.775
Responsibility	0.734
Shaded area	0.613
Maintenance	0.590
Lost private space	0.514
Wind amount	0.322
Location	0.133

Table 5.3: Ordered range per attribute

The next paragraphs elaborate on the results for each attribute. The first paragraph covers the climate adaptation attributes; temperature reduction and wind let-through amount. The second paragraph covers the greenery specific attributes; shaded area and location. The third paragraph covers the value attributes; implementation cost and maintenance. The final paragraph covers the attributes of lost private space and location.

Climate adaptation

According to the results of the MNL analysis shown in table 10, some conclusions can be drawn for the climate adaptation attributes. First, for the attribute temperature reduction, both coefficients are significant at the 99% level. The coefficient for the first level is negative with a value of 0.795, which corresponds to the attribute level low cooling. The coefficient of the second level shows a positive value of 0.294, which corresponds to the attribute level medium cooling. The negative value of the sum of both coefficients corresponds to the utility of the third level. The third level is the reference level and shows a positive value of 0.501 for the attribute level maximum cooling. The part-worth utilities of the attribute temperature reduction show that the respondents favour Green-Based Solutions (GBS) with high-temperature reduction properties. Additionally, the part-worth utilities show that respondents strongly disfavour GBS with low-temperature reduction properties.

The second attribute within this group is the wind let-through amount. The results of the MNL analysis show both coefficients are significant to the 95% level. The coefficient for the first level is negative with a value of 0.143, which corresponds to the attribute level low wind. The second level shows a positive value of 0.179, which corresponds to the attribute level of medium wind. The coefficient of the third level, which is the reference level, shows to be negative with a value of 0.036. The part-worth utilities of the attribute wind let-through amount show that the respondents favour GBS with medium level wind. Noticeable is the slightly negative part-worth utility for high wind. The respondents favour GBS that disrupt some of the wind flow.

Greenery specific

The first attribute within this group is the shaded area. The first coefficient of this attribute is significant at a 99% confidence level and shows a negative value of 0.328. This coefficient corresponds to the first attribute level, little canopy. The second coefficient is not significant but shows a positive value of 0.043, which corresponds to the level medium canopy. The reference level coefficient shows a positive value of 0.285 and corresponds to the level large canopy. The results of this attribute show that the respondents favour a GBS with a large canopy volume, and therefore a large shaded area. However, noticeable is the smaller difference between the part-worth utilities, which corresponds to a less significant preference between the three levels.

The second attribute within this group is the location. Neither of the coefficients for this attribute is significant. The first coefficient shows a positive value of 0.076, which corresponds to the first attribute level of the front garden. The second coefficient shows a slightly negative value of 0.019, which corresponds to the attribute level house. The third coefficient, and reference level, shows a negative value of 0.056. This coefficient corresponds to the attribute level street. The results show that respondents have a slight preference for GBS that are located in the front garden. However, the differences between the part-worth utilities are small, which means the respondents did not display a large preference of one level over the other.

Value
According to the results of the MNL analysis, the two coefficients corresponding to the attribute cost are significant to the 99% level. The first coefficient shows a positive value of 0.241, corresponding to the attribute level €0, -. The second coefficient shows a positive value of 0.267, corresponding to the attribute level €80, -. The third coefficient is determined to be a negative value of 0.508, which corresponds to the attribute level €250, -. The results for this attribute show that the respondents favour a GBS with an implementation cost of €80, -. Noticeable is that the respondents favour the level with a higher implementation cost over no implementation cost.

The second attribute within this group is maintenance. The coefficients for these levels are both shown significantly to the 99% level. The first coefficient shows a positive value of 0.373, which corresponds to the attribute level €0, -/month. The second coefficient shows a negative value of 0.217, which corresponds to the attribute level €10, -/month. The third coefficient is determined at a negative value of 0.156, which is the reference level and corresponds to the attribute level 0 hours/month. The results show that the respondents prefer not to spend time or money on maintenance on the GBS. Noticeable is that the respondents also showed a higher preference for manual labour of 10 hours per month, than paying €10, - per month to have the maintenance done.

Other
The first attribute in this group is the lost private space. Only the first coefficient of this attribute is significant to the 99% level. The first coefficient shows a positive value of 0.281, corresponding to the attribute level 0 meters. The second coefficient shows a negative value of 0.048, corresponding to the attribute level of 1.5 meters. The third coefficient is determined at a negative value of 0.233, which is the reference level and corresponds to the attribute level of 2.5 meters. The results show that the respondents prefer not to lose private space for the implementation of GBS around their house. Additionally, the comparison between the two negative part-worth utilities shows that the respondents prefer to lose as little private space as possible. Therefore, showing the least preference to the attribute level 2.5 meters.

The last attribute is responsibility. Both the coefficients of this attribute are significant to the 99% level. The first coefficient shows a positive value of 0.380, which corresponds to the attribute level municipality. The second coefficient shows a negative value of 0.354, which corresponds to the attribute level resident. The third coefficient is determined at a negative value of 0.026, which corresponds to the attribute level neighbourhood. The results show that the respondents prefer the municipality to be responsible for the GBS. The smaller negative value of the attribute level neighbourhood compared to the resident shows that the respondents favour a neighbourhood initiative to be responsible for being responsible themselves for the GBS.

Figure 5.7 below illustrates the part-worth utilities as a result of the MNL analysis.

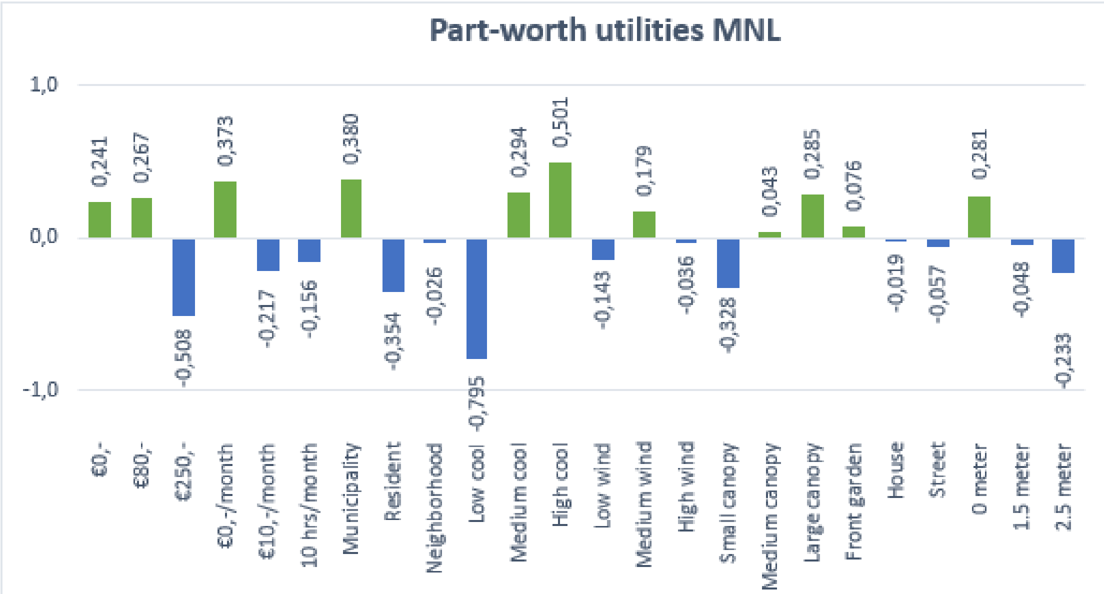


Figure 5.7: Illustration of the MNL model analysis results

5.4.2 Willingness to Pay (WTP)

Considering the MNL results, the willingness to pay (WTP) for each GBS attribute is determined. These results represent the average WTP of the complete sample of respondents. As described in chapter 4, the WTP for attribute j is calculated as the ratio of the utilities of the attribute of interest and the cost, j and c respectively. Table 12 shows the utility (range) for the cost attribute is 0.775. The corresponding attribute level range is €250, -. The ratio of the j and c is multiplied by €250, - to determine the actual value for the WTP. Table 5.4 below shows the values of the WTP for each of the attributes. Formula 4.1 shows an example of how the WTP is calculated.

$$WTP_{\text{Maintenance}} = \frac{\beta_{\text{Maintenance}}}{\beta_{\text{Imp cost}}} * €250 = \frac{0.590}{0.775} * €250 = €190,32 \quad (5.1)$$

$$WTP_{\text{M. } e \text{ 0, -/month}} = \frac{\beta_{\text{M. } e \text{ 0, -/month}}}{\beta_{\text{Imp cost}}} * €250 = \frac{0.373}{0.775} * €250 = €120,32 \quad (5.2)$$

Attribute	Attribute level	β	β_{xi}	WTP
Implementation cost			0.775	
	€0, -	0.241		
	€80, -	0.267		
	€250, -	-0.508		
Maintenance			0.590	€190,32
	€0, -/month	0.373		€120,32
	€10, -/month	-0.217		€-70,00
	10 hrs/month	-0.156		€-50,32
Responsibility			0.734	€236,77
	Municipality	0.380		€122,58
	Resident	-0.354		€-114,19
	Neighbourhood	-0.026		€-8,39
Temperature reduction			1.296	€418,06
	Low cooling	-0.795		€-256,45
	Medium cooling	0.294		€94,84
	High cooling	0.501		€161,61
Wind amount			0.322	€103,87
	Low wind	-0.143		€-46,13
	Medium wind	0.179		€57,74
	High wind	-0.036		€-11,61
Shaded area			0.613	€197,74
	Little canopy	-0.328		€-105,81
	Medium canopy	0.043		€13,87
	Large canopy	0.285		€91,94
Location			0.133	€42,90
	Front garden	0.076		€24,52
	House	-0.019		€-6,13
	Street	-0.057		€-18,39
Lost private space			0.514	€165,81
	0 meters	0.281		€90,65
	1.5 meters	-0.048		€-15,48
	2.5 meters	-0.233		€-75,16

Table 5.4: Respondents' willingness to pay for GBS attributes

Based on these results, the conclusion can be drawn that urban residents are willing to pay a one-time implementation cost of approximately €160, - more for GBS with a high cooling capacity. Similarly, urban residents are willing to invest approximately €90, - extra if it means they do not lose any private space to the GBS. Accordingly, the WTP for a GBS with a lost private space of 1.5 meters is approximate - €15, -. What this means that if the price of the GBS is reduced by €15, - the choice behaviour of the resident will not be influenced by the reduced amount of 1.5 meters private space. Each of the values presented in table 5.4 can be reasoned similarly.

5.5 Latent Class Model Analysis

In this section, the results of the Latent Class Model (LCM) analysis will be discussed. The LCM analysis is performed to discover classes within the model. These classes contain individuals that have similar choice behaviour. The results of the LCM analysis can be used to determine whether respondents belonging to a class also share similar socio-demographic characteristics. This can be achieved by comparing the results of the LCM analysis to the socio-demographic results. Additionally, the LCM analysis results are compared to the environmental questions to see if the respondents belonging to a class also share similar environmental views.

5.5.1 LCM Results

The next paragraphs will elaborate on the results of the LCM analysis. These results can also be seen in table 5.5. Two classes have been discovered by the LCM analysis. Latent Class 1 holds 96 respondents, whereas Latent Class 2 holds 52 respondents, corresponding to 65% and 35% respectively. The model has a Log-Likelihood of -684.99 and a corresponding McFadden's rho-square value of 0.298. According to the McFadden's rho-square goodness-of-fit rule, the two-class model is an excellent fit as the value lies between 0.2 and 0.4. The Log-Likelihood value is smaller than the Log-Likelihood value of the MNL model and the null model, therefore it can be concluded that the LCM model performs better than the MNL model. The constants of the LCM model for Class 1 and Class 2, show to be 3.897 and 0.106, respectively. What this shows, is that the respondents of Class 1 much more often chose the presented combination of attributes, than they chose to select neither of the combination options. The constant of Class 2 shows that the respondents in class two chose the presented combinations less often, but still more often than the option to choose neither. The original results of the NLogit LCM analysis can be found in Appendix III: Stated Choice analysis.

Based on the coefficients, a general description can be made regarding the preferences of the respondents within each Class. Class 1 prefers to pay €80, - for the implementation of the GBS and is willing to give up 1.5 meters of private space for the GBS. For this Class, the preferred location of the GBS is at the house, which could mean the respondents would prefer a green roof or a green wall. Based on these preferences, Class 1 is now represented by the name "GBS enthusiastic Class". Class two prefers not to pay for the implementation cost and prefers not to lose any private space to the GBS. Additionally, the Class prefers the GBS to be placed on the street, as conventional street-side trees. It is based on these results, that Class 2 is named the "GBS sceptics Class".

Attribute	Attribute level	Coefficient MNL	Coefficient Latent Class 1		Coefficient Latent Class 2	
Respondents per class		148	96		52	
Percentage per class		100%	65%		35%	
Constant		1.349	3.897	***	0.106	
Implementation cost	€0, -	0.241	0.106		0.355	**
	€80, -	0.267	0.376	***	0.255	*
	€250, -	-0.508	-0.482		-0.610	
Maintenance	€0, -/month	0.373	0.737	***	0.026	
	€10, -/month	-0.217	-0.313	**	-0.073	
	10 hrs/month	-0.156	-0.424		0.047	
Responsibility	Municipality	0.380	0.543	***	0.368	**
	Resident	-0.354	-0.617	***	-0.177	
	Neighbourhood	-0.026	0.074		-0.191	
Temperature reduction	Low cooling	-0.795	-1.073	***	-0.653	***
	Medium cooling	0.294	0.451	***	0.180	
	High cooling	0.501	0.622		0.473	
Wind amount	Low wind	-0.143	-0.190	*	-0.291	*
	Medium wind	0.179	0.342	**	0.125	
	High wind	-0.036	-0.152		0.166	
Shaded area	Little canopy	-0.328	-0.627	***	-0.389	
	Medium canopy	0.043	0.120		0.122	
	Large canopy	0.285	0.507		0.267	
Location	Front garden	0.076	0.133		-0.026	
	House	-0.019	0.210		-0.056	
	Street	-0.057	-0.343		0.082	
Lost private space	0 meters	0.281	0.153		0.548	***
	1.5 meters	-0.048	0.272	*	-0.408	**
	2.5 meters	-0.233	-0.425		-0.140	

Table 5.5: Results of the Latent Class Model analysis

Similar to the MNL model, table 14 shows the ranges of the attributes. Alternatively, these ranges are specific for each of the Classes. The ranges represent the differences between the highest and the lowest part-worth utility of each attribute. Table 5.6 shows each attribute and its range for the GBS enthusiast Class and the GBS sceptic Class, ordered from the highest range to the lowest. The results show that for the GBS enthusiast Class and the GBS sceptic Class, the attribute with the highest influence is different. For the GBS enthusiast Class, the attribute of most influence is the maintenance attribute, for the GBS sceptic Class, the temperature reduction is most influential. Noticeably, the maintenance attribute that is most influential for the GBS enthusiast Class, is least influential for the GBS sceptic Class.

Attribute	β_{xi} Class 1		Attribute	β_{xi} Class 2
Maintenance	1.161		Temperature reduction	1.126
Responsibility	1.160		Implementation cost	0.965
Shaded area	1.134		Lost private space	0.956
Temperature reduction	1.073		Shaded area	0.656
Implementation cost	0.858		Responsibility	0.545
Lost private space	0.697		Wind amount	0.457
Location	0.553		Location	0.138
Wind amount	0.532		Maintenance	0.120

Table 5.6: List of utility ranges for Classes 1 and 2, ordered by influence

Latent Class 1 (the GBS enthusiast Class)
The first attribute for the GBS enthusiast Class is the responsibility, where both the first and the second coefficients show a significance level of 9%. The first coefficient shows a positive value of 0.737, which corresponds to the attribute level municipality. The second coefficient shows a negative coefficient of 0.617 and corresponds to the attribute level resident. The third coefficient is the reference level which shows a positive value of 0.074 and corresponds to the attribute level neighbourhood. The results of this attribute are also similar to the results of the MNL model. The respondents in the GBS enthusiast Class favour the responsibility to be with the municipality. The next attribute is the temperature reduction. The first and second coefficients are both significant at the 99% level. The first coefficient shows a negative value of 1.073 and corresponds to the attribute level of low cooling. The second coefficient shows a positive value of 0.451 and corresponds to the attribute level of medium cooling. The third coefficient is the reference level and shows a positive value of 0.622 and corresponds to the attribute level high cooling. This result is similar to the result of the MNL model, where the respondents also preferred GBS with high cooling properties. The next attribute is the implementation cost. The first coefficient is not significant and shows a positive value of 0.106. This coefficient corresponds to the attribute level €0, -. The second coefficient is significant to the 99% level and shows a positive value of 0.376, corresponding to the attribute level €80, -. The third coefficient is the reference level and shows a negative value of 0.482, corresponding to the attribute level €250, -. These results are similar to the results of the MNL model, which also showed a preference for €80, - implementation cost for the GBS. The second attribute is the maintenance. Both the first and the second coefficient are significant to the 99%. The first coefficient shows a positive value of 0.737 and corresponds to the attribute level €0, - per month. The second coefficient shows a negative value of 0.313 and corresponds to the attribute level €10, - per month. The third coefficient shows a negative value of 0.424, which corresponds to the attribute level of 10 hours per month. These results are also similar to the results of the MNL model, which also showed a preference for the first attribute level. However, in the GBS enthusiast Class, the least favourable attribute level is 10 hours per month. In the MNL model, the least favourable attribute level was €10, - per month.

For the attribute, wind amount is the first coefficient significant to the 90% level, and the second coefficient to the 95% level. The first coefficient shows a negative value of 0.190 and corresponds to the attribute level of low wind. The second coefficient shows a positive value of 0.342 and corresponds to medium wind. The third coefficient corresponds to the attribute level high wind and is determined at a negative value of 0.152. The results show respondents prefer a GBS which lets a medium amount of wind through, which is similar to the results of the MNL model. The attribute shaded area shows the first coefficient to be significant to the 99% level with a negative value of 0.627. This coefficient corresponds to the attribute level little canopy. The second coefficient is not significant but shows a positive value of 0.120 and corresponds to the attribute level medium canopy. The third coefficient is the reference coefficient and shows a positive value of 0.507 and corresponds to the attribute level high canopy. This result shows that respondents favour a GBS with a large shaded area, which was also the result of the MNL model. The next attribute is the lost private space which only shows a significant second coefficient within the 90% level. The first coefficient shows a positive value of 0.153 and corresponds to the attribute level 0 meter. The second coefficient shows a positive value of 0.272 and corresponds to the attribute level 1.5 meter. The third coefficient is determined at a negative value of 0.425 and corresponds with the attribute level of 2.5 meters. This result is different than the result of the MNL model. The respondents of the GBS enthusiast Class show a preference to lose 1.5 meters of private space, whereas, in the MNL model, the preference was to lose 0 meters of private space. For the attribute location, none of the coefficients shows to be significant. The respondents seem to not have a preference for the placement of the GBS, this is similar to the result of the MNL model.

Latent Class 2 (the GBS sceptic Class)
For the attribute implementation cost in the GBS, sceptic Class is the first coefficient significant to the 95% level and shows a positive value of 0.355. This coefficient corresponds to the attribute level €0,-. The second coefficient is significant to the 90% level and shows a positive value of 0.276, corresponding to the attribute level €80, -. The third coefficient is the reference level and shows a negative value of 0.610, corresponding to the attribute level €250, -. These results are different than the GBS enthusiast Class and the MNL model. The respondents of the GBS sceptic Class show a strong preference to not have any implementation cost for the GBS. For the maintenance attribute, neither coefficients are significant. This means that the respondents of the GBS sceptic Class do not have a preference concerning maintenance for the GBS. The next attribute is the responsibility, only the first coefficient is significant to the 90% level and shows a positive value of 0.368, which corresponds to the attribute level municipality. The second coefficient shows a negative coefficient of 0.177 and corresponds to the attribute level resident. The third coefficient is the reference level which shows a negative value of 0.191 and corresponds to the attribute level neighbourhood. The results of this attribute are similar to the results of the GBS enthusiast Class and the MNL model. The respondents in the GBS enthusiast Class favour the responsibility of the GBS to be with the municipality.

The next attribute is the temperature reduction. The first coefficients are significant at the 99% level. The first coefficient shows a negative value of 0.653 and corresponds to the attribute level of low cooling. The second coefficient shows a positive value of 0.180 and corresponds to the attribute level of medium cooling. The third coefficient is the reference level and shows a positive value of 0.473 and corresponds to the attribute level high cooling. This result is similar to the result of the GBS enthusiast Class and the MNL model, where the respondents also preferred GBS with high cooling properties. For the attribute, wind amount is only the first coefficient significant to the 90% level. This coefficient shows a negative value of 0.291 and corresponds to the attribute level of low wind. The second coefficient shows a positive value of 0.125 and corresponds to medium wind. The third coefficient corresponds to the attribute level high wind and is determined at a positive value of 0.166. The results show respondents prefer a GBS which lets the maximum amount of wind through, which is a different result than the GBS enthusiast Class and the MNL model. For the attributes shaded area and location, none of the coefficients shows to be significant. For both those attributes, the respondents of the GBS sceptic Class do not have a significant preference. The last attribute is the lost private space which shows the first and second as significant coefficients within the 99% and 90% level respectively. The first coefficient shows a positive value of 0.548 and corresponds to the attribute level 0 meter. The second coefficient shows a negative value of 0.408 and corresponds to the attribute level 1.5 meter. The third coefficient is determined at a negative value of 0.140 and corresponds with the attribute level of 2.5 meters. The respondents of the GBS sceptic Class show a strong preference to lose no space for the implementation of GBS. This result is different than the result from the GBS enthusiast Class, where the respondents preferred to lose 1.5 meters to GBS.

Figure 5.8 below illustrates the part-worth utilities for Latent Class 1 (the GBS enthusiast Class) and Latent Class 2 (the GBS sceptic Class) once more.

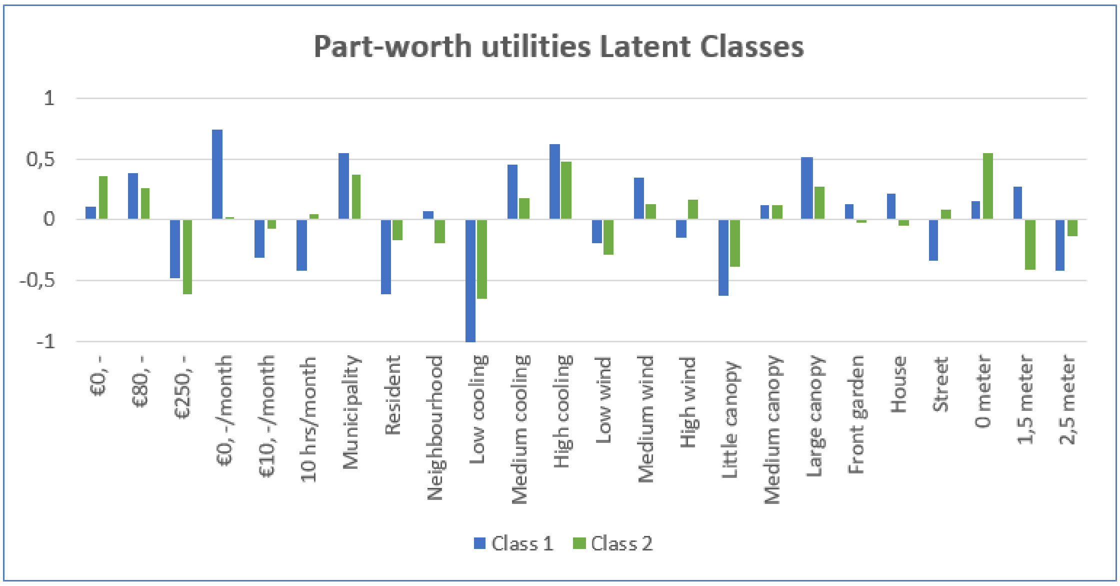


Figure 5.8: Illustration of the Latent Class model analysis results

Class description

The Latent Class model analysis identified two classes of respondents showing per class similar choice behaviour. For each respondent, the model determines the probability that the respondent belongs to each class. Each respondent is assigned to the class with the highest probability. Subsequently, 96 respondents are assigned to the GBS enthusiast Class, and 52 respondents are assigned to the GBS sceptic Class. More information can be gained about the two classes by combining the class information with the socio-demographic and environmental results. The objective is to determine if there is a relation between the choice behaviour of the class and the characteristics of the respondents within the class. To find these relations, crosstabs are created in Excel. Table 5.7 and 5.8 present the results of the crosstabs. The crosstab output of the socio-demographic characteristics of each class is shown in table 5.7. Table 5.8 shows the crosstab output of the environmental questions of each class. The next two paragraphs will describe the differences in characteristics between the two classes. The chi-square is determined to examine if the differences are significant. The differences are significant for the subjects age, income, health, and garden.

In table 5.7, the results for each group concerning the socio-demographics can be seen. For the subject 'age', a significant difference can be seen between the GBS enthusiast Class and the GBS sceptic Class. the GBS enthusiast Class consists of significantly more young respondents, whereas class 2 has a relatively high number of respondents within the age of 36 to 45 years. For the subject 'income', the respondents in the GBS enthusiast Class have a significantly lower income than the respondents in the GBS sceptic Class. The GBS sceptic Class holds approximately 10% more respondents in the income categories of €2.500, - to €5.000, -, and €5.000, - or more. the GBS enthusiast Class holds approximately 14% more respondents in the income category less than €1.000, -. Lastly, the socio-demographics show a significant difference between the two classes in the subject 'health'. the GBS enthusiast Class holds significantly more respondents of the attribute level generally healthy. The group of respondents in the GBS sceptic Class show to have weaker health than those in the GBS enthusiast Class.

Subject	Level	Frequency sample	% sample	Frequency enthusiasts	% enthusiasts	Frequency sceptics	% sceptics	Chi-square
Gender	Male	87	58.8%	57	58.8%	30	58.8%	0.244
	Female	58	39.2%	39	40.2%	19	37.3%	
	Other	1	0.7%	0	0.0%	1	2.0%	
	Rather not say	2	1.4%	1	1.0%	1	2.0%	
Age	15-25	26	17.6%	23	23.7%	3	5.9%	0.003
	26-35	47	31.8%	30	30.9%	17	33.3%	
	36-45	30	20.3%	16	16.5%	14	27.5%	
	46-55	21	14.2%	13	13.4%	8	15.7%	
	56-66	19	12.8%	13	13.4%	6	11.8%	
	66+	4	2.7%	2	2.1%	2	3.9%	
	Rather not say	1	0.7%	0	0.0%	1	2.0%	
Residence	Terraced house	28	18.9%	16	16.5%	12	23.5%	0.312
	Semi-detached house	41	27.7%	28	28.9%	13	25.5%	
	Detached house	28	18.9%	17	17.5%	11	21.6%	
	Apartment/studio/flat	51	34.5%	36	37.1%	15	29.4%	
Income	Less than €1.000, -	28	18.9%	23	23.7%	5	9.8%	0.000
	€1.000, - to €2.500, -	53	35.8%	37	38.1%	16	31.4%	
	€2.500, - to €5.000, -	60	40.5%	36	37.1%	24	47.1%	
	€5.000, - or more	7	4.7%	1	1.0%	6	11.8%	
Health	Chronic health problems	5	3.4%	1	1.0%	4	7.8%	0.007
	Occasional physical/psychological complaints	23	15.5%	14	14.4%	9	17.6%	
	Generally healthy	120	81.1%	82	84.5%	38	74.5%	

Table 5.7: Socio-demographic characteristics of LCM classes

In table 5.8, the results for each group concerning the environmental questions are presented. The chi-square values show that only for the attribute ‘garden’, there is a significant difference between the two classes. For the other attributes, heat, climate, future, and vegetation, the distribution of the respondents is, therefore, similar for both groups. Emphasizing on the attribute ‘garden’ the results show a significantly higher number of residents who have a front and back garden in the GBS sceptic Class. The difference between the GBS enthusiast Class and 2 is more than 15%. the GBS enthusiast Class holds more respondents that have a home without a garden, or only have a back garden. The percentage of respondents that do not have a garden at all, is approximately 8% higher for the GBS enthusiast Class. Note, the chi-square test value for the subject ‘residence’ does not show a significant difference between the two classes. So, whereas having a garden makes a difference in preferences, living in a certain type of residence does not.

Subject	Level	Frequency sample	% sample	Frequency enthusiasts	% enthusiasts	Frequency sceptics	% enthusiasts	Chi-square
Heat	No complaints	8	5.4%	7	7.2%	1	2.0%	0.22
	Slight irritation	53	35.8%	36	37.1%	17	33.3%	
	Slight physical complaints	68	45.9%	42	43.3%	26	51.0%	
	Physical complaints	19	12.8%	12	12.4%	7	13.7%	
Climate	Yes, frequently	46	31.1%	31	32.0%	15	29.4%	0.207
	Yes, sometimes	88	59.5%	59	60.8%	29	56.9%	
	No, not really	14	9.5%	7	7.2%	7	13.7%	
Future	Yes	134	90.5%	91	93.8%	43	84.3%	0.215
	No	14	9.5%	5	5.2%	4	7.8%	
Garden	Yes, both	79	53.4%	46	47.4%	33	64.7%	0.018
	Yes, front garden	2	1.4%	1	1.0%	1	2.0%	
	Yes, back garden	22	14.9%	18	18.6%	4	7.8%	
	No	45	30.4%	32	33.0%	13	25.5%	
Vegetation	Yes	141	95.3%	92	94.8%	49	96.1%	0.898
	No	7	4.7%	5	5.2%	2	3.9%	

Table 5.8: Characteristics of LCM classes

5.5.2 Willingness to Pay (WTP)

Similar to the MNL model, the willingness to pay (WTP) can be determined for each of the latent classes. Alternatively, the results of the WTP will be specific for each of the classes. Whereas the results of the WTP for the MNL model was an average for the total group of respondents. The

WTP of each Class is determined in reference to the utility of the implementation cost for that Class. For the GBS enthusiastic Class, the cost-utility is 0.858. For the GBS sceptic Class, the cost-utility is 0.965.

Table 5.9 below shows the results of the WTP per GBS attribute for both Classes. There are some noticeable differences to point out between the two Class results. For starters, the respondents of the GBS enthusiastic Class have shown to be willing to pay approximately €215, - extra to have no monthly contribution to the GBS. In comparison, the GBS sceptic Class shows very little difference in WTP for the maintenance attribute. For the responsibility, both Classes are willing to pay extra for a GBS if the municipality is responsible. However, the GBS enthusiastic Class is also willing to pay approximately €20, - extra if the neighbourhood is responsible for the GBS, whereas the GBS sceptic Class shows a WTP of approximately -€55, -. This means that for the attribute responsibility to not influence the choice behaviour of the GBS sceptic Class, the cost for the GBS needs to be reduced by €55, -. Both Classes show a high WTP for a GBS with high-temperature reduction characteristics. Though the GBS enthusiastic Class values the medium temperature reduction more than the GBS sceptic Class. For the attribute wind amount, the GBS enthusiastic Class shows a negative WTP for high wind amount, whereas the GBS sceptic Class shows a positive WTP for that characteristic. Which means the GBS enthusiastic Class needs the cost for a GBS with a high wind amount to be reduced in order for the choice behaviour to not be influenced, and the GBS sceptic Class would be willing to pay extra for the same GBS. For the attribute location, the WTP for the GBS enthusiastic Class shows the positive value for both house and garden and a negative WTP for the street. Alternatively, the GBS sceptic Class shows a negative WTP for both house and garden and a positive WTP for the street. What this means is that whereas respondents in the GBS enthusiastic Class is willing to pay extra for GBS that are located at the house and garden, respondents in the GBS sceptic Class are willing to pay extra for GBS that are located at the street. Finally, the attribute lost private space shows both Classes are willing to pay extra for GBS with 0 lost private space. However, for the GBS enthusiastic Class, the characteristic 1.5 meters lost private space holds an even higher WTP value than 0 meters. For the GBS sceptic Class, the 1.5 meters lost private space holds the largest negative value, as the WTP for 2.5 meters lost private space only has a WTP of approximately -€40, -. Though the preference for losing 2.5 meters over 1.5 meters by the GBS sceptic Class is remarkable, a possible reason is that respondents expect to gain additional benefits by losing 2.5 meters compared to 1.5 meters.

Attribute	Attribute level	β Enthusiasts	WTP	β Sceptics	WTP
Implementation cost		0.858		0.965	
	€0, -	0.106		0.355	
	€80, -	0.376		0.255	
	€250, -	-0.482		-0.61	
Maintenance		1.161	€338,29	0.12	€34,97
	€0, -/month	0.737	€214,74	0.026	€7,58
	€10, -/month	-0.313	€-91,20	-0.073	€-21,27
	10 hrs/month	-0.424	€-123,54	0.047	€13,69
Responsibility		1.16	€338,00	0.545	€158,80
	Municipality	0.543	€158,22	0.368	€107,23
	Resident	-0.617	€-179,78	-0.177	€-51,57
	Neighbourhood	0.074	€21,56	-0.191	€-55,65
Temperature reduction		1.695	€493,88	1.126	€328,09
	Low cooling	-1.073	€-312,65	-0.653	€-190,27
	Medium cooling	0.451	€131,41	0.18	€52,45
	High cooling	0.622	€181,24	0.473	€137,82
Wind amount		0.532	€155,01	0.457	€133,16
	Low wind	-0.19	€-55,36	-0.291	€-84,79
	Medium wind	0.342	€99,65	0.125	€36,42
	High wind	-0.152	€-44,29	0.166	€48,37
Shaded area		1.134	€330,42	0.656	€191,14
	Little canopy	-0.627	€-182,69	-0.389	€-113,34
	Medium canopy	0.12	€34,97	0.122	€35,55
	Large canopy	0.507	€147,73	0.267	€77,80
Location		0.553	€161,13	0.138	€40,21
	Front garden	0.133	€38,75	-0.026	€-7,58
	House	0.21	€61,19	-0.056	€-16,32
	Street	-0.343	€-99,94	0.082	€23,89
Lost private space		0.697	€203,09	0.956	€278,55
	0 meter	0.153	€44,58	0.548	€159,67
	1,5 meters	0.272	€79,25	-0.408	€-118,88
	2,5 meters	-0.425	€-123,83	-0.14	€-40,79

Table 5.9: Willingness to pay per GBS attribute for Class 1 and Class 2

5.6 Conclusions

This chapter presented the output obtained by the survey and the Stated Choice experiment. These results included the choice behaviour of respondents and the distribution of the sample. The objective was to determine which attributes of Green-Based Solutions (GBS) are decisive in the respondent's decision to be supportive of the implementation. The data collection was done through an online survey, which took place for two weeks in December 2020. The data shows 148 respondents finished the survey in its entirety. This chapter discusses the results of the survey and the results from two statistical model analyses. The next chapter will discuss the consequences of the findings.

The chapter starts by presenting the distribution of socio-demographic characteristics of the obtained sample, which are later compared to the distribution of the Dutch population. The comparison shows that the obtained sample is not representative of the Dutch population. The obtained sample holds relatively more people within the ages of 25 to 45 than the Dutch distribution and much fewer people with older age. However, the information that is gained by this research will be most relevant for generations that are likely to move to a different house in the future. It is, therefore, more relevant to emphasise on the preferences of younger residents, and not a problem that the sample is not representative of the Dutch population. The chapter then moves on to analysing the results of the environmental questions, compared to the socio-demographic characteristics of the respondents. It can be concluded that almost all respondents were aware of the heat advantages of vegetation, though very little respondents have ever been encouraged by a third party to implement more vegetation around their home. The results also show that the younger the group of respondents is, the more per cent of the group is concerned with climate change.

The third part of the chapter elaborates on the results of the Stated Choice experiment. These results provide information concerning the choice behaviour of the respondents. First, the Multinomial Logit model analysis is performed on the full sample. The results of the MNL model can be seen as the average response of the respondents. From the MNL model, it can be concluded that the most influential variable is the temperature reduction property of GBS. The second most influential variable was the implementation cost. The respondents have also shown to favour medium wind reduction and a large canopy. Furthermore, the results show that there is no preference regarding the location of the Green-Based Solution. The overall preference is to not lose any private space to the Green-Based Solution, although losing 1.5 meters received a neutral reaction. The results of the Willingness to Pay (WTP) analysis show that the respondents are willing to pay approximately €160, - euros extra for GBS with high-temperature reduction properties, and €95, - for medium temperature reduction. Similarly, the results show a WTP of €122, - for GBS if the municipality is responsible. What these results show is that if the cost of the GBS is higher than these numbers, the choice behaviour will be influenced by the cost attribute.

Lastly, the Latent Class Model analysis is performed on the sample. This analysis discovers clusters of respondents who share similar choice behaviour. According to the analysis, two classes can be found in this experiment. Class 1 and Class 2 hold 96 and 52 respondents, respectively. Based on the responses, Class 1 can be seen as the GBS enthusiasts, Class 2 can be seen as the GBS sceptics. For the respondents in the GBS enthusiastic Class, the attribute maintenance is the most influential, closely followed by responsibility and shaded area. For the GBS sceptics Class, the most influential attribute is the temperature reduction, followed by the cost and lost private space. The Willingness to Pay (WTP) analysis shows more differences between the two Classes. Where the GBS enthusiasts are willing to pay €215, - extra for a GBS if the responsibility lies with the municipality, the GBS sceptics are only willing to pay €7, - extra in that situation. For the attribute lost private space, the GBS enthusiasts are willing to pay an additional €80, - if only 1.5 meters of private space is lost. Whereas the GBS sceptics require a reduction of €118, - for the cost not to be influential in the choice behaviour. Besides these differences, both Classes are willing to pay more than €130, - extra for GBS with high-temperature reduction properties.

Furthermore, to gain additional insight into the two Classes, the socio-demographic and environmental characteristics of the respondents are added to the Classes. The chi-square test is determined to show which differences are significant. As a result, the socio-demographic characteristics age, income and health show a significant difference between the two Classes. According to the results, the GBS enthusiastic Class consists of significantly more young respondents compared to the GBS sceptics Class. The respondents in the GBS enthusiastic class have a significantly lower income than the respondents in the GBS sceptics Class. The GBS enthusiastic Class holds approximately 14% more respondents in the income category less than €1.000, -. Furthermore, the group of respondents in the GBS enthusiastic Class show to be of better health than those in the GBS sceptics Class. As for the environmental answers, only the subject 'garden' showed a significant chi-square value. The results show a significantly higher number of residents who have a front and back garden in the GBS sceptics Class. The difference between the two Classes is more than 15%. The percentage of respondents that do not have a garden at all, is approximately 8% higher for the GBS enthusiastic Class.

6 Conclusion

Citizens of urban areas in the Netherlands are expected to experience increasing temperatures in the future. Increased temperatures lead to higher numbers of illnesses and deaths during the summer, especially among residents with weaker health. In urban areas, higher temperatures are registered than in non-urban areas, which is referred to as the Urban Heat Island (UHI) effect. The UHI effect has caused the European Union and the Dutch government to encourage the use of Green-Based Solutions (GBS) against heat. GBS can be defined as the use of natural and semi-natural green spaces to solve climate and environmental objectives.

This study provided insight into the preferences and Willingness to Pay (WTP) of urban residents in the Netherlands regarding Green-Based Solutions (GBS). The research focussed on the currently available GBS and the motivations of individuals with given socio-demographic characteristics to implement more GBS in urban areas. On that basis, scientific conclusions can be drawn. First, the two sub-questions are answered, followed by the main research question. Furthermore, recommendations will be made for stakeholders and future research. Finally, the recommendations are discussed based on the limitations of this study.

6.1 Sub-Questions

In order to answer the main research question, the two sub-questions need to be answered first. The first sub-question involves understanding what types and characteristics of GBS are currently available to be implemented in urban neighbourhoods for heat adaptation. These GBS types include grass, trees, bushes, green roofs, and green walls. Each of these types of GBS have different characteristics. Grass and bushes are inexpensive but also have little cooling capacity. Whereas trees have a high cooling capacity and a large shading area if the tree type has a large canopy. Although, the large canopy of trees can also constrict the airflow in urban areas, which is a disadvantage during hot days. The placement of grass, bushes and trees require available space in urban areas. The placement of a tree in an urban street requires the available space between houses to become 1.5 to 2.5 meters wider. The greatest advantage of green roofs and green walls is that they both require very little additional space for the implementation, as they are constructed on available roof and wall spaces. As with trees, different types of green roofs and walls exist. The plant species, concentration and construction method influence the cooling capacity of these GBS. It can be concluded that trees are the best GBS type for heat adaptation. However, increasing the total amount of vegetation cover in urban areas reduces the Urban Heat Island effect, and the placement of green roofs and green walls are best suitable for increasing the amount of vegetative cover in urban areas due to the small footprint. So even though the individual cooling effect of a green roof or wall is lower than that of a tree, the placement of green roofs and walls as GBS in urban areas is important to reduce the overall temperature.

The second sub-question refers to the results of the actual Stated Choice (SC) experiment. By means of the SC experiment, it could be determined whether the preferences and Willingness to Pay (WTP) of urban residents for GBS are influenced by the characteristics of the person or type of house. By executing a Latent Class model analysis, two Classes are found with respondents of similar choice behaviour. The GBS enthusiastic Class and the GBS sceptic Class. Comparing these results to the socio-demographic characteristics shows that the following characteristics influence people's preferences regarding GBS: age, income, health and the presence of a garden. The GBS enthusiastic Class holds significantly more younger people (age 35 and below), people with a lower income and good health. The results for the presence of a garden show people are more interested in GBS if they do not have a garden. The WTP shows that the GBS enthusiastic Class is more willing to pay extra for GBS with high heat adaptation characteristics than the GBS sceptics Class. Even though the GBS enthusiastic Class holds significantly more people with a lower income. Younger people also responded to be more concerned about climate change than older people. Therefore, it can be concluded that the younger generation (age 35 and below) is more interested in GBS for heat adaptation than older generations. Additionally, the younger generation is willing to pay significantly more money on GBS relative to their income.

6.2 Main Research Question

The objective of this study was to gain insight into the preferences of urban residents in the Netherlands regarding GBS by finding an answer to the research question:

What Green-Based Solutions attributes are preferred by urban residents in the Netherlands for heat adaptation, and how much are urban residents willing to pay?

The results of the Stated Choice experiment show that the urban residents in the Netherlands prefer GBS that have a high cooling attribute and a large shaded area. The results of the Latent Class model analysis show that both Classes prefer these GBS attributes. Additionally, both Classes prefer the municipality to be responsible for the GBS. The Willingness to Pay (WTP) shows that both Classes are willing to pay more than €130, - extra for GBS with a high cooling attribute. Both Classes are also willing to pay extra for GBS with a medium cooling attribute, though the GBS enthusiasts significantly more. Similarly, the WTP for a large shaded area is positive for both Classes but significantly higher for the GBS enthusiasts. Differences between the two classes can be pointed out as well. The GBS enthusiasts prefer the GBS to be located at the house, whereas the sceptics prefer the GBS to be located at the street. Additionally, the GBS enthusiasts prefer GBS with a medium amount of wind, whereas the GBS sceptics almost equally prefer a medium or high amount of wind. Considering the WTP, the GBS enthusiasts are willing to pay up to €80, - extra for GBS that require 1.5 meters of private space to be lost. In comparison, the GBS sceptics require the GBS cost to be reduced by at least €120,- to consider losing 1.5 meters of private space.

6.3 Discussion

This study contributes to the available knowledge about GBS, and the decisive motivations of urban residents regarding the implementation of GBS. The existing literature was reviewed to gain a collective overview of the available GBS and different characteristics. The GBS covered in this study focus specifically on urban residential homes, and streets, as opposed to neighbourhoods. Additionally, the available literature regarding community, municipal, and organisational views is studied to gain information about the decisive motivations for the implementation of GBS. The information gained by performing the Stated Choice Experiment adds valuable insight to the existing knowledge regarding urban residential preferences for GBS.

One of the assumptions made for this study based on the literature was that very little people are aware of the advantages of GBS. The results gained by this study is that almost all the respondents were aware of the cooling effects of GBS. This could be the effect of the increasing awareness over time, or it means that people are more aware of the cooling properties of GBS than the water drainage properties. Either way, the conclusion can be made that people are aware of the advantages of GBS for heat. Another assumption made for this study was that urban residents are unwilling to lose private space for the placement of GBS around their home. The results of this study show that people are still hesitant to give up their private space for the GBS, though people are willing to give up private space if the cost of the GBS will be lowered. The assumption by organisations such as Arcadis is that urban residents are unwilling to pay for GBS. From this study, it can be concluded that urban residents are willing to pay for GBS if they have specific attributes. For instance, GBS with a high cooling attribute, residents have shown to be willing to pay up to €160, - extra. For GBS with a large shaded area, residents are willing to pay up to €90, - extra. What these results show is that residents are willing to pay extra money for GBS, but the amount is dependent on the characteristics of the GBS.

6.3.1 Limitations of the Study

Some limitations of this study need to be formulated.

Attributes and attribute levels
For this study, only a limited number of attributes and attribute levels could be included. This leads to the conclusion that some other attributes may have been excluded that do influence the choice behaviour of urban residents. For instance, the layout of the street, or the proximity from the house to green space, or personal characteristics such as having children. Similarly, attribute levels needed to be chosen to present logical options to respondents, these levels may have excluded important distinctions.

Sample
The survey was completed by 148 respondents. The spatial-distribution of the respondents was highly clustered in the province of Noord-Brabant. Though the assumption is made that the results provide a good indication of the preferences of urban residents in the Netherlands, it would provide more accurate results to have better spatial distribution across the country. Additionally, the distribution of socio-demographic characteristics of the respondents was not in accordance with the distribution of the Dutch population. The results of this study are based on relatively younger urban residents than should have been according to the distribution of the Dutch population. Therefore, recommended is to involve a larger and more representative sample in the experiment.

Covid-19
Some limitations can also be mentioned that have been due to the presence of the Covid-19 decease in the entire duration of this study. Fortunately, the subject and method of the study combined well with reduced social contact. However, the close working relationship that would otherwise have been present between the student and the first supervisor, and the team working at Arcadis, was forced to the background. Virtual meetings replaced face-to-face discussions and brainstorms. Though questions can be answered through virtual meetings, working closely together would possibly have resulted in additional insight from the Arcadis team members.

Despite these limitations, the results of this study provide new insight into the preferences of urban residents of the Netherlands regarding GBS. The study builds onto the available knowledge of residential preferences for GBS and may be an influencing factor in the higher implementation rate of GBS in the future.

6.3.2 Recommendations

This section provides recommendations to the organisations working on urban (re)development projects, such as Arcadis. Additionally, the section also provides recommendations for future scientific research.

Recommendations for organisations
The information provided by this study shows that urban residents are becoming more aware of the advantages of vegetation in urban areas. The awareness is important for the future implementation of more GBS. The results of this study show that the younger generation of ages below 35 years is more interested in GBS. They show to be more willing to pay for the implementation of GBS at their house. For organisations such as Arcadis, these results provide some opportunities. People of this age range are buying their first or second house in the near future and are more likely to be buying a house in urban areas than older generations. For new urban (re)development projects where the target audience is people around the age of 35 years, the assumption can be made that they are willing to pay €180, - extra for GBS with a high cooling attribute, and €140,- for GBS with a large canopy volume around their home. Besides, the results of this study show that the

younger generation prefers the placement of GBS at the house, therefore showing a preference for green roofs and green walls, with a willingness to pay up to €60, - extra. Based on the climate change concerns of the younger generation, it can also be assumed that the next generation will be just as willing, or even more willing to implement more GBS.

Based on the specific outcomes of the Stated Choice experiment, the characteristics of the GBS that people value the most are a high cooling effect, medium wind reduction and a large shaded area. The recommendation can be made based on these results, to include GBS with these attributes in new urban (re)development projects. In this recommendation, the residents that are considered are the ones that are going to buy a house in the future, excluding residents that could implement GBS at their current home. The recommendation is to mostly implement trees in urban neighbourhoods. Trees have a high cooling effect and provide a large shaded area. Based on this study, the assumption can be made that people are willing to invest up to €160, - for the GBS. The placement of a tree costs about €80, -. Therefore, fits perfectly into the budget of the residents. Additionally, the placement of a tree would require residents to give up some private space. The results of this study show that losing 1.5 meters of private space would be acceptable if the cost of the GBS would go down by €15,-. Considering the €160, - for a GBS with a high cooling attribute, the €15, - can be compensated.

Considering the placement of green roofs and green walls, some recommendations can be made as well. Based on the results of the Classes, the residents of the younger generation (age 35 years or below) prefer GBS that are located at the house level. What this means is that these residents prefer the placement of a green roof or wall on their home over a tree at the street side. Considering the willingness to pay, the younger generation would be willing to pay €60, - extra for the placement of a green roof or wall. Although the placement of such a GBS is more expensive than €60, - the interest in investing in the green roofs and walls will reduce the costs that would otherwise have to be covered in its totality by an organisation. Additionally, the research study provided information on subsidies for green roofs and green walls by municipalities. In combination with the €60, - that residents are willing to pay, the costs can be carried by all three stakeholders in the future. Based on the preference of GBS with a large shaded area, installing a pergola in gardens may also provide a good solution. Pergolas are generally perceived as a great addition to a home, but homeowners often find it too much work to create one themselves. The results of this study also show that almost all the residents prefer the municipality to be responsible for the GBS. Based on this result, the recommendation is to have the municipality to carry the responsibility for the GBS and the maintenance or have the municipality assign a third party. Considering the maintenance, based on the results of this study, residents are unwilling to pay a monthly fee for maintenance to the GBS. A final recommendation is to inform the future residents of new and redeveloped houses of the advantages of the installed GBS. The awareness of the advantages helps in the appreciation of the GBS. If more people are aware of the advantages, more people appreciate the implemented GBS.

Recommendations for further research

Future studies could include urban situations such as a street layout illustrating the limited space to the respondents. By illustrating the urban situations, the study can provide an even more realistic result taking more urban elements into account. Another direction would be to increase the area of interest from urban streets to a complete neighbourhood. Doing this will provide the possibility to include neighbourhood parks. Additionally, by increasing the area of interest, it would also be possible to include water elements into the research. The results of this study provide a concise basis for future expansion of the research subject. Another element that would be interesting to include in future research is the spatial distribution of the respondents. In this study, the partial postal codes are only used to get an indication of the spatial distribution. If the preferences and WTP of residents could be specified by area of residence, more relationships could be formed between area specifics and preferences. These results would provide a specific answer that could be used to create an even more preference-based urban plan.

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Appendix I: Survey

One of the nine versions of the survey

Load unfinished survey Language: English

Test for urban preferences in vegetation options

To start, I'd like to **thank you** for your participation in this research.

My name is Renée, this experiment is part of my masters graduation programme at the TU Eindhoven. The subject of my research is **green solutions for heat** within urban areas. In this context, green solutions represent the placement of trees, bushes, grass etc. The goal of this experiment is to get insight into the **preferences and attitudes of urban residents** towards the implementation of green solutions for heat, in order to use this information in future (re)development projects.

The experiment consists of a quick introduction of the subject and the choice alternatives, followed by a couple of **choice questions**. Here, you need to give your preference between **2 alternative options**. The experiment will take **10 minutes** of your time. Your answers will be saved **anonymously**, and the information will not be publicly shared.

Once again thank you for participating in the research, and feel free to **share** the link with other people!

Sincerely,
Renée

Next

Consent to save answers

I declare that I am participating voluntarily in this study and that I am aware that at any point in time I have the right to quit the survey or withdraw my data without the need of any motivation. The purpose and aim of the study is made clear to me. My retrieved data will be aggregated to group level, evaluated and published for scientific purposes, such as research papers and a PhD dissertation. When the research process is completed my individual records will be deleted by the research team. All data on group level will be kept on secure and encrypted university storage. No third party will have access to my data and only the principal researcher and his team have the right to look into the data. If the data will be made public in any way, all personal information will be completely anonymized.

*I agree to these conditions to participate in the study.

Yes No

Previous Next

Part 1 of 5: Introduction of the subject

This section will shortly introduce the subject of heat in urban areas and explain why it is important to conduct this research. The four questions at the bottom are meant to make you start to think about your current knowledge and awareness of the subject.

Last year, the Dutch National heat record was broken when the temperature rose above 40 degrees celsius in the Netherlands. Previous studies have shown the temperatures in urban areas have been rising significantly compared to non-urban areas. One of the reasons for the increase in heat is the reduced amount of vegetation in urban areas. Vegetation has the ability to absorb the heat, and therefore cool down the direct area surrounding the vegetation.

*The placement of trees and other vegetation types ensures lower surface temperatures in the surrounding area. Are you aware of these advantages of vegetation?

Yes No

*What advantages of greenery do you value the most?

Check all that apply
Please select at most 3 answers

- Better air quality
- Noise reduction
- Water drainage
- Increased neighborhood value
- Cooling
- Aesthetics

*Have you ever been encouraged to increase the amount of vegetation in your garden/house by a third party?

Choose one of the following answers

- No
- Yes (please leave the method in the comment section)

Please enter your comment here:

*Imagine a situation where your home / room / living space has a temperature of 25 degrees Celsius for a longer period of time. In this space you have to work, sleep and / or relax. What best describes your reaction in this situation?

Choose one of the following answers

- Physical complaints (exhaustion and fainting, loss of concentration, insomnia, severe headache)
- Slight physical complaints (fatigue, headache, concentration problems, sleeping problems)
- Slight irritation from the temperature, difficulty falling asleep
- No problems with the temperature

*Do you worry about the effects of climate change?

Choose one of the following answers

- Yes, frequently
- Yes, sometimes
- No, not really

Part 2 of 5: Introduction of the attributes

Before we start with the choice questions, this section will explain each of the 8 attributes that will be used in the choice questions. **NOTE! Please take the two minutes to read this through, as it is neccessary to understand the questions in the next section.**

1. Temperature reduction

The thermometers below show the three levels of temperature reduction in the experiment. For instance, the high temperature in the left thermometer shows there is little temperature reduction by the green solution.

Little change in heat | Medium heat reduction | Maximum heat reduction

2. Amount of let-through wind

The windflags below represent the amount of wind allowed through the green solution in the experiment. You may recognize the positive effect of a cooling breeze during the summer.

Little wind coming through | Moderate wind coming through | Maximum wind coming through

3. Shaded area

Shade provides a significant reduction in surface temperatures during the summer, additionally, the perceived temperature lowers significantly due to shade. As a reference, imagine the difference between the shaded area of a large tree and a small tree, and now compare that to the shaded area of low vegetation types like bushes.

Tree, small | Tree, large | Low vegetation

4. Location

Three location types are used in the experiment. This location is where the green solution will be placed. The options in this experiment are: Connected to the house (for instance: green roof or wall), on streetside (Trees, bushes etc) or in the front garden (small tree, green wall etc).

In the front garden | Connected to the house | On streetside

Did you know: A green roof or green wall can reduce the indoor temperature in your house by 3 degrees Celsius during the summer!

Part 3 of 5: Introduction of the attributes

5. Implementation cost

This is a one time payment by the resident for the implementation of the green solution.

6. Maintenance

Maintenance can be explained in two ways, either by payment or effort by the resident. The payment or effort is a monthly value.

7. Lost private space

The lost private space presents a trade off. More private space leaves less space for green borders, trees or other vegetation in public space. The private space can be seen as space in the front garden, or if there is no front garden, space that would otherwise have been part of the house. You might be able to imagine that the placement of trees takes away more private space than the placement of a green wall or roof on the house.

8. Responsibility

This attribute describes who is responsible for the green solution. Three options are presented; The resident, the municipality or the neighborhood. By responsibility is meant which group needs to take care of the green solution. As an example: Imagine a regular street with streetside trees, where the municipality is responsible for cutting overhanging branches.

May you have doubts about the attributes during the questionnaire, you can always take a step back and your answers will be saved.

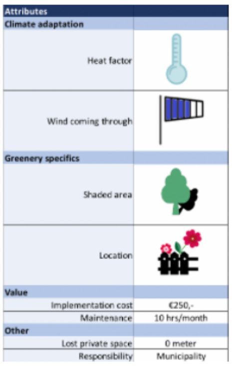
Part 4 of 5: Choice questions

This section shows you 6 choice options, you can choose between 2 situations in each choice option.The situations will be described using several attributes, based on these attributes you can select which of the two situations you prefer, or select neither.

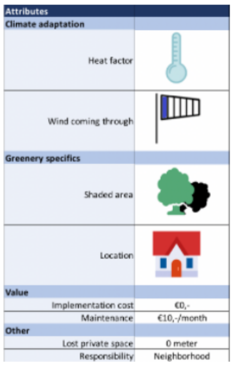
Don't forget, you can always go back to the previous sections if you've forgotten what the illustrations represent!

Good luck!

*



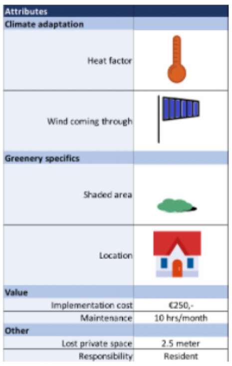
Attributes	
Climate adaptation	
Heat factor	
Wind coming through	
Greenery specifics	
Shaded area	
Location	
Value	
Implementation cost	€250,-
Maintenance	10 hrs/month
Other	
Lost private space	0 meter
Responsibility	Municipality



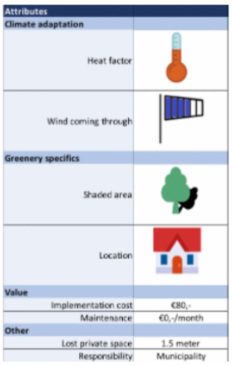
Attributes	
Climate adaptation	
Heat factor	
Wind coming through	
Greenery specifics	
Shaded area	
Location	
Value	
Implementation cost	€0,-
Maintenance	€10,-/month
Other	
Lost private space	0 meter
Responsibility	Neighborhood

	A	B	Neither
Which alternative has your preference?	○	○	○

*

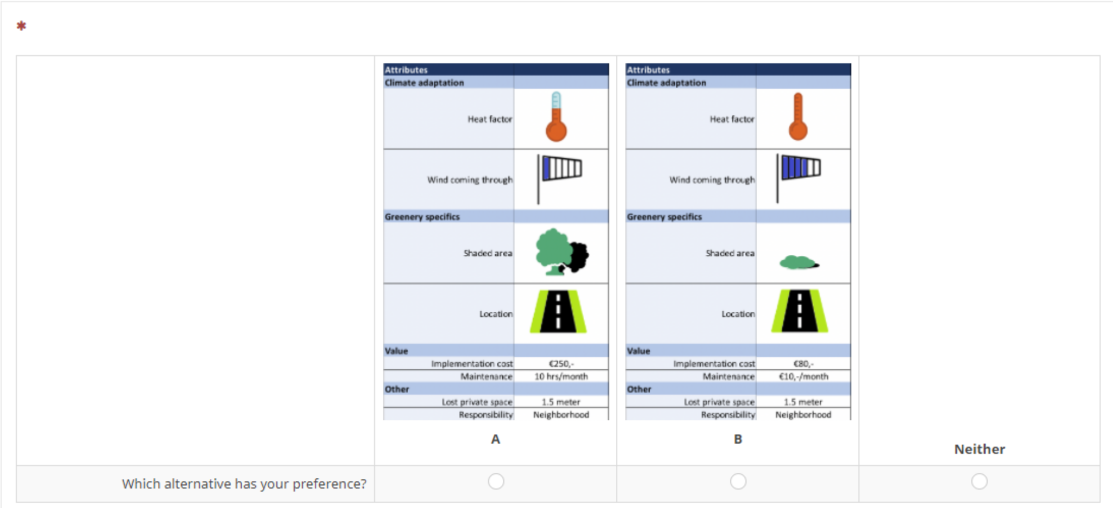


Attributes	
Climate adaptation	
Heat factor	
Wind coming through	
Greenery specifics	
Shaded area	
Location	
Value	
Implementation cost	€250,-
Maintenance	10 hrs/month
Other	
Lost private space	2.5 meter
Responsibility	Resident



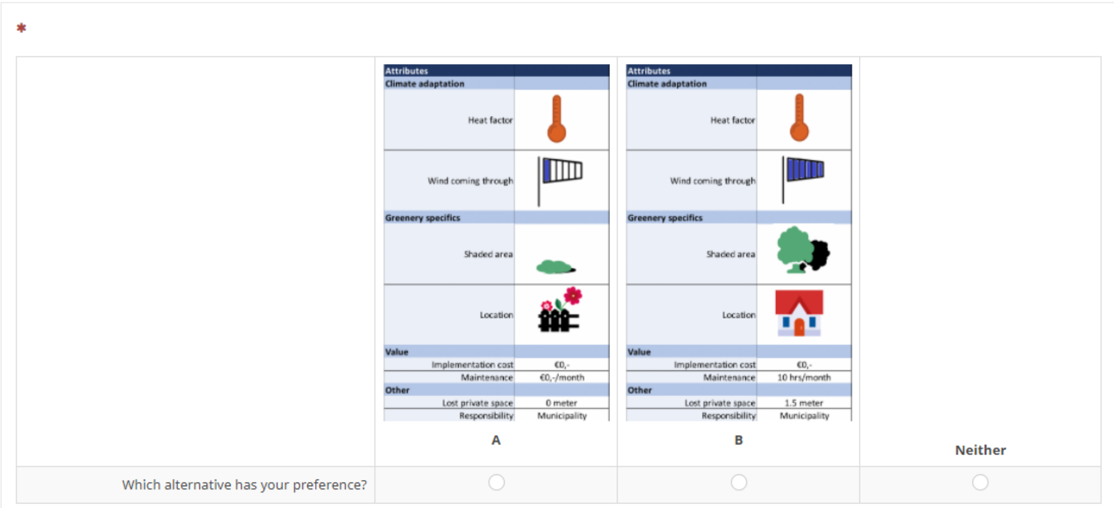
Attributes	
Climate adaptation	
Heat factor	
Wind coming through	
Greenery specifics	
Shaded area	
Location	
Value	
Implementation cost	€80,-
Maintenance	€0,-/month
Other	
Lost private space	1.5 meter
Responsibility	Municipality

	A	B	Neither
Which alternative has your preference?	○	○	○



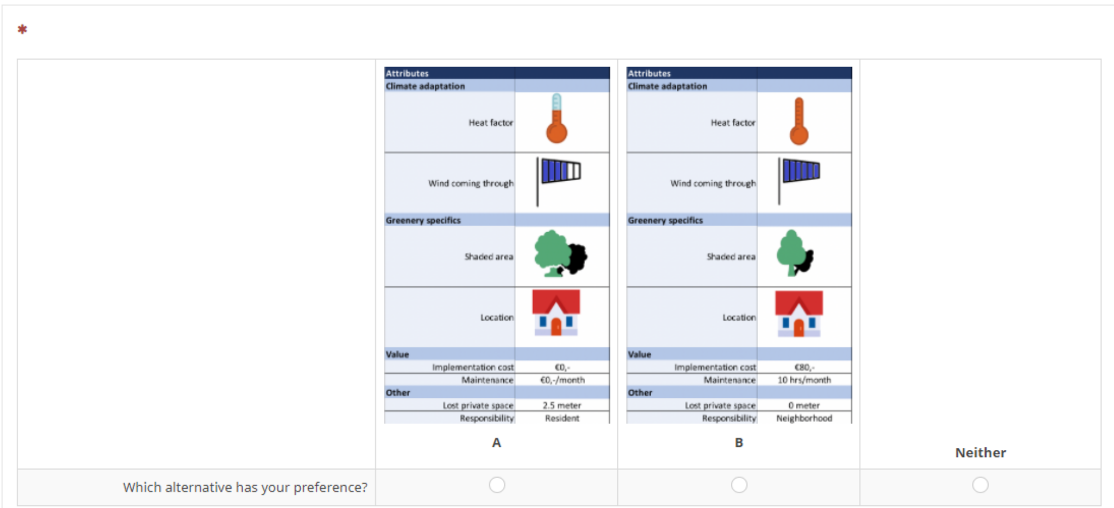
Attributes	A	B
Climate adaptation		
Heat factor		
Wind coming through		
Greenery specifics		
Shaded area		
Location		
Value		
Implementation cost	€250,-	€80,-
Maintenance	10 hrs/month	€10,-/month
Other		
Lost private space	1.5 meter	1.5 meter
Responsibility	Neighborhood	Neighborhood

	A	B	Neither
Which alternative has your preference?	○	○	○



Attributes	A	B
Climate adaptation		
Heat factor		
Wind coming through		
Greenery specifics		
Shaded area		
Location		
Value		
Implementation cost	€0,-	€0,-
Maintenance	€0,-/month	10 hrs/month
Other		
Lost private space	0 meter	1.5 meter
Responsibility	Municipality	Municipality

	A	B	Neither
Which alternative has your preference?	○	○	○



Attributes	A	B
Climate adaptation		
Heat factor		
Wind coming through		
Greenery specifics		
Shaded area		
Location		
Value		
Implementation cost	€0,-	€80,-
Maintenance	€0,-/month	10 hrs/month
Other		
Lost private space	2.5 meter	0 meter
Responsibility	Resident	Neighborhood

	A	B	Neither
Which alternative has your preference?	○	○	○

*

Attributes	A	B
Climate adaptation		
Heat factor		
Wind coming through		
Greenery specifics		
Shaded area		
Location		
Value		
Implementation cost	€0,-	€250,-
Maintenance	€0,-/month	€0,-/month
Other		
Lost private space	1.5 meter	1.5 meter
Responsibility	Neighborhood	Resident

	A	B	Neither
Which alternative has your preference?	○	○	○

Part 5 of 5: Demographic questions

Lastly, this section contains a couple of demographic questions. This information will show if there are relationships between choices and demographics for this subject. Your choices and therefore preferences may be based on your lifestyle, age, or income.

These outcomes can help improve future urban (re)development designs!

*What is your gender?

Check all that apply

Male | Female | Other | I'd rather not say

*What age group are you in?

Choose one of the following answers

- ○ Younger than 25
- ○ 25 - 35
- ○ 36 - 45
- ○ 46 - 55
- ○ 56 - 65
- ○ 66 +
- ○ I'd rather not say

*Please select the health status that is most applicable to you.

- ◯ Chronic health problems (heart and vascular disease, diabetes etc)
- ◯ Regular physical/psychological complaints (low energy, high stress levels, low vitality, recurring body aches)
- ◯ Occasional physical/psychological complaints (low energy, high stress levels, low vitality, recurring body aches)
- ◯ Generally healthy (feeling fit, healthy eating/movement patterns, good mental health)

*What kind of residence do you currently live in?

Choose one of the following answers

◯ Terraced house (row house)	◯ Semi-detached house (houses separated by garage)	◯ Detached house	◯ Apartment/studio/flat

*Does your home have a front and/or back garden?

Choose one of the following answers

- ◯ Yes, both
- ◯ Yes, front garden
- ◯ Yes, back garden
- ◯ No

*What are the first 4 numbers of your postal code?
(If you'd rather not say, please type 0000)

Only numbers may be entered in this field.

*What is your net monthly income?

Choose one of the following answers

- ◯ Less than €1.000,-
- ◯ €1.000,- to €2.500,-
- ◯ €2.500,- to €5.000,-
- ◯ €5.000,- or more

Once again, **thank you** for your participation! Hopefully the images helped visualize the options and made it a bit more fun!

The outcome of this research will be used in future (re)development projects, but don't forget you can implement green solutions in your homes **yourself**! Most dutch municipalities provide **subsidies** for the replacement of tiles by grass, placement of green roofs etc. Curious?

Check https://hetgroeneloket.nl/subsidies/ and https://groenesubsidiewijzer.verbeterjehuis.nl/groenesubsidiewijzer/ to see what subsidies your municipality provide for adding greenery to **your current home**.

Appendix II: Flyer

Appendix III: Stated Choice Analysis

NLogit results Multinomial Logit analysis

```
|-> RESET
|-> read ; Nobs    = 2664
    ; Nvar    = 23
    ; Names   = Id,Set,Alt,Num,Task,Choice,Const,Cost1,Cost2,Main1,Main2,
    Resp1,Resp2,Cool1,Cool2,Wind1,Wind2,Cano1,Cano2,Loc1,Loc2,Space1,Space2
    ; File    = ResultsNW.csv$
|-> DISCRETECHOICE;Lhs = Choice
    ;Choices = 1,2,3
    ;Rhs     = Const,Cost1,Cost2,Main1,Main2,
    Resp1,Resp2,Cool1,Cool2,Wind1,Wind2,
    Cano1,Cano2,Loc1,Loc2,Space1,Space2$
Iterative procedure has converged
Normal exit:   6 iterations. Status=0, F=    .7314078D+03
```

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function      -731.40783
Estimation based on N =    888, K =  17
Inf.Cr.AIC  =   1496.8 AIC/N =    1.686
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only   -851.5443  .1411 .1328
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=    888, skipped    0 obs
--------+--------------------------------------------------------------------
        |                Standard            Prob.      95% Confidence
  CHOICE|  Coefficient     Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
   CONST|   1.34910***     .11123   12.13  .0000     1.13109    1.56711
   COST1|    .24137***     .07395    3.26  .0011      .09643     .38631
   COST2|    .26684***     .07452    3.58  .0003      .12079     .41289
   MAIN1|    .37273***     .07836    4.76  .0000      .21915     .52630
   MAIN2|   -.21664***     .08052   -2.69  .0071     -.37446    -.05882
   RESP1|    .37980***     .07914    4.80  .0000      .22468     .53492
   RESP2|   -.35383***     .08450   -4.19  .0000     -.51944    -.18822
   COOL1|   -.79476***     .08103   -9.81  .0000     -.95358    -.63595
   COOL2|    .29420***     .08170    3.60  .0003      .13408     .45432
   WIND1|   -.14251**      .06940   -2.05  .0400     -.27853    -.00649
   WIND2|    .17908**      .07280    2.46  .0139      .03640     .32176
   CANO1|   -.32751***     .08156   -4.02  .0001     -.48737    -.16765
   CANO2|    .04296        .09073     .47  .6359     -.13487     .22079
    LOC1|    .07631        .08442     .90  .3661     -.08916     .24177
    LOC2|   -.01958        .08643    -.23  .8208     -.18898     .14982
  SPACE1|    .28081***     .08072    3.48  .0005      .12261     .43902
  SPACE2|   -.04822        .08013    -.60  .5473     -.20527     .10883
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jan 02, 2021 at 11:51:39 AM
-----------------------------------------------------------------------------
```

NLogit results Latent Class model

```
|-> CREATE ; p1 = 0 ; p2 = 0 $
|-> NAMELIST ; cp = p1,p2$
|-> DISCRETECHOICE;Lhs = Choice
    ;Choices = 1,2,3
    ;Rhs     = Const,Cost1,Cost2,Main1,Main2,
    Resp1,Resp2,Cool1,Cool2,Wind1,Wind2,
    Cano1,Cano2,Loc1,Loc2,Space1,Space2
    ;lcm
    ;classp=cp
    ;pds=6
    ;pts=2
    ;Maxit=250$
Iterative procedure has converged
Normal exit:   6 iterations. Status=0, F=    .7314078D+03
```

```
-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function      -731.40783
Estimation based on N =    888, K =  17
Inf.Cr.AIC  =   1496.8 AIC/N =    1.686
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only    -851.5443  .1411 .1238
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of obs.=   888, skipped    0 obs
--------+--------------------------------------------------------------------
        |                Standard            Prob.       95% Confidence
  CHOICE|  Coefficient     Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
 CONST|1|    1.34910***    .11123    12.13  .0000     1.13109    1.56711
 COST1|1|     .24137***    .07395     3.26  .0011      .09643     .38631
 COST2|1|     .26684***    .07452     3.58  .0003      .12079     .41289
 MAIN1|1|     .37273***    .07836     4.76  .0000      .21915     .52630
 MAIN2|1|    -.21664***    .08052    -2.69  .0071     -.37446    -.05882
 RESP1|1|     .37980***    .07914     4.80  .0000      .22468     .53492
 RESP2|1|    -.35383***    .08450    -4.19  .0000     -.51944    -.18822
 COOL1|1|    -.79476***    .08103    -9.81  .0000     -.95358    -.63595
 COOL2|1|     .29420***    .08170     3.60  .0003      .13408     .45432
 WIND1|1|    -.14251**     .06940    -2.05  .0400     -.27853    -.00649
 WIND2|1|     .17908**     .07280     2.46  .0139      .03640     .32176
 CANO1|1|    -.32751***    .08156    -4.02  .0001     -.48737    -.16765
 CANO2|1|     .04296       .09073      .47  .6359     -.13487     .22079
  LOC1|1|     .07631       .08442      .90  .3661     -.08916     .24177
  LOC2|1|    -.01958       .08643     -.23  .8208     -.18898     .14982
SPACE1|1|     .28081***    .08072     3.48  .0005      .12261     .43902
SPACE2|1|    -.04822       .08013     -.60  .5473     -.20527     .10883
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jan 02, 2021 at 11:52:01 AM
-----------------------------------------------------------------------------
```

```
Iterative procedure has converged
Normal exit:  48 iterations. Status=0, F=    .6849872D+03

-----------------------------------------------------------------------------
Latent Class Logit Model
Dependent variable                CHOICE
Log likelihood function      -684.98721
Restricted log likelihood    -975.56771
Chi squared [ 35](P= .000)    581.16100
Significance level              .00000
McFadden Pseudo R-squared      .2978578
Estimation based on N =    888, K =  35
Inf.Cr.AIC  =   1440.0 AIC/N =    1.622
---------------------------------------
            Log likelihood R-sqrd R2Adj
No coefficients  -975.5677  .2979  .2837
Constants only   -851.5443  .1956  .1794
At start values  -731.4078  .0635  .0446
Note: R-sqrd = 1 - logL/Logl(constants)
Warning:  Model does not contain a full
set of ASCs. R-sqrd is problematic. Use
model setup with ;RHS=one to get LogL0.
---------------------------------------
Response data are given as ind. choices
Number of latent classes =             2
Average Class Probabilities
     .647  .353
LCM model with panel has     148 groups
Fixed number of obsrvs./group=         6
Number of obs.=   888, skipped    0 obs

--------+--------------------------------------------------------------------
        |                Standard            Prob.       95% Confidence
  CHOICE|  Coefficient     Error       z    |z|>Z*          Interval
--------+--------------------------------------------------------------------
        |Random utility parameters in latent class -->> 1....................
 CONST|1|     3.89724***      .87052     4.48  .0000     2.19105   5.60342
 COST1|1|      .10629         .12365      .86  .3900     -.13606    .34863
 COST2|1|      .37570***      .13407     2.80  .0051      .11293    .63847
 MAIN1|1|      .73710***      .16376     4.50  .0000      .41614   1.05805
 MAIN2|1|     -.31251**       .14369    -2.17  .0296     -.59413   -.03089
 RESP1|1|      .54254***      .14315     3.79  .0002      .26198    .82311
 RESP2|1|     -.61706***      .16711    -3.69  .0002     -.94459   -.28954
 COOL1|1|    -1.07246***      .16062    -6.68  .0000    -1.38727   -.75765
 COOL2|1|      .45106***      .13970     3.23  .0012      .17726    .72487
 WIND1|1|     -.19009*        .10966    -1.73  .0830     -.40501    .02483
 WIND2|1|      .34187**       .13801     2.48  .0132      .07138    .61236
 CANO1|1|     -.62735***      .16005    -3.92  .0001     -.94105   -.31365
 CANO2|1|      .12044         .15244      .79  .4295     -.17834    .41922
  LOC1|1|      .13320         .13890      .96  .3376     -.13905    .40544
  LOC2|1|      .21018         .17169     1.22  .2209     -.12632    .54668
SPACE1|1|      .15251         .12526     1.22  .2234     -.09299    .39800
SPACE2|1|      .27180*        .16260     1.67  .0946     -.04689    .59049
        |Random utility parameters in latent class -->> 2....................
 CONST|2|      .10587         .21861      .48  .6282     -.32260    .53433
 COST1|2|      .35530**       .15481     2.30  .0217      .05188    .65872
 COST2|2|      .25514*        .14273     1.79  .0738     -.02460    .53488
 MAIN1|2|      .02647         .15127      .17  .8611     -.27002    .32295
 MAIN2|2|     -.07342         .17190     -.43  .6693     -.41034    .26349
 RESP1|2|      .36805**       .15189     2.42  .0154      .07035    .66576
 RESP2|2|     -.17742         .15174    -1.17  .2423     -.47481    .11998
 COOL1|2|     -.65290***      .18031    -3.62  .0003    -1.00631   -.29949
 COOL2|2|      .18031         .15695     1.15  .2506     -.12731    .48792
 WIND1|2|     -.29117*        .15058    -1.93  .0532     -.58630    .00396
 WIND2|2|      .12485         .13845      .90  .3672     -.14650    .39620
 CANO1|2|     -.03892         .15744     -.25  .8047     -.34750    .26965
 CANO2|2|      .12183         .14776      .82  .4096     -.16778    .41144
  LOC1|2|     -.02655         .15965     -.17  .8679     -.33946    .28636
  LOC2|2|     -.05620         .15510     -.36  .7171     -.36019    .24779
SPACE1|2|      .54814***      .15037     3.65  .0003      .25342    .84287
SPACE2|2|     -.40775**       .16134    -2.53  .0115     -.72396   -.09153
        |Estimated latent class probabilities................................
 PrbCls1|      .64686***      .06959     9.29  .0000      .51046    .78327
 PrbCls2|      .35314***      .06959     5.07  .0000      .21673    .48954
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jan 02, 2021 at 11:52:02 AM
```