MASTER

Tenant valuation of green roofs

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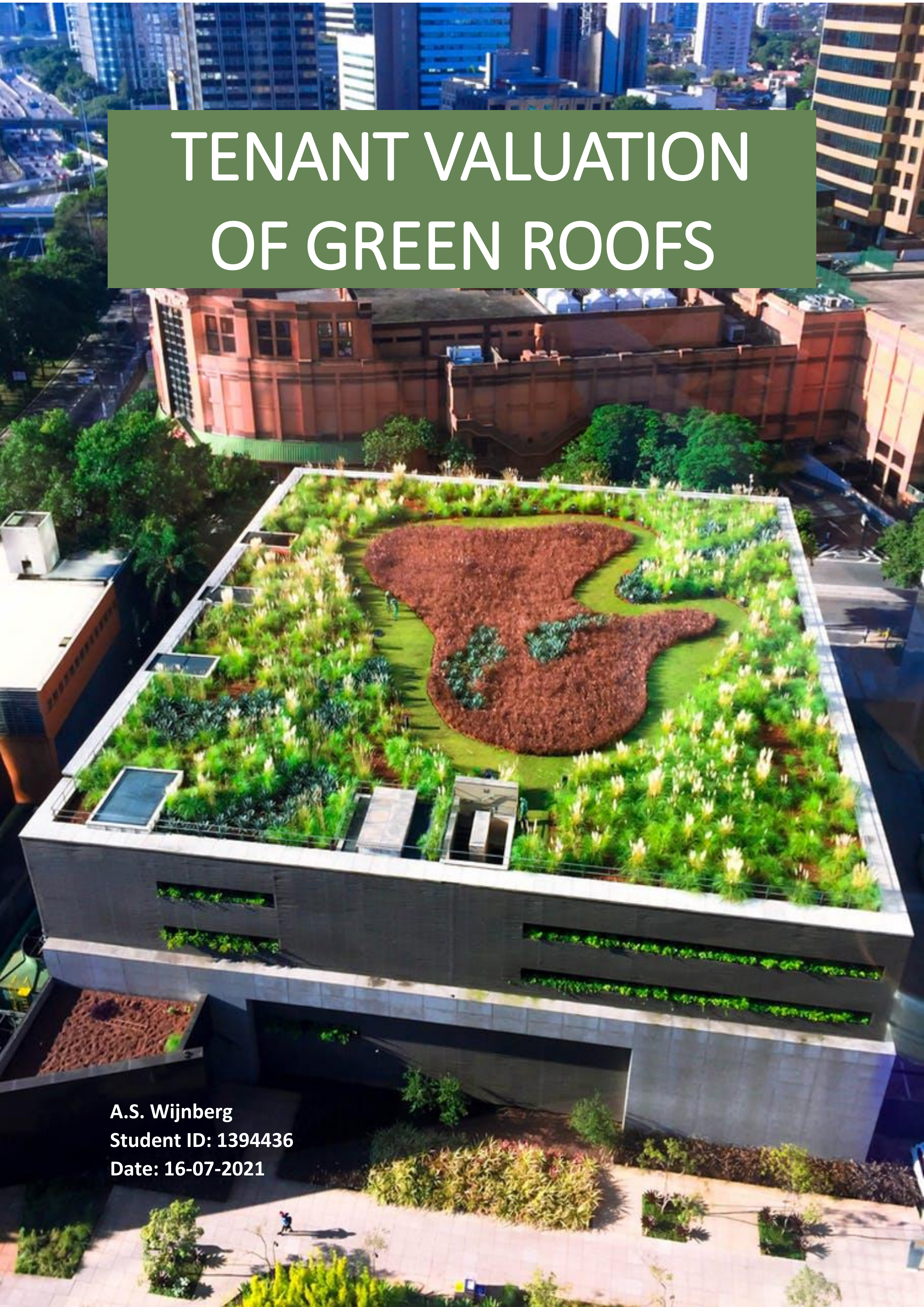
TENANT VALUATION OF GREEN ROOFS



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Preface

This report is written as the final report for my master Urban Systems and Real Estate (USRE) at the Eindhoven University of Technology (TU/e). The research will discuss the valuation of green roofs by tenants.

This subject is a combination of two interests that I have. Since my bachelor the passion for redevelopment has emerged. Creating a more pleasant place in spaces that are either not used or have lost their function is what I like doing most. I interpret the construction of a green roof on an existing roof as a small redevelopment. In addition, I am concerned about the consequences of climate change for the quality of life in cities. I am convinced that green roofs can offer a solution for this and that they also have an aesthetic added value. Therefore, I wanted to contribute to the knowledge about green roofs so it will be easier to implement them in the future.

I would like to thank my supervisors, Theo Arentze, Pauline van den Berg and Astrid Kemperman. All three of them gave me great guidance and helped me when I needed it. I would also like to thank Jan Alers from Volkshuisvesting Arnhem and Eva Bienias from Heimsteden for distributing my survey, without them I would not have been able to reach a large sample. I would also like to thank Linda Groenen of Atriensis for sharing the 'Duurzaamheidskaart' and giving me the opportunity to speak at their seminar. Jan Henk Tigelaar and Friso Klapwijk from Nationaal DakenPlan helped me in the initial process of understanding the knowledge gap of green roofs. I would also like to thank all the other green roof professionals I spoke to for their time and input. Finally, I would like to thank my family and friends for their support during the writing of this thesis and the past study period. I also got a lot of energy from my fellow students with whom I could brainstorm.

As a collaborator, I found it a challenge to work on my thesis alone during COVID-19. Fortunately, I started to enjoy it and my subject was clearly defined. As a practical student with an HBO background, I learned a lot of new academic skills during my master's and especially while writing my thesis. Now, I am ready to put my skills into practice both in the Netherlands and abroad.

All that remains is that I hope you enjoy reading this thesis.

Sophie Wijnberg

Eindhoven, July 2021

Summary

Green roofs can be a part of the solution to the problems created by climate change and the increasing density of cities. They reduce the risk of flooding, stimulate biodiversity, reduce the urban heat island effect, air pollution and environmental noise. In addition, they offer personal benefits, including reduction of interior noise, increased longevity, thermal insulation and aesthetic appreciation. The size of the effect of the benefits depends on the type of green roof. The effect is generally larger with intensive green roofs (roof with larger plants such as shrubs), than extensive green roofs (roof with smaller vegetation such as grasses and moss).

More knowledge is needed to convince people to install green roofs. For large organizations, the decision to install green roofs often depends on the costs and revenues. For housing associations and commercial landlords it is not clear how their tenants value green roofs. This makes it difficult for them to draw up a strategy for the implementation of green roofs. Only a small part of the existing literature on green roofs addresses the valuation of green roofs. Furthermore, hardly any literature discusses the rental sector. The aim of this study is to provide insights into the valuation of green roofs for Dutch tenants of housing associations and commercial landlords. The valuation will be quantified by the willingness to pay. Reference dependent choice behaviour is taken into account. The reference dependent theory holds that people evaluate outcomes and express preferences relative to an existing reference point, or status quo. The research question is formulated as follows:

How do green roof characteristics and personal characteristics influence the willingness to pay for a green roof? What are the motivations for the willingness to pay?

A literature study was set up to collect information on green roofs and personal characteristics that can influence the willingness to pay for a green roof. It emerged that if there is a view of a green roof, the type of vegetation is important. In addition, it matters whether a green roof can be accessed or not. Finally, the type of green on the dwelling makes a difference, as an intensive green roof has a larger impact than an extensive green roof. For the personal characteristics, recent literature indicates that knowledge about green roofs, environmental attitude, the presence of greenery, socio-demographic characteristics and dwelling characteristics can influence the willingness to pay.

To determine the willingness to pay, a stated choice experiment was set up. With this approach, respondents are asked by means of a survey to choose between two or more hypothetical alternatives in a choice set, which is repeated for a number of choice sets. The hypothetical alternatives are created based on an experimental design. The stated choice Experiment contains 4 attributes with multiple levels. The first attribute is the type of roof with the levels bitumen, extensive green roof and intensive green roof. The levels of the attribute accessibility vary from a roof that is not accessible to a roof that is accessible. The next attribute is the view, in which the levels are subdivided into views of a bitumen, extensive or intensive roof. The price is the last attribute to be included. The price is expressed as a percentage rent increase varying from 0%, 2.5%, 5% and 10%. Specifically, a factorial design was used to create 16 alternatives. These alternatives are random divided over 8 choice sets with a choice between one of the two alternatives or none of them. A survey with the stated choice experiment and questions on personal characteristics was distributed among tenants.

The data of 378 respondents were included in this study. The descriptive statistics show that the sample is higher educated than the Dutch average. Results from a Chi^2 test indicate that knowledge about green roofs has a significant relationship with age, education level and gender. ANOVA analysis shows that the attitude towards the environment is related to age and gender. Respondents find reducing air pollution together with reducing urban heat in summer the most important environmental

benefits of choosing a green roof. As personal benefits, improving the indoor climate and decreasing energy consumption are the most important features.

In this study a multinomial logit model is stimulated. The results of this model show that the utility for the attribute price is the highest. People have a strong preference for a low rent. Next, the attribute own roof type is important followed by the type of view. The results show that the attribute accessibility has the lowest utility. With the coefficients of the attributes, the willingness to pay can be determined. On average, tenants are willing to pay 9.1% more rent for an intensive green roof on their dwelling compared to a bitumen roof. For an extensive green roof this is 7.9%. Respondents are willing to pay an increase in rent of 8.3% and 6.2% for a view of an intensive and extensive green roof compared to a bitumen roof, respectively. The willingness to pay for an accessible roof compared to one that cannot be accessed is 2.8%.

Interaction variables were added to the multinomial logit model to determine the influence of reference-dependent choice behaviour and personal characteristics. A limited reference dependent effect can be seen in this study. Tenants with a garden are more likely to choose neither alternative, this can be explained by the fact that they are more satisfied with their current situation. In addition, there is significant evidence that people who are more satisfied with the greenery in their neighbourhood are more likely to choose a roof alternative. People who have above-average satisfaction with the insulating effect of their home are willing to pay more rent for an intensive roof on their dwelling. The personal characteristics were added one by one to the multinomial logic model. Knowledge of green roofs and housing position were shown to have no significant influence on willingness to pay. Tenants with a positive attitude towards the environment, a lower rent than €750, living non-urban and tenants in a terraced house have a higher willingness to pay for a green roof compared to a bitumen roof. A mixed logit model was run to detect variation in the preferences variation. The results show that there is considerable variation in preference among the attributes. The willingness to pay for the attributes is consistent with previous research. The influence of personal characteristics occasionally deviates from existing literature.

It can be concluded from this study that tenants are willing to pay for a green roof over a bitumen roof. The preference for an intensive green roof is slightly higher than an extensive green roof. Having access to a roof is the lowest priority among tenants. Policy makers can use this knowledge for the implementation of green roofs. Besides, policy makers can select target groups where the willingness to pay is highest, such as tenants of terraced houses. This research provides more specific knowledge on the appreciation of green roofs by tenants, which makes it an addition to the existing literature.

The study has some limitations that gives recommendations for further research. First of all, the sample could be biased because the group that is more interested in green roofs would be more likely to fill out the survey. It would also be better to test the sample on Dutch tenants rather than the total Dutch population. Limitations of the stated choice experiment is that it presents hypothetical scenarios to the respondents that could lead to different results than in a real situation. A revealed approach like a hedonic price model could tackle this. Besides, there could be missing attributes like vegetation type these should be added in additional research. Overall, this study provides comprehensive results that offer insight for policy makers and form a solid basis for future research.

Samenvatting

Groene daken kunnen een oplossing bieden voor de problemen die ontstaan door de klimaatverandering en de dichter bebouwde steden. Ze reduceren het risico op overstromingen, hitte-eiland effect, luchtvervuiling omgevingsgeluid en stimuleren biodiversiteit. Daarnaast biedt een groen dak persoonlijke voordelen zoals reductie van het binnen geluid, langere levensduur, thermisch isolerend effect en is er esthetische waardering. Het effect is over het algemeen groter bij intensieve groene daken (een dak met grotere planten zoals struiken), dan bij extensieve groene daken (een dak met en kleinere vegetatie zoals grassen en mos).

Om mensen te overtuigen om meer groene daken aan te leggen is er meer kennis nodig. De overweging om groene daken aan te brengen hangt voor grote partijen vaak samen met de kosten en opbrengsten. Voor woningbouw corporaties en commerciële verhuurders is het niet duidelijk hoe hun huurders groene daken waarderen. Dit maakt het lastig voor hen om een strategie op te stellen voor het implementeren van groene daken. Maar een klein deel van de bestaande literatuur over groene daken gaat in op de waardering hiervan. Daarnaast wordt er in de literatuur nauwelijks in gegaan op de huursector. Het doel van dit onderzoek is om inzichten te bieden in de waardering van groene daken voor Nederlandse huurders van woningbouwcorporaties en commerciële verhuurders. De waardering zal gekwantificeerd worden door middel van de betalingsbereidheid. Ook wordt er gekeken naar het referentieafhankelijk keuzegedrag. De referentieafhankelijke theorie noemt dat mensen uitkomsten evalueren en voorkeuren uiten ten opzichte van een bestaand referentiepunt, of status-quo. De onderzoeksvraag is als volgt geformuleerd:

Hoe beïnvloeden kenmerken van groene daken en persoonlijke kenmerken de betalingsbereidheid voor een groen dak? Wat zijn de beweegredenen voor de betalingsbereidheid?

Doormiddel van een literatuuronderzoek is er gekeken naar groene daken en persoonlijke kenmerken die invloed kunnen hebben op de betalingsbereidheid voor een groen dak. Er komt naar voren dat het type beplanting belangrijk is bij uitzicht op een groen dak. Daarnaast maakt het uit of een groen dak wel of niet te betreden is. Als laatste maakt het type groen op de eigen woning uit aangezien een intensief groen dak een grotere thermische voordelen heeft dan een extensief groen dak. Voor de persoonlijke kenmerken geeft de recente literatuur aan dat kennis over groene daken, houding ten opzichte van het milieu, aanwezigheid van groen, sociaal-demografische kenmerken en woningkenmerken invloed kunnen hebben op de betalingsbereidheid.

Om de betalingsbereidheid te bepalen is er een stated choice experiment opgesteld. Het stated choice experiment heeft 4 attributen met meerdere niveaus. Het eerste attribuut is het eigen dak type met de levels bitumen, extensief groen dak en intensief groen dak. Daarnaast komt het attribuut toegankelijkheid waarin de niveaus variëren van een dak wat niet toegankelijk is en een dak wat wel toegankelijk is. Vervolgens is het attribuut uitzicht waarin de niveaus bestaan uit uitzicht op een bitumen, extensief dak of intensief dak. De prijs is het laatste meegenomen attribuut. De prijs wordt uitgedrukt is een percentage huurstijging gevarieerd van 0%, 2,5%, 5% en 10%. Er is een factorial design gebruikt om 16 alternatieven te maken. Deze alternatieven zijn willekeurig over 8 keuzesets verdeeld waarbij er de keuze is tussen één van de twee alternatieven of geen van beide. Een enquête met de keuzesets en vragen over persoonlijke kenmerken is verspreid onder huurders.

De data van 378 respondenten zijn meegenomen in dit onderzoek. Uit de descriptieve statistieken komt naar voren dat de sample hoger opgeleid is dan het Nederlandse gemiddelde. Verder laat een Chi test zien dat de kennis over groene daken een significante relatie heeft met leeftijd, educatie niveau en geslacht. Met een ANOVA analyse is zichtbaar dat de houding ten opzichte van het milieu een relatie heeft met leeftijd en geslacht. Uit de resultaten komt naar voren dat respondenten het

reduceren van de lucht vervuiling samen met het reduceren van stedelijke hitte in de zomer de belangrijkste milieu gerelateerde motivatie is voor een groen dak. Als persoonlijke voordelen zijn het verbeteren van het binnenklimaat en lager energieverbruik als belangrijkste kenmerken.

In dit onderzoek wordt een multinomiale logit regressie gebruikt. De resultaten van dit model laten zien dat het nut voor het attribuut prijs het grootste is. Mensen hebben een sterke voorkeur voor een lage huurstijging. Hierna is het attribuut eigen daktype belangrijk gevolgd door het type uitzicht. De resultaten laten zien dat de toegankelijkheid van een dak het minst belangrijke attribuut is. Met de coëfficiënten van de attributen kan de betalingsbereidheid bepaald worden. Huurders willen gemiddeld 9,1% meer huur betalen voor een intensief groen dak op hun eigen woning ten opzichte van een bitumen. Voor een extensief groen dak is dit 7,9%. Respondenten willen een huurstijging van 8.3% en 6.2% betalen voor uitzicht op respectievelijk intensief en extensief groen dak ten opzichte van een bitumen dak. De betalingsbereidheid voor toegankelijk dak ten opzichte van een dat wat niet betreden kan worden is 2,8%.

Interactie variabelen zijn aan het multinomial logit model toegevoegd om de invloed van referentieafhankelijk keuzegedrag en persoonlijke kenmerken te bepalen. Een beperkt referentieafhankelijk effect is terug te zien in dit onderzoek. Huurders met een tuin kiezen vaker voor de geen van beide keuze, dit is te verklaren doordat ze meer tevreden over hun huidige situatie zijn. Daarnaast is er significant bewijs dat mensen die een grotere tevredenheid hebben over het groen in hun omgeving sneller voor een dak alternatief kiezen. Mensen die boven gemiddeld tevredenheid hebben over de isolerende presentatie van hun woning zijn bereid meer huur te betalen voor een intensief dak op hun eigen woning. De persoonlijke kenmerken zijn één voor één aan het multinomial logit model toegevoegd. Kennis van groene daken en de woning positie bleken geen invloed te hebben op de betalingsbereidheid. Huurders met een positieve houding ten opzichte van het milieu, een lagere huurprijs dan €750, die in buitenwijken wonen en huurders in een rijwoning hebben een hogere betalingsbereidheid voor een groen dak ten opzichte van een bitumen dak. Een mixed logit model is uitgevoegd om de voorkeursvariatie te ontdekken. De resultaten laten zien dat er een aanzienlijke variatie voorkeursvariatie in de attributen uitzicht en huurstijging zit. De betalingsbereidheid voor de attributen komen overeen met voorgaand onderzoek. De invloed van persoonlijke kenmerken wijken soms af met bestaande literatuur.

Uit dit onderzoek kan geconcludeerd worden dat huurders bereid zijn te betalen voor een groen dak over een bitumen dak. De voorkeur voor een intensief groen dak ligt net wat hoger dan een extensief groen dak. Heb hebben van toegang tot een dak heeft de laagste prioriteit bij huurders. Deze kennis kunnen beleidsmakers gebruiken voor het implementeren van groene daken. Beleidsmakers kunnen doelgroepen selecteren waar de betalingsbereidheid het grootste is zoals huurders van rijwoningen. Dit onderzoek geeft meer en specifiekere kennis over de waardering van groene daken door huurders waardoor het een aanvulling op de bestaande literatuur.

Het onderzoek heeft enkele beperkingen waardoor er aanbevelingen zijn voor vervolgonderzoek. Allereerst kan de steekproef selectief zijn doordat de groep die meer geïnteresseerd is in groene daken sneller de enquête zou vullen. Ook zou het beter zijn om de sample te testen aan Nederlandse huurders in plaatst van de totale Nederlandse populatie. Beperkingen van een stated choice experiment is dat het een hypothetisch scenario is. Een revealed-preferences methode zoals een hedonisch prijsmodel zou een goed ander alternatief zijn. Bovendien zouden er attributen kunnen ontbreken, zoals vegetatietype, die in aanvullend onderzoek zouden moeten worden toegevoegd. Over het algemeen kan geconcludeerd worden dat dit onderzoek uitgebreide resultaten geeft die inzicht bieden voor beleidsmakers en een degelijke basis vormen voor toekomstig onderzoek.

Abstract

Green roofs can be part of the solution to the problems created by climate change and the increasing density of cities. To implement green roofs, landlords need more knowledge about the valuation of green roofs. This study provides new information regarding tenants' willingness to pay (WTP) for green roofs in the Netherlands. A stated choice experiment is conducted to measure the preference en WTP of green roof characteristics taking into account personal characteristics. The results of the Multinomial Logit (MNL) model analysis of 378 responsdents show that tenants are willing to pay a rent increase of 7.9%-9.1% for a green roof on their dwelling. In addition, the results show that a view of a green roof is worth a rent increase of 6.2%-8.3%. An accessible roof is valued more than a non-accessible roof with a rent increase of 2.8%. Results of the interaction MNL model show reference dependent choice behaviour. Tenants with a positive attitude towards the environment, a lower rent than €750, living in non-urban areas and tenants in a terraced house have a higher willingness to pay for a green roof compared to a bitumen. The mixed logit model shows that there is considerable variation in preference among the attributes. Integrating the preferences and willingness to pay regarding green roof and personal characteristics can help policy makers of housing associations and commercials landlords to make a strategy for implementing green roofs.

Keywords

Green roofs, willingess to pay, valuation, stated choice experiment, reference dependent behavior

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1 Introduction

This chapter provides an introduction to green roof studies. First of all, background information about green roofs and their added value is given. Then the problem outline and statement are discussed, which is followed by the main and sub questions. Lastly, the relevance of the research is explained.

1.1 Background

As towns and cities become more densely populated, green spaces are declining in urban areas. Therefore, several environmental problems, such as the lack of biodiversity, flooding, air pollution and the urban heat effect, are increasing(McCarthy et al., 2010; Skougaard Kaspersen et al., 2017). Various studies have shown that the installation of green roofs counteracts these negative effects (Bass & Koukidis, 2012; Benvenuti, 2014; Oberndorfer et al., 2007; Paithankar & Taji, 2020; Yang et al., 2008).

A green roof is a roof covered with plants, herbs or grasses. Within green roofs, a distinction is made between extensive and intensive green roofs. Intensive green roofs are associated with roof gardens; they have larger and taller plants which require a reasonably thick substrate layer, which is related with more weight. These roofs require constant maintenance. Extensive green roofs have a thin substrate layer and a sedum vegetation, possibly supplemented with herbs and grasses. This makes these roofs weigh less and require less maintenance (Molineux et al., 2009).

The benefits of green roofs can be divided into environmental benefits and private benefits. The first environmental benefit is reducing the risk of flooding. The absorbent effect of green roofs means that more water is (temporarily) stored on the roof, which relieves sewer systems during storms (Paithankar & Taji, 2020; Talebi et al., 2019). In addition, green roofs stimulate biodiversity in cities (Benvenuti, 2014; Brenneisen, 2017; Kadas, 2006; Williams et al., 2014). Köhler & Ksiazek-Mikenas (2018) mention that green roofs can be used as green corridors to reduce fragmentation of some plants and animal species. Another benefit is that the environment heats up less with green roofs, because of evaporation, and because less heat is retained from the sun than with a black roof. If half of the roofs are green, the urban heat island effect is reduced by 2°C (Bass & Koukidis, 2012; Oberndorfer et al., 2007). Furthermore, a green roof can bind air pollutants such as CO_2, particulate matter, nitrogen oxides and other harmful substances (Damen & Brouwers, 2012; J. Yang et al., 2008). The final environmental benefit of green roofs is that they absorb noise such as traffic noise, thereby noise reduction in courtyards can be 3 dBA (Van Renterghem et al., 2013).

Besides environmental benefits, there are also private benefits for the user or owner of a building with a green roof. First of all, the lifespan of the roof layer is extended to approximately 50 years, which is almost double the current lifespan (Kantor, 2017; Porsche & Köhler, 2003). Green roofs have an extra insulating effect that keeps buildings cooler in summer and warmer in winter, which saves on energy and gas costs (Damen & Brouwers, 2012; Delemarre & Somers, 2012; Huang, 2013). The insulating effect of a green roof also dampens noise from the outside to the inside of a building and vice versa (Grant et al., 2003; Van Renterghem & Botteldooren, 2011). In addition, a view of a green roof offers several advantages. Various studies have shown that people appreciate the aesthetic qualities of green roofs (Fernandez-Cañero et al., 2013; Jungels et al., 2013; Loder, 2014; Mesimäki et al., 2019; White & Gatersleben, 2011). Looking out over green roofs results in better work performance (K. E. Lee et al., 2015) and a faster recovery from illnesses (Ulrich, 1984).

Attention for green roofs is growing: 10% more green roof surface has been installed compared to 3 years ago (READAR real estate radar, 2019). However, only 0.5% of Dutch roofs have a green roof, while there is an estimated 400 km^2 of potential roof area that can be made greener in the Netherlands

(Rooftop Revolution, 2020). In order to get more green roofs in cities, different types of roof owners will have to choose for green on their roofs.

It is important to bring the rental sector into the green roof transition because they own a large part of the housing market. Within the housing market, 42% of the dwellings are rental dwellings. Rental properties can be from housing associations or commercial landlords. The high share of rented houses makes them a large and important party among the various roof owners. Housing associations own 30% of the total dwelling stock in the Netherlands, which is 75% of the rental dwelling stock (CBS, 2020). Dutch housing associations build, rent out and maintain homes. They have dwellings in different rental segments. More than 90% of the rental homes of housing associations are social housing (Centraal Planbureau, 2017). These are homes with a maximum rental price, also known as the liberalization limit (737.14 euros in 2020), especially for people with lower incomes. These rental homes are subject to certain rules. For example, the rent may not be higher than permitted on the basis of the points system for rental homes. In addition, the government sets the maximum annual percentage by which these rents may increase. (Centraal Planbureau, 2017). Rental houses that do not belong to housing associations can be rented out by commercial investors or private individuals. In general, they own houses with a rent above the liberalization limit. This sector is also called the private sector and it has no restrictions as maximum rents.

1.2 Problem outline & statement

For housing associations and commercial landlords it is not clear how their tenants value green roofs. Although tenants have low responsibility for implementing green roofs, they are still an important stakeholder. In addition, tenants also benefit from green roofs. As city dwellers, they benefit from lower urban heat stress, cleaner air and reduced risk of flooding Oberndorfer et al., 2007; Paithankar & Taji, 2020; J. Yang et al., 2008). Tenants who live directly under the roof benefit from the improved indoor climate due to thermic insulation and noise reduction (Damen & Brouwers, 2012; Grant et al., 2003; Jungels et al., 2013). Having a view on green roofs enhances well-being with a view of greenery(K. E. Lee et al., 2015; Ulrich, 1984).

The satisfaction of their clients is important for landlords. When housing associations or commercial landlords make investments, they want to know what the added appreciation of their tenants is. One way of expressing the valuation of green roofs is the willingness to pay (WTP). By knowing what tenants are willing to pay for a green roof, landlords can better make the consideration of constructing a green roof. In addition, insight into tenants' motives for participating in green roofs provide assistance for policy strategies of landlords. The private rental sector could pass on the valuation of green roofs to its tenants.

Studies on the economic value of green roofs are not new; over the last two decades, a number of studies have already been carried out research on this subject. Many studies are looking into the (social) costs and benefits of green roofs. Because the personal value of green roofs has not yet been properly researched, unsubstantiated assumptions are regularly used in cost-benefit analyses (Bianchini & Hewage, 2012; Nurmi et al., 2016; Rosenzweig et al., 2003).

There are only a few studies that have investigated the WTP for a green roof. Zhang et al., (2019) interviewed 841 households in Beijing, and their results show that respondents are willing to pay 220.56 dollar more income tax per household (1.2% of their disposable income) for cooling roofs that mitigate the urban heat effect. Tam et al. (2016) surveyed 357 professionals in Hong Kong. The study revealed that about 80% of the respondents are willing to invest at most 208 €/m2 to have a green roof. Vanstockem et al. (2018) investigated the WTP of different green roof designs of 155 Flemish respondents. However, not all conditions for reliable estimation were met in this study. Therefore, only attribute importance could be mentioned instead of the WTP. None of the above studies focus on rental housing. The above studies are based on homeowners or professionals; therefore their conclusions are not directly applicable to the WTP of tenants. Tenants have a different responsibility which influences attitudes and interest in housing transitions (Jansma et al., 2020).

The only study that distinguishes the WTP for green roofs between tenants and home owners segments is by Teotónio et al. (2020). They conducted a direct survey to investigate the WTP for green roofs and green walls in Portugal. About 40% of individuals are willing to pay up to a maximum of 2.5% per month of the rent value or bank mortgage for the installation of inaccessible green roofs. The conclusion of the above study cannot be adopted directly for rental dwellings in the Netherlands. First of all, in their research there is no significant difference in the WTP for house buyers and tenants which leads to general conclusions. In addition, the study was carried out in Portugal, where they have a different spending pattern than in the Netherlands. Finally, the researchers mention that a different methodology or sampling method could easily lead to different outcomes. For these reasons, additional research is needed. This means that there is a gap in information about economic value and, in particular, the WTP for green roofs with tenants as the target group.

In addition, current studies for green roofs do not take into account the reference-dependent theory. The concept of reference-dependent choice behaviour was introduced in the prospect theory by Kahneman and Tversky (1979). According to the theory, decision makers' choices depend on a specific reference point (i.e. status quo). The choice is based on possible losses or gains relative to the reference point. Results show that decision makers are more sensitive to losses than to gains. If refence-dependence in choice behaviour is omitted, the results may be biased. This makes it important to add this theory to the research.

Current research into the WTP for green roofs cannot be implemented for rental houses in the Netherlands to know the valuation of tenants of green roofs. That is why additional research is needed so that landlords have more knowledge and insights to implement green roofs.

In conclusion, there is a lack of knowledge about how tenants of housing associations and commercial sector value green roofs, what they are willing to pay for green roofs and what motives they have for doing so. This makes it difficult for housing associations to draw up strategies to provide the building of green roofs.

1.3 Research objective and questions

The objective of this study is to provide insights into how tenants of housing associations and commercial sector value green roofs through the WTP, identify which personal and green roof characteristics influence this and which motives they have. The insights that are gained, can be used by policymakers of housing associations and landlords in general. To achieve this aim, the following research question will be examined:

> *How do green roof characteristics and personal characteristics of tenants influence the WTP for a green roof? What are the motives for WTP?*

In order to answer this question, sub-research questions are determined. The sub-research questions that will be answered are:

- *Which personal characteristics of tenants and which green roof characteristics can influence the WTP for green roofs (according to literature)?*
- *What are the motives of tenants for WTP of a green roof?*
- *To what extent do green roof characteristics influence the WTP for a green roof?*

- *To what extent does the reference dependent choice behaviour influence the WTP?*
- *To what extent do personal characteristics of tenants influence the WTP for a green roof?*

1.4 Relevance

1.4.1 Practical relevance

This research is relevant for housing associations and other commercial landlords. Landlords gain insight into the tenant's position in the transition to green roofs. With an exact value of the WTP, they know how much a green roof is worth to tenants. By knowing which characteristics influence the WTP, housing associations can differentiate between certain target groups and choose suitable green roof characteristics. If landlords know the reasons why tenants want to contribute to green roofs, they can use these in their strategy.

1.4.2 Scientific relevance

Existing literature on the WTP for green roofs focuses on private homeowners or professionals. As a result, there is limited knowledge on what the WTP of tenants is. This is an essential different target group as the responsibilities of tenants are different. Hence, this study investigates the WTP for green roofs of tenants. This study is executed in the Netherlands. Therefore, the insights of this study will be interesting for Dutch researchers and policy makers, but also researchers from other countries might be interested in the results of this study.

In addition to filling the research gap, there will also be a methodological scientific relevance. The research will use a discrete choice method to assess the reference-dependent choice behaviour. This method has rarely been used in housing preference studies. Habib & Miller (2009) found significant loss aversion effects for service attributes in residential location choices. Ossokina & Arentze (2020) give insight specifically on reference-dependence of housing choices of elderly households.

In conclusion, this research will fill the knowledge gap about the WTP for green roofs with tenants as the target group and examines the role of reference points and loss aversion attitudes of decision makers in making transition decisions.

1.5 Research design

Several research methods will be used to answer the research questions. Firstly, a literature review will be conducted. The literature review will result in a comprehensive understanding of the preferences of green roof characteristics and personal characteristics that can influence the WTP. The findings of this part will be used to refine the conceptual models, which is a base for the survey.

Secondly, a quantitative approach will be used to answer other questions. For this part a stated choice model shall be drawn up. The survey will be distributed among tenants of housing associations and commercial landlords in the Netherlands. Respondents are given a set of alternatives with green roof variables from which they must make a choice. Furthermore, data will also be retrieved about the personal characteristics and motivations about their WTP.

Lastly, to analyse the data retrieved from the stated choice questionnaire will be used to perform the mixed logit model to check the variation. Finally, advise for policy makers of housing associations and commercial landlord will be given and recommendations for future research will be made.

1.6 Reading guide

This thesis consists of five chapters. Chapter 2 implies the literature review regarding benefits of green roofs, green roofs characteristics that could influence the willingness to pay and personal characteristics that could have an influence. The stated choice Experiment will be explained in Chapter 3, including the attributes and variables extracted from the literature review and the decisions made regarding the models and analyses. Chapter 4 shows and explains the results of the data collection based on the stated choice Experiment. First, the descriptive statistics are discussed followed by the Multinomial Logit Model and an interaction model. Then the Mixed Logit model is discussed. Chapter 4 ends with a comparison of the findings of this study with the existing literature. Chapter 5 discusses the conclusions of this research for practical and scientific relevance. The limitations and recommendations for future research are given.

2 Literature review

This chapter contains a review of the existing literature regarding green roofs. First of all, the structure of a green roof, the costs and conditions are discussed. Secondly, the advantages of green roofs are explained. Then the characteristics of green roofs that can influence the WTP are discussed. After that, the personal characteristics that influence the WTP for green roofs are examined. Based on the literature study, characteristics can be selected that should be included in the discrete choice model. Finally, the methods used in studies on the WTP for green roofs are reviewed.

2.1 Structure, restrictions and cost

Green roofs are flat or pitched roofs with vegetation. Green roofs are in general classified into two major categories; intensive green roofs and extensive green roofs. These types differ in structure, restrictions, costs and benefits. The basic construction of both types of roof is the same. On the supporting structure there is a waterproof membrane, possibly an insulation layer, drainage material, a filter to prevent loss of soil particles, a substrate layer and vegetation (Figure 1). The difference between extensive and intensive roof is the thickness of the substrate layer and type of vegetation. There is no agreement between different sources regarding the thickness of the substrate for various roof types; examples are given in Table 1. In general, an extensive roof has a substrate thickness of 50-150 mm and an intensive roof has a substrate thickness of more than 200 mm. The vegetation on an extensive green roof is grasses, herbs, flowering and herbaceous plants. An intensive roof has perennials, shrubs and grasses.

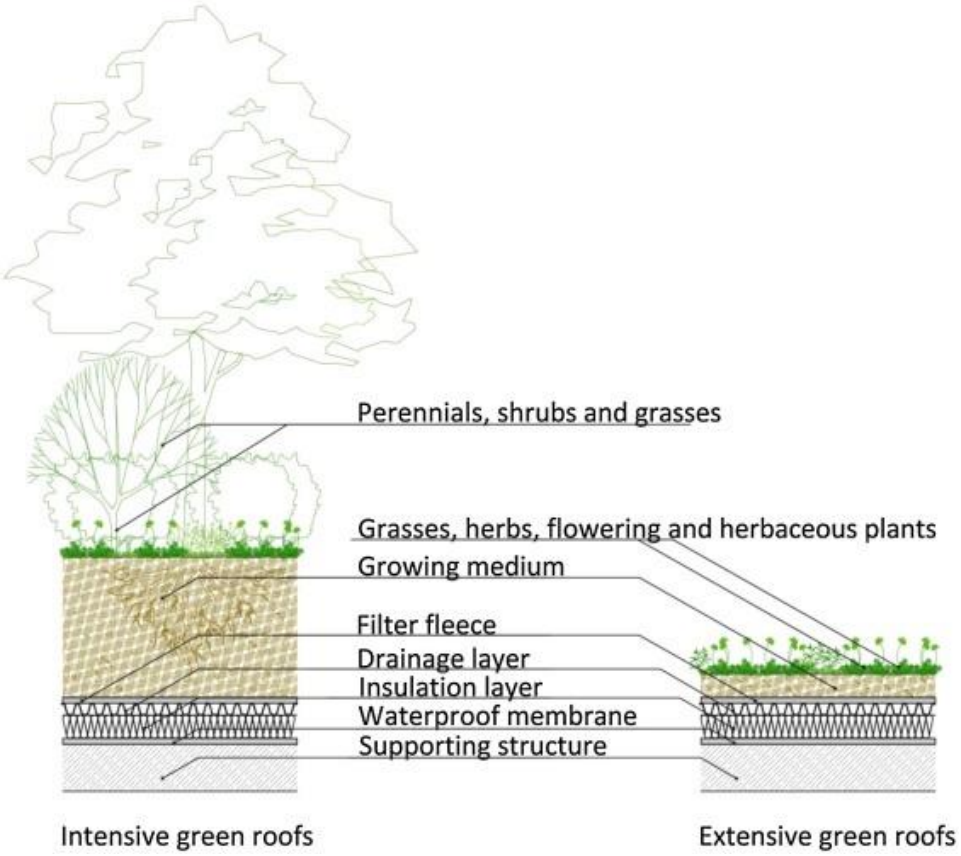

Figure 1 The construction layers typical for green roofs (Brudermann & Sangkakool, 2017)

A green roof cannot be installed on every roof. The first restriction is the maximum weight a roof can carry. Extensive green roofs have a lower weight than intensive green roofs, visible in Table 2, which makes them easier to apply on roofs. The slope is also a restriction for a green roof. An extensive green roof can have a maximum slope of 45 degrees, while the slope of an intensive green roof cannot exceed 10 degrees (Mentens et al., 2006). Green roofs require more maintenance than a regular bitumen roof. Maintenance is highly dependent on the type of vegetation. According to Kantor (2017), an extensive green roof requires maintenance once a year for the first 3 years. An intensive green roof that is equivalent to a garden will also need maintenance with the same intensity as a garden.

The cost of a green roof depends heavily on the type of vegetation, because prices depend on the location, the costs of a green roof were assessed on the basis of Dutch sources (Table 2). The costs for an extensive green roof range between €30 and €120 per m2. An intensive green roof often starts at €120.

Table 1 substrate depth (mm) and weight (kg/m2) green roofs

	Extensive		**Intensive**	
Source	depth (mm)	weight (kg/m2)	depth (mm)	weight (kg/m2)
(Naing et al., 2017)	20-200		150>	
(Oberndorfer et al., 2007)	20-200	70-170	200>	290-970
(Mentens et al., 2006)	30-140		150-350	
(Kosareo & Ries, 2007)	50-150		150-1200	
(Fernandez-Cañero et al., 2013)	60-200	60-150	150-1000>	180-500
(Patnaik et al., 2018)	100-150		300-450>	
(Paithankar & Taji, 2020)	<150		150 >	
(Shafique et al., 2020)	<150		150>	
(Brudermann & Sangkakool, 2017)	<150	60-150	200 >	300>
(Chagolla-Aranda et al., 2017)	<200		200>	

Table 2 Construction costs of green roofs (euros/m2)

	extensive roof	**intensive roof**
source	cost (€/m2)	cost (€/m2)
(*Groen Dak | Milieu Centraal*, n.d.)	30>	120
(*Groene Daken - De Dakdokters*, n.d.)	30-110	130+
(*Groen Dak | Verbouwkosten.Com | 2021*, n.d.)	40-120	120-150
(*Sedumdak Prijs: Ontdek Richtprijzen & Bepalende Factoren*, n.d.)	45-100	120+
(*Kosten Groendak - [Nuttige Informatie + Tips] | Homedeal*, n.d.)	75	150

2.2 Advantages of green roofs

This section discusses the benefits of both extensive and intensive green roofs. First, the environmental benefits of green roofs are considered, namely reducing the risk of flooding, stimulating biodiversity, reducing air pollution and reducing environmental noise. Then the benefits that owners or users can experience from a green roof are described, including reduction of interior noise, longer life expectancy, thermic insulating effect and appreciating aesthetic.

2.2.1 Reducing risk of flood

Climate change is causing us to face more extreme storms with heavy rainfall (Rijksoverheid, 2020). Many sewer systems are not prepared for this, resulting in flooding. Green roofs have an absorbing effect, which allows water to be stored temporarily. Various studies have investigated the reduction of rainwater runoff from green roofs. Results are very diverse due to differences in climate, including rainfall depth, intensity and antecedent dry days. Also differences in vegetation and substrate type influence runoff reduction. A study in the UK showed water retention from 26.8% to 61.8%, depending on vegetation and substrate type (Stovin et al., 2015). A pilot study in Seoul to evaluate runoff quantity from green roofs found that green roofs are 42.8-60.8% effective in reducing runoff for 200 mm soil depth and 13.8-34.4% effective in reducing runoff for 150 mm soil (J. Y. Lee et al., 2015). Mentens et al. (2006) showed with a study in Brussels that extensive roof greening on just 10% of the buildings would already result in a runoff reduction of 2.7% for the region and of 54% for the individual buildings. Talebi et al. (2019) conducted research into water retention in various areas in Canada. Of the cities studied, the city of Vancouver has the most similar climate as in the Netherlands. The runoff reduction in Vancouver is 35% and 23% for high and low water use plants, respectively.

According to the above-mentioned studies, the water runoff is between 13.8% and 54% for extensive green roofs and between 42.8% and 61.8% for intensive green roofs. During big storms, the risk of flooding can be reduced by green roofs.

2.2.2 Stimulate biodiversity

The burgeoning study of urban ecology, has shown that urbanization has profound impacts on both ecological and evolutionary processes as well as on humans inhabiting urban areas (Johnson & Munshi-South, 2017). The term "biodiversity" has been used since the late 1980s, and encompasses species diversity (taxonomic abundance, or species richness), ecosystem diversity (habitat diversity, and interaction with non-living aspects of the environment) and genetic diversity (frequencies and distribution of genes and inherited traits) (Harper & Hawksworth, 1995).

Several studies have investigated the effects of installing green roofs on biodiversity. Williams et al. (2014) did a peer-reviewed literature study examining green roof biodiversity of 23 studies and found that green roofs have greater species diversity than conventional roofs and can provide a habitat for generalist and some rare species. Several studies mention a multiplication of spiders, beetles, birds and snails on green roofs (Brenneisen, 2006; Kadas, 2006). A small number of the reviewed studies claim they facilitate the movement of organisms through cities (Williams et al., 2014).

The difference in effect of extensive and intensive roofs on biodiversity is little researched. Rumble & Gange (2013) mention in their study that the expected overall diversity on extensive green roofs could be limited compared to intensive green roofs.

2.2.3 Reducing urban heat island effect

Due to a decrease in vegetation cover and an increase in impervious surfaces, the surface temperature in cities is higher than in rural and non-urban areas, which is known as the urban heat island (UHI) phenomenon (Jabareen, 2013). UHIs have serious consequences, including an increase in mortality rates and health dangers, energy consumption, carbon emissions, and global warming (Kleerekoper et al., 2012). It has been estimated that the temperature in about 20% of the world's cities will increase up to more than 4°C and 7°C by 2050 and 2100, respectively (Estrada et al., 2017).

Due to evaporation and because less heat is retained than with a black roof, the UHI effect is reduced with green roofs. In comparison to a black roof the green roof reduces urban excess heat by 15%-51% with sustainable irrigation (Heusinger et al., 2018). Several studies have examined the effect of a certain amount of green roofs on temperature in the environment. Bass & Koukidis (2012) showed a temperature reduction as great as 2°C in some areas with a regional simulation model using 50% green-roof coverage distributed evenly throughout Toronto. Imran et al. (2018) has similar results, their research in Melbourne found that the maximum roof surface UHI effect is reduced during the day by

1°C to 3.8°C by increasing green roof fractions from 30% to 90%. Research of Asadi et al. (2020) has more favourable results. With a case study in Austin, considering 2D/3D urban characteristic, they demonstrate that by greening 3.2% of total building roofs, the average of land surface temperature decreased by 1.96°C.

In addition, CO_2 is absorbed by green roofs during photosynthesis and is stored as plant biomass (Rowe, 2018). Less CO_2 in the air will cause less global warming. Shafique et al. (2020) conducted a review of 9 studies about the results of green roofs on sequestering carbon. The studies found a carbon sequestration between 0.031-1.89 kg CO2/m2 year.

It can be concluded that the installation of green roofs has a significant influence on the UHI effect. The number of green roofs needed for a few degrees of reduction is very divided. Studies do not distinguish between extensive or intensive green roofs.

2.2.4 Reducing air pollutants

City air often contains high levels of pollutants that are harmful to human health (Mayer, 1999). Green roofs can reduce air pollutants through a dry deposition process and microclimate effects. Several studies have investigated the effects of green roofs on air quality. Yang et al. (2008) conducted a research to quantify the air pollution removal by adopting green roofs in Chicago by using a dry deposition model. The results showed that by using 19.8 ha of green roof, 1675 kg of air pollution was removed in a year which include 52% of O3, 27% of NO2, 14% of PM10, and 7% of SO2. The absorption of air pollution depends on the type of plants. Sedum (mostly used on extensive green roofs) may not be the optimal choice if the primary purpose of the roof is reducing air pollution (Gourdji, 2018; Rowe, 2018).

It can be concluded that green roofs have positive effects on air pollution. Intensive green roofs can remove more pollution from the air than extensive green roofs, depending on the vegetation type.

2.2.5 Environmental noise reduction

The presence of mainly acoustically rigid materials in cities (streets, bricks, concrete, glazing, etc.) leads to a strong amplification of the emitted sound from road traffic noise, and large sound pressure levels are observed in city canyons. The noise problem has indeed become one of the major environmental challenges in the urban environment (WHO, 2011). Several studies have examined the effects of green roofs on the absorption of environmental noise such as road traffic noise. Yang et al. (2012) studied with laboratory measurement the acoustic effects of green roof systems on a low-profiled structure at street level. Most optimised absorption treatment could bring up to 4 dBA noise reduction for traffic noise. A note on this research is that in general, roofs are installed far above street level, which could reduce the effect. In contrast, Van Renterghem & Botteldooren (2008) do take account of the height in their model. The results show that the effect of the presence of a green roof, relative to a rigid one, increases with increasing octave band centre frequency, and amounts to 6 dB at 1000 Hz. Van Renterghem et al. (2013) specifically looked at the noise reduction in courtyards by green roofs and facades. Favourable combinations of roof shape and green roofs have been identified, leading to reductions up to 7.5 dBA in confined courtyards.

Some studies have explored the difference in effect of extensive and intensive green roofs. Van Renterghem & Botteldooren (2008) conclude that the sound absorption differs with substrate thicknesses between 50 and 200 mm. Connelly & Hodgson (2015) add that the sound absorption is not improved with a substrate thickness higher than 200mm.

It can be concluded that there is a significant environmental noise reduction when installing green roofs. The higher the substrate layer (up to 200 mm), the more sound absorption. The size of the effect due to increasing thickness is not known.

2.2.6 Internal noise reduction

As urban residential buildings are increasingly built closer to transportation infrastructure, acoustic environmental quality in urban residential areas has become a critical factor (Hong et al., 2020). In older houses with poor insulation, a lot of noise can come in through the roof. Green roofs act as an insulating layer that better insulates against outside noise. Various researchers have examined the internal noise reduction of a green roof compared to a traditional roof. Van Renterghem & Botteldooren (2011) found a noise reduction of 5db with a substrate layer of 20-30mm. A thicker substrate layer of 180mm provides a noise reduction of more than 10 dB, in the frequency range between 300 Hz and 1 kHz. Kalzip Roof systems (2020) mentions similar results. The results suggested that a green roof can reduce sound by 8dB compared with a conventional roof system. Connelly & Hodgson, (2013) showed that the transmission loss of vegetated roofs is greater than that of non-vegetated reference roofs by up to 10 and 20 dB in the low and mid frequency ranges, respectively. They mention that the increase of transmission loss due to the addition of 50 mm of substrate was 2.6 dB, and the addition of another 100 mm to a total of 150 mm of substrate yielded another increase of 3.6 dB.

It can be concluded that the sound comfort in houses directly under the roof is greatly improved by the installation of a green roof. The noise reduction with an intensive green roof can be 5 dB more than with an extensive green roof.

2.2.7 Roof longevity

A regular bitumen roof has to be replaced after about 20-25 years (Kantor, 2017). In contrast, a green roof has a longer life. By reducing the temperature on the roof covering (membrane), the life span will be extended. In addition, the UV radiation does not reach the roof directly and the roof will suffer less physical damage because the roof is not, or is less directly, walked on (Damen & Brouwers, 2012). Various studies have assumed a life span of 40-50 years for a green roof in their cost-benefit analysis (United States General Services Administration, 2011). This lifespan is difficult to justify because, according to Porsche & Köhler (2003), modern green roofs are no more than 35 years old. However, there are some examples where a green roof has already been in place for a long time. In Berlin there is a green roof in good condition that has been there for over 90 years (Porsche & Köhler, 2003). At a department store in London, where a green roof was applied in 1938, the roofing was found to be in excellent condition after 50 years (Damen & Brouwers, 2012).

Based on literature, it can be assumed that the lifespan of a green roof is 40 to 50 years, which is double of a conventional roof. As the roof covering is protected in both extensive and intense green roofs, these types of roofs have the same life expectancy.

2.2.8 Thermal insulation effect

Poorly insulated buildings lose a lot of heat through the roof in winter and heat up too much in summer. Green roofs have an insulating effect that reduces these effects. The cooling effect has been calculated by several studies. A study in Shanghai states that compared to common roofs, the green roof had an average cooling effect of 2.9 °C (He et al., 2020). Research in a semi-warm climate in Mexico states that the maximum cooling effect of a day is 6.4 °C (Chagolla-Aranda et al., 2017). A report with three case studies in Hong Kong shows that green roofs can reduce the inside temperature by up to 3.4 °C (Tam et al., 2016). These results may outperform the Dutch climate. Damen & Brouwers (2012) compared 4 studies in which the climatic situation is almost comparable to that of the Netherlands.

These studies mainly showed that in summer, heat flows into the interior are reduced by approximately 90%.

The thermal insulation of green roofs keeps the heat inside in winter. Bevilacqua et al. (2016) found in their research that compared to a bituminous roof, a green roof is 4 °C warmer in winter. This reduces outgoing thermal energy by 30 to 37%. According to Liu & Minor (2005), a green roof gives off 10 to 30% less heat in winter compared to a traditional roof. Damen & Brouwers (2012) concludes that heat loss in winter from the inside to the outside is reduced by 20%. Various studies on the thermal comfort of green roofs conclude that the effect is greater with a higher substrate (Eksi et al., 2017; Y. He et al., 2020; Tam et al., 2016).

It can be concluded that energy costs can be reduced in both summer and winter by installing green roofs. The extent of the effect strongly depends on the existing insulation the outdoor temperature and the thickness of the substrate layer.

2.2.9 Appreciating aesthetic

In a city, buildings often have a difference in height, which means that people often have a view on a roof of another building. Research shows that a vegetated roof is more appreciated than a black tar or gravel roof (Jungels et al., 2013; Loder, 2014; Mesimäki et al., 2019; White & Gatersleben, 2011). White & Gatersleben (2011) show that houses with (some types of) building-integrated vegetation were significantly more preferred, beautiful, restorative, and had a more positive affective quality than those without. The research of Mesimäki et al. (2019) revealed the following visual and other sensory experiences; beauty, suitability of the place for oneself and the urban context, nature, desire to explore the place and interest, positive excitement, and safety. Furthermore, answers to the open questions revealed a wide range of other observations and feelings, such as peace, joy, excitement and hope. Jungels et al. (2013) add that in their research aesthetic reactions were, in general, positive. Green roofs not only have aesthetic appeal, but also a positive environmental association for many viewers. Design and plant selection are clearly important to how well a green roof is aesthetically received. Similarly, Loder, (2014) shows in her research that the type of green roof makes a difference in terms of aesthetic value. Results show that while ‘wilder’ prairie-style green roofs are not always well-liked, they are more likely to be associated with fascination, creative thinking, and calm well-being than sedum green roofs. Green roofs were also linked to an ethic of care and restoration, and may provide ‘loose fit’ places for respite and better health for office workers (Lottrup et al., 2013).

Finally, the aesthetic value of green space can be expressed in improved health and well-being. A study with a 40 second viewing break on a green roof versus a black roof shows that those who looked out on the green roof made fewer mistakes in their computer task (K. E. Lee et al., 2015). Looking out on the green roof also means that patients take 30% less painkillers and stay in hospital an average of 1 day shorter (Ulrich, 1984).

It can be concluded that green roofs have a positive aesthetic value. This can be expressed in improved well-being. The aesthetic value depends on the type of greenery.

2.3 Relevant green roof characteristics influencing the WTP

This section examines which characteristics of green roofs, according to literature, influence the WTP. First of all, the accessibility of a green roof is discussed, followed by the view of a green roof. Finally, the value of having noise and thermal comfort will be described.

2.3.1 Accessibility of a green roof

Several studies have examined the appreciation of the accessibility of green space in general or a green roof (Jungels et al., 2013; Loder, 2014; Lottrup et al., 2013; Teotónio et al., 2020; Williams et al., 2019; Yuen & Hien, 2005). The term accessibility refers to whether a green roof can be entered and used as a communal or private living area such as a garden.

The perception and level of importance of green roofs is increased by accessibility (Loder, 2014). The research of Yuen & Hien (2005) shows that respondents perceive accessibility and convenience as reasons for more green roof facilities. Jungels et al. (2013) suggest in their research on attitudes and aesthetic reactions toward green roofs that the outcomes would be different if visitors could access a green roof. Other studies show the psychological impact of access to green roofs which can result in higher appreciation (Lottrup et al., 2013; Williams et al., 2019). Williams et al. (2019) mention that if the green roof allows physical access, it has the potential to play further roles in supporting psychological restoration. Lottrup et al. (2013) adds that access to workplace greenery is related to decreased levels of stress and increased positive attitudes toward the workplace. Teotónio et al. (2020) measured with a questionnaire the WTP for green roofs as a percentage of the monthly rent value or monthly bank mortgage. They found that users value the accessibility of green roofs, and significant differences are found in the willingness-to-pay for accessible and inaccessible green roofs highly, varying from 4% and 2%, respectively. A note on the methodology of this study is that they used a Chi-square test and Cramer's V and not a multiple regression. This makes the results less conclusive (Teotónio et al., 2020). From the above literature, it can be concluded that there is a difference in the WTP for an accessible and inaccessible roof, which is why it is important to include this characteristic in this research.

2.3.2 View on green roofs

Various studies indicate that people appreciate views of greenery as described in section 2.2.9. It has widely been found that people prefer natural landscapes over built ones (Ulrich, 1983; van den Berg et al., 2003). Other studies have looked specifically at the view from a green roof and found that people experience less stress (Lottrup et al., 2013), feelings of beauty, desire to explore, safety (Mesimäki et al., 2019) and fascinating (Loder, 2014). Jungels et al. (2013) mention that the distance to a green roof plays a part in the assessment.

The aesthetic value of green roofs can even be expressed in an increase in the value of dwellings. Bianchini & Hewage (2012) assumed, based on studies that examined the relationship between house prices and the presence and visibility of parks, that the aesthetic value in terms of property appreciation would increase the property value from 2% to 5% for an extensive green roof and from 5% to 8% for an intensive green roof. Nurmi et al., (2016) estimated a scenic benefit of green roofs up to 37 €/m2 in Helsinki based on the application of the spatial hedonic price theory in terms of the purchase price per square meter.

When looking at greenery, the type of vegetation is important (Fernandez-Cañero et al., 2013; Jungels et al., 2013; Loder, 2014; Teotónio et al., 2020; Vanstockem et al., 2018; White & Gatersleben, 2011). Fernandez-Cañero et al. (2013) conducted a visual preference study in which respondents had to rate 9 types of green roofs on a 5-point Likert-type scale. Results have shown that green roofs with a more careful design, with a good maintenance, greater variety of vegetation structure and colours are preferred by people over more natural alternatives. A Pearson chi-squared test and one-way ANOVA were used for this study (Fernandez-Cañero et al., 2013).

The results of Vanstockem et al. (2018) indicate that vegetation gaps and weedy species, together with a diverse vegetation have a considerable impact on green roof perception. Loder (2014) adds that 'wilder' prairie-style green roofs are not always well- liked. White & Gatersleben (2011) looked at the appreciation of different types of vegetation on the roof. It emerges that ivy and meadow were rated higher on beauty, affective quality, and restoration. This suggests that these types of vegetation may be most beneficial to people. Indeed, turf, sedum, and brown vegetations were generally not significantly different from the no vegetation condition (White & Gatersleben, 2011).

It can be concluded that having a view of a green roof has a positive influence on the WTP compared to no view of a green roof. The type of vegetation on the roof can influence the WTP. A large vegetation difference is visible between extensive (sedum) and intensive (shrubs and high grasses) green roofs.

2.3.3 Insulation benefits

Green roofs have personal building related benefits as written in chapter 2.2, such as better thermal comfort, lower energy cost and noise reduction. However, these benefits will only be enjoyed if the dwelling/living space is directly underneath the roof. In an apartment building, it may be the case that the upper floor has different benefits than the floors below. In a terraced house, the top floor benefits from better insultation with a green roof. In the section below, the valuation of the building related benefits, when having a green roof is described.

Studies on sustainable homes show that people are willing to pay for better comfort and pleasure (Li et al., 2018), energy cost savings (He et al., 2019; Khan et al., 2020; Zalejska-Jonsson, 2014) and noise reduction (Khan et al., 2020). Zalejska-Jonsson (2014) asked a direct question whether respondents were willing to pay a premium for dwelling in a low-energy building. The respondents had the possibility to indicate the size of the premium expressed as a percentage (5% or 10%) of the purchasing price or rental fee compared to a conventional building. The results indicate that a stated WTP for low-energy buildings of 5% can be considered a rational investment decision (Zalejska-Jonsson, 2014). He et al. (2019) studied in China the WTP for different attributes of green housing by a discrete choice model. They mention that energy saving and water saving could attract less than 250 RMB/m2 (€32/m2) and between 18 and 80 RMB/m2 (€0.23-€10.32/m2) for a better thermal comfort. Results from Khan et al. (2020) show that the influence on the WTP for a sustainable house is for 23% influenced by reduction of energy bills and for 11% by noise insulation. Results of Tam et al. (2016) show that respondents agree that they benefit from building insulation and energy efficiency. From the above literature, it can be concluded that noise and thermal insulation can be of value to the resident of a building. Extensive and intensive green roofs have a different thermal (section 2.2.8) and sound (section 2.2.6) insulation effect compared to a regular roof. Therefore, it is important that the type of green roof with regard to noise and thermal insulation is included in the study to determine the WTP.

2.4 Relevant personal characteristics influencing the WTP

The previous section mentioned green roofs characteristics that can influence WTP. This section discusses personal characteristics that can influence WTP for green roofs. First of all, the influence of knowledge about green roofs is mentioned. In addition, literature shows the influence of a pro environmental attitude. The influence of the current housing type and the amount of green in the current environment are also explained. Finally, the influence of social demographic characteristics such as gender, age, level of education and income are discussed. For each characteristic, the literature on green projects such as sustainable houses is reviewed first. After that, literature specifically on green roofs is mentioned.

2.4.1 Knowledge about the effects of green roofs

Many studies on the valuation of green roofs or sustainable housing have investigated the influence of prior knowledge on the subject (He et al., 2019; Jungels et al., 2013; Khan et al., 2020; Teotónio et al., 2020; Zhang et al., 2019a, 2019b). People who have a deeper knowledge of environmental issues and the remedies are more likely to take actions to protect the environment (Kaiser & Fuhrer, 2003; Kollmuss & Agyeman, 2002). This corresponds to studies on sustainable housing. He et al. (2019) classified the respondents into different groups. The group with the most knowledge wants to pay more for green housing. Also Khan et al. (2020) show that environmental knowledge influences the WTP for sustainable homes.

Studies specifically on green roofs give corresponding answers. Jungels et al. (2013) show that participants who had previous knowledge of green roofs had significantly higher support and benefits value. In the survey by Teotónio et al. (2020), knowledge of the benefits of green roofs had the highest correlation coefficient with WTP. By only looking at the coefficient of relationship and not controlling for other variables, the results of this study are not strong. The research of Zhang et al. (2019a) varies with the above research. They found no significant relation with knowledge about the effect of green roof in mitigating UHI and households' WTP for green roof for mitigating heat island effects in Beijing.

With the exception of a few, most studies find a relationship between the prior knowledge and the appreciation for green projects. Therefore, it is also likely that there is a relationship between prior knowledge of green roofs and the WTP. That is why it is important to include this attribute in the analysis.

2.4.2 Pro environmental attitude

There have been several studies on the relation between having a pro environmental attitude and the appreciation of sustainable projects. People with a pro environmental attitude are willing to pay more for sustainable homes according to Khan et al. (2020) and He et al. (2019). The study by Zhang et al. (2019a) indicates that respondents who believe that they have enough time and resources to participate in pro-environment activities are more willing to pay for green roofs for mitigating UHI effects in Beijing. Few studies on green roofs look at the relationship between attitude and the appreciation of green roofs. Fernandez-Cañero et al. (2013) mention that interest in taking action to improve the urban environment has a small effect on the interest in green roofs.

From previous studies, it seems clear that there may be a relationship with the environmental attitude and the WTP for green roofs. However, this question has not yet been specifically investigated.

2.4.3 Amount of green space in current environment

Some studies have looked at the valuation of green roofs in relation to the amount of green space in the current environment of a participant. This can be done by making a distinction between urban and suburban areas with the assumption that there is more green in suburban areas. Jungels et al. (2013) suggest that the appreciation of green roofs may differ in a dense, urban context. However, the research of Zhang et al. (2019) does not reveal any significant difference in the WTP for green roofs mitigating UHI effect in central urban areas and suburban areas. Also Fernandez-Cañero et al. (2013) found no significant relation between interest in installing green roofs and the present environmental background. When asked more specifically about the amount of green in a respondent's environment, significant differences are found. Teotónio et al. (2020) mention that people are willing to pay more for green roofs in areas of residence with few green spaces. Also Fernandez-Cañero et al. (2013) show that respondents who had no garden at home were more interested in installing a green roof.

It can be concluded that in previous studies no significant difference was found between the WTP for people living in urban and suburban areas. However, a relationship can be seen between the WTP and the degree of green in the environment of people. Therefore, it is important to include the current degree of green environment in the research.

2.4.4 Socio-demographic characteristics

Many studies have examined the social, economic, and demographic characteristics and their relationship to the appreciation of green projects or specifically green roofs. The characteristics gender, age, education level and income emerge in most studies. In several studies, there is no significant difference between men and women and the appreciation of sustainable houses (Portnov et al., 2018) or green roofs (Jungels et al., 2013; Teotónio et al., 2020; Zhang et al., 2019a). In contrast, other studies document that women have a greater environmental concern (Stern et al., 1993). Li et al. (2018) show that female residents have the highest WTP for comfort and pleasure in green housing. In the study of Zhang et al. (2019b), women are willing to pay more for green roofs for mitigating UHI effects compared to men. Also Fernandez-Cañero et al. (2013) show that women rate vegetation higher. The research of Khan et al. (2020) on sustainable houses varies with this. The WTP is higher for males than females according to the utility scores given to price premiums (Khan et al., 2020). Lottrup et al. (2013) reveal that the relationship with level of stress, attitude and green workplaces is clearly different by gender. Due to these different outcomes for men and women, it is important that the attribute gender is included in the research.

The second social demographic characteristic that appears in much of literature is age. Some studies found no significant difference by age group in the appreciation of sustainable houses (Portnov et al., 2018) or green roofs (Teotónio et al., 2020; Zhang et al., 2019b, 2019a). On the other hand, some studies have found differences in age groups. Results from Li et al. (2018) show that residents aged 60 years and above have the highest WTP for sustainable homes, and residents aged 30-39 years have the lowest. Also the study of Zalejska-Jonsson (2014) indicates that people with a higher age are willing to pay more for a low energy building. Khan et al. (2020) add that the WTP increases with age as respondents between 51-60 years old are more willing to pay for sustainable homes as compared to other age groups. The explanation given for the fact that younger respondents have a lower WTP is because of affordability and economic stability (Khan et al., 2020). Specific research on the relationship between the appreciation of green roofs and age is mixed. Research by Fernandez-Cañero et al. (2013) find that respondents older than 40 years had less interest than younger respondents in installing a green roof. On the other hand Jungels et al. (2013) state that reactions about aesthetics were more negative from younger participants. Due to the various conclusions, it is important to include the attribute age in the research.

Third, the relationship of income and the valuation of green projects has been studied. A few studies found no significant relationship between income and the appreciation of sustainable homes (Portnov et al., 2018) and green roofs (Zhang et al., 2019b). On the other hand, other researchers do mention a relationship. Li et al. (2018) state that high income families are more likely to purchase green housing to meet their comfort and investment needs compared to lower income residents. According to Zhang et al. (2019a), higher income households are willing to pay more for green roofs for mitigating UHI effect compared to lower income households. Also Teotónio et al. (2020) found that higher income respondents are willing to pay more for a green roof. In contrast to the above literature, Khan et al. (2020) state that the income level has a negative correlation with the WTP for sustainable houses. The results of this study are not strong because it only assessed the correlation without controlling for other variables. Since most studies see a positive relationship between income and WTP, there is a high probability that people with higher incomes are willing to pay more for green roofs, therefore this attribute is included in this study.

Finally, education levels are often mentioned in literature on sustainable homes or green roofs. Education is positively correlated to the WTP for green roofs (Teotónio et al., 2020; Zhang et al., 2019b, 2019a). Teotónio et al. (2020) remarked that the relationship with higher educated people is probably influenced by the fact that they more often have a higher income and are more true to environmental issues. The results of Fernandez-Cañero et al. (2013) also show that the level of education is a factor that influences attitudes and preferences toward green roof technology. Jungels et al. (2013) state that reactions about aesthetics were more negative from less educated participants. Research into sustainable housing also found that level of education positively correlates with the WTP (Khan et al., 2020). Because literature clearly shows a relation between level of education and WTP for green roofs, this attribute is included in this study.

2.4.5 Dwelling type

There is little research that has explored the relationship of dwelling type and the valuation of green roofs. Teotónio et al. (2020) looked at the relationship between dwelling type and WTP for green roofs, but found no significant outcomes. On the other hand, Fernandez-Cañero et al. (2013) found that the type of housing in which respondents were living appeared to significantly influence their assessment of the different alternatives of green roofs. In six of the eight categories, respondents who lived in a flat or an apartment gave a higher score. The above conclusion shows that a relationship with dwelling type is possible, which is why this attribute is incorporated into the study.

2.5 Methods used for calculating the WTP of green roofs

The previous section discusses personal characteristics that influence the WTP for green roofs. These studies have been done through different methods. This section discusses the various methods used in existing literature. Respondents may react differently to different methods, which give different results.

The study by Nurmi et al. (2016) is one of the few that has used a hedonic price theory in terms of the purchase price per square meter to value scenic benefit of green roofs. Other studies have used stated preference methods. Tam et al. (2016) and Teotónio et al. (2020) use direct surveys asking for WTP. Tam et al. (2016) conducted a questionnaire survey and interviews professionals, owners, and end-users with a 6-level scale question what is the WTP per meter square for the capital costs for a green roof. Teotónio et al. (2020) asks with a 6-level scale what percentage more rent or bank mortgage the respondent is willing to pay for a dwelling with a green roof. Zhang et al. (2019a) use a double-bounded dichotomous choice model with different prices to investigate the WTP for green roof for mitigating heat island effects in Beijing.

According to Brown et al. (1996), it is cognitively easier for respondents to decide whether a certain price is acceptable compared to assigning a price to a product themselves. Therefore, a discrete choice method would be more suitable. Vanstockem et al. (2018) used a discrete choice model to identify the visual characteristics of extensive green roofs (e.g., vegetation gaps, vegetation type) affecting users' preferences and their impact on choice situations measured in terms of WTP. However, conditions for a fully reliable WTP were not met in this study. Therefore, attribute importance was considered next to WTP measures.

Due to the fact that several studies only looked at the correlation between attributes and because discrete choice is a more convincing method than a direct survey, it is useful to conduct additional research in order to use a stronger method to calculate the WTP.

2.6 Conclusion

This chapter gave an overview of the literature on green roofs. When constructing a green roof, there are restrictions on the weight that can be added to the roof and the slope.

Green roofs can be divided into two types, extensive and intensive. These types differ in structure, maintenance and costs. In general, but not in all cases, the benefits are greater with intensive green roofs. Environmental benefits that are mentioned are reducing the risk of flooding, stimulating biodiversity, reducing the urban heat island effect, reducing air pollution and reducing environmental noise. Personal benefits that owners or users of a building with a green roof experience are internal noise reduction, longer life span of the roof, better indoor climate and appreciation of the aesthetics.

Relevant green roof characteristics that influence the WTP have been extracted from the literature. These characteristics will have to be included in the discrete choice method in order to conduct a valid research. First of all, whether or not a green roof is accessible influences the WTP. In addition, having a view of a green roof and the type of vegetation have an influence. The last characteristic to be included in this study having thermal and noise insulation. This differs between extensive and intensive green roofs and the position dwelling in a building.

This literature review investigated the relevant personal characteristics that influence WTP. Characteristics that emerged will have to be included in the survey to avoid biased results. First of all, knowledge about the effect of green roofs influences the WTP. In addition, respondents' pro-environmental attitude will be assessed, as this affects the WTP. Next, several sources state that the amount of green space in the current environment have an influence. Finally, socio-demographic characteristics including gender, age, income and education level will be included in the survey as these can influence the WTP for green roofs. The conceptual model in Figure 2 shows relationships between the green roof characteristics and personal characteristics that can influence the WTP for a green roof. Characteristics of the dwelling also influence the willingness to pay. For instance, the position and type of dwelling in a building affects the benefits experienced by a tenant.

Previous studies on the WTP for green roofs have used different methods. In most studies, a direct survey was used. However, a discrete choice method has been used infrequently and not in a way that revealed the WTP. Therefore, in this study, there is an opportunity to use the discrete choice method. This method is more comprehensible for respondents and give a better trade-off between variables

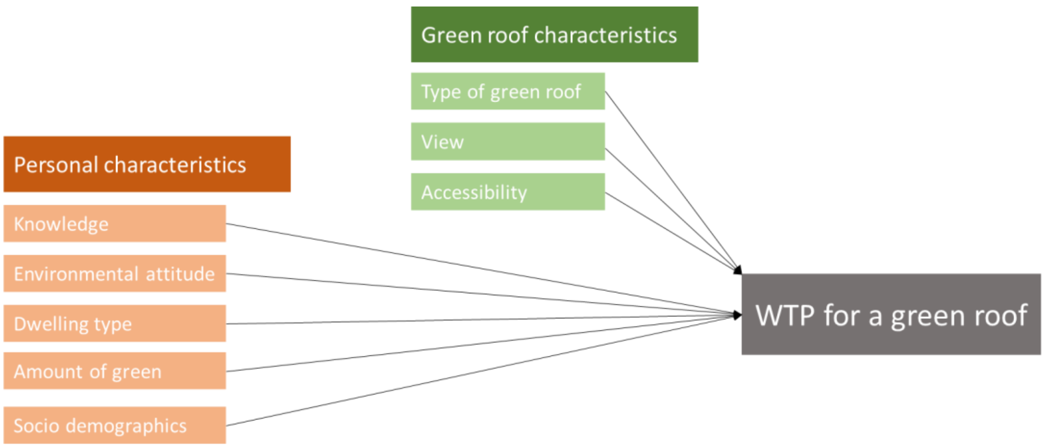

Figure 2 Conceptual model influences on WTP for green roof

3 Methodology

In this chapter the methodology used in this research will be discussed more extensively. The stated choice model will be discussed in the first section. A process with steps has been established to develop a stated choice experiment, all the steps will be discussed in the second section. Hereby, the content of the questionnaire will be determined. After this, an explanation will be given about the analyses which will be conducted after data collection.

3.1 Choice modelling

To gain insight into how tenants value green roofs, various choice methods can be used. Figure 3 shows the different possibilities to measure preferences and choices. First of all, there is a distinction between revealed preference and stated preference. Revealed preference methods are based on data retrieved from real market conditions while stated preference models are based on respondent's observations from an experimental environment. Kemperman (2000) concluded that revealed preference methods are an appropriate tool for deriving utilities and estimating demands. However, it has several limitations. First, it can be difficult to obtain sufficient variation in the revealed preference data. Second, the attributes of alternatives are often correlated. These correlations may lead to biased parameter estimates. For example, price and quality are often correlated. When people choose the best quality, it often comes with the highest price. This makes it hard to provide a trade-off ratio of the attributes separately. Moreover, it is not always possible because required data is not always available.

Stated preference and choice methods on the other hand, offer different characteristics. In this approach, hypothetical situations are used to construct someone's choice or preference. This increases the control over the existing alternatives and the attributes that are tested. Because experimental designs are used to create the hypothetical alternatives, the trade-offs between attributes can be measured without bias. With stated preference and choice methods, there is also a low correlation between the attributes. The disadvantage of a stated preference or choice experiment is that it is a hypothetical concept, which means that respondents in the 'real world' would make a different choice than the one they indicate. It is therefore important that the hypothetical concept seems as real as possible.

The stated preference and choice methods can be divided into compositional and decomposition experiments. Compositional preference data is obtained when the respondents are asked to evaluate the attractiveness of the levels of the attributes within an alternative by means of a rating scale. Next, the respondents need to express their opinion on the relative importance of each attribute describing the alternatives. The decompositional preference and choice data is used to predict respondents' preferences and choices. For this, importance weights of the attributes are derived based on respondents' answers given under controlled experimental conditions. For the decompositional preference approach, respondents are asked to rate alternatives on a scale or in order of preference. The decompositional choice approach asks respondents to choose between two or more alternatives in a choice set and this is repeated for a number of choice sets for each respondent (Kemperman, 2000). This last approach has been selected for this study, which is further elaborated in Section 3.2 stated choice experiment.

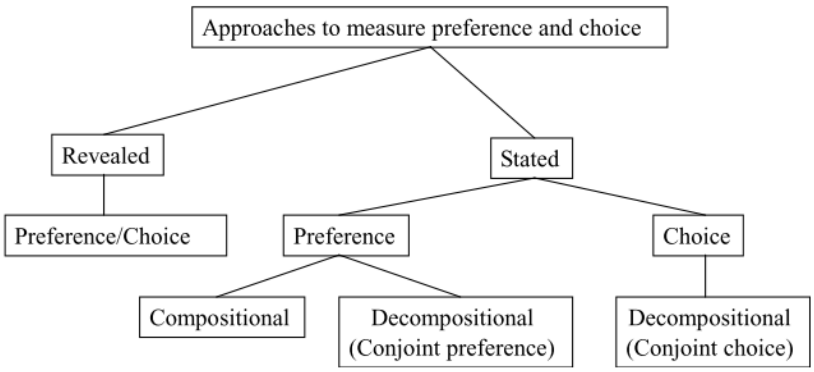

Figure 3 An overview of preference and choice measurement approaches Kemperman (2000)

3.2 Stated choice experiment design

The previous section shows that a stated choice (SCE) experiment is a suitable method for this research. The foundation for any SCE is an experimental design. The experimental design assures that all stages from design until the execution of the experiment are well thought out. For stated choice experiments, the results are very dependent on the choices that have been made before execution. To guarantee that all stages of the experimental design process are taken, the experimental design framework of Hensher et al. (2015) is used (Figure 4). The design process starts with the refinement of the problem. Stimuli refinement is the second step in the design process. In this stage, the alternatives, attributes and levels are defined. After determining the content of the SCE, the third stage, the consideration of the experimental design, needs to be completed. In this stage the considerations regarding the design of the attributes and levels will be determined, which will lead to the generation of the design in stage 4. In stage 5, the attributes are assigned to the design columns. This is followed by the step of making choice sets with the alternatives in stage 6. The next step is to randomize the choice sets. The final step, stage 8, is to set up a survey. This includes additional questions on revealed preference and socio demographic characteristics to answer the research question.

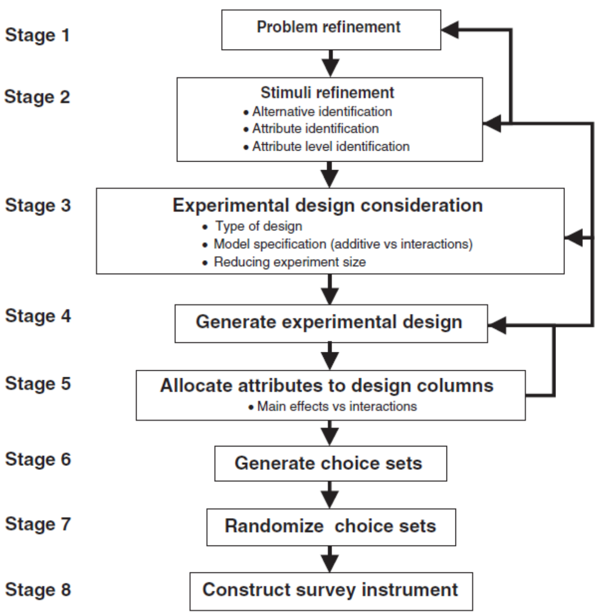

Figure 4 Experimental design process for stated choice experiment Hensher et al., (2015)

3.2.1 Problem refinement (stage 1)

The problem definition is outlined in section 1.2. As explained, some research has already been done on green roofs. However, this has not often been expressed quantitively by means of a willingness to pay. Also, the target group tenants has often been neglected in previous studies. Therefore, this study examines the willingness of tenants to pay for a green roof and which characteristics influence this. Characteristics include both personal characteristics and green roof characteristics. To answer this question, a survey with stated choice experiment is set up with varying green roof characteristics. Personal characteristics are asked in a different part of the survey.

3.2.2 Stimuli refinement (stage 2)

3.2.2.1 Alternatives

In order to conduct a SCE, alternatives must be developed. To find out how tenants value green roofs, different housing profiles are drawn up in which the roof characteristics vary. These characteristics were identified in the literature study, section 2.3. In the housing profiles, the other housing characteristics remain the same as in their current situation, such as housing type, size, year of construction, location, number of rooms, outdoor space, maintenance status. By only varying the attributes of green roofs and leaving other characteristics equal to the current situation, a decision maker will not be biased in his or her choice. The green roof attributes with their levels are explained below.

3.2.2.2 Attributes

<u>Own roof type</u>

Section 2.1 shows that there are intensive and extensive green roofs. These types of roofs differ in soil thickness and type of planting. As a result, the different roofs also have different environmental and personal benefits. In reality, there is also a variant between these types of roofs, namely semi-intensive roofs. Different types of roofs could also be combined. In order to keep things clear for the decision maker, it has been decided to only use a fully extensive, a fully intensive green roof and a regular bitumen roof as levels within this attribute. To clearly communicate the advantages of the various types of roofs to the decision maker, a 3-minute video has been made that explains the benefits. In the literature study, section 2.2, the benefits of green roofs were described. The benefits that relate to tenants are included in the explanation video and are listed in Table 3.

.

Table 3 Green roof benefit included in explanation video

	Extensive green roof	Intensive green roof
Environmental benefits		
Flood risk	Approximately 30% less water discharged to sewer, which reduces the risk of flooding	Approximately 50% less water discharged to sewer, which reduces the risk of flooding
Biodiversity	More biodiversity /animal species (butterflies, bees, birds) in cities.	
Outdoor temperature	The outdoor temperature on hot days in cities can be reduced with 2°C	
Air pollutions	Minimum reduction of air pollution	Capture up to 200 gr of particulate matter per m2 / some reduction in air pollution
Environmental noise	3dB less sound reflection outside	7dB less sound reflection outside
Personal benefits		
Interior noise	Medium noise reduction, 5 dB lower than a regular roof	High noise reduction, 10 dB lower than a regular roof
Thermal comfort	Medium thermal comfort on top floor, 2°C cooler in summer and 1°C warmer in winter than a regular roof.	Good thermal comfort on top floor, 4°C cooler in summer and 2°C warmer in winter than a regular roof.

Accessibility of roof

The literature study in section 2.3.1 concludes that people value a green roof that they can stay on more highly than a roof that is not accessible. For this reason, the attribute 'accessibility' of the roof has been included as an attribute. The levels of this attribute are 'no access to the roof' and 'access to the roof, you can access and stay on the roof in a similar way to a balcony'. Whether the roof is private or shared with other residents depends on the current situation of the decision-maker. If the whole house is private, like in a terraced house, the roof is private too. If the decision-maker lives in a multi-tenant building, he shares the roof with other tenants.

Roof view

Views of greenery yield a higher willingness to pay according to various studies, see literature study section 2.3.2. Therefore, the type of roof the decision maker has a view on is included as an attribute. Many variations can be made in the type of plants for a roof. However, it was decided to keep the variety low and to vary the type of roof that can be viewed at three levels: regular bitumen roof, extensive roof with low plants such as sedum and moss and an intensive roof with higher plants such as shrubs. In the experiment, the decision-maker has to imagine that he/she has a view of another roof from his home. In order to visualise this, images have been made of the view on a bitumen, extensive and intensive green roof. The advantage of visual stimuli over verbal descriptions is that it is less prone to variation due to individual interpretations (Louviere et al., 1987). The images are of both views of another building and views of sheds so that the decision-maker can properly indicate his current situation, see Figure 5 Images of roof type levels.

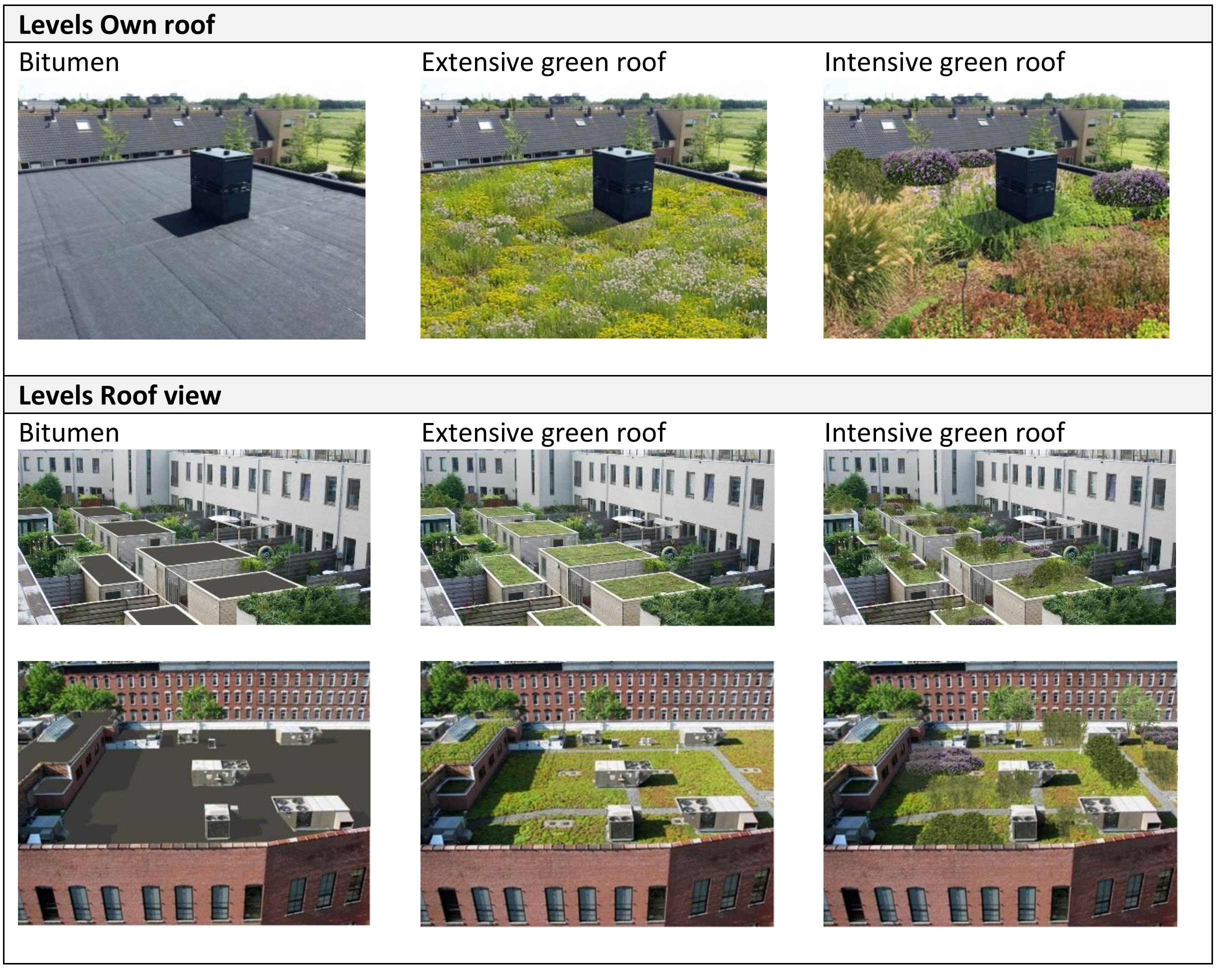

Figure 5 Images of roof type levels

<u>Price</u>

In order to measure the willingness to pay, a price is linked to the list of attributes. The choice was made not to use an exact price, but a relative rent increase. By using a relative rent increase, the alternatives are more in line with the choices within the respondent's reach. A fixed amount would not give an equal sacrifice due to the income difference of decision makers.

To determine the levels for this attribute, the research of (Teotónio et al., 2020) was used. In their research on the WTP for green roofs and facades, they use a relative increase of the monthly rent or bank mortgage. This increase is divided over six levels; 0%, 0-2.5%, 2.6%-5%, 5.1%-7.5%, 7.7%-10% and 10% or higher. A normal distribution can be seen in the choices made by the respondents over the various levels. The maximum frequency that a level is chosen is 28.6% and a minimum of 5.3% for an accessible green roof. For this reason, it is assumed that a price difference between 0% and 10% is acceptable. For this study, four levels are preferred so that fewer alternatives need to be designed. In addition, an exact percentage is used instead of a percentage range. The four levels are '0% rent increase', '2.5% rent increase', '5% rent increase' and '10% rent increase'. Table 4 shows all attributes with the levels who are used for the SCE.

Table 4 Attributes and levels SCE

Attributes	Levels	
Own roof type	0	Bitumen
	1	Extensive
	2	Intensive
Access	0	No access
	1	Access
View	0	Bitumen
	1	Extensive
	2	Intensive
Price	0	0% rent increase
	1	2.5% rent increase
	2	5% rent increase
	3	10% rent increase

3.2.3 Experimental design (stage 3, 4 and 5)

The experimental design can be further elaborated with the selected attributes and corresponding levels. With the four attributes and their levels in Table 4Attributes and levels SCE there are 72 possible combinations for a full factorial design. In order to test all these possibilities, many respondents are needed. Therefore, a fractional factorial design was chosen. Sixteen alternatives, also called profiles, have been constructed using orthogonal main-effect plans from Addelman (1962) (see Table 5). This method allows the estimation of all main effects of a factorial arrangement without correlation, when the interactions are negligible (Addelman, 1962). This assumption is mostly reasonable because main effects explain the largest amount of variance in response data (Hensher et al., 2015; Kemperman, 2000).

Table 5 Profiles with attributes

Profiles	Own roof type	Access	View	Price
1	0	0	0	0
2	1	0	2	0
3	2	1	1	0
4	1	1	1	0
5	1	1	1	1
6	0	1	1	1
7	1	0	2	1
8	2	0	0	1
9	2	1	2	2
10	1	1	0	2
11	0	0	1	2
12	1	0	1	2
13	1	0	1	3
14	2	0	1	3
15	1	1	0	3
16	0	1	2	3

3.2.4 Choice sets and Randomization (stage 6 and 7)

The 16 profiles can be divided into 8 choice sets with a choice between 2 profiles. In this way, every decision maker gets to see all the alternatives. In addition to the two houses alternatives in the choice set, a neither alternative is given. To prevent the choice for a dominant alternative within a choice set, 3 different blocks have been made with the same profiles but a different combination of profiles in a choice set. With this, the order of the visible profiles is also different in each block. Decision makers will see one of the three blocks. Which block a decision maker will see, is chosen randomly. An overview of the choice sets is visible in Appendix I.

3.2.5 Survey development (stage 8)

The questionnaire is developed in LimeSurvey. The survey is divided into five parts. The first part contains questions about the current living situation in order to measure the reference dependency. In the second part, statements are set up to measure the environmental attitude of a respondent. Then, the respondent is shown a video about extensive and intensive green roofs and their advantages. After this, questions were asked about green roofs. The fourth part of the survey is the SCE as described in this chapter. Finally, personal characteristics of the respondent are asked. In the following paragraphs, the questions are further explained. The complete survey can be seen in Appendix II. The survey was conducted in both English and Dutch to have a greater audience in the Netherlands, and by doing so, not neglecting non-Dutch speaking inhabitants. The survey link was shared by housing associations and a commercial landlord with their tenants. In addition, the survey was distributed within the researcher's own network. Respondents were able to change language in the menu at all times. The survey started with a short introduction to the context of the research, followed by an ethical introduction Current living situation.

The survey starts with the question if and from whom the respondent rents a house. This question is used to check whether there is a relationship in the WTP with the type of landlord. By knowing how much rent a respondent is paying, the percentage rent increase he is willing to pay can be converted into an amount in Euros. This question also examines whether there is a relationship between the current rent and the WTP. The question 'In what kind of dwelling do you live in?' is used to examine whether there is a link between the type of dwelling and the WTP. Respondents are then asked whether they have outdoor space. A distinction is made between a garden and a balcony that can be accessed either privately or communally. This enables checking the assumption that people who have less garden space value an additional outdoor space more highly. Green roofs have an internal thermal and noise level only on the top floor. The question 'Do you live on the top floor of the building (directly under the roof)?' is used to check whether people who experience this extra comfort are willing to pay more for a green roof. Some studies found significant results between a green environment and WTP. Therefore, this study looks at whether there is a link between the urbanity in which a respondent lives and WTP. To know the urbanity, the 6-digit zip code of a respondent is asked. CBS has linked zip codes to the degree of urbanization by means of 5 scales. The first scale is 'very urban' (surrounding address density of 2500 or more addresses/km^2) and the fifth scale is 'non-urban' (surrounding address density of less than 500 addresses/km^2) (Centraal Bureau voor de Statistiek, 2019). The last question of this section examines how satisfied respondents are with their current living situation. The satisfaction is divided into 5 elements; nature in your current street, private or shared garden/balcony, temperature in your home, the energy consumption of your home and sound insulation of your current dwelling. The respondents could indicate their satisfaction with a 5-point Likert scale from very satisfied to very dissatisfied. The assumption that people who are dissatisfied would be willing to pay more for improvements can be checked with this.

3.2.5.1 Environmental attitude

The literature section 2.4.2 shows that there is a higher WTP with a pro environmental attitude. Therefore, this will also be checked for this study. The revised New Environmental Paradigm (NEP) Scale was used to measure environmental attitude (Dunlap et al., 2000). Dunlap and Van Liere's NEP Scale, published in 1978, has become a widely used measure of pro-environmental orientation. In 2000, there is a revised NEP Scale designed to improve upon the original one in several respects. It taps a wider range of facets of an ecological worldview, it offers a balanced set of pro- and anti-NEP items, and it avoids outmoded terminology. The revised NEP Scale consists of 15 statements. Respondents choose the extent to which they agree with the statements by using a 5-point Likert scale from strongly disagree to strongly agree. Of the 15 statements, the sum score will be calculated. This total score indicates how pro-environmental a respondent is.

3.2.5.2 Green roofs and current situation

After a three-minute video explaining green roofs, there are questions about green roofs. First of all, the survey asked how much knowledge of green roofs there was prior to the survey. This allows us to check whether there is indeed a link between the existing knowledge and the WTP, which should be the case according to the literature, section 2.4.1. The following questions focus on green roofs in the respondent's current situation. By knowing whether the respondent has a green roof, has access to it and looks out on a green roof, the loss aversion can be measured. It can also be examined whether people who have experience with a green roof value it more highly than people without a green roof.

3.2.5.3 Personal characteristics

As a final part of the survey, after the choice experiment, a number of personal characteristics that also emerge from the literature are asked. The questions examine the relationship between gender, age, education level, household composition and income with the WTP.

3.2.6 Pre-testing

During the development of the survey, multiple versions were made to focus on clarity and readability. After the conceptual version was completed in LimeSurvey, a test was completed by the supervisors, a strategist of a housing association, close relatives and friends. Through a diverse group of people, different types of errors could be tackled. First of all, words have been simplified so that everyone can understand the survey. Readability was also optimised. Some questions that were not clear have been better described. It has also been checked that the mobile version works correctly. A smaller group tested the survey for a second time and after there were no more comments, the survey was ready for distribution.

3.2.7 Privacy

In the survey the data collection is done anonymously, no data collected is traceable to the respondent. At the beginning of the survey, a privacy statement was presented to the respondent. Without acceptance of this statement continuation to the survey was not possible, as should be incorporated according to the approval conditions of the Ethics Committee of the TU/e. Explanations regarding data collection and data saving were presented and respondents were made aware of the publication of results in the thesis. A respondent was given a random number ID which was not traceable. Further, date of completion was added as well. Because of the limited amount of requested personal data, neither a special procedure regarding ethics approval, nor an extensive data management was necessary.

3.2.8 Sample size

The survey needs to achieve a minimum number of respondents before it is suitable for accurate data analysis. There are multiple approaches to calculate the sample size for a choice experiment. Most calculations are using a rule of thumb formula. In the research of Orme (1998) the minimum sample size is calculated with the following formula where (n) is the number of respondents, (t) is the number of tasks, (a) is number of alternatives per task (excluding the none alternative), and (c) is the number of analysis cells (Orme, 1998).

$$\frac{nta}{c} > 500 \tag{3.1}$$

The number of tasks (t) for one respondent has been set on 8 and the number of alternatives (a) in a choice setting is 2. The number of analysis cells (c) is the maximum number of levels in an attribute, which is 4. This calculation suggests that there are at least 125 respondents needed.

3.2.9 Noise reduction protocol

For various reasons, the data generated by the survey may be unusable. A number of rules have been drawn up to ensure that only carefully completed surveys are included in the research. It is mentioned beforehand that the survey is only for people who rent. This is checked in the first question of the survey. Those who fill in that they do not rent are thanked and sent to the end page. Only fully completed surveys are included. In the survey, every question is mandatory, which reduces the amount of missing values. Instead, the option "not prefer to answer" was given to the respondent at the questions. After the export of the survey, the first part of the noise reduction protocol was to check for missing values. Secondly, a check was done for the outliers in the responses. The main focus of noise reduction was to check for 'no preference', neutral response, or answers with the same alternative in every question. Also, an age check was applied, ages below 18 years old were eliminated from the data due to relevance issues. Finally, the time people took to complete the survey was taken into account. It is assumed that if the time is less than 4 minutes, the respondent did not fill out the survey attentively enough. Therefore, respondents who completed the survey within 4 minutes are deleted from the data set.

3.3 Data analysis

For the analysis of the survey data, several methods were applied. At first, the data needed to be coded. After this, analysis of descriptive statistics followed. Two models were used to analyse the choice data, a Multinomial logit model and a Mixed logit model.

3.3.1 Coding

Effect coding is applied for the variables, because it has the advantage that nonlinear effects in the attributes may be measured. Also, there is no perfect confounding of the base attribute level with the grand average of the utility function, which does occur with dummy coding (Hensher et al., 2015). The number of new variables created, is equal to the number of attribute levels of the attribute, minus one. The attributes differ between 2 and 4 levels. So the maximum amount of dummy variables is 3, see Table 6.

Table 6 Attribute levels and effect coding

Attributes	ID	Level	X_a	X_b	X_c
Own roof type	0	Bitumen	1	0	
	1	Extensive	0	1	
	2	Intensive	-1	-1	
Access	0	No access	1		
	1	Access	-1		
View	0	Bitumen	1	0	
	1	Extensive	0	1	
	2	Intensive	-1	-1	
Price	0	0% rent increase	1	0	0
	1	2.5% rent increase	0	1	0
	2	5% rent increase	0	0	1
	3	10% rent increase	-1	-1	-1

3.3.2 Descriptive analysis

It is important to know if the research sample is a representative group. An unrepresentative research sample can lead to biased results. It is best to compare the research sample with tenants in the Netherlands. However, there is only information available on the total population of the Netherlands. Therefore, the socio-demographic questions of the survey will be statistically compared with the CBS data of the total Dutch population (CBS, 2021). In addition, the relationships between different personal characteristics will be examined by means of cross-tabs in SPSS.

3.3.3 Choice analysis

Discrete choice models aim to describe individuals' choices between a choice set containing a number of alternatives (Train, 2009). In order to understand and predict this choice behaviour, the variability in reasoning between individuals should be captured in the data collected, in the SCE. This variability is also referred to as heterogeneity. In general individuals derive a certain satisfaction from the attributes associated with an alternative. This satisfaction is more commonly referred to as utility and it is assumed that an individual will choose the alternative from a choice set that provides the individual with the highest level of utility from its attributes. This is captured in the generally assumed behavioral rule 'utility-maximizing behavior', which believes that an individual will act as if they are maximizing their overall utility when choosing an alternative (Hensher et al., 2015).

The goal of discrete choice modelling is the identification of the contribution of a certain attribute to the overall level of utility associated with every alternative in a choice set. The overall utility of an alternative is represented by U_{iq}, in which i represents a specific alternative, and q an individual. It should be noted that this is the utility associated with an alternative relative to the utility of another alternative in the same choice set. As mentioned previously, it is aimed to capture as much heterogeneity in the data as possible, but in reality a part will stay unobserved (Hensher et al., 2015). Actually, this is the theory underpinning the Random Utility Model, in which V_{iq} represents the structural utility (observed) and ε_{iq} the random utility (unobserved) (Hensher et al., 2015; Kemperman, 2000):

$$U_{iq} = V_{iq} + \varepsilon_{iq} \quad (3.2)$$

U_{iq} = $Utility\ value\ of\ alternative\ i\ for\ respondent\ q$
V_{iq} = $Structual\ utility\ (observed)\ of\ alternative\ i\ for\ respondent\ q$
ε_{iq} = $Random\ utility\ (onobserved)\ of\ alternative\ i\ for\ respondent\ q$

Since the unobserved utility is a stochastic error component, the utility is mainly calculated by the structural observed component. The structural utility can be defined as the sum of the parameters representing the weight β of attribute n for alternative i multiplied by the score of alternative i on attribute n for individual q as stated in the following formula: (Hensher et al., 2015):

$$V_{iq} = \sum_{n} \beta_{in} * X_{inq} \quad (3.3)$$

V_{iq} = $Structual\ utility\ (observed)\ of\ alternative\ i\ for\ respondent\ q$
β_{in} = $Weight\ of\ attribute\ n\ for\ alternative\ i$
X_{inq} = $Score\ of\ alternative\ i\ on\ attribute\ n\ for\ individual\ q$

3.3.4 Multinomial logit

If the random utility components ε_{iq} are assumed to be Independently and Identically and Distributed (IID) following a double exponential (Gumbel) distribution, this results in the most common and easy to use choice model; the multinomial logit (MNL) model (Hensher et al., 2015). This means that the unobserved terms are not correlated (Independent) and they have the same variance (Identical) (Train, 2009). The model calculates the probability that individual q will choose alternative i from the choice set of J alternatives. The 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. The result consists of a probability between 0 and 1. The formula which incorporates the calculation of the probability P_{iq} to choose an alternative is as follows (Hensher et al., 2015):

$$P_{iq} = \frac{exp(v_{iq})}{\sum_{j=1}^{J} exp(V_{jq})} \quad (3.4)$$

P_{iq} = $Probability\ of\ alternative\ i\ for\ individual\ q$
V_{iq} = $Observed\ component\ of\ aternative\ i\ for\ individual\ q$
V_{jq} = $Observed\ component\ of\ the\ number\ of\ aternatives\ in\ the\ choiceset\ for\ individual\ q$

3.3.4.1 The Log-Likelihood ratio test

Before the results can be evaluated, the model performance must be checked. The McFadden Rho Squared tests will be performed to prove the level of performance. The test is using the log-likelihood value to determine the model performance. The MNL model assumes that the choice observations are independent over both decision makers and choice situations. With this assumption the log-likelihood can be estimated (by software packages) using the formula (Hensher et al., 2015):

$$LL(\beta) = \sum_{q}^{N} \sum_{i} y_{iq} * ln(P_{iq}) \quad (3.5)$$

$LL(\beta)$ $= Log - likelihood\ with\ estimated\ parameters\ (\beta)$
N $= total\ number\ of\ choices\ made\ in\ model$
i $= Alternative$
Y_{iq} $= Choice\ made\ by\ a\ individual\ q\ for\ an\ alternative\ i\ (value\ 1\ of\ chosen, 0\ is\ not\ chosen)$
P_{iq} $= Probability\ of\ alternative\ i\ for\ individual\ q$
Ln $= Natural\ Logarithm$

In the base model there are three choice possibilities (House 1, House 2 and neither). Therefore LL(0) can be calculated by multiplying the number of choices with ln(1/3).

3.3.4.2 Goodness of fit: Mc Fadden Rho Square Test

Total fit of the model can be determined by McFadden's ρ^2 formula. To calculate the goodness of fit, the log-likelihood of the estimated model function needs to be calculated and divided by the loglikelihood of the null model. Finally, the result subtracted from 1 for the ρ^2. According to Hensher et al (2005) values for ρ^2 values between the 0.2 and 0.4 represent sufficient goodness of fit. Values higher than 0.5 are considered as unrealistic for behavioural experiments.

$$\rho^2 = 1 - \frac{LL(B)}{LL(0)} \quad (3.6)$$

ρ^2 $= Rho\ square$
$LL(\beta)$ $= Log - likelihood\ of\ estimated\ model$
$LL(0)$ $= Log - likelihood\ of\ null\ model$

3.3.5 Interaction coefficients

To determine gains and losses, interaction coefficients are included in the model. In the survey, questions are asked about the respondents' current situation. These characteristics are multiplied by the constants and the related attribute to measure gains and losses. The effect of personal characteristics is also compared with interaction coefficients. Personal characteristics are multiplied by the attribute price to determine the interaction coefficient.

3.3.6 Mixed logit

The random parameters or mixed logit (ML) model differs from the MNL model in the assumption that there is a taste variation among individuals. ML models will consider taste heterogeneity by estimating the standard deviation of the attribute parameters. Also, ML takes panel effects into account which implies that the choices that individuals make can be correlated since all individuals have multiple observations

ML models will account for the correlations across the choice of an individual by estimating all sequences of choices made by one respondent (Train, 2009). In general, a higher number of repetitions in ML will result in a higher accuracy of the results and a higher explanation power (stronger utility scores).

$$P(Choice_{qt} = i|x_{qt,i}, z_q, v_q) = \frac{exp(v_{qt,i})}{\sum_{j=1}^{J_{qt}} exp(V_{qt,j})} \quad (3.7)$$

Where, $v_{qt,i} = \beta_q{}' x_{qt,j}$ and $\beta_q = \beta + \Delta z_q + \Gamma \text{v}_q$

$p \ = Probability$

$x_{qt,j} \ = The\ N\ attributes\ of\ alternative\ j\ in\ choice\ set\ t\ for\ individual\ q$

$J_{qt} = \ The\ J\ alternatives\ in\ choice\ set\ t\ for\ individuals\ q$

$z_q = set\ of\ M\ characteristics\ of\ indivdual\ q\ that\ infuence\ the\ mean\ of\ that\ variation\ parameters$

$V_q \ = a\ vector\ of\ K\ random\ variables\ with\ zero\ means\ and\ known\ varianceas\ and\ zero\ covariances$

3.3.7 Willingness to pay

A SCE 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 an individual. By doing this, the preferences of the individuals 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 different attributes of green roofs. According to (Hensher et al., 2015), the Willingness to Pay for attribute n can be calculated as follows:

$$WTP_n = \frac{\beta_n}{\beta_c} \quad (3.8)$$

$WTP_n \ = The\ willingness\ to\ pay\ for\ attribute\ n$

$\beta_n = The\ marginal\ utility\ for\ attribute\ n$

$\beta_c = The\ marginal\ utility\ for\ the\ attribute\ of\ cost$

3.4 Conclusion

In this chapter, the methodology of this study is explained. First of all, it is explained which methods are available. It is concluded that a stated choice experiment is suitable for this study. The SCE is explained in the 8 stages according to the theory of (Hensher et al., 2015). The selection of attributes and levels are as follows; Own roof type (bitumen - extensive green roof - intensive green roof), accessibility (no access, access), view (bitumen - extensive green roof - intensive green roof) and price (0% rent increase - 2.5% rent increase - 5% rent increase - 10% rent increase). With a fractional factorial design, 16 profiles were drawn up. Each respondent was shown all 16 profiles by means of 8 choice sets with two housing choices and one neither option. To prevent the choice for a dominant alternative within a choice set, 3 different blocks have been made with the same profiles but a different combination of profiles in a choice set. In LimeSurvey, the questionnaire was created and, in addition to the choice experiment, questions were asked about the current living situation, environmental attitude, green roofs and current situation, and personal characteristics.

The personal questions will be analysed using descriptive statistics, but also with cross-tabs in order to determine differences in choice based upon a identified group. The data will be analysed with a multinomial logit model and a mixed multinomial logit model. From the coefficients the willingness to pay can be determined. With an interactive model gains and losses and personal characteristics logistic will be analysed. The gathered data and the results of the analyses are discussed in the next chapter.

4 Results

In this chapter the way in which the questionnaires were administered and the results of the analyses will be discussed. The first section describes the response of the survey. The second part explains the description of the sample. Also, the sample will be discussed regarding socio-demographic characteristics and whether the sample is representative for the Dutch population. Relationships between different personal characteristics will be discussed. After this section a description of the results of the Multinomial Logit model and the Mixed Logit model will be given. Finally, the results of this study are compared with the outcomes of existing literature.

4.1 Data collection

In order to determine tenants' willingness to pay for green roofs, a survey was drawn up with an SCE. The data collection took place between April 15th 2021 and May 27th 2021. Multiple channels were used to distribute the survey in order to reach as many tenants as possible. The first way was to share the link to the survey in the online newsletter of May of the housing association Volkshuisvesting Arnhem. This newsletter reached circa 8.400 tenants of the housing association. A commercial landlord, Heimsteden, sent a letter to a part of their tenants to fill in the survey. The selected group are 321 tenants with green roofs or where green roofs may be installed. Additionally, the survey was also shared by the distribution of flyers in the area of Eindhoven. The flyer included a QR code and website URL to the online survey. A copy of the flyer can be seen in Appendix III. Finally, 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. A total of 621 people started the questionnaire, and 380 completed the whole questionnaire. Two respondents were deleted, one because he completed the survey under the minimum time limit of 4 minutes and the other because he chose 'neither' all the times when it came to housing preference in the stated choice section. Hence, the data that will be used for the SCE consist of 378 respondents including only tenants.

4.2 Descriptive statistics

4.2.1 Social demographic

The survey provided social-demographic questions to deduce the characteristics of the respondents. The characteristics of all the respondents combined show the sample distribution of the retrieved data, see Table 7. The table also compares the distribution of the respondents with the distribution of the Dutch population. Only tenants were selected for the survey. The data of the Dutch population is about the whole population and not only about tenants. Therefore, the sample is not likely to be representative for the total population. For this reason, no test has been carried out for the representativeness of the sample. However, the distribution of the Dutch population can provide a rough indication of what could be expected.

Table 7 Sample distribution social demographics compared to sample distribution Dutch population

Social demographic		**Freq.**	**%**	Netherlands
Gender	Male	147	38.9	49.7
	Female	228	60.3	50.3
	Neither	3	0.8	
Age	18-29	65	17.2	15.3
	30-44	104	27.5	18.2
	45-64	147	38.9	27.8
	65+	60	15.9	19.5
Education level merged	Low educated	55	14.6	30.1
	Middle educated	101	26.7	36.8
	High educated	211	55.8	31.5
	Other	11	2.9	1.6
Household income per month	Less than €2,000	168	44.4	39.6
	€2,000 - €3,000	94	24.9	34.1
	€3.000 and more	58	15.3	26.2
	No answer	58	15.3	
Household composition	Single-person household without child(ren)	201	53.2	31.1
	Single-person household with child(ren)	32	8.5	7.4
	Multiple-person household without child(ren)	101	26.7	32.6
	Multiple-person household with child(ren)	37	9.8	28.9
	Other	7	1.9	

The first part of Table 8, shows that there is a higher participation rate for women than for men in the collect sample. The percentage of the Dutch population also shows a higher female percentage, but this difference is much smaller than in the sample. The largest age group is 45-64 years with 40%, followed by 30-44 years with 28%. Compared to the Dutch population, the sample group is younger. This could have something to do with the fact that the survey was completed online, which could be more difficult for the older generation. The education level is divided into three categories. The group of low educated includes primary education and high school (VMBO, MAVO). Middle educated includes high school (HAVO, VWO) and Vocational Education (MBO). Applied university (HBO) and university bachelor's/master's degrees belong to the high education category. In the distribution of the Dutch population, a distinction is made between MBO levels. MBO-1 belongs to the low-educated group and MBO-2, MBO-3 and MBO-4 to the middle-educated group. Therefore, the sample population cannot be completely compared to the total Dutch population. What is noticeable is the high percentage of high educated people in the sample size. More than half of the sample size is highly educated, which deviates strongly from the Dutch population. This could give a biased result of the analyses.

For the income distribution of the Dutch population, the annual income divided by 12 months was applied. This does not correspond exactly to the monthly income due to allowances, but is reasonably close. The largest group of the sample population, 44%, earns less than €2,000 per month. This is logical as there is a maximum income limit for social housing and the vast majority of respondents rent their homes from a housing association.

Just over half of the research sample has a single-person household without children. This is almost twice as much as the Dutch population. In the research sample, the category multiple-person household without children is over a quarter of the respondents. In the sample population there are few households with children. Compared to the Dutch population, there are especially few multiple-person households with children in the sample population. In some aspects, the sample seems to correspond well to the Dutch population, but still nothing can be said about the representativeness of the sample because the sample group only contains tenants. This means that the results only apply to this specific sample and cannot be exported to other contexts.

4.2.2 Current dwelling characteristics

In addition to social demographic questions, the survey also included questions about the respondent's current home and surroundings, which are shown in Table 8. 87% of the respondents live in a dwelling owned by a housing association and 13% rent from a commercial landlord. Of the occupied rental properties in the Netherlands, 71% belong to a housing association, which is close to the sample population.

Table 8 Sample distribution current dwelling compared to sample distribution Dutch population

Current dwelling		**Freq.**	**%**	Netherlands
Landlord	Housing association	327	86.5	70.7
	Commercial landlord	51	13.5	29.3
Dwelling type	Flat, apartment, studio	197	52.1	35.9
	Terraced house, (semi-)detached house	169	44.7	64.1
	Private room in a shared dwelling	12	3.2	
Rent price monthly	Below €550	146	38.6	
	Between €550 and €650 euro	124	32.8	
	Between €650 and €750 euro	60	15.9	
	Above €750	47	12.4	
	No answer	1	0.3	
Outdoor space	Garden	191	48.1	
	Balcony or roof terrace	183	46.1	
	No	22	5.8	
Urbanity	Very highly urban	175	46.4	
	Highly urban	147	38.7	
	Moderately urban	49	13.1	
	Little urban	5	1.3	
	Not urban	2	0.5	

Half of the sample population lives in a flat, apartment or studio. A little less than half of the sample lives in a terraced or semi-detached house. In contrast, terraced and semi-detached houses dominate the Dutch housing stock. Only 3% of the sample population lives in a private room in a shared dwelling.

The largest group of tenants pays less than €550 for their home per month. This is followed by the group that pays between €550 and €650. The higher the rent, the smaller the respondent group. This can be explained by the fact that the majority of respondents rent from a housing association, which has a maximum rent for its houses. 48% of the respondents have a private or shared garden and 46% have a private or shared balcony or roof terrace. Only 6% of the sample population has no outdoor spaces. The majority, almost half, of the sample population lives very highly urban. The size of the urbanity groups decreases as urbanity decreases.

4.2.3 Satisfaction current living situation

Satisfaction of the current living situation could influence the WTP for green therefore it is important to measure. Satisfaction with the current living situation has been measured with 5 items, see Figure 6. First of all, the satisfaction about the nature in the current street has been looked at. The largest group, 37%, is satisfied with the nature in their street. On a scale of 1 to 5, the respondents give the nature in the current street a 3.3. Of the respondents 44% are satisfied with their garden or balcony, 25% indicated to be neutral about their garden or balcony. On average, respondents give their garden or balcony a 3.5. The largest group of 30% is dissatisfied with the temperature in their homes. This is also reflected in an average mark of 2.8. The question about satisfaction with energy consumption scores rather neutrally. 32% of the respondents indicate a satisfaction of neutral for the energy consumption of their home. The average score for this question on a scale of 1 to 5 is also very neutral, namely 2.9. Respondents are most dissatisfied with the sound insulation of their current home.30% indicate they are unsatisfied and 23% are very unsatisfied. The average score for this question is 2.5, the lowest of all the satisfaction questions.

The satisfaction questions cannot be combined in a total sum score. If all five questions were to be combined, the reliability would be too low and the Cronbach's alpha would be below 0.7 (Taber, 2018). The last three questions, about the insulation effect of the dwelling, can be combined as the Cronbach's Alpha is 0.74 and therefore reliable.

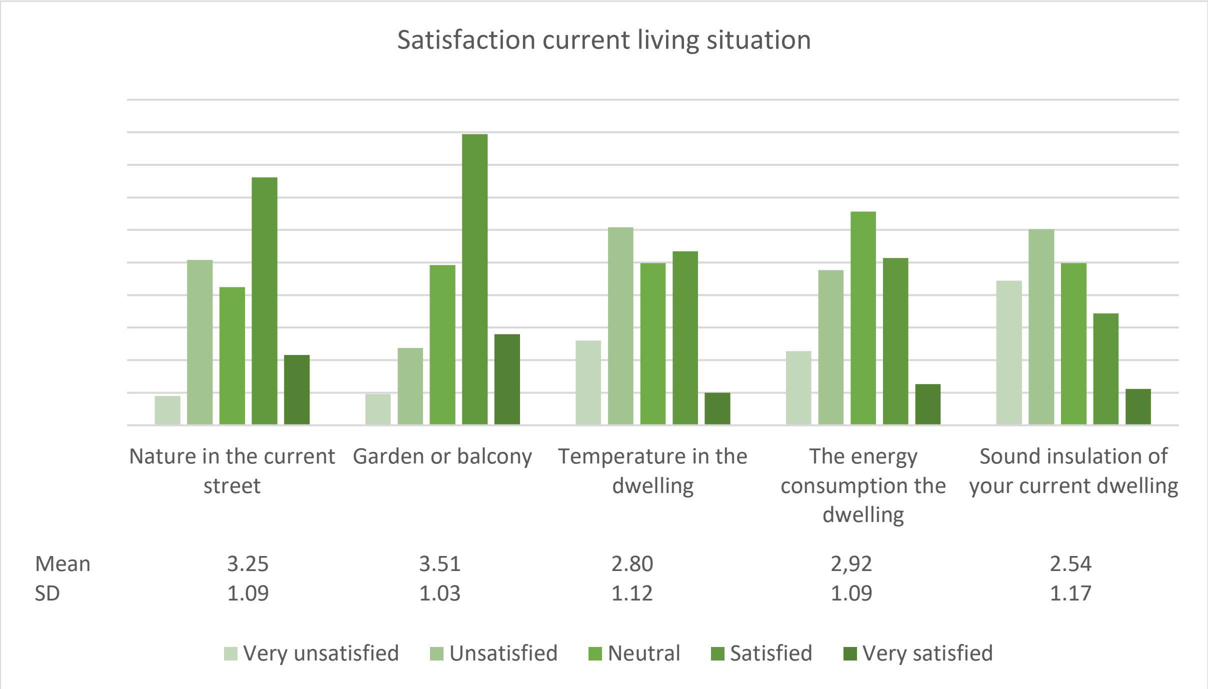

Figure 6 Distribution satisfaction current living situation

4.2.4 Knowledge

The survey asked how familiar respondents were with green roofs prior to the survey. By making a distinction in the knowledge of green roofs, it can be examined whether the assumption that respondents with more knowledge have a higher WTP is correct. The average response to the question of whether respondents were familiar with green roofs was as shown in Figure 7. 37% of the respondents were slightly familiar with green roofs and 36% were moderately familiar with them. Of the respondents, 16% are not familiar at all with green roofs and 11% are very familiar.

The sociodemographic characteristics are stratified to examine whether there are significant differences between groups. Appendix IV shows the complete statistics of the crosstabs. The Chi square test is used to check the significance. The significant characteristics are further explained below.

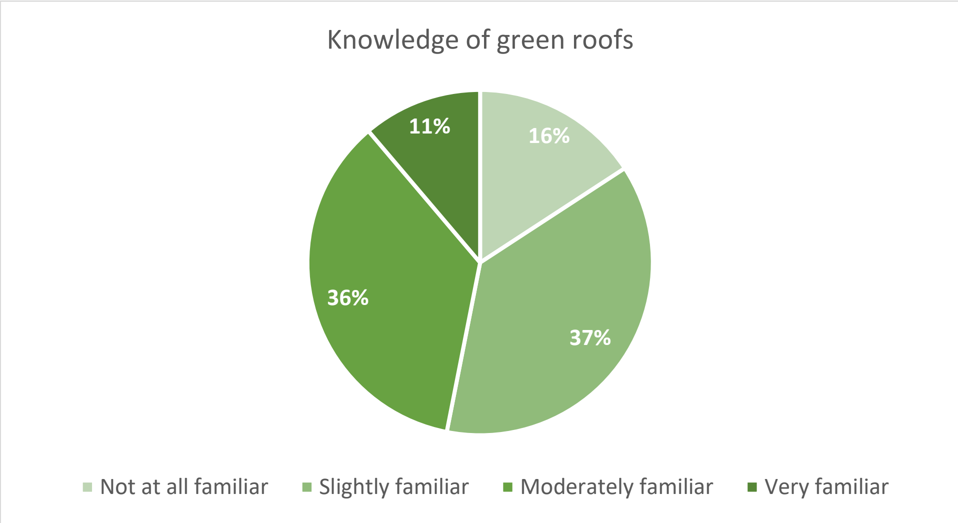

Figure 7 Distribution knowledge of green roofs

The respondents' knowledge of green roofs is compared to the socio-demographic characteristics by creating crosstabs. Appendix IV includes all cross tabs of knowledge of green roofs in relation to age, income, education level, and gender. Chi square tests are used to check if there are differences between groups. There is a relation between knowledge of green roofs and age (X^2=21.1, $p<0.05$).

Figure 8 shows that younger people are more familiar with green roofs. In the age of 18-29 22% of the people are very familiar with green roofs. This is much higher compared to the 65+ group of whom only 5% say they are very familiar with green roofs. A relationship was also established between knowledge and education level (X^2=24.4, $p<0.001$). Figure 9 shows that people with a higher education have more knowledge about green roofs. 15% of high educated people compared to 4% of low educated people are very familiar with green roofs. In addition, relationship was established between knowledge and gender (X^2=21.9, $p<0.001$). Men have more knowledge about green roofs than females, see Figure 10.

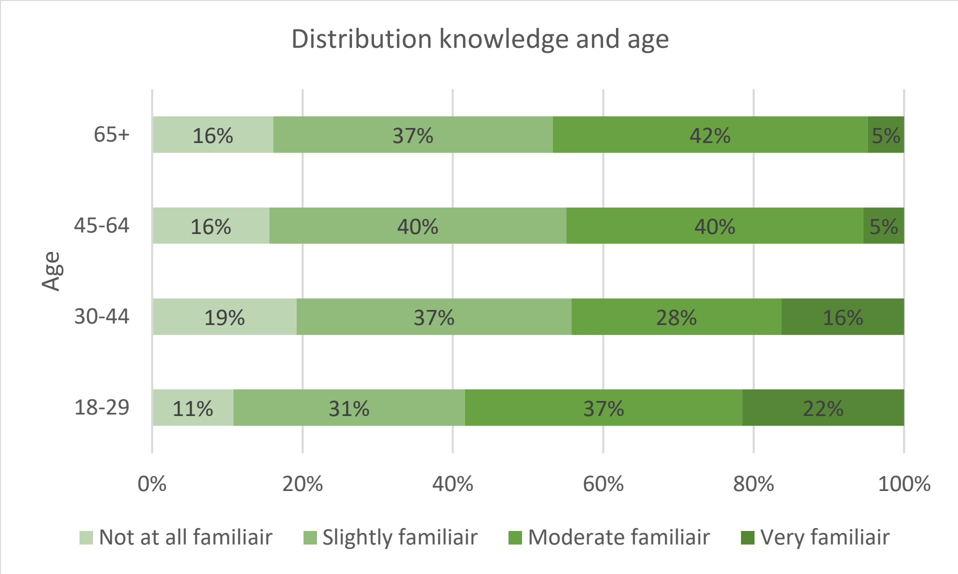

Figure 8 Relationship knowledge and age (P<0.05)

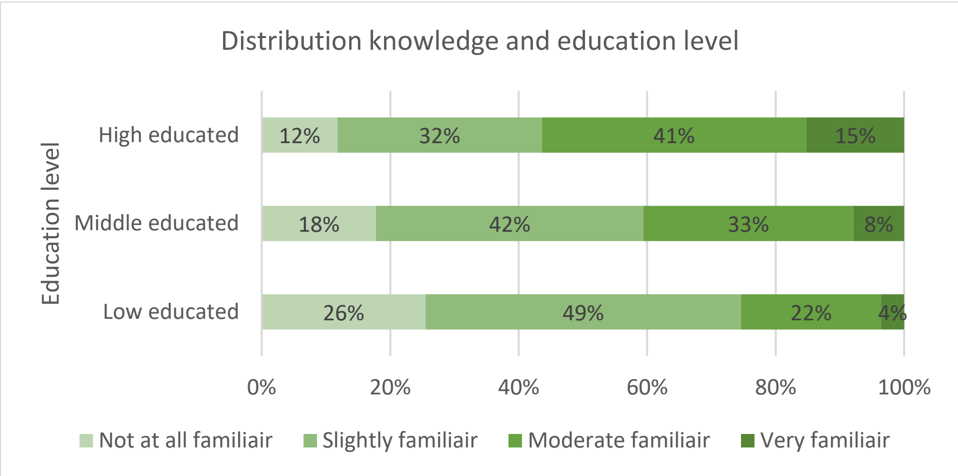

Figure 9 Relationship knowledge and education level (P<0.01)

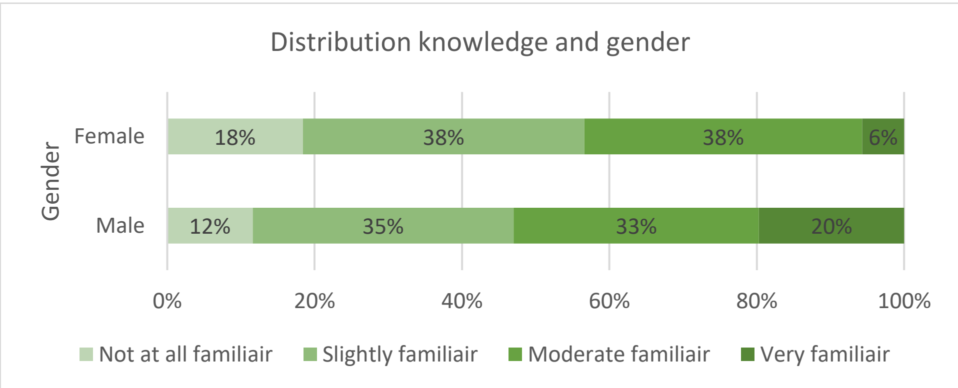

Figure 10 Relationship knowledge and gender (P<0.01)

4.2.5 Environmental attitude

The revised New Ecological Paradigm (NEP) scale of Dulap et al. (2000) was used to measure the environmental attitude of the respondents. The NEP scale contains 15 statements on environmental themes. Agreement with the eight odd-numbered items and disagreement with the seven even-numbered items indicate pro-NEP responses. The answers were recoded so that 'strongly agree' is a pro-NEP answer for all questions. All 15 questions were combined into one attitude scale. The Conbrach's Alpha of 0.80 indicates that merging is possible. The 5-point Likert scale responses of the 15 statements were summed. The average score is 55 with a standard deviation of 7.4. The maximum score given is 75 and the minimum score is 25. Figure 11 shows the distribution of environment.

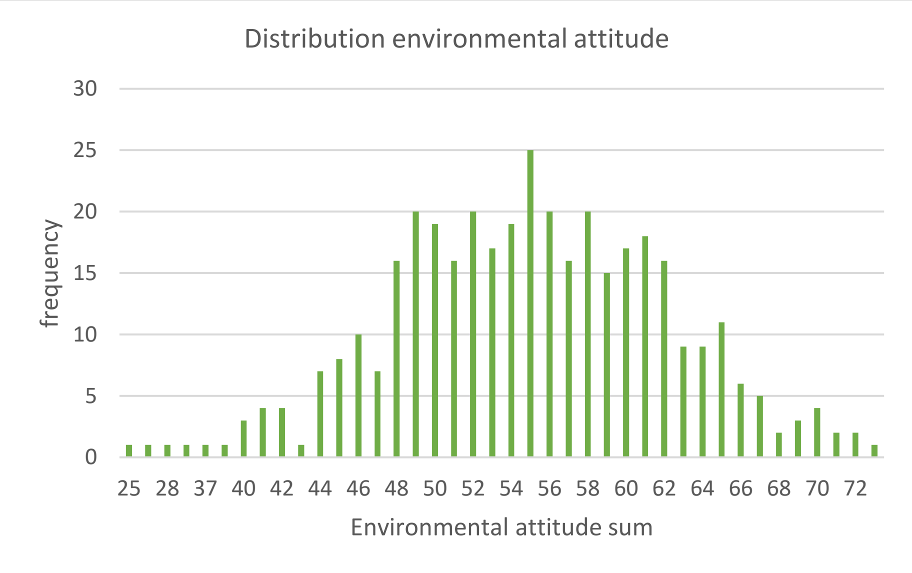

Figure 11 Distribution environmental attitude

The relationship of Environmental attitude Sum with age, income, education level and gender are determined by ANOVA analysis and an independent T-test, see Appendix V. The relationship between environmental attitude and age is significant at 5% level (F = 2.657). Figure 12 shows that older age groups have a higher environmental attitude compared to younger age groups. There is also a significant relationship between environmental attitude and gender found on a 1% significance level (t = -4.049). On average, women care more about the environment than men, see Figure 13.

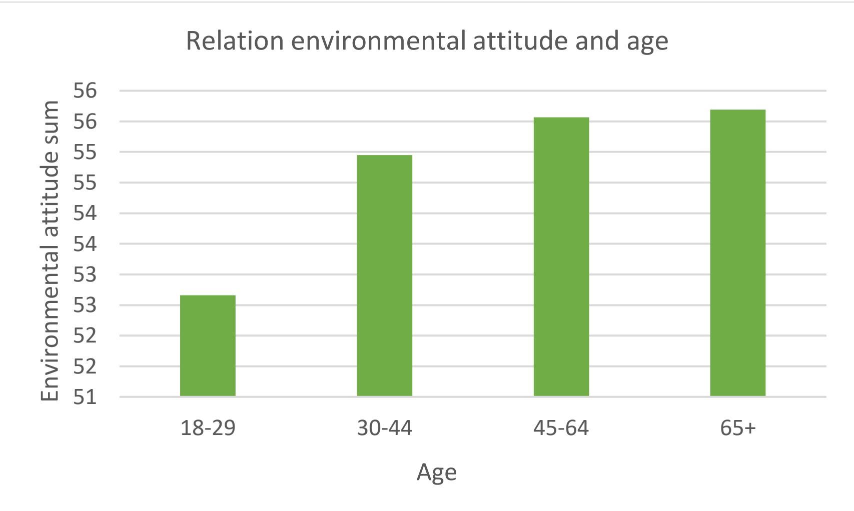

Figure 12 Relationship environmental attitude and age

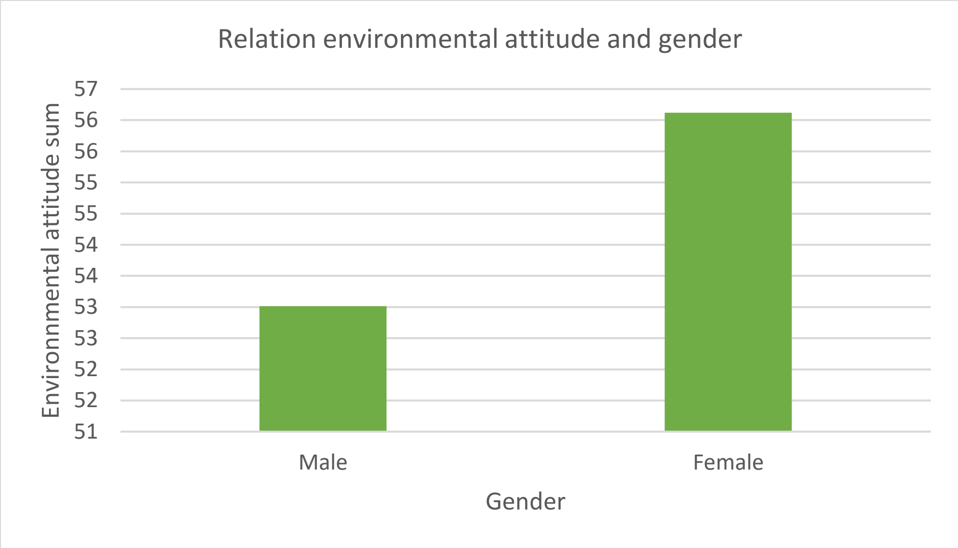

Figure 13 Relationship environmental attitude and gender

4.2.6 Motivation for green roofs

There are various reasons to install green roofs. The motivation can be both personal and environmental, see table 3. In order to find out the importance of the different advantages for tenants, the following question was asked: 'How important are the following characteristics of green roofs to you in the choices you made?'. Respondents could rate 9 characteristics on a 5-point Likert-type scale. Value 1 is very unimportant and value 5 is very important. Appendix VI shows the distribution of the 9 characteristics. The average rating and the standard deviation have been calculated. These are ranked from high to low in

Table 9. The importance of the characteristics are fairly close to each other. The two most important motivations for a green roof for tenants are 'Reducing air pollution' and 'Improved thermal insulation'. Then 'Reducing urban warming in summer' and 'Lower energy consumption' are the most important characteristics. The least important feature is 'Reducing risk of flood'. Results shows that both personal and environmental benefits are important to tenants.

Table 9 Importance characteristics green roofs

Motivation	Mean	SD
Reducing air pollution	4.44	0.649
Improved thermal insulation	4.44	0.661
Reducing urban warming in summer	4.37	0.702
Lower energy consumption	4.37	0.656
View on green	4.31	0.792
Stimulate biodiversity	4.24	0.819
Internal noise reduction	4.08	0.830
Environmental noise reduction	4.04	0.832
Reducing risk of flood	3.75	0.877

4.3 MNL model

To find out how the green roof attributes influence the preferences, a MNL model was estimated with the software program 'Nlogit'. Based on the choices, a model is estimated that illustrates the influence of the attributes type of own roof, accessibility of the own roof, the type of roof that is viewed and the rent price increase. Table 10 Results Multinomial logit model shows the results of the analysis. Due to the used effect coding schemes, only two of three attribute levels are estimated by coefficients. These coefficients are presented in the third column. The third level is calculated by the sum of both levels multiplied by -1. These coefficients represent a value that reflects the part worth utility someone attaches to that attribute level. The mean part worth utility of each attribute is equal to zero. The higher the coefficients the more influence this factor has on the choice (Hensher et al., 2015). There is the possibility that this coefficient represents a negative number, this means that the attribute has a negative effect on the choice made by the respondents. The fourth factor represents the two-tailed significance value, which determines the significance of the attribute value. The complete output of the MNL model is presented in Appendix VII.

Table 10 Results Multinomial logit model

Attributes	Level	Coefficient MNL	Significance	Standard error
Choosing an alternative (const)		0.7126	***	0.055
Own roof type	Bitumen	-0.884	***	0.055
	Extensive	0.347	***	0.043
	Intensive	0.538		
Access	No access	-0.225	***	0.033
	Access	0.225		
View	Bitumen	-0.755	***	0.049
	Extensive	0.200	***	0.044
	Intensive	0.555		
Price	0% rent increase	0.720	***	0.048
	2.5% rent increase	0.251	***	0.048
	5% rent increase	-0.113	**	0.052
	10% rent increase	-0.858		

***, **, * --> Significance at 1%, 5%, 10% level

Furthermore, the performance of the model is shown in Table 11. McFadden's ρ^2 is 0.247. According to Hensher et al. (2015) a value between 0.2 and 0.4 represents a satisfactory fit. Therefore, it could be concluded that this model has a good fit, and functions better compared to the null model.

Table 11 Goodness of fit of the MNL model

Observations	3024
LL(B)	-2502.7
LL(0)	-3322.2
Rho Square	0.247

The ranges of the attributes show the differences between the highest and the lowest part-worth utility of each attribute. Table 12 shows each attribute and the relative importance. A high range of utility shows that the attribute has a high influence on the respondents' choice behaviour. Therefore, the attribute has a high relative importance. The results show that the attribute with the most influence is the price with 33%. The type of roof and view follow closely on the attribute price with a relative importance of 30% and 28% respectively. Whether a roof is accessible or not has a smaller relative importance of only 9%.

Table 12 Ordered range per attribute

Attribute	Range (βxi)	Relative importance
Price	1.578	33%
Own roof type	1.422	30%
View	1.310	28%
Access	0.450	9%

The coefficient of the constant shows that respondents more often chose one of the two roofs, than they chose to select the option neither. Figure 14 shows the utility scores of all the attribute levels in a visual way. The next paragraphs elaborate on the results for each attribute.

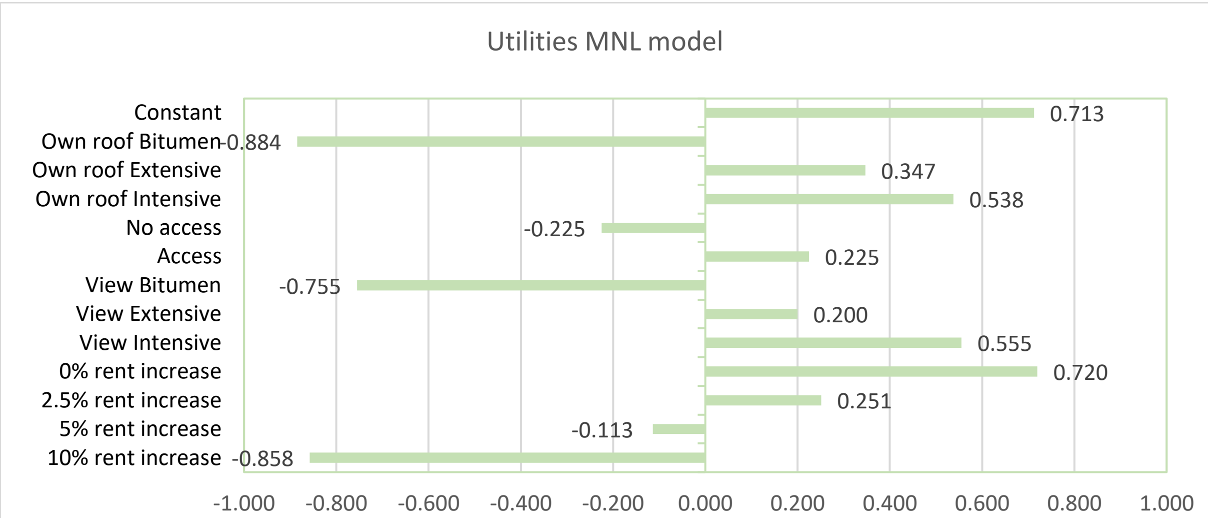

Figure 14 Utilities MNL model

Own roof type

The attribute roof type on own dwelling is divided over 3 levels; bitumen, extensive green roof and intensive green roof. All attributes levels are significant at 1% level. The attribute bitumen shows a negative value of -0.884. The second level, extensive green roof, shows a positive value of 0.347. The last coefficient, intensive green roof, shows a positive value of 0.538. These numbers show that respondents prefer an intensive green roof over the other attributes levels. However, the difference between an intensive and extensive roof is smaller than the difference with a bitumen roof. The attributes bitumen is the least preferred option.

Access

The attribute roof access has two levels: access to the roof and no access to the roof. Both levels are significant at 1% level. The level ‘no access’ shows a negative value of 0.225. The level ‘access’ has a positive coefficient of 0.225. This means that the respondents prefer a roof with access over a roof without access.

View

There are three levels of the attribute view: view of a bitumen roof, extensive green roof and intensive green roof. All attribute levels are significant at 1% level. The level bitumen shows a negative value of -0.755. The second level, extensive green roof, shows a positive value of 0.200. The last coefficient, intensive green roof, shows a positive value of 0.555. These numbers show that respondents prefer a view of an intensive green roof over the other attributes. However, the difference between an intensive and extensive roof is smaller than the difference with a bitumen roof. The level bitumen is the least preferred option.

Rent price
There are 4 levels of rent price increase; 0%, 2.5%, 5% and 10% of the monthly rent. Both the 0% and 2.5% rent increase levels are significant at 1% level. The level 5% rent increase is significant at 5% level which is still fine. The first level, 0% rent increase, has the highest coefficient namely 0.720. As the rent increase rises, the level becomes less preferred. The coefficients for the levels 2.5%, 5% and 10% are 0.251, -0.113 and -0.858 respectively. So people would rather pay nothing, but they are willing to go up to 5% increase, only at 10% does it really become an issue.

A rent increase of 10% is thus clearly least preferred. If coefficients with the rent increase are plotted in a graph, it can be seen that a negative linear line goes from 0% to 10% rent increase. Therefore, one coefficient can be determined for the rent increase. Table 13 shows the MNL model with one price parameter. To do this, the price levels are used as scale instead of categorical levels. The model with one price parameter gives a ρ^2 of 0.246. This is almost the same goodness of fit as the basic model with three price parameters. The substitution coefficient for price is -0.156 per percentage increase in price.

Table 13 MNL model one price coefficient

Attributes	Level	Coefficient MNL	Significance
Constant		1.388	
Own roof type	Bitumen	-0.882	***
	Extensive	0.347	***
	Intensive	0.534	
Access	No access	-0.221	***
	Access	0.221	
View	Bitumen	-0.756	***
	Extensive	0.207	***
	Intensive	0.549	
Price	Rent price increase in %	-0.156	***
ρ^2 = 0.246			

***, **, * --> Significance at 1%, 5%, 10% level

4.3.1 Willingness to pay

The willingness to pay (WTP) for the attributes in the MNL model has been determined. These results represent the average WTP of the complete sample of respondents. As described in section 3.3.7, the WTP for attribute j is calculated as the ratio of the utilities of the attribute of interest and the price, j and c respectively. The β_j is the coefficient difference between the relevant coefficient and the first level of the attribute.

$$WTP_{extensive\ green\ roof\ relative\ to\ bitumen} = \frac{1.229}{0.156} = 7.9 \qquad (4.1)$$

Respondents are willing to pay 7.9% more rent for an extensive green roof compared to a bitumen roof and 9.1% more for an intensive green roof compared to a bitumen roof. Respondents are willing to pay 2.8% more rent for an accessible roof than a non-accessible roof. Finally, respondents are willing to pay 6.2% and 8.3% more rent for views on an extensive and intensive green roof compared to a bitumen roof, respectively. These results indicate that tenants prefer to have a green roof on their own property rather than a view. A roof that is accessible has a slightly higher WTP. For both a view of a roof and own roof type, the WTP for an intensive green roof is slightly higher than for an extensive green roof.

Table 14 Willingness to pay for green roof characteristics

Attributes	Level	β	$\beta_{j\ resp}$	WTP
Price increase in percentage		-0.156		
Own roof type	Bitumen	-0.882		
	Extensive	0.347	1.229	7.9% more than bitumen
	Intensive	0.534	1.416	9.1% more than bitumen
Access	No access	-0.221		
	Access	0.221	0.441	2.8% more than no access
View	Bitumen	-0.756		
	Extensive	0.207	0.963	6.2% more than bitumen
	Intensive	0.549	1.304	8.3% more than bitumen

4.3.2 Interaction model

The survey included questions to measure reference dependence and personal characteristics effects. To measure the effect of these characteristics on the WTP for green roofs, interaction effects of the characteristics are include in in MNL model. The interaction effect are the reference dependence and personal characteristics multiplied with the attributes 'own roof type', 'access' and 'view'. Table 15 shows the interactions. With these interactions, the variation of the Utility for different groups has been calculated, Table 16. With the utilities, the WTP for the groups is determined in Table 17. In the section below, the results of the interaction MNL model are explained.

4.3.3 Reference dependence

To determine gains and losses, interaction parameters are created for the attributes 'own roof type', 'access' and 'view'. The survey revealed that six of the 378 respondents have a green roof and two respondents have access to their green roof. These samples are too small for an interaction effect to be measured for these variables. However, interaction effects were included for the satisfaction with the indoor temperature with the attribute 'own roof type', the type of outdoor space with the attribute 'access' and both the satisfaction with green in the environment and the variable view of a green roof with the attribute 'view'. The interaction effect with the constant was also compared for all these characteristics.

Three interaction effects are significant in the MNL model (see Table 15). The interaction coefficient on the attribute 'own roof type' multiplied with the insulation satisfaction variables is -0.215 and significant at 5% level. This means that respondents who are more satisfied than average with the insulation have a greater preference for a green roof than a bitumen roof. In other words, people who are more than average satisfied with the insulation of their homes are willing to pay around 2% more rent increase for an intensive green than tenants who are less than average satisfied with the insulation of their homes. This is not in line with the reference dependence expectation that people who are less satisfied with the insulation would value a green roof more highly, because for them there are more benefits in terms of the insulation effect of green roofs. Perhaps because they value insulation highly, they have already moved into a home that is better insulated.

The next significant interaction effect is the constant coefficient multiplied by having a garden. The coefficient of -0.550 at a significance level of 1% indicates that people with a garden are more likely to choose the neither alternative. They are more satisfied with their current situation and therefore less likely to choose one of the alternatives. This is in line with the reference dependent theory.

The last significant interaction is the satisfaction with green in current environment multiplied by the attribute view. The coefficient of 0.195 with a significant level of 10% indicates that people who are more satisfied than average with green space in their environment are more likely to choose one of the two roof options rather than the neither option. This is contrary to expectations. The expectation was that those who are less satisfied with green space in their neighbourhood would attach extra value to an alternative with a green roof. An explanation could be that people who find greenery important have moved to a neighborhood with more greenery. Another explanation could be that people who rent and are dissatisfied are more likely to move or do not see this as their future home, thus do not want to invest in their home.

Table 15 Significant interaction parameters for personal characteristics in MNL model

Attributes	Level	Coefficient MNL	Significance
Choosing an alternative (const.)		0.264	
Own roof type	Bitumen	1.236	***
	Extensive	0.354	***
	Intensive	-1.591	
Access	No access	-0.199	***
	Access	0.199	
View	Bitumen	0.859	***
	Extensive	0.244	***
	Intensive	-1.103	
Price	Rent price increase in %	-0.169	***
Reference dependent and personal characteristics interaction			
Own roof type - bitumen * satisfaction insolation		-0.176	*
Constant * garden		-0.616	***
Constant * satisfaction green		0.200	**
Own roof type - bitumen * Environmental attitude		-0.038	***
View - bitumen * Environmental attitude		-0.029	***
Constant * Rent price current dwelling		1.051	**
Own roof type - bitumen * Rent price current dwelling		-0.353	***
View - bitumen * Rent Price current dwelling		-0.615	***
View - extensive * Rent Price current dwelling		0.429	***
Price * Rent price current dwelling		-0.230	***
Price * Urbanity		0.065	***
Access * Landlord		-0.202	*
View extensive* Dwelling type – terraced house		-0.131	*
Price * Dwelling type – terraced house		0.033	**
ρ^2 = 0.274			

***, **, * --> Significance at 1%, 5%, 10% level

Table 16 Utility and WTP interaction MNL model

	Base		**Satisf. Insulation**		**Envirmental attitu.**		**Current rent price**		**Urbanity**		**Landlord type**		**Dwelling type**	
Base level			low satisfaction		Attitude score 55		<€750		High urban		Housing assoc.		Apartment	
Interaction level			High satisfaction		Attitude score 65		>€750		Low urban		Commercial		Terraced house	
	Coeff	WTP	Coeff	WTP	Utility	WTP	Coeff	WTP	Coeff	WTP	Coeff	WTP	Coeff	WTP
Own roof type														
Bitumen	**-0.845**		-1.022		**-1.224**		**-1.199**		-0.845		-0.845		-0.845	
Extensive	**0.354**	-7.1%	0.354	-8.2%	**0.354**	**-9.4%**	**0.354**	**-3.9%**	0.354	-11.6%	0.354	-7.1%	0.354	-8.8%
Intensive	**0.491**	-7.9%	0.667	-10.0%	**0.869**	**-12.4%**	**0.844**	**-5.1%**	0.491	-12.9%	0.491	-7.9%	0.491	-9.8%
Access														
No access	-0.199		-0.199		-0.199		-0.199		-0.199		**-0.401**		-0.199	
Access	0.199	-2.4%	0.199	-2.4%	0.199	-2.4%	0.199	-1.0%	0.199	-3.9%	**0.401**	**-4.8%**	0.199	-2.9%
View														
Bitumen	**-0.751**		-75.1%		**-1.043**		**-1.365**		-0.751		-0.751		**-0.751**	
Extensive	**0.244**	-5.9%	24.4%	-9.6%	**0.244**	**-7.6%**	**0.673**	**-5.1%**	0.244	-9.6%	0.244	-5.9%	**0.113**	**-6.4%**
Intensive	**0.507**	-7.5%	50.7%	-12.2%	**0.799**	**-10.9%**	**0.693**	**-5.2%**	0.507	-12.2%	0.507	-7.5%	**0.637**	**-10.2%**
Price														
per percentage			-0.169		-0.169		**-0.399**		**-0.103**		-0.169		**-0.136**	

Table 17 WTP interaction model

	Base	Satisf. Insulat.	Environ. attitu.	Current rent price	Urbanity	Landlord type	Dwelling type
Base level		Low satisf.	Score 55	<€750	High urban	Housing assoc.	Apartment
Interaction level		High satisf.	Score 65	>€750	Low urban	Commercial	Terr. house
Own roof type							
Bitumen							
Extensive	-7.1%	-8.9%	-9.4%	-3.9%	-11.6%	-7.1%	-8.8%
Intensive	-7.9%	-10.0%	-12.4%	-5.1%	-12.9%	-7.9%	-9.8%
Access							
No access							
Access	-2.4%	-2.4%	-2.4%	-1.0%	-3.9%	-4.8%	-2.9%
View							
Bitumen							
Extensive	-5.9%	-5.9%	-7.6%	-5.1%	-9.6%	-5.9%	-6.4%
Intensive	-7.5%	-7.5%	-10.9%	-5.2%	-12.2%	-7.5%	-10.2%

4.3.4 Personal characteristics interaction

Personal characteristics parameters were set up to examine the interaction with the attributes 'own roof type', 'access', 'view' and 'price', Table 15. The personal variables were added one by one. The characteristics age, gender, income and education level are not added to the model because these variables have a strong relationship with the parameters of knowledge and environmental attitude. A non-significant variable was directly removed from the model and a new variable was added. The characteristics knowledge and dwelling position (directly under the roof or not) where not significant. With the utilities score the WTP is estimated in Table 17.

The environmental attitude score is a scale variable. The average score is 55, therefore this is taken as the base level. To see how respondents with a higher environmental attitude score value green roofs, a score of 65 is used. For the attributes 'own roof type' and 'view', it can be seen that people with a pro environmental attitude have a higher willingness to pay for a green roof compared to respondents with an average environmental score.

For the interaction with current price increase it can be seen that the WTP for a green roof on their own roof and a view of a green roof is around 3% higher among respondents with a rent higher than €750 compared to a rent lower than €750. This can be explained by the fact that the WTP is expressed as a percentage rent increase instead of an absolute price.

Respondents who live in a low urban environment (urbanity score 3-4-5) have a lower utility for price compared to respondents who live in a high urban environment (urbanity score 1-2).

So, respondent with a low urbanity score are less bothered about paying a higher rent for the levels of the attributes. There is no significant parameter for urbanity on the other attributes. Therefore, one cannot speak of a higher WTP of one level compared to another.

The utility for access to the roof is higher among respondents who rent a house from a commercial landlord than from a housing association. This makes that the WTP for a roof with access is 2.4% higher for commercial housing tenants than tenants from housing associations. Finally, it can be concluded that people with a terraced house have a higher WTP for a green roof on their own home and a view of a green roof. This can be explained by a significant relationship between landlord and income (X^2=19.6, p<0.01). Tenants of a commercial landlord have a higher income. Therefore, they have more to spend for their preferences.

4.4 Mixed logit model

The Random Parameter Mixed Logit (ML) model is estimated to check for taste variation within the sample. For the random parameters, an extra parameter, the standard deviation σ, has to be estimated to express the taste variation. The random parameters are assumed to follow a normal distribution (approximated using 1000 Halton draws), hence for each individual a random value βi is drawn from $N(\beta, \sigma)$ (Hensher et al., 2015). In the first place only one of the levels of an attribute is included as a random parameter in the model. This is because the levels are not independent of each other. The standard deviation of the constant gave an error. Besides, the standard deviation for the attribute own roof type and accessibility were not significant. Therefore they are excluded in the ML model.

The ρ^2 of the ML model is 0.279 which means that a relatively large part of the variance seems to be explained by the model. Besides, the ML model has a slightly better fit compared to the MNL model. The results of the ML model, Table 18, show that the standard deviations for the element view of extensive (SD=0.701, p<.001) and rent increase (SD=0.149, p<.001) are significant. A small standard deviation suggests that the respondents have similar preferences, while a large standard deviation suggests a lot of taste differences between the respondents. Thus, for this study it may be assumed that the parameters view of a roof and rent vary from one individual to another. It can be concluded that ML model outperforms the MNL model. Figure 15 shows the coefficients and standard deviations of the ML model. The standard deviation of the elements with a random parameter are included as error bars. The error bars run from one standard deviation below the mean to one standard deviation above the mean.

Table 18 Results ML model

Attributes	Level	Coefficient MNL	Significance	Stan. Dev.	Sign
Constant		1.791	***		
Own roof type	Bitumen	1.496	***		
	Extensive	0.389	***		
	Intensive	-1.885			
Access	No access	-0.196	***		
	Access	0.196			
View	Bitumen	0.914	**		
	Extensive	0.322	**	0.701	***
	Intensive	-1.236			
Price	Rent price increase in %	-0.221	***	0.149	***
Reference dependent interaction					
Own roof type - bitumen * satisfaction isolation		-0.200	*		
Constant * garden		-0.684	**		
Constant * satisfaction green		0.227	**		
Own roof type - bitumen * Environment. attitude		-0.043	***		
View - bitumen * Environmental attitude		-0.032	***		
Constant * Rent price current dwelling		1.170	***		
Own roof type - bitumen * Rent price cur dwelling		-0.398	**		
View - bitumen * Rent Price current dwelling		-0.654	***		
View - extensive * Rent Price current dwelling		0.498	**		
Price * Rent price current dwelling		-0.257	***		
Price * Urbanity		0.0796	***		
Access * Landlord		-0.214	**		
View - extensive* Dwelling type - terraced		-0.167	*		
Price * Dwelling type - terraced		0.034	*		

$\rho^2 = 0.279$

***, **, * --> Significance at 1%, 5%, 10% level

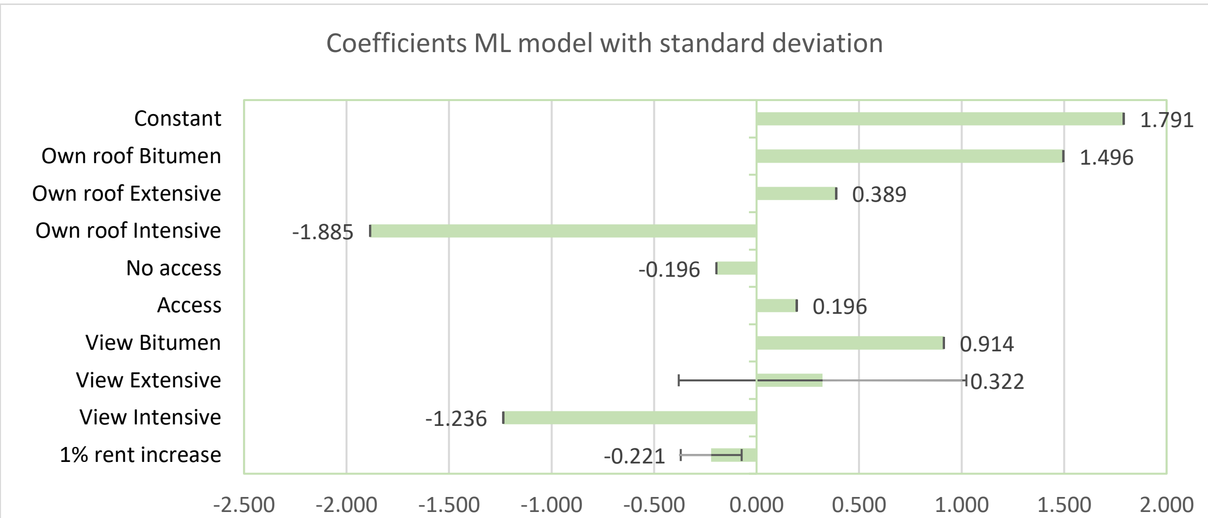

Figure 15 Coefficients ML model with standard deviation

4.5 Discussion

This section discuss the findings and compare them with previous similar studies.

This study found that respondents prefer an intensive green roof on their own roof than an extensive green roof or bitumen roof. It can therefore be assumed that respondents appreciate the higher insulation effect of an intensive green roof. This is in line with other studies on sustainable homes who show that people are willing to pay for better comfort and pleasure (Li et al., 2018), energy cost savings (He et al., 2019; Khan et al., 2020; Zalejska-Jonsson, 2014) and noise reduction (Khan et al., 2020). The study of Teotónio et al. (2020) is one of the few studies that gives a specific number for the WTP for a green roof through a rent or mortgage increase. They found an average WTP for green roofs of 3%. Our results have a higher WTP for a green roof on one's own home. The basic MNL model gives a WTP of 7.9% and 9.1% for an extensive and intensive green roof respectively.This could be explained by the fact that the sample of this study has a relatively high income.

The basic MNL model of this research shows that tenants are willing to pay 2.8% more rent for an accessible roof compared to a roof that has no access. This is a similar outcome to the study by Teotónio et al. (2020). They found significant difference in WTP of a accessible roof over a inaccessible roof of 2%.

This study shows that there is a higher WTP for a green roof compared to a bitumen roof. Similarly, existing literature shows that having a view of a green roof has a positive influence on the WTP compared to no view on a green roof (Fernandez-Cañero et al., 2013; Jungels et al., 2013; Loder, 2014; Teotónio et al., 2020; Vanstockem et al., 2018; White & Gatersleben, 2011). Bianchini & Hewage (2012) mention a property value increase from 2% to 5% for an extensive green roof and from 5% to 8% for an intensive green roof. This cannot be completely compared to a rent increase because property value is a different way of measuring. Nevertheless, the outcomes are quite similar to the results of this study, which found a rent increase of 6.2% and 8.3% for an extensive and intensive green roof respectively.

This study found no relationship with a person's knowledge of green roofs and the WTP. This is consistent with Zhang et al. (2019a) who also found no significant difference. However, several studies such as Jungels et al. (2013) and Teotónio et al. (2020) do show that people with more knowledge about green roofs have a higher support and benefits value. The results of this study show that people who have a pro-environment attitude are more willing to pay for a green roof. This is in line with the literature where Khan et al. (2020) and He et al. (2019) show that there is a relationship between having a pro environmental attitude and the appreciation of sustainable projects. Contradictory results are found with the amount of green spaces in the current environment. This study found no evidence that people living in more urban areas have a higher WTP for green roofs. This is in line with the study of Zhang et al. (2019). They does not reveal any significant difference in the WTP for green roofs mitigating UHI effect in central urban areas and suburban areas. Also Fernandez-Cañero et al. (2013) found no significant relation between interest in installing green roofs and the present environmental background. While on the other side, Teotónio et al. (2020) mention that people are willing to pay more for green roofs in residential areas with few green spaces. This study shows that tenants in a terraced house are more willing to pay for a view on green than those in a flat. This is contrary to the study by Fernandez-Cañero et al. (2013), in which respondents in an apartment value the view of greenery higher.

It can be concluded that the valuation of the attributes from this study are in line with the results of other studies. However, this survey has some overestimates compared to earlier literature. The influence of the personal characteristics on the WTP are not fully in line with previous literature. This can be explained by the fact that the studies have a somewhat different focus.

4.6 Conclusion

This chapter analyse the results of the stated choice experiment for the WTP of green roofs. First of all, the descriptive statistics of the survey sample were examined. The survey concerns only tenants as respondents. However, a comparison was made with the Dutch population. The main deviation of the research sample from the Dutch population is that the sample is relatively higher educated. This can be explained by the fact that higher educated people are more willing to fill in a questionnaire. The satisfaction with the current environment, knowledge and environmental attitude of respondents have been described. The latter two were checked for significant relationships with other personal characteristics using cross-tabs and ANOVA test. The motivation to contribute in green roofs was examined. The results of the survey show that 'Reducing urban warming in summer' and 'Lower energy consumption' are the important green roof characteristic for respondents.

MNL analysis was carried out on the SCE data for the attributes 'own roof type', 'access', 'view' and 'price'. All coefficients are significant and the ρ^2 show a good fit (0.246). The attribute 'price' has the highest relative importance, followed by 'own roof type'. Because the coefficients of the levels for the attribute 'price' are linear, the coefficients of the levels are replaced by one price coefficient. The MNL model was used to calculate the willingness to pay for the attributes. Reference dependence is determined with interaction parameters. A gain has been measured for a bitumen roof compared to a green roof for respondents who have a green roof on their current roof. The influence of personal characteristics on the model has also been determined by means of interaction parameters. Environmental attitude, urbanity, current rent price, gender and income have a significant influence on the attribute 'price'. An ML model has been drawn in order to obtain a better fit and to check for taste variation. The rho square of the model is 0.279. The parameters view of a roof and rent vary from one individual to another. The results of this study match with previous research. Most personal characteristics have an equal influence on the WTP for green roofs as previous literature.

5 Conclusion implications and recommendations

Green roofs can offer a solution to the changing climate in cities. They reduce the risk of flooding, stimulate biodiversity, reduce the urban heat island effect, air pollution and environmental noise. In addition, for residents it offers benefits such as a reduction in interior noise, roof longevity, thermal insulation effect and aesthetic appreciation. However, the implementation of green roofs is proceeding slowly. For large parties, the consideration to install green roofs is often related to the costs and revenues. For housing associations and commercial landlords it is not clear how their tenants value green roofs. This makes it difficult for them to draw up strategies to implement green roofs on their property. Therefore, the objective of this study is to provide insights into how tenants of housing associations and the commercial sector value green roofs through the willingness to pay, identify which personal and green roof characteristics influence this and which motives they have. This resulted in the main research question:

How do green roof characteristics and personal characteristics of tenants influence the WTP for a green roof? What are the motives for WTP?

To answer this question, a literature study and a stated choice experiment are developed. The green roof characteristics that could influence the WTP according to literature are used as attributes in the stated choice experiment.

An extensive literature study was carried out into green roof characteristics and the personal characteristics of tenants that influence the appreciation of a green roof. First of all, the type of roof makes a difference to the valuation. An intensive green roof has greater advantages, as a result of which it can be valued more highly than an extensive green roof. In addition, the accessibility of a green roof can affect the WTP. As a final green roof characteristic, the literature revealed that having a view of various types of green roof affects the WTP.

Literature also shows that various personal characteristics can influence the appreciation of green roofs. First of all, knowledge about the effect of green roofs influences the WTP. In addition, the literature indicates that environmental attitude has an influence. Next, several sources state that the amount of green space in the current environment can have an influence. Finally, literature states that socio-demographic characteristics including gender, age, income and education level can influence the WTP for green roofs. House characteristics can also influence the willingness to pay. For example, the position and type of dwelling in a building affects the benefits experienced by a tenant

Of the green roof characteristics that can have an influence according to literature, four attributes for the SCE have been drawn up: 'own roof type', 'accessibility', 'view of roof' and 'price'. By means of a factorial design 16 alternatives were created with different levels of the attributes. These alternatives were randomly divided over 8 choice sets. Respondents of the survey could choose between two roof types or a neither option. In addition to the SCE, the survey contained personal questions and questions about the living situation to measure the reference dependent behavior. 378 tenants completed the survey. After getting insight in de descriptive statistics a multinomial logit model and a mixed logit model were used.

The survey showed that the benefits 'reduction of air pollution' and 'improved thermal comfort' are most important to the tenants. These are followed by 'reduction of city heating in summer' and 'lower energy consumption'. It can therefore be concluded that both personal and environmental characteristics are important to the tenants. In communicating to tenants, landlords could focus on these benefits.

The results of multinomial logit model show that on average tenants are willing to pay 9.1% more rent for an intensive green roof on their own home compared to a bitumen one. For an extensive green roof, tenants are willing to pay 7.9% more than for a bitumen roof. The second green roof feature that tenants find important is the view. Respondents are willing to pay a rent increase of 8.3% and 6.2% for a view of an intensive and extensive green roof, respectively, compared to a bitumen roof. The valuation for having or not having access to the tenant's roof has the lowest valuation compared to the previously mentioned green roof characteristics. Respondents have a rent increase of 2.8% for an accessible roof compared to a non-accessible roof.

A number of significant reference dependence interactions emerged from the MNL model. The reference dependent theory holds that people evaluate outcomes and express preferences relative to an existing reference point, or status quo. Tenants with a garden are more likely to choose to stay in their current home than to choose one of the roof alternatives. It can be concluded from this that the roof attributes are less important to them. This can be explained by the fact that people with a garden are more satisfied with their current home. In addition, it can be concluded that people who are more satisfied with the greenery in their environment are more likely to choose a roof alternative. Just for one reference dependence effect, a difference in WTP can be measured. People who are above average satisfied with the insulation performance of their home (temperature in the home, energy use of the home and noise insulation of the home) are willing to pay 2% more rent for an intensive roof on their home than people who are below average satisfied with the insulation performance of the home. This contrasts with the reference dependence expectations, as the insulating benefit of a green roof would have a greater effect in homes that are poorly insulated. Therefore, one cannot speak of a gain or a loss.

The influence of personal characteristics was calculated using interaction variables. The characteristics knowledge and dwelling position (directly under the roof or not) have no significant influence on the WTP for a green roof. Tenants with a pro environmental attitude have a higher WTP for a green roof on their own residence and a view on a green roof than people with an average environmental score. This is in line with earlier studies. Tenants with a rent above €750 prefer a lower rent price increase for a green roof compared to tenants with a rent below €750. Tenants living in a low urban environment find the attribute price less important and are therefore willing to pay more for a green roof than tenants living in a high urban environment.

Tenants who rent from a commercial tenant compared to tenants who rent from a housing association have a higher WTP for access to the roof. This can be explained by a significant relationship between landlord and income. Tenants of a commercial landlord have a higher income. Therefore, they have more to spend for their preferences. Finally, it can be concluded that the WTP for a view on a green roof is higher for people living in a terraced house than for people living in a flat.

5.1 Practical implications

Policy makers of housing associations and commercial landlords can use the results of this study to better validate their policies.

The results of this study show that the WTP for a green roof on the dwelling is slightly higher, 7.9-9.1%, than for a view of a green roof, 6.2-8.3%. This indicates that if a decision-maker has to choose between a green roof on the home and a building with a view, such as a shed, the preference will be for a green roof on the home. In both cases there is a slight preference for an intensive green roof compared to an extensive green roof. So, tenants prefer an intensive green roof, but the difference with an extensive green roof is small. Therefore, an extensive green roof can also be a good investment because the installation costs are lower. Indirectly, it could be assumed that the value of a dwelling with a green roof and the surrounding dwellings that have a view on it will increase. However, this should be further supported by a study focusing on property values. The rent increase tenants are willing to pay for an accessible roof compared to a non-accessible roof is 2.8%. So compared to the attributes own roof type and view the accessibility of the roof is the least important attribute. Nevertheless the combination of an accessible green roof gives the highest WTP. For policymakers, this indicates that when considering installing a green roof, making the roof accessible gives a little extra value for tenants.

The right location for a green roof can be chosen from environmental considerations such as places where the chance of flooding is high or where there is a large urban heat island effect. In addition, the results of this research can also be used to specifically target tenant groups to install green roofs in places where the WTP is the highest.

Green roofs are more appreciated by tenants with a pro-environment attitude. However, this characteristic is not clearly identifiable by a landlord. A characteristic that landlords can better identify is the rent price. Tenants who pay over €750 are willing to pay less rent percentage wise for a green roof than tenants who pay less than €750. From this it could be argued that a fixed amount for a green roof is more appropriate than a percentage depending on the current rent.

Tenants who live in low urban density areas are more willing to pay for a green roof than tenants who live in high urban density areas. If policymakers choose to install green roofs in low urban areas for this reason, they must be aware that the environmental benefits are smaller than in a high urban area because often there is already more greenery in low urban areas. The appreciation of having a view of a green roof is greater by terraced houses than in apartments. For this reason, policy makers can designate sheds near terraced houses as suitable locations for green roofs.

Tenants indicate that reducing air pollution and reducing urban warming in summer are the main environmental benefits of a green roof. In addition, improved thermal insulation and lower energy consumption are the most important personal benefits. Policy makers can use these benefits in their marketing strategy to convince tenants to participate in the construction of green roofs. For policy makers it is important to know that the WTP can be overestimated. The next section explains why.

5.2 Scientific relevance

This research contributes by providing knowledge about the valuation on green roofs specific for tenants. There are quite a number of studies focusing on the features and benefits of green roofs. However, only a small part of the literature deals with the valuation of such roofs. In addition, the rental sector is underexposed in existing studies. Only the research of Teotónio et al. (2020) was found to make a distinction between renters and homeowners. However, they did not find significant differences, so they only drew general conclusions.

This study provides more knowledge on the valuation of green roofs and their various characteristics. Both a green roof on one's own home, a view on a green roof and an accessible roof are highly valued. Previous studies investigated some of these characteristics, but no study was found that examined these three characteristics together. Teotónio et al. (2020) examined the appreciation of a private green roof and the accessibility of the roof with a Chi-square test and Cramer's V instead of a multiple regression. The present research has a stronger basis for the results by means of an MNL model, which can supplement the research of Teotónio et al. (2020).

This research shows that there is appreciation through rent increase for the view on a green roof. Only Bianchini & hewage (2012) mention a WTP for the view on green roofs. They base the property price increase on assumptions from other studies that examined the relationship between house prices and the presence and visibility of parks. This assumption can be better substantiated with this research that specifically looks at green roofs instead of the general presence of parks.

In comparison with other studies, this research examined more extensively which personal characteristics are related to the WTP for a green roof. Significant results were found for satisfaction with one's own home, outdoor space, environmental attitude, current rent, urbanization, type of landlord and type of dwelling of tenants. This gives extra insight to the subject compared to previous studies.

This research looked at reference dependent choice behaviour. This has not been done before in studies on green roofs. According to the theory, decision makers' choices depend on a specific reference point (i.e. status quo). The choice is based on possible losses or gains relative to the reference point. This research has shown that only respondents who have a garden are more likely to choose the status quo alternative over one of the roof options. More research will be necessary to get a better understanding of the reference dependent choice behaviour.

5.3 Limitations

Despite the fact that the study was carried out carefully, it has some limitations. First of all, the representativeness of the sample can be questioned. People who are triggered by the introduction text about green roofs are more likely to fill it out. Therefore, people who have a positive association with green roofs, or green projects in general, might be more likely to fill out the survey. People who have no affinity with green roofs are more likely not to fill out the survey, which means that negative appreciation of green roofs is less likely to be included. Therefore, the WTP can be overestimated.

The sample is on average much higher educated than the Dutch population, which lowers the representativeness. This is enhanced by the assumption that the education level of people who rent from a housing association is lower than the Dutch average. Higher educated people generally have a higher income, more knowledge about green roofs and a higher environmental attitude. Therefore, the WTP of the sample may be higher than in other contexts. This means that the results cannot be applied to other contexts directly. Policy makers should be careful with implementing these outcomes.

About 293 of the 378 respondents rent from the housing association Volkshuisvesting Arnhem. All these dwellings are located in or around Arnhem. Characteristics of the housing association such as the quality of their housing and appreciation of previous green projects may have played a role in the choices of respondents. The city of Arnhem, a green and left oriented political city, may also have played a role. It could be assumed that the appreciation of green roofs could be different in other areas. The last limitation of the sample is that only a few people had experience with a green roof. This group was too small to determine clear gains and losses.

Another limitation is the use of a SCE. First of all, a SCE is a hypothetical situation so people can react differently in a real situation. A potential problem with a SCE approach is that the external validity may be lower as compared to the revealed choice approaches (Kemperman, 2000). Often, the price attribute is overestimated in an SCE compared to the real situation. Another limitation is that despite careful selection, the attributes are limited. An unexpected attribute could also have influenced the WTP (Hensher et al., 2015). This study distinguished three types of roofs that can be viewed: bitumen, extensive and intensive green roof. Other studies into views of green roofs made a more specific distinction in the type of plants on a green roof (Fernandez-Cañero et al., 2013; Jungels et al., 2013; Loder, 2014). This might lead to a better imagination for respondents. For this study, however, it was decided to keep the attributes limited in order to reduce the number of respondents needed.

In the SCE, images have been used in the choice alternative to give an idea of the types of green roofs. These images show a specific scenario. It is possible that a respondent appreciates the view of the image differently due to external effects such as the type of dwellings the green roof is located on.

A few respondents indicated in the survey that they did not understand the SCE properly. For this group, an extra check was made on how they filled in the experiment and they were removed from the sample if necessary. However, it is possible that more respondents did not understand the SCE part and therefore did not make the choice they would make in a real situation. To be able to make a good assessment of whether or not people are prepared to pay for a green roof, the advantages of green roofs must be clear. This was made clear in a 3-minute video in the survey. However, the advantages have been highlighted briefly in order to keep the duration of the video minimal. This may mean that the advantages of green roofs are not fully understood. Besides that, by not watching the entire video, some respondents might miss the total knowledge. A check was made for the complete time of the survey, but this did not show how long it took the respondents to watch the video. In addition, the results of studies on the benefits of green roofs are quite diverse. The video could therefore be an overstatement of the actual benefits of green roofs. This may lead to an overestimation of the benefits of green roofs by the respondents.

In the experimental design, a factorial design was chosen to reduce the minimum sample size. However, in a factorial design, the main effect of an independent variable is its overall effect averaged across all other independent variables. To determine the interaction effects of the attributes another, but lager, design should have been chosen. This would have the advantage that variables that have a significant relationship with each other in this study could be included in de MNL model. But on the other side more respondents are needed to fill in the survey. This is why a lager design was not the right option for this study.

5.4 Recommendations for further research

The previous section outlined the limitations of this research. By conducting new research, some of these limitations can be overcome. Recommendations for further research are given below.

First of all, it is recommended that this study be repeated with a better sample distribution. In order to be able to measure reference dependent choice behaviour, a significant proportion of the respondents will have to have a green roof on their house or a view of a green roof in order to measure gains and losses.

When presenting the choice alternatives, multiple images with a view of a green roof can be used so that respondents will not consider external effects such as the type of dwelling the roof is located on.

Another recommendation for follow-up research is to set up the choice design in such a way that interaction effects between the attributes can be measured. In addition, the number of attributes and/or the levels can be expanded. However, a bigger sample size is needed. Different literature found a varying appreciation for certain types of plants (Fernandez-Cañero et al., 2013; Jungels et al., 2013; Loder, 2014). This would be an extension of the attribute ‘view’. With this knowledge, landlords can better select the vegetation desired by tenants. Besides, the levels for the attribute price could be adjusted to see if this changes the WTP.

Besides the target group tenants, this research can also be extended to people with a private home. With this information, buyers can be better convinced to install green roofs on their homes. The results of an investigation into the property value change would also be an additional argument the invest in green roofs for landlords.

As a final recommendation, a hedonic price study can be set up that examines the value change of dwellings with and without a green roof. The change in value of the surrounding dwellings could also be included, which would make the valuation of the view of green roofs clear. This method tackles the problem that people found it difficult to fill in a stated choice experiment. Also, a hedonic price method provides insight into practice instead of a hypothetical scenario.

Overall it can be concluded that this study give compressive insight in the WTP for green roofs. Policy makers got insight in how to implement green roofs on their property. The study provide a solid basis for further research.

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Appendix I – Choice set blocks

Table 19 Choice sets with profiles

	Block A		Block B		Block C	
	House 1	House 2	House 1	House 2	House 1	House 2
Choice set	Profiles					
1	11	5	13	12	5	16
2	7	4	15	8	2	15
3	2	10	6	1	3	9
4	13	6	3	11	13	4
5	16	9	9	10	12	1
6	12	8	2	14	11	6
7	3	15	16	7	14	10
8	14	1	4	5	8	7

Appendix II – Survey

Survey valuation green roofs

Thank you for participating in this short survey that will take no longer than 10 minutes to complete. This survey has been set up for my thesis research for the master Urban Systems and Real Estate at Eindhoven University of Technology. My research is about tentants' valuation of green roofs.

This survey will ask questions about your background and current living situation. In addition, there will be questions about your preferred living situation in the (hypothetical) situation that you are looking for a dwelling. To clarify, this is an independent survey and is not related to your landlord and its green roof ambitions.

All information requested in this survey will remain anonymous and will not be used further outside of this study. Participation is voluntary. However, your written consent is required to participate. Before you decide whether you want to participate in this study, you will receive an explanation of what the study entails. Please read this information carefully and if you have any questions feel free to contact me for further explanation.

Kind regards,

Sophie Wijnberg

a.s.wijnberg@student.tue.nl (mailto:a.s.wijnberg@student.tue.nl)

There are 47 questions in this survey.

Group 2 Dwelling

Are you renting your dwelling? *

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ Yes, I rent from a housing association
◯ Yes, I rent from commercial landlord
◯ Yes, I rent but I do not know who the landlord is
◯ No

What is your monthly rent (exclusive service costs and exclusive rent allowance)? *

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ Below €550
◯ Between €550 and €650 euro
◯ Between €650 and €750 euro
◯ Between €750 and €850 euro
◯ Between €850 and €950 euro
◯ Between €950 and €1050 euro
◯ Between €1050 and €1150 euro
◯ Between €1150 and €1250 euro
◯ Above €1250
◯ I don't know

What kind of dwelling do you live in?

*

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Flat, apartment
- ◯ Studio (one-room apartment)
- ◯ Terraced house
- ◯ Semi-detached house
- ◯ Detached house
- ◯ Private room in a shared dwelling

Do you have outdoor space?

*

❶ Check all that apply
Please choose **all** that apply:

- ☐ Yes, I have a private garden
- ☐ Yes, I have a private balcony or roof terrace
- ☐ Yes, I have a shared garden
- ☐ Yes, I have a shared balcony or roof terrace
- ☐ No

Do you live on the top floor of the building (directly under the roof)? *

Only answer this question if the following conditions are met:
Answer was 'Flat, apartment' *or* 'Studio (one-room apartment)' at question '3 [DWELTYPE]' (What kind of dwelling do you live in?)

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Yes
- ◯ No
- ◯ I don't know

What is your present 6 digit zip code? (eg. 1234AB) *

Please write your answer here:

How satisfied are you with the characteristics of your current living situation? *

Please choose the appropriate response for each item:

	Very unsatisfied	Unsatisfied	Neutral	Satisfied	Very satisfied
Nature in your current street	○	○	○	○	○
Private or shared garden/balcony	○	○	○	○	○
Temperature in your home	○	○	○	○	○
The energy consumption of your home	○	○	○	○	○
Sound insulation of your current dwelling	○	○	○	○	○

Group 3 Enviromental attitude

To what extent do you agree or disagree with the following statements? *

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
We are approaching the limit of the number of people the Earth can support.	○	○	○	○	○
Humans have the right to modify the natural environment to suit their needs.	○	○	○	○	○
When humans interfere with nature it often produces disastrous consequences.	○	○	○	○	○
Human ingenuity will insure that we do not make the Earth unlivable.	○	○	○	○	○
Humans are seriously abusing the environment.	○	○	○	○	○
The Earth has plenty of natural resources if we just learn how to develop them.	○	○	○	○	○
Plants and animals have as much right as humans to exist.	○	○	○	○	○
The balance of nature is strong enough to cope with the impacts of modern industrial nations.	○	○	○	○	○
Despite our special abilities, humans are still subject to the laws of nature.	○	○	○	○	○
The so-called “ecological crisis” facing humankind has been greatly exaggerated.	○	○	○	○	○
The Earth is like a spaceship with very limited room and resources.	○	○	○	○	○
Humans were meant to rule over the rest of nature.	○	○	○	○	○
The balance of nature is very delicate and easily upset.	○	○	○	○	○
Humans will eventually learn enough about how nature works to be able to control it.	○	○	○	○	○
If things continue on their present course, we will soon experience a major ecological catastrophe.	○	○	○	○	○

Video about benefits green roofs

Group 4 Green roof

How familiar are you with green roofs and their characteristics (prior to this survey)? *

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Very familiar
- ◯ Moderately familiar
- ◯ Slightly familiar
- ◯ Not at all familiar

Do you currently have a green roof on your dwelling? *

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Yes
- ◯ No

Can you stay on/ access your roof? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '11 [GFCURRENT]' (Do you currently have a green roof on your dwelling?)

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Yes, on the entire roof
- ◯ Yes, on a part of the roof
- ◯ No

Do you currently have a view on another roof (including sheds)? *

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Yes
- ◯ No

Do you currently have a view on a green roof? *

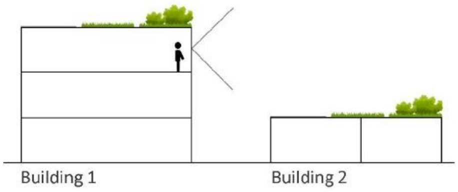
Only answer this question if the following conditions are met:
Answer was 'Yes' at question '13 [ROOFVIEW]' (Do you currently have a view on another roof (including sheds)?)

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Yes, completely
- ◯ Yes, party
- ◯ No

Group 5 Stated choice Intro

For a choice experiment, imaginary houses has been drawn up. You will be shown 8 times two housing profiles. You will be asked to choose which home you would most like to live in. If both profiles do not appeal to you, you can choose 'neither'. Imagine that in all housing profiles, the quality of the home is equivalent to your current situation. Think of house type, size, year of construction, location, number of rooms, outdoor space, maintenance status. In the housing profiles, your own roof (building 1) and the roof you have a view of (building 2) vary, this is visualised in the figure below. The rent in this fictitious example varies in the options.
The roof attributes are explained below.



Please note this hypothetical choice experiment does not affect your current rental situation.

Attribute own roof type

The type of roof on the suggested homes varies between a:

- regular roof with bitumen covering
- extensive roof with small plants like moss and sedum
- intensive roof with higher plants and small shrubs

The living quarters are located directly under the roof. This means that the insulating effect of the roof affects the thermal comfort inside. An extensive green roof keeps the temperature 2 °C cooler in summer and 1 °C warmer in winter than a regular roof. An intensive green roof keeps the temperature 4 °C cooler in the summer and 2 °C warmer in the winter than a regular roof. Also, an extensive roof can block up to 5 decibels more sound than a regular roof. For an intensive roof, this is up to 10 decibels.

Attribute accessibility of the roof

The level of accessibility varies in the options between:

- no access to the roof
- access to the roof, you can reside on the roof in a similar way to a balcony.

Attribute roof view

You can have a view on a:

- regular roof with bitumen covering
- extensive roof with small plants like moss and sedum
- intensive roof with taller plants and small shrubs

This view could be on a roof of another building or over sheds.

Attribute rent

The price of the homes in the choice examples varies with respect to your current rent by:

- 0% rent increase
- 2.5% rent increase
- 5% rent increase
- 10% rent increase

Example choice set

Which home would you most prefer to live in?

Attributes	House 1	House 2	Neither
Own Roof	Bitumen 	Extensive 	
Accessibility of roof	No access	Access	
Roof view	Extensive 	Extensive 	
Price	5% rent increase	2.5% rent increase	

*

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ House 1
◯ House 2
◯ Neither

Group 6 motivation

How important are the following characteristics of green roofs to you in the choices you made?

*

Please choose the appropriate response for each item:

	Very unimportant	Unimportant	Neutral	Important	Very important
Reducing risk of flood	○	○	○	○	○
Stimulate biodiversity (more/different animals)	○	○	○	○	○
Reducing urban warming in summer	○	○	○	○	○
Reducing air pollution	○	○	○	○	○
Environmental noise reduction	○	○	○	○	○
Internal noise reduction	○	○	○	○	○
Improved thermal insulation of the dwelling (cooler in summer)	○	○	○	○	○
Lower energy consumption	○	○	○	○	○
View on green/vegetation	○	○	○	○	○

Group 1 General

What is your gender? *

❶ Choose one of the following answers
Please choose **only one** of the following:

○ Male
○ Female
○ Other

What is you date of birth? (eg. 1985) *

❶ Only an integer value may be entered in this field.
Please write your answer here:

What is your highest completed level of education? *

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Primary education
- ◯ High School (VMBO, MAVO)
- ◯ High School (HAVO,VWO)
- ◯ Vocational Education (MBO)
- ◯ Applied university (HBO)
- ◯ University bachelor's /master's
- ◯ Other

What is your household composition? *

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Single-person household
- ◯ Multiple-person household with child(ren)
- ◯ Multiple-person household without child(ren)
- ◯ Single-parent household with child(ren)
- ◯ Other

What is your household monthly net income (in euros)? *

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Less than €2.000
- ◯ €2.000 till €3.000
- ◯ €3.000 till €4.000
- ◯ €4.000 till €5.000
- ◯ € 5.000 or more
- ◯ I prefer not to answer

Group 7 questions

This is the end of the survey, thank you for your time. If you have any comments please fill them out below.

Please write your answer here:

Appendix III – Flyer

Beste bewoner,

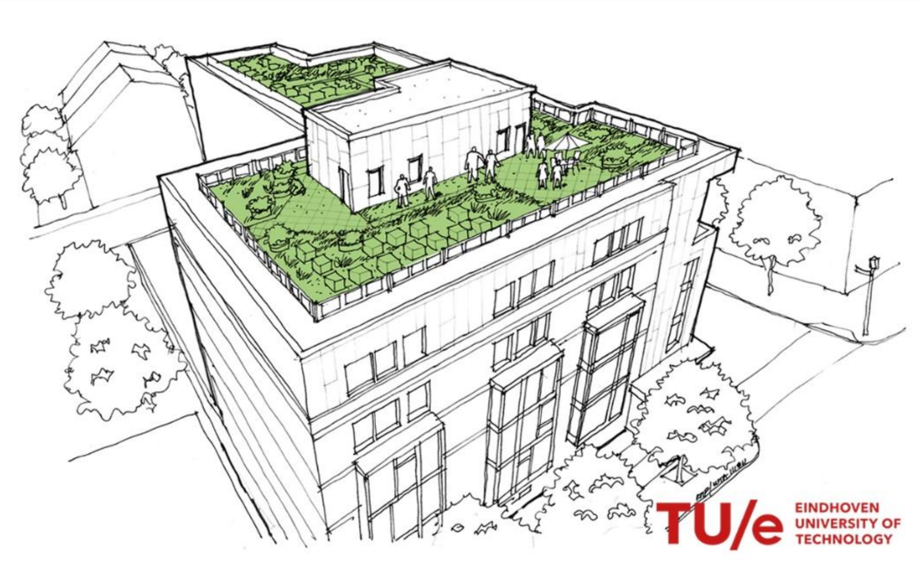
Dat we een probleem hebben met het klimaat zal niet aan u voorbij zijn gegaan helaas. Eén van de mogelijkheden om daar wat aan te doen is het aanleggen van groene daken. Ze bieden verkoeling bij hete dagen, vangen regenwater op bij hoosbuien, zijn een oase voor insecten en vogels én laten zonnepanelen meer opbrengen.

Om deze reden doe ik voor mijn master onderzoek naar de waardering van groene daken door huurders. Zou u mijn 10 minuten durende **enquête willen invullen** via onderstaande link of QR code?

Alvast bedankt voor de moeite!

Groene groeten, Sophie Wijnberg

https://tueindhoven.limequery.com/766541?lang=nl



Appendix IV – Cross tabs personal characteristics

Table 20 Cross-tabs knowledge attitude

Knowledge			Very familiair	Moderate familiair	Slightly familiair	Not at all familiair	Total
Age	18-29	Count	14	24	20	7	65
		%	22%	37%	31%	11%	100%
	30-44	Count	17	29	38	20	104
		%	16%	28%	37%	19%	100%
	45-64	Count	8	58	58	23	147
		%	5%	40%	40%	16%	100%
	65+	Count	3	26	23	10	62
		%	5%	42%	37%	16%	100%
Income	Less than €2,000	Count	18	62	65	23	168
		%	11%	37%	39%	14%	100%
	€2,000 - €3,000	Count	9	38	33	14	94
		%	10%	40%	35%	15%	100%
	€3.000 and more	Count	10	19	18	11	58
		%	17%	33%	31%	19%	100%
	No answer	Count	5	18	23	12	58
		%	9%	31%	40%	21%	100%
Education	Low educated	Count	2	12	27	14	55
		Count	4%	22%	49%	26%	100%
	Middle educated	%	8	33	42	18	101
		Count	8%	33%	42%	18%	100%
	High educated	%	32	87	67	25	211
		Count	15%	41%	32%	12%	100%
	Other	%	0	5	3	3	11
		Count	0%	46%	27%	27%	100%
Gender	Male	Count	29	49	52	17	147
		%	20%	33%	35%	12%	100%
	Female	Count	13	86	87	42	228
		%	6%	38%	38%	18%	100%
	Other	Count	0	2	0	1	3
		%	0%	67%	0%	33%	100%

	Chi-square	df	Sign
Age	21.1	9	0.012
Income	6.3	9	0.714
Education	24.4	9	0.004
Gender	21.9	6	0.001

Appendix V – Compare means environmental attitude

Table 21 ANOVA and T-test environmental attitude

Environmental attitude sum		Mean	Std. Deviation	Std. Error	95% Conf.		Min	Max
Descriptives					Lower b.	Upper b.		
Total		54.9	7.4	0.4	54.2	55.7	25	75
Age	18-29	52.7	7.5	0.9	50.8	54.5	27	66
	30-44	55.0	7.3	0.7	53.5	56.4	28	72
	45-64	55.6	7.5	0.6	54.3	56.8	25	75
	65+	55.7	6.8	0.9	54.0	57.4	38	71
Income	Less than €2,000	55.1	7.5	0.6	54.0	56.3	27	75
	€2,000 - €3,000	54.8	6.8	0.7	53.4	56.1	38	71
	€3,000 and more	56.0	6.9	0.9	54.2	57.8	40	72
	No answer	53.5	8.3	1.1	51.3	55.7	25	70
Education level	Low educated	53.2	6.3	0.9	51.5	54.9	38	65
	Middle educated	55.0	7.1	0.7	53.6	56.4	28	72
	High educated	55.5	7.8	0.5	54.4	56.5	25	75
	Other	51.7	4.2	1.3	48.9	54.6	47	61
Gender	Male	53.0	8.0	0.7				
	Female	56.1	6.7	0.4				

ANOVA		**Sum of Sq.**	**df**	**Mean Sq.**	**F**	**Sig.**
Age	Between Groups	430	3	143	2.657	0.048
	Within Groups	20169	374	54		
Income	Between Groups	196	3	65	1.196	0.311
	Within Groups	20403	374	55		
Education level	Between Groups	332	3	111	2.042	0.108
	Within Groups	20266	374	54		
T-test			**df**	_	**t**	**Sig.**
Gender	Equal variances assumed		373	-	-4.049	0.000

Appendix VI – Motivation figures

Figure 16 Importance green roof characteristics

Appendix VII – Output Nlogit models

MNL MODEL BASIS

```
|-> NLogit
    ;Choices = RoofA, RoofB, None
    ;LHS=PREF
    ;panel=8
    ;RHS= CON,OWR_A,OWR_B,ACC_A,VIEW_A,VIEW_B,PRICE_A,PRICE_B,PRICE_C$
Iterative procedure has converged
Normal exit:   5 iterations. Status=0, F=    .2502654D+04

-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -2502.65371
Estimation based on N =   3024, K =   9
Inf.Cr.AIC  =   5023.3 AIC/N =    1.661
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -3084.6385  .1887 .1875
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.=   3024, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
    PREF|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
     CON|     .71260***      .05594    12.74  .0000      .60297    .82224
   OWR_A|    -.88445***      .05542   -15.96  .0000     -.99307   -.77583
   OWR_B|     .34676***      .04350     7.97  .0000      .26151    .43202
   ACC_A|    -.22482***      .03359    -6.69  .0000     -.29066   -.15898
  VIEW_A|    -.75499***      .04931   -15.31  .0000     -.85164   -.65834
  VIEW_B|     .19957***      .04432     4.50  .0000      .11269    .28644
 PRICE_A|     .71987***      .04891    14.72  .0000      .62401    .81573
 PRICE_B|     .25137***      .04893     5.14  .0000      .15547    .34726
 PRICE_C|    -.11346**       .05258    -2.16  .0309     -.21653   -.01040
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jun 03, 2021 at 01:36:39 PM
-----------------------------------------------------------------------------
```

MNL MODEL ONE PRICE PARAMETER

```
|-> DISCRETECHOICE;Lhs=PREF;Choices=1,2,3;Rhs=CON,OWR_A,OWR_B,ACC_A,VIEW_A
    ,VIEW_B,PRICE$
Iterative procedure has converged
Normal exit:   5 iterations. Status=0, F=    .2503252D+04

-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable                Choice
Log likelihood function     -2503.25183
Estimation based on N =    3024, K =   7
Inf.Cr.AIC  =    5020.5 AIC/N =    1.660
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -3084.6385  .1885 .1875
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.=  3024, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
    PREF|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
     CON|   1.38753***      .06145    22.58  .0000     1.26710   1.50797
   OWR_A|   -.88155***      .05556   -15.87  .0000     -.99045   -.77266
   OWR_B|    .34719***      .04258     8.15  .0000      .26373    .43064
   ACC_A|   -.22057***      .03339    -6.61  .0000     -.28601   -.15512
  VIEW_A|   -.75556***      .04931   -15.32  .0000     -.85219   -.65892
  VIEW_B|    .20700***      .04380     4.73  .0000      .12114    .29285
   PRICE|   -.15645***      .00836   -18.72  .0000     -.17283   -.14008
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jun 07, 2021 at 11:41:19 AM
-----------------------------------------------------------------------------
```

MNL MODEL INTERACTION REFERENCE DEPENDENCE + PERSONAL CHARACTERISTICS

```
|-> DISCRETECHOICE;Lhs=PREF;Choices=1,2,3;Rhs=CON,OWR_A,OWR_B,ACC_A,VIEW_A
    ,VIEW_B,PRICE,X14,X15,X16,X19,X22,X34,X35,X38,X39,X40,X48,X53,X69,X71$
Iterative procedure has converged
Normal exit:   7 iterations. Status=0, F=    .2412165D+04

-----------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable               Choice
Log likelihood function     -2412.16494
Estimation based on N =   3024, K =  21
Inf.Cr.AIC  =   4866.3 AIC/N =    1.609
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -3084.6385  .2180 .2153
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.=  3024, skipped    0 obs
```

PREF	Coefficient	Standard Error	z	Prob. |z|>Z*	95% Confidence Interval	
CON	1.52623***	.10454	14.60	.0000	1.32133	1.73113
OWR_A	1.27133***	.35692	3.56	.0004	.57177	1.97089
OWR_B	.35245***	.04355	8.09	.0000	.26709	.43781
ACC_A	-.19485***	.03613	-5.39	.0000	-.26565	-.12404
VIEW_A	.86267***	.32706	2.64	.0083	.22165	1.50368
VIEW_B	.25342***	.05968	4.25	.0000	.13644	.37040
PRICE	-.16826***	.01199	-14.03	.0000	-.19176	-.14475
X14	-.17641*	.09526	-1.85	.0641	-.36313	.01030
X15	-.61598***	.11432	-5.39	.0000	-.84005	-.39192
X16	.20031*	.10378	1.93	.0536	-.00309	.40371
X19	-.03785***	.00649	-5.83	.0000	-.05057	-.02512
X22	-.02927***	.00600	-4.88	.0000	-.04103	-.01751
X34	1.05103***	.22783	4.61	.0000	.60448	1.49757
X35	-.35348**	.17984	-1.97	.0494	-.70596	-.00099
X38	-.61476***	.18109	-3.39	.0007	-.96969	-.25982
X39	.42863***	.15801	2.71	.0067	.11895	.73832
X40	-.23003***	.04054	-5.67	.0000	-.30949	-.15058
X48	.06547***	.01862	3.52	.0004	.02897	.10196
X53	-.20207**	.10237	-1.97	.0484	-.40272	-.00143
X69	-.13084*	.07752	-1.69	.0915	-.28278	.02110
X71	.03273**	.01560	2.10	.0359	.00215	.06331

```
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jun 21, 2021 at 01:34:50 PM
-----------------------------------------------------------------------------
```

X14 = Own roof type A * satisfaction isolation
X15 = Constant* Outdoor space 2 (garden)
X16 = Constant * satisfaction green environment
X19 = Own roof type A * Environmental attitude
X22 = View A * Environmental attitude
X34 = Constant * Rent price current dwel
X35 = Own roof type A * Rent price current dwel
X38 = View A * Rent Price current dwel
X39 = View B * Rent Price current dwel
X40 = Price * Rent price current dwel
X48 = Price * Urbanity
X53 = Access * Landlord
X69 = View B* Dwelling type1
X71 = Price * Dwelling type 1

ML MODEL

```
|->
DISCRETECHOICE;Lhs=PREF;Choices=1,2,3;Rhs=CON,OWR_A,OWR_B,ACC_A,VIEW_A,VIEW_B,PRICE
,X14,X15,X16,X19,X22,X34,X35,X38,X39,X40,X48,X53,X69,X71;RPL;panel;Fcn=VIEW_B(n),PR
ICE(n);halton;pts=1000$
Iterative procedure has converged
Normal exit:   7 iterations. Status=0, F=    .2412165D+04

-----------------------------------------------------------------------------
Start values obtained using MNL model
Dependent variable                 Choice
Log likelihood function      -2412.16494
Estimation based on N =   3024, K =  21
Inf.Cr.AIC  =   4866.3 AIC/N =    1.609
---------------------------------------
            Log likelihood R-sqrd R2Adj
Constants only  -3084.6385  .2180 .2150
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.=   3024, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
    PREF|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
  VIEW_B|    .25342***      .05968     4.25  .0000      .13644    .37040
   PRICE|   -.16826***      .01199   -14.03  .0000     -.19176   -.14475
     CON|   1.52623***      .10454    14.60  .0000     1.32133   1.73113
   OWR_A|   1.27133***      .35692     3.56  .0004      .57177   1.97089
   OWR_B|    .35245***      .04355     8.09  .0000      .26709    .43781
   ACC_A|   -.19485***      .03613    -5.39  .0000     -.26565   -.12404
  VIEW_A|    .86267***      .32706     2.64  .0083      .22165   1.50368
     X14|   -.17641*        .09526    -1.85  .0641     -.36313    .01030
     X15|   -.61598***      .11432    -5.39  .0000     -.84005   -.39192
     X16|    .20031*        .10378     1.93  .0536     -.00309    .40371
     X19|   -.03785***      .00649    -5.83  .0000     -.05057   -.02512
     X22|   -.02927***      .00600    -4.88  .0000     -.04103   -.01751
     X34|   1.05103***      .22783     4.61  .0000      .60448   1.49757
     X35|   -.35348**       .17984    -1.97  .0494     -.70596   -.00099
     X38|   -.61476***      .18109    -3.39  .0007     -.96969   -.25982
     X39|    .42863***      .15801     2.71  .0067      .11895    .73832
     X40|   -.23003***      .04054    -5.67  .0000     -.30949   -.15058
     X48|    .06547***      .01862     3.52  .0004      .02897    .10196
     X53|   -.20207**       .10237    -1.97  .0484     -.40272   -.00143
     X69|   -.13084*        .07752    -1.69  .0915     -.28278    .02110
     X71|    .03273**       .01560     2.10  .0359      .00215    .06331
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jul 09, 2021 at 04:46:48 PM
-----------------------------------------------------------------------------

Iterative procedure has converged
Normal exit:  34 iterations. Status=0, F=    .2405012D+04

-----------------------------------------------------------------------------
Random Parameters Multinom. Logit Model
Dependent variable                   PREF
Log likelihood function      -2405.01232
Restricted log likelihood    -3322.20356
Chi squared [ 23](P= .000)    1834.38248
Significance level                .00000
McFadden Pseudo R-squared       .2760792
Estimation based on N =   3024, K =  23
Inf.Cr.AIC  =   4856.0 AIC/N =    1.606
---------------------------------------
```

```
            Log likelihood R-sqrd R2Adj
No coefficients -3322.2036  .2761 .2733
Constants only  -3084.6385  .2203 .2173
At start values -2412.1649  .0030-.0008
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
Replications for simulated probs. =1000
Used Halton sequences in simulations.
Number of obs.=  3024, skipped    0 obs
--------+--------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
    PREF|  Coefficient       Error       z    |z|>Z*         Interval
--------+--------------------------------------------------------------------
        |Random parameters in utility functions..............................
  VIEW_B|     .32193***      .07672     4.20  .0000      .17156    .47230
   PRICE|    -.22121***      .02216    -9.98  .0000     -.26464   -.17777
        |Nonrandom parameters in utility functions...........................
     CON|    1.79080***      .14315    12.51  .0000     1.51024   2.07136
   OWR_A|    1.49645***      .41031     3.65  .0003      .69226   2.30064
   OWR_B|     .38865***      .05223     7.44  .0000      .28628    .49101
   ACC_A|    -.19604***      .04051    -4.84  .0000     -.27543   -.11664
  VIEW_A|     .91357**       .37218     2.45  .0141      .18412   1.64303
     X14|    -.19984*        .10817    -1.85  .0647     -.41185    .01217
     X15|    -.68394***      .12706    -5.38  .0000     -.93297   -.43491
     X16|     .22666**       .11500     1.97  .0487      .00127    .45206
     X19|    -.04335***      .00756    -5.73  .0000     -.05817   -.02853
     X22|    -.03184***      .00688    -4.63  .0000     -.04532   -.01836
     X34|    1.17013***      .24876     4.70  .0000      .68256   1.65770
     X35|    -.39794**       .19988    -1.99  .0465     -.78969   -.00619
     X38|    -.65389***      .19508    -3.35  .0008    -1.03624   -.27153
     X39|     .49774***      .18464     2.70  .0070      .13585    .85963
     X40|    -.25745***      .04754    -5.42  .0000     -.35063   -.16427
     X48|     .07956***      .02409     3.30  .0010      .03234    .12678
     X53|    -.21379*        .11559    -1.85  .0644     -.44033    .01275
     X69|    -.16686*        .09578    -1.74  .0815     -.35458    .02086
     X71|     .03430*        .01934     1.77  .0761     -.00360    .07221
        |Distns. of RPs. Std.Devs or limits of triangular..................
NsVIEW_B|     .70149***      .23353     3.00  .0027      .24378   1.15920
 NsPRICE|     .14858***      .03038     4.89  .0000      .08904    .20812
--------+--------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Jul 09, 2021 at 05:06:28 PM
-----------------------------------------------------------------------------
```