

Household adoption of urban nature-based solutions

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Executive summary

Cities are increasingly dealing with environmental problems like heat islands, droughts and floods, biodiversity loss, poor air quality and more. To deal with these issues many seek to implement urban nature-based solutions all throughout the built environment. To achieve this objective private households also need to adopt urban nature-based solutions. This paper looks specifically at the influence of the urban nature-based solutions' attributes on their adoption likelihood.

The literature on urban nature-based solutions largely focuses on two things. First, it explores new methods in which urban NbS can be implemented. Second, it investigates the effects they have on the area they could be implemented in. Apart from literature on urban NbS, papers on photovoltaic and water management systems can be used as parallels. These also go into the same subjects as literature on urban NbS, but go a step further by also researching what led to their adoption by people. For urban NbS there are some that also look at that, but they only incorporate socio-psychological factors and housing factors. This shows that this literature is very much in its infancy and leaves a gap on the influence of attributes of the urban NbS itself on the adoption likelihood. From this knowledge gap the following research question is formulated:

'What are the key attributes of urban nature-based solutions that lead to the adoption and implementation of the urban NbS by households in the Netherlands?'

To be able to answer this research question the following sub-questions first need to be answered:

1. What are attributes of urban nature-based solutions that the literature suggests play a role in the decision-making process of households when adopting an urban nature-based solution?
2. In which ways can these attributes be given a quantity to make sure that a clear picture is formed for all involved, so that no confusion can arise?
3. What are fitting numbers to use for the quantification, so that the largest range is generated and the numbers are realistic?

The thesis used a conjoint experiment in a survey questionnaire (N=1000). The survey was focused on households in the Netherlands. It was set up by using a conjoint experiment where respondents were shown 9 different profiles with varying attribute levels and asked to rate the likelihood that they would adopt an urban nature-based solution with these attributes (values). These profiles make use of 4 different attributes that describe the properties of the

urban nature-based solutions. The attributes are: capital expenditure, environmental benefit, cost savings on insulation, and maintenance required. The attributes were quantified and given a set of values, which are the following: respectively, €30, €90 and €150 per m², low, normal and high environmental benefit, 5%, 15% and 25% cost savings and 2, 4 and 6 hours of maintenance required per month. With this information the profiles were constructed using basic plan 2 to ensure orthogonality and attribute level balance. Thus, the profiles and their attribute levels were determined. Conjoint analysis using multiple regression analysis was then performed to find the relative influence of the attributes.

The results were first tested on the representativeness of the sample as a way to check for their validity. This was done by performing a chi-square goodness of fit test on all the demographics. Such a test compares the distribution of groups of people in the sample and the population and determines how similar they are. A total of 7 demographic factors have been accounted for: gender, age, education, income, owner/renter status, type of house and place of residence. Out of these a total of 4 showed to be representative in the sample for the population: gender, age, education and type of house. Analysis of the results generated the following. Capital expenditure was found to be the most influential attribute explaining 40% of the variance. It was followed by environmental benefit with 25% and cost savings with 22%. In last place was maintenance with 13%. Respondents were willing to pay an extra 37 euros per square metre for a higher level of environmental benefit. The utility people get from the attributes all follow a linear relationship.

There are differences to be observed between groups of people. Some of the most prominent are: higher educated people and those with higher incomes are influenced much more by the values of the attributes. The influence of the attributes starts off small for young people, then rises until middle-aged people and falls again for older respondents. The findings in this paper can be used to support the formulation of policy that seeks to stimulate the adoption of urban nature-based solutions by households.

To conclude, the attributes that the literature suggests are influential are: capital expenditure, environmental benefit, cost savings and maintenance. These have been quantified by appropriate methods to ensure clarity for the reader. The values linked to the attributes give realistic and wide ranges, providing the most accurate results. With all the sub-questions answered and the survey completed the main research question could be answered. It turns out that the most prominently influential attribute is capital expenditure. It is followed by environmental benefit and cost savings, which are very comparable in their effect. Maintenance has much less influence on adoption likelihood and is sometimes even negligible.

AI statement

During the making of this paper artificial intelligence has been used in a couple of different ways. This statement aims to clarify in which ways it has and in which ways it has not been used.

The first area in which it has assisted is the research required for the theoretical background that forms the basis of this research. Any information provided by AI chatbots in this manner has been screened for validity by checking the sources. The second major area in which AI has been used is transcribing the dataset. The data that was gathered was all in a single file and often needed to be transcribed to allow for data analysis. Transcribing of said data was primarily done by artificial intelligence. To ensure proper transcription every action and its result has been manually checked. Thus, the risk of transcription mistakes was kept to a minimum.

No AI has been used to write any part of the report. All the content in this paper has been manually written by the author. Also, determining the content of the paper has all been done by the author and no AI was involved in it.

Introduction

In 2018, an estimated 55% of the world's population lived in urban areas. This is projected to increase to 68% by 2050 and 85% by 2100 (European Commission, Knowledge4Policy, 2020). While there are many potential benefits that come with this development there are also quite a few challenges that need to be faced. One such issue is the environmental circumstances that are created by urban sprawl and are present within it. This takes many different forms like, for example, rising temperatures, more extreme weather, rising sea levels and air pollution (McNutt, 2013). These effects already have great impact on the liveability of cities and will only become bigger in the future. Urban areas deal with relatively high levels of heat (Sharma et al., 2026), disproportionately high levels of air pollution (Castells-Quintana et al., 2021) and great threats from rising sea levels (Neumann et al., 2015). These circumstances will only become more extreme with the development of climate change. An interesting interplay is created whereby urban areas influence their environmental circumstances and are in turn influenced by environmental effects (Kalnay & Cai, 2003).

Urban nature-based solutions

This interplay between the built environment and climate change forms a great challenge for humanity to overcome. This calls for interventions that reduce the impact of urban activities on the climate and/or make it more resilient against the impacts of climate change. A concept that has become ever more interesting is that of applying urban nature-based solutions (Faivre et al., 2017). Nature-based solutions (NbS) are defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (International Union for Conservation of Nature (IUCN), 2025). The focus of this research is on the cases where these solutions are applied to urban environments. Some examples are: green roofs, urban forestry and green corridors (WWF, 2025). Projects that fall in this category have become more and more widespread throughout the world with them having shown benefits to people and nature alike. For example, nature-based solutions have been shown to have beneficial effects on the health of the public by reducing the risk of cardiovascular disease (van den Bosch & Ode Sang, 2017).

Wide-scale implementation

For urban nature-based solutions to be effective it is imperative that they are adopted and implemented on a large scale as they are most effective if present all throughout an urban area. This creates a cohesive ecosystem that is connected and can thus flourish (PBL Netherlands Environmental Assessment Agency, 2022). A large role to be fulfilled is by public actors in public spaces. Much of the urban space belongs to public actors that can be turned into green and blue areas by them. Some examples of ways in which this has been implemented are: green corridors, green forestry, parks, providing room for rivers and other bodies of water and green streets (WWF, 2025). Apart from public spaces, however, a large portion of urban space is in the hands of private actors. As said before, both these spaces need to adopt nature-based solutions for them to be most effective.

Research aim

This research will look into the factors that influence and determine the adoption and implementation of urban nature-based solutions by private actors. More specifically, it will look at households in the Netherlands. The participation of these actors is crucial to the success of wide-scale implementation. The key determinants that influence the decision-making of these actors will be investigated. Which factors play the biggest and most important role in determining the adoption of urban nature-based solutions by households on their property is what this research seeks to find. For the purposes of this research there will be a focus on the following urban nature-based solutions: green roofs, walls and gardens. These are specifically chosen, because they are relatively simple to implement and can be done completely independently by households.

Geographical scope

The Netherlands has been chosen for this research, because it serves as a prime example of the effects of urbanisation and how they can be addressed with urban nature-based solutions. Like many other cities, those in the Netherlands deal with the effects of heat islands (European Commission Joint Research Centre, 2024) and other ecological issues.

Thesis content

This research consists of many different chapters which will be presented here. After the introductory chapter that this paper started with there will be a literature review. It will delve into the research that has already been done on the subject and identify the knowledge gap that this research seeks to fill. Some concepts that lie at the core of what is to come will also be defined. This aims to make sure the reader and author are on the same page when talking about a certain term. Then, the research approach will be laid out in detail in Chapter 3. In Chapter 4, the theoretical background that is used to conceptualise the method will be explored. Next, Chapter 5 presents the operationalisation of the method that is used to carry

out the survey part of the research. It will outline how the survey is set up and how it is taken by participants. The content of the survey is also explained with the method being explained in detail. Chapter 6 presents the results that are found using the data gathering. It will show the performance indicators in accordance with the data that has been gathered. Using the results, conclusions will be made in Chapter 7. Finally, Chapter 8 presents the discussion and recommendations for further research.

Link with CoSEM study programme

In order to justify doing this research, it needs to be argued for how it makes sense to perform it in connection with the complex systems engineering and management study programme. The main requirement is that it concerns a complex system. The first part is identifying that it concerns a system in general. It is clear that there is a system which involves a plethora of different components that together make up the topic of this research. Next, there needs to be a social aspect to the system. This can be found in the collection of actors that constitute the system. Some actors that are involved are: governments, households, contractors to build nature-based solutions etc. Another part is that there has to be a technological aspect to the system. While nature-based solutions do not seem like a technology they can definitely be seen as a technology in the way that they are used in this system. Lastly, the part that makes it complex is the behaviour of people. This can be different every time even with the same input variables, thus making it complex.

2

Literature

2.1 Core concepts

Throughout this research a couple of concepts will keep returning. These lie at the core of what this research is all about. To clarify what they mean exactly, they are defined in this section to make sure both the reader and the author have the same things in mind.

2.1.1 Urban nature-based solutions

The concept of nature-based solutions entails a collection of a non-exhaustive list of interventions that incorporate natural elements in some way. Clearly, this is quite a vague description stemming from the nature of the concept being quite vague as well, because it can mean a lot of things and be interpreted in many different ways. For the purposes of this research there is a focus on the solutions that can be implemented by households on their own. These being green roofs, green walls and green (rain) gardens. The key attributes that will be investigated specifically apply to these interventions. Thus, when used in the context of the research itself urban nature-based solutions refers to this specifically. When used in the context of urban nature-based solutions in general, it refers to any nature-based solution that is applied in urban areas. This could also include the publicly implemented solutions like: green forests, corridors, parks and bodies of water.

2.1.2 Urban area

What some people call an urban area is not called so by others. The definition used in this research is based on what is most useful. The aim of this research is to investigate within the context of urban areas. This distinction can be made in several ways, but the most prominent are population density and population size. Sources that mention population density are rare, but those that include population size are not. Thus, population size will be used as a measure. In this research 'urban areas' is defined as cities, towns and suburbs with a population of at least 50,000 inhabitants (Eurostat, 2026).

2.1.3 Households

Households in the context of this research are defined not as the collection of people, but the owner or renter of an urban building that also lives there; the owner-resident or renter. This

choice has been made, because this is the person that has the authority to make decisions about the implementation of urban nature-based solutions on their property and is also interested in what happens with their property.

2.2 Literature review

In this section a review of the available literature is performed in order to identify where the state of the art research is at. It will make use of 41 articles that focus on the adoption of urban nature-based solutions by households. Preferably, ones that specifically look at the factors that influence and/or determine their adoption.

2.2.1 Search method

In order to be able to do a literature review, a search engine has to be used. For the purposes of this research the search engine Scopus was used. All the searches were done in April 2026. This resulted in the generation of 274 articles. These were screened for relevance in relation to this research, which resulted in the elimination of 233 of them, leaving 41 to be considered for the rest of this literature review. The full search strings can be found in Table 2.1 and the search and selection process in Figure 2.1.

The literature review requires search prompts that effectively find the papers relevant to the subject of this paper. What it needs to do is find those papers that fulfil the following criteria. The first is that the research needs to focus on the household level. Urban nature-based solutions can be implemented in many different ways like for example, an urban corridor on public space. This research, however, focuses on those solutions that take place at the household level and can be implemented by the owner-resident themselves.

The next point is that the right urban nature-based solutions come up in the search. These must be the green wall, roof, garden and rain garden. What the search query also needs to find, however, are comparable situations where the decision-making behaviour is similar to that regarding urban nature-based solutions. Examples of these are solar photovoltaic adoption, storm water management systems and building greenery.

Lastly, the query needs to specify that the factors that lead to the adoption of urban nature-based solutions are what we are interested in. Thus, it needs to add 'adoption' to the title. Searching for only 'adoption' does not yield the right results, though. Such a search will also return how an adoption can be made, what it will result in, what barriers there are etc. As this is not wanted here the term 'factor' is added.

The first term that was found to be effective is the following: 'household urban nature-based solution*'. It returns 58 papers that investigate urban nature-based solutions at the household level. Something to note is that the query does not include the term that defines 'adoption factors'. The reason is that the current language returns a number of papers that can be screened manually. This method ensures that a minimal number of relevant papers will be left out.

'Urban nature-based solutions' was found to be a relatively new term in the literature. Thus,

many papers that are quite relevant are left out of the review, because of the language used. In order to circumvent this issue another term was also used: 'green buildings'. The result is the following full query: 'household green* building* adoption factor*'. In contrast to the first search result, this one does include 'adoption factor' as a term. The reason is that 'household green* building*' yields way too many results to be able to screen them all. Thus, the consideration was made to use this search term to get a manageable number of returns.

In addition to the quite general searches seen above, some more specific searches were also conducted. These focus on a specific urban nature-based solution, resulting in more results than would be found with the general searches alone. The reason is that in many cases papers look into specific solutions and do not mention the more general ideas. This means they do not come up when looking for the general terms. The search terms are: 'green* roof* adoption factor*', 'green* wall* adoption factor*', 'green* garden* adoption factor*' and 'rain garden* adoption factor*'. Again, it should be noted that these queries exclude the 'household' term. It was found that it was not necessary to include here, because these solutions are, mostly, inherently on a household level. Some results did include papers that do not focus on household level, but given the amount of total results, these could be easily screened manually. An overview of all the search queries can be found in Table 2.1.

In general, this combination of searches yields the papers that are directly relevant to this paper and are thus perfect for usage in the literature review. It also, however, yields those papers that are adjacent enough to the subject to be useful as well.

SCOPUS 2026)	(April	Full search string used	Number of references
		TITLE-ABS-KEY (household urban nature-based solution*)	58
		TITLE-ABS-KEY (household green* building* adoption factor*)	24
		TITLE-ABS-KEY (green* roof* adoption factor*)	83
		TITLE-ABS-KEY (green* wall* adoption factor*)	59
		TITLE-ABS-KEY (green* garden* adoption factor*)	31
		TITLE-ABS-KEY (rain garden* adoption factor*)	19
		Total of all searches	274
Manual assessment for relevance		exclusion of articles that do not contain elements regarding the determinants of households' adoption of urban nature-based solutions	41

Table 2.1: Search strings for key terms in SCOPUS.

2.2.2 Review of selected studies

Now that the relevant studies have been selected a structured review can be performed that will lead to the identification of an academic knowledge gap.

The literature about urban nature-based solutions is mainly focused on two things. The first category of studies focuses on the exploration of different urban NbS's. Herein, different designs, like green walls or roofs are explored. Another direction that much of the research takes is that of the effects they have on people, places and a lot of other things, like economic

Reference	Area	Application	Method(s)
Aghimien et al., 2026	South Africa	Blue-green roof	Survey
Ahmed et al., 2025	Canada	Green storm-water infrastructure	Literature review
Amaranto et al., 2025	Italy	Rooftop photovoltaic	Survey
Amir et al., 2025	Pakistan	Solar home systems	Interviews
Bad'ura et al., 2021	Prague	Urban nature-based solutions	Survey
Baiyegunhi, 2015	South Africa	Rainwater harvesting	Survey
Boafo et al., 2025	Ghana	Flood mitigation	Survey
Boateng et al., 2023	Ghana	Urban nature-based solutions	Survey/Interview
Buehler et al., 2025	Switzerland	Circular water systems	Survey
Çildik et al., 2025	UK	Green roof	Survey
Diep et al., 2022	São Paulo	Urban nature-based solutions	Survey/Focus groups
Enu et al., 2026	Ghana	Urban nature-based solutions	Survey
Farm et al., 2024	Malaysia	Rooftop photovoltaic	Survey
Gao et al., 2016	Indiana	Rain barrel	Survey
Gillariose et al., 2026	India	Rooftop photovoltaic	Q-sort
Joyram et al., 2022	Mauritius	Eco-block	Literature review
Kaur et al., 2025	Florida	Urban nature-based solutions	Survey
Khan and Munawar, 2025	New Delhi	Green wall	Survey
Kumah et al., 2022	Ghana	Green buildings	Survey
Latai-Niusulu et al., 2024	Samoa	Urban nature-based solutions	Interviews/Focus groups
López-Maciél et al., 2023	Eindhoven	Urban nature-based solutions	ADOPT modelling
Martínez-Castrejón et al., 2022	Mexico	Rainwater harvesting	Survey
McCarthy and Liu, 2022	Australia	Rooftop photovoltaic	Survey
Nawrath et al., 2024	China	Urban nature-based solutions	Survey
Newburn and Alberini, 2016	US	Rain garden	Survey
Oberti and Plantamura, 2018	Italy	Greenery systems	Survey
Oke et al., 2025	Nigeria	Green wall	Survey
Owusu, 2025	Ghana	Urban trees	Questionnaire
Rauniyar et al., 2024	Hong Kong	Green wall	Survey
Rawal and Thapa, 2022	Nepal	Rooftop garden	Survey
Ren et al., 2020	US	Green storm-water infrastructure	Survey
Roffe and Trop, 2025	Israel	Green wall	Survey
Sangkakool et al., 2018	Thailand	Green roof	Survey
Shih, 2022	Taiwan	Urban nature-based solutions	Simulation
Shin and McCann, 2018	Missouri	Green storm-water infrastructure	Survey
Tomczyk and Łapniewska, 2025	Poland	Rooftop photovoltaic	Survey
Tsvuura et al., 2023	South Africa	Urban nature-based solutions	Focus group/Interview/Survey
Ureta et al., 2021	US	Green storm-water infrastructure	Survey
Wu et al., 2025	China	Green roof	Survey
Yoo et al., 2020	South Korea	Energy efficiency	Survey
Zhang and He, 2021	China	Green roof	Systematic literature review

Table 2.2: List of articles used, their contents, geographical area and the methods applied.

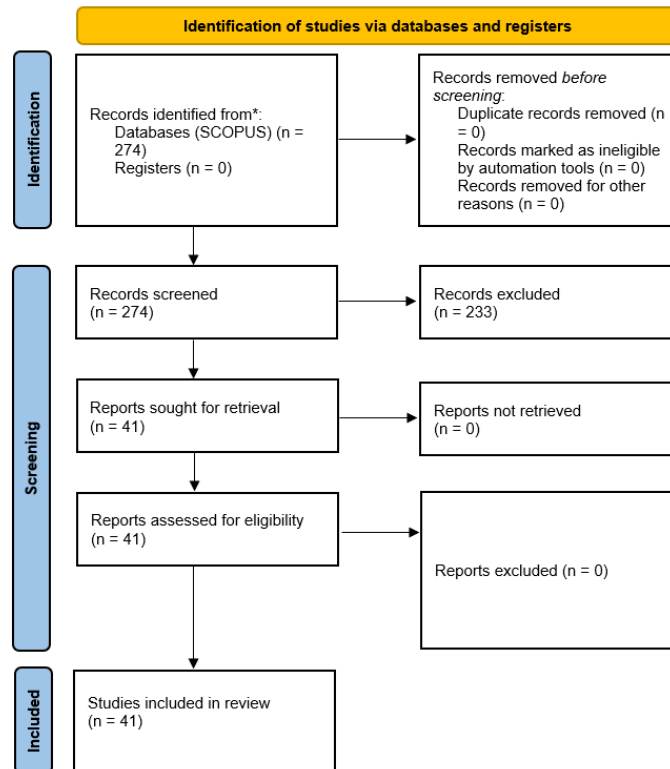


Figure 2.1: PRISMA flow diagram of study identification and selection.

performance. Far fewer of the studies delve into the factors that determine the adoption likelihood of them. Thus, this is a field that is quite novel in the research domain. In regards to the literature that can be found on it, there is an even smaller amount that looks at the key determinants for households to adopt them in particular. The literature that is available, however, provides an interesting overview of the extent of the current state of the art knowledge.

One of the first things that stands out in the literature is the point of view that is taken. While many papers do look at the adoption through the lens of the household, a vast amount take a different approach. A lot of papers look at it from the perspective of the construction industry. They will have surveys or interviews with professionals in the industry, like contractors, developers, architects and engineers. This automatically drives the research in the direction of new construction. Some of the papers also look at retrofitting through this lens, but there is a heavy focus on the new construction industry.

There is an interesting divide in the literature. A section of it looks at the adoption of urban nature-based solutions in the broadest sense. Thus, looking at the whole system to identify enablers and barriers to the adoption. These papers try to identify the enablers and barriers of widespread adoption (López-Maciél et al., 2023). The papers that take this approach usually interview built environment professionals and come to conclusions. Some of the main barriers that have been found are a lack of knowledge (Çildik et al., 2025), financial constraints (Sangkakool et al., 2018) and housing factors (Rawal & Thapa, 2022). Some of the main enablers that have been found are the environmental benefits (Oke et al., 2025), plant diversity (Rawal & Thapa, 2022) and pro-environmental attitudes (Khan & Munawer,

2025).

Another part of the literature specifically looks at the people that are supposed to adopt said behaviour. For these papers a whole plethora of different factors are explored and what their relationship is with the adoption behaviour. Demographic factors like age, gender and income are some of the main occurrences. Household factors like roof size, family size and building type are also recurring. Socio-psychological and socio-economic factors also play an important role in the literature. Then, there are some papers that investigate the adoption likelihood when properties of the urban nature-based solutions themselves change (Bad'ura et al., 2021). Also, some papers explore the price premium people are willing to pay for a house with urban nature-based solutions (Roffe & Trop, 2025). More generally, the willingness to pay for implementation also comes across (Newburn & Alberini, 2016). Interestingly, some novel measurements are taken in the form of the willingness to contribute space and the willingness to contribute time (Nawrath et al., 2024).

Some papers are much more abstract. They do not try to identify factors that lead to adoption, but instead identify what the priorities of communities and individuals are. Thus, a picture of what they would like the urban nature-based solutions to look like. This does create a challenging problem, however, as it becomes quite hard to create policy based on such findings.

Furthermore, there seems to be a lack of standardisation in the language used and the theory that could explain the adoption behaviour. In this paper the term 'urban nature-based solutions' is used, but the literature has many different terms for it. Some do also use 'urban nature-based solutions', but the older papers use terms like greenery systems and green buildings. Apart from that many of the papers had to be found by using specific urban nature-based solutions terms like green roofs, green walls and rain garden. There would be no mention of their wider role as an urban nature-based solution. Also, the factors at the core of the research are very often just made up without being supported by a framework making it hard to compare between articles.

In terms of research area, there seems to be a balance present. The adoption of the behaviour is approached from many different points of view and many different areas in the world. This provides the literature with information on all fronts.

Comparable interventions

Although some literature can be found on the adoption of several urban nature-based solutions, the quantity of papers is quite limited. There are, however, other interventions that are quite similar to that of urban nature-based solutions. Given that the central point of this research is the adoption behaviour of such an intervention, these parallel interventions can be used for effective analysis of the literature. These additional papers also put the adoption of the intervention at the centre of the research. Additionally, they are interventions that can be implemented by a household themselves and are generally seen as pro-environmental behaviour. Thus, with all these similarities, this literature can be effectively used in this review.

The first intervention that continues to appear in the literature is the adoption of rooftop photovoltaic by households. This intervention adds extra information to the literature, because

it is a technology that can be observed in almost every different stage of its diffusion. There are cases where it has been fully adopted (Tomczyk & Łapniewska, 2025), is surging rapidly (Amaranto et al., 2025), is at the beginning of adoption (McCarthy & Liu, 2022) or has not been adopted at all (Amir et al., 2025). Unlike urban nature-based solutions, which have very rarely been widely implemented, solar photovoltaic has many such cases. This can provide additional insights.

The connection between solar PV and urban nature-based solutions might not be very obvious, but there are some relevant similarities that allow for the comparison. First, the environmental benefit aspect. Both are, to a certain degree, altruistic behaviours, because a significant part of the benefits are the external effects to the environment. These are effects that cannot be internalised by the owner. Second is the investment they represent. Both require an upfront capital investment that pays back over time (respectively by generating electricity and savings on the utilities bill). By contrast, there are also some differences that mean the adoption behaviour is comparable, but not exactly the same. For example, solar PV barely requires any maintenance, while urban NbS requires regular upkeep. Also, there is more certainty that solar PV will pay back over time.

With the adoption of solar PV being quite mainstream and prominent in the literature, the research is also very mature in that it incorporates a wide range of factors. The socio-psychological factors are one such determinant that keeps recurring. The literature looks into social influence, financial motivation, environmental protectionism, energy self-reliance, facilitating conditions and technophile attitude as determinants of solar PV adoption (Gillariose et al., 2026). Additionally, demographic factors, like age, gender and income, but also housing factors, like rooftop size (McCarthy & Liu, 2022), are central to these papers. The influence of environmental benefit, financial aspects and knowledge is also included in the research.

While most of these studies implicitly make use of socio-psychological theories they do not always explicitly make use of their frameworks. There is one that incorporates the values, beliefs, norm theory and the norm activation theory into the method though (Farm et al., 2024).

Another intervention adoption that is comparable to the adoption of urban nature-based solutions is water management. In particular, storm water management and rain gathering systems. An interesting first observation is that many of the papers looking into these interventions are set in the United States (Ureta et al., 2021; Ren et al., 2020; Shin & McCann, 2018; Gao et al., 2016). Apart from that discrepancy the literature is quite similar to that of solar PV. It also looks into the connection of several factors with the adoption behaviour. Demographic factors, socio-psychological factors, knowledge and housing factors are all explored. An interesting addition is that the influence of previous experiences is also taken into account (Ureta et al., 2021). Apparently, the literature assumes that people's previous experience with flooding can influence their adoption behaviour. Such a measure of previous experiences is not seen with the other interventions. Furthermore, many of the papers uncover the willingness to pay (Buehler et al., 2025) and adopt (Martínez-Castrejón et al., 2022) water management systems. Lastly, the literature notes that there are distinct differences between the exact factors that lead to the adoption of different green water management systems/nature-based solutions (Ahmed et al., 2025). For example, rain barrels,

circular water systems and rain gardens have distinct variances between them in terms of what the most important factors are.

Additionally, Joyram et al. (2022) look into the adoption of a so-called 'eco-block'; a building material that regulates airflow. They make use of an extensive literature review and look into the influence of contextual, psychological and demographic factors on the adoption of it. Another, stand-alone paper looks into the adoption of energy efficient household behaviour. It is different in that it is about the adoption of habits and not an intervention, necessarily, but it still looks into the influence of psychological, socio-economic and housing factors on its adoption (Yoo et al., 2020).

In conclusion, the literature on the adoption of these other interventions can be used to draw comparisons with the behaviour of adopting urban nature-based solutions. The insights gained can be effectively used for the research.

Methods

The methods applied in the literature have some diversity to them meaning that it is not all reliant on the same techniques. This would create a one-sided vision of the situation where a bias might occur. The methods that are used are: Surveys, focus groups, face-to-face interviews and literature reviews. Much of the literature makes use of either a quantitative method or a qualitative one. In most cases the qualitative ones makes use of discussion groups and the quantitative ones make use of surveys. There are also instances where they are combined. In these cases the research starts with a discussion group where the most important points are identified after which the survey is constructed using those findings. What should be noted is that the literature used in the reviews also makes use of the same methods. Given the overwhelming use of these methods it is clear that they are the most suitable. What does stand out is that all the methods are reliant on the correspondence with people; information is passed from one person to another. This does create the potential for bias to occur.

The methods used to analyse the data gathered and the exact structure of the surveys do differ more substantially. The data analysis methods range from factor analysis to linear regression and principal component analysis to logistic regression. The survey techniques also differ, ranging from Q-sorts to simple questions and conjoint experiments to choice experiments.

In conclusion, the methodologies are quite heavily reliant on human subjects, thus creating the potential for bias. The wide range of exact methods (that can be) applied, however, somewhat negates this bias. These methods are naturally a good fit when trying to identify factors that determine the behaviour of people and a version of them will thus also be applicable to this paper.

2.2.3 Academic knowledge gap

Now that a clear picture has been formed of the available literature it is possible to identify a knowledge gap that will lead to the focus of this study.

The literature about adoption behaviour as a whole is quite mature and lacks any obvious knowledge gaps. They only become apparent when looking specifically at the case of urban nature-based solutions. This is quite a novel field of research, which becomes apparent by being less mature than other fields. Research into solar photovoltaic, for example, is quite extensive and touches upon many aspects of adoption behaviour. It looks into socio-psychological factors, social influence, financials, demographic factors, environmental benefit and much more. The same level of maturity can be observed in the case of water management systems. The research on this subject also varies widely taking into account personal factors, financials, social factors, properties of systems and even previous experiences. Comparing the field of urban nature-based solutions to these it becomes clear that more work can be done. The literature on urban NbS also looks into the same factors, but mostly the obvious ones, like demographics, enablers and barriers and household factors. Socio-economic factors and socio-psychological factors are also explored, but to a limited degree. The most obvious discrepancy is in the properties of the interventions themselves. Whereas solar PV and water management systems literature addresses this well it is largely lacking in the case of urban nature-based solutions.

These findings in the literature culminate in the following knowledge gap: The influence of the properties of urban nature-based solutions themselves on their adoption likelihood by households is unknown.

2.2.4 Research question

Having completed the literature review and identified where the gaps in the knowledge lie the following main research question can be formulated:

'What are the key attributes of urban nature-based solutions that lead to the adoption and implementation of the urban NbS by households in the Netherlands?'

Sub-questions

The first phase of the research is focused on creating a theoretical background. Thus, the first sub-question should reflect this. In this phase, exploration of the attributes that determine the decision is included. Only knowing the attributes that need to be included in the research is not enough to be able to answer the main research question. The second and third sub-questions provide the information that is needed to be able to perform the final analyses. Answering sub-question two will create a way to measure the attributes in a quantitative manner. This is necessary to make sure both the researcher and respondents are on the same page. The last sub-question, when answered, will provide actual numbers for the quantification methods. It is important that these are realistic and provide a wide range of numbers. When all of these sub-questions have been answered, the main research question can be answered as well.

1. What are attributes of urban nature-based solutions that the literature suggests play a role in the decision-making process of households when adopting an urban nature-based solution?

2. In which ways can these attributes be given a quantity to make sure that a clear picture is formed for all involved, so that no confusion can arise?
3. What are fitting numbers to use for the quantification, so that the largest range is generated and the numbers are realistic?

3

Research approach

This chapter presents the approach that will be taken in the research. It also takes into consideration the fit of the sub-questions to the approach taken. Then, the methods that will be used in the approach are given after which all the data requirements are discussed.

3.1 Research approach

In order to provide structure to the research it has been split into three different phases. This has been done, because different parts require different approaches to be taken. Given that a combination of approaches will be used in the research it can be concluded that the overall approach is that of mixed-methods.

3.1.1 Phase 1

In the first phase, the focus will be on grounding the research in theory. For these purposes, thorough research into the available literature will be done. This is thus a qualitative method. This approach aims to make use of general theory on conjoint experimentation and analysis. This would also allow for consistency across others' research, because they could make use of the same theory used in this research. Additionally, there will be information on who actually makes the final decision. When using the term 'household' it is not very clear who is actually meant with this. The theory will be used in order to ascertain who actually makes the decision. Is it the person leading the house or perhaps it is a collective decision.

Also, apart from extracting information from the theories that are available, a literature search will be done as a complementary method. In this literature search there will be a focus on earlier papers that have taken a look at the same subject, comparable subjects, make use of the same method etc. From these sources different attributes will be found. This will be in order to find the attributes that could potentially influence the respondents' perception of the urban nature-based solution.

Moreover, there is a need for more research into urban nature-based solutions in general. There is a need to identify which different ones there are, what effects they have, what costs are considered with them, the positive effects, the psychological effects they might have, who reaps the rewards etc. This process is also included in the literature review that makes up this phase.

3.1.2 Phase 2

The second phase will not be qualitative, but quantitative. In this stage an experiment will be set up in order to find the factors that turn out to play a role in the decision-making. A conjoint experiment will be set up in such a way that the underlying attributes can be analysed. When designing this experiment a consideration was made between a conjoint or a choice experiment. The choice experiment would have allowed for the estimation of a model that could predict the utility of a certain profile. This paper, however, does not seek to find such information. Thus, given that a choice experiment would only add unnecessary effort, the conjoint experiment was chosen instead. It allows for estimating the relative influence of the different attributes using regression analysis. Also, the experiment will identify the demographics of the respondents. By collecting that data it is possible to compare differences between demographic groups. This method suffices for the purposes of this research. Once this experiment has been set up, it will be sent out to households all across the Netherlands via a survey. This will result in a large sample (N=1000). In deciding upon the method of data collection another choice was presented: make use of a survey or interviews and/or focus groups. The main difference is that a survey allows for quantitative analysis, while interviews/focus groups are mainly qualitative. The purpose of this research is to quantitatively determine the influence of the attributes. Therefore, the fitting method is a survey.

3.1.3 Phase 3

After the data has been collected it is time for the third phase of the research; interpreting and analysing the data. With the large amount of data collected it will now be possible to identify which of the attributes are the key determinants when it comes to the decision-making. If the effect of a certain attribute is higher than 0 and statistically significant, it can be concluded that it plays a role in the decision-making process. This analysis will be done using multiple regression analysis which will be determined for different demographic groups separately. At that point the model shall be determined which will show the relative influence of all the different relevant attributes. This will then allow for identification of the key determinants concluding the research.

3.2 Research methods

In order to answer the sub-questions that have been formulated, which fit with the approach that is to be taken, certain methods will be employed. It is a mix of a qualitative method and a quantitative one.

3.2.1 Qualitative methods

The first phase of the research requires the construction of a theoretical background. In order to create this the methods literature review and desk research will be applied. In theory, this could also be done via direct interviews, thus making use of primary data. Given the time constraints of this research, however, secondary qualitative data will be used. Using this method, the sub-questions can be answered.

3.2.2 Quantitative methods

The main research question will be answered using a completely different method. Phase 2 and 3 of the approach are focused on quantitative data and thus require a quantitative method. The method that will be applied is that of a survey. The analysis method is also quantitative, being multiple regression analysis.

3.3 Data requirements, sources and analysis tools

In order to be able to answer the questions formulated certain data is required. Firstly, data on the demographic factors of the households will be needed. Secondly, the data on the adoption likelihood that they express for a certain urban nature-based solution needs to be gathered. This will be gathered via a survey that is set up by the author of this research and distributed by a professional surveying company. The type of respondent that is relevant for the survey are all the owner-residents and renters in the Netherlands that live in a place with at least 50,000 inhabitants. In order to be able to analyse the data in such a way that metrics like statistical significance and variance can be determined a data analysis tool will be required. SPSS 29.0 will serve to fulfil this purpose. Given the experience with this tool it will not be too difficult to learn how to use it for this research, thus saving time and effort.

4

Method conceptualisation

A helpful step in the research is to first lay the groundwork upon which the survey is built. This chapter consists of two sections. The first section explores conjoint analysis theory to illustrate what kind of data analytics will be applied. Then, it explores the literature to find the specific attributes that play a role in the process. The second section delves into the attributes of the urban nature-based solutions that might play a role in the perception of the intervention and then makes a selection that will be used in the research.

4.1 Conjoint analysis

The right way to do data analysis on the influence of attributes on adoption likelihood is by making use of a conjoint experiment. It is shortly explained here after which the details of how it has been set up will be explored in the rest of the report.

Conjoint analysis is a data-analysis method that determines the influence of a set of attributes on the decision-making of the respondents. A combination of the attributes is shown to the respondent in a profile after which they are asked to rate the profile. Regression analysis of the respondents' valuation allows for finding the influence of every individual attribute. With that information the utility of a profile can be predicted and with it the likely behaviour.

To be able to do a conjoint analysis a couple of things are required. First of all, the type of study needs to be determined. The experiment can be ranking, rating or choice based. These all have different advantages, disadvantages and implications. For the purposes of this research a rating mechanism will be applied. The second piece of information required is what attributes shall be included in the analysis. This will be explored in Section 4.2. The attributes also need to be assigned levels and a way to quantify them in the first place needs to be identified. Both of these will be explored in Chapter 5. Lastly, a questionnaire needs to be designed that allows for the proper analysis of the attributes and the influence they exert. This will also be addressed in Chapter 5.

4.2 Attributes of urban nature-based solutions

An urban nature-based solution is not a homogeneous intervention. There is a vast array of different options available that all fall under this category. In the context of the urban

environment the choice has been made to focus on the ones that owner-residents and renters can privately implement on their property. Thus, green walls, roofs and (rain) gardens. The adoption of these solutions comes with certain benefits and costs that are defined by their attributes. The idea is that the attributes affect the desirability of the solutions and they will have an effect on the adoption likelihood. When scouring through the literature there are some costs and benefits (attributes) that keep recurring in the discussion. Thus, it can be concluded that these are suitable for use in this research design. This approach has found that there are 4 attributes which are prominent in the discussion. For that reason a total of 4 attributes, specifically these, have been chosen.

Starting with the main benefit they bring and what has made them popular: their environmental benefits. Another benefit associated with urban nature-based solutions (in particular green roofs) is the insulation value it brings to a home (Harbiankova et al., 2025). Apart from benefits there are, of course, also costs associated with them. The first of these is the initial capital expenditure and the other is the maintenance required to keep them in good shape (Climate Technology Centre and Network (CTCN), 2024).

Environmental benefit

The first attribute that needs to be included in the design of the urban nature-based solutions is the effect it has on the environment. There are many ways in which the environment is affected by an urban nature-based solution. In general, nature-based solutions can have benefits for whole ecosystems and completely transform complete areas. The same can be said for urban nature-based solutions. A complete implementation of them in and throughout an urban area can completely transform the area. An example of this can be seen in Paris, where the widespread implementation of urban NbS has drastically improved air quality and reduced the heat island effects (C40 Cities Climate Leadership Group, 2015).

For the purposes of this research the implementations will be much more small-scale. Thus, they will, individually, not bring upon large-scale change in an area. They will, however, still be beneficial for the environment around them through its positive effects. The first benefit they offer is improved air quality (Wageningen University & Research, 2026). Plants naturally filter the air around them by removing fine particulates and carbon dioxide from the atmosphere. Especially in urban areas where air pollution is much worse than in other places, this is a major benefit to the environment. The second benefit is water management (Huynh Thi Ngoc et al., 2024). Urban areas often deal with water stress where there is either a lack of it or an over-abundance. The built environment is often unable to deal with too much, because the infrastructure cannot handle it. Urban nature-based solutions inherently combat this issue by taking up water when there is too much of it in the soil and environment. In periods of drought this stored water can then be used to combat a lack of water overall. Another issue that urban areas face more often has to do with temperature management (Copernicus Climate Change Service, 2024). The lack of natural environments means that heat cannot be managed by the surroundings themselves. This leads to extreme temperatures in the summer rising to levels much higher than other areas. Plants naturally manage the temperature level through shading, evapotranspiration and photosynthesis. This ensures that the urban environment does not have to deal with extreme levels of heat ("Differing potential of nature-based solutions for

heat mitigation across European urban areas”, 2026). The last environmental benefit is to the ecosystem (de Vries, Chappin, et al., 2024). The existence of the plants in the solutions themselves already means that these species get a chance to thrive. This in and of itself already boosts the biodiversity of the area. Additionally, they often support local wildlife, like bees and birds, as well. Overall, they boost biodiversity and support the local ecosystem ensuring that the area is alive. Apart from these four benefits there are much more, subtle beneficial impacts like carbon sequestration, water quality improvement, resilience to the climate, soil health and erosion control and circular resource use.

Insulation value

Apart from the positive external effects generated by urban nature-based solutions there is also a positive internal effect that the owner of one directly benefits from. This benefit is in the form of the insulation value provided by the solution (Turhan et al., 2025). The exact mechanism differs per application, but the general effect is that a residence experiences better insulation value as a result of having an urban nature-based solution on or next to it. Just like insulation through multiple layered glass windows or insulation materials in walls offer.

In the case of green walls, air is trapped between the plants and the wall providing an extra layer to the insulation. Green roofs also create an extra layer to the insulation except it is mainly due to the soil used for the plants. The soil itself shelters the building from the elements keeping it a much more stable temperature. The soil itself is also, inherently, quite resistant to changes in temperature. Adding plants to the roof even makes the insulation active through the evapotranspiration that moves heat around. Green gardens create a micro-climate next to the building. Shade from trees and plants prevents the building from heating up too much in the summer. They also shield the walls and roofs from cold wind in the winter. The air temperature is much more stable throughout different periods due to plants. In short, the pleasant micro climate created next to the building means that less energy needs to go into creating a pleasant environment indoors.

Capital expenditure

Another attribute that needs to be included in the design of urban nature-based solutions is the costs that are associated with it (Environmental Valuation & Cost-Benefit News, 2020). This attribute describes the up-front costs that are associated with the adoption and thus installation of the product. It does not include any running costs as they will be part of the last attribute.

The capital expenditure includes any costs that need to be made in order to get the solutions completely installed. For example, the acquisition of structural components required in order to provide structural integrity are included in this attribute. Apart from that any labour that needs to be outsourced is also part of the capital expenditure. Several other items are also part of this attribute, like buying the plants and soil and paying for the design.

Maintenance

Urban nature-based solutions, by definition, make use of natural elements like plants, animals and bodies of water. In the natural world, these can simply be left alone and they will manage themselves. In an urban environment, however, they cannot be left alone to do their own thing. The urban environment poses issues in terms of restrictive factors, like available space. Plants would overgrow into places where they are not supposed to be for example. Thus, in the urban environment urban nature-based solutions will need to be maintained by the residents (Vertiss, 2026).

Maintenance can be seen as the work that needs to go into the urban nature-based solution in order to ensure it keeps operating the way it is supposed to. This can, for example, entail that a green wall needs to be trimmed in order to prevent it from overgrowing. Another example is fertilising a green roof to keep it green. Mowing grass in a garden could also be included in this maintenance. Watering plants, removing dead ones and planting new ones are all part of it.

5

Method operationalisation

Through the desk research done in phase 1 it has now become possible to set up the survey. In Chapter 4, the potential attributes have been identified. Thus, these can be included in the survey. This chapter gives an outline of what the survey is like, how it is set up and how it will be able to identify the relevant determinants.

5.1 Quantification of the attributes

As identified in Chapter 4 there are quite a few attributes that could be included in the survey. There could be an attribute for every environmental effect. This would, however, mean that there are already a lot of attributes just to describe this. Also, it would be difficult to quantify the effects for the participants. Therefore, these will be grouped together into environmental benefits in general. The insulation value, capital expenditure and maintenance are more straightforward. They do not combine different attributes into one and can thus all be separate attributes. The next part explains how every attribute will be quantified in the experiment.

Environmental benefit

The first attribute is immediately challenging to quantify. There are two main reasons for this. First is the fact that it does not reflect a single benefit, like improved air quality. Instead, it is a collection of different ways in which the environment benefits from its adoption. With the plethora of different benefits, a plethora of different quantifiers should also be used for them. Otherwise, it would be very unclear in which ways the intervention benefits the environment. Given, however, that all these cannot be included, only one quantifier will have to be used. While it is theoretically possible to have a different attribute and quantifier for every aspect, it is in practice not doable. It would quickly create too many variables for the respondents to take into account when rating the profiles. It would only create confusion and make the results unusable.

The second reason is that quantifying the environmental effect of something is itself very hard. For example, the improvement in air quality as a result of this one adoption cannot be measured. Thus, saying that the adoption of this option improves air quality by a set percentage cannot be done. A way around this could be to quantify it by the amount of fine particulates it filters, but that is a measurement that means nothing to the average person. The same problems are found with the other environmental benefits.

A fitting way to quantify this attribute is thus by its relative benefit compared to the other options. It is thus not an absolute value, but gives the relative amount of benefit to the environment with all options providing benefits to some degree.

Insulation value (cost savings)

This parameter can entail how well a building deals with either heat or cold. Logically, it would require a quantifier that describes its insulation values against, respectively, heat and cold. In practise, however, individuals will, mostly, not be concerned with these values. Also, it will be hard for most people to understand what they mean. This would lead to bad survey results as the participants do not know what they are rating. A much more practical way of quantifying the effects of insulation is possible: the savings it brings to the utilities bill of the household. This captures both the heating and cooling effects of the insulation value as less heating is required in winter and less cooling in summer. Furthermore, it is also a way in which the attribute becomes understandable to all the participants.

Again, a choice is presented. Will it be quantified in terms of absolute monetary savings or as a percentage of monthly costs? Given the wide range of buildings that will be part of the survey, there will also be a wide range of utility costs. Thus, it would be most suitable to represent the insulation values as a percentage savings on the monthly heating and cooling bill.

Capital expenditure

Like the insulation value there are many different (types of) buildings that will be part of this research. Therefore, there will also be a widely varying possibility and surface area where urban nature-based solutions can actually be implemented. In order to deal with the discrepancies of different buildings, the attribute needs to be quantified in such a way that it will be applicable to all buildings. What all urban nature-based solutions in this research have in common is that they require space to be implemented. Either horizontal space or vertical. This is also what differentiates the degree to which they are possible to be implemented. Thus, a fitting measurement takes into account the limitations of space. A fitting way to quantify it is therefore the cost of installation per square metre.

Maintenance

When mentioning the maintenance required to keep the urban nature-based solution functional, people probably imagine different things. One individual could imagine how hard it is to perform the labour, another could imagine the time it would take or the resources that need to be diverted into it. Additionally, one could hire gardeners to do it for them and will thus imagine it as the costs of hiring them.

A way to come up with a universal way of quantification is not to look at how people will deal with the effort needed, but the amount of effort that has to be taken for it in the first place. This allows for a universal measurement and for people to deal with it however they like. As the green walls, roofs and gardens are all made up of plants, it is logical to conclude that a

good measurement is the amount of gardening it takes to maintain them. Describing it as gardening gives an idea of the difficulty of the labour and the tools and resources required for it. More specifically, the hours of gardening required per month on average. It is on average, because the exact amount depends on the season.

5.2 Experimental setup

It is now clear that a total of four attributes will have to be included in the survey. The task at hand is to identify a manner in which it will be possible to evaluate the relative influence on adoption likelihood of the different attributes.

Experimental method

Given that multiple variables are included in the survey, the logical field of science that the research is headed in is that of multivariate data-analysis. Within this field the method that is used for sets of options that have attributes to them is a conjoint experiment. This method presents the subject with profiles that vary the values of the different attributes. Then, the surveyed must either respond with how attractive they find the profile or whether they would choose the profile or not. In setting up these profiles a lot of choices need to be made. First is the number of profiles that will be used. This is largely led by the number of attributes that the researcher wishes to include.

In order to set up these profiles it would be possible to use full factorial designs. That is when all possible combinations of profiles are used and presented. This would, however, result in an enormous amount of profiles that the surveyed would need to rate. Thus, that is not very practical. Instead, the literature provides different experimental designs; basic plans. They are mathematically determined constructions of sets of profiles that, if used correctly, ensure orthogonality and attribute level balance.

The four basic plans available all provide the possibility to use a varying amount of attributes and attribute levels. Given that this research involves four attributes, basic plan 2 fits the setup. The principles of basic plan 2 are visualised in Figure 5.1. It allows for the construction of 9 different profiles involving 4 different attributes and allowing for either 2 or 3 attribute levels per attribute. For the purposes of this research, 3 attribute levels have been chosen that will be varied over the 9 profiles of basic plan 2.

The choice in attribute levels is also not a trivial task. It is essential that this is done in the right manner to ensure validity. It is important to make the range of levels as big as possible as it gives the lowest possible uncertainty in the estimation of the regression coefficient. What must be kept in mind, however, is that the values remain realistic. Thus, a range should not be made bigger than is possible even with adjusted policies. Also, all combinations of the levels of the attributes need to be possible. Lastly, the jump between level 1 and level 2 must be the same as that of level 2 to level 3. The next section determines what the attribute levels will be.

BASIC PLAN 2: 3 ⁴ , 2 ⁴ , 9 trials							
1	2	3	4	1	2	3	4
0	0	0	0	0	0	0	0
0	1	1	2	0	1	1	0
0	2	2	1	0	0	0	1
1	0	1	1	1	0	1	1
1	1	2	0	1	1	0	0
1	2	0	2	1	0	0	0
2	0	2	2	0	0	0	0
2	1	0	1	0	1	0	1
2	2	1	0	0	0	1	0

Figure 5.1: A visualisation of basic plan 2.

5.2.1 Attribute levels

Environmental benefit

As discussed in Section 5.1 environmental benefit is hard to quantify. Ideally, the environmental benefit would be quantified by a numerical value. This would ensure that the surveyed all have the same idea in their head. Given that this is not possible, however, the next best thing, nominal levels will have to be used. Since ratio and interval levels are not possible, nominal levels will have to suffice. Thus, for the purposes of this study the attribute levels have been chosen as low, normal and high.

Cost savings

Secondly, some realistic savings need to be identified for the utilities bill through green roofs and walls. Some typical savings are between 10 and 30% for cooling in summer and between 10 and 15% for heating in winter (Environmental Studies Institute (EVS), 2025). Another source estimates that the combined energy savings annually are roughly between 4 and 15% (Nasr et al., 2024). Another paper did a comparable analysis and found that it lies somewhere in between 4 and 9% (Turhan et al., 2025). In some extreme cases, where the building was previously very badly insulated, the urban nature-based solutions are very intensive and/or the climate has high cooling demands, the savings on cooling can be between 30 and 80% (European Federation of Green Roof and Living Wall Associations (EFB), 2025) or between 15 and 48% in terms of heating (Manso et al., 2021). In the average scenario, the energy savings would result in a drop of around 5 to 15 percent of total costs. In rare scenarios, however, it can be a lot more. A realistic set of energy savings is 5, 15 and 25 percent on energy costs.

Capital expenditure

Thirdly, the costs of implementation need to be identified. The challenge here is finding values that fit all of the options for urban nature-based solutions. Thus, green walls, roofs and (rain)

gardens.

The average cost for a green roof in the Netherlands ranges from €40 to €100 per square metre (Sedum-World, 2026). For professionally installed ones, it ranges from €60 to €150 (Urban Green-Blue Grids, 2025). There is also difference between extensive and intensive green roofs, respectively ranging from €35 to €100 and €75 to €200 (Dakdekkers247, 2025). Additionally, there is often a subsidy available of around €20 to €30 per square metre (Immovlan, 2025). Regarding green walls, a distinction needs to be made between different levels. Simple ones range between €30 and €75 per square metre, intermediate ones range from €100 to €400 and high end ones can be €400+ (Ottelé, 2010). Gardens can be given the same ranges as they require approximately the same input. For simple versions, the range is between €30 and €70 per square metre. For intermediate versions this rises to between €70 and €120 and for high end, luxury editions it falls more between €120 and €200 (Bricknest, 2025). These numbers are verified by another source stating that the average for standard landscaping lies between €40 and €80 (Zoofy, 2025). Taking all these values into the equation a valid set of price points would be 30, 90 and 150 euros per square metre.

Maintenance

Lastly, finding values for the hourly maintenance demands is quite challenging, because the literature rarely provides these numbers. Instead, it provides the activities required and the amount of times these need to be done. Using this information and estimating how long they would take a realistic range of values can be constructed. In terms of green roofs, a distinction needs to be made between simple ones and intensive ones (multiple plants/more like a garden). For simple systems, only 1 to 3 visits a year are required (Green-Roof-Organisation, 2021). For the first few years, when the roof is establishing, it ranges more from 3 to 4 times per year (Philadelphia-Water-Department, 2026). For more elaborate roofs and gardens, the range becomes 4 to 8 times per year ((FLL), 2018). Another source states that 8 visits a year are required (Columbia Green Technologies, 2017). During such a visit a number of activities are required, like weeding, irrigation, fertilising, pruning, replanting etc. (Green-Roofs, 2026). For green walls, it is recommended that a maintenance session is done monthly (Vertiss, 2026). Another source confirms this figure and suggests fertilising once or twice a year (Profilo, 2026). Typically, such a maintenance session requires trimming, monitoring, structure checks, irrigating and fertilising (The Wright Gardner, 2025). These sources all quantify the maintenance requirements in the amount of times per year or month that it is required. This method, however, remains quite vague, because it does not say anything about the amount of time such a visit takes. Thus, in order to clarify this attribute quantity it is converted into hours per month of maintenance required. This conversion is done by looking at the activities required and the amount of time they will likely take and then averaging it out over every month. Estimating the maintenance requirements with this information results in values of 2, 4 and 6 hours per month.

1: Environmental benefit	2: Cost savings	3: Capital expenditure	4: Maintenance
0: Low	0: 5% cost savings	0: €30 per m ²	0: 2 hours/month
1: Normal	1: 15% cost savings	1: €90 per m ²	1: 4 hours/month
2: High	2: 25% cost savings	2: €150 per m ²	2: 6 hours/month

Table 5.1: An overview of all the values that will be used for the attributes and how they are coded.

Profiles construction

With all the information gathered, it is now possible to construct the 9 profiles that will be presented to the subjects. The figure below shows a representation of the profiles.

Profile 1	Profile 2	Profile 3
Low	Low	Low
5% cost savings	15% cost savings	25% cost savings
€30 per m ²	€90 per m ²	€150 per m ²
2 hours/month	6 hours/month	4 hours/month
Profile 4	Profile 5	Profile 6
Normal	Normal	Normal
5% cost savings	15% cost savings	25% cost savings
€90 per m ²	€150 per m ²	€30 per m ²
4 hours/month	2 hours/month	6 hours/month
Profile 7	Profile 8	Profile 9
High	High	High
5% cost savings	15% cost savings	25% cost savings
€150 per m ²	€30 per m ²	€90 per m ²
6 hours/month	4 hours/month	2 hours/month

Table 5.2: Complete profiles making use of basic plan 2 and the values found in Section 5.2.1.

5.3 Overall setup

In this section, the complete setup of the questionnaire will be described. The final questionnaire makes use of all the work that has been done in phase one to create the survey of phase 2. For the complete survey, as it was shown to the respondents, please refer to Appendix A. Note that the survey was performed in collaboration with another researcher, because they work on research with the same subject. Their research is on socio-psychological factors and combining the work into one questionnaire turned out to be most beneficial. Thus, setting up the overall questionnaire has to keep in mind both studies.

Accompanying additional info

The questionnaire is not simply a collection of questions directly presented to the participant. Some explanatory information must be given, such that the participant has all the knowledge they require. The first piece of additional information is the opening statement. This is the required piece of text that ensures the respondent knows what they are getting into and what

the terms and conditions are. It lays out the data that will be gathered from them, how it will be used, stored etc. Furthermore, an explanatory introduction is required. Not everyone knows what urban nature-based solutions are. Thus, it is required to start the survey with a short introduction of the concept. This introduction will only explain the concept of urban nature-based solutions and not any of the costs, benefits, consequences or anything like it. This is in order to ensure that the respondent does not become biased by the introduction and takes the answers to the questions as neutral as possible. Lastly, the part where the respondents are asked to rate 9 profiles also requires some explanation. The profiles make use of four attributes that describe their costs and benefits. The definition of these attributes, what they mean and entail, needs to be explained as well. This is in order to ensure that all the respondents are thinking of the attributes in the same manner. Also, it means that the researchers know that the respondents are thinking of the same thing as them.

Rating mechanism

Apart from designing the questions that form the survey, it is also necessary to design the way in which they will be answered. Many choices can be made in this regard. Will there be open questions? Will there be closed questions? In rating the profiles, the participant will be asked to give the likelihood of them adopting an urban nature-based solution with the shown characteristics. A natural way for the respondent to answer is on an 11-point scale where 0 represents the lowest likelihood and 10 represents the highest likelihood. It is an 11-point scale and not the more rounded 10-point scale, because it provides a perfect mid-point. That being 5. Additionally, there are some questions that need additional answer options. It can be that an individual will not be able to answer a question on the scale and needs an option to indicate this. Thus, some questions also include the option to answer 'I don't know' and/or 'not applicable'.

Demographic factors

In addition to the questions on attributes of the urban nature-based solutions some questions on demographics will be added. The first benefit that this brings has to do with representativeness. When doing a survey like the one in this research it is best if the sample taken represents the population that is to be analysed. The demographic factors age, gender, education, income and more will be used to identify whether the sample is representative. Their representativeness will be tested using the chi-square equation shown in Equation 5.1. The 'O' stands for the observed quantity in the survey and the 'E' stands for the expected quantity given the numbers of the population.

$$X^2 = \sum \frac{(O - E)^2}{E} \quad (5.1)$$

Furthermore, the questions can be used to make differentiations between different groups of people to see whether they give different responses. The most interesting distinction for this research is the place of residence. A result that is of interest to be found is the differences between people in different provinces. Especially, between the larger regions: the Randstad, southern Netherlands and Eastern Netherlands. Apart from that, these questions can all be

used to distinguish between groups of people based on common identifiers. Whether this is included in the results is dependent on the statistical significance of the correlations.

Lastly, the demographics include a question to identify whether someone is an owner-resident or a renter. The differences between these groups is interesting to see, because renters might respond completely different given that they have less control over what happens to their residence.

Order of questions

When designing a questionnaire, one must always keep the order of the questions in mind. The reason is that it can have consequences for the results by influencing the respondents' subconscious. The questionnaire consists of two parts. One where the respondent is asked to rate 9 different profiles and one where their socio-psychological factors are inquired about. In the survey, the socio-psychological questions make up the first questions. After that, the 9 profiles will be presented. The reason is that having the respondents rate the urban nature-based solutions first will likely bias them. This will lead to them answering the questions about socio-psychology in the context of urban nature-based solutions, which is not wanted. The order in which the profiles are presented does not matter as they are balanced and orthogonal. Lastly, the demographic questions will be placed as much as possible at the end of the questionnaire. The reason is that people quickly become tired of answering questions. The demographics do not require much thought. Putting them first means that energy is lost before any of the harder questions come up. Putting them at the back means that when all energy and attention is used up, the respondents only need to answer easy questions.

6

Results

This chapter analyses the data that has been gathered with the survey and finds the results necessary to come to concluding remarks at the end of the research. It will start with a description of the sample of the population that shows how representative it is. After that the analysis of the attributes will take place.

6.1 Sample representativeness

To start with the data analysis it is necessary to check the representativeness of the sample (N=1000). This is done to ensure that the findings using the dataset can be generalised to the population. In order to find this, the demographic factors perfectly fit. They are known for the sample and for the population allowing for the proper analysis. The dataset contains quite some useful demographics that can be used: Gender, age, education, income, resident owner/renter, type of house and place of residence.

Gender

The first demographic is that of gender. A total of 485 men took part in the questionnaire and a total of 514 women did. Also, 1 non-binary person took part.

	Sample	Population
Male	485 (48.5%)	6,311,377 (48.4%)
Female	514 (51.4%)	6,736,865 (51.5%)

Table 6.1: The distribution of males and females in the sample and the population.

The population that is of interest in this research is every person that owns or rents a residence in the Netherlands. The total amount of men in the Netherlands in 2025 was 8,978,451 (Centraal Bureau voor de Statistiek (CBS), 2026b). This includes all males. The children and people in institutional care should be subtracted from this number. That leaves 6,311,377 males as part of the population. Doing the same for females results in a total of 6,736,865 females in the population. An interesting observation from both the sample and the population numbers is that there are more females in both.

Now that the distribution of both the sample and the population are known it is possible to mathematically determine the representativeness of the dataset. With a nominal variable like

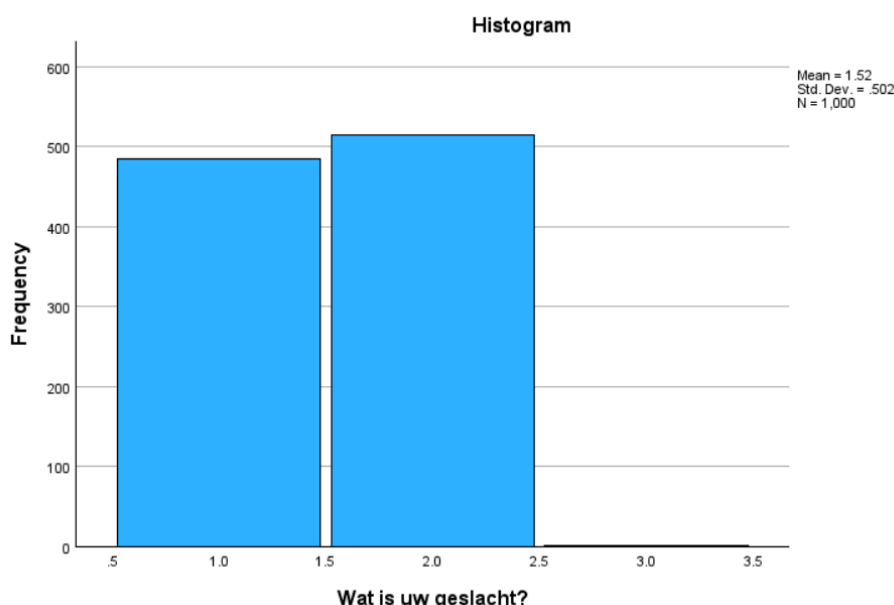


Figure 6.1: A histogram to show the distribution of gender in the sample. ('Wat is uw geslacht?' = 'What is your gender?')

gender, the appropriate test is a chi-square goodness-of-fit test. Using the general equation of chi-square shown in Equation 5.1 the resulting value is 0.0004. The critical value of the chi-square with a $df=1$ is 3.84. The score of 0.0004 is lower than that critical value. Thus, the test shows representativeness. The full equation can be seen in Equation B.1.

Age

The descriptive statistics of gender are not very useful as it is a nominal factor, thus many of the descriptives do not work with it and are not addressed. In contrast, 'Age' allows for the descriptives to mean much more. The lowest age of the respondents is 18 years old and the oldest respondent is 80 years old. The average age in the survey is 48.92 years with a standard deviation of 17 years. Overall, the distribution of age looks quite uniform. Perhaps with a more bulbous middle around the average.

Unfortunately, no data can be found on the age distribution of households specifically. As a proxy the general age distribution of the Netherlands is used, excluding everyone under 18 and above 80. They are not represented in the data set and logically do not fit the description of the population. The representativeness of the age distribution can be found using two methods. The first is a one sample T-test comparing the means and the second is again a chi-square test. For the latter, age brackets are used, instead of a continuous range. Both methods are applied.

Using the population pyramid of the Netherlands (Centraal Bureau voor de Statistiek (CBS), 2026a) the mean age and bracket distribution can be found. The mean age is 47.7 years. Performing a one-sample T-test produces a T-value of 2.258, which corresponds to a p-value of 0.024. Thus, the sample shows representativeness.

	Sample	Population
18-25	105 (10.5%)	13.2%
26-35	169 (16.9%)	17.3%
36-45	166 (16.6%)	16.1%
46-55	170 (17.0%)	16%
56-65	187 (18.7%)	17.6%
65+	203 (20.3%)	19.8%
Mean	48.92	47.7
Standard deviation	17.031	-
Minimum	18	-
Maximum	80	-

Table 6.2: The distribution of age categories in the sample and the population and some descriptive statistics.

Wat is uw leeftijd?

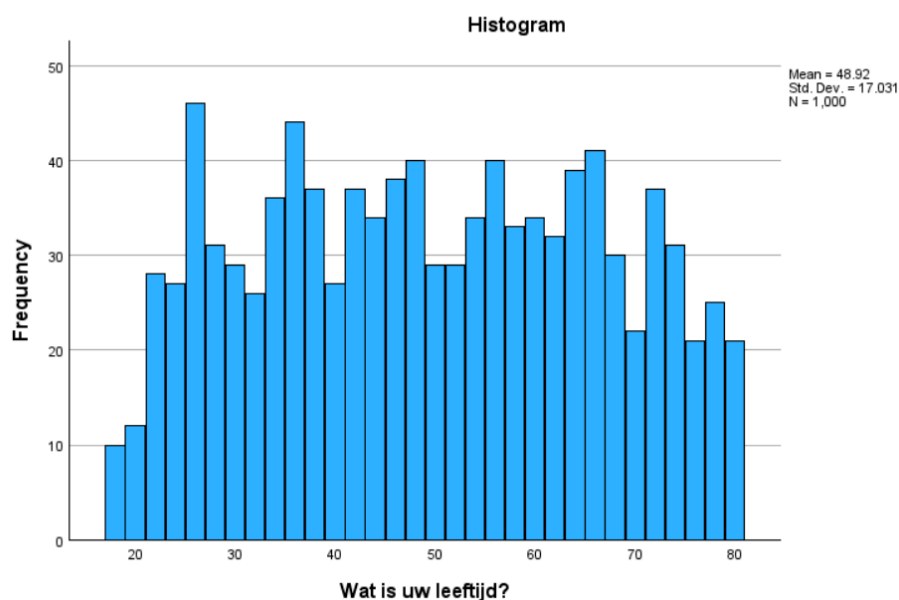


Figure 6.2: A histogram to show the distribution of age in the sample. ('Wat is uw leeftijd?' = 'What is your age?')

The population has the following age-bracket distribution: 18-25: 13.2%, 26-35: 17.3%, 36-45: 16.1%, 46-55: 16%, 56-65: 17.6% and 66+: 19.8%. After calculating the chi-square it comes out to be 0.72. The critical value for a $df=5$ is 11.07, thus the sample falls well within limits and can be considered representative. The full equation can be seen in Equation B.2.

Education

Just like with the demographic 'gender' more advanced descriptive statistics like average and interquartile range are not applicable to education levels. The only thing of use that can be said about this data is the distribution of the levels. The most common education level is MBO (any level) with 28.5 percent of the sample. A close second is the HBO/VO-bachelor with 25 percent. 11 people did not receive any education or only primary and the next lowest is LBO/VBO/VMBO/MBO 1.

	Sample	Population
No education/Primary	11 (1.1%)	-
LBO/VBO/VMBO (kader)/MBO 1	76 (7.6%)	-
MAVO/HAVO (1-3)/VWO (1-3)/ULO/MULO/VMBO (theoretical)	116 (11.6%)	-
Primary/VMBO/MBO1	-	26%
MBO 2-4	285 (28.5%)	-
HAVO/VWO/HBS/MMS/HBO 1st year/VO 1st year	128 (12.8%)	-
HAVO/VWO/MBO 2-4	-	37%
HBO bachelor/VO bachelor	250 (25%)	-
VO master/HBO master/PhD/postdoc	134 (13.4%)	-
HBO/VO	-	36.4%

Table 6.3: The distribution of education levels in the sample and the population.

The level of education of the population could not be found for home-owners only. As a substitute the total population of people from 15 to 75 has been used (Centraal Bureau voor de Statistiek (CBS), 2024). In 2023, 26 percent of the population had an education in primary, vmbo or mbo 1. Combining group 2 and 3 the sample has a total of 19.2 percent in this group. HAVO, VWO and MBO 2-4 make up 37 percent of the population. In the sample, they make up 41.3 percent. Lastly, HBO and VO make up 36.4 percent of the population and they make up 38.4 percent of the sample. This shows a slight bias towards the higher educated individuals in the sample.

Just like the gender distribution, the education distribution representativeness is also tested by using a chi-square method. This will make use of the three groups that the population is represented in. The chi-square equation is used to find a value of 2.39. The critical value for a $df=2$ is 5.99 and the chi-square falls far below it, thus the sample is representative. The full equation can be found in Equation B.3.

Income

The interval categories that have been used in the survey mean that descriptives like average and interquartile range cannot be calculated accurately. Instead, some income brackets

are given. Most families fall in the range of 29,601 to 50,300. In second place are those ranging from 50,301 to 79,600. The smallest group of people earn more than 123,400 with 5.5 percent of the sample.

	Sample	Population
Less than 29,600	147 (16.6%)	20%
29,601 - 50,300	252 (28.5%)	20%
50,301 - 79,600	233 (26.3%)	20%
79,601 - 123,400	204 (23.1%)	20%
More than 123,400	49 (5.5%)	20%
No response	115	-

Table 6.4: The distribution of income in the sample and the population.

The income brackets used in the survey correspond to quintile cut-offs used by the CBS. Thus, every group in the population is by definition 20% of total (Centraal Bureau voor de Statistiek (CBS), 2025). The group of people that indicated 'do not know/do not want to say' in the survey are excluded from analysis and the remainder will be adjusted to sum to 100%.

Income is a ratio variable as it has an absolute zero, an order and every increment means the same. In the questionnaire, however, it is structured in groups making it perfect for the chi-square test. A value of 17.16 is found using the chi-square equation. See Equation B.4 for the full equation. The critical value for a $df=4$ is 9.49, so the sample does not show representativeness on this demographic. This phenomenon can, however, be explained by the central limit theorem. Looking at the distribution of the sample data supports said conclusion. Also, the fact that the population distribution is uniform and the sample distribution looks normal supports said conclusion.

Resident owner/renter

This is another nominal demographic determining whether the respondent owns or rents their home and whether they are part of a home-owners association. Again, the only useful information is in the frequencies of each category. 48 percent of respondents reported to be owner of their residence and not be part of an HOA. A further 18.8 percent report owning their home and being part of an HOA. The remaining respondents report renting their home with a total of 33.2 percent of the respondents.

	Sample	Population
Resident-owner (No HOA)	480 (48.0%)	48.5%
Resident-owner (HOA)	188 (18.8%)	8.6%
Renter	332 (33.2%)	42.9%

Table 6.5: The distribution of owners and renters in the sample and in the population.

Finding the population distribution for this demographic was not as easy as some of the others. While the CBS does provide figures on the distribution between those that are part of an HOA or not it does not distinguish between renters and owners (Goedhuys et al., 2023). The government, however, provides figures on the total amount of rental homes (Government

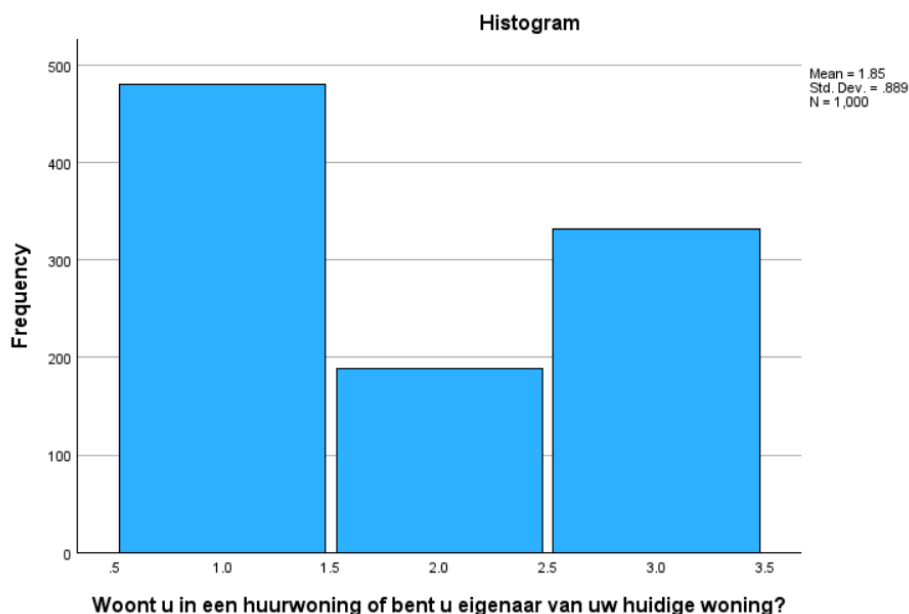


Figure 6.3: A histogram to show the distribution of renters/owners in the sample. ('Woont u in een huurwoning of bent u eigenaar van uw huidige woning?' = 'Do you live in a rental property or to you own your current residence?')

of the Netherlands, 2026). Combining the sources gives the following population data: the renters make up 42.9 percent, the owner-residents (HOA) make up 8.6 percent and the owner-residents (not HOA) make up 48.5 percent.

Once again, this demographic is presented in nominal categories making the chi-square test perfect to test for representativeness. A value of 14.30 was found using the chi-square equation (the complete formula can be found in Equation B.5). The critical value for a $df=2$ is 5.99, so the sample does not show representativeness on this demographic.

Type of house

This variable describes the type of house that the respondent lives in. Once again it is a nominal variable. Thus, the only relevant descriptives are the frequencies of the categories. Some interesting observations are that 38.6 percent of people live in apartments. Furthermore, 28.2 percent live in terraced homes and 8.0 percent live in a detached house.

The population for this demographic can be found by looking at the total housing stock of the market of 8,334,953 (Centraal Bureau voor de Statistiek (CBS), 2026c). It does not mention numbers on single family homes. To circumvent this issue both single-family homes and 'other' are excluded from the equation. The other categories are adjusted to their sum. In 2026, there were a total of 3,105,433 multiple family homes which translates to the apartments in the sample. This reflects 37.3 percent of the population. There were a total of 716,574 semi-detached homes; representing 8.6 percent. With a total of 1,062,201 the detached houses make up 12.7 percent. End-of-terrace homes represent 12.5 percent of the total with 1,040,482 homes. And lastly, in-betweens, with 2,411,304 make up 28.9 percent of the total.

This demographic can once again be tested for representativeness using the chi-square test.

	Sample	Population
Apartment (1st floor)	89 (9.7%)	-
Apartment (higher floors)	265 (28.9%)	-
Apartments	-	3,105,433 (37.3%)
semi-detached homes	95 (10.4%)	716,574 (8.6%)
Detached	73 (8.0%)	1,062,201 (12.7%)
End-of-terrace homes	135 (14.8%)	1,040,482 (12.5%)
Terraced homes	258 (28.2%)	2,411,304 (28.9%)
Single family homes	74	-
Other	11	-

Table 6.6: The distribution of type of house in the sample and the population.

The equation used can be found in Equation B.6, which gives the value of 2.607. The critical value for a $df=4$ is 9.49, thus the sample falls well within limits and can thus be considered representative.

Place of residence

Lastly, the place of residence shows the region that the respondent lives in. It is divided into the 3 big cities in the Netherlands (Amsterdam, Rotterdam, Den Haag), the rest of the west, east, north and west. Once again, these are nominal variables preventing in depth descriptive analysis. For this research, the North was excluded, because of the lack of urbanisation. Furthermore, about a quarter of the participants live in the big three and a further 36.3 percent live in the west.

	Sample	Population
Big three	251 (25.1%)	13.3%
Rest west	363 (36.3%)	37.5%
East	219 (21.9%)	23.5%
South	167 (16.7%)	25.7%

Table 6.7: The distribution of place of residence for the sample and the population.

Using population figures for every province (AlleCijfers.nl, 2026) and the population numbers of the big three cities (Nielsen-region: big cities) (Huurstunt, 2026) allows for finding the Nielsen-region distribution of the population. While these population numbers include everyone and thus not only the heads of households it is the best approximation that can be found. Figures that only include households do not split in a useful manner. The total population figures, however, only add children. Given that they are unlikely to shift the distribution dramatically they can be included. The Nielsen 1 region makes up 13.3 percent of the population, Nielsen 2 37.5, Nielsen 3 23.5 and Nielsen 4 25.7 percent.

Lastly, the place of residence is also represented in nominal categories. This means that it also requires a chi-square test for goodness-of-fit. The chi-square equation is used to find the value of 13.77. For the full formula find Equation B.7. The critical value for a $df=3$ is 7.81. Thus, the sample is not representative of the population on this demographic.

6.2 Attributes analysis

The analysis of the attributes is done using multiple regression analysis. This is what allows for a conjoint experiment to take place. For every respondent and every profile, the attributes of said profile need to be encoded and their ratings by the respondents need to be added. At that point, simple multiple regression analysis has been applied. The results of which are shown in Table 6.8. Note that in the dataset the lowest possible value for adoption likelihood is coded as 1 and 11 is the highest possible value. This does not change anything about the results except that the constant is artificially one point too high. Thus, to be able to measure the utility on a rating scale of 0 to 10, the constant coefficient needs to have one point subtracted from it. For example, the constant (overall) in Table 6.8 is 5.901, but the rating would be 4.901. This means that the adoption likelihood overall, with all the attributes being 0, would be 4.901 on a scale of 0 to 10.

Overall	Coefficient	T-value	Significance
Constant	5.901	48.752	<0.001
Environmental	0.222	6.660	<0.001
Cost savings	0.018	5.381	<0.001
Capital	−0.006	−10.238	<0.001
Maintenance	−0.056	−3.378	<0.001
Only renters	Coefficient	T-value	Significance
Constant	5.932	28.154	<0.001
Environmental	0.172	2.965	0.003
Cost savings	0.011	1.859	0.063
Capital	−0.006	−6.285	<0.001
Maintenance	−0.056	−1.919	0.055

Table 6.8: Results of the conjoint analysis for all respondents and only the renters.

For the analysis of the attributes a consideration had to be made. Whether to include renters into the analyses or not. The argument can be made that renters do not apply to this situation, because they have limited power to implement urban nature-based solutions. Thus, it would not matter what the attributes of the NbS are to the likelihood of adoption. To check this assumption analysis has been done using only renters as data points. While some can be observed to, indeed, not change their adoption likelihood with differing attributes, most of them do. Analysis of the data shows that ‘cost savings’ and ‘maintenance’ are not significant in their decision-making process, but environmental benefit and capital expenditure are. This can be explained by the fact that cost savings and maintenance do not apply to them, but environmental benefit and capital expenditure do. Given these findings, the argument is made that useful data is contained in the ‘renters’ respondents and will thus be used in the further analyses. This data also shows that there is logical validity behind including them.

As can be seen, all the attributes show statistical significance. Also, the R square of the model is 0.021 showing validity and the F-value is 47.384 with a p-value of 0.001. For every increase in the environmental benefit, the adoption likelihood increases by 0.222. For every percent that is saved on the utilities bill, the adoption likelihood increases by 0.018 and for every euro per square metre increase, the adoption likelihood falls by 0.006. Lastly, the

adoption likelihood falls by 0.056 for every hour of extra maintenance. These relations and their directions make sense from a theoretical standpoint.

	Coeff.	Lowest level	Utility	Highest level	Utility	Range utility	Rank impact
Environmental	.222	1	.222	3	.666	.444	2 (25%)
Cost savings	.018	5	.09	25	.45	.36	3 (22%)
Capital	-.006	30	-.18	150	-.9	-.72	1 (40%)
Maintenance	-.056	2	-.112	6	-.336	.224	4 (13%)

Table 6.9: Calculation of the utility range of every attribute.

Using the coefficients found in Table 6.8 the total relative utility provided by every attribute can be calculated. Thus, the relative influence of the attributes on the adoption likelihood can be determined. It starts by determining the lowest possible utility value by multiplying the lowest level with the coefficients. Then, the highest utility is calculated by multiplying by the highest level. The difference between these is the utility range. The share that an attributes' utility range has in the total utility range represents how much it influences the decision-making behaviour. These numbers can be seen in Table 6.9.

Linearity

When estimating a utility model like above it is important to check whether the utility functions of the attributes are linear or not. Therefore it should be tested. For every attribute a quadratic component has been computed and tested in the model to check for non-linear relations.

	Coefficient	T-value	Significance
Constant	5.993	18.443	<0.001
Environmental	0.055	0.235	0.814
Cost savings	0.007	0.425	0.671
Capital	-0.007	-2.255	0.024
Maintenance	0.023	0.197	0.844
Environmental ²	0.042	0.724	0.469
Cost savings ²	0.000	0.603	0.547
Capital ²	5.231E-6	0.326	0.744
Maintenance ²	-0.010	-0.686	0.492

Table 6.10: The coefficients of the attributes and their significance including the quadratic variables.

The table shows that none of the quadratic variables are statistically significant in the model. Thus, it can be concluded that all the attributes have a linear effect on the utility.

Willingness to pay

Another interesting data point that can be gathered from a conjoint experiment is the willingness to pay of the respondents. In the case of this study the central question is how to create more environmental benefit. Thus, for this analysis the question is what the willingness to pay for environmental benefit is.

Calculating the WTP is done by seeing how much the price can rise with an increase in

environmental benefit and still result in the same utility. The utility rises by 0.222 for every higher level of environmental benefit. The utility would lower by 0.006 for every extra euro per square metre. This produces the following formula:

$$0.222 - 0.006 \cdot \text{price}_{\text{rise}} = 0 \quad (6.1)$$

Solving it results in a price rise of 37. This is interpreted as meaning that respondents are willing to pay an extra 37 euros per square metre to rise a level in the environmental benefit.

Utility

Estimating the utility function allows for the prediction of the adoption likelihood of a profile with certain attributes. Now that the coefficients are known it has become possible for an equation to be constructed. The first part of the equation is the constant. This represents the base adoption likelihood in the imaginary scenario that all the attributes have a value of zero. The second part of the equation are the attribute coefficients. Multiplying them by the value of the attribute either adds or subtracts adoption likelihood from the result. The equation is shown below.

$$4.901 + 0.222 \cdot \text{Environmental} + 0.018 \cdot \text{Cost savings} - 0.006 \cdot \text{Capital} - 0.056 \cdot \text{Maintenance} = \text{Adoption likelihood} \quad (6.2)$$

6.2.1 Distinction between genders

The data collected also includes measures for demographic factors like gender. This allows for analyses to take place that look at potential differences between demographic groups. The first of these analyses will see if there is a difference between males and females.

Males	Coefficient	T-value	Significance
Constant	6.087	35.131	<0.001
Environmental	0.202	4.239	<0.001
Cost savings	0.018	3.692	<0.001
Capital	-0.005	-6.600	<0.001
Maintenance	-0.046	-1.936	0.053
Females	Coefficient	T-value	Significance
Constant	5.725	33.996	<0.001
Environmental	0.241	5.198	<0.001
Cost savings	0.018	3.940	<0.001
Capital	-0.006	-7.908	<0.001
Maintenance	-0.066	-2.843	0.004

Table 6.11: Results of the conjoint analysis split by gender.

There are some slight differences that can be observed between males and females. First is that females place more importance on the environmental benefit for their adoption likelihood than males with respectively .241 and .202 on the coefficient. Second, is that females are

slightly less likely to adopt urban nature-based solutions as the capital expenditure rises. Lastly, the biggest difference can be found in the maintenance attribute. More maintenance required seems to be drastically more impactful for females than males. What should be noted, however, is that the attribute is not quite statistically significant for the analysis of the males. Also, an interesting observation is that there seems to be no difference in the cost savings attribute for males and females.

6.2.2 Distinction between regions

A question that has been interesting to answer throughout the whole research is whether there are differences between the regions that a person lives in. Thus, the differences between different regions are analysed here.

Big Three	Coefficient	T-value	Significance
Constant	6.163	24.012	<0.001
Environmental	0.169	2.384	0.017
Cost savings	0.015	2.065	0.039
Capital	−0.005	−4.506	<0.001
Maintenance	−0.053	−1.511	0.131
Rest West	Coefficient	T-value	Significance
Constant	5.810	29.545	<0.001
Environmental	0.239	4.414	<0.001
Cost savings	0.017	3.152	0.002
Capital	−0.007	−7.549	<0.001
Maintenance	−0.053	−1.949	0.051
East	Coefficient	T-value	Significance
Constant	5.722	22.817	<0.001
Environmental	0.272	3.931	<0.001
Cost savings	0.021	3.006	0.003
Capital	−0.004	−3.832	<0.001
Maintenance	−0.049	−1.421	0.156
South	Coefficient	T-value	Significance
Constant	5.940	20.388	<0.001
Environmental	0.201	2.498	0.013
Cost savings	0.021	2.635	0.008
Capital	−0.005	−4.102	<0.001
Maintenance	−0.078	−1.939	0.053

Table 6.12: Results of the conjoint analysis split by region.

The first thing to notice is that in none of the regions maintenance shows statistical significance. While it did show it with the complete dataset it quickly becomes insignificant as the data shrinks. The second thing to notice is the impact of environmental benefit. It is most influential in the west and the east with .239 and .272 with the south following behind. With a score of .169 the big cities come in significantly lower than the other places. The influence of the savings on costs seems to be divided into .015 and .017 for the big cities and the west and .021 for both the south and the east. The influence of capital investment seems to be comparable everywhere, only showing a higher value in the west. Overall, the influence of

the attributes seems to matter less for residents of the big cities and more for the rest of the regions.

6.2.3 Distinction between education levels

The next distinction that can be made is between the different education levels that participants have received. There are two demographic measures that can be used for its analysis. Detailed data on the exact education or a more general low/middle/high distinction. For the purposes of this analysis the second one fits best.

Low-level	Coefficient	T-value	Significance
Constant	5.876	21.265	<0.001
Environmental	−0.28	−0.367	0.714
Cost savings	0.009	1.154	0.249
Capital	−0.004	−2.954	0.003
Maintenance	−0.034	−0.884	0.377
Middle-level	Coefficient	T-value	Significance
Constant	5.948	33.042	<0.001
Environmental	0.202	4.067	<0.001
Cost savings	0.013	2.676	0.007
Capital	−0.006	−7.011	<0.001
Maintenance	−0.058	−2.351	0.019
High-level	Coefficient	T-value	Significance
Constant	5.863	29.578	<0.001
Environmental	0.376	6.889	<0.001
Cost savings	0.028	5.093	<0.001
Capital	−0.007	−7.254	<0.001
Maintenance	−0.066	−2.423	0.15

Table 6.13: Results of the conjoint analysis split by education levels.

The first thing that stands out is that all the influences of the attributes are insignificant for the low education group, except for capital expenditure. The attributes in middle and high education groups are all significant. The biggest takeaway here is that the highly educated are way more sensitive to the attribute levels than the middle educated. For example, the influence of environmental benefit is almost twice as big and that of cost savings is more than twice as large.

6.2.4 Distinction between income levels

Furthermore, differences might be observed between income levels. Once again there are two measures for income. One goes more into detail and one distinguishes between low/middle/high. The latter will be used once more. It should be noted, however, that 115 respondents did not disclose their income. These are excluded from the analysis.

A recurring result is that maintenance is not statistically significant in the decision-making process. For income levels it is also not significant in the low group. Further observations

Low income	Coefficient	T-value	Significance
Constant	5.862	29.833	<0.001
Environmental	0.132	2.438	0.015
Cost savings	0.011	2.106	0.035
Capital	−0.006	−6.572	<0.001
Maintenance	−0.033	−1.234	0.217
Middle income	Coefficient	T-value	Significance
Constant	6.070	24.961	<0.001
Environmental	0.212	3.159	0.002
Cost savings	0.022	3.351	<0.001
Capital	−0.006	−5.454	<0.001
Maintenance	−0.080	−2.380	0.017
High income	Coefficient	T-value	Significance
Constant	5.975	25.114	<0.001
Environmental	0.342	5.215	<0.001
Cost savings	0.025	3.778	<0.001
Capital	−0.005	−4.853	<0.001
Maintenance	−0.076	−2.321	0.020

Table 6.14: Results of the conjoint analysis split by income levels.

are that the influence of capital barely changes with differing income levels. The influence of maintenance also does not significantly change between middle and high incomes. There are, however, significant differences in the influence of environmental benefit and cost savings with differing income levels. The higher the income level the more sensitive the adoption likelihood becomes due to these attributes.

6.2.5 Distinction between ages

The last distinction that can be made and might yield interesting results is between different ages. For the purposes of the analysis the ages have been grouped in brackets of 10 years.

Before presenting the results it must be noted that some of the attributes are not statistically significant for some of the analyses. The most likely cause for this is the limited number of respondents in every group. This could be solved by increasing the range of every group. The downside, however, is that the resolution of differences between groups will diminish. Given that most parts do show statistical significance and those that do not are only slightly so, meaningful results can still be extracted in this manner.

The first thing to notice is that the influence of environmental benefit starts off quite low, then rises to peak between the ages of 46-55 and then drastically lowers again. The same phenomenon can be observed for the cost savings attribute with an outlier in the youngest group. Here it is significantly higher. The influence of capital expenditure barely changes with age and maintenance is insignificant in almost all cases.

18-25	Coefficient	T-value	Significance
Constant	6.747	21.712	<0.001
Environmental	0.141	1.650	0.099
Cost savings	0.019	2.261	0.024
Capital	-0.004	-2.724	0.007
Maintenance	-0.033	-0.760	0.448
26-35	Coefficient	T-value	Significance
Constant	6.640	22.769	<0.001
Environmental	0.226	2.810	0.005
Cost savings	0.011	1.362	0.173
Capital	-0.006	-4.540	<0.001
Maintenance	-0.065	-1.620	0.106
36-45	Coefficient	T-value	Significance
Constant	6.225	22.370	<0.001
Environmental	0.247	3.221	0.001
Cost savings	0.021	2.684	0.007
Capital	-0.004	-2.920	0.004
Maintenance	-0.081	-2.108	0.035
46-55	Coefficient	T-value	Significance
Constant	5.741	20.269	<0.001
Environmental	0.327	4.195	<0.001
Cost savings	0.025	3.253	0.001
Capital	-0.007	-5.664	<0.001
Maintenance	-0.062	-1.582	0.114
56-65	Coefficient	T-value	Significance
Constant	5.306	18.345	<0.001
Environmental	0.226	2.840	0.005
Cost savings	0.020	2.449	0.014
Capital	-0.006	-4.551	<0.001
Maintenance	-0.061	-1.543	0.123
65+	Coefficient	T-value	Significance
Constant	5.265	19.733	<0.001
Environmental	0.149	2.021	0.043
Cost savings	0.013	1.798	0.072
Capital	-0.006	-5.036	<0.001
Maintenance	-0.032	-0.871	0.384

Table 6.15: Results of the conjoint analysis split by ages.

Conclusions

Having the results at hand means conclusions can be made about the influence of attributes on the adoption likelihood of the urban nature-based solutions. In the general population, the capital expenditure is the most influential attribute and can explain 40% of the variance in adoption likelihood due to attributes. The second and third most influential are environmental benefit and cost savings with, respectively, 25% and 22%. Lastly, the maintenance can explain 13% of the variance. It should be noted, however, that maintenance quickly becomes insignificant with a smaller sample. Thus, the conclusion could be made that maintenance does not significantly influence the adoption likelihood. Additionally, these conclusions can only be made about the relative changes in adoption likelihood. The full range of utility changes is quite limited indicating that the influence of attribute levels on the adoption likelihood is also quite limited. The rating only changes by about 1 or 2 points with varying attribute levels. Thus, the absolute influence of attributes on the adoption likelihood is small.

Additional conclusions are that all the attribute influences are linear and that the respondents are willing to pay an extra 37 euros for every level increase of the environmental benefit.

By distinguishing the results between different demographic groups, some interesting conclusions can be made on the differences between them in terms of the influence of attributes on the adoption likelihood. First of all, males tend not to consider maintenance when deciding to adopt or not. Also, females are a bit more concerned with environmental benefit, but apart from that no significant differences can be found between genders.

Secondly, residents of the big cities are influenced relatively less by attributes than other areas. Only capital expenditure matters the same for all regions. The western and eastern regions seem to be more concerned with environmental benefit and the eastern and southern with potential cost savings.

Thirdly, some major differences can be found between education levels. The main conclusion that can be found is that the attribute levels matter increasingly more with higher education levels. The differences are quite large with highly educated individuals being twice as sensitive to environmental benefit and cost savings than middle educated people.

The same general trend that can be found with education levels can also be observed with income levels. Interestingly, the capital expenditure attribute matters the same across all levels. Also, an interesting conclusion can be made that potential cost savings matter more to higher income levels than lower levels.

The differences between ages indicate that capital expenditure does change between groups, but randomly. Thus, this is probably the result of random variances and not an actual pattern. What does get impacted by age is the influence of environmental benefit and cost savings. Both follow an inverted-U pattern, peaking in the 46-55 age group.

The available literature on urban nature-based solutions is relatively novel, but provides interesting insights. Most of it focuses on concepts of implementations and what the effects of it would be. Some look at factors that influence adoption, but none take into account the influence of the solutions' attributes. This thesis adds those insights to the literature as a novel contribution. Not only is that added to the literature, but major differences between groups of people and what choices they make have been discovered as well. The implications of these findings are largely related to the uptake of urban nature-based solutions. Policies to promote the uptake of urban nature-based solutions can now be tailored to maximise the likelihood of adoption. Different groups can, for example, be shown the urban NbS they are most likely to adopt.

With the thesis coming to a conclusion it has become possible to answer the research questions that started the thesis in the first place. The literature has provided an answer to which attributes potentially played a role in the decision-making behaviour. It provided four: environmental benefit, capital expenditure, cost savings and maintenance. These could then be quantified by relative environmental benefit, costs per square metre, percentage savings on utilities bill and average hours of maintenance required per month. The third sub-question was answered by finding accurate values for these that can be found in Table 5.1. Finally, the main research question could be answered: the key attributes that lead to the adoption of urban nature-based solutions are capital expenditure, environmental benefit and cost savings. Maintenance also has some influence, but much less than the others and is therefore not key.

Additionally, it can be concluded that the utility gained from the attributes follows a linear relation. This means that every marginal change at every level does the same to the likelihood of adoption. The novel concept of willingness to pay has shown that people are willing to pay an extra 37 euros per square metre if it increases the environmental benefit gained. Lastly, with the utility function, it can be concluded that the attributes do have some influence on adoption likelihood overall. The rating given, however, does not vary greatly. Thus, there are likely other influences as well.

8

Discussion

This chapter goes into discussions that can be had about the research that has been done. This can be about the methods employed, the results gathered or any other part. It also explores ideas for additional research that can be done to build on what has been found here.

Survey setup

The first thing that should be noted regards the setup of the survey. When designing the survey a limit of 15 minutes had to be taken into account. With all the information that needed to be gathered, it was a struggle to fit all the desired questions into the questionnaire. All the questions together would have taken around 20 minutes. This means that questions had to be cut, edited or merged regularly. The issue that arises is that not all factors could be measured like they usually are in the literature. Instead, simplifications or shortened versions had to be used. The conjoint experiment, specifically, could theoretically be made more extensive by including more attributes and/or profiles. This means that discussion can be had about the validity of the results of the questionnaire.

Sample representativeness

Overall, the sample shows representativeness on gender, age, education and type of house. The first demographic it does not show representativeness on is income. This observation, however, can be explained away with the central limit theorem. Secondly, the data shows a bias towards resident-owners and against renters and is biased towards residents of the big cities. These biases are not problematic, however, because the research itself is biased towards the big cities and resident-owners. The research focuses on urban areas and people that can implement urban nature-based solutions. These are represented by the bias. Thus, discussion can be had about the representativeness of the sample, but does not significantly undermine the data and might even strengthen it.

Questionnaire framing

One of the things that should always be taken into consideration when performing a survey is that the manner in which the questions are asked will likely influence the way in which they

are answered. In order to mitigate this risk the questions have been carefully considered to be as neutral as possible. For the conjoint experiment a comparable problem arises with the choice of attributes and their levels. The attributes chosen might not represent all that a respondent will take into consideration during their choice. Extensive research has been done to try to make sure that all the relevant attributes are included. Regarding the levels; they have been chosen in such a way that they represent values as realistic as possible and a wide range to minimise any bias.

Limited overall influence

While this report concludes that the adoption likelihood is influenced by the attributes of urban nature-based solutions, in particular capital expenditure, environmental benefit and cost savings, there is a caveat to it. Through the utility function it has been possible to estimate the influence of attributes, in general, on the adoption likelihood. It was found that the attributes have a limited influence on the rating given by people. In general, it only raises or lowers the rating by 1 or 2 points at most. This means that changing attributes have a limited influence on the adoption likelihood as a whole. These findings point to the presence of other influences. Therefore, it should be kept in mind that attributes do influence adoption likelihood, but only in a limited manner.

Context of willingness to pay

This thesis provides the willingness to pay for a more environmentally beneficial urban nature-based solution. The manner in which it has been found, however, is quite circumstantial and will be hard to translate into any real-world use. The willingness to pay shows how much more people will pay for a higher level of environmental benefit. While this makes sense in the context of this thesis, it will be hard to translate into a real-world application.

Interpretation on environmental benefit levels

In the survey used for this thesis the 'environmental benefit' was quantified by using the levels: low, normal, and high. While the information gathered by using these levels can be useful it also has its limitations. The usefulness comes from being able to identify how much importance people place on the environmental benefit (compared to other attributes). Therefore, it can be a guideline for how much focus it should get in any effort to increase the adoption by households. In contrast, it cannot be used to find the appreciation people will have for an urban nature-based solution with a certain absolute environmental benefit. This is because the way in which it has been formulated only works in the context of this thesis/survey.

Future research

This section explores ideas for research that can build upon what has been done here. It gives some suggestions on what can be added to the findings of this paper, but also next steps that can be taken, making use of the information that has been created here.

Effectiveness of widespread adoption

In the introduction of this paper it was said that widespread adoption of urban nature-based solutions was needed to achieve the desirable effects. A significant part of it can be achieved by public entities themselves, through urban design of publicly owned spaces. The other part needs to be implemented by private owners of land and buildings. This paper focuses on the adoption of urban nature-based solutions by residents. These are the households in urban areas that live in their residence. What this paper does not investigate is whether widespread adoption by this group of people will actually be effective. There are constraints that can be identified in this case. In urban areas, the group of residents might be too small to make a significant impact. If the majority of land and buildings in an urban area belongs to renters, corporations, institutions etc., then widespread adoption by residents might be insufficient to make an impact. Thus, further research should find whether a significant effect is achieved in the scenario that residents widely adopt urban nature-based solutions.

Additional factors

This paper has analysed the role of attributes in determining the decision-making process of the adoption of urban nature-based solutions. From the results, conclusions can be made on which of these have the most influence. What cannot be concluded with absolute certainty, however, is that these attributes present an extensive list. There might be other variables that can explain the behaviour that is subject of this research. For example, demographic factors might be directly related to the behaviour people show. Such an analysis is not part of this research, but can be done. Additionally, demographic factors might be able to explain the socio-psychological factors that people possess. Given that socio-psychological factors cannot be directly observed, but demographics can, it might be quite useful to identify this for the purposes of formulating policies. Thus, research into the role of additional factors, like demographics and socio-psychological factors has the potential to be very useful.

Policy creation

A contribution to the literature has been made with this research. It has created deeper understanding of the thought and decision-making process that happens before someone decides whether to adopt an urban nature-based solution on their own property. The author of this paper invites the research community to make use of the findings and formulate strategies, policies, frameworks etc. that will maximise the number of private urban nature-based solutions. This paper provides the theory that can be used to create actually implementable strategies, which target the right attributes as they have been found. The results of this paper enable policy-makers to target that which actually matters and make effective strategies.

Whatever the goal of future research, policy and/or strategy is, it can make use of the findings in this paper.

Separate environmental effects

In order to conduct this research the environmental effects of urban nature-based solutions had to be grouped together under the term 'environmental benefits'. In the research, it was used in the part where profiles were constructed, which were rated by the respondents. This needed to be done, because it prevents the questions from being overwhelming to the participants. It does, however, mean that the distinction between the different environmental effects cannot be gathered from the data; it is lost. It would be interesting to see how the differentiated environmental effects influence the desirability of the profiles and thus the likelihood of adoption. With that data, the relative influence of the environmental effects can then be estimated using data analysis. Future research can be done to identify these differences. An example of how this can be done is in the same manner that the profiles in this research have been set up. Instead of having the four attributes as: environmental benefit, cost savings, capital expenditure and maintenance they can be: air quality improvement, water retention, heat reduction and biodiversity effects. What has to be kept in mind is that, just like in this research, these remain hard to quantify attributes. Thus, a great deal of thought and effort has to go into their quantification.

A

Appendix: Transcript of questionnaire

This appendix is the complete questionnaire that was shown to the respondents of the survey. Note that this version is in English, but the version given to the respondents was given in Dutch, because they all spoke Dutch and it could not be guaranteed that they all spoke English. This is not the full survey that was presented to the respondents. Only the part relevant to this research is presented. There is also a part that incorporates socio-psychological factors, but those are part of ongoing research and will thus not be shown.

Introductory statement

You are invited to participate in a study titled: Key factors influencing the adoption of nature-based solutions in urban environments by households. This study is being conducted by Dave Meertens from TU Delft and is funded by the NL2120 programme. The aim of this study is to gain insight into the factors that determine whether or not someone chooses to implement a nature-based solution on private property in an urban area. Completing the questionnaire will take approximately 15 minutes. The data will be used to identify key factors through data analysis. We will ask you questions about your values, views, and beliefs. Additionally, you will be presented with an urban nature-based solution featuring specific characteristics and asked to rate the likelihood of adopting it. The survey is anonymous; your answers cannot be traced back to you. The data will be made public upon completion of the research project. Participation in this study is entirely voluntary, and you may withdraw at any time. You are free to skip questions. Data cannot be deleted after the survey has been completed because the responses are anonymous. For questions, please contact ... or

The survey consists of the following sections:

- Views on nature-based solutions.
- Perceptions of urban climate impacts.
- Social interactions regarding nature-based solutions and climate impacts.
- A presentation of 9 profiles, followed by a request to rate their attractiveness.
- Demographic characteristics.

By proceeding to the survey, you agree to this opening statement. Do you agree to the above?

Answers

- Yes, I understand that I give permission to participating in this research by choosing this answer.
- No, I do not want to participate.

Introduction to the concept of urban nature-based solutions

Urban nature-based solutions are solutions that utilise natural systems and thus contribute to solving ecological and societal challenges. This questionnaire concerns nature-based solutions that households can install on their private property. Examples include:

- Green roofs: a roof with vegetation, such as moss, herbs, or larger plants.
- Rain gardens: a landscaped depression in the garden where plants grow
- Green walls: an exterior wall covered with plants

Question A

What is your gender?

- Male
- Female
- Non-binary
- I would rather not say

Question B

What is your age?

- Open answer

Question 1-11

These questions are part of ongoing research by Lune Massop at TU Delft. For information or questions about this part, please contact

Introduction attributes of urban nature-based solutions

Not all urban nature-based solutions are the same. They can have differing benefits and costs. You will now be asked to rate the likelihood that you will adopt an urban nature-based solution with certain attributes (profile). Please do so on a scale of 0 to 10 where 0 is the lowest likelihood and 10 is the highest likelihood. The attributes that the profiles differentiate between and their explanations are:

Environmental benefits (low, normal, high): All urban nature-based solutions provide benefits for the environment (better air quality, water management, heat management, biodiversity etc.). This attribute reflects their relative benefits.

Insulation value (5%, 15%, 25%): urban nature-based solutions can provide insulation value to your residence. This attribute reflects the average amount of cost savings on heating and cooling per month.

Capital expenditure (30, 90, 150): the installation/adoption of urban nature-based solutions comes with a cost. This attribute reflects the costs for every square metre installed. It can be both horizontal and vertical.

Maintenance (2, 4, 6 hours): given that urban nature-based solutions consist of mostly plants they require regular maintenance. This attribute reflects the average hours of maintenance required per month.

Question 12

What is the chance that you will adopt an urban nature-based solution with these attributes? The respondents rated the 9 profiles below based on how likely they would be to adopt it.

Profile 1	Profile 2	Profile 3
Low	Low	Low
5% Cost savings	15% Cost savings	25% Cost savings
€30 per m ²	€90 per m ²	€150 per m ²
2 hours/month	6 hours/month	4 hours/month
Profile 4	Profile 5	Profile 6
Normal	Normal	Normal
5% Cost savings	15% Cost savings	25% Cost savings
€90 per m ²	€150 per m ²	€30 per m ²
4 hours/month	2 hours/month	6 hours/month
Profile 7	Profile 8	Profile 9
High	High	High
5% Cost savings	15% Cost savings	25% Cost savings
€150 per m ²	€30 per m ²	€90 per m ²
6 hours/month	4 hours/month	2 hours/month

Question 13

What are the four numbers of your address?

- Open answer

Question 14

What is the highest education level you have completed?

- No education, primary education, civic integration course, Dutch language course
- LBO, VBO, VMBO (middle management or vocational track), MBO 1 (assistant-level training)
- MAVO, HAVO or VWO (first three years), ULO, MULO, VMBO (theoretical or mixed learning pathway), secondary special education
- MBO levels 2, 3, 4 (basic vocational, vocational, middle-management, or specialist training) or MBO under the old structure (pre-1998)
- HAVO or VWO (promoted to the 4th year), HBS, MMS, HBO first-year certificate, or WO first-year certificate
- HBO (except HBO master), WO candidates or WO bachelor
- University-level doctoral or master's degree, or HBO master's degree; postgraduate education

Question 15

Which type of building fits your current residence best?

- Apartment (1st floor)
- Apartment (higher floors)
- Single family home
- Terraced home
- End-of-terrace home
- Semi-detached home
- Detached
- Other

Question 16

Do you live in a rental property or are you the owner and are you part of an HOA?

- Rental
- Owner (with HOA)
- Owner (without HOA)

Question 17

What is your total gross family income per year?

- Less than €29,600
- €29,601 – €50,300
- €50,301 – €79,600

- €79,601 – €123,400
- More than €123,400
- I do not know/would rather not say

B

Appendix: representativeness equations

This appendix exhibits all the equations that have been used for the sample representativeness with all of the values filled in.

$$X^2 = \sum \frac{(O - E)^2}{E} = \frac{(48.5 - 48.4)^2}{48.4} + \frac{(51.4 - 51.5)^2}{51.5} \approx 0.0004 \quad (\text{B.1})$$

$$\begin{aligned} X^2 = \sum \frac{(O - E)^2}{E} &= \frac{(10.5 - 13.2)^2}{13.2} + \frac{(16.9 - 17.3)^2}{17.3} + \frac{(16.6 - 16.1)^2}{16.1} \\ &\quad + \frac{(17 - 16)^2}{16} + \frac{(18.7 - 17.6)^2}{17.6} + \frac{(20.3 - 19.8)^2}{19.8} \\ &= 0.55 + 0.01 + 0.02 + 0.06 + 0.07 + 0.01 = 0.72 \end{aligned} \quad (\text{B.2})$$

$$\begin{aligned} X^2 = \sum \frac{(O - E)^2}{E} &= \frac{(19.2 - 26)^2}{26} + \frac{(41.3 - 37)^2}{37} + \frac{(38.4 - 36.4)^2}{36.4} \\ &= 1.78 + 0.5 + 0.11 = 2.39 \end{aligned} \quad (\text{B.3})$$

$$\begin{aligned} X^2 = \sum \frac{(O - E)^2}{E} &= \frac{(16.6 - 20)^2}{20} + \frac{(28.5 - 20)^2}{20} + \frac{(26.3 - 20)^2}{20} \\ &\quad + \frac{(23.1 - 20)^2}{20} + \frac{(5.5 - 20)^2}{20} \\ &= 0.58 + 3.61 + 1.98 + 0.48 + 10.51 = 17.16 \end{aligned} \quad (\text{B.4})$$

$$\begin{aligned} X^2 = \sum \frac{(O - E)^2}{E} &= \frac{(33.2 - 42.9)^2}{42.9} + \frac{(48 - 48.5)^2}{48.5} + \frac{(18.8 - 8.6)^2}{8.6} \\ &= 2.19 + 0.01 + 12.10 = 14.30 \end{aligned} \quad (\text{B.5})$$

$$\begin{aligned} X^2 = \sum \frac{(O - E)^2}{E} &= \frac{(38.6 - 37.3)^2}{37.3} + \frac{(28.2 - 28.9)^2}{28.9} + \frac{(14.8 - 12.5)^2}{12.5} \\ &\quad + \frac{(10.4 - 8.6)^2}{8.6} + \frac{(8.0 - 12.7)^2}{12.7} \\ &= 0.05 + 0.017 + 0.42 + 0.38 + 1.74 = 2.607 \end{aligned} \quad (\text{B.6})$$

$$\begin{aligned} X^2 &= \sum \frac{(O - E)^2}{E} = \frac{(25.1 - 13.3)^2}{13.3} + \frac{(36.3 - 37.5)^2}{37.5} + \frac{(21.9 - 23.5)^2}{23.5} \\ &\quad + \frac{(16.7 - 25.7)^2}{25.7} \quad (\text{B.7}) \\ &= 10.47 + 0.04 + 0.11 + 3.15 = 13.77 \end{aligned}$$

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