

MASTER

Loneliness and the built environment

'How are objective and subjective built environment factors associated with feelings of loneliness and how can planning and design of the built environment reduce loneliness?'

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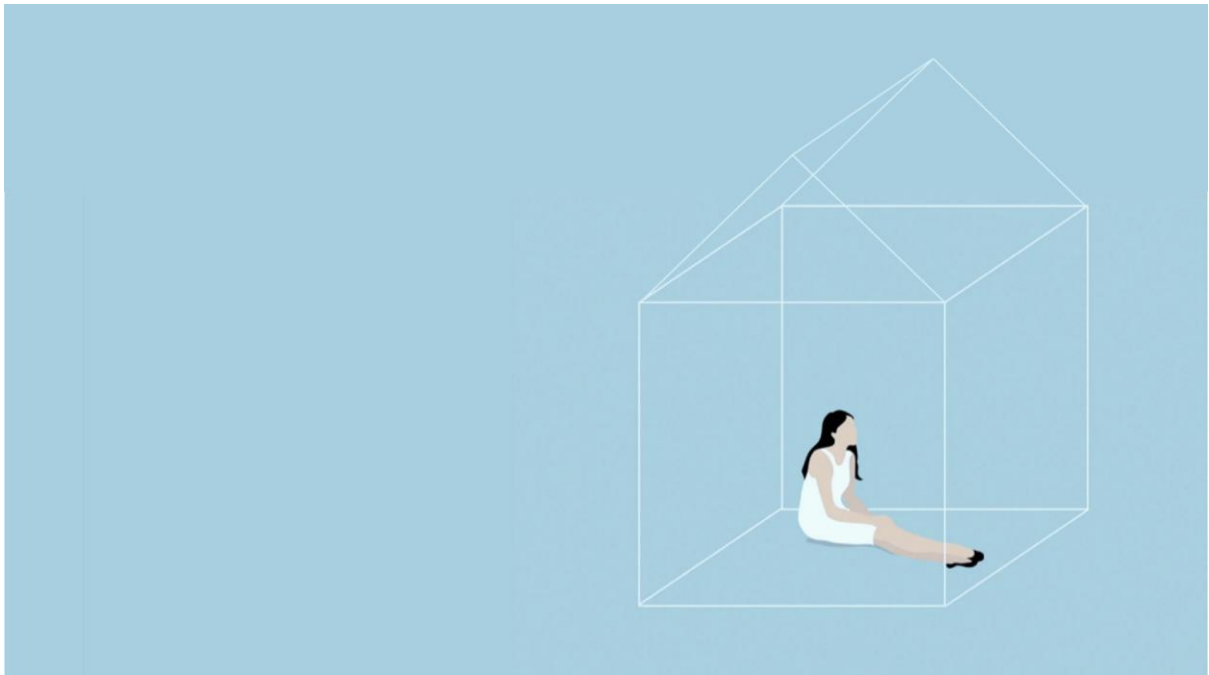
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Loneliness and the built environment

‘How are objective and subjective built environment factors associated with feelings of loneliness and how can planning and design of the built environment reduce loneliness?’

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General information

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Summary

Loneliness is a growing concern. It can be experienced temporarily in specific moments or situations, known as state loneliness. This often encourages individuals to reach out to others. However, if they are unable to form new connections or improve existing ones, it can lead them to spiral downward and become chronically lonely. Chronic loneliness arises when people perceive a gap between the quality and quantity of their relationships compared to their expectations. Those who feel lonely may lack close emotional bonds or have fewer social contacts than they desire. This can result in various psychosocial difficulties, mental health issues, and physical well-being concerns. Furthermore, chronic loneliness can lead to a loss of social capital, weakened social bonds, reduced social cohesion, and an increased burden on healthcare services. Addressing loneliness requires understanding its causes, and finding solutions necessitates personalized approaches. The socio-ecological model highlights that loneliness can be influenced by individual factors, the social environment, and the built environment. While it is challenging to make external improvements to individual and social determinants, interventions in the built environment offer viable opportunities. By examining the built environment, it is possible to investigate how its different elements can promote social interaction and connection among individuals. However, there is a significant research gap regarding the specific factors within the built environment that impact loneliness. Limited studies have investigated how design elements contribute to or alleviate feelings of loneliness. To address the research gap, the objective of this thesis is to synthesize and comprehend how built environment factors are associated with feelings of loneliness and what interventions can be made to reduce loneliness.

Hence, Part I of the study focuses on synthesizing existing research to offer valuable insights into the nature of loneliness, the factors influencing its occurrence, and the effect of built environment factors on individuals' experiences of loneliness. The systematic literature review revealed that satisfaction with dwellings, the availability and quality of amenities, facilities, recreational services, and the usability of the built environment play a role in reducing loneliness. In addition, access to adequate community healthcare and convenient public transport can reduce loneliness. Social environments and safety were also found to be crucial. However, it is important to note that the research on the perception of green attributes in relation to loneliness is limited, and there is a lack of studies specifically examining state loneliness.

Consequently, Part II of the research involved a virtual reality experiment to investigate the relationship between green perceptions and interventions on state loneliness, while considering individual factors and trait loneliness. The findings indicated that crowdedness, the presence of grass, and the presence of trees can reduce state loneliness. Additionally, a latent class analysis identified three distinct groups. Class 1, labeled as "partially environmentally sensitive," experienced reduced state loneliness when exposed to high crowdedness, the presence of grass, and the presence of trees. Class 2, known as "environmentally sensitive," exhibited reduced state loneliness with all considered attributes, including high crowdedness, the absence of grass, the absence of water, the presence of benches, the presence of trees, the presence of vertical greening, and high traffic volume. On the other hand, class 3, referred to as "non-environmentally sensitive," did not have their state loneliness affected by any of the attributes. Each group exhibited different characteristics, with class 3 scoring highest in extraversion and feeling safe and experiencing the lowest state loneliness while watching the videos. Conversely, class 1 felt the least safe and had the highest state loneliness.

These findings underscore the heterogeneity within the sample and emphasize the importance of recognizing individual differences when developing interventions to alleviate loneliness. Policymakers, urban planners, and designers can tailor their strategies by understanding the characteristics and preferences of each class, thus effectively combating loneliness.

Preface

By writing this preface, I am not only concluding my graduation thesis but also saying goodbye to my time as a student. It is a bittersweet ending, as I have immensely enjoyed my time at the faculty of the Built Environment at the Technical University of Eindhoven. However, the moment has come to embark on new adventures, after a well-deserved break, if I may say so.

My parents, brother, and partner deserve my deepest appreciation for believing in me and supporting me no matter. Your ongoing encouragement has been essential in my achievements. A particular thank you also goes out to my friends, who have been by my side since the very beginning. Your presence has made my time as a student extremely memorable, from amazing trips to lots of laughter and nights we may or may not remember. My former housemates, who began their studies a year before me and gave me crucial advice along the road, deserve a great deal of appreciation. I wouldn't have been able to complete all of my courses satisfactorily without them. I also want to thank SERVICE for providing me with a place where I found new friends, had discussions, vented when necessary, and utilized the ever-reliable coffee maker.

I am immensely grateful to everyone who played a part in making my graduation a reality. Firstly, I want to thank Noor Dinnissen for working with me on this thesis. Being able to work through the challenges of graduation with someone was pleasant. My sincere gratitude is extended to my supervisors, Astrid Kemperman and Pauline van den Berg. You not only shed light on the issue of loneliness in the Netherlands but also inspired me to explore how the built environment can contribute to addressing this rising problem. Your guidance and support have been invaluable. Lastly, I would like to acknowledge Yuwen Zhao and her research, which served as a cornerstone for my own findings.

It is my sincere hope that you find my graduation thesis enjoyable to read, and I aspire for the insights and discoveries within it to make a meaningful impact on real-world interventions, ultimately contributing to the reduction of loneliness.

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1. Introduction

Loneliness among the Dutch has experienced a worrisome increase in recent years, with 43% of individuals aged 15 and older reporting feelings of loneliness in 2021, a significant increase from the 34% recorded in 2019 (Rademaker 2022). So, almost half of the Dutch population is lonely at times. While temporary loneliness is not an immediate problem, people who feel lonely occasionally run the risk of being lonely for a long time if they do not address it (Van Beuningen & De Witt, 2016). Essentially, loneliness causes a downward spiral that reinforces itself. The feeling of loneliness might motivate people to improve their social relationships. However, if they fail to do so, they often develop in a negative way that can cause them to spiral downward. In this spiral of withdrawal, stress levels rise, negative thinking patterns develop, self-esteem falls, and a deeper withdrawal occurs (Movisie, 2020). Therefore, it is important to take preventive steps to avoid loneliness (Ministerie van Volksgezondheid, 2019).

In order to determine the right approach, the understanding of loneliness is necessary. Loneliness can be categorized into two forms: temporary loneliness, also known as state loneliness, and prolonged loneliness, also known as trait loneliness (Mote et al., 2020). State loneliness is characterized by the temporary experience of loneliness in a specific moment or situation, and it reflects the fluctuating nature of loneliness, which can vary throughout the day or in response to specific events or circumstances. When state loneliness persists and is not resolved, it can develop into trait loneliness, commonly referred to as loneliness. However, there are many different definitions for loneliness in the literature, which are either positive or negative. A positive definition of loneliness is when it is defined as creative, productive, and a way to focus on greater goals in life, whereas a negative definition is when it involves physical, emotional, or social alienation (Karnick, 2005). The lack of consensus on a definition for loneliness indicates how each author views the phenomenon from his or her own perspective. The most commonly used definition of loneliness is that of De Jong Gierveld, et al. (2006, p. 495) who defined loneliness as “the negative outcome of a cognitive evaluation of a discrepancy between (the quality and quantity of) existing relationships and relationship standards”. To put in simple words, people who are lonely lack a close, emotional bond or have fewer social contacts than they would like. The definitions illustrate that loneliness is twofold. This is consistent with Weiss’s theory (1973), which separates emotional loneliness from social loneliness. Weiss explained that people who lack a close, emotional bond are feeling emotionally lonely because existing relationships fall short of what is expected of them. This form of loneliness can only be solved by forming a new emotionally close bond. Social loneliness occurs when people have fewer social contacts than they would like due to a discrepancy between the quantity of existing relationships and relationship standards. When discussing loneliness, De Jong Gierveld, van Tilburg and Dykstra’s definition will be used in this thesis.

There are several reasons why loneliness may be a concern for individuals. Heinrich and Gullone (2006) conducted a literature review to determine the impacts of loneliness. According to the authors, several psychosocial difficulties are associated with loneliness, including low self-esteem, low social competence and poor social interaction quality. In addition, loneliness is associated with mental health issues, such as anxiety, depression, and suicidal behavior, as well as physical health issues, such as weakened immune, cardiovascular dysfunction, and sleep deprivation. Therefore, chronic loneliness presents a substantial threat to psychosocial function, mental health, and physical well-being, and should therefore be addressed through interventions. Moreover, the rise in loneliness alarms society because loneliness causes health problems that if not resolved can have significant social consequences for society. These consequences include the loss of social capital, weakened

social bonds, weakening of social cohesion, and an increase in the burden on health care services (Rijks, 2022; Van Beuningen & De Witt, 2016). The government also recognizes that loneliness needs to be tackled and therefore will allocate 40 million euros extra over the next four years to combat loneliness (Ministerie van Volksgezondheid, 2022). The government developed an approach that is aimed at Dutch people of all ages.

Although it can affect people of any age and background, loneliness is not randomly distributed over the population. There are clearly certain groups that are more likely to experience feelings of loneliness. Van Beuningen & De Witt (2016) found that men appear to feel lonelier than women, non-western immigrants more often than natives and western immigrants, older people more often than young people, non-working people and people with the lowest incomes more often than the employed and people with the highest incomes. The differences between the groups can be explained on the basis of the theory of Fokkema and Van Tilburg (2007). The authors have divided the causes of loneliness into three categories. The first category is individual causes. Individual causes include personal traits such as lack of social skills, self-confidence, and problem-solving ability, but also health problems and an insufficient income to engage in social activities. The second category is causes of changes in the social network. Events such as serious illness or death of the partner, the loss of family and friends, divorce or a move could lead to a change or loss of contacts. The final category is social causes. Social causes concern the ease with which people make contact with each other. Psychological or physical disabilities can make it more difficult to have meaningful social contact.

It is clear that loneliness is a complex phenomenon with diverse causes and consequences. Therefore, identifying the causes and finding solutions requires a personalized approach. However, the current knowledge of effective strategies to reduce loneliness remains limited. While the standard advice emphasizes the importance of connecting with others, implementing this advice can be challenging for individuals (Rijks, n.d.). Therefore, it is crucial to explore approaches that can help individuals by encouraging social interactions. A promising direction of research is to look into the impact of the built environment in shaping social interactions and creating a sense of connectivity. The built environment, encompassing aspects such as urban design, architecture, and public spaces, has the potential to significantly impact social well-being and social behaviors (Mouratidis, 2017). By studying the built environment, it is possible to explore how its various elements can encourage individuals to engage with others. However, there is a significant research gap concerning the specific factors within the built environment that affect loneliness. Although the impact of the built environment on loneliness has received more attention lately, limited studies have investigated how design elements contribute to or alleviate feelings of loneliness. In the past, more emphasis has been placed on researching individual determinants and the social environment, leaving the influence of the built environment comparatively understudied.

To address the research gap, the goal of this thesis is to synthesize and comprehend how built environment factors are associated with feelings of loneliness. These built environment factors are divided into two categories: objective factors and subjective factors. The objective factors represent the actual environmental conditions, such as the presence of trees. While the subjective factors show people's perceptions and judgements of those environmental conditions, such as if they perceive a neighborhood to be green (RIGO, 2008). Understanding these relationships will make it possible to determine which built environment interventions can effectively minimize loneliness. Consequently, this research will also focus on testing specific interventions in the built environment with a virtual reality experiment.

This research is highly relevant as it has practical implications for policymakers, urban planners, designers, and developers. The findings can inform the creation of environments that promote social connections and effectively alleviate loneliness. Furthermore, it is essential to emphasize that addressing loneliness should not only focus on guidelines for individuals currently experiencing loneliness but also prioritize preventive measures for the future (De Jong Gierveld, 1983). Given the knowledge gaps, the main question of the thesis is:

‘How are objective and subjective built environment factors associated with feelings of loneliness and how can planning and design of the built environment reduce loneliness?’

To effectively address the main research question, the research is divided into two distinct parts. Part I focuses on conducting a systematic literature review to explore the influence of built environment factors on loneliness. This involves synthesizing existing findings and analyzing the relationship between objective and subjective built environment factors and loneliness. The initial step involves establishing a comprehensive understanding of loneliness and identifying all the factors contributing to loneliness, which will be covered in Chapter 2. Subsequently, Chapter 3 involves conducting a through systematic literature review specifically focusing on built environment factors that impact loneliness. This will help to gain insight of prior research and its findings. These steps will be accomplished by addressing the following sub-questions:

1. What is loneliness and what factors are associated with the feelings of loneliness?
2. What is the influence of objective and subjective built environment factors on feelings of loneliness?

The analysis of the results obtained from the sub-questions reveals a notable research gap. Namely, that research has only been carried out on trait loneliness, and not on state loneliness. Therefore, Part II of the research entails conducting a virtual reality experiment to investigate the relationship between built environment factors and state loneliness. This experiment utilizes virtual environments to test possible interventions on state loneliness. Additionally, it considers the potential influences of socio-demographic factors, personality traits, and trait loneliness on this relationship. The initial step involves establishing what methods will be used to investigate the relationship between built environment factors and state loneliness, which will be discussed in Chapter 4. Subsequently, Chapter 5 contains a discussion of the experiment's results. The final sub-question is:

3. What is the influence of built environment factors on feelings of state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?

The insights gained from addressing the three sub-questions will be used to answer the main research question in the concluding Chapter 6. In addition, Chapter 6 will provide a comprehensive summary of all the findings and will offer suggestions for reducing loneliness in current projects and guiding future ones. Additionally, this chapter will critically examine the strengths and limitations of the research conducted and provide recommendations for future research. The overarching goal of this research is to expand the existing understanding of loneliness, particularly in relation to the built environment. By doing so, it aims to offer practical insights that can effectively address loneliness and inform the planning and development practices of the future.

Part I: 'A systematic literature review about the influence of built environment factors on loneliness'

Part I provides a literature review that focuses on addressing the first two sub-questions. In Chapter 2, the first sub-question, "What is loneliness and what factors are associated with the feelings of loneliness?" will be answered. This chapter aims to establish a comprehensive understanding of loneliness and its various components by examining the evolution of its definition. Additionally, this chapter investigates the factors that contribute to loneliness within a socio-ecological framework. In Chapter 3, the second sub-question, "What is the influence of objective and subjective built environment factors on feelings of loneliness?" will be answered. This chapter explores the impact of built environment factors on loneliness through a systematic literature review. By conducting a thorough examination of existing research, the review aims to provide a comprehensive understanding of the extent, scope, and nature of the research in this area. Furthermore, it will help identifying specific research gaps that will be further investigated in Part II: 'A virtual reality experiment to investigate the relation between built environment factors and state loneliness. Overall, Part I aims to synthesize existing research to offer valuable insights into the nature of loneliness, the factors influencing its occurrence, and the effect of built environment factors on individuals' experiences of loneliness.

2. Loneliness in a socio-ecological framework

This chapter aims to explore the meaning of loneliness and the factors that influence it. To achieve this, the evolution of loneliness will be discussed, including several theories about its nature. Following that, an investigation will be conducted into the factors that impact loneliness, utilizing a socio-ecological framework.

2.1. The evolution of loneliness

The meaning of loneliness has evolved over time and several definitions have been developed. The evolution of loneliness will be addressed in this sub-chapter, and the definitions that will be applied for this thesis will be chosen at the end.

Ancient philosophers were the first to mention loneliness. In their view, loneliness was a voluntary withdrawal from daily stress and can serve as an opportunity to focus on greater goals in life, like reflection, meditation, and communication (De Jong Gierveld, 1998). A similar positive view of loneliness can be found in German literature, in which the well-known philosopher Johann von Zimmerman (1808) wrote: 'The mind, when withdrawn from external objects, adopts, freely and extensively, the dictates of its own ideas, and implicitly follows the taste, the temperament, the inclination, and the genius, of its possessor.'. Nevertheless, Von Zimmerman emphasized the advantages of occasional retirement and argues that neither constant solitude nor never retiring are favorable in the long run. It is notable that Von Zimmerman discusses solitude rather than loneliness. Although loneliness is an ancient phenomenon, currently there are few scientific books or publications that have been published.

Robert Weiss was the first to establish the fundamentals of the theories currently in use. Weiss' theoretical investigation of loneliness was based on his interest in the benefits that come from interpersonal connections (DiTommaso & Spinner, 1997). According to Weiss (1973), people require relationships for their well-being, which is why they need a range of specialized relationships to maintain their health. Different types of specialized relationships require different provisions, all of which may be needed in certain situations. According to Weiss, the lack of a certain social provision,

or the lack of a combination of social provisions, can result in loneliness. He identified six social provisions, which are attachment, social integration, reliable alliance, guidance, reassurance of worth, and opportunity for nurturance. As every social provision has a different underlying assumption, he suggested that relationships must be specialized in terms of their provisions. It is therefore impossible for one relationship to satisfy all needs, but intimate relationships can contribute to satisfaction of a multiplicity of those needs. In his theory, Weiss differentiated loneliness of social isolation from loneliness of emotional isolation. Loneliness of social isolation (social loneliness) is caused by the absence of an engaging social network, while loneliness of emotional isolation (emotional loneliness) is caused by the absence or loss of close relationships. Hence, he proposed that emotional loneliness can be caused by the lack of social provision attachment, while social loneliness can be caused by the lack of the social provision social integration. So, the solution to emotional loneliness is establishing a satisfying attachment relationship or restoring or replacing one that has been lost and the solution to social loneliness is access to a satisfying social network. Due to his distinction between emotional and social loneliness, Weiss is considered to be a leading representative of the interactionist approach (Perlman & Peplau, 1982). This approach is based on the attachment theory that states that loneliness arises from the combination of the absence of an adequate social network and the lack of an intimate figure (Rijks, 2022). The interactionist approach is one of the four predominant theories of loneliness. The three other predominant theories of loneliness are the psychodynamic models, the existential approach, and the cognitive approach (Rijks, 2022).

According to the psychodynamic theory, loneliness is primarily the result of deficiencies during the attachment phase. In other words, children who lack the social skills to develop intimate relationships with their parents are more likely to experience loneliness in adulthood (Rijks, 2022). Zilboorg was probably the first to perform a psychological analysis of loneliness (Perlman & Peplau, 1982). According to Zilboorg (n.d.), loneliness can be traced back to the cradle and exemplifies traits such as narcissism, megalomania, and hostility. After Zilboorg, Sullivan and Fromm-Reichmann also traced the origins of loneliness to childhood experiences. However, the cause of their perception of loneliness might be related to their work in clinical settings, which can explain their tendency to perceive loneliness as pathological.

According to the existential theory, people are essentially alone since no one else can experience their thoughts and feelings (Perlman & Peplau, 1982). Therefore, the theory does not attempt to solve loneliness, but rather to cope with it. The main advocate for the existential theory is considered to be Moustakas. Moustakas (1972) made a distinction between loneliness anxiety and true loneliness. As a defense mechanism, loneliness anxiety keeps people from dealing with essential life questions and drives them to seek out social interaction constantly, whereas true loneliness results from the reality that one is alone and must confront life's greatest experiences alone. Although he acknowledges that loneliness may be difficult, Moustakas believes that true loneliness can be a creative force, much like Zimmerman did.

The cognitive approach emphasizes the importance of cognitive processes in experiencing, as well as manipulating and alleviating loneliness. The leading advocates of the cognitive approach are Peplau and Perlman (Perlman & Peplau, 1982). The authors argue that a discrepancy between a person's desired and actual levels of social contact may result in loneliness. Additionally, De Jong Gierveld adopted a cognitive approach, because it considers how people evaluate and value situations based on cognitive processes (De Jong Gierveld, 1983). As a result, person-related cognitive processes link a lack of contacts to emotional responses either in the form of loneliness or not. Experiences are interpreted and analyzed based on a variety of factors. These factors include the situation

characteristics, as well as the values, norms and wishes of the individual as well as the other relevant people in his or her life and the assessed ability of the individual to influence or change the situation. In order to detect subjective evaluations of people's situations and the degree of loneliness, measuring instruments are needed. De Jong Gierveld felt that the existing loneliness instruments showed too many shortcomings. This led to the development of the De Jong Gierveld Loneliness Scale, which measures how intensely loneliness affects people. This scale is a well-known questionnaire for measuring loneliness in the Netherlands and abroad (Minister van Volksgezondheid, 2019). The scale approaches loneliness as a multidimensional concept and differentiates between two types of loneliness. The two types of loneliness, defined by Weiss, are emotional loneliness, associated with the absence of intimate relationships, and social loneliness, associated with the absence of a wide social network (De Jong Gierveld & Van Tilburg, 2008). The scale has been empirically tested and found to function as a valid and reliable measuring instrument.

More recently, the research on state loneliness has become a topic of interest. According to Wiseman (1997), state loneliness arises from an immediate lack of interpersonal connections in a specific situation and is usually brief, fading away as circumstances change over time. Although literature does not provide other specific definitions, state loneliness is generally understood as the temporary experience of feelings of loneliness at a given moment or in a specific situation. It captures the fluctuating nature of loneliness, which can change throughout the day or in a response to specific events or circumstances. State loneliness differs from trait loneliness in the sense that trait loneliness represents a more stable and enduring tendency to feel lonely across different situations and over an extended period of time. To measure people's state loneliness, many studies use Experience Sampling Method (ESM), and respondents are asked to rate the item 'I feel lonely' on a Likert scale (Hopf et al., 2022; Jensen-Campbell et al., 2020; Tang et al., 2022; Van Roekel et al., 2018; Van Winkel et al., 2017; Zilioli et al., 2017). Asking people directly if they feel lonely at the moment might not be the most reliable approach since people might feel hesitant to admit their loneliness. Hence, alternative approaches have been employed by researchers to assess state loneliness. For instance, van Roekel et al. (2015, 2018) utilized a set of four items, including feeling lonely, isolated, left out, and abandoned, to measure state loneliness. While Snyder & Newman (2019) adapted the 6-item UCLA loneliness scale by modifying the statements to reflect current experiences, like "Right now, I feel left out," or "Right now, I feel isolated from others,". In 1989, Marangoni & Ickes emphasized the importance of measuring both state loneliness and trait loneliness as this can help to understand what distinguishes individuals with chronic loneliness traits from those experiencing temporary states of loneliness. However, existing literature still predominantly concentrates on chronic loneliness, overlooking the investigation of how loneliness relates to the meaningfulness of activities, specifically in terms of moment-to-moment experiences of loneliness and their connection to assessing meaning (Tam & Chan, 2019).

In conclusion, the concept of loneliness has undergone evolution over time, leading to the development of various definitions. Ancient philosophers were the earliest to acknowledge loneliness, however, theory development about it only began in the past century. Oftentimes, these theories conflict with one another regarding the nature, the origin, and the solution of loneliness. The majority of theories agree that loneliness is a negative feeling, but existential theorists believe it has a positive side. Both interactionists and cognitive theorists believe that loneliness results from the discrepancy between a person's desired and actual levels of social contact, while psychodynamic theorists believe that loneliness has its roots in childhood. In the same way that all theories explain loneliness in different ways, all theories will propose different solutions to loneliness. State loneliness, a temporary experience of loneliness in specific situations, has gained recent research interest but remains

understudied compared to chronic loneliness. State loneliness is often measured using ESM, but no standardized measure has been developed. While chronic loneliness has been extensively studied, both state loneliness and trait loneliness deserve equal attention. By considering the interplay between these dimensions of loneliness, a more comprehensive understanding of loneliness and its connection to the meaningfulness of activities can be achieved. In summary, loneliness is a complex phenomenon with differing theories and definitions. This complexity will be addressed by using the definitions of De Jong Gierveld for trait loneliness and Wiseman for state loneliness. These definitions will help to answer the second sub-question regarding the objective and subjective built environment factors that influence loneliness.

2.2. Factors influencing loneliness

Loneliness is generally viewed as a negative experience and as a problem in the long run. The initial step in mitigating loneliness involves identifying its root causes. Therefore, this section aims to explore the factors that influence loneliness within the context of a socio-ecological framework.

After defining loneliness, De Jong Gierveld (1983) categorized a broad set of its determinants. The author categorized these determinants into socio-structural characteristics, values/norms/wishes regarding relationships, and personal traits/attitude. In terms of socio-structural characteristics, the authors discovered a significant relationship between marital status, living circumstances, and gender and loneliness. In terms of values, norms, and wishes regarding relationships, no significant association was seen between the size and variety of the accomplished network. Yet, perceiving a discrepancy between the desired and realized contacts has a significant impact on loneliness. Furthermore, it was found that the frequency of contact with neighbors had a significant impact. In terms of personal traits and attitude, the author discovered a significant relationship between self-image, social fear, introversion and loneliness.

Since De Jong Gierveld's findings, there has been an increase in research focusing on the various factors that contribute to loneliness. To better understand and categorize these factors, the social ecological model of health will be used. The model can be seen in Figure 1. This model provides a comprehensive framework taking into account different levels. For this research, the levels considered are individual determinants, social environment, and built environment (Bornstein & Davis, 2014). Utilizing this model will help to gain insight into the diverse elements that impact an individual's experience of loneliness. The factors that are found will be discussed below. Nevertheless, identifying the broad set of factors that influence loneliness is nearly impossible; determinants vary according to age categories and life stages, most relationships are reciprocal and the mechanisms behind the relationships are difficult to unravel (De Jong Gierveld, 1998).

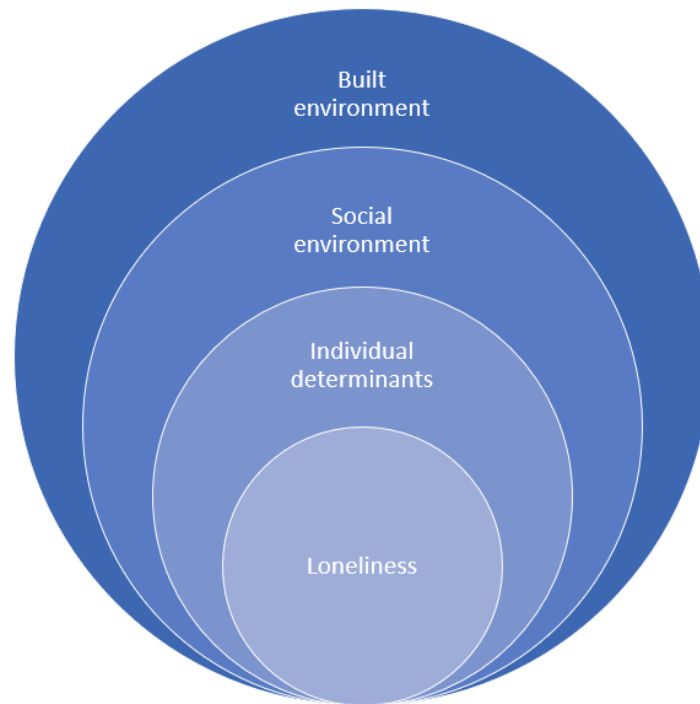


Figure 1 Social ecological model

The most common factors identified are part of the level individual determinants. Consistent with De Jong Gierveld (1983) findings, many authors have observed that gender (De Jong Gierveld, 1998; Hysing et al., 2020), household composition (Asadollahi et al., 2023; De Jong Gierveld, 1998; De Jong Gierveld & Van Tilburg, 1999; Ernst et al., 2023; Hysing et al., 2020; Ray, 2021) and relationship status (De Jong Gierveld, 1998; Ernst et al., 2023; Hysing et al., 2020; Ray, 2021) have an impact on loneliness. Notably, many authors have also demonstrated that age (Asadollahi et al., 2023; De Jong Gierveld, 1998; Ernst et al., 2023; Hysing et al., 2020) and health (Hajek & König, 2020; Macià et al., 2021; Mullins et al., 1996; Peltzer & Pengpid, 2019) are factors that contributes to loneliness. Furthermore, several studies have revealed that income (Ernst et al., 2023; Khan et al., 2018; Liu & Guo, 2007; Peltzer & Pengpid, 2019) and education (Asadollahi et al., 2023; Liu & Guo, 2007) have an influence on loneliness, but one could argue that these two variables are correlated. Research on personality traits and psychosocial functioning in relation to loneliness has been somewhat limited. The majority of studies have focused on the Big Five personality traits, which consists of five dimensions where personality traits tend to distribute along. These dimensions are extraversion, agreeableness, conscientiousness, neuroticism, and openness (Gosling et al., 2003). Research has shown that extraversion is associated with lower levels of loneliness, with two studies finding that more extraverted people were less likely to experience loneliness (Direkvand-Moghadam et al., 2020; Vanhalst et al., 2013). However, one study found no correlation between extraversion and loneliness (Itzick et al., 2020). Agreeableness has also been linked to lower levels of loneliness, with four studies finding that individuals with higher levels of agreeableness were less likely to experience loneliness (Direkvand-Moghadam et al., 2020; Itzick et al., 2020; Ormstad et al., 2020; Vanhalst et al., 2013). Yet, one study found that high levels of agreeableness were associated with a higher risk of loneliness in women (Ormstad et al., 2020). The relationship between loneliness and conscientiousness is less clear. While two studies found that individuals with high levels of conscientiousness were less likely to experience loneliness (Ormstad et al., 2020; Wang & Dong, 2018), two other studies found no association between the two variables (Itzick et al., 2020; Vanhalst et al., 2013). Finally, research has

consistently shown that high levels of neuroticism are associated with higher levels of loneliness (Direkvand-Moghadam et al., 2020; Ormstad et al., 2020; Wang & Dong, 2018) and high levels of openness are associated with lower levels of loneliness (Itzick et al., 2020; Vanhalst et al., 2013). In addition to personality traits, research has also examined the relationship between loneliness and various psychosocial functions. It was found that loneliness is associated with increased levels of depressive symptoms, stress, generalized anxiety, panic disorder, social phobia, and lower levels of self-esteem and emotional stability (Vanhalst et al., 2013). These findings suggest that loneliness can have a detrimental effect on mental health and wellbeing, which may in turn contribute to further loneliness (Dykstra, 1995). Further research is needed to better understand the complex interplay between personality traits, psychosocial functions, and loneliness.

The second level where various factors related with loneliness are identified is the social environment. Studies have consistently found that individuals with greater social capital, which includes satisfaction with family relationships (Refaeli & Achdut, 2022), frequency of talking to friends and relatives (De Jong Gierveld, Keating, et al., 2015; De Jong Gierveld, Van der Pas, et al., 2015; Refaeli & Achdut, 2022), and perceived support (Dykstra, 1995; Refaeli & Achdut, 2022), are less lonely. These findings are consistent with De Jong Gierveld (1983) findings that people who are generally satisfied with their contacts and have sufficient number of relationships tend to be less lonely. Dykstra (1995) found that people who view being single as less desirable and being with a partner as more desirable tend to experience more loneliness. This is consistent with the finding of De Jong Gierveld (1983), that unfulfilled explicit desire for one or more specific relationships can lead to loneliness. Additionally, the loss of a spouse has been associated with increased loneliness (Hajek & König, 2020), which is somewhat related to De Jong Gierveld (1983) findings that people who lack intimacy in their relationship with the person who means the most to them experience more loneliness. While De Jong Gierveld (1983) found no significant association between the size and variety of a person's social network, Liu & Guo (2007a) discovered that social support, as defined by the number of social ties and the diversity of social networks, is negatively associated with loneliness. The findings of Liu & Guo (2007a) are supported by other studies that found fewer people and less diversity in a person's social network are related to higher levels of loneliness (De Jong Gierveld, Keating, et al., 2015; De Jong Gierveld, Van der Pas, et al., 2015; Lam et al., 2023; Liebke et al., 2017). However, it is unclear whether these associations also apply to online social networks, as Brown et al., (2021) found that a larger Facebook network size is negatively related to loneliness, while Refaeli & Achdut, (2022) discovered that higher use of online social networks increases loneliness. Finally, perceived opportunities for improving personal relationships are associated with loneliness, where people who perceive fewer opportunities tend to experience more loneliness (Dykstra, 1995).

Finally, factors related to the built environment have a significant impact on loneliness. There is a wide range of built environment factors that can influence loneliness, such as the presence of public space and infrastructure. Notably, the built environment factors differ from those of the other two categories in that it is challenging to make external improvements in the latter. Therefore, this study focusses on investigating the factors that can be influenced, specifically those associated with a person's built environment. In the next chapter, extensive research will be conducted on the factors of the built environment that are associated with loneliness. By doing so, light can be shed on potential interventions that can be implemented to address loneliness. The focus point of the next chapters will be the relationship between the built environment and loneliness.

3. Systematic literature review

This chapter aims to address the second sub-question: "What is the influence of objective and subjective built environment factors on feelings of loneliness?". The first step in answering this question involves providing a description of three existing papers that present a systematic literature review on built environment factors and loneliness. This description will help identifying the research gap that the present study aims to fill. The subsequent step focuses on addressing this research gap by performing a systematic literature review. The methodology employed for this purpose will be elaborated upon in the following section. Additionally, a descriptive analysis of the articles included in the review will be presented. Finally, the chapter will delve into the findings derived from the reviewed articles. These findings will contribute to identifying the areas for further exploration and will play an important role in determining the research objective for Part II of this study.

3.1. Description of existing systematic literature reviews

To evaluate the research on built environment factors influencing loneliness, three papers were identified that conducted systematic literature reviews. The findings from these papers will be discussed, offering valuable insights and a comprehensive understanding of the existing literature in this domain.

Lyu & Forsyth (2022) performed an in-depth review of the literature to investigate the relationships between loneliness and built environments at the block, neighborhood, and city scales of older adults. The authors included thirty-six studies after the identify and screen phases. The findings of these studies will be discussed. Studies have shown that older individuals experience less loneliness when they have access to better resources and destinations in their neighborhood and perceive their neighborhood to be walkable and of high quality. Additionally, having access to green spaces and transportation facilities, particularly affordable and convenient public transport can reduce loneliness in the general population. The factors influencing loneliness vary among residents living in different housing types. Aging in place can help to reduce loneliness, but alternative housing options may be beneficial for those in need of assistance. Loneliness cannot be predicted by the urban context. Loneliness can be reduced by implementing built environment strategies such as improving the design and planning of local resources and destinations, promoting overall age friendliness and environment quality, and potentially also green space, housing options, and affordable and convenient transport facilities. The authors suggest that more research is needed to assess the effectiveness of these measures and to explore other environmental factors that may contribute to loneliness.

Syed et al. (2017) conducted a systematic literature review to describe existing information on social isolation and loneliness of older adults living in urban areas in Western societies. The authors included 19 articles. The studies analyzed in this review suggest that immediate family members, especially adult children, are the primary source of social support for Chinese immigrant families who value traditional Chinese cultural values and have positive familial relationships. Ethnic-enclave neighborhoods, such as "Chinatowns" with Chinese symbols, can also increase affiliation with one's community. Chinese-speaking professionals in the social service sector can encourage Chinese older adults to access community and health services. Some Chinese older adults who live alone may prefer it, while others may be vulnerable to social isolation and loneliness. Extended social networks and financial security can be helpful in these situations. Chinese older women living alone are particularly vulnerable to social isolation and loneliness compared to those living with others. The review suggests that the age-friendly approach could address social isolation and loneliness in ethnic-minority older adults in Western communities. Future research, policy, and practice should focus on this issue, including more comparisons across gender-specific outcomes.

Hsueh et al. (2022) conducted a systematic literature review with the aim of synthesizing information on community-based interventions that target place-based factors to address loneliness and mental problems. The authors identified seven relevant articles and evaluated the impact of the interventions on loneliness and mental health. The authors found evidence that using local community facilities and engaging in green spaces can promote social connectedness and improve mental health in certain groups. However, the acceptability of housing regeneration interventions to residents remains unclear, as potential disruptions due to building work may be a concern. No significant harms were identified in the interventions evaluated, but the mechanisms by which place-based interventions influence mental health through improving social connectedness were not clearly described in any of the included studies. The authors highlight the need for further research investigating the effectiveness, acceptability, and potential harms of a broader range of place-based interventions to address loneliness and mental health problems. They suggest that interventions focused on using local community facilities and engaging in green spaces are the most promising and might be prioritized for formal trials. The authors also recommend investigating the theoretical basis for place-based interventions by identifying mechanisms and active ingredients and testing their acceptability in a variety of target groups.

In summary, the three identified papers that conducted systematic literature reviews provided valuable insights into the relationship between built environment factors and loneliness, as well as potential interventions to address loneliness. Lyu & Forsyth (2022) focused on older individuals and highlighted the importance of resources, destinations, walkability, and high-quality neighborhoods in reducing loneliness. Syed et al. (2017) explored the experiences of urban-dwelling Chinese older adults and emphasized the role of family support, cultural values, and community affiliation in mitigating social isolation and loneliness. Hsueh et al. (2022) examined community-based interventions targeting place-based factors, such as local community facilities and green spaces, and their potential to promote social connectedness and improve mental health. While these papers contribute to the understanding of built environment influences on loneliness, there are still research gaps to address. Firstly, the studies conducted by Lyu & Forsyth (2022) and Syed et al. (2017) primarily focused on older adults, leaving a need for investigations that encompass other age categories. Furthermore, while Hsueh et al. (2022) explored interventions, the limited number of papers included and the lack of clear explanations on the mechanisms of impact indicate the need for further research in this area. Therefore, a systematic literature review will be conducted that includes all papers that examine the relationship between built environment factors and loneliness. The systematic literature review process will be outlined in section 3.2, providing insights into the steps taken. A descriptive analysis of the included papers will be presented in section 0, offering a comprehensive overview. Finally, section 3.3 will delve into the discussion of the findings derived from the reviewed articles, shedding light on the key outcomes.

3.2. Steps followed to perform the systematic literature review

As the current knowledge is limited, and to answer the question ‘How can the objective and subjective built environment factors influence feelings of loneliness?’ a systematic literature review is performed. A systematic review is a literature review that is designed to locate, appraise, and synthesize the best available evidence relating to a specific research question in order to provide informative and evidence-based answers (Clarke, 2011). The advantage of a systematic literature review in this case is that it allows for an in-depth examination of the extent, scope, and nature of existing research and identifies a specific research need. To find the best available evidence related to the research question, certain steps will be performed.

The first step is to define inclusion and exclusion criteria based on the research question. The inclusion criteria are attributes that must be present in the study to be selected, while exclusion criteria are attributes that should not be included in the study, or it will be excluded. The inclusion criteria of this research were: a) loneliness should be one of the main topics, so either a mediating or a dependent variable; b) a link should be made between loneliness and the Built Environment and its characteristics; c) the article is written in English; d) the document type is an article. Studies will be excluded if they: a) are systematic literature reviews; b) were published prior to 20 years ago.

The second step of the systematic literature review is to design the search strategy. The bibliographic database used for the search is Scopus. The search strategy is based on the inclusion criteria and was developed in collaboration of two students. As a result, it was first ensured that loneliness was the main subject of the studies. The second step was to establish a link between loneliness and the built environment and its characteristics. Attributes related to this needed to be included. In addition, the articles must have been written in English. Finally, studies published before 2002 were excluded. The overview of steps to get to the final search query can be found in appendix 1. The final search was performed in November 2022 and the search query is:

```
( KEY ( lonel* ) AND TITLE-ABS-KEY ( "urban planning" OR "built environment" OR "spatial factor*" OR "spatial planning" OR neighborhood OR "living environment" ) AND TITLE-ABS-KEY ( green* OR "open space" OR garden OR nature OR housing OR building* OR facilit* OR utilit* OR amenit* OR "local resource*" OR accessib* OR transport* OR mobility OR safety OR "environment* quality" OR "neighborhood attachment" OR walkab* OR recreational OR "residen* characteristic*" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) OR LIMIT-TO ( DOCTYPE , "re" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) AND ( EXCLUDE ( PUBYEAR , 1990 ) )
```

The third step of the systematic literature review is screening and selecting the relevant studies from the 102 remaining documents. Studies are screened and checked for the inclusion criteria based on the titles and abstracts. Studies with a primary focus on health, interior of dwellings, and technology were determined to be excluded. In addition, studies that did not include a measurable relationship between loneliness and the Built Environment were also excluded. After screening the titles and abstracts, 33 studies were considered to be relevant. From these studies, full-text papers were obtained and reviewed. Six additional studies were excluded after reviewing the full-text papers, of which three were systematic literature reviews and three did not show a (measurable) link between the built environment and loneliness. The PRISMA flow diagram of this process can be seen Figure 2 (Boland et al., 2017).

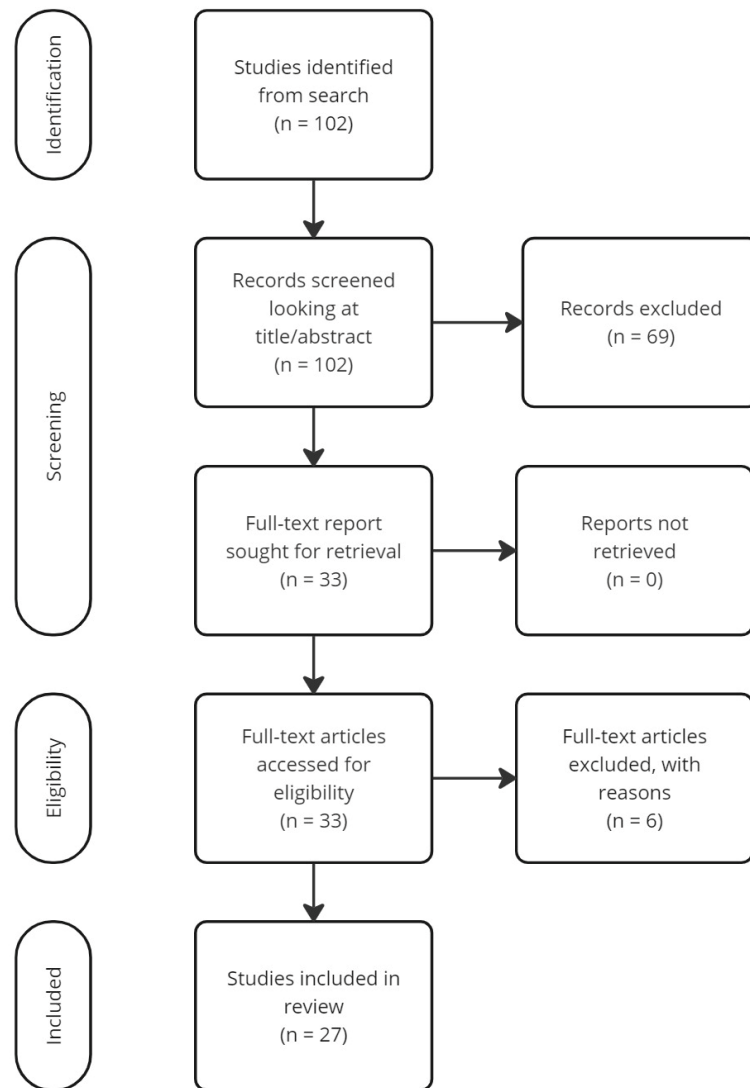


Figure 2 PRISMA flow chart

The fourth step of the systematic literature review is data extraction. Relevant descriptive data and analytical data is extracted from the 27 studies. Table 1 shows the overview of the included studies. To complete this systematic literature review, the data gathered from the data extraction is used to create an overview of the objective and subjective built environment factors that have been included and tested in the studies, and how these factors affect loneliness feelings. Based on the variables found in the selected studies, the built environment variables are grouped into the categories: dwelling, neighborhood general, amenities, urban density, mobility/infrastructure, green, SES, social safety, and social environment. In Table 2, the variables and article numbers for each category are listed.

This section outlined the steps undertaken to conduct the systematic literature review. It involved a careful selection process resulting in the identification of 27 relevant studies and 10 variable categories for further examination. The subsequent section will provide a descriptive analysis of these selected studies, offering valuable insights into their characteristics.

Table 1 Included studies in systematic literature review

Nr. Authors (Publication year)	Title	Aim	Target group	Country	Sample size	Method
1. Gan, Wister, Best (2022)	Environmental Influences on Life Satisfaction and Depressive Symptoms Among Older Adults With Multimorbidity: Path Analysis Through Loneliness in the Canadian Longitudinal Study on Aging	“To identify policy goals by examining theoretical pathways through which the environment influences their mental well-being and the potential mediating effects of sociobehavioral attributes and loneliness”	People aged 65 and up	Canada	14,301	Quantitative
2. Bustamante, Guzman, Kobayashi, Finlay (2022)	Mental health and well-being in times of COVID-19: A mixed-methods study of the role of neighborhood parks, outdoor spaces, and nature among US older adults	“To examine the role of parks and nature to support well-being during the COVID-19 pandemic”	People aged 55 and up	USA	6,551	Quantitative and qualitative
3. Dahlberg, McKee, Lennartsson, Rehnberg (2022)	A social exclusion perspective on loneliness in older adults in the Nordic countries	“To explore the potential of a social exclusion framework for understanding loneliness by examining associations between indicators of social exclusion and loneliness among older adults”	People aged 60 and up	Nordic countries	7,755	Qualitative
4. Chen, Gong (2022)	Loneliness in urbanising China	“To investigate how urbanization is associated with loneliness”	People aged 18-75 years	China	3,229	Quantitative
5. Lam, Wang (2022)	Built Environment and Loneliness Among Older Adults in South East Queensland, Australia	“To examine associations between characteristics of the built environment and loneliness among older adults”	People aged 60 and up	Australia	298	Quantitative

6. Mao, Lou, Lu (2021)	Perceptions of neighborhood environment and loneliness among older Chinese adults: the mediator role of cognitive and structural social capital	“To examine the mediating role of social capital in the association between perceived physical neighborhood environment and loneliness among older adults”	People aged 60 and up	China	472	Qualitative
7. Yu, Yang, Yin, Jiang, Zhang (2021)	Loneliness mediates the relationships between perceived neighborhood characteristics and cognition in middle-aged and older adults	“To examine whether loneliness mediates these associations between perceived neighborhood characteristics and cognition among middle-aged and older adults”	People aged 50 and up	America	15,142	Quantitative
8. Lai, Sarkar, Kumari, Gallacher, Webster (2021)	Calculating a national Anomie Density Ratio: Measuring the patterns of loneliness and social isolation across the UK's residential density gradient using results from the UK Biobank study	“To examine associations between residential density and loneliness and social isolation”	People aged 37-73	UK	39,017	Quantitative
9. Timmermans, Motoc, Noordzij, Van Lenthe, Huisman (2021)	Social and physical neighbourhood characteristics and loneliness among older adults: Results from the MINDMAP project	“To examine the associations between objectively measured social and physical neighborhood characteristics and loneliness in older adults”	People aged 63 and above	The Netherlands	1,959	Quantitative
10. Buecker, Ebert, Götz, Entringer, Luhmann (2021)	In a Lonely Place: Investigating Regional Differences in Loneliness	“To systematically describe and explain differences in loneliness on a fine-grained regional level”	People aged 18-103	Germany	17,602	Quantitative
11. Bower, Buckle, Rugel, Phibbs, Teesson (2021)	‘Trapped’, ‘anxious’ and ‘traumatised’: COVID-19 intensified the impact of housing inequality on Australians’ mental health	“To understand the role of multiple aspects of housing and perceived neighborhood belonging on Australians’ mental health during COVID-19 by examining loneliness, depressive symptoms and anxiety symptoms”	People aged 18 and up	Australia	2,065	Quantitative

12. Yang, Xiang (2021)	Examine the associations between perceived neighborhood conditions, physical activity, and mental health during the COVID-19 pandemic	“To examine how neighborhood conditions changed during the pandemic and how neighborhood conditions were associated with PA and mental health during the pandemic”	People aged 18 and up	USA	2,667	Quantitative
13. Domènech-Abella, Switsers, Mundó, Dury, De Donder (2021)	The association between perceived social and physical environment and mental health among older adults: mediating effects of loneliness	“To analyze social and emotional loneliness as mediating factors in the association of social (social cohesion and social participation) and physical (basic services availability, traffic density, mobility and safety) environmental characteristics with mental health in a sample of older adults (aged 60 and over)”	People aged 60 and up	Belgium	869	Qualitative
14. Victor, Pikhartova (2020)	Lonely places or lonely people? Investigating the relationship between loneliness and place of residence	“To examine the relationship between loneliness and three distinct types of geographical area: deprivation, geographical region, and area typology (urban or rural) among older people”	People aged 50 and up	UK	4,663	Quantitative
15. Domènech-Abella, Mundó, Leonardi, Haro, Olaya (2020)	Loneliness and depression among older European adults: The role of perceived neighborhood built environment	“To determine the role of BE in the association between loneliness and depression”	People aged 50 and up	Finland, Poland, and Spain	5,912	Qualitative
16. Glass (2020)	Sense of community, loneliness, and satisfaction in five elder cohousing neighborhoods	“To understand more about who lives in elder cohousing neighborhoods, their reasons for moving, their satisfaction, and to explore the intersection between loneliness and sense of community”	People aged 55 and above	USA	86	Quantitative

17. Shovestul, Han, Germine, Dodell-Feder (2020)	Risk factors for loneliness: The high relative importance of age versus other factors	“To examine several proposed risk factors for loneliness as a function of factors related to the person, place, and their interaction”	People aged 10-97	USA	4,536	Quantitative
18. Bergefurt, Kemperman, Van Den Berg, Oosterhuis, Hommel (2019)	Loneliness and life satisfaction explained by public-space use and mobility patterns	“To gain insights into how public-space use mediates the relations between personal, neighborhood, and mobility characteristics on the one hand and loneliness and life satisfaction on the other hand”	People aged 18 and up	The Netherlands	200	Quantitative
19. Matthews, Odgers, Danese, Moffitt, Arseneault (2019)	Loneliness and Neighborhood Characteristics: A Multi-Informant, Nationally Representative Study of Young Adults	“To investigate how aspects of the neighborhoods that young adults live in relate to their feelings of social disconnection”	People aged 18	UK	2,232	Qualitative
20. En Wee, Tsang, Yi, Oen, Koh (2019)	Loneliness amongst low-socioeconomic status elderly Singaporeans and its association with perceptions of the neighbourhood environment	“To identify associations between loneliness and sociodemographic characteristics, as well as neighborhood perceptions”	People aged 60 and up	Singapore	528	Quantitative
21. Kemperman, Van Den Berg, Weijs-Perrée, Uijtdewillegen (2019)	Loneliness of older adults: Social network and the living environment	“To explain the relationships between sociodemographics, mobility level, characteristics of the living environment, social participation, and feelings of loneliness among the aging population”	People aged 65 and up	The Netherlands	182	Quantitative
22. Finaly, Kobayashi (2018)	Social isolation and loneliness in later life: A parallel convergent mixed-methods case study of older adults and their residential contexts in the Minneapolis metropolitan area, USA	“To identify interrelated personal and neighborhood influences on social isolation and loneliness in a community-based study of older men and women”	People aged 55 and up	USA	124	Qualitative

23. Yu, Cheung, Lau, Woo (2017)	Associations between perceived neighborhood walkability and walking time, wellbeing, and loneliness in community-dwelling older Chinese people in Hong Kong	“To examine the associations of walkability with walking time, physical activity, subjective wellbeing, and loneliness”	People aged 60 and up	Hong Kong	181	Quantitative
24. Van Den Berg, Kemperman, De Kleijn, Borgers (2016)	Ageing and loneliness: The role of mobility and the built environment	“To explain feelings of loneliness as a result of personal and household characteristics, attributes of the residential location and mobility characteristics”	People aged 35-75	The Netherlands	344	Quantitative
25. Weijs-Perrée, Van Den Berg, Arentze, Kemperman (2015)	Factors influencing social satisfaction and loneliness: A path analysis	“To analyze the spatial and mobility-related factors that influence loneliness and social satisfaction”	People aged 40 and up	The Netherlands	177	Quantitative
26. Maas, Van Dillen, Verheij, Groenewegen (2009)	Social contacts as a possible mechanism behind the relation between green space and health	“To investigate whether social contacts are a possible mechanism behind the relation between green space and health”	People aged 12 and up	The Netherlands	10,089	Quantitative
27. Wen, Hawkey, Cacioppo (2006)	Objective and perceived neighborhood environment, individual SES and psychosocial factors, and self-rated health: An analysis of older adults in Cook County, Illinois	“To investigate the relationships among objectively assessed neighborhood SES, subjective perceptions of neighborhood environment, individual SES and psychosocial factors, and self-rated health in a population-based sample of middle-aged and older adults”	People aged 50-67	USA	214	Quantitative

Table 2 Variables per category

Category	Variables
Dwelling	Housing type (4, 5, 11, 24); Housing tenure (4, 11, 20, 25); Outside space (11); Structural defects (11); Bothered by noise (11); Dwelling affordability (11); Housing quality (1); Natural light (11)
Neighborhood	
Quality	Neighborhood quality (27); Physical environment (20); Aesthetics (12, 23)
Amenities	Land use mix (9); Land use mix-access (23); Accessibility to shops (13, 21, 24); Accessibility to nearest city center (10); Accessibility to highway (24); Accessibility to sport/leisure facilities (10); Satisfaction with amenities/facilities (6, 21, 24); Satisfaction with community health care (6); BE usability (15)
Urban density	Population density (4, 10); Urban density (12, 14, 21, 24, 25, 26); Residential density (8, 17, 22); Unoccupied dwellings (9)
Mobility/infrastructure	Street type (22); Street connectivity (23); Presence of sidewalks (12; 22); Walkability (15, 18, 23); Crime and traffic is a barrier of walking (12, 23); Traffic density (13); Distance to public transport (10); Convenience of public transport (6); Mobility (13)
Green	Amount of green (2, 26); Distance to green (10, 21, 24)
Social environment	Cognitive social capital (6); Structural social capital (6); Satisfaction with sense of community (16); Advantages to living in a community (16); Neighborhood satisfaction (24); Social cohesion (1, 7, 12, 13, 18, 25); Neighborhood belonging (11); Neighborhood attachment (18, 21, 25); Relation to neighbors (10)
Social safety	Crime (9, 12); Safety (3, 6, 7, 13, 20, 21); Neighborhood physical disorder (7); Neighborhood disadvantage (20)
Composition	Neighborhood composition (5); Percentage of non-Western ethnic minorities (25); Age density (17); Sex density (17); Race density (17); Ethnic density (17); Percentage of low educated residents (9)
SES	Neighborhood SES (27); Deprivation (14); Neighborhood poverty (12); Average income (9, 17); Percentage of social security beneficiaries (9)

Descriptive analysis of articles included in the systematic literature review

Besides the title, authors, the journal, publication year, and the aim of the research additional data was collected from the studies, including target group, region, method, and loneliness scale. The data contained several noteworthy aspects, which will be reviewed further in this section.

First, the majority of studies are relatively recently published, with 80% within the last five years (Figure 3). This demonstrates a growing interest in the subject. It should be noted that the figure only includes papers published up until November 2022, when the review was conducted.

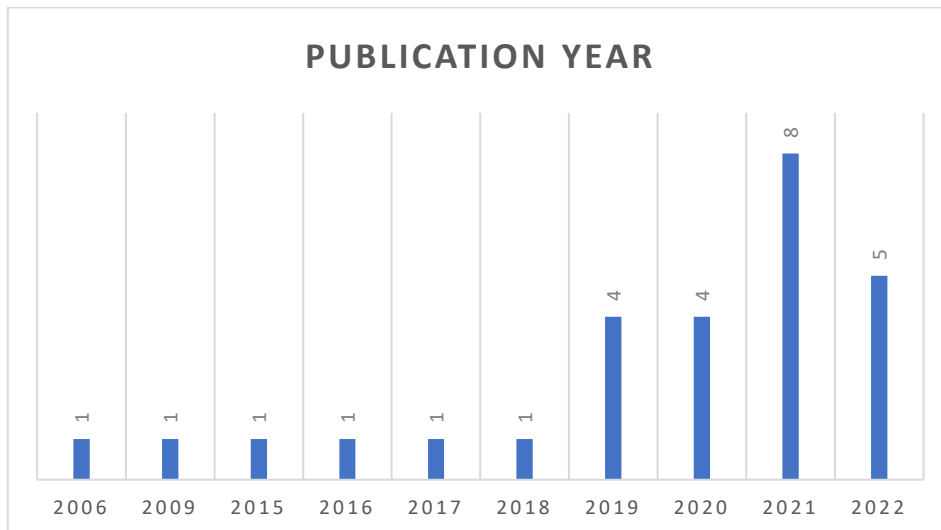


Figure 3 Publication year

Secondly, most studies primarily target the older generation, with over half of the target groups being people over 50 years of age (Figure 4).

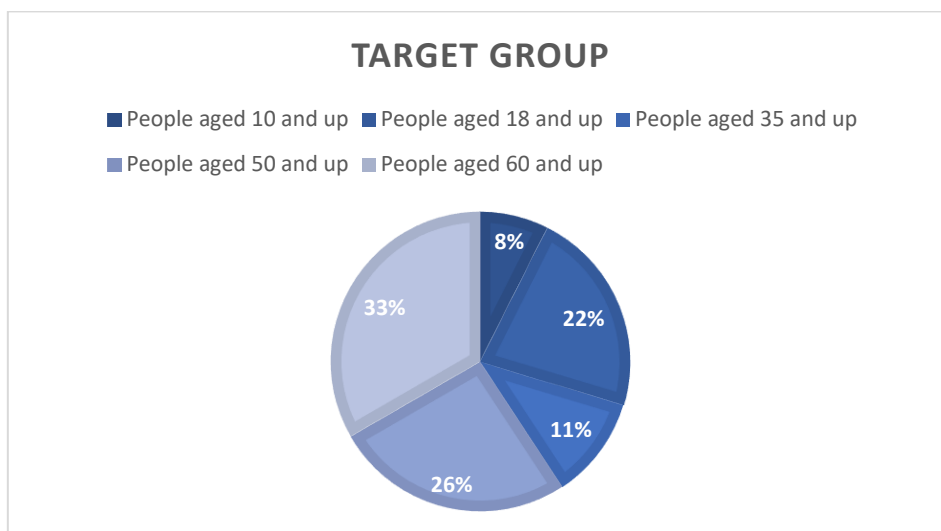


Figure 4 Target group

Thirdly, most studies have been conducted in the region of Europe, followed by North America (Figure 5). However, no studies have been conducted in Africa or South America.

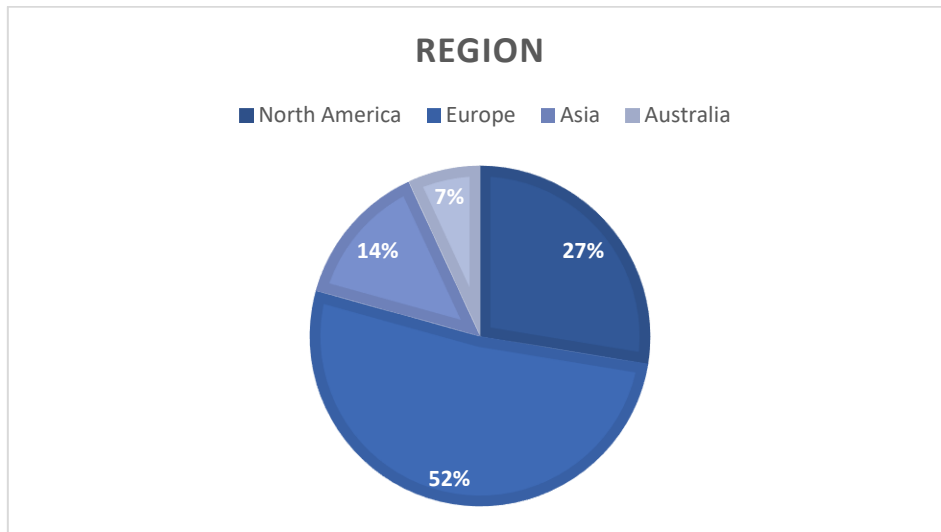


Figure 5 Region

Fourthly, regarding the data collection, most studies have used quantitative methods to perform research, such as questionnaires (Figure 6).

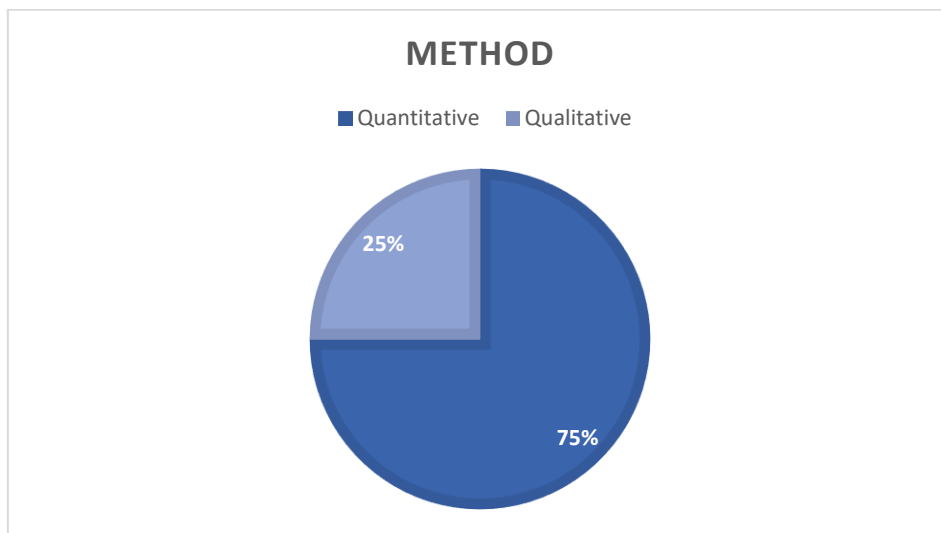


Figure 6 Method

Lastly, loneliness has been measured using several methods. The first method used is the 3-item UCLA scale. This scale consists of three questions to assess three aspects of loneliness: relational connectedness, social connectedness, and self-perceived isolation (Hughes et al., 2004). The questions are: 1) 'How often do you feel that you lack companionship?'; 2) 'How often do you feel left out?'; 3) 'How often do you feel isolated from others. The second method used is the R-UCLA loneliness scale. This scale was created to address the shortcomings of the original UCLA Loneliness Scale. This Revised UCLA Loneliness scale contains 20-items (D. Russell et al., 1980). Half of the questions reflect the satisfaction with social relationships, while the other half of the question reflect dissatisfaction. Some of the questions are: 1) 'I feel in tune with the people around me'; 2) 'I lack companionship'; 3) 'There is no one I can turn on'; 4) 'I do not feel alone'. Some of the research selected some of the items rather than surveying everything. The third method used is the 11-item De Jong Gierveld Loneliness Scale.

This scale consists of 11 items; six of which are negatively formulated and five of which are positively formulated (De Jong Gierveld & Van Tilburg, 2008). Some of the items are: 1) 'There is always someone I can talk to about my day-to-day problems'; 2) 'I miss having a really close friend'; 3) 'I experience a general sense of emptiness'; 4) 'There are plenty of people I can lean on when I have problems'. It was developed from a cognitive perspective and therefore, depending on the research question, researchers can choose to either use the complete loneliness scale, or the emotion and social subscales. The fourth method used is the 6-item De Jong Gierveld Loneliness Scale, which is a shortened version of the 11-item scale. (De Jong Gierveld & Van Tilburg, 2006). This version was designed in such a manner that the original scale's triple application, an overall loneliness scale as well as emotional and social subscales, was kept ensured. Some of the items are: 1) 'I experience a general sense of emptiness'; 2) 'I miss having people around'; 3) 'I often feel rejected'; 4) 'There are plenty of people I can rely on when I have problems'. In all four loneliness scales, the higher the scores, the more likely an individual is to be lonely. Finally, other studies choose to ask a particular question such as 'How much of the time during the past week have you felt lonely' or 'Do you feel lonely'. Most studies use the 3-item UCLA Loneliness scale, followed by the 6-item De Jong Gierveld Loneliness scale (Figure 7). It is notable that no research has measured or investigated short-term loneliness. Remarkably, no study has investigated state loneliness and therefore also no state loneliness measurement was used.

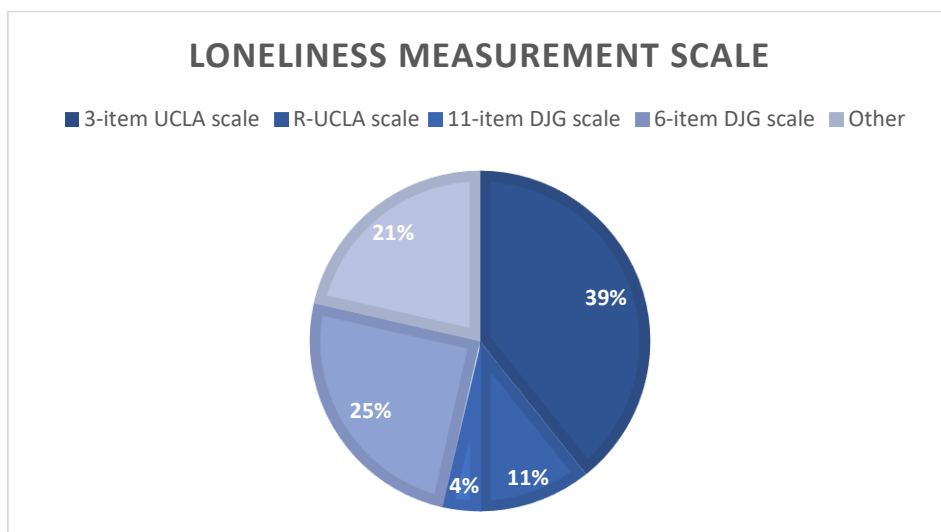


Figure 7 Measurement

In order to complete this systematic literature review, the data gathered from the data extraction is used to create an overview of the objective and subjective built environment factors that have been included and tested in the studies, and how these factors affect loneliness feelings. Based on the variables found in the selected studies, the built environment variables are grouped into the categories: dwelling, neighborhood general, amenities, urban density, mobility/infrastructure, green, SES, social safety, and social environment. In Table 2, the variables and article numbers for each category are listed.

The descriptive analysis of the studies revealed several notable findings. Firstly, a significant proportion of the studies were recently published, indicating a growing interest in the topic. Secondly, the studies predominantly focused on the older generation, indicating a focus on learning about loneliness within this group. Furthermore, most of the studies were conducted in Europe and tended to use quantitative methods. Additionally, versions of the UCLA scale were mostly used in the studies, but remarkably, state loneliness was not examined, indicating a notable gap in the existing literature.

3.3. Results of the systematic literature review

Previous section revealed that the variables examined to explore their relationship with loneliness can be divided into ten distinct categories. In this section, the findings of the studies will be discussed within each of these categories. This analysis will provide useful information to direct the research in Part II of the study. Furthermore, it will allow for the identification of interventions and recommendations for practitioners in the future, with the goal of reducing loneliness.

3.3.1. Dwelling

The 27 papers that were included were evaluated to examine the relationship between objective and subjective dwelling characteristics and the feelings of loneliness. Among the studies, seven assessed the influence of dwelling characteristics on loneliness. The variables that have been tested are: housing type, housing tenure, outside space, major structural/ physical problem, frequency bothered by noise, perceived dwelling affordability, housing quality, and natural light in dwelling.

The type of housing 'apartment' was correlated positively with loneliness, according to one study (Van den Berg et al., 2016). This study concluded that those who live in apartments experience increased loneliness. The housing type 'apartment' was also tested by another study, but there was no correlation between this housing type and loneliness (Bower et al., 2021). Other housing types tested in this study did not show a relationship with loneliness either. Several housing types were also evaluated in two studies, but neither study found any link between loneliness and housing types (Chen & Gong, 2022; Lam & Wang, 2022). So, living in an apartment might make people feel lonelier compared to other housing types. An explanation for this could be that people who live in apartments may feel less connected to their neighborhood and community. One potential factor contributing to this phenomenon is the relatively shorter duration of residency for apartment dwellers, which may result in fewer opportunities for social interaction with neighbors. Consequently, these individuals may have fewer chances to establish meaningful social connections with their surrounding community, leading to a sense of anonymity and reduced identification with the local community.

Four studies have examined the relationship between housing tenure and loneliness. Regarding the owner-occupied housing tenure, two studies found no correlation with loneliness (Chen & Gong, 2022; Weijs-Perrée et al., 2015). Regarding the rental housing tenure, one study found that loneliness increases when people are staying in a rental apartment relative to staying in an owner-occupied housing (En Wee et al., 2019). However, another study found no evidence that renters were lonelier than homeowners (Bower et al., 2021). A reason for this difference can be that Bower et al. (2021) considered both social and private rental housing, whereas En Wee et al. (2019) only considered public rental housing, which was already associated with poorer physical and mental health.

Furthermore, it was found that having access to outside space at one's home did not influence loneliness (Bower et al., 2021). They also concluded that having a structural/physical defect in housing increases loneliness (Bower et al., 2021) and frequency bothered by noise also has a positive correlation with loneliness (Bower et al., 2021). In other words, when there is an extra structural defect in the house, or when noises are more prevalent at home, people feel more alone. The perception of dwelling affordability (Bower et al., 2021), housing quality (Gan et al., 2022), and natural light (Bower et al., 2021) all affect loneliness negatively. Thus, when people are content with their housing affordability, the quality of their dwelling, and the amount of natural light in their dwelling, they feel less lonely. As a result, it can be said that individuals are less lonely when they are satisfied with their houses and lonelier when their homes have defects.

The relationship between housing type, tenure and loneliness has been examined by several studies. In addition, several housing-related factors, including housing quality, have been investigated.

However, contradictory findings have been reported concerning the association between housing type or tenure and loneliness. Although there was no correlation identified between having access to outside space and loneliness, it has been shown that individuals tend to experience lower levels of loneliness when they are satisfied with the affordability, quality, and natural lighting of their home.

3.3.2. Neighbourhood quality

Only four studies assessed the influence of neighborhood quality on feelings of loneliness. The variables that have been tested are neighborhood quality, perceptions of the neighborhood physical environment, and aesthetics.

Wen et al. (2006) found a negative relationship between neighborhood quality and loneliness. So, when the perceived general neighborhood quality increases, loneliness decreases. This seems in line with the finding of En Wee et al. (2019) that a poorer perceived physical environment increases loneliness. The relationship may be explained by the fact that a decline in the attractiveness of the public areas discourages people from being or going there, yet this is where social and communal interactions occur. The reviewing paper of Lyu & Forsyth (2022) discovered the same relation between perceived neighborhood quality and loneliness.

The finding of a study that aesthetics is positively correlated with loneliness appears out of place since it implies that when aesthetics increase, loneliness increases as well (Yang & Xiang, 2021). Remarkably, a second study uncovered no correlation between loneliness and aesthetics (R. Yu et al., 2017). However, both studies measured aesthetics in a different way. (Yang & Xiang, 2021) measured aesthetics as the increased aesthetics over the pandemic, while Yu et al. (2017) measured aesthetics as 'there are trees along the streets in my neighborhood'. Both methods of evaluating aesthetics have limitations since one focuses primarily on the differences during the COVID-19 outbreak while the other seems to be more about landscaping. Consequently, it is difficult to draw conclusions based on these findings.

Overall, limited research has been conducted on the relationship between neighborhood quality factors and loneliness. Therefore, more research should be conducted on the three variables that have been investigated. The available evidence suggests that individuals may experience higher levels of loneliness in areas with poorer neighborhood quality and poorer perceived physical environment.

3.3.3. Amenities

Several studies looked at the relationship between amenity characteristics and loneliness. The variables that have been tested are land use mix; land use mix (access), accessibility to several amenities, satisfaction with amenities, facilities, and recreational services, satisfaction with community health care, and BE usability.

One study tested the relation between land use mix and loneliness (Timmermans et al., 2021), and another study tested the relationship between land use mix-access and loneliness (R. Yu et al., 2017). In neither study was there a connection between the land use mix (access) and the feelings of loneliness.

In addition to the accessibility to land use mix, the impact of the accessibility to various amenities has been looked at. No correlation was found between the distance to shops and basic services available and the nearest city center (Buecker et al., 2021; Domènech-Abella et al., 2021; Kemperman et al., 2019; Van den Berg et al., 2016). While loneliness is positively correlated with the distance to the highway and sport/leisure facilities (Buecker et al., 2021; Van den Berg et al., 2016). Thus, as the distance to the highway and sport/leisure facilities increases, so do the feelings of loneliness. It is unclear why the accessibility to some amenities does not correlate with loneliness and why others do.

Perhaps the quality of the amenities is more important than their accessibility, as loneliness is negatively correlated with satisfaction with amenities, facilities, and recreational services. Two studies have found a direct negative correlation (Mao et al., 2022; Van den Berg et al., 2016) and another study found an indirect negative correlation (Kemperman et al., 2019). Therefore, people would feel less lonely when they are more satisfied with the amenities. This finding also became apparent in the paper describing a systematic literature review by Lyu & Forsyth (2022), which focused on older adults. It is also consistent with the finding that the usability of the neighborhood environment has a negative relation with loneliness (Domènech-Abella et al., 2020). As this means that people will feel less lonely if they perceive their neighborhood to have interesting places to visit, accessible transit stops, and seating areas. This link could be explained by the fact that the BE's physical characteristics influence the ability of individuals to participate in activities outside of their homes and increase their opportunities for socializing. The BE usability variable appears to have a lot of overlap with the previously described neighborhood quality variable, which also revealed that the greater the overall neighborhood quality, the less lonely people are.

Finally, people tend to feel less lonely when they are more satisfied with community health care (Mao et al., 2022). This relationship might be explained by the fact that health care facilities not only provide medical treatment but also play a vital role in maintaining social interactions.

A considerable amount of research has been done on the relationship between loneliness and amenity characteristics. No significant association was identified between land use mix (access) and loneliness. In contrast, certain amenities were found to have a correlation with loneliness depending on their proximity. Notably, individuals tend to experience lower levels of loneliness when they are satisfied with the quality of available amenities, facilities, recreational services, usability of the BE, and community healthcare.

3.3.4. Urban density

Almost half of the included studies have looked at factors related to urban density and their relationship with loneliness.

No correlation between the percentage of unoccupied dwellings in a neighborhood and loneliness was found (Timmermans et al., 2021). Eleven studies examined the relationship between density and loneliness. The types of densities that were tested were population density, urban density, and residential density. Three studies examined the relationship between population density and loneliness. One study found a positive relationship (Chen & Gong, 2022) but the other two studies found no correlation (Buecker et al., 2021; Shovestul et al., 2020). So, it remains unclear if people feel lonelier when population density increases. Six studies examined the relationship between urban density and loneliness and no study found a correlation (Kemperman et al., 2019; Maas et al., 2009; Van den Berg et al., 2016; Victor & Pikhartova, 2020; Weijs-Perrée et al., 2015; Yang & Xiang, 2021). This indicates that whether people live in an urban or rural area has no effect on their feelings of loneliness. However, when urban density increases, it indicates that the number of people living in a certain area increases as well. Two studies examined the relationship between residential density and loneliness and both studies found a positive relationship with loneliness (Finlay & Kobayashi, 2018; Lai et al., 2021). This indicates that the higher the residential density, the lonelier people are.

The findings on urban density and residential density appear to be contradictory. An explanation for this discrepancy might be because density generates a lot of contradictions. On the one hand, higher density, for example, provides more facilities and better walkability, which may lead to less loneliness. On the other hand, the community is often less close and people may feel more anonymous, which

might contribute to an increase in loneliness. The example demonstrates that density is linked to many more variables and is challenging to grasp.

3.3.5. Mobility and infrastructure

Nine articles have examined the relationship between mobility and infrastructure and the feelings of loneliness. The articles investigated various aspects of traffic in general, public transportation, and walking opportunities.

Relative to the street type main road, living on an avenue or a residential street has a negative correlation with loneliness (Finlay & Kobayashi, 2018). Thus, people living on an avenue or on a residential street are less lonely than people living on a main road. An explanation could be that the increased traffic on the main road creates a physical barrier between individuals and their neighbors, leading to a sense of disconnection and reduced social cohesion. However, traffic density does not correlate with loneliness (Domènech-Abella et al., 2021). Street connectivity, which is defined as there are many alternative routes for getting from place to place in a neighborhood, also has no relation with loneliness (R. Yu et al., 2017).

Domènech-Abella, Switsers, Mundó, Dierckx, Dury, & De Donder (2021) discovered a negative correlation between mobility and loneliness. However, it is unclear how the authors defined or measured mobility and therefore no conclusion can be formed. On the other hand, walking distance to public transport has no correlation to loneliness (Buecker et al., 2021), but the convenience of public transport has a negative correlation (Mao et al., 2022). This means that if people are satisfied with the convenience of public transport, they are less lonely. Remarkably, this is the same association observed with the amenities, were quality and, in this case, convenience may be more important than accessibility. Although it is possible that if an amenity is regarded as convenient, it already implies that it is accessible.

A study found no association between the presence of sidewalks and loneliness (Yang & Xiang, 2021), although another identified a negative correlation (Finlay & Kobayashi, 2018). Thus, it is unclear if the presence of sidewalks reduces loneliness. Additionally, two studies discovered that loneliness decreases when the walkability of a neighborhood increases (Domènech-Abella et al., 2020; R. Yu et al., 2017), whereas a third study found no correlation (Bergefurt et al., 2019). Since each author assessed walkability in a different way, the results are difficult to interpret and compare. Finally, one study found a negative relation between decreased crime, violence, and traffic as a barrier to walking (Yang & Xiang, 2021), while another study found no correlation between traffic safety and safety from crime with loneliness (R. Yu et al., 2017). Therefore, it remains unclear if the presence of obstacles like crime and traffic that prevent people from walking lessen loneliness.

Several aspects regarding mobility and infrastructure have been examined in the studies conducted. Results suggest that living on an avenue or on a residential street is associated with lower levels of loneliness compared to living on a main road. Traffic density and street connectivity show no correlation with loneliness. Walking distance to public transport has no correlation, but convenience of public transport decreases loneliness. However, the findings regarding the presence of sidewalks, walkability, and the impact of crime, violence, and traffic as a barrier on walking to loneliness are inconsistent. Further research on these variables may be warranted. Furthermore, no research has been undertaken on cycling or cyclists, which could be very valuable, particularly in the Netherlands.

3.3.6. Green

Only five studies have examined the relationship between green and feelings of loneliness. The two variables that are tested are the amount of green and the distance to green.

Two studies investigated the relationship between amount of green and loneliness. The average percentage of green space has a negative relation with loneliness (Maas et al., 2009). Therefore, loneliness feelings reduce as the quantity of green space grows. However, the number of neighborhood parks does not correlate with loneliness (Bustamante et al., 2022). Three studies examined the relationship between the distance to green and loneliness. While (Kemperman et al., 2019) and (Van den Berg et al., 2016) showed no correlation between distance to public green spaces and loneliness, Buecker et al. (2021) discovered that those who reported a great walking distance to public parks were lonelier. It is unclear where the difference in outcome comes from, and hence if loneliness rises with distance from public green.

There has been very little research on the association between green and loneliness. According to one study, an increase in the average amount of green space is associated with a reduction in loneliness. Conversely, no relationship was found between the number of parks and loneliness. It remains unclear whether distance to public green correlates with loneliness. Further research can be conducted on the accessibility, the convenience, and quality of various types of green in relation to loneliness. This is because green areas can offer individuals the chance to connect with others and engage in social interactions.

3.3.7. Social environment

Most research has been conducted regarding the social environment of an individual. Cognitive social capital and structural social capital have a negative influence on loneliness (Mao et al., 2022). This means that people experience less loneliness when trust in others, reciprocity, sense of belonging, social participation, and social network size grow. Glass (2020) performed a study to understand more about elder cohousing neighborhoods. The author discovered that when individuals are satisfied with sense of community, they feel less lonely, but that the advantages of living in a community have no correlation with loneliness.

Five studies have found that social cohesion has a negative influence on loneliness (Bergefurt et al., 2019; Domènech-Abella et al., 2021; Gan et al., 2022; Yang & Xiang, 2021; X. Yu et al., 2021). Thus, loneliness diminishes as social cohesiveness rises. Although one study found no correlation between social cohesion and loneliness (Weijs-Perrée et al., 2015), it is generally accepted that loneliness decreases as social cohesiveness increases. This is also consistent with the findings that relation to neighbors has a negative influence on loneliness (Buecker et al., 2021), as well as neighborhood belonging (Bower et al., 2021). So, people who have good relationships with their neighbors and feel like they belong to a neighborhood, experience less feelings of loneliness. Overall, when people are more satisfied with their neighborhood, they feel less lonely (Van den Berg et al., 2016). Two studies found that neighborhood attachment has a negative influence on loneliness (Kemperman et al., 2019; Weijs-Perrée et al., 2015), while another study found no correlation (Bergefurt et al., 2019). Therefore, it remains unclear if people who are more attached to their neighborhood, are less lonely.

Many studies have been conducted to explore the relationship between the social environment and loneliness. According to research, individuals with a strong social capital, a sense of community, high social cohesion, and positive relationships with their neighbors tend to experience lower levels of loneliness. Therefore, it appears that greater satisfaction with the social environment is associated with reduced loneliness. While the impact of neighborhood attachment on loneliness remains uncertain, there is evidence to suggest that individuals who are more attached to their neighborhood tend to experience lower levels of loneliness.

3.3.8. Social safety

Eight studies assessed the influence of social safety on loneliness. The variables that have been tested are: crime, safety, neighborhood physical disorder, and neighborhood disadvantage.

The relationship between crime and loneliness has been examined, both objectively and subjectively, and it was found that crime does not correlate with loneliness (Timmermans et al., 2021; Yang & Xiang, 2021). In contrast to crime, six studies found that safety does have a negative influence on loneliness (Dahlberg et al., 2022; Domènech-Abella et al., 2021; En Wee et al., 2019; Kemperman et al., 2019; Mao et al., 2022; X. Yu et al., 2021). So, people tend to feel less lonely when they believe their neighborhood or community to be safe. This can be explained by the fact that reduced safety often results in less social interaction, which in turn, can lead to feelings of loneliness. Additionally, it was found that the perceived physical disorder has a positive relation with loneliness (X. Yu et al., 2021). This implies that, for instance, if vandalism rises, loneliness rises as well. This seems consistent with the findings of with En Wee et al. (2019), who found that when people view their neighborhood as more disadvantaged, they feel lonelier.

All the results are consistent, and considerable study has been conducted on social safety. Interestingly, while crime does not appear to be linked to loneliness, an improvement in safety is associated with a decrease in loneliness. Moreover, an increase in perceived physical disorder was found to be associated with higher levels of loneliness.

3.3.9. Neighbourhood composition

Several characteristics of neighborhood composition have been examined. However, no correlations were found between any of these aspects and loneliness. The aspects that have been examined are: neighborhood composition, percentage of non-Western ethnic minorities, age density, sex density, race density, ethnic density, and percentage of low-educated residents (Lam & Wang, 2022; Shovestul et al., 2020; Timmermans et al., 2021; Weijs-Perrée et al., 2015). An explanation could be that people's perceptions of their social environment and social safety might have a stronger influence on their feelings of loneliness, as well as the behaviors and emotions that contribute to loneliness (such as social cohesion, relationships with neighbors, and safety), than neighborhood conditions that people are not always aware of. As a result, it is likely that neighborhood composition does not correlate with loneliness.

3.3.10. SES

The relation between loneliness and the social economic status of a neighborhood has been examined by looking into five aspects. No correlation was found between most of the factors related to neighborhood SES and loneliness. One study found a negative correlation between median household income and loneliness (Shovestul et al., 2020). However, another study found no correlation (Timmermans et al., 2021). Therefore, it remains unclear whether loneliness decreases when the median household income increases. Regarding neighborhood SES, deprivation, neighborhood poverty level, and percentage of social security beneficiaries no correlation was found between these factors and loneliness (Timmermans et al., 2021; Victor & Pikhartova, 2020; Wen et al., 2006; Yang & Xiang, 2021). The same explanation applies as for neighborhood composition. The sense of people's social environment and social safety is likely to have a greater influence than neighborhood SES. It can be concluded that there is little evidence linking neighborhood SES and loneliness.

3.3.11. Conclusion

The systematic literature review was carried out to determine what research has been conducted, what findings have been discovered, and where further research is required. This systematic literature review looked at 27 articles that examined the relationship between built environment characteristics

and loneliness. A summary of all findings can be seen in Table 3. To gain a clear overview, ten categories were created. The results for each category will be summarized below.

In terms of the dwelling category, it has been discovered that, in most circumstances, housing type and tenure have no effect on loneliness. People are less lonely when they are content with their homes regarding affordability, quality and natural lighting, and they are lonelier when their homes have defects. There has been limited research on the category of neighborhood quality, which should be extended. Loneliness lessens as the quality of the neighborhood or physical environment improves. However, it is uncertain if aesthetics impact loneliness. In terms of amenities, most of the time, access to amenities has no correlation with loneliness. However, when people are more satisfied with the amenities, loneliness decreases. The more satisfied people are with the amenities, facilities, and services in the neighborhood, the less lonely they are. Many studies have focused on urban density, however, the results are contradictory. It was discovered that while population density and urban density had no effect on loneliness, residential density did. This is odd because all densities are linked. One explanation might be the nature of urban density, which is inherently contradicting. Again, there is a lot of inconsistency when it comes to mobility and infrastructure. It matters what sort of road individuals reside on, for example, but it seems like traffic density is unrelated. Also, just as with the amenities, distance does not correlate with loneliness but when people are satisfied with the convenience of public transport, they are less lonely. Because of the contradictory results, no conclusion could be formed on any of the walking-related subjects. As a result, study on these subjects should be broadened and research on cycling might be of interest. There has been very little research about green. It has been discovered that as the percentage of green space increases, so does loneliness. However, the quantity of parks has little effect on loneliness. Furthermore, it is uncertain if loneliness increases when the distance to public green increases. More study on the accessibility, convenience, and quality of various types of green in relation to loneliness should be conducted as green space can provide opportunity for people to see and meet other people and have social interactions.

Much research has been conducted to investigate the link between the social environment and loneliness. This leads to the conclusion that when people are satisfied with their social environment, they feel less lonely. In terms of social safety, crime does not correlate with loneliness, but when individuals feel safer, they tend to feel less lonely. Furthermore, people feel lonelier when they perceive more neighborhood physical disorder and disadvantage. Only a few studies have investigated the association between neighborhood composition and loneliness, but no correlation was discovered with any of the variables. An explanation could be that people's perceptions of their social environment and sense of safety may have a stronger impact on their feelings of loneliness than neighborhood factors that they may not always be aware of. As a result, it is likely that neighborhood composition does not correlate with loneliness. Similarly, research on the association between neighborhood socioeconomic status (SES) and loneliness is limited, and only one study found a correlation. The same explanation for neighborhood composition applies here as well, with individuals' sense of social environment and safety likely have a more significant impact than neighborhood SES. To summarize, many topics have been examined but additional study is required on numerous aspects of neighborhood quality, mobility and infrastructure, and green in relation to loneliness.

The existing findings can still be utilized to inform future planning and design efforts aimed at reducing loneliness. Some potential areas of focus for future developments or improvements to developments include ensuring that people are satisfied with the affordability, quality, and natural lighting of their homes, as well as the availability and quality of amenities, facilities, and recreational services.

Additionally, the usability of the built environment and access to community healthcare should be adequate, while public transport should be convenient. Ultimately, it is crucial to recognize the importance of social environment and social safety in combating loneliness. So, the reduction of loneliness can be addressed in a variety of areas.

However, perhaps the most beneficial approach is to prevent loneliness altogether since temporary loneliness can lead to long-term loneliness. As already noticed, research into the relationship between the built environment and short-term loneliness has not been conducted, despite the potential relevance of this relationship. Therefore, the next phase of the research, Part II: 'A virtual reality experiment to investigate the relation between built environment factors and state loneliness', will focus on investigating possible interventions on state loneliness. Additionally, the analysis will consider the influence of socio-demographic factors, personality traits, and trait loneliness. By doing so, the research aims to address the final sub-question "What is the influence of built environment factors on state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?".

Table 3 Overview relations

		Objective			Subjective		
		+	0	-	+	0	-
Dwelling							
Housing type	Apartment	24	11				
	House		5				
	Self-built housing						
	Commercial housing		4				
	Public housing		4				
	Resettlement housing		4				
	Temporary housing		4				
	Town house		11				
	Other		11				
Housing Tenure	Owner-occupied		4, 25				
	Rental	20	11				
Outside space					11		
Major structural/ physical problem					11		
Frequency bothered by noise					11		
Perceived dwelling affordability						11	
Housing quality						1	
Natural light in dwelling						11	
Neighborhood quality							
Neighborhood quality							27
Perceptions of neighbourhood physical environment					20		
Aesthetics					12	23	
Neighborhood amenities							
Land use mix			9				
Land use mix-access						23	
Accessibility (distance to)	Shop (km) and basic services available					13, 21, 24	

	Nearest city center					10	
	Highway (km)	24					
	Sport/leisure facilities				10		
Satisfaction with amenities and facilities and recreational resources							6, ^21, 24
Satisfaction with community health care							^6
BE usability							15
Urban density							
Population density		4	10, 17				
Urban Density		14	12, 21, 24, 25, 26				
Residential density		8, 22					
Percentage of unoccupied dwellings			9				
Mobility and infrastructure							
Street type	Avenue				22		
	Residential				22		
Street connectivity						23	
Presence of sidewalks					22	12	
Walkability						18	15, 23
Crime and traffic are a barrier of walking						23	12
Traffic density						13	
Distance to public transport			10				
Public transportation convenience							6
Mobility							13
Green							
Amount of green			2		26		
Distance to green		10	21, 24				
Social environment							
Cognitive social capital							6
Structural social capital							6
Satisfaction with Sense of community							16
Advantages to living in a community						16	
Social cohesion						25	1, 7, 12, 13, 18

Relation to neighbors							10
Neighborhood-belonging							11
Neighborhood satisfaction							24
Neighborhood attachment						18	21, 25
Social safety							
Crime			9			12	
Safety							3, 6, 7, 13, 20, 21
Neighborhood physical disorder					7		
Neighborhood disadvantage					20		
Neighborhood composition							
Neighborhood composition			5				
Percentage of non-Western ethnic minorities			25				
Age density			17				
Sex density			17				
Race density			17				
Ethnic density			17				
Percentage of low educated residents			9				
Neighborhood SES							
Neighborhood SES			27				
Deprivation			14				
Neighborhood poverty			12				
Average income			9		17		
Percentage of social security beneficiaries			9				

Part II: ‘A virtual reality experiment to investigate the relation between built environment factors and state loneliness’

Part II: ‘A virtual reality experiment to investigate the relation between built environment factors and state loneliness’ involves an experiment focused on addressing the third sub-question “What is the influence of built environment factors on feelings of state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?”. To answer this question, Chapter 4 will provide an explanation of the methods employed in the experiment, covering the experimental design and data collection procedures, the measurement, and model estimation. Subsequently, Chapter 5 will delve into the discussion of the results, including an examination of sample characteristics and data analysis. Ultimately, Part II aims to generate novel insights into potential interventions to reduce state loneliness.

4. Methods

To investigate the relation between interventions such as adding green elements and the experience of state loneliness, an online video-based stated preference experiment was conducted. An explanation of the experimental design, measurements, and model estimation will be presented in this chapter.

4.1 Experiment design and data collection

Data was collected with a survey that incorporated an experiment. This experiment was based on the PhD study of Yuwen Zhao, which will appear on the TU/e website in 2023. In the survey, participants were shown four different videos’ featuring a person walking through a virtual public space along a pre-designed route (Zhao et al., 2023). The chosen spatial unit for the experiment was a neighborhood, representing the typical scale of the environment residents interact with on a daily basis. Since the data were collected in the Netherlands, the design of the street block reflected the style of a Dutch neighborhood (Zhao et al., 2022). Examples of what the scenario’s look like can be seen in Figure 8.

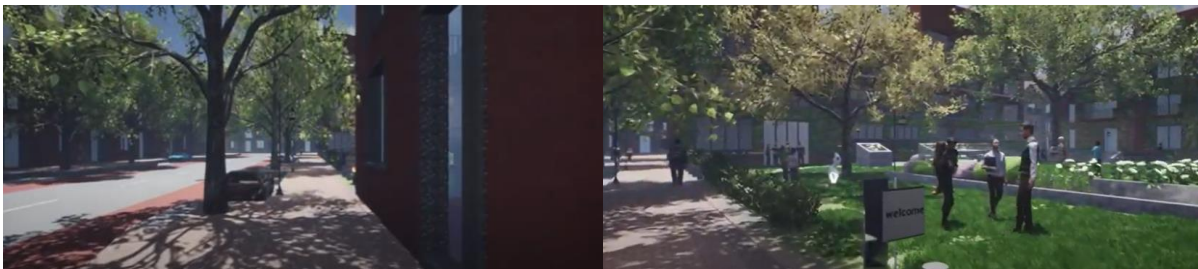


Figure 8 Example shots of video's

After watching the video’s, the participants were asked to report their emotional responses and perceptions regarding the environments. By doing so, their state loneliness and level appreciation for specific features within the environments could be measured. Respondents were asked to indicate their perceptions of the amount and quality of greenery, as well as their levels of three positive emotions (relaxed, excited, and safe) and two items related to state loneliness (lack of companionship and feeling isolated from others). All questions started with the phrase ‘When roaming in this street block, I felt...’ to which the respondent could rate their feelings on a 5-point Likert scale varying from 1 ‘not at all’ to 5 ‘extremely’. Therefore, after watching each video, each respondent was required to respond to 7 statements.

The videos incorporated seven attributes, which were crowdedness, the presence of grass, the presence of water, the presence of benches, the presence of trees, the presence of vertical greening,

and traffic volume. The systematic literature review in Chapter 3.2 revealed a significant research gap regarding the impact of greenery on loneliness and regarding state loneliness. To address this gap, the present study incorporates three interventions focusing on green with the following variables: the presence of grass, trees, and vertical greening to investigate their influence on state loneliness. Furthermore, this study aims to explore other potential interventions in the built environment that have not been examined in existing literature, which are crowdedness, the presence of water, the presence of benches, and traffic volume. By including these variables, novel insights can be gained, expanding the understanding of the relationship between the built environment and state loneliness. Each attribute was presented with two levels, as outlined in Table 4.

Table 4 Attributes and their levels

Attributes	Attribute levels	
	Low	High
Crowdedness	Low	High
The presence of grass	No	Yes
The presence of water	No	Yes
The presence of benches	No	Yes
The presence of trees	No	Yes
The presence of vertical greening	No	Yes
Traffic volume	Low	High

To estimate all attribute main effects, an orthogonal fractional factorial design with eight profiles was used. The design can be seen in Table 5. Each respondent viewed and rated four randomly selected video alternatives, resulting in a total evaluation of 4×7 statements.

Table 5 Orthogonal design

Attributes	Videos							
	1	2	3	4	5	6	7	8
Crowdedness	Low (0)	Low (0)	Low (0)	Low (0)	High (1)	High (1)	High (1)	High (1)
The presence of grass	No (0)	No (0)	Yes (1)	Yes (1)	No (0)	No (0)	Yes (1)	Yes (1)
The presence of water	No (0)	No (0)	Yes (1)	Yes (1)	Yes (1)	Yes (1)	No (0)	No (0)
The presence of benches	No (0)	Yes (1)	No (0)	Yes (1)	No (0)	Yes (1)	No (0)	Yes (1)
The presence trees	No (0)	Yes (1)	No (0)	Yes (1)	Yes (1)	No (0)	Yes (1)	No (0)
The presence vertical greening	No (0)	Yes (1)	Yes (1)	No (0)	No (0)	Yes (1)	Yes (1)	No (0)
Traffic volume	Few (0)	A lot (1)	A lot (1)	Few (0)	A lot (1)	Few (0)	Few (0)	A lot (1)

Furthermore, the survey also gathered information about the respondents' socio-demographic characteristics, personality traits and trait loneliness. This allowed for an examination of the influence of these factors on the relationship between built environment factors and the experience of loneliness. How this information was measured will be elaborated in section 4.2.

This survey was targeted at young adults in the Netherlands who were under the age of 35. To reach this specific group, the survey was distributed through various social media platforms and email channels. The survey was made available online on the 4th of April 2023 and the data was retrieved on the 8th of May 2023.

4.2 Measures

To examine the impact of the attributes presented in the videos on the participants' experiences, data was collected regarding their reactions to the videos as well as certain personal characteristics. This section provides a comprehensive explanation of all the measures employed in the experiment to assess the influence experienced by the participants.

4.2.1 State loneliness

Given the absence of a comprehensive measurement for assessing state loneliness, a new measurement was developed using a modified version of the 3-item UCLA Loneliness Scale. Two items from the original scale were selected for inclusion in the study. Participants were asked to rate the extent to which they experienced feelings of lacking companionship and isolation. The item "I feel left out" was not included in the analysis as feeling left out primarily relates to situations where individuals feel excluded by their social circle. Since the videos shown to the respondents features generic people walking by, this item was not considered relevant to the context of the study. Participants were required to rate the two items on a 5-point Likert scale, ranging from 'not at all' to 'extremely' after watching a video. The sum of the two items' scores was utilized as the dependent variable.

4.2.2 Green perceptions and positive emotional responses

Furthermore, participants were asked to rate two items regarding their perception of green elements and three items regarding their positive emotional responses after watching a video. These additional five statements also had to be rated on a 5-point Likert scale, ranging from 'not at all' to 'extremely'. The green-related items focused on whether the respondents felt the amount of green was good and whether the quality of green was good. As for the positive emotional responses, participants were asked whether they felt relaxed, excited, and safe.

4.2.3 Socio-demographics

As found in Chapter 2.2, individual determinants are influential on trait loneliness, so it is important to determine if those factors affect state loneliness as well. Therefore, within the survey, participants were asked to provide responses to six questions regarding socio-demographics. It included questions concerned age, gender, ethnicity, household composition, highest level of education achieved, and income.

4.2.4 Personality traits

As well as some socio-demographic factors, individual determinants such as personality traits influenced trait loneliness; their impact on state loneliness will therefore be investigated. To assess the personality traits of the participants, the brief measure of the Big Five personality domains, developed by Gosling et al. (2003) was employed. This measurement instrument comprises 10 personality statements, and respondents were asked to rate the degree to which each pair of traits applied to them. Based on their responses, scores were computed to determine the individuals' levels of extraversion, agreeableness, conscientiousness, emotional stability, and openness to experiences. This approach allowed for a concise evaluation of the respondents' personality traits within these key domains. The test can be found in Appendix 2.

4.2.5 Trait loneliness

To assess the trait loneliness of the participants, the third version of the UCLA Loneliness Scale was employed. This scale comprises 20 items, and respondents were asked to rate the frequency with which they experience specific feelings related to loneliness. The responses were scored, with higher scores indicating higher levels of loneliness experienced by the individuals (D. W. Russell, 1996). The UCLA Loneliness Scale can be found in Appendix 3.

4.3 Model specification

To analyze and derive insights from the collected data, two model estimation methods will be utilized in the experiment: the Ordinary Least Square (OLS) regression and the Latent Class Analysis (LCA). This section offers an overview of these approaches, highlighting their capabilities and the necessary assumptions.

4.3.1 Ordinary least squares (OLS)

The ordinary least squares (OLS) method is a linear regression technique commonly used to predict an ordinal dependent variable based on multiple independent variables (How to Perform an Ordinal Regression in SPSS | Laerd Statistics, n.d.). In this study, state loneliness is the dependent variable, and the seven attributes of the videos are considered as independent variables. By applying the OLS method, it is possible to determine which attributes have a statistically significant effect on state loneliness. In a linear regression model, the relationship between the dependent variable (y) and the independent variables (x_1, x_2, \dots, x_n) can be represented by Equation 1 (Kumar, 2023). y is the dependent variable (state loneliness), b_0 is the intercept of the model, b_1, b_2, \dots, b_n are the coefficients of the independent variables x_1, x_2, \dots, x_n (the seven attributes of the videos), and e is the error term.

Equation 1 Linear regression model

$$y = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n + e$$

The goal of the OLS method is to estimate the unknown parameters (b_1, b_2, \dots, b_n) by minimizing the sum of squared residuals (RSS). The RSS represents the difference between the actual values and the predicted values. This is achieved by finding the best-fit line that represents the relationship between the dependent variable (state loneliness) and the independent variables (the interventions). Mathematically, this can be expressed as Equation 2. Where y_i represents the actual value (observed value of state loneliness) and \hat{y}_i represents the predicted value for each observation.

Equation 2 RSS

$$\text{Minimize } \sum (y_i - \hat{y}_i)^2$$

For the OLS method to be valid, several assumptions need to hold (Kumar, 2023). Firstly, there should be a linear relationship between the dependent variable and the independent variables. Secondly, the observations should be independent of each other. Thirdly, the variance of the residuals should be constant across all levels of the independent variables. Fourthly, the residuals (errors) should follow a normal distribution. Finally, the independent variables should not exhibit high correlation with each other. These assumptions are important for obtaining reliable and meaningful results from the OLS analysis.

4.3.2 Latent class analysis (LCA)

To investigate the impact of various attributes, in this case socio-demographic factors, personality traits, and trait loneliness, on individuals' experiences while considering potential response variations, a latent class regression analysis will be conducted in NLogit. Latent class analysis (LCA) is a statistical method utilized to identify distinct subgroups within a population that may exhibit similar outward characteristics (Weller et al., n.d.). LCA assumes that individual's membership in unobserved groups or classes can be explained by patterns of scores across survey questions, assessment indicators, or scales. In LCA, a model is defined for the probability density function $f(y_i)$, which represents the likelihood of the multivariate response vector y_i (Vermunt, 2022). LCA is based on two main assumptions. First, the model involves a weighted average of class-specific densities. This means that

each latent class represents the typical response patterns of individuals in that class. By combining these class-specific densities, it is possible to estimate the overall probability of observing a particular set of responses.

Second, LCA assumes local independence. This assumption implies that the responses to the questions or indicators are considered independent of each other within the same latent class. In other words, knowing how someone responded to one question does not influence or predict their responses to other questions within the same latent class. Based on these assumption, the model for the probability density function $f(y_i)$ in LCA is formulated as Equation 3. In this equation, $P(v_i = c)$ represents the probability that the individual belongs to latent class c , and $f(y_{ij}|v_i = c)$ denotes the class-specific density function associated with class c . The summation is taken over all C latent classes.

Equation 3 LCA

$$f(y_i) = \sum_{c=1}^C P(v_i = c) \prod_{j=1}^J f(y_{ij}|v_i = c)$$

To estimate the posterior membership probability, which indicates the likelihood of an individual belonging to a specific latent class based on their observed responses, Bayes rule in Equation 4 can be applied (Vermunt, 2022). The respondents will be assigned to the latent class which has the highest posterior membership probability to be able to analyze the class membership with the socio-demographic factors, the personality traits, and the trait loneliness. In this equation, $P(v_i = c)$ represents the prior probability of the individual belonging to latent class c . $f(y_i|v_i = c)$ represents the likelihood of observing the responses y_i given the individual's membership in latent class c . $f(y_i)$ is the overall probability density function of the responses y_i .

Equation 4 Bayes rule

$$P(v_i = c|y_i) = \frac{P(v_i = c)f(y_i|v_i = c)}{f(y_i)}$$

To assess the appropriateness of the number of latent classes in the analysis, two widely used criteria will be used: Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Vermunt, 2022). These criteria serve as quantitative measures of model fit, where lower values indicate a better fit. The formulas are Equation 5 and Equation 6. In the equations, LL represents the log-likelihood of the model, N is the number of observations, and k is the number of estimated parameters.

Equation 5 AIC

$$AIC = -2 * LL + 2 * k$$

Equation 6 BIC

$$BIC = -2 * LL + \log(N) * k$$

To assess the goodness of fit for the models for the latent class analysis, the McFadden Rho² (R^2_{McF}) will be calculated using Equation 7. In this equation $\ln(L_M)$ represents the log-likelihood of the model with M classes, and $\ln(L_0)$ represents the log-likelihood of the null model. Typically, higher values of Rho-squared indicate a better fit between the model and the data. A value between 0.2 and 0.4 can be considered an adequate model fit (McFadden D., 1978).

Equation 7 McFadden Rho²

$$R^2_{McF} = 1 - \frac{\ln(L_M)}{\ln(L_0)}$$

Firstly, an OLS regression will be conducted to assess the influence of the seven attributes on state loneliness. Subsequently, a latent class analysis will be employed to examine how socio-demographic factors, personality traits, and trait loneliness affect individuals' experiences. This analysis will be followed by the application of Bayes rule to estimate the class membership of individuals. To determine the appropriate number of latent classes, AIC and BIC will be utilized, while the McFadden Rho-squared will be employed to evaluate the goodness-of-fit.

5. Results

Following the completion of data collection through the survey, this chapter aims to provide an in-depth analysis of the respondents and address the fourth sub-question “What is the influence of built environment factors on feelings of state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?”. The analysis will involve examining the characteristics of the sample and investigating the answer to the question through the implementation of OLS regression and LCA methodologies.

5.1 Sample characteristics

The online survey was completed by a total of 155 respondents. However, three cases were excluded from the analysis as they exceeded the age of 35. Consequently, there were 152 remaining respondents included in the final analysis.

5.1.1 Socio-demographic factors

In the sample, the participants' ages range from 18 to 33, with a significant proportion falling between 22 and 24 years old. The gender distribution is roughly equal, with an approximate balance between females and males. Most respondents identify as Native Dutch. Regarding household composition, the distribution is fairly even across categories, except for multi-person households with family, which represents the smallest proportion. Most participants have obtained a bachelor's degree, but a considerable number of individuals earn a net monthly income of less than €1000. The results can be found in Table 6. Considering these demographic factors, generalizing the findings of this study to broader population requires caution.

Some adjustments were made to account for missing data and small group sizes. Nine respondents did not provide their age, and the mean age of 24 years old was imputed for these cases. Additionally, certain groups were merged for better analysis. The groups for ages 28-30 and 31-33 were combined into a single group labeled 28+ years old. One respondent chose ‘I'd rather not say’ for ethnic group, this group was therefore too small and the cases was added to the largest group, which is ‘Native Dutch background’. Similarly, one respondent choose ‘I'd rather not say’ for household composition, this group was therefore also added to the largest group, which is ‘one person household’. One respondent indicated ‘Secondary vocational education’ as the highest level of education, and as this group was too small the case was added to the group most related, which is ‘secondary education’. The group becomes ‘secondary (vocational) education (VMBO/HAVO/VWO/MBO)’. Four respondents answered ‘Doctor, PhD’ for highest level of education, this group was therefore too small and the cases were added to the group most related, which is ‘University master’s degree’. The group becomes ‘University master’s degree/Doctor, PhD). Two respondents answered ‘I'd rather not say’ for income, these cases were added to the largest group, which is ‘Lower than €1000 net per month’. Finally, only three respondents answered ‘Higher than €3001 net per month’ for income, these cases were added to the group most related, which is ‘between €2001 and €3000 net per month’. The group becomes ‘Higher than €2001 net per month’.

Table 6 Socio-demographic characteristics

Variable	Levels	Sample
Age	18 - 21	6.6%
	22 - 24	59.2%
	25 - 27	24.3%
	28 +	9.9%
Gender	Female	52.6%
	Male	47.4%
Ethnic group	Native Dutch background	86.2%
	Western foreign background	5.3%
	Non-western foreign background	8.6%
Household composition	One person household	27.0%
	Multi-person household with partner	21.1%
	Multi-person household with family	13.2%
	Multi-person household with 1-3 other people	15.8%
	Multi-person household with at least 4 other people	23.0%
Highest level of education	Secondary (vocational) education (VMBO/HAVO/VWO/MBO)	7.2%
	Higher vocational education (HBO)/Bachelor degree (WO)	67.1%
	University master's degree/Doctor, PhD	25.7%
Income	Lower than €1000 net per month	57.9%
	Between €1001 and €2000 net per month	25.7%
	Higher than €2001 net per month	16.4%

5.1.2 Personality traits

As previously mentioned, participants were presented with 10 personality statements and asked to indicate the extent to which each statement applied to them (Gosling et al., 2003). These responses were then utilized to calculate the levels of extraversion, agreeableness, conscientiousness, emotional stability, and openness to experiences. To derive these scores, two specific personality statements were considered for each trait. The test yields scores ranging from 2 to 14, with higher scores indicating a stronger inclination towards the respective personality trait. The results can be found in Table 7. The average scores of the respondents indicate a moderate level of extraversion, conscientiousness, and emotional stability. This suggests that, overall, the participants are not extremely extroverted or introverted, have a decent level of being responsible and disciplined, and are generally able to handle their emotions well. Furthermore, the average scores suggest that the respondents tend to be relatively agreeable, suggesting that the participants tend to be quite friendly and cooperative. Additionally, the mean score indicates that the respondents are relatively open to experiences, indicating that they are interested in new ideas and are willing to try new things.

Table 7 Personality traits

Trait	Items	Mean
Extraversion	I see myself as extraverted, enthusiastic	8.69
	I see myself as reserved, quiet	
Agreeableness	I see myself as critical, quarrelsome	10.95
	I see myself as sympathetic, warm	
Conscientiousness	I see myself as dependable, self-disciplined	9.42
	I see myself as disorganized, careless	
Emotional stability	I see myself as anxious, easily upset	9.29
	I see myself as calm, emotionally stable	
Openness to experiences	I see myself as open to new experiences, complex	9.98
	I see myself as conventional, uncreative	

5.1.3 Trait loneliness

As previously explained, trait measurement is assessed with the use of the 20-item UCLA Loneliness Scale. This scale asks individuals to rate statements using a 4-point Likert scale, where a score of 1 represents "never" and a score of 4 represents "always." Some of the items in the scale are worded in a way that requires reverse scoring, meaning higher scores indicate lower levels of loneliness. For all items, the scores are added up, so the minimum possible score on the scale is 20, while the maximum score is 80. In the sample, the mean score for trait loneliness was 36.26. This suggests that, on average, the respondents experienced relatively low levels of trait loneliness. Figure 9 shows the division of trait loneliness scores. To assess the reliability of the scale used in this research, a Cronbach's alpha measurement test was conducted, despite its previous establishment of reliability. This test evaluates the internal consistency of the twenty items and higher Cronbach's alpha values indicate stronger reliability. While the standards for good internal consistency may differ depending on the source, it is generally recommended to have values of 0.7 or higher (DeVellis, 2003). In the current study, the scale exhibited a robust level of internal consistency, as indicated by a Cronbach's alpha coefficient of 0.903.

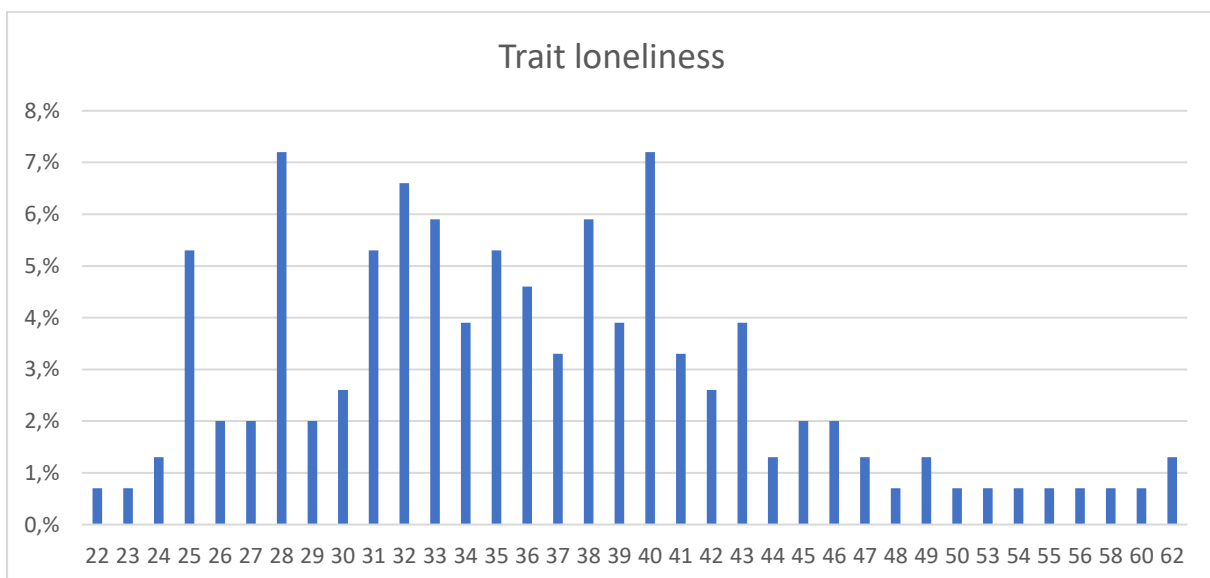


Figure 9 Trait loneliness

5.1.4 State loneliness

State loneliness was assessed after each video, Figure 10 shows the mean score of state loneliness per video. The range of state loneliness scores varied between a minimum of 2, indicating no state loneliness, and a maximum of 10, representing extreme state loneliness. On average, respondents experienced the highest level of state loneliness, with a mean score of 5.54, after watching video 1. In contrast, the lowest level of state loneliness was observed after video 7, with a significantly lower mean score of 2.96. Therefore, after watching video 1, respondents generally experienced a range of slight to moderate levels of state loneliness. Conversely, after watching video 7, respondents reported feeling either no state loneliness or only slight levels of state loneliness. A one-way ANOVA was conducted to determine if the level of state loneliness was different for the eight videos and a statistically significant different was found $F(7, 600) = 17.653, p < .001$.

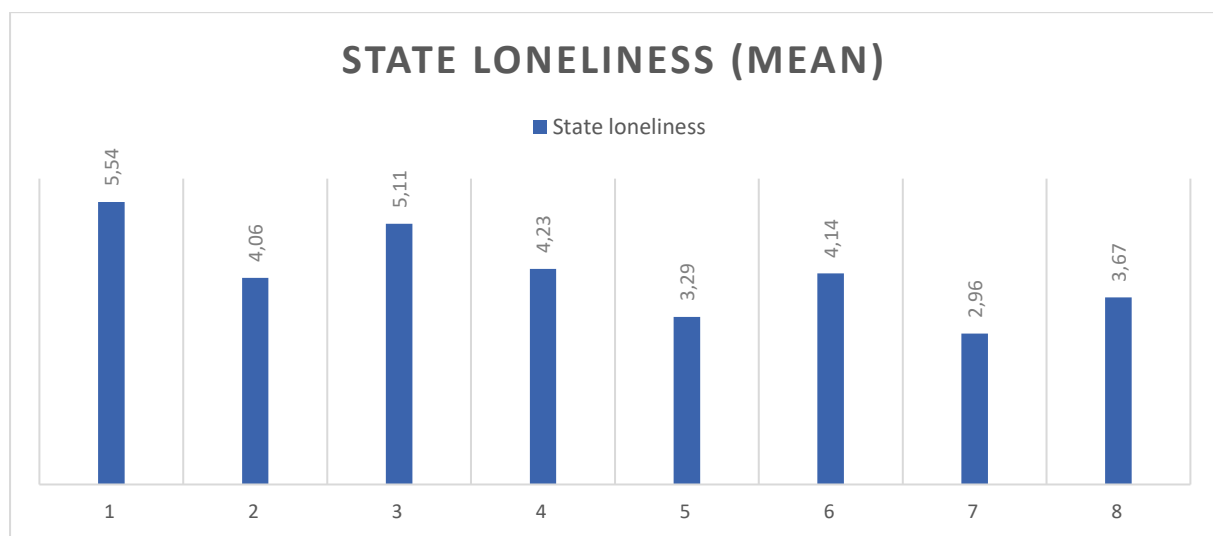


Figure 10 Distribution of state loneliness

To assess the reliability of the self-developed scale for state loneliness, a Cronbach's alpha measurement test was performed. This test evaluates the internal consistency of the two items: "I felt a lack of companionship" and "I felt isolated from others". Higher values of Cronbach's alpha indicate greater reliability. The criteria for good internal consistency may vary depending on the source, but generally recommended values are 0.7 or higher (DeVellis, 2003). In this study, the scale demonstrated a strong level of internal consistency, as evidenced by a Cronbach's alpha coefficient of 0.789.

5.1.5 Green perceptions and positive emotional responses

Green perceptions and positive emotional responses were assessed after each video. Figure 11 shows the mean score of the two items related to the green perceptions per video. Figure 12 shows the mean score of the three items related to the positive emotional responses per video.

The range of scores for both the amount of green and quality of green varied from a minimum of 1, indicating low satisfaction with the item, to a maximum of 5, representing a high level of satisfaction. One-way ANOVA tests were conducted to determine if the satisfaction with the amount of green and quality of green was different for the eight videos. A statistically significant different was found for the amount of green $F(7, 600) = 98.728, p < .001$, as well as for the quality of green $F(7, 600) = 48.189, p < .001$. On average, respondents perceived video 7 to have the highest satisfaction levels for both the amount of green, with mean scores of 4.36, and the quality of green, with a mean score of 4.08. In contrast, video 1 received the lowest ratings for both the amount of green (mean score of 1.56) and quality of green (mean score of 2.07). Hence, the respondents considered the amount of green and

quality of green in video 7 as very good. Conversely, they regarded the amount of green and quality of green in video 1 to be not at all to slightly good. It is worth noting that respondents who perceived the amount and quality of green as satisfactory may have experienced less state loneliness, as video 7 shows the highest mean score for the green items and the lowest mean score for state loneliness. Conversely, those who felt that the amount and quality of green were unsatisfactory may have experienced higher levels of state loneliness, as video 1 shows the lowest mean score for the green items and the highest mean score for state loneliness. To examine this assumption, a Pearson Correlation test was conducted, and it revealed a significant negative relationship between the amount and quality of green with state loneliness. Specifically, there was a negative correlation between the perceived amount of green and state loneliness ($r(608) = -.299, p < .001$), as well as a negative correlation between the perceived quality of green and state loneliness ($r(608) = -.267, p < .001$). These findings indicate that as the perceived amount and quality of green increase, state loneliness tend to decrease. Thus, higher levels of green and better quality green are indeed associated with reduced state loneliness.

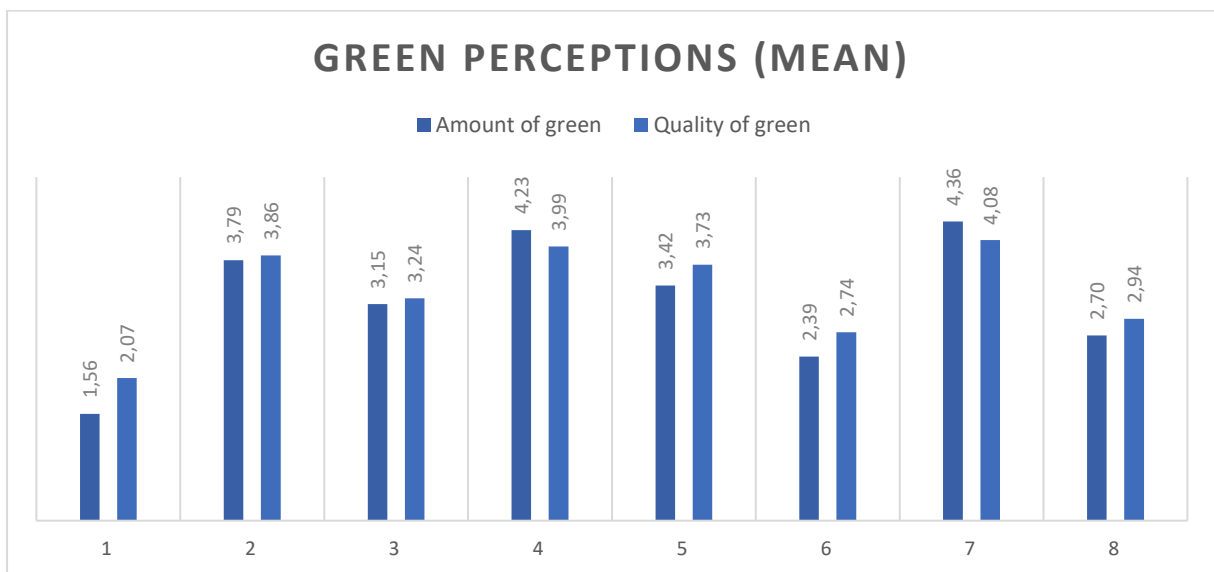


Figure 11 Distribution of green perceptions

The range of scores for the three items of positive emotional responses also varied from a minimum of 1, indicating low satisfaction with the item, to a maximum of 5, representing a high level of satisfaction. One-way ANOVA tests were conducted to determine if the positive emotional responses were different for the eight videos. A statistically significant difference was found for feeling relaxed $F(7, 600) = 36.901, p < .001$, as well as for feeling excited $F(7, 600) = 31.173, p < .001$ and feeling safe $F(7, 600) = 20.789, p < .001$. On average, respondents felt most relaxed, excited, and safe in video 7, with mean scores of 3.86, 3.55, and 4.05, respectively. While video 1 received the lowest ratings for feeling relaxed (mean score of 2.16), excited (mean score of 1.54), and safe (mean score of 2.85). So, the respondents felt very relaxed, excited, and safe in video 7, while they felt slightly relaxed and excited and moderately safe in video 1. Again, the same trend is visible as for green perceptions and state loneliness, where video 7 seems to be the seen as the best environment and video 1 seems to be seen as the worst environment. To investigate whether positive emotional responses are also correlated with state loneliness, another Pearson correlation test was conducted. The results revealed significant negative relationships between feeling relaxed, excited, and safe, and state loneliness. Specifically, there was a negative correlation between feeling relaxed and state loneliness ($r(608) = -.391, p < .001$), as well as a negative correlation between feeling excited and state loneliness ($r(608) =$

-.348, $p < .001$), and a negative correlation between feeling safe and state loneliness ($r(608) = -.417, p < .001$). These findings indicate that as feelings of relaxation, excitement, and safety increase, state loneliness tends to decrease. Thus, higher levels of relaxation, excitement, and a sense of safety are indeed associated with reduced state loneliness. Considering the effects of both green perceptions and positive emotions on state loneliness, it becomes evident that positive emotions have a greater influence on state loneliness than the perception of green. In particular, feeling safe has the strongest correlation with state loneliness. The systematic literature review in Part I of the study also revealed that feeling safe decreases loneliness.

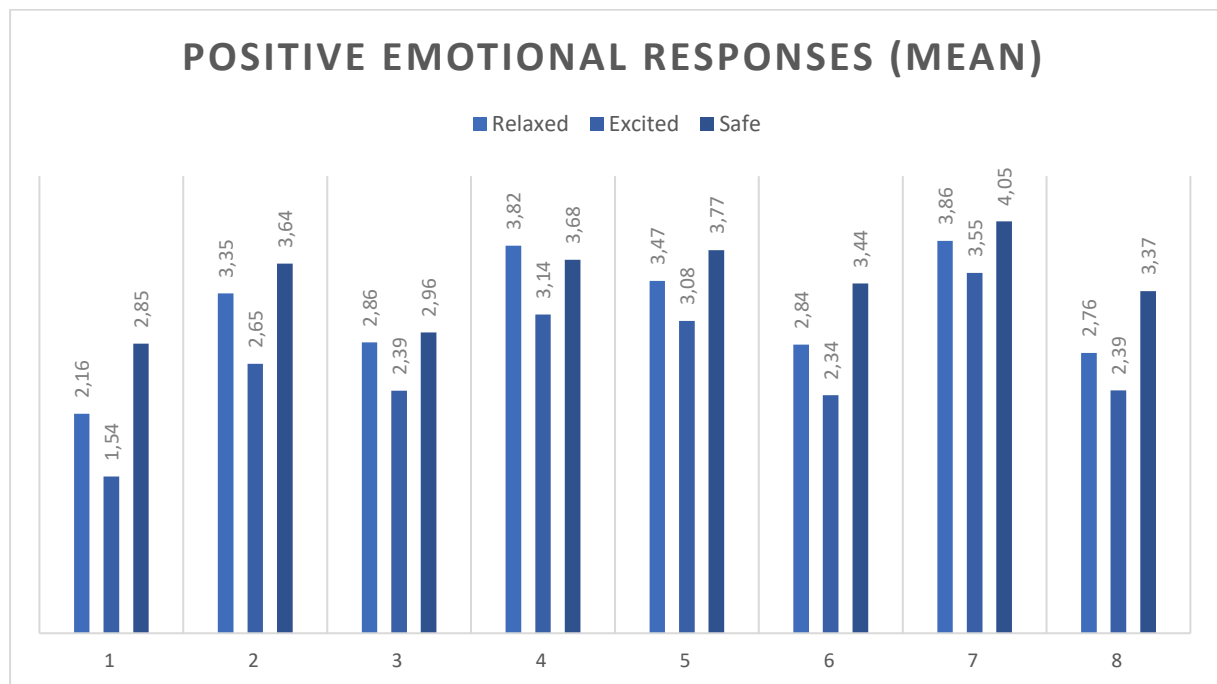


Figure 12 Distribution of positive emotional responses

5.2 Model estimation

To address the final sub-question “What is the influence of built environment factors on feelings of state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?”, two analytical approaches were employed. Firstly, the ordinary least squares (OLS) regression was conducted using NLogit. Secondly, the latent class analysis (LCA) was performed to identify distinct subgroups within the data. Finally, to determine the relationships between class membership and socio-demographic characteristics, personality traits, trait loneliness, as well as the association between class membership and green perceptions and positive emotional reactions, Chi-square tests and ANOVA tests will be performed.

5.2.1 OLS

The analysis was run to determine the effect of crowdedness, the presence of grass, the presence of water, the presence of benches, the presence of trees, the presence of vertical greening and traffic volume on state loneliness. The results of this regression can be found in Table 8. Three variables showed statistically significant effects on the predication of state loneliness.

The variable with the largest influence was crowdedness, indicated by a coefficient of -1.220 at a 1% significant level. The coefficient suggests that when crowdedness increases, state loneliness decreases. This implies that individuals tend to feel less lonely when there are more people present on the street. One possible explanation is that the presence of others in the environment may create

a sense of safety for the respondents. Feeling safer could contribute to reduced feelings of loneliness. This finding aligns with the negative impact of safety on loneliness identified in the systematic literature review conducted in this study. Additionally, the presence of people on the street may provide the respondents with a perception of available social interaction. Knowing that social interaction is possible and accessible in the environment can alleviate feelings of loneliness. The presence of others may serve as a reminder of the potential for social connections, which could reduce the feelings of loneliness.

The presence of trees has the second largest influence on the prediction of state loneliness with a coefficient of $-.984$ at a 1% significant level. The coefficient indicates that when trees are present, individuals tend to feel less lonely. One explanation for this effect could be the association between trees and improved mental health and overall well-being. Previous research has shown that trees are linked to lower prevalence of psychological distress and better self-rated health, and a similar association may extend to state loneliness (Astell-Burt & Feng, 2019). Another possible explanation for the impact of trees on state loneliness is the notion that natural elements contribute to a stronger sense of attachment to a place, thereby enhancing the perception of social inclusivity (Hammoud et al., 2021). This finding is also in line with the negative impact of neighborhood attachment on loneliness identified in the systematic literature review.

Finally, the presence of grass showed a smaller influence on the prediction of state loneliness with a coefficient of $-.264$ at a 10% significant level. The coefficient suggests that when grass is present, individuals tend to experience lower levels of loneliness. One explanation for this effect could be that the presence of grass creates a sense of accessibility to green spaces. Visiting green spaces has been associated with higher social cohesion, which, in turn, is linked to reduced levels of loneliness (Hammoud et al., 2021).

The results of the OLS regression suggest that increasing social interactions through crowdedness, as well as incorporating natural elements like trees and grass, can potentially contribute to reducing loneliness. The impact of greenery can have a dual effect. Firstly, the presence of green spaces can significantly contribute to improving overall mental health and well-being. Moreover, the addition of greenery enhances the visual appeal of the environment, making it more attractive. Consequently, this enhanced attractiveness encourages more individuals to spend time outdoors. As a result, the increased outdoor presence creates opportunities for greater social interactions and fosters a sense of crowdedness, ultimately contributing to reducing loneliness.

Table 8 Results of OLS

State loneliness	Coefficient	Standard Error	z	Prob. z >Z*	95% Confidence Interval	
Constant	5.543***	.201	27.62	.000	5.150	5.937
Crowdedness	-1.220***	.147	-8.30	.000	-1.508	-.932
Grass	-.264*	.147	-1.80	.072	-.553	.024
Water	.136	.147	.93	.355	-.152	.424
Benches	-.201	.147	-1.37	.172	-.489	.084
Trees	-.984***	.147	-6.69	.000	-1.273	-.696
Vertical green	-.116	.147	-.79	.432	-.404	.173
Traffic volume	-.187	.147	-1.27	.203	-.475	.101

***, **, * ==> Significance at 1%, 5%, 10% level.

5.2.2 LCA

The second analysis conducted is a latent class regression. This analysis is conducted as heterogeneity in individuals' responses are expected. To find out the optimal number of classes, the model has been estimated 3 times. The results are shown in Table 9. To determine the optimal number of classes, the AIC and BIC values are computed. Lower values of both AIC and BIC indicate a better fit for the model. In this case, the AIC is lower for the three-class model, while the BIC is lower for the two-class model. However, it is important to note that the BIC for the three-class model is only slightly higher than for the two-class model. To evaluate the goodness of fit, the McFadden Rho-squared has been calculated. Higher values of the McFadden Rho-squared indicate a better fit for the model. In this analysis, the three-class model exhibits the highest McFadden Rho-squared value, further supporting its superiority. As a result, the model with three classes will be chosen for further analysis.

Table 9 Latent class analysis

No. Of Class	Parameters (k)	Log Likelihood (LL)	AIC	BIC	Rho ²
1	9	-1218.2	2454.4	2494.1	0.17
2	19	-1135.7	2309.3	2393.1	0.22
3	29	-1110.8	2279.7	2407.6	0.24

N = 608

Table 10 shows the results of the one-class model compared to the three-class model, with an improved model fit.

After determining the appropriate number of classes, the probabilities for each latent class are computed for each individual. Individuals are allocated to the class with the greatest probability. Class 1 represents the largest proportion of the sample, encompassing 67.8% of the respondents. This class can be described as "partially environmentally sensitive" because, similar to the Ordinary Least Squares (OLS) model, individuals in this class experience a decrease in state loneliness when exposed to high crowdedness, the presence of grass, and the presence of trees. Class 2 comprises the second largest share of the sample, accounting for 18.4% of respondents. It can be labeled as "environmentally sensitive" since state loneliness in this class is affected by all the attributes considered. Individuals in this class experience a decrease in state loneliness with high crowdedness, the absence of grass, the absence of water, the presence of benches, the presence of trees, the presence of vertical greening, and high traffic volume. Interestingly, while the presence of grass leads to a decrease in state loneliness for individuals in class 1, it actually increases state loneliness for those in class 2. Lastly, class 3 represents the smallest group, consisting of 13.8% of the sample. This class can be referred to as "non-environmentally sensitive" since state loneliness in this class is not impacted by any of the attributes considered. A clustered chart of coefficient of each class can be seen in Figure 13.

Table 10 Estimation results of one class model and three class model

	One class model		Three Latent Classes Model					
	Coefficient	p-value	Class 1 Partially environmentally sensitive		Class 2 Environmentally sensitive		Class 3 Non-environmentally sensitive	
			B	Sig	B	Sig	B	Sig
Constant	5.543***	.000	6.463***	.000	4.751***	.000	2.550***	.000
Crowdedness	-1.220***	.000	-1.497***	.000	-1.497***	.000	.046	.842
Grass	-.264*	.072	-.392*	.068	.259*	.090	-.260	.234
Water	.136	.355	-.003	.989	.427**	.014	.112	.596
Benches	-.201	.172	-.259	.195	-.499***	.006	.0460	.834
Trees	-.984***	.000	-1.093***	.000	-.875***	.000	-.329	.177
Vertical green	-.116	.432	-.181	.366	-.446**	.036	.238	.410
Traffic volume	-.187	.203	-.065	.739	-.709***	.000	-.125	.529
Class membership probability	1		.696***	.000	.171***	.000	.133***	.000
McFadden Rho ²	.171		0.244					

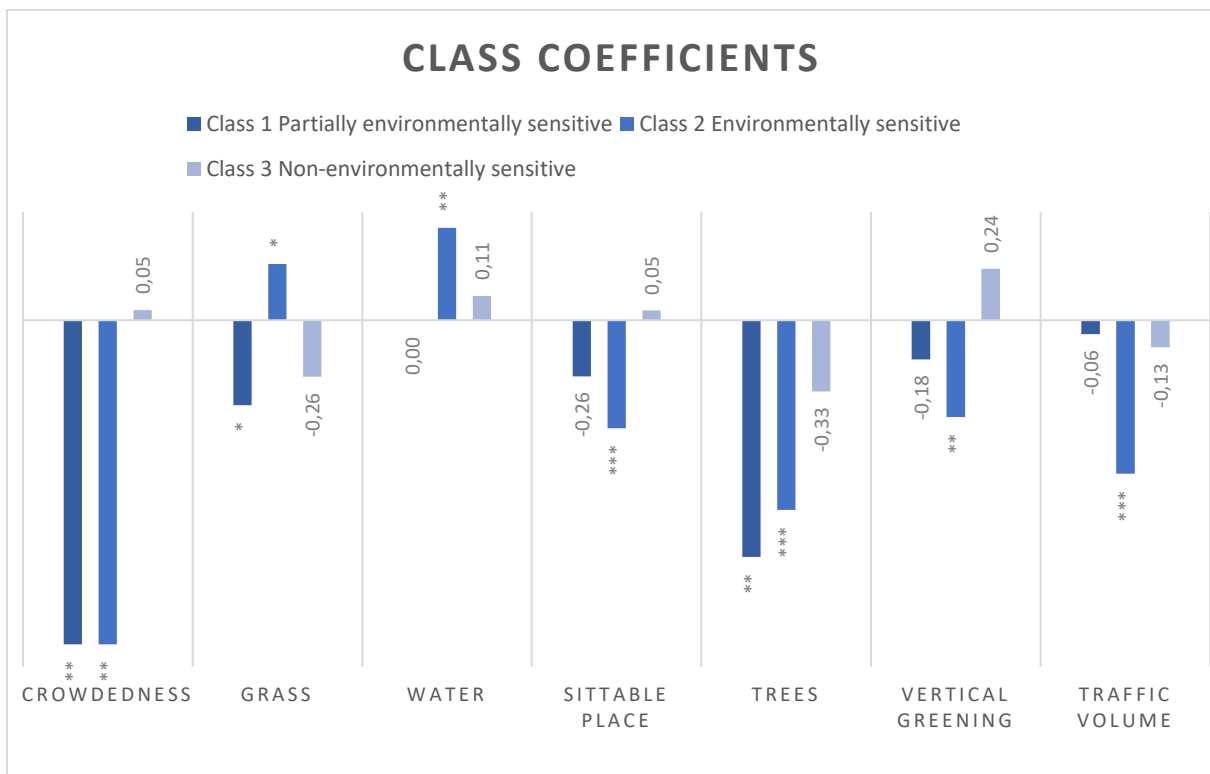


Figure 13 LC coefficients

5.2.3 Relationship between class membership and socio-demographic factors, personality traits, and trait loneliness

After identifying the built environment factors that influence the three groups, the next step in addressing the sub question involves considering socio-demographic factors, personality traits, and trait loneliness. To explore the relationship between class membership and socio-demographic factors, Chi-Square tests were conducted in SPSS. For the personality traits and trait loneliness, ANOVA tests were conducted using SPSS. The results of these analyses can be found in Table 11.

The results indicate that there is no statistical difference between the socio-demographic variables and the three groups. This suggests that socio-demographic factors did not play a significant role in determining an individual's membership in a specific group. However, a statistically significant association was found between the personality trait extraversion and class membership at a 10% significance level, indicating that individuals' levels of extraversion were linked to their placement in one of the three identified groups. However, a significant relationship was only identified using a Chi-Square test. It appears that individuals in Class 2, Environmentally sensitive, tend to rate themselves around a neutral level regarding extraversion. Individuals in Class 1, Partially environmentally sensitive, indicate slightly higher agreement with extraversion. Class 3, Non-environmentally sensitive, portrays the highest self-perceived extraversion among the three classes. These findings indicate that individuals' levels of extraversion might play a role in their sensitivity to the built environment and subsequent class membership. When examining the personality trait agreeableness, both Class 1 and Class 2 participants rate themselves as agreeable, while Class 3 individuals strongly agree with being agreeable. However, no statistically significant difference was found between agreeableness and the three classes. Regarding conscientiousness, the respondents of all three classes rated themselves approximately the same, indicating a somewhat agreeable level of conscientiousness. Consequently, no statistically significant difference was observed between conscientiousness and the three classes. This suggests that conscientiousness does not significantly influence an individual's membership in a particular group. When considering emotional stability, it is difficult to draw straightforward conclusions as the responses varied significantly among the classes. Class 1 participants provided almost equal ratings across all categories, while respondents in Class 2 tended to either disagree or somewhat agree with being emotionally stable. On the other hand, participants in Class 3 displayed a tendency to somewhat disagree or somewhat agree to strongly agree with being emotionally stable. Nonetheless, no statistically significant difference was found between emotional stability and the three classes. Regarding openness to new experiences, all classes tended to rate themselves from neutral to strongly agree, suggesting a general inclination towards being open to new experiences. However, similar to the other personality traits, no statistically significant difference was observed between openness to experience and the three classes. Finally, trait loneliness was also examined to determine its association with class membership. However, no statistically significant difference was found between trait loneliness and the three identified groups. The means of trait loneliness for each class were observed to be relatively close to each other, suggesting that trait loneliness does not significantly influence an individual's membership in a particular group.

In conclusion, the findings suggest that the personality trait extraversion appears to be the only significant factor influencing an individual's membership in a specific class. This implies that individuals' levels of extraversion are linked to their placement within the identified groups. However, it is important to acknowledge that the limited significant results in this study may be attributed to the unequal distribution of participants across the levels of the examined variables. In nearly all cases, a substantial portion of the sample is concentrated within one level, while the proportions in the other levels are relatively smaller, which may have restricted the ability to detect significant differences between the variables and the three groups. To gain further insights, it would be beneficial to achieve a more balanced representation across the various levels of the variables in future research.

Table 11 Socio-demographic factors, personality traits, and trait loneliness and their relationship with class membership

Variable	Level	Class 1 Partially environmen tally sensitive	Class 2 Environmen tally sensitive	Class 3 Non- environmen tally sensitive	Chi-square or ANOVA
Age	18-21	7.8%	3.6%	4.8%	$\chi^2(6)=0.648$ $p = 0.648$
	22-24	55.3%	60.7%	76.2%	
	25-27	25.2%	28.6%	14.3%	
	28+	11.7%	7.1%	4.8%	
Gender	Female	51.5%	53.6%	57.1%	$\chi^2(2)=0.238$ $p = 0.888$
	Male	48.5%	46.4%	42.9%	
Ethnicity	Native Dutch background	83.5%	92.9%	90.5%	$\chi^2(4)=2.798$ $p = 0.592$
	Western foreign background	6.8%	0.0%	4.8%	
	Non-Western foreign background	9.7%	7.1%	4.8%	
Household composition	One person household	29.1%	21.4%	23.8%	$\chi^2(8)=2.376$ $p = 0.967$
	Multi-person household with partner	19.4%	25.0%	23.8%	
	Multi-person household with family	13.6%	14.3%	9.5%	
	Multi-person household with 1-3 other people	16.5%	10.7%	19.0%	
	Multi-person household with at least 4 other people	21.4%	28.6%	23.8%	
Education	Secondary (vocational) education (VMBO/HAVO/VWO/MBO)	8.7%	3.6%	4.8%	$\chi^2(4)=2.585$ $p = 0.629$
	Higher vocational education (HBO)/Bachelor degree (WO)	63.1%	75.0%	76.2%	
	University master's degree/Doctor, PhD	28.2%	21.4%	19.0%	
Income	Lower than 1000 net per month	61.2%	50.0%	52.4%	$\chi^2(4)=3.135$ $p = 0.535$
	Between 1001 and 2000 net per month	21.4%	35.7%	33.3%	
	Higher than 2001 net per month	17.5%	14.3%	14.3%	

Extraversion	(Strongly) disagree	5.8%	3.6%	0.0%	$\chi^2(10)=17.226$ $p = 0.070$
	Disagree-somewhat disagree	14.6%	32.1%	23.8%	
	Somewhat disagree-neutral	30.1%	7.1%	9.5%	
	Neutral-somewhat agree	25.2%	25.0%	28.6%	
	Somewhat agree-agree	17.5%	32.1%	28.6%	
	(Strongly) agree	6.8%	0.0%	9.5%	
	Mean	8.641	8.429	9.286	$F(2, 149) = 0.700, p = .498$
Agreeableness	Mean	10.971	10.893	10.952	$F(2, 149) = 0.013, p = .987$
Conscientiousness	Mean	9.311	9.857	9.381	$F(2, 149) = 0.660, p = .518$
Emotional stability	Mean	9.126	9.536	9.762	$F(2, 149) = 0.572, p = .566$
Openness to experience	Mean	9.932	10.214	9.905	$F(2, 149) = 0.151, p = .860$
Trait loneliness	Mean	37.155	35.178	33.381	$F(2, 149) = 2.251, p = .109$

5.2.4 Relationships between class membership and green perceptions, positive emotional responses, and state loneliness

Finally, two investigations were carried out to assess potential variations in green perceptions and positive emotional responses among the three classes, as well as to determine correlations between green perceptions, positive emotional responses, and state loneliness within each class

ANOVA tests were performed to examine potential differences in green perceptions, positive emotional responses, and state loneliness across the classes. The results can be found in Table 12. The results indicate no significant differences between the classes regarding the perceived amount and quality of green, as well as the feeling of relaxation and excitement while watching the videos. However, there are significant differences observed between feelings of safety and state loneliness among the classes. Specifically, class 3 reported the highest levels of feeling safe and the lowest level of state loneliness, while class 1 reported the lowest levels of feeling safe and the highest level of state loneliness. These findings align with the results of the systematic literature review of Chapter 3, which emphasized the role of feeling safe in reducing loneliness.

Table 12 Relationship between class membership, green perceptions, positive emotional responses, and state loneliness

Variable	Class 1 Partially environmentally sensitive	Class 2 Environmentally sensitive	Class 3 Non- environmentally sensitive	F test
Amount of green (mean)	3.141	3.295	3.333	F(2, 605) = 1.268, p = .282
Quality of green (mean)	3.296	3.348	3.417	F(2, 605) = .439, p = .645
Relaxed (mean)	3.080	3.205	3.298	F(2, 605) = 1.940, p = .145
Excited (mean)	2.568	2.821	2.631	F(2, 605) = 2.216, p = .110
Safe (mean)	3.401	3.509	3.667	F(2, 605) = 3.557, p = .029
State loneliness (mean)	4.789	3.170	2.417	F(2, 605) = 87.154, p < .001

As observed in section 5.1.5, there might be correlations between green perceptions, positive emotional responses, and state loneliness. To explore these correlations within each class, Pearson correlation tests were conducted and the results are presented in Table 13.

These findings indicate that in class 1, individuals who experience higher levels of relaxation, excitement, and a sense of safety while watching the videos tend to have lower levels of state loneliness. Similarly, those who perceive greater amounts and higher quality of green also tend to experience lower levels of state loneliness. These findings align with the Latent Class Analysis (LCA) conducted in Chapter 5.2.2, which revealed that the state loneliness of class 1 is influenced by the presence of grass and trees as green attributes. Likewise, for class 2, significant negative relationships were observed between the perception of the amount of green, the perception of the quality of green, feeling relaxed, feeling excited, and feeling safe. This suggests that individuals in class 2 who perceive higher amounts and better quality of green, as well as those who feel more relaxed, excited, and safe while watching the videos, are likely to experience lower levels of state loneliness. These findings are consistent with the LCA results, which indicated that the state loneliness of class 2 is influenced by all the green attributes, including grass, trees, and vertical green. Interestingly, in class 3, only feeling relaxed and feeling safe exhibited a significant negative relationship with state loneliness. The perception of the amount of green, the perception of the quality of green, and feeling excited did not show significant relationships. This suggests that for individuals in class 3, feeling more relaxed and safer while watching the videos is associated with lower levels of state loneliness, while the perceived amount and quality of green, as well as feeling excited, do not significantly influence state loneliness in this class. These findings are in line with the LCA, which indicated that the state loneliness of class 3 is not influenced by any of the green attributes.

Table 13 Relationship between state loneliness and green perceptions and positive emotional responses for each class

Variable	Class 1 Partially environmentally sensitive	Class 2 Environmentally sensitive	Class 3 Non-environmentally sensitive
Amount of green	$r(412) = -.326, p < .001$	$r(112) = -.366, p < .001$	$r(84) = -.134, p = .223$
Quality of green	$r(412) = -.311, p < .001$	$r(112) = -.304, p = .001$	$r(84) = -.027, p = .810$
Relaxed	$r(412) = -.430, p < .001$	$r(112) = -.331, p < .001$	$r(84) = -.346, p = .001$
Excited	$r(412) = -.408, p < .001$	$r(112) = -.372, p < .001$	$r(84) = -.078, p = .481$
Safe	$r(412) = -.443, p < .001$	$r(112) = -.444, p < .001$	$r(84) = -.191, p = .081$

In conclusion, notable differences exist in feelings of safety and state loneliness among the classes. Specifically, class 3 exhibits the highest levels of perceived safety and the lowest level of state loneliness, whereas class 1 demonstrates the lowest levels of perceived safety and the highest level of state loneliness. This highlights the crucial role of feeling safe in mitigating loneliness. Furthermore, the state loneliness experienced by individuals in class 1 and class 2 is influenced by their green perceptions and positive emotional responses. Specifically, when they perceive a higher quantity and better quality of green and experience greater relaxation, excitement, and a sense of safety, their state loneliness tends to decrease. These findings align with the results of the Latent Class Analysis (LCA), which indicated that the state loneliness of these classes is influenced by crowdedness and presence of green attributes in the videos. Conversely, the state loneliness of individuals in class 3 is not affected by their green perceptions or the green attributes in the videos. One possible explanation for this discrepancy is that individuals in class 1 and 2 may have higher expectations or standards regarding the sufficiency and quality of green and the liveliness in their surroundings, making them more sensitive to the impacts.

5.3 Conclusion

A total of 155 respondents initially participated in the survey, out of which 152 responses were deemed suitable for analysis. The analyses conducted will be summarized in this section. Descriptive analysis revealed that the respondents' age ranged from 18 to 35, with a significant portion falling between 22 and 24 years old. The gender distribution was roughly equal, and the household composition categories were relatively balanced. Most respondents had a Native Dutch background and held a bachelor's degree, although a notable number reported a monthly income of less than €1000. Overall, respondents showed moderate levels of extraversion, conscientiousness, and emotional stability, and they were relatively agreeable and open to experiences. Trait loneliness was reported as low among the respondents.

During the experiment, respondents experienced the highest level of state loneliness when watching video 1 and the lowest level when watching video 7. The perception of green also varied across videos, with respondents rating the amount and quality of green as highest in video 7 and lowest in video 1. Correlational analysis revealed a negative association between state loneliness and the perception of green, indicating that higher levels of green and better green quality were associated with lower loneliness levels. Respondents also reported feeling most relaxed, excited, and safe in video 7 and least in video 1. Similarly, positive emotional responses correlated with lower state loneliness, suggesting that increased feelings of relaxation, excitement, and safety were linked to reduced loneliness.

To further examine the effects of various factors on state loneliness, an OLS regression analysis was conducted. The results demonstrated that increased crowdedness, the presence of grass, and the presence of trees had a significant negative impact on state loneliness. These findings suggest that promoting social interactions through crowdedness and incorporating natural elements, such as grass and trees, could potentially contribute to reducing loneliness

Subsequently, a latent class analysis was conducted as heterogeneity in the sample was expected. The latent class analysis helped to determine the optimal number of classes, revealing that three classes were deemed appropriate. These classes were identified as class 1 partially environmentally sensitive, class 2 environmentally sensitive, and class 3 non-environmentally sensitive. In class 1, state loneliness was influenced by trees, crowdedness, and grass. Class 2 exhibited influences from all green attributes and possible interventions on state loneliness. Conversely, in class 3, none of the attributes were found to have an impact on state loneliness. To further explore the characteristics of each class, chi-square tests and ANOVA tests were performed. While there are some similarities among the classes, notable differences were observed. Class 3 exhibits slightly higher levels of extraversion compared to class 1 and class 2. In terms of perceived safety while watching the videos, class 3 reported the highest levels, followed by class 2 and class 1. Notable, class 3 did not experience any feelings of loneliness during the videos, while class 2 experienced extremely low levels of loneliness and class 1 reported low levels of loneliness. Additionally, the state loneliness of individuals in class 1 and class 2 is influenced by their perceptions of green and positive emotional responses, whereas the state loneliness of individuals in class 3 is unaffected by these factors. One possible explanation for this disparity is that individuals in class 1 and 2 may hold higher expectations or standards regarding the adequacy, quality, and vibrancy of green in their environment, which makes them more attuned to its effects.

In conclusion, the latent class analysis identified three distinct classes, each with unique characteristics and responses to the built environment. These findings highlight the heterogeneity within the sample and emphasize the importance of considering individual differences when designing interventions to address loneliness. By understanding the characteristics and preferences of different classes, policymakers, urban planners, and designers can tailor their approaches to effectively reduce loneliness. An overview of the class characteristics can be found in Table 14.

Table 14 Class and sample characteristics

Class 1 Partially environmentally sensitive	Class 2 Environmentally sensitive	Class 3 Non-environmentally sensitive
Influenced by some attributes considered	Influenced by all attributes considered	Influenced by no attributes considered
Neutral extraverted	Neutral extraverted	Somewhat extraverted
Felt moderately safe when watching the videos	Felt very safe when watching the videos	Felt very safe when watching the videos
Felt low levels of loneliness when watching the videos	Felt extremely low levels of loneliness when watching the videos	Felt not at all lonely when watching the videos
State loneliness is influenced by green perceptions and liveliness of the environment	State loneliness is influenced by green perceptions and liveliness of the environment	State loneliness is not influenced by green perceptions

6. Conclusion and discussion

Loneliness is a growing problem, with the number of lonely people increasing considerably over the years. This is a real concern as loneliness can have a significant negative effect on psychosocial function, mental health, and physical well-being for individuals and a significant negative effect on social capital, social bonds, social cohesion, and the health care system for society. While research on the factors that contribute to loneliness has been conducted, research specifically on built environment factors is scarce. In combination with the challenge of making external changes to individual determinants and the social environment, this study specifically investigated the influence of built environment factors on loneliness by conducting a systematic literature review.

The research objective is therefore 'How are the objective and subjective built environment factors associated with feelings of loneliness and how can planning and design of the built environment reduce loneliness?'

To answer the main question, this study was divided into two parts. Part I: 'A systematic literature review about the influence of built environment factors on loneliness' aims to answer the first part of the main research question by addressing the sub-questions:

1. "What is loneliness and what factors are associated with the feelings of loneliness?" in Chapter 2;
2. "What is the influence of objective and subjective built environment factors on feelings of loneliness?" in Chapter 3.

Part II: 'A virtual reality experiment to investigate the relation between built environment factors and state loneliness' aims to answer the second part of the research question while addressing the found research gap in Part I by addressing the final sub-question:

3. "What is the influence of built environment factors on feelings of state loneliness, taking into account the influence of socio demographic factors, personality traits, and trait loneliness?" in Chapter 4 and 5.

In Chapter 2.1, the literature review revealed that loneliness manifests in two forms: state loneliness, which is temporary, and trait loneliness, which persists over a longer period. Loneliness, regardless of its duration, is universally viewed as a negative experience. In Chapter 2.2 the literature review revealed that the factors influencing loneliness can be categorized into individual determinants, social environment, and built environment. Among individual determinants, socio-demographic factors such as age and gender have been identified to influence loneliness, as well as personality traits such as extraversion, which is associated with lower levels of loneliness. While social environment factors primarily revolve around the quantity and satisfaction of social interactions, built environment factors present a unique opportunity for intervention as they can be externally modified. Acknowledging this distinction, the present study specifically concentrates on exploring the built environment factors associated with loneliness, aiming to identify potential interventions for addressing this issue.

In Chapter 3, a systematic literature review was conducted to find out what built environment factors influence loneliness. In this review, 27 studies were examined, categorizing the variables into ten categories: dwelling, neighborhood quality, amenities, urban density, mobility, green, social environment, social safety, neighborhood composition, and neighborhood socioeconomic status. The

findings indicate that individuals experience less loneliness when they are content with their homes and more loneliness when their homes have defects. Similarly, satisfaction with neighborhood quality, amenities, and social environment is associated with reduced loneliness. Furthermore, satisfaction with the convenience of public transport was linked to lower levels of loneliness within the mobility category. In terms of social safety, individuals tend to feel less lonely when they feel safer and feel lonelier when they perceive more neighborhood physical disorder and disadvantage. However, the impact of urban density and green facilities remained inconclusive. Furthermore, no significant correlations between neighborhood composition, neighborhood socioeconomic status, and loneliness were found. The findings of this systematic literature review revealed that several built environment factors have the potential to either increase or decrease loneliness. Various stakeholders can play an active role in mitigating loneliness by addressing these factors. Practical implications can be derived from the literature review, guiding policymakers, urban planners, designers, and developers towards effective interventions. Policymakers have a crucial role in ensuring that individuals have access to community healthcare services and promoting a social environment that fosters connection and safety. Urban planners can contribute to loneliness reduction by designing neighborhoods and public spaces that provide a range of amenities, facilities, and recreational services of good quality. Designers play a vital role in designing houses that prioritize quality and incorporate elements such as ample natural light. Developers should as well ensure that the dwellings they develop are of good quality as well as being affordable. By prioritizing and implementing these interventions, stakeholders can actively contribute to combating loneliness. It is crucial to address solutions for individuals experiencing chronic loneliness, while also recognizing the importance of prevention methods to prevent the problem from exacerbating further.

Therefore, the objective of Part II was to determine what factors influence state loneliness, which refers to momentary feelings of loneliness in daily life and to test some interventions. To identify what elements influence state loneliness, an online video-based stated preference experiment was conducted. This experiment was based on the PhD study of Yuwen Zhao, who created the videos included in the survey. The videos simulated walking through a virtual public space along a pre-designed route. After watching the videos, participants were asked about their experience of companionship and isolation. More explanation of the design, measurements, and model estimation can be found in Chapter 4. In Chapter 5, the findings revealed significant influences on state loneliness, including crowdedness, the presence of grass, and the presence of trees. Participants reported feeling less lonely when there were more people present on the street and when grass and trees were present. Additionally, a latent class regression analysis identified three distinct classes: the partially environmentally sensitive class, the environmentally sensitive class, and the non-environmentally sensitive class. The partially environmentally sensitive class experienced reduced state loneliness with high crowdedness, presence of grass, and presence of trees. The environmentally sensitive class exhibited decreased state loneliness with a high crowdedness, absence of grass and water, presence of benches, presence of trees, vertical greening, and high traffic volume. In contrast, the non-environmentally sensitive class did not show any significant impact of the considered attributes on state loneliness. These findings have important implications for urban planners and designers, highlighting the significance of incorporating elements that promote social interaction and address state loneliness. By creating public spaces that encourage crowdedness and include well-designed green spaces, urban environments can contribute to reducing state loneliness and enhancing social well-being. Furthermore, prior to watching the videos, respondents were given questions about socio-demographic characteristics (e.g., age), personality traits (e.g., extraversion), and trait loneliness (chronical loneliness). Using Chi-Square and ANOVA analyses, the role of socio-demographic characteristics, personality traits, and trait loneliness on the relationship between built environment

factors and state loneliness was evaluated. The results showed no significant differences in socio-demographic characteristics among the three groups. However, extraversion exhibited a statistically significant association with class membership, suggesting that individuals with higher levels of extraversion were more likely to be in the non-environmentally sensitive class. No other personality traits or trait loneliness exhibited a significant influence on class membership. In addition, an investigation was conducted to determine if the three classes exhibited different green perceptions and positive emotional responses towards the videos. The analysis showed no significant differences in respondents' perceptions of green, relaxation, or excitement between the classes. Significant differences were observed in feelings of safety and state loneliness. Class 3 felt the safest and experienced the lowest state loneliness, while class 1 felt the least safe and experienced highest state loneliness. These findings align with Chapter 3's literature review on the importance of safety in reducing loneliness. Furthermore, the state loneliness experienced by individuals in class 1 and class 2 is influenced by their perceptions of green and positive emotional responses, whereas individuals in class 3 do not exhibit any significant impact on their state loneliness from these factors. These findings seem to be in line with the LCA, where it was found that the state loneliness of individuals in class 1 and 2 is influenced by crowdedness and green attributes, whereas individuals in class 3 do not exhibit any significant impact on their state loneliness from these factors. This difference in the findings may be attributed to the possibility that individuals in class 1 and 2 have higher expectations or standards regarding the sufficiency, quality, and vibrancy of green in their environment, which makes them more sensitive to its effects. In summary, the latent class analysis revealed three distinct classes, each displaying unique characteristics and responses to the built environment. These findings underscore the heterogeneity within the sample and underscore the significance of recognizing individual differences when developing interventions to combat loneliness. By comprehending the characteristics and preferences of each class, policymakers, urban planners, and designers can customize their strategies to effectively alleviate loneliness.

This study has provided valuable insights into the relationship between the built environment and loneliness, specifically focusing on both trait and state loneliness. However, it is important to acknowledge the limitations of the study while also recognizing the strengths and identifying potential areas for future research.

One of the limitations of this study is the relatively small and homogenous sample. To gain further insights and enhance the validity of future research, future research should aim to include larger and more diverse sample to ensure the findings can be more representative of different demographic groups. This would enable a more comprehensive examination of the relationships between personality traits, trait loneliness, and class membership. Furthermore, this study focused on specific built environment attributes, such as crowdedness, the presence of grass, and the presence of trees. While these factors were found to have a significant influence on state loneliness, there may be other attributes that were not considered in this study. Future research could explore additional built environment factors to further expand the understanding of the relationship between the built environment and loneliness.

A strength of the research is the use of video-based simulation. Using these simulations provided a valuable opportunity to test the effectiveness of interventions. Conducting such interventions in the actual built environment would have been costly, time-consuming, and uncertain in terms of their efficacy. A notable strength of video-based simulations is their ability to simulate real-life experiences in a controlled and efficient manner. However, it is important to acknowledge a limitation of the videos, namely the absence of sound, which may have influenced respondents' perceptions of factors

such as traffic density or crowdedness. Future research could address this limitation by incorporating sound into the videos. Additionally, it would be valuable to explore the measurement of state loneliness in real environments, allowing for a comprehensive comparison of the results obtained from video simulations. Such research would provide a deeper understanding of how the built environment impacts individuals' momentary experiences of loneliness.

Another strength of this research was the development of a new measurement for assessing state loneliness. Although the reliability of the measurement was established, it would also be valuable for future research to focus on the development of a standardized scale for measuring state loneliness. This would allow for more consistent and comparable assessment across different studies.

The aim of this study was to gain insights into how individuals' perceptions and emotional responses to various elements of the built environment influence their feelings of loneliness. Additionally, the study sought to examine the interaction between individual characteristics, personality traits, trait loneliness and built environment elements in shaping the experience of loneliness. The findings of this study underscore the significance of considering built environment factors in addressing loneliness and highlight key recommendations for interventions and policies. Firstly, the study emphasizes the importance of prioritizing improvements in housing conditions, neighborhood quality, amenities, and addressing social safety concerns as crucial steps in alleviating chronic loneliness. Furthermore, the study highlights specific built environment elements that have a significant impact on reducing state loneliness. Notably, increased crowdedness, the presence of grass, and the presence of trees were found to be associated with lower levels of state loneliness. Moreover, the study demonstrated that an increase in the perceived amount and quality of green was linked to a decrease in state loneliness. Additionally, higher levels of relaxation, excitement, and safety were found to be correlated with lower levels of state loneliness.

These findings provide practical insights for urban planners, designers, and policymakers to incorporate green spaces, adequate social interaction opportunities, and well-designed public spaces into the built environment to promote social connectedness and reduce loneliness. The results of this study contribute to a broader understanding of loneliness and its relationship with the built environment. In conclusion, this study highlights the importance of considering built environment factors in addressing loneliness and provides valuable recommendations for effective interventions to reduce loneliness in the future.

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Appendices

1. Overview Search Strategy

Step	Search within	Search documents	Query string	Results
1.	Keywords	Lonel*	KEY (lonel*)	13,885
AND				
2.	Article title, Abstract, Keywords	"urban planning" OR "built environment" OR "spatial factor*" OR neighbo?rhood OR "living environment"	(KEY (lonel*) AND TITLE-ABS-KEY ("urban planning" OR "built environment" OR "spatial factor" OR "spatial planning" OR neighbo?rhood OR "living environment"))	206
AND				
3.	Article title, Abstract, Keywords	green* OR "open space" OR garden OR nature OR housing OR building* OR facilit* OR utilit* OR amenit* OR "local resources" OR accessib* OR transport* OR mobility OR safety OR "environment* quality" OR "neighb?rhood attachment" OR walkab* OR recreational OR "residen* characteristics"	(KEY (lonel*) AND TITLE-ABS-KEY ("urban planning" OR "built environment" OR "spatial factor" OR "spatial planning" OR neighbo?rhood OR "living environment") AND TITLE-ABS-KEY (green* OR "open space" OR garden OR nature OR housing OR building* OR facilit* OR utilit* OR amenit* OR "local resources" OR accessib* OR transport* OR mobility OR safety OR "environment* quality" OR "neigho?rhood attachment" OR walkab* OR recreational OR "residen* characteristics"))	113
LIMIT TO				
4.		DOCTYP, "ar" OR DOCTYPE, "re" OR LANGUAGE, "English" OR LANGUAGE, "Dutch"	(KEY (lonel*) AND TITLE-ABS-KEY ("urban planning" OR "built environment" OR "spatial factor" OR "spatial planning" OR neighbo?rhood OR "living environment") AND TITLE-ABS-KEY (green* OR "open space" OR garden OR nature OR housing OR building* OR facilit* OR utilit* OR amenit* OR "local resources" OR accessib* OR transport* OR mobility OR safety OR "environment* quality" OR "neigh?rhood attachment" OR walkab* OR recreational OR "residen* characteristics")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (103

			LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Dutch")	
EXCLUDE				
5.		PUBYEAR, 1990	(KEY (lonel*) AND TITLE-ABS-KEY ("urban planning" OR "built environment" OR "spatial factor*" OR "spatial planning" OR neighbo?rhood OR "living environment") AND TITLE-ABS-KEY (green* OR "open space" OR garden OR nature OR housing OR building* OR facilit* OR utilit* OR amenit* OR "local recourse*" OR accessib* OR transport* OR mobility OR safety OR "environment* quality" OR "neighborhood attachment" OR walkab* OR recreational OR "residen* characteristic*")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Dutch")) AND (EXCLUDE (PUBYEAR , 1990))	102

2. Brief measure of the Big-Five personality domains

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
1	2	3	4	5	6	7

I see myself as:

1. ____ Extraverted, enthusiastic.
2. ____ Critical, quarrelsome.
3. ____ Dependable, self-disciplined.
4. ____ Anxious, easily upset.
5. ____ Open to new experiences, complex.
6. ____ Reserved, quiet.
7. ____ Sympathetic, warm.
8. ____ Disorganized, careless.
9. ____ Calm, emotionally stable.
10. ____ Conventional, uncreative.

TUPI scale scoring ("R" denotes reverse-scored items): Extraversion: 1, 6R; Agreeableness: 2R, 7; Conscientiousness; 3, 8R; Emotional Stability: 4R, 9; Openness to Experiences: 5, 10R.

3. Measure for trait loneliness

<u>NEVER</u>	<u>RARELY</u>	<u>SOMETIMES</u>	<u>ALWAYS</u>	
1	2	3	4	
*1.	How often do you feel that you are "in tune" with the people around you?			_____
2.	How often do you feel that you lack companionship?			_____
3.	How often do you feel that there is no one you can turn to?			_____
4.	How often do you feel alone?			_____
*5.	How often do you feel part of a group of friends?			_____
*6.	How often do you feel that you have a lot in common with the people around you?			_____
7.	How often do you feel that you are no longer close to anyone?			_____
8.	How often do you feel that your interests and ideas are not shared by those around you?			_____
*9.	How often do you feel outgoing and friendly?			_____
*10.	How often do you feel close to people?			_____
11.	How often do you feel left out?			_____
12.	How often do you feel that your relationships with others are not meaningful?			_____
13.	How often do you feel that no one really knows you well?			_____
14.	How often do you feel isolated from others?			_____
*15.	How often do you feel you can find companionship when you want it?			_____
*16.	How often do you feel that there are people who really understand you?			_____
17.	How often do you feel shy?			_____
18.	How often do you feel that people are around you but not with you?			_____
*19.	How often do you feel that there are people you can talk to?			_____
*20.	How often do you feel that there are people you can turn to?			_____

Scoring:

Items that are asterisked should be reversed (i.e., 1 = 4, 2 = 3, 3 = 2, 4 = 1), and the scores for each item then summed together. Higher scores indicate greater degrees of loneliness.