Impact of access to urban green space on social and emotional loneliness

How does the accessibility of urban green space impact social and emotional loneliness in the Dutch context?

June 3rd, 2023

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Abstract

Loneliness has been linked to an array of physical and mental health problems. It consists of two dimensions: social and emotional loneliness, which refer to lack of social network and lack of close relationship respectively. There are various factors contributing to loneliness; this research focuses on the factor urban green space, in terms of size, function and accessibility. Various studies have found that green space impacts loneliness, but there is no research on whether and how this impact differs for social and emotional loneliness. This thesis addresses this knowledge gap by answering the following research question: “How does the accessibility of green space impact social and emotional loneliness in the Dutch urban context?”. This is done by a combination of GIS and statistical analyses. This thesis uses two separate indicators: the percentage of neighbourhood area that consists of green space, and an indicator based on a distance decay function. The analyses are repeated considering only green spaces of certain sizes and functions. The indicators are assessed using Pearson’s correlation test and a multiple linear regression that accounts for a range of built environment and sociodemographic factors, and compared using Dunn & Clark’s z-test. Results indicated that, although access to urban green space is correlated with both social and emotional loneliness, there is no significant effect on social loneliness once other factors are controlled for. For emotional loneliness, the evidence is mixed, with green space that has a function other than sport, play or nature having a significant effect. Size was not found to be a relevant factor. Overall, the impact of urban green space access on social and emotional loneliness is found to be limited. Hence, future research should focus less on the links between these factors, and more on how to incorporate broader health objectives into spatial planning processes.

Key words: Social loneliness; Emotional loneliness; Urban green space; Accessibility; Spatial planning and health; GIS analysis.

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List of abbreviations

B: regression slope

$DDGSI_y$: the distance decay-based green space indicator (i.e. the percentage of theoretical maximum weighted urban green space area) for neighbourhood *y*

df: degrees of freedom

MA_x: municipality area within zone *x*

N: sample size

R: multiple correlation coefficient

R Square: explained proportion of variance

Sig.: significance

Std. Error: standard error

t: t-value

$UGSA_x$: urban green space area within zone *x*

VIF: variance inflation factor

1. Introduction

One of the many effects of the COVID-19 pandemic was that it led to both increased prevalence of and attention to loneliness. In fact, Ernst et al. (2022) identified at least 34 papers on the effect of the pandemic on loneliness, and their findings generally suggested that levels of loneliness had increased since the outbreak. Nonetheless, the issue of loneliness of course far predates the pandemic – indeed, Cacioppo et al. (2014) already noted that its prevalence was increasing. This increased level of loneliness is an issue, because loneliness is associated with a wide array of physical and mental health and well-being issues (Park et al., 2014).

However, loneliness is also quite a multifaceted phenomenon, and hence there have been attempts to subdivide it into separate aspects. Perhaps the most popular such subcategorisation is that coined by Weiss (1973), who proposed the concepts of social loneliness, which refers to a self-perceived lack of social network, and emotional loneliness, which means an experienced lack of intimate relationships (De Jong Gierveld & Van Tilburg, 2006). There are many factors that have been found to influence loneliness and, as Weiss (1973) already suggested, these only partially overlap between social and emotional loneliness. However, the most relevant factors from a spatial planning perspective are those of the built environment. In addition to subjective indicators such as perceived usability and walkability (Domènech-Abella et al., 2020), residential density and building typology have been found to impact loneliness (Lai et al., 2021). However, the most commonly studied built environmental factor is green space.

Green space has a role in fostering social contacts and increasing health and well-being (Maas et al., 2009). Considering the link between social contacts and loneliness, it is perhaps not surprising that the latter has often been pointed to as a mechanism through which green space impacts well-being (Maas et al., 2009). Various studies have found a link between the presence of or access to green space on the one hand, and the degree of loneliness on the other hand (Maas et al., 2009; Astell-Burt et al., 2022).

However, there is a lack of research distinguishing between types of loneliness when it comes to the relationship with green space (Astell-Burt et al., 2022). This is perhaps surprising, because the important role of social contacts in the impact of green space on well-being would suggest that social loneliness is more closely related to green space than emotional loneliness. Indeed, Astell-Burt et al. (2022) suggested a focus on social loneliness in future research on the matter.

The aim of this thesis is to address this knowledge gap by studying social loneliness and emotional loneliness as separate entities. In doing this, the size and function of green spaces is taken into account, as the extent to which green spaces influence wellbeing is dependent on both (Wood et al., 2017). The accessibility of these green spaces is also important, as it impacts their usage (Schipperijn et al., 2010a).

To fulfil this aim, the following research question is used in this thesis:

- How does the accessibility of urban green space impact social and emotional loneliness in the Dutch context?

To answer this research question, this thesis makes use of the following three subquestions, which incorporate the main aspects identified above.

- To what extent does the accessibility of urban green space impact social loneliness in the Dutch context?

- To what extent does the accessibility of urban green space impact emotional loneliness in the Dutch context?
- How does the size and function of urban green space influence the two dimensions of loneliness?

1.1 Outline

This thesis will first proceed by discussing the existing literature on all aspects of social and emotional loneliness and green space that are relevant to the research problem. Consideration of these aspects leads to the theoretical framework and with it, the hypotheses. Next, the case study, data and method used to answer the research question are introduced. This is naturally followed by presenting the outcomes of this analysis in the results section. Finally, the discussion and conclusion draw upon these outcomes to answer the research question.

2. Literature review

2.1 Green space, well-being and health

Although there is a large body of research concerning the impacts of green space on health and well-being (Lyu & Forsyth, 2022), there remains some debate regarding the existence of such a relationship. This can be illustrated by the findings of two leading review articles in this field. On the one hand, Gascon et al. (2015) conclude that there is only limited evidence for the existence of a causal relationship between surrounding greenness and mental health in adults. Moreover, for children, as well as for the effects of both access to and quality of green spaces, evidence for such a relationship is insufficient. On the other hand, Kondo et al. (2018) find that urban green space exposure leads to lower levels of mortality, heart rate, and violence, as well as better attention and mood and more physical activity. However, evidence for an effect on general health, weight, depression and stress was found to be inconclusive. Of course, there are differences in focus between both papers – Gascon et al. (2015) focus on mental health as opposed to overall health and well-being, whereas Kondo et al. (2018) base their work on urban green space rather than all green space. Yet that does not mean there is no debate, and the papers I discuss in this section (which mostly underpin the existence of such a relationship) should be viewed in that light.

With this nuance in mind, let us consider some key works that underpin the case for green space impacting health and well-being. Maas et al. (2006) conclude that a greater amount of green space near a person's residence is related to better overall health, at all degrees of urbanity, in all age groups (but especially for the youth and the elderly), and particularly for lower-educated individuals. This is consistent with Stigsdotter et al. (2010), who find that those living closest to green space have the highest levels of self-reported health. Coppel & Wüstemann (2017) found the same effect on self-reported health using both metrics, especially for younger, female and childless people. Moreover, various health indicators have been found to be related to green space. These include stress (Stigsdotter et al., 2010), physical activity levels (Coombes et al., 2010; Richardson et al., 2013), cardiovascular disease risk (Richardson et al., 2013), and life satisfaction (Bertram & Rehdanz, 2015). Another such indicator, loneliness (e.g. Maas et al., 2009), will be discussed in more detail later. In addition to this, Van den Berg et al. (2010) conclude that living in a neighbourhood with more green space access tends to lessen the effect of stressful life events on both overall and mental health.

In terms of gender differences, it should be noted that Richardson & Mitchell (2010) found that both respiratory and cardiovascular disease mortality decreased with the amount of green space in men, but not in women, indicating gender differences in the health and well-being impacts of green space. Moreover, whilst men's mental health increased with the amount of green space, moderate amounts of green space were associated with the highest levels of mental health in women (Astell-Burt et al., 2014). This is consistent with Bertram & Rehdanz (2015)'s finding that life satisfaction started to fall again once the highest levels of green space were reached. In addition to this, the ages for which the relationship between green space and mental health was found to be significant differed between men and women (Astell-Burt et al., 2014). Finally, Wood et al. (2017) found that, although all green spaces are related to better mental health, the effect is largest when the green spaces are larger and when they have a sports (as opposed to a recreational or nature) function. It is suggested that this may be because people use green spaces of certain functions and/or sizes more frequently than others. This brings us to another key point: factors influencing the use of green space, which will be discussed in the next section.

2.2 Green space use

Aside from functionality and size, a wide range of other factors has been linked to the usage of green space. Although Coombes et al. (2010) and Schipperijn et al. (2010b) find that living further away from green space is associated with visiting green space less often, Schipperijn et al. (2010a) conclude that the nearest green space is also the most commonly used one for barely half of their sample. Predictors of the nearest green space being the most used are a larger size and closer proximity to the residence, as well as the user being elderly, in poorer health, or having a dog or young child. Moreover, in their case studies of Brussels (Belgium), Luxembourg (Luxembourg) and Rouen (France), Schindler et al. (2022) find that the median distances to the most commonly-used green spaces range from 1.4 to 1.9 kilometres between the three cities, whereas the median distance to the closest green space ranges from 0.3 to 1.2 kilometres. This suggests that many people indeed tend to visit green spaces other than the one closest to their residence. In contrast to Schipperijn et al. (2010a), the article finds that people who visit larger green spaces do not travel longer to reach them. Instead, living further from the city centre, being less satisfied with local green spaces, being lower-educated, being European, being aged 25 to 55 and not having a job were found to predict longer travel times, with mixed results for household size and car ownership.

Regarding frequency of green space use, Schipperijn et al. (2010a) found that the predictors differ depending on whether the closest green space is also the most-used one. If so, only having a dog was found to be associated with more frequent use. If not, age (lower for those aged 17 to 29, higher for ages 60 to 69), self-evaluated health (higher when evaluated as better) and distance to the nearest green space (higher when further) were associated. In terms of demographic factors, Schipperijn et al. (2010b) found that people who were higher-educated and had a western background were more likely to use green space often. Moreover, among men, higher age was correlated with higher usage levels until age 80. In terms of motivational reasons, enjoying the weather/fresh air and stress reduction/relaxation were the most commonly cited, the latter less so amongst those of retirement age. Notably, among respondents aged 16 to 24, women were more likely to state either reason. Other reasons were exercising/keeping in shape, doing something with family/friends and following the seasons/observing flora and fauna. The former two motivations decreased in importance with age, while the opposite is true for the latter. Finally, Balram & Dragićević (2005) find that both usefulness (in terms of use and valuation) and to a lesser extent behaviour (in terms of willingness to participate and degree of salience) are linked to more positive attitudes towards green spaces. Such attitudes are especially found among respondents aged 35 to 64 and with a higher income.

It should be noted that the links between lower socio-economic status (in terms of education level and income) and use of and attitude to green space may not be coincidental. Indeed, Schipperijn et al. (2010b) find that lower-educated people are less likely to live in close proximity of green space. Moreover, most papers that studied the United States, United Kingdom and/or Australia also found that richer, whiter neighbourhoods tend to have more green space (Wolch et al., 2014). As Groenewegen et al. (2006) note, people with lower incomes often cannot choose their location of residence based on factors like access to green space. In addition to this, the aforementioned benefits of green spaces mean that interventions to make neighbourhoods greener can lead to increased housing prices and thereby gentrification (Wolch et al., 2014; Cole et al., 2017). In this way, greening interventions can even have an adverse effect, as gentrification itself has been linked to health issues among those being displaced, whilst the benefits are mainly experienced by richer, already less vulnerable people (Cole et al., 2017). As a result, Wolch et al. (2014) recognise the need to find a balance between improving health by increasing green space provision on the one hand, and preventing ‘green gentrification’ on the other hand. The implications of this on planning will be discussed further on in the context of loneliness, which will be the focus of this theoretical framework from this point onward. Any lessons for planning practice that may be drawn from this thesis cannot disregard these findings. That, however, is a matter for the conclusion and discussion – instead, it is now time to turn to the main aspect of the research question that is yet to be discussed: loneliness.

2.3 Social and emotional loneliness

Loneliness is a state of being that has been found to influence the structures and processes of the brain (Cacioppo et al., 2014). In this light, it is perhaps not surprising that an array of studies has found that loneliness leads to increased chances of poor mental health, general well-being, and to a lesser extent physical health, self-rated health, sleep and cognition, especially in males (Park et al., 2014). In line with these negative health effects, loneliness has also been found to lead to increased risk of mortality (Patterson & Veenstra, 2010). Moreover, the prevalence of loneliness is increasing and thereby the issue is becoming more pressing (Cacioppo et al., 2014). However, loneliness is also quite a multifaceted phenomenon, and this is something that is not always fully appreciated in the literature that studies it (Qualter & Munn, 2002). In this thesis, I use the division of loneliness into the concepts of social and emotional loneliness to account for this heterogeneity.

The distinction between emotional and social loneliness was first coined by Weiss (1973). The former refers to the absence of a close and intimate relationship with another person, the latter stems from an individual's lack of being part of a network of social relationships (Weiss, 1973, cited by Russell et al., 1984). Weiss (1974, cited by Russell et al., 1984) relates this to deficits in what he terms as social provisions. Weiss distinguishes six such provisions: attachment, social integration, opportunity for nurturance, reassurance of worth, reliable alliance, and guidance. Weiss (1974, cited by Russell et al, 1984) postulated that it is the deficit or absence of the former two that lead to loneliness. Attachment, provided by relationships that foster a sense of security and safety in an individual, is linked to emotional loneliness, while social integration, the product of social relationships in which individuals share concerns and interests with each other, relates to social loneliness. This difference in causes between both kinds of loneliness led Weiss (1973, cited by Russell et al., 1984) to suggest different remedies. For him, these can be found in the most common sources of attachment and social integration: forming an intimate (romantic) relationship and developing a network of friendships, respectively. While other authors have found different provisions to be key (e.g. Russell et al. (1984), DiTommaso & Spinner, 1997), they all came to the conclusion that and emotional loneliness are different in nature, thereby validating Weiss (1973)'s distinction (DiTommaso & Spinner, 1993). Hence, the concepts of social and emotional loneliness are valid for use here.

2.4 Sociodemographic factors and loneliness

The most important deviation from Weiss (1993) for this thesis is that, although being married (Stack, 1998) or in a romantic relationship (Diehl et al., 2018; Green et al., 2021) is associated with lower levels of emotional loneliness non-romantic relationships also play a key role. Indeed, if romantic relationships were essential, children would be inherently emotionally lonely (DiTommaso & Spinner, 1993), whereas research shows that, much like adults, they can be socially but not emotionally lonely (and vice versa) (Qualter & Munn, 2002). That being said, the presence of a romantic relationship remains important for adults and has even been linked to lower levels of social loneliness (Green et al., 2021).

While earlier research on social and emotional loneliness was often characterised by an overreliance on student samples (Stack, 1998), a later wave of research focused on older adults, often in the context of divorce, widowhood and remarriage. This can be linked to the higher prevalence of loneliness among the elderly (Drennan et al., 2008). Dykstra & De Jong Gierveld (2004) confirmed the relationship between marriage and emotional loneliness, while finding none with social loneliness. Moreover, they concluded that divorce and especially widowhood are associated with higher levels of emotional loneliness, although this was not the case for remarried individuals, suggesting that marriage is the more important factor. Finally, their findings suggest key differences between men and women. By contrast, Drennan et al. (2008) found that never-married older people are as likely as their divorced and widowed peers to experience romantic emotional loneliness, although family emotional loneliness was linked to widowhood. Among married older couples, Korporaal et al. (2008) established that both own and spousal disability were linked to emotional loneliness, while disability in females was associated with social loneliness for both them and their husbands. De Jong Gierveld et al. (2009) expand on this importance of own and spousal health to draw attention to the importance of marriage quality, which is linked to both emotional and social loneliness. In terms of mental health, Holmén et al. (2000) concluded that dementia is associated with higher levels of social loneliness, but lower levels of emotional loneliness.

More recent research has confirmed that, although there is some overlap in prevalence and predictors of social and emotional loneliness, they are empirically different states of being (Dahlberg & McKee, 2014; Diehl et al., 2018). Otherwise, there appears to have been little expansion of existing knowledge on the topic, as research on social and emotional loneliness in potentially vulnerable demographics has been limited. A notable exception to this is the attention to the effect of the COVID-19 pandemic on social and emotional loneliness. Van Tilburg et al. (2020) found a strong increase in emotional and a small increase in social loneliness amongst older individuals following the implementation of lockdown measures. This is consistent with Labrague et al. (2021), who concluded that, among college students, the pandemic had led to an increase in emotional loneliness in particular.

A notable feature of the literature discussed so far in this section is that most studies concern loneliness in either younger adults or the elderly, reflecting the idea that these age groups are most prone to social and/or emotional loneliness. Indeed, Drennan et al. (2008) found that, among those above the age of 65, older age was correlated with social loneliness, while Labrague et al. (2021) concluded that, amongst college students, the youngest cohorts were most impacted by the COVID-19 pandemic in terms of emotional loneliness. However, the importance of age is disputed, as Green et al. (2001) found no significant differences between age groups in terms of the prevalence of either emotional or social loneliness, although their predictors did differ with age.

I have already briefly touched upon gender-based differences in social and emotional loneliness. These vary, dependent on which age group is studied. Among children, Junttila & Vauras (2009) concluded that emotional loneliness was higher in boys than in girls, with no difference for social loneliness. They observed a similar gender divide among the children's parents. Regarding students, DiTommaso & Spinner (1997), Green et al. (2001) and Diehl et al. (2018) all find no significant differences, although Labrague et al. (2021) found that social loneliness had increased more in female than male students during the COVID-19 pandemic. As for the elderly, the existing evidence is more conflicting, perhaps in part due to the greater number of studies. Men were found to be more socially lonely by Dykstra & De Jong Gierveld (2004), Drennan et al. (2008), Korporaal et al. (2008), De Jong Gierveld et al. (2009), Dahlberg & McKee (2014) and Van Tilburg et al. (2020). However, Holmén et al. (2000) concluded that women were the more socially lonely group, while Green et al. (2001) found no association. In terms of emotional loneliness, Holmén et al. (2000), Green et al. (2001), Dykstra & De Jong Gierveld (2004) and Korporaal et al. (2008) found that women were, on average, more emotionally lonely, while Drennan et al. (2008) concluded this was only the case for family emotional loneliness and De Jong Gierveld et al. (2009), Dahlberg & McKee (2014) and Van Tilburg et al. (2020) found no significant relationship.

Another factor that has often been linked to social and emotional loneliness is income. Dahlberg & McKee (2014) found that low income comfort was a predictor of both social and emotional loneliness in the elderly. This is consistent with Stack (1998), who concluded that lower financial satisfaction was related to greater loneliness. Drennan et al. (2008) found that lower income was correlated with family emotional loneliness only, while De Jong Gierveld et al. (2009) find that the relationship is only with social loneliness. On the other hand, Dykstra & De Jong Gierveld (2004) and Van Tilburg et al. (2020) found no association. It should be noted that, other than Stack (1998), the only studies to incorporate income focused on the elderly.

A number of studies on loneliness in the elderly have also drawn attention to the relevance of religion and church attendance. De Jong Gierveld et al. (2009) found that religious affiliation predicted both social and emotional loneliness. Dykstra & De Jong Gierveld (2004) concluded that weekly church attendance was linked to lower levels of emotional loneliness in women and social loneliness in both men and women. Conversely, Drennan et al. (2008) found no relationship between church attendance and either of social and emotional loneliness.

Finally, there are a number of factors that were only found to be relevant by one of the studies discussed here. These are low perceived community integration, high activity restriction (Dahlberg & McKee, 2014), having an immigrant background (Diehl et al., 2018), nationality (Stack, 1998), and, in the context of the COVID-19 pandemic, being personally affected by reduced social contact, work and activities (Van Tilburg et al, 2020).

A final concept linked to social and emotional loneliness is the wider notion of health. Of course, this is a two-way relationship, as health and loneliness can be causes as well as consequences of each other (Drennan et al., 2008). I already discussed the effects of disability and dementia in the elderly. Other aspects of health that were linked to social and emotional loneliness in the elderly are low self-esteem and well-being (Dahlberg & McKee, 2014), whilst for emotional loneliness, having more functional limitations was also a predictor (De Jong Gierveld et al., 2009). However, students can also experience this, as Diehl et al. (2018) found that changes in diet were linked to emotional loneliness, whilst physical inactivity and change in weight predicted social loneliness. As for overall health, Stack (1998) concluded that overall health impacted loneliness in adults, but for the elderly, Drennan et al. (2008) found that it was related only to social loneliness and Van Tilburg et al. (2020) found no such association with either form.

Of course, it should be noted that different studies incorporated different variables in their models, and only age and gender were commonplace. Moreover, there remains a great number of studies being published to this day that do not separate loneliness into a social and emotional dimension (Diehl et al., 2018) and have therefore not yet been discussed. As Qualter & Munn (2002) note, the uptake of the concepts of social and emotional loneliness has differed between fields. This is also the case for the areas of built environment in general and green space in particular, which I will return to now.

2.5 Built environment and loneliness

There are a number of factors found to predict loneliness by papers discussed in the previous section that do not pertain to sociodemographics, but to the area in which people live and the extent to which they are outdoors. These are living in a rural area (Drennan et al., 2008), living in a hospital or nursing home (Holmén et al., 2000), and, again in the context of the COVID-19 pandemic, being outdoors less frequently (Van Tilburg et al, 2020). In that light, it is perhaps not surprising that there have been quite a few studies on the relationship between loneliness and a topic closer to home for the spatial planner: the built environment. Much like the wider body of research concerning loneliness, a significant share of these studies have focused on older adults (Lyu & Forsyth, 2022). Yet, to the best of my knowledge, only Domènech-Abella et al. (2021) incorporated the distinction between social and emotional loneliness. Moreover, much like in the previous section, it is important to consider that certain aspects have been studied more often than others. In their scoping review of studies on built environment and loneliness, Lyu & Forsyth (2022) find that the neighbourhood environment has been studied most often, although urban contexts, transportation access and housing have also received a significant amount of attention. Finally, all studies incorporate a number of sociodemographic factors similar to those discussed previously, findings on these will not be repeated here.

An early work related to the matter was conducted by Scharf & De Jong Gierveld (2008), who studied neighbourhood effects on loneliness in older adults in the UK and the Netherlands. In both countries, a higher perceived quality of the neighbourhood, in terms of resident satisfaction and perceived safety, was linked to lower levels of loneliness. However, urbanity and financial status of the neighbourhood had no significant effect once perceived quality and demographic characteristics were controlled for.

Van den Berg et al. (2016) studied the effects of mobility and the built environment on loneliness in Dutch adults. They find that living in an apartment increases loneliness in adults aged 64 and under, while higher satisfaction with both the neighbourhood and its facilities and being closer to a highway were associated with lower levels of loneliness in general. On the other hand, urban density and the distance to shops and green facilities had no significant effect. In terms of mobility, the use of a car and public transport were both associated with lower levels of loneliness, and the same was true for the use of a bicycle in adults aged 34 and under.

Remaining in the Dutch context, Kemperman et al. (2019) researched the effects of social network and the living environment on loneliness in older adults; I will focus on the effects of the latter here. Higher neighbourhood attachment was found to be related directly to lower levels of loneliness, while perceived safety and satisfaction with neighbourhood amenities and services had an indirect effect. Other studied factors, including intensity of mobility, urban density, distance to shops and distance to green, were not found to have a significant effect.

In a rare case study outside of Europe, Wee et al. (2019) studied the impact of perceived neighbourhood environment on loneliness in less well-off older adults in Singapore. They concluded that both living in a rental apartment (as opposed to being a homeowner) and perceiving the neighbourhood physical environment as poor were associated with higher levels of loneliness. Living in a standalone block, living in a smaller residence, living in a neighbourhood perceived as more disadvantaged and lower perceived safety and convenience of the neighbourhood were only correlated with loneliness when other factors were not taken into account.

Returning to Europe, Domènech-Abella et al. (2020) assessed the effect of perceived neighbourhood built environment on loneliness and depression in older people in Finland, Poland and Spain. They found that the usability of the built environment (in terms of accessibility and facilities) and the walkability of the neighbourhood impacted levels of loneliness. The usability of the built environment was only statistically relevant for non-depressed respondents, for whom walkability was the more important factor. Moreover, this study highlights the difference between countries in terms of loneliness, as respondents from Finland were found to be significantly less lonely.

A study by Hammoud et al. (2021) focused on the impacts of the social and built environment on self-reported loneliness in adults. Higher levels of overcrowding and population density and lower levels of perceived social inclusivity and contact with nature were found to be related to lower levels of loneliness. Moreover, when respondents were in contact with nature, the effect of perceived social inclusivity increased.

Lai et al. (2021) researched the impact of residential density on loneliness in the UK, controlling for, amongst other things, other built environment factors. Higher residential density was associated with higher levels of loneliness. This can be related to their finding that higher densities of flats and lower densities of detached housing were also linked to increased loneliness. In addition to this, less time spent walking, lower street-level activity potential and lower neighbourhood greenness were also associated with increased loneliness. Destination accessibility from the residence, movement density, steepness of roads in the neighbourhood, walkability and traffic intensity were not found to have a significant effect.

Lam & Wang (2022) studied the effect of built environment on loneliness in older Australian adults. They found that lower levels of loneliness were reported by those living in neighbourhoods that were more compact, had a higher population, road and housing density, consisted of smaller land parcels and had greater access to green space. Conversely, land and housing diversity, lot density, prevalence of particular housing types and more households in the neighbourhood that did not own a car were not found to be relevant.

Finally, Domènech-Abella et al. (2021) researched how social and emotional loneliness mediated the effects of physical and social environment on mental health. Emotional loneliness was found to have a far stronger mediating (i.e. indirect) effect for lower levels of all studied aspect. Its presence explained the link between poorer mental health and lower levels of mobility and safety most strongly, but to a lesser degree also that with social cohesion and participation, suggesting that the mediating effect is stronger for the physical than the social environment. However, it should be noted that such an effect does still exist for all four aspects for social loneliness as well.

Clearly, there are major differences between these studies. In terms of the most relevant aspects for this thesis, Van den Berg et al. (2016) and Kemperman et al. (2019) found that the distance to green was not related to loneliness. On the other hand, Lam & Wang (2022) did find a significant relationship between the two. Moreover, Hammoud et al. (2021) and Lai et al. (2021) highlight the effects on loneliness of contact with nature and neighbourhood greenness, respectively. However, these papers all did not focus specifically on green space, and so it is to the limited number of studies that did do so that I turn next.

2.6 Green space and loneliness

As mentioned previously, there is much evidence for the role that green space plays in health and well-being. However, the literature for the link with loneliness is much more limited (Lyu & Forsyth, 2022). Moreover, as Astell-Burt et al. (2022) note, this existing literature does not incorporate a distinction between social and emotional loneliness. Yet there are still four important papers that are to be discussed here, indeed, it is on these papers that this thesis most directly builds. These papers can be split into two halves: Maas et al. (2009) and Van den Berg et al. (2019), not dissimilarly to the aforementioned paper by Domènech-Abella et al. (2021), focus on how loneliness mediates the effect of green space on (mental) health, whereas Bergefurt et al. (2019) and especially Astell-Burt et al. (2022) discuss loneliness directly as a consequence of green space.

The study by Maas et al. (2009) concerns the mediating effects of social contacts, in terms of social support (which is not relevant here) and loneliness, in the effect of green space on (self-reported) overall health. It draws on data on Dutch individuals aged 12 and over, and controls for factors related to demographics, socio-economic status and household size. The findings indicate that more green space in the living environment is related to lower levels of loneliness, especially amongst children, younger adults, the elderly, and the lower-educated and lower-income groups. Recall that these age groups and socio-economic characteristics have been most often related to loneliness in the literature discussed previously. Moreover, both more green space and less loneliness are associated with better overall health. The authors then test for the mediating effect of loneliness, which is found to partially explain the relationship between green space and general health.

Van den Berg et al. (2019) studied whether loneliness, physical activity and social cohesion mediate the effect of visiting green space on mental health and vitality (the latter relates to general well-being). Their work draws on surveys of adults aged 18 to 75 in the cities of Barcelona, Spain; Doetinchem, The Netherlands; Kaunas, Lithuania; and Stoke-on-Trent, United Kingdom, and focused on the usage of green space (although access to green space was a criterion for defining the study area). Similarly to the findings of Maas et al. (2009), green space use was found to be related to both mental health and vitality. Moreover, more green space use indicated lower levels of loneliness, as well as more physical activity and social cohesion. Of the three studied mediating variables, loneliness was found to have the strongest mediating effect on mental health and the second-strongest (behind physical activity) on vitality. Again, similarly to Maas et al. (2009), the mediating effect only explained part of the link between green space and mental health/vitality.

Bergefurt et al. (2019) researched the effect of public space use (in which all studied public spaces are green spaces) and mobility patterns on loneliness and life satisfaction, with controls for personal and neighbourhood characteristics similar to the aforementioned studies. The study concerned adults in the Dutch city of 's-Hertogenbosch. Much like the study of Van den Berg et al. (2019), this paper focused on the use of, rather than the access to, green spaces. However, the results are quite different: the impacts of both public space use and mobility patterns on loneliness were both found to be limited. Moreover, green space use was not significantly associated with loneliness. That being said, the paper does suggest some effect of green space use on overall health, as more green space use was linked to more time spent walking.

Finally, Astell-Burt et al. (2022) studied the link between the amount of green space in the neighbourhood and overall loneliness. This study was based on a sample of residents of major Australian cities aged 15 and over, with similar control variables to the previously-discussed papers. While the amount of green space near the residence was indeed found to impact loneliness, this was only the case if green space within a sufficient radius (i.e. 1600 instead of 800 metres) was considered. As in previous studies that found a correlation, more green space was linked to lower loneliness levels. Notably, the effect was stronger amongst respondents who lived alone.

Overall, although there is a substantial amount of studies indicating an effect of green space on overall loneliness, the evidence for such an effect does not appear to be conclusive. How this translates to social and emotional loneliness remains untested.

2.7 Conceptual model

2.7.1 Key concepts and relations

Having discussed the literature, it is now time to turn the focus towards the most important points discussed there in terms of the way they are defined for the purposes of this thesis. There is a distinction here between the dependent variables (those related to loneliness) and the independent variables (those related to the prevalence of loneliness).

For the former of the two, we of course return to the distinction between social loneliness and emotional loneliness. Both are defined in line with the work of Weiss (1973). **Social loneliness**, here, is the adverse state of being caused by a limited or absent network of social relationships of which the individual is a part. Conversely, **emotional loneliness** is the adverse state of being caused by the lack of a close, intimate relationship with another individual. As discussed previously, there is some overlap between the two.

Moving on to the predictors of loneliness, we can divide these into two groups for the purposes of this thesis: those that are related to the built environment and those that are not (i.e. sociodemographic factors. From the former group, it is then necessary to single out the key factor studied in this thesis: **urban green space**. The specification of the green spaces being urban is due to the cases that are studied. It is defined here in line with Schipperijn et al. (2010a) and Coppel & Wüstemann (2017) as freely accessible spaces within an urban area that are green in terms of their vegetation, such as parks. The distance to these urban green spaces is a key factor in both their usage and their health effects and is thereby the basis for the geographic approach deployed here. In terms of the **quality of the urban green space**, which is relevant for the third subquestion, we must consider its size and function, as these influence the extent of impact on mental health (Wood et al., 2017) and, in the case of the former, also usage frequency (Schipperijn et al., 2010a). **Other built environment factors** here include residential density and housing types, in line with the factors found to be most important in the literature review. **Sociodemographic factors**, again in line with the literature review, include age, gender, socio-economic status, being religious and ethnicity. The latter is included in part as it is an important factor that influences the use of green space. This is an example of how other factors are interrelated with urban green space factors. Other such interrelations include the fact that socioeconomic status is related to green space access and the fact that a number of studies mentioned here only found certain built environment factors to influence loneliness when non-built environment factors were not included in the regression model.

The relations betweent the factors discussed here can be seen in the conceptual model (Figure 1).

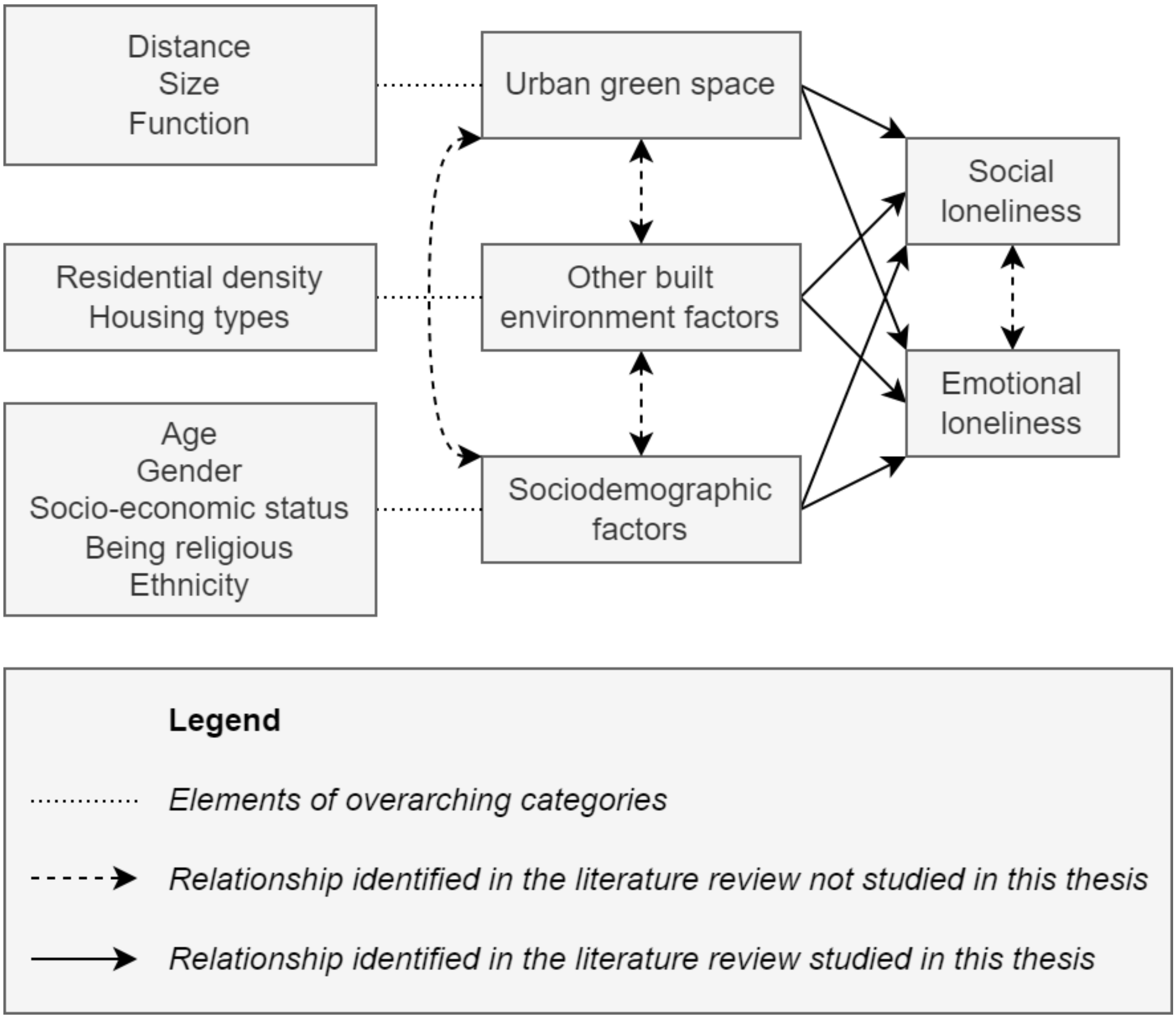

Figure 1 – Conceptual model (Source: Author)

2.7.2 Hypotheses

For the hypotheses, let us first draw on the definitions of social and emotional loneliness given above. Social loneliness is more related to the wider social network, whereas the definition of emotional loneliness focuses on a single, close relationship. However, as Maas et al. (2009) claim, the link between access to and use of green space on the one hand, mental health in general and loneliness in particular on the other hand, can be explained by social contacts, as green space can help foster more social contacts. It seems logical that an increased volume of social contacts have a greater effect on the social network than on the formation of a close relationship. Hence, if access to urban green space impacts loneliness, it would seem that it is social loneliness that is the more important driver behind this relationship. Hence, it is hypothesised for the first subquestion that social loneliness is significantly impacted by access to urban green space, whereas, for the second subquestion, emotional loneliness is not. This difference in hypothesis mirrors the fact that the evidence for the impact of access to green space on loneliness in general is inconclusive – if both social and emotional loneliness had a significant impact on loneliness, then this evidence could perhaps be expected to be less mixed. However, it should be noted that, as discussed previously previous studies have repeatedly confirmed that there is an overlap in the predictors of social and emotional loneliness. Therefore, the possibility that levels of emotional loneliness are *also* significantly related to access to urban green space should not be discarded out of hand.

Finally, in terms of size and function, recall that Wood et al. (2017) found that larger green spaces and green spaces with a sports function had a greater impact on mental health. The authors suggested that this was because such green spaces were used more often. Logically, if the intensity of green space use increases, there is more opportunity for social contacts. Hence, for the third subquestion, it is hypothesised that both larger green spaces as well as green spaces with a sports or play function have a *greater* impact on both social and emotional loneliness than all green spaces combined, whereas green space with nature or other functions do not.

It is important to note here that, in statistical testing, the *null* hypotheses were always that there was no significant impact between the independent variable (i.e. the tested form of green space or the control variable) and the dependent variable (i.e. social or emotional loneliness), and therefore also that significance as referred to here is always two-tailed.

3. Methodology

3.1 Study area

The study area for this thesis is the municipality of Eindhoven, the fifth-largest city in the Netherlands and largest altogether in the southern part of the country at 243700 inhabitants (CBS, 2023c). Eindhoven is a suitable location for a study on the impact of urban green space on social and emotional loneliness because it has suitable attributes for all three. Firstly, it is one of 22 Dutch municipalities (of which there are 351 in total) that is classified as very strongly urban (CBS, 2021), which suggests that the green spaces will be comparatively urban as well. Moreover, it has the joint seventh-highest rate of emotional loneliness and the nineteenth-highest rate of social loneliness in the country (RIVM, 2023), so it is a city where both types of loneliness are relatively pressing issues. In addition, as can be seen in Figure 2 and 3, the prevalence of loneliness is quite unevenly distributed across the city.

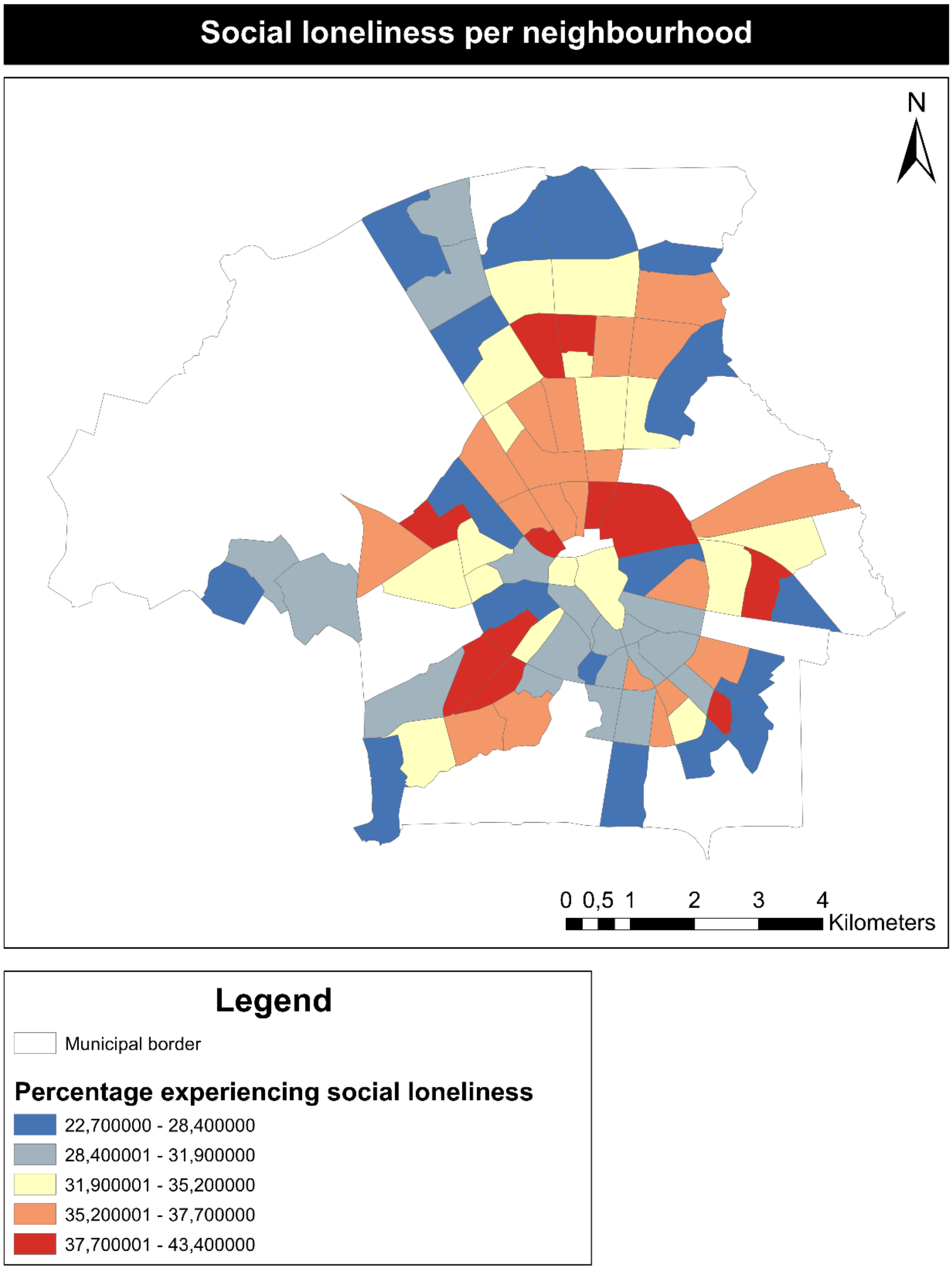

Figure 2 – Social loneliness per neighbourhood in Eindhoven (Source data: RIVM (2023))

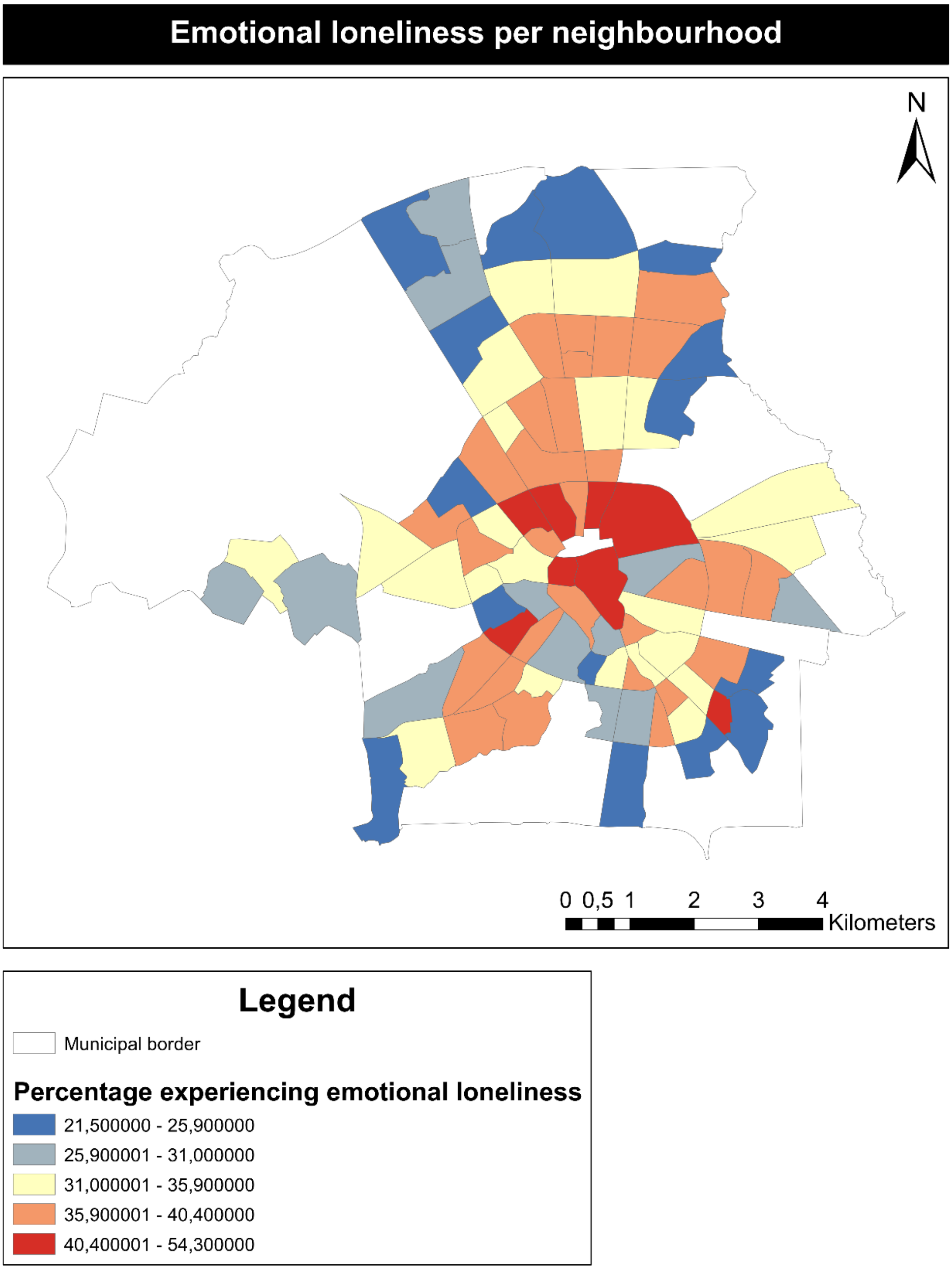

Figure 3 – Emotional loneliness per neighbourhood in Eindhoven (Source data: RIVM (2023))

Furthermore, it ranks in the bottom quarter for percentage of the area that is green (Groenmonitor & RTLNieuws, 2017), which means that green space provision is also a larger issue than in most other municipalities. This can also be seen in Figure 4 from the inequal distribution of green space across the municipality Finally, it has data available for all relevant indicators, not just for sociodemographic and built environment factors (CBS, 2023a; RIVM, 2020), but also a highly extensive green space dataset (Gemeente Eindhoven, 2023a) that allows for detailed analysis. These datasets (all consisting of secondary data) will be introduced in the next sections.

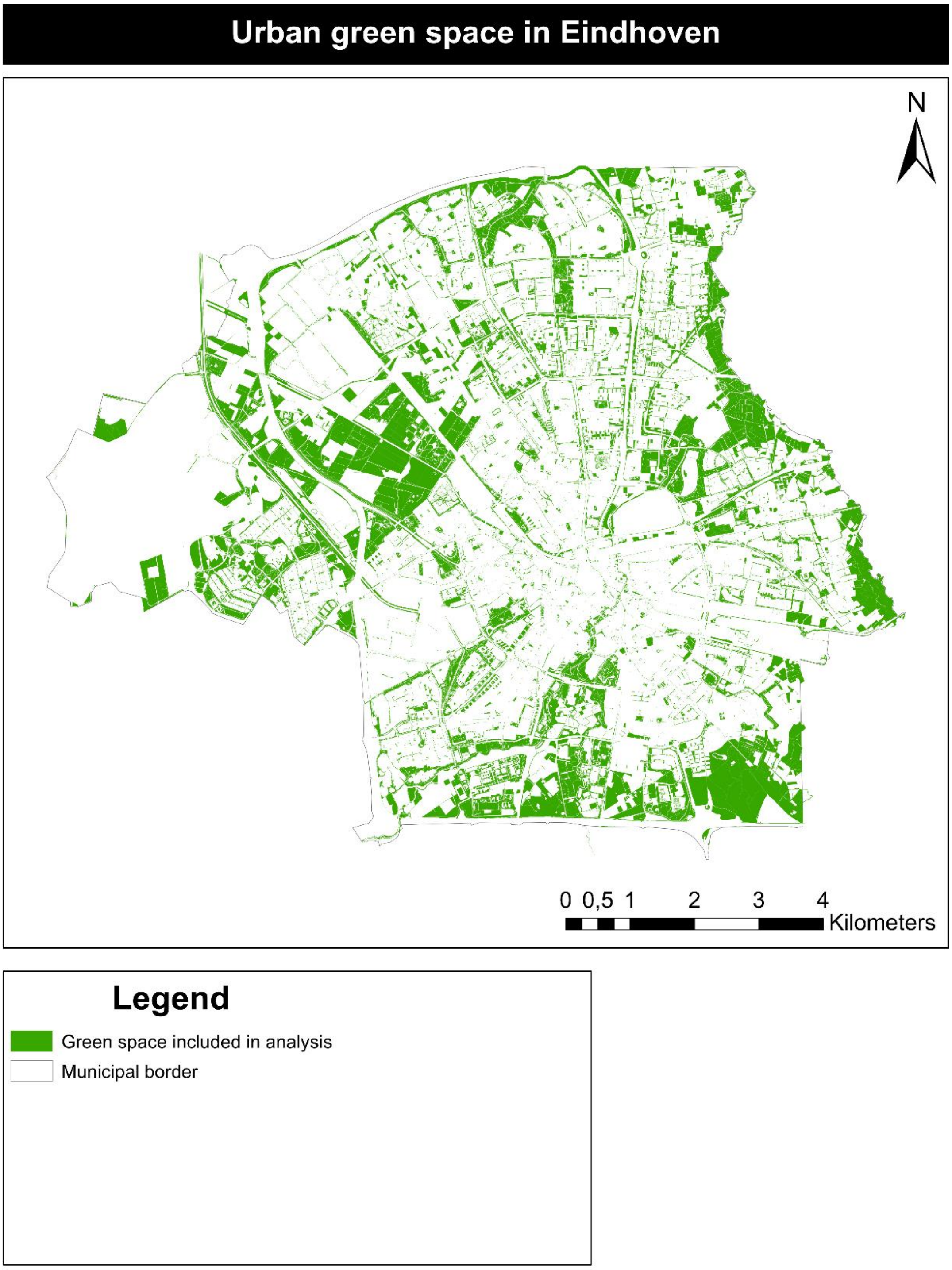

Figure 4 – Urban green space in Eindhoven (including green space intersected by the municipal boundary) (Source data: Gemeente Eindhoven (2023a))

3.2 Data collection and adjustment

As mentioned previously, the green space data is obtained from Gemeente Eindhoven (2023a). Comprising over 45000 bodies of green space represented as polygons, this dataset makes a distinction based on the type of green space in terms of its function and plant types (Gemeente Eindhoven, 2023a). While some of the green space included does not qualify as urban green space under the definition used here (e.g. agricultural terrain in the limited nonurban parts of the municipality or green areas on traffic islands), these can easily be filtered out, which was done as follows. In the dataset, green space is categorised into a wide array of groups. Those that were explicitly agricultural in type (e.g. arable land) or explicitly inaccessible (e.g. grass on traffic islands or in road verges) were removed prior to analysis. A manual check of the remaining data was performed to ensure no agricultural or inaccessible green space is included.

The data on social and emotional loneliness is derived from RIVM (2023), the *National Institute for Public Health and the Environment*, and is based on the 11-item version of the De Jong Gierveld Loneliness scale. This scale asks six questions regarding emotional loneliness (e.g. 'I miss having a really close friend') and five for social loneliness (e.g. 'There are enough people I feel close to') (De Jong Gierveld & Van Tilburg (2006), p. 586) – for a full version of this scale, see Appendix 1. People are defined as emotionally or socially lonely when they give answers indicating loneliness (i.e. 'agree' for the former and 'disagree' for the latter example) for at least half of the questions on the relevant type of loneliness (De Jong Gierveld & Van Tilburg, 2006). The most granular level at which this data is available is that of the neighbourhood, hence this is used here. Of the 116 neighbourhoods, 6 have no data on loneliness, hence these are excluded from the analysis. The most recent data available is for 2020, hence all other statistics used are for that year as well for the sake of consistency.

The data on other built environment factors, as well as the data on sociodemographic factors, is derived from the national statistics agency CBS (2023a). In accordance with the conceptual model, the factors included are residential density and housing types on the one hand, and age, gender, socio-economic status, and ethnicity on the other hand. Being religious had to be excluded due to a lack of available data at a more granular level than that of the municipality, which is not relevant for this thesis. Residential density is measured in two steps: first, the number of addresses located within a kilometre of each address is computed by CBS (2023b). Then, the average of the former is calculated for each neighbourhood (i.e., if a neighbourhood has two addresses, one of which has 2 addresses within a kilometre and the other has 4 addresses within this range, then the residential density score is (2+4)/2 = 3). This is done to incorporate housing just outside the – often somewhat arbitrary – administrative border of the neighbourhood into the statistic. An apartment block (or another type of multi-family housing), of course, will consist of multiple addresses in this calculation. Neighbourhoods with an average of 1000 addresses within a kilometre or less are defined by CBS (2023b) as not or hardly urban and are therefore not included in the analysis, as the research question explicitly focuses on urban areas. For housing types, the data makes a distinction between single-family housing (detached houses, semi-detached houses and terraced houses) and multi-family housing (all other forms of housing, such as apartments) and gives percentages of both for each neighbourhood (CBS, 2023b).

Moving on to sociodemographics, for age, the findings from some papers discussed in the literature review that young adults and senior citizens are more prone to loneliness is followed. Hence, the *percentage* of the population in the groups 15 ≤ age < 25 on the one hand, and age ≥ 65 on the other hand are considered here. While it would have been desirable to include more age groups, it became clear upon testing that this led to issues of multicollinearity in the regression analysis (which will be introduced later in this section) For gender, the data does not include a category outside of male or female citizens (CBS, 2023b), so this can be incorporated as a binary variable: male or not male. Again, this statistic is calculated as a percentage. For socio-economic status, the finding of Braveman et al. (2005) that education and income cannot be used as substitutes for each other is followed here. Hence, both are used here. CBS (2023b) distinguishes between lower, middle and higher degrees of education. In Eindhoven, the percentage of higher-educated people is greater than the percentage of lower-educated people (CBS, 2023a), so lower and middle ecudation groups are grouped together to create a binary variable. For income, average income is only given for neighbourhoods with a population of over 2500 people who receive income, and ignores the fact that many students do not receive an income outside of study financing (CBS, 2023b). Hence, the percentage of households with a low income, a statistic that does not include students and student households, is taken here. For ethnicity, this thesis limits itself to a distinction between immigrants (or 'people with a migration background', as CBS (2023b) defines it) and non-immigrants, as populations for separate ethnic groups (e.g. people with a Turkish migration background) can be quite small at the neighbourhood level.

As only urban green space is considered, it makes sense here not to include nonurban neighbourhoods. CBS (2023b) defines five groups of urbanity based on address density: not urban, slightly urban, somewhat urban, highly urban and very highly urban. While the amount of neighbourhoods in Eindhoven falling in them is low, those neighbourhoods in the first two categories are not included in the analysis. However, the green space in them is included, as parks sometimes form a separate administrative neighbourhood in Eindhoven as discussed previously.

After exclusion of nonurban neighbourhoods and neighbourhoods with missing data on social or emotional loneliness and/or one of the control variables, 86 neighbourhoods remained, which is sufficient for a regression analysis. As mentioned previously, Eindhoven consists of 116 neighbourhoods and the majority of those removed do not contain any residential zones, hence the missing data does not cause much loss of information. This also highlights the fact that most Eindhoven neighbourhoods are urban and thereby the suitability of the case for answering this research question.

3.3 Choice of method

As discussed in chapter 2, there have been many studies concerning the provision of green space, so it should be unsurprising that a wide array of methods has been deployed. However, there has generally been a preference for quantitative methods, which can perhaps be related to the preference in these studies for geographically larger cases (at the level of one or even multiple cities). While there are exceptions to this (e.g. Balram & Dragićević, 2005), such studies tend to focus on perceptions of green space, which are not especially relevant to the research question. Therefore, this thesis will not rely on qualitative methods.

As for quantitative methods, both surveys and geographical methods are commonly used to study green space. Surveys are often used to measure the use of green space (e.g. Bergefurt et al., 2019; Van den Berg et al., 2019) whereas geographical methods are mainly used to study accessibility of green space (e.g. Maas et al., 2009; Astell-Burt et al., 2022). This can be explained by the subjective nature of the use of green space, as opposed to the (more or less) objective nature of its accessibility, as surveys often rely upon subjective answers whereas geographical methods generally do not. Considering that the research question concerns accessibility, geographical methods are more applicable for the green space analysis here. Of course, this thesis does rely on survey data elsewhere, as the the secondary data on loneliness used here *is* based on a survey.

Broadly, three geographical methods can be distinguished in research on access to green space: distance to the nearest green space, proportion of green space within a neighbourhood, and proportion or units of green space within a given distance from a residence or neighbourhood centroid. Distance to the nearest green space is perhaps less suitable when green space size is a factor, which it is in this thesis. Moreover, it is measured from the residences of individual respondents (Coombes et al., 2010; Schipperijn et al., 2010a; Schipperijn et al., 2010b; Bertram & Rehdanz, 2015; Coppel & Wüstemann, 2017). Even if the exact addresses are replaced by indicating a nearby location, such as the nearest intersection to the residence, this has proven to be problematic given privacy concerns (Jiang et al., 2021). Finally, it ignores the fact that the nearest urban green space is often not the most-used one (Schipperijn et al., 2010a; Schindler et al., 2022). Hence, it is not used here.

Proportion of green space within a neighbourhood, on the other hand, suffers from none of these issues: it calculates the area of the green space, thereby addressing the size issue, it does not rely on addresses of residences, and it includes more green spaces than solely the nearest one. On the other hand, it does, of course, fail to consider green spaces outside the neighbourhood, which may be frequently used by residents living near the border of their neighbourhood in particular. In addition to this, it ignores the fact that a green space in a certain part of a neighbourhood will likely not be used equally by residents of different parts of the neighbourhood, if they are not equidistant from this green space. In spite of this, this is a fairly common method, and has been deployed by (amongst others) Richardson et al. (2010), Richardson et al. (2013), Astell-Burt et al. (2014), and Wood et al. (2017).

Finally, amount of green space within a given distance is the method with the most variations. It may take the residence of an individual (e.g. Hillsdon et al., 2006; Maas et al., 2006; Nielsen & Hansen, 2007; Maas et al., 2009; Van den Berg et al., 2010; Bertram & Rehdanz, 2015; Coppel & Wüstemann, 2017) or less commonly the centroid of a neighbourhood (e.g. Astell-Burt et al., 2022) as the point from which distance is measured. Of course, for aforementioned reasons, the former is not considered as an option in this thesis. Moreover, this method can count the percentage of green space cover (e.g. Maas et al., 2006; Maas et al., 2009; Van den Berg et al., 2010; Bertram & Rehdanz, 2015; Coppel & Wüstemann, 2017, Astell-Burt et al., 2022), similar to the proportion of green space within a neighbourhood method, but also the number of green spaces (e.g. Hillsdon et al., 2006; Nielsen & Hansen, 2007). Finally, the given distance used varies strongly from paper to paper, with the rationale for the chosen distance often not clearly substantiated. Coppel & Wüstemann (2017) use a buffer of 250 metres, whereas Bertram & Rehdanz (2015) take a range of 1 km. Maas et al. (2006), Maas et al. (2009) and Van den Berg et al. (2010) use the latter range as well, but separately calculate a buffer of 3 km. Astell-Burt et al. (2022) go a step further by calculating for three separate distances, of 400 m, 800 m, and 1.6 km. Finally, perhaps the most sophisticated method is adopted by Hillsdon et al. (2006) and Nielsen & Hansen (2007), who use a distance decay function, in which green space closer to the centroid is more heavily weighted than green space further away from it. Notably, both of these papers used number of green spaces rather than green space area. Moreover, to the best of my knowledge, no other authors have used a distance decay function in research concerning green space, hence the combination of distance decay and green space area remains unexplored. This opens up an interesting option for this thesis.

The choice of method is dependent in part on the data that is used. This thesis concerns the city of Eindhoven, in part due to the extensive dataset on public green space that is made publicly available by the municipality. This dataset consists of polygon rather than point data, which means that the area of green spaces can be incorporated into the method.

A second consideration is that the administrative division of districts into neighbourhoods in Eindhoven often entails categorising larger green areas, such as parks or urban nature areas, as separate neighbourhoods (Gemeente Eindhoven, 2023b). It would appear likely that these play a role in the use of green space by the residents of adjacent neighbourhoods in particular. Therefore, any results based solely on green space within the formally-defined neighbourhood are likely to be flawed. On the other hand, some urban neighbourhoods are on the municipal border and the dataset does not include green space outside of the municipality of Eindhoven. This means that the inability to consider green space outside the limits of the neighbourhood will cause an undercount for those neighbourhoods on the municipal border. This can be partially counteracted by calculating the green space distance decay metric as a percentage of the maximum possible score (i.e. what the score would be if the entire municipality consisted of green space), as this maximum will be lower for neighbourhoods with a larger percentage of their buffer outside the municipal borders. In this way, the fact that neighbourhoods closer to the municipal border have a larger portion of their buffers overlapping with area for which no data is available does not result in unjustly low scores. However, it will still miss the importance of green spaces (or lack thereof) close to the neighbourhood but outside the municipality.

Clearly, none of the methods are without their shortcomings, but these issues mostly do not overlap between methods. Hence, this thesis applies a multitude of geographical methods, as similar results from different methods can provide a more solid basis for any conclusions than results from a single method. On the one hand, this thesis relies on the proportion of green space within a neighbourhood (referred to hereafter as the area in neighbourhood indicator) to provide a method in which the municipal border issue does not have the potential to cause bias. On the other hand, it uses the proportion of green space within a given distance from the centroid of a neighbourhood, including a distance decay function (referred to hereafter as the distance decay-based indicator), to include a method in which the neighbourhood border issue does not come into effect. These two methods are suitable for the purposes of this thesis, as they can consider size of a green space, do not require addresses, and consider other green spaces than the nearest one. Moreover, if both methodologies yield similar findings, that would substantiate the conclusions of this thesis.

The most important consideration for operationalisation is which buffer is to be applied. As mentioned previously, these buffers often appear to be arbitrarily selected, and when they are not, they are based on planning guidelines rather than empirically-validated data (e.g. Astell-Burt et al., 2022). However, the work of Schipperijn et al. (2010a) contains estimates by respondents of the distance to their most-used green space (see Table 1). These can be used to base the distance decay parameters on. Given that the study of Schipperijn et al. (2010a) concerns a mid-sized city in Denmark, a country that, like the Netherlands, is Western European, wealthy, and has a high modal share for cycling (Achermann Stürmer et al., 2020). Hence, in absence of Dutch data in this area, the results of Schipperijn et al. (2010a) seem sufficiently transferable to the context of Eindhoven.

Table 1 – Respondents' estimated distance to most-used and nearest green space

Distance interval	**% of respondents who estimated this distance to their most-used green space**	**% of respondents who estimated this distance to their nearest green space**
0-100 m	17,1	31,4
100-300 m	18,9	31,4
300-600 m	17,9	23,3
0.6-1 km	14,2	10,0
1-2 km	11,1	2,5

2-5 km	7,0	0,2
5-10 km	2,7	0,0
> 10 km	3,7	0,0
Do not know	7,4	1,1

Source: Schipperijn et al. (2010a, p. 28)

Geographic analysis is done in ArcGIS in accordance with the methodology defined above. The buffers for the distance decay analysis are based on Table 1. To counteract for the fact that many people do not have green space within the two smallest ranges available, the first three ranges were merged. Moreover, green space with a distance above 10 km or with an unknown distance was excluded as these groups cannot be operationalised. The weights (given in Table 2) are then calculated based on the percentages of people for whom a green space within a certain range is the most-used one. The ranges used in this thesis are calculated as the distance to the centroid of the neighbourhood. In other words, closer green spaces are given greater weighting, as is the underlying idea behind a distance decay analysis. The underlying assumption is that green spaces that are more likely to be used will have a greater effect on loneliness, assuming that the two have a significant relationship.

Finally, these values are divided by the hypothetical maximum possible value, i.e. the score that would have resulted if the entire municipality consisted of green space, to account for the fact that green space outside the municipality is not included in the dataset and therefore neighbourhoods closer to the municipal border cannot score as high as more central neighbourhoods without this correction due to the lack of green space data for areas outside the municipality. In other words, the sum of the weighted urban green space area is divided by a smaller number for neighbourhoods closer to the border, because a larger part of their buffers consists of area for which no green space data is available. The formulas comprising all this are given after the table, together with a visual explanation.

Table 2 – Weighting for distance decay calculation

Zone number	**Distance interval**	**% of respondents who estimated this distance to their most-used green space (excluding > 10 km and do not know, merged categories)**	**Weight**
1	0-600 m	60,63	0,6063
2	0.6-1 km	15,97	0,1597
3	1-2 km	12,49	0,1249
4	2-5 km	7,87	0,0787
5	5-10 km	3,04	0,0304

Source: own calculations based on Schipperijn et al. (2010a)

$$DDGSI_y = \frac{0.6063 * UGSA_1 + 0.1597 * UGSA_2 + 0.1249 * UGSA_3 + 0.0787 * UGSA_4 + 0.0304 * UGSA_5}{0.6063 * MA_1 + 0.1597 * MA_2 + 0.1249 * MA_3 + 0.0787 * MA_4 + 0.0304 * MA_5}$$

Where $DDGSI_y$ is the distance decay-based green space indicator (i.e. the percentage of theoretical maximum weighted urban green space area) for neighbourhood *y*, $UGSA_x$ is urban green space area within zone *x* and MA_x is municipality area within zone *x*. For the sake of clarity, the areas that comprise $UGSA_1$ to $UGSA_5$ and MA_1 to MA_5 for the southwestern neighbourhood Ooievaarsnest are displayed in Figures 5 and 6.

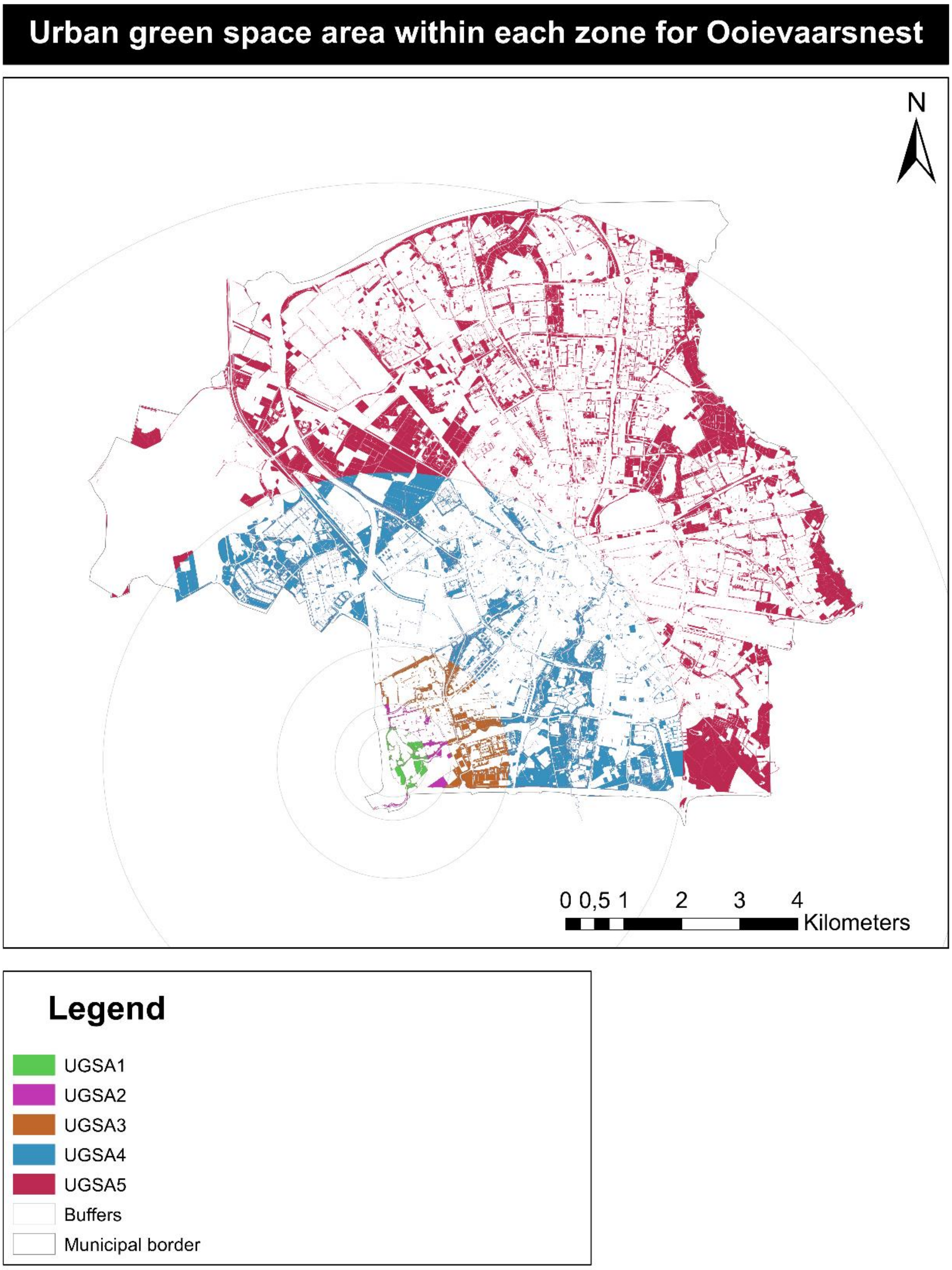

Figure 5 – Urban green space area within each zone for neighbourhood Ooievaarsnest – All green space (source data: Gemeente Eindhoven (2023))

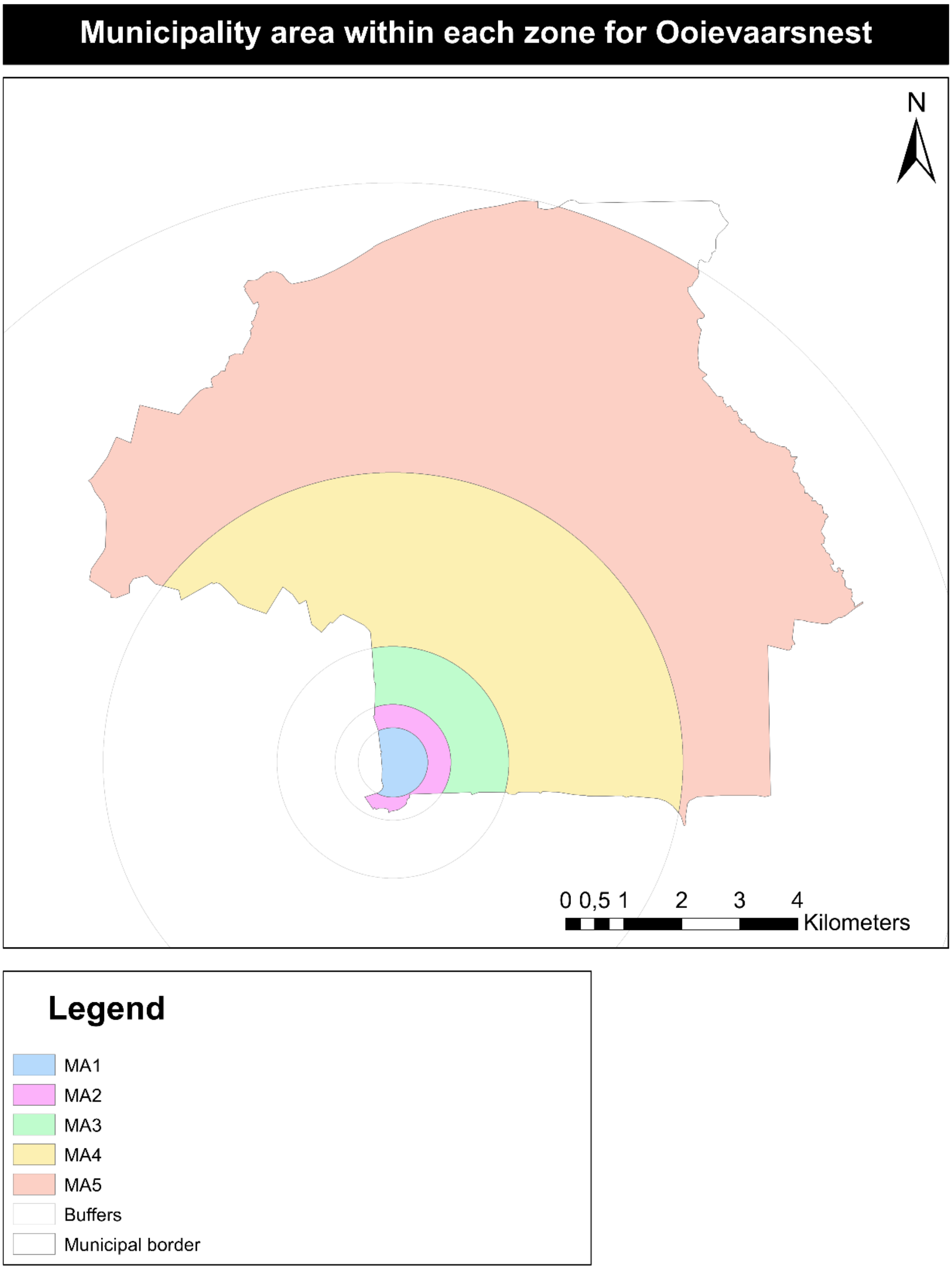

Figure 6 – Municipality area within each zone for neighbourhood Ooievaarsnest

The analyses are repeated including only green spaces of a given size and function. In terms of size, a combination of meta analysis and case studies by Annerstedt van den Bosch et al. (2015) suggested a minimum size of 1 ha for urban green space, so the analysis is repeated including only green spaces meeting this size requirement. Prior to making the size-based selection, green spaces that shared a boundary are merged so that larger mixed-vegetation green spaces were not excluded. For function, groups of sport and play functions (e.g. playgrounds and public football pitches), nature functions (e.g. forest), and other functions are made based on the classifications in the dataset. The analyses are then done using only one of these three categories.

Statistical analysis is then performed in SPSS. Multiple linear regressions are used for each analysis, incorporating the green space indicators as the independent variable and the other built environment and demographic factors as control variables, with social or emotional loneliness as the dependent variable. Moreover, Pearson's correlation is computed for the correlation between the respective green space indicators and social/emotional loneliness, as the results of this can be compared to each other by analysing the difference in correlations between green space access and social/emotional loneliness using the Dunn & Clark's z-test in the cocor model (Diedenhofen & Musch, 2015). This test compares two correlations in which one variable in the former correlation is *not* independent of one variable in the latter correlation. Because the dependent variable in the compared correlations is the same, these are obviously not independent of each other. Therefore, it is a requirement for the test that the correlation between the independent variables is also given; aside from that, the only other required inputs are the sample size and of course the correlations that are being compared (Diedenhofen & Musch, 2015). It is these comparisons that lead to the final conclusions, as this is a statistically more sound methodology than simply comparing correlations based on whether or not they are significant.

4. Results

In this section, the results are presented following the order of the subquestions. This means that the analysis of the effect of all urban green space on social loneliness is discussed first, followed by that on emotional loneliness. Finally, the size and then function effects are shown. Note that any reference to significance refers to two-tailed significance at the 95% confidence level.

4.1 Social loneliness

Table 3 shows the Pearson correlations of both green space indicators with social loneliness. Both correlations are significant, however the correlation strength of the distance decay-based indicator is weak and that of the area in neighbourhood indicator is even negligible.

Table 3 – Pearson correlation between both green space indicators and social loneliness

Indicator		**Percentage experiencing social loneliness**
Distance decay-based indicator	Pearson Correlation	-0,367
	Sig. (2-tailed)	0,001
	N	86
Area in neighbourhood indicator	Pearson Correlation	-0,264
	Sig. (2-tailed)	0,014
	N	86

However, the multiple linear regression paints a different picture. Correcting for other variables, the impact of green space becomes insignificant for both indicators. A significant, positive effect can be observed for percentage aged 65 and over, percentage households with a low income, percentage with a western migration background, and percentage with a nonwestern migration background for both indicators. On the other hand, percentage single-family housing and percentage higher-educated had a significant, negative effect for each indicator, as well as residential density for the area in neighbourhood indicator. The model explained variances (R^2) are high at 0.927 and 0.929 respectively, suggesting that the selected variables together explain social loneliness rates to a high degree.

Table 4 and 5 – Multiple linear regression output: Distance decay-based indicator and social loneliness

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
				R Square Change	F Change	df1	df2	Sig. F Change	
,963	0,927	0,917	1,2754	0,927	95,520	10	75	< 0,001	2,079

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	31,269	6,960		4,493	< 0,001					
Distance decay-based indicator	-0,053	0,200	-0,012	-0,264	0,792	-0,367	-0,031	-0,008	0,469	2,131
Residential density	> -0,001	< 0,001	-0,079	-1,507	0,136	0,295	-0,171	-0,047	0,357	2,802

Percentage single-family housing	-0,021	0,009	-0,126	-2,449	0,017	-0,350	-0,272	-0,076	0,365	2,742
Percentage aged 15-24	-0,019	0,036	-0,024	-0,531	0,597	0,275	-0,061	-0,017	0,478	2,093
Percentage aged 65 and over	0,106	0,023	0,192	4,572	< 0,001	-0,096	0,467	0,142	0,550	1,819
Percentage male	-0,105	0,088	-0,070	-1,190	0,238	0,241	-0,136	-0,037	0,284	3,525
Percentage higher educated	-0,063	0,016	-0,210	-3,955	< 0,001	-0,607	-0,415	-0,123	0,344	2,906
Percentage of households with a low income	0,336	0,056	0,327	6,005	< 0,001	0,760	0,570	0,187	0,327	3,060
Percentage of people with a western migration background	0,240	0,061	0,226	3,943	< 0,001	0,346	0,414	0,123	0,295	3,394
Percentage of people with a nonwestern migration background	0,247	0,018	0,583	13,612	< 0,001	0,839	0,844	0,424	0,529	1,891

Table 6 and 7 – Multiple linear regression output: Area in neighbourhood indicator and social loneliness

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
				R Square Change	F Change	df1	df2	Sig. F Change	
,964	0,929	0,920	1,2567	0,929	98,602	10	75	< 0,001	2,083

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	31,121	4,775		6,518	< 0,001					
Area in neighbourhood indicator	-0,025	0,017	-0,062	-1,522	0,132	-0,264	-0,173	-0,047	0,574	1,743
Residential density	> -0,001	< 0,001	-0,104	-2,100	0,039	0,295	-0,236	-0,064	0,386	2,594
Percentage single-family housing	-0,025	0,009	-0,149	-2,814	0,006	-0,350	-0,309	-0,086	0,335	2,989
Percentage aged 15-24	-0,020	0,035	-0,025	-0,565	0,574	0,275	-0,065	-0,017	0,478	2,094
Percentage aged 65 and over	0,111	0,023	0,203	4,873	< 0,001	-0,096	0,490	0,150	0,545	1,836

Percentage male	-0,102	0,087	-0,068	-1,177	0,243	0,241	-0,135	-0,036	0,284	3,517
Percentage higher educated	-0,062	0,015	-0,207	-4,011	< 0,001	-0,607	-0,420	-0,123	0,353	2,832
Percentage of households with a low income	0,329	0,055	0,321	5,965	< 0,001	0,760	0,567	0,183	0,326	3,065
Percentage of people with a western migration background	0,219	0,062	0,206	3,554	0,001	0,346	0,380	0,109	0,280	3,574
Percentage of people with a nonwestern migration background	0,249	0,018	0,588	13,938	< 0,001	0,839	0,849	0,428	0,529	1,889

4.2 Emotional loneliness

Table 8 shows the Pearson correlations of both green space indicators with emotional loneliness. Both correlations are significant and somewhat stronger than for social loneliness: moderate for the distance decay-based indicator and weak for the area in neighbourhood indicator.

Table 8 – Pearson correlation between both green space indicators and emotional loneliness

Indicator		**Percentage experiencing emotional loneliness**
Distance decay-based indicator	Pearson Correlation	-0,548
	Sig. (2-tailed)	< 0,001
	N	86
Area in neighbourhood indicator	Pearson Correlation	-0,424
	Sig. (2-tailed)	< 0,001
	N	86

The regression models also yield different results, as the effect of the area in neighbourhood indicator is significant and negative. The other variables also change in terms of significance. Unlike for social loneliness, percentage aged 65 and over, percentage higher educated and residential density have no significant impact, but percentage male does. This leaves percentage of households with a low income, percentage male, percentage with a western migration background and percentage with a nonwestern migration background as the control variables with a significant, positive effect and percentage single-family housing with a significant, negative effect. The explained variances are very similar to those for social loneliness at 0.923 and 0.930 respectively.

Table 9 and 10 – Multiple linear regression output: Distance decay-based indicator and emotional loneliness

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
				R Square Change	F Change	df1	df2	Sig. F Change	
0,961	0,923	0,912	1,8673	0,923	89,622	10	75	< 0,001	2,273

Variable	**Unstandardized Coefficients**	**Standardized Coefficients**	**t**	**Sig.**	**Correlations**	**Collinearity Statistics**

	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	45,264	10,189		4,442	< 0,001					
Area in neighbourhood indicator	-0,293	0,292	-0,047	-1,003	0,319	-0,548	-0,115	-0,032	0,469	2,131
Residential density	> -0,001	< 0,001	-0,031	-0,571	0,569	0,531	-0,066	-0,018	0,357	2,802
Percentage single-family housing	-0,081	0,012	-0,344	-6,480	< 0,001	-0,636	-0,599	-0,208	0,365	2,742
Percentage aged 15-24	0,072	0,053	0,063	1,365	0,176	0,500	0,156	0,044	0,478	2,093
Percentage aged 65 and over	-0,007	0,034	-0,010	-0,220	0,826	-0,337	-0,025	-0,007	0,550	1,819
Percentage male	-0,259	0,129	-0,121	-2,013	0,048	0,503	-0,226	-0,065	0,284	3,525
Percentage higher educated	-0,029	0,023	-0,069	-1,266	0,209	-0,343	-0,145	-0,041	0,344	2,906
Percentage of households with a low income	0,474	0,082	0,325	5,795	< 0,001	0,690	0,556	0,186	0,327	3,060
Percentage of people with a western migration background	0,365	0,089	0,242	4,100	< 0,001	0,599	0,428	0,132	0,295	3,394
Percentage of people with a nonwestern migration background	0,246	0,027	0,409	9,263	< 0,001	0,800	0,730	0,297	0,529	1,891

Table 11 and 12 – Multiple linear regression output: Area in neighbourhood indicator and emotional loneliness

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
				R Square Change	F Change	df1	df2	Sig. F Change	
0,964	0,930	0,921	1,7774	0,930	99,698	10	75	< 0,001	2,322

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	41,129	6,753		6,091	< 0,001					
Area in neighbourhood indicator	-0,070	0,024	-0,120	-2,982	0,004	-0,424	-0,326	-0,091	0,574	1,743
Residential density	> -0,001	< 0,001	-0,067	-1,354	0,180	0,531	-0,154	-0,041	0,386	2,594
Percentage single-family housing	-0,091	0,012	-0,389	-7,361	< 0,001	-0,636	-0,648	-0,225	0,335	2,989
Percentage aged 15-24	0,069	0,050	0,061	1,383	0,171	0,500	0,158	0,042	0,478	2,094
Percentage aged 65 and over	0,006	0,032	0,007	0,178	0,860	-0,337	0,021	0,005	0,545	1,836

Percentage male	-0,248	0,122	-0,116	-2,029	0,046	0,503	-0,228	-0,062	0,284	3,517
Percentage higher educated	-0,029	0,022	-0,068	-1,332	0,187	-0,343	-0,152	-0,041	0,353	2,832
Percentage of households with a low income	0,453	0,078	0,311	5,811	< 0,001	0,690	0,557	0,177	0,326	3,065
Percentage of people with a western migration background	0,311	0,087	0,206	3,572	0,001	0,599	0,381	0,109	0,280	3,574
Percentage of people with a nonwestern migration background	0,253	0,025	0,420	10,006	< 0,001	0,800	0,756	0,306	0,529	1,889

4.3 Size and function

4.3.1 Social loneliness

Table 13 shows the Pearson correlations of both green space indicators for all subsets of green space with social loneliness. As the secondary research question refers to the effect of size and function, the outcome for all green space is shown for comparison. For both indicators, large green space and green space with nature function show a significant, but weak correlation with social loneliness, whereas green space with sport/play functions and with other function are not significantly correlated with social loneliness.

Table 13 – Pearson correlation between both green space indicators and social loneliness (all subsets)

Indicator		**Percentage experiencing social loneliness**				
		All green space	Large green space	Green space with sport/play functions	Green space with nature function	Green space with other function
Distance decay-based indicator	Pearson Correlation	-0,367	-0,428	-0,139	-0,439	0,001
	Sig. (2-tailed)	0,001	< 0,001	0,201	< 0,001	0,996
	N	86	86	86	86	86
Area in neighbourhood indicator	Pearson Correlation	-0,264	-0,406	0,068	-0,438	-0,032
	Sig. (2-tailed)	0,014	< 0,001	0,531	< 0,001	0,767
	N	86	86	86	86	86

Tables 14 and 15 show the model summaries as well as the beta coefficients and significance of the green space indicators for all subsets of green space. For the sake of legibility of this thesis, the full coefficient tables are in the appendix, as the significant control variables are the same for each subset as they are for all green space. The key result here is that, for both indicators and each subset of green space, the effect of access to urban green space on social loneliness becomes insignificant when other variables are controlled for. The model explained variance remains consistently high (0.927 to 0.929) for all ten regressions.

Table 14 – Multiple linear regression output: Model summaries for all regressions with social loneliness as the dependent variable

Indicator	**Urban green space subset**	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
						R Square Change	F Change	df1	df2	Sig. F Change	
Distance decay-based indicator	All green space	0,963	0,927	0,917	1,275	0,927	95,520	10	75	< 0,001	2,079
	Large green space	0,963	0,927	0,918	1,275	0,927	95,637	10	75	< 0,001	2,100
	Green space with sport or play functions	0,963	0,927	0,918	1,273	0,927	95,900	10	75	< 0,001	2,076
	Green space with nature function	0,963	0,927	0,918	1,275	0,927	95,544	10	75	< 0,001	2,099
	Green space with other function	0,963	0,928	0,918	1,271	0,928	96,168	10	75	< 0,001	2,061
Area in neighbourhood indicator	All green space	0,964	0,929	0,920	1,257	0,929	98,602	10	75	< 0,001	2,083
	Large green space	0,964	0,929	0,920	1,258	0,929	98,392	10	75	< 0,001	2,053
	Green space with sport or play functions	0,963	0,928	0,918	1,272	0,928	96,122	10	75	< 0,001	2,092
	Green space with nature function	0,963	0,928	0,919	1,267	0,928	96,853	10	75	< 0,001	2,074
	Green space with other function	0,963	0,928	0,919	1,266	0,928	97,065	10	75	< 0,001	2,105

Table 15 – Multiple linear regression output: Beta coefficients and significance of green space indicators for all regressions with social loneliness as the dependent variable

Urban green space subset	**Area in neighbourhood indicator**		**Distance decay-based indicator**	
	Beta coefficient	Significance	Beta coefficient	Significance
All green space	-0,025	0,132	-0,053	0,792
Large green space	-0,028	0,406	0,077	0,694
Green space with sport or play functions	-0,092	0,478	-0,732	0,558
Green space with nature function	-0,031	0,311	0,073	0,296
Green space with other function	-0,024	0,278	-0,264	0,464

4.3.2 Emotional loneliness

Table 16 shows the Pearson correlations of both green space indicators for all subsets of green space with emotional loneliness. As with table 13, the correlations for all green space are given for comparison. For both indicators, large green space and green space with nature function show a significant, moderate correlation with emotional loneliness, in contrast to the weak correlations that these had with social loneliness. Moreover, the distance decay-based indicator of green space with sport/play functions has a significant, but negligible correlation with emotional loneliness. The area in neighbourhood indicator for this subset, as well as both indicators for green space with other function, function are not significantly correlated with emotional loneliness.

Table 16 – Pearson correlation between both green space indicators and emotional loneliness (all subsets)

Indicator		**Percentage experiencing emotional loneliness**				
		All green space	Large green space	Green space with sport/play functions	Green space with nature function	Green space with other function
Distance decay-based indicator	Pearson Correlation	-0,548	-0,527	-0,219	-0,545	-0,187
	Sig. (2-tailed)	< 0,001	< 0,001	0,043	< 0,001	0,084
	N	86	86	86	86	86
Area in neighbourhood indicator	Pearson Correlation	-0,424	-0,552	-0,002	-0,546	-0,158
	Sig. (2-tailed)	< 0,001	< 0,001	0,986	< 0,001	0,147
	N	86	86	86	86	86

Tables 17 and 18 show the model summaries as well as the beta coefficients and significance of the green space indicators for all subsets of green space. Again, the full coefficient tables are in the appendix. Perhaps surprisingly, it is other green space, the sole green space subset without a significant correlation with emotional loneliness when other variables are not controlled for, that is found to have a significant, negative impact in this regression, independent of which indicator is used. The remaining three subsets of green space are found to have no significant impact. Much like for social loneliness, the model explained variance is consistently high (0.922 to 0.930) for all ten regressions. As for the control variables, the only difference with all green space is that the percentage of male inhabitants is not significant at the 95% confidence level for all subsets of green space. This is perhaps not surprising, given that the probability was barely below 0.05 (0.046 and 0.048 for the area in neighbourhood indicator and distance decay-based indicators respectively) for all green space. Of the subsets, the percentage of male inhabitants was only found to have a significant impact on emotional loneliness when other green space was also an independent variable, this was true for both methods.

Table 17 – Multiple linear regression output: Model summaries for all regressions with emotional loneliness as the dependent variable

Indicator	**Urban green space subset**	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
						R Square Change	F Change	df1	df2	Sig. F Change	
Distance decay-based indicator	All green space	0,961	0,923	0,912	1,867	0,923	89,622	10	75	< 0,001	2,273
	Large green space	0,960	0,922	0,911	1,879	0,922	88,441	10	75	< 0,001	2,295
	Green space with sport or	0,961	0,923	0,912	1,868	0,923	89,575	10	75	< 0,001	2,268

	play functions										
	Green space with nature function	0,960	0,922	0,912	1,876	0,922	88,713	10	75	< 0,001	2,300
	Green space with other function	0,963	0,927	0,918	1,813	0,927	95,581	10	75	< 0,001	2,255
Area in neighbourhood indicator	All green space	0,964	0,930	0,921	1,777	0,930	99,698	10	75	< 0,001	2,322
	Large green space	0,961	0,923	0,913	1,863	0,923	90,034	10	75	< 0,001	2,264
	Green space with sport or play functions	0,960	0,922	0,911	1,878	0,922	88,475	10	75	< 0,001	2,288
	Green space with nature function	0,962	0,925	0,915	1,839	0,925	92,585	10	75	< 0,001	2,292
	Green space with other function	0,963	0,927	0,918	1,812	0,927	95,585	10	75	< 0,001	2,358

Table 18 – Multiple linear regression output: Beta coefficients and significance of green space indicators for all regressions with emotional loneliness as the dependent variable

Urban green space subset	**Area in neighbourhood indicator**		**Distance decay-based indicator**	
	Beta coefficient	Significance	Beta coefficient	Significance
All green space	-0,070	0,040	-0,293	0,319
Large green space	-0,032	0,253	0,082	0,775
Green space with sport or play functions	-0,063	0,742	-1,797	0,328
Green space with nature function	-0,080	0,072	0,198	0,588
Green space with other function	-0,074	0,020	-1,215	0,020

4.3.3 Comparison

Table 19 shows the correlations between the green space indicators for each subset. As mentioned previously, because the dependent variables (i.e. social or emotional loneliness) are the same in each comparison and therefore not independent, the correlations between the independent variables are a requirement to perform the Dunn & Clark's z-test.

Table 19 – Input for Dunn & Clark's z-test: Correlations between independent variables

Green space subset (independent variable 1)		**All green space (independent variable 2)**	
		Distance decay-based indicator	Area in neighbourhood indicator
Large green space	Pearson Correlation	0,898	0,702
	Sig. (2-tailed)	< 0,001	< 0,001
	N	86	86
Green space with sport/play functions	Pearson Correlation	0,363	0,378

	Sig. (2-tailed)	0,001	< 0,001
	N	86	86
Green space with nature function	Pearson Correlation	0,854	0,652
	Sig. (2-tailed)	< 0,001	< 0,001
	N	86	86
Green space with other function	Pearson Correlation	0,591	0,819
	Sig. (2-tailed)	< 0,001	< 0,001
	N	86	86

Table 20 then shows the outcome of the Dunn & Clark's z-test for all sixteen comparisons. For social loneliness, the correlation with large green space does not significantly differ from that with all green space. The correlations with green space with sport/play functions and with nature function only differs significantly from the one with all green space for the area in neighbourhood indicator (being lower and higher respectively), whereas that with green space with other function is not significantly different from the correlation with all green space for both indicators. For emotional loneliness, the correlations with large green space and with green space with nature function does not differ significantly from that with all green space for either indicator, whereas the opposite is true for the correlation with green space with sport/play functions and with green space with other function. Both subsets of green space had a significantly smaller correlation with emotional loneliness than all green space. Of course, in the linear regression, the opposite proved to be true for the latter. In any case, this points towards a significantly different impact of function, but not size.

Table 20 – Outcome of Dunn & Clark's z-test for all 16 comparisons

Green space subset (independent variable 1)		**All green space (independent variable 2)**			
	Dependent variable	Social loneliness		Emotional loneliness	
		Distance decay-based indicator	Area in neighbourhood indicator	Distance decay-based indicator	Area in neighbourhood indicator
Large green space	Dunn & Clark's z	1,3507	1,8066	-0,5079	1,7864
	Significance	0,1768	0,0708	0,6115	0,0740
	N	86	86	86	86
Green space with sport/play functions	Dunn & Clark's z	-1,9437	-2,7817	-3,0434	-3,6792
	Significance	0,0519	0,0054	0,0023	0,0002
	N	86	86	86	86
Green space with nature function	Dunn & Clark's z	1,3396	2,0732	-0,0614	1,5672
	Significance	0,1804	0,0382	0,9511	0,1150
	N	86	86	86	86
Green space with other function	Dunn & Clark's z	-3,8882	-3,5975	-4,1301	-4,3244

	Significance	0,0001	0,0003	< 0,0001	< 0,0001
	N	86	86	86	86

5. Discussion and conclusion

Loneliness is a health issue of which the importance is increasingly recognised but of which the causes are not yet fully understood. This thesis attempted to assess whether the impact of green space access on loneliness, that is found in some previous studies differs between social and emotional loneliness, drawing on a proposal by Astell-Burt et al. (2022). In this, the effects of size and function of said green space on loneliness were also studied for the first time, drawing on the findings by Wood et al. (2017) that the impacts of green space on mental health depends on these. Moreover, this thesis represents the first time that a distance decay function has been used in a green space study that includes the area of green space. The methodology was further substantiated by using a second methodology to assess the access to urban green space and the incorporation of a wide array of built environment and sociodemographic factors.

5.1 Discussion

The data presented in the previous section suggests that there is no link between social loneliness and access to urban green space, and at most a limited impact of access to urban green space on emotional loneliness. Hence, the results suggest little to no impact of access to urban green space on loneliness overall. This is consistent with the findings of Bergefurt et al. (2019), and partially with those of Astell-Burt et al. (2019), who found different outcomes dependent on methodology, just like how the area in neighbourhood indicator and the distance decay-based indicator yielded different results in terms of the effect of access to all green space on emotional loneliness in this paper. However, this is clearly at odds with the findings of Maas et al. (2009) and Van den Berg et al. (2019), who both found a clear relation between green space (in terms of access for the former and use for the latter paper) and loneliness. This may be related to the control variables applied, as neither paper used any built environment factors other than those related to green space. However, in this thesis, percentage of single-family housing was significantly correlated with both social and emotional loneliness in all regressions. Moving on to size and function, the finding that – in comparison to all green spaces – large green spaces do not have a significantly different correlation with both social and emotional loneliness, whereas green spaces with a sport/play function have, if anything, a weaker correlation, is not in line with the findings of Wood et al. (2017), who concluded that it is these types of green spaces that impact mental health levels most strongly. Finally, it should be noted that Domènech-Abella et al. (2021) found that emotional loneliness mediated the effect of physical environment on mental health more strongly, so to an extent the limited discrepancy between social and emotional loneliness found here corroborates that.

Moving on to the other built environment control variables, residential density was not correlated with emotional loneliness and only correlated (negatively) with social loneliness when the area in neighbourhood indicator was used as an independent variable. Hence, just like urban green space, it would appear that residential density has little to no impact on loneliness. This matches the findings of Scharf & De Jong Gierveld (2008), Van den Berg et al. (2016) and Kemperman et al. (2019), but contradicts those of Hammoud et al. (2021), Lai et al. (2021) and Lam & Wang (2022). Given that the first three studies also concerned Dutch cases whereas the latter three did not, the absence of a link between residential density and loneliness may be a Dutch rather than a general phenomenon. On the other hand, a higher percentage of single-family housing was linked to lower levels of both social and emotional loneliness. This corroborates the findings of Lai et al. (2021) and to a lesser extent Van den Berg et al. (2016), who only found such a link for adults aged 64 and lower, whereas it contradicts those of Wee et al. (2019) and Lam & Wang (2022).

Regarding sociodemographic control variables, the percentage of residents aged 15-24 was not correlated with either form of loneliness, whereas the percentage aged 65 and over was positively correlated with social loneliness and not correlated with emotional loneliness. Previous research was mixed in its findings on age and loneliness: Drennan et al. (2008) found that older adults were more likely to experience social loneliness, while Labrague et al. (2021) concluded that the COVID-19 pandemic had caused emotional loneliness especially in younger college students. On the other hand, Green et al. (2001) found that age was not related to either social or emotional loneliness.

In terms of gender effects, it was already discussed in the literature review that findings depend on which age group is studied. Among students, typically no link is found, whereas among the elderly, most studies find that men are more prone to social loneliness while the evidence is mixed as to whether women are more emotionally lonely or not. This thesis is somewhat at odds with previous papers: while no gender effect was observed for social loneliness, it was found that neighbourhoods with a higher percentage of *men* were more emotionally lonely. Although this effect was barely significant when all green space was the independent variable and not at all for some of the subsets of green space, this is still surprising, because only Junttila & Vauras (2009) found such a gender divide. This begs the question whether gender effects are different for college students and the elderly, who were the age groups studied in all papers *except* for that by Junttila & Vauras (2009) discussed in the literature review that included gender in their analysis, than for adults in general.

Regarding socio-economic demographics, a higher percentage of higher-educated residents was found to have a negative impact on social but not emotional loneliness levels, whereas a higher percentage of low-income households was positively related to both types of loneliness. Previous studies on loneliness typically included only income as a socio-economic variable (if they included any) and found mixed results, although the only paper to focus on adults as a group rather than only the elderly did find that less financially satisfied people were more lonely (Stack, 1998). Education levels have mainly been studied in terms of their relation to green space access and overall health, with lower levels of education being associated with lower levels of both these factors.

Finally, higher percentages of both residents with a western and residents with a non-western migration background were found to be positively correlated with both types of loneliness. This is in line with the findings of Stack (1998) and Diehl et al. (2018).

Overall, the literature is divided on the impact of most sociodemographic factors on social and emotional loneliness and this thesis reflects that, finding significant effects for some but not all of these factors.

5.2 Conclusion

While access to green space was found to have a significant correlation with both social and loneliness, a significant effect on social loneliness was no longer found when other built environment and sociodemographic factors were controlled for. Hence, the results indicate that access to urban green space of any size or function has no significant impact on levels of social loneliness. Hence, the null hypothesis of the first subquestion must be accepted, thereby rejecting the actual hypothesis, which posited that such an effect would exist. The results are inconclusive regarding the effect of access to urban green space on emotional loneliness, as the outcome is different depending on whether the distance decay-based indicator or the area in neighbourhood indicator is used. Hence, both the null hypothesis and the actual hypothesis can be neither rejected nor accepted. Finally, large green space does not appear to have a different effect on either social or emotional loneliness than all green space, whereas the effect of green space with a sport or play function seems to be smaller than that of all green space. This means that the null hypotheses for both are respectively accepted and rejected, whereas the actual hypotheses are both rejected because it was expected that larger green space and green space with a sport or play function would have a greater effect on social and emotional loneliness. On the other hand, greater access to other green space (i.e. with a function that is neither sport or play nor nature) was linked to lower levels of emotional loneliness.

On the other hand, the results did confirm that the predictors of social and emotional loneliness are partially the same and partially different. A lower percentage of single-family housing, higher percentage of lower-income residents, higher percentage of residents with a western migration background and a higher percentage of residents with a nonwestern migration background were linked to higher levels of both social and emotional loneliness. For higher prevalence of social loneliness, a lower percentage of higher-educated residents was also found to have a significant impact, whereas a higher percentage of male residents was related to higher levels of emotional loneliness.

The fact that it is (mostly) other built environment and sociodemographic factors that explain social and emotional loneliness levels in a neighbourhood, in spite of the correlation of the latter which access to green space, suggests that access to urban green space may be a symptom of these other factors. That would be consistent with the findings of previous papers that suggest whiter, richer and more highly-educated neighbourhoods enjoy greater levels of access to green space (Schipperijn et al., 2010b; Wolch et al., 2014). This would impact how the findings of this thesis should be used in practice, however, this will be discussed after the research limitations have been assessed.

Overall, the final conclusion is that the accessibility of urban green space in the Dutch context has no impact on social loneliness and only a limited impact on emotional loneliness, because both types of loneliness are explained largely by other factors.

5.2.1 Research limitations

There are two types of research limitations relevant here: limitations that apply to any research of this kind, and limitations specific to this thesis. Looking at the former, some assumptions in terms of ontology, epistemology and truth are inherent to any form of research. As Næss (2004) notes, spatial planning relies on an epistemological assumption in particular: the notion that it is possible to predict social phenomena. The argument against this notion is made by some critical realists, who argue that what they see as the contextual, open-system nature of such phenomena inhibits doing so. If a prediction is impossible, then there is no epistemological foundation to intervene in society and/or market, because the effects of such an intervention could then not be predicted, thereby invalidating spatial planning as it currently exists. Therefore, this epistemological assumption is inherently necessary for this research, and thereby is made here so that any value can be placed on the conclusions presented here.

However, it is necessary to address this ontological view of social phenomena. Not only does it influence many more recent planning approaches, such as collaborative planning (Næss, 2004), but it is also hard to deny that culture, place and time influence these phenomena. In the context of this research, for example, it has been argued that the social function of green space differs between different cultures, and therefore changes over time as these cultures evolve (Thompson, 2002). The epistemological assumption must therefore hold in the face of this ontology. Næss (2004) argues that this is possible, but it does pose limitations. Generalisation becomes reliant on the representativeness of a case, in terms of both people and location, and the extent to which these can be assumed to have impacted findings. These issues are corroborated by case studies, an example being the aforementioned finding of Domenèch-Abella et al. (2020) that Finnish people are significantly less lonely than those in Poland and Spain, which means that findings on loneliness in the former country are likely not to be representative for the latter. Moreover, causality must be understood as the *possibility* that one phenomenon leads to another. In other words, even if there is a causal relationship between access to green space and loneliness, a lonely person with poor access to green space may not be lonely for that reason. For this reason, Næss (2004) claims that a single statistical study cannot truly prove causation. Therefore, these assumptions mean that the possibility for generalisation of all correlations that are found – and not found – in this thesis is limited and that the findings can only suggest causation. This is especially the case because previous research has produced mixed results on the effect of both green space and the other variables included in here.

The extent to which true statements can be found in this research mirrors this. Of course, objective truth necessitates the ontological assumption of the existence of an objective reality, but this is not denied by critical realists and moreover, the distance to green space is inherently objective and the existence of loneliness is hardly open to doubt. However, the extent to which a statement can be true is also bounded by the limits of generalisation and proving causality discussed above. Yet, such issues are inherent to research in spatial planning, and therefore must be accepted here as limitations.

As for limitations pertaining specifically to this thesis, five main aspects can be identified. Firstly, the distance decay analysis was based on Euclidean distance rather than network distance. Of course, it should be noted that the latter would have been difficult, if not impossible, to implement here, as the neighbourhood centroids are not necessarily connected to the road network and, more importantly, the focus on areas means the green spaces were represented by polygons, which makes it unclear which part of the green space would have been within, for example, 1 kilometre from the centroid. This issue could theoretically have been solved by adding access points to the polygons, but many green spaces do not have specific access points and can be accessed at any point of their boundary. However, it remains the case that walking routes will not be equally direct in each part of the city, and Euclidean distance cannot account for this.

Secondly, as mentioned in the methodology, the lack of green space data for areas just outside of the municipality border means that the distance decay-based indicator paints a less complete picture for neighbourhoods close to the border. This would especially be the case if there are areas with a high percentage of green space just outside the municipal border, which is not something that can be accurately verified. However, this potential bias was counteracted as much as possible by adding the division by the municipality area per zone to the indicator. Moreover, the use of a second method in the area in neighbourhood indicator (which does not have such a bias) provides a method to compare to, and the results showed great similarity between both methodologies (the key exception being the impact of all green space on emotional loneliness). Hence, the potential for such a bias was minimised.

Thirdly, it remains the case that the used data on social and emotional loneliness, as well as that on sociodemographic factors, is aggregated by neighbourhood and not individual. The rationale for this was explained in detail in the methodology, but it remains the case that it cannot be proven that, in an area that has e.g. a high percentage of low-income households and also a high percentage of people who are socially lonely, it is disproportionately the people that are a part of low-income household who are socially lonely. This links back to the previous point that causation cannot be truly proven by this research alone.

Fourthly, it is not fully certain that the weighting used for the distance decay-based indicator is appropriate or, indeed, correct. While Odense, the case city that was the object of the research by Schipperijn et al. (2010a) upon which the weights were based, was found to be similar to Eindhoven, similarity does not mean transferability is certain, only that it is more likely. In addition, it is of course possible that there are shortcomings in the work of Schipperijn et al. (2010a) that makes the data from which the weights are derived inaccurate even from Odense, but that is an inherent possibility when an existing empirical study is drawn on. In any case, it remains more appropriate to base the weights and distances on empirics rather than arbitrary values, as has often been the case in green space research.

Finally, a point that the author was not aware of until a comment at the Graduate Research Day, very late in the research process, is that autism rates in children in Eindhoven are three to five times as high in Eindhoven as in Dutch cities of similar size (Roelfsema et al., 2012), which suggests that unusually high autism levels in the population of Eindhoven as a whole are quite likely. This may pose an issue for the ability to generalise from this case, as both children (Bauminger et al., 2003) and adults (Ee et al., 2019) are more likely to be lonely if they are on the autism spectrum. However, it should be noted that, even in Eindhoven, only 2.29% of children have autism (Roelfsema et al., 2012), so if that percentage is similar in the overall population, the extent to which this will influence findings is likely to be limited given that the prevalence of social and emotional loneliness in Eindhoven are 33.2% and 34.1% respectively (RIVM, 2023).

5.2.2 Impacts on spatial planning in practice

In spite of the variety of research concerning the effects of green space (and other built environment factors) on loneliness (and other health factors), there is a paucity of works on the translation of this knowledge to the realm of spatial planning. When studies have approached this area of research through the lens of spatial planning, they have often called for fairly simple measures, such as Coppel & Wüstemann (2017)'s proposal to increase the green space in neighbourhoods where their supply is lacking. Moreover, as noted by Wolch et al. (2014) and Cole et al. (2017), such a measure can also have the undesirable effect of pricing existing residents out of the neighbourhood through gentrification. Wolch et al. (2014) stipulate the need to balance neighbourhood greening and the prevention of gentrification, but how this should translate to planning remains unclear. In addition to this, there is very little literature on built environment interventions to address loneliness (Lyu & Forsyth, 2022) and what little studies there are focus on small-scale interventions that are more about engagement with rather than provision of green space, resulting in limited evidence of the effectiveness of such interventions (Hsueh et al., 2022). Despite this, there are still some works that do make an attempt to integrate spatial planning with health objectives in the context of green spaces that merit discussing here.

Corcoran & Marshall (2017) discuss ways in which urban design can be mobilised to reduce loneliness. They note that social loneliness appears to be more strongly related to urban design than emotional loneliness. It should be noted that this is not reflected by the findings of this thesis, as access to urban green space was not found to impact social loneliness at all. They also state that sectoral policy and technical rationales in urban design inhibits its potential to address issues such as loneliness. To address this, they suggest widening the focus from the built environment to the living environment and from economic growth to welfare, as well as integrated decision making. However, it remains unclear what such an approach would look like in practice. Moreover, their notion that urban design is more strongly related to social than emotional loneliness is not corroborated by the findings in this paper.

Douglas et al. (2017) discuss the effects of green space on health and well-being through the lens of planning. In response to this, they propose a life-course approach, in which the different needs and desires of different age groups that green space should cater to are integrated. They suggest that all green space users, especially those from groups to whom green space provision caters the least well at present (lower socio-economic status, minorities), should be included in the planning of these green spaces. However, they also state that green space provision should be maximised, when evidence suggests that this would lead to gentrification (Wolch et al., 2014; Cole et al., 2017). In a separate article, the same authors also propose an affordances-based framework, in which the dimensions of space, time, scale, objects within and actions undertaken within the green space, and the users interact to produce the perceived quality of a green space (Lennon et al., 2017). By using this affordances framework in practice (based on the experiences of users), lessons on the quality of a green space can be drawn and these can be used to enhance green spaces in a qualitative rather than only a quantitative way.

One thing that is missing from these papers is a connection to overarching planning theory. However, in my view, the proposals made in the papers discussed above can be linked to communicative planning theory. I cannot incorporate the wealth of thinking present in the debates surrounding communicative planning, and will therefore focus here on its application in the context of this thesis. According to this theory, spatial planning becomes, in the words of Healey (1996, p. 230), "a process of facilitating community collaboration in the construction of strategic discourse, in strategic consensus-building". In practice, as De Roo (2003) states, such an approach entails not only a focus on process and participation, but also the incorporation of multiple goals in the process. This wider, more integrated inclusion of multiple goals in the planning process is not only consistent with Corcoran & Marshall (2017)'s proposals, but has also already been used in practice in Norway. Here, a communicative turn in the planning process have led health considerations to be included in all policies, including those of spatial planning (Synnevåg et al., 2018). Moreover, the notion of participation resonates strongly with the ideas of Douglas et al. (2017).

In addition to this, a better inclusion of green space users in the planning process can also garner a better response to a number of other issues. Firstly, lack of green space provision is not only about differences in quantity, but also due to the fact that many individuals within certain demographic groups, such as minorities, feel that existing green spaces do not meet their needs and desires (Kabisch & Haase, 2014). Secondly, different types of green spaces are experienced as more or less valuable for dealing with health issues such as loneliness (Jing et al., 2019). Such qualitative issues can perhaps be dealt with better in a more communicative approach. Quantitative approaches such as the one in this thesis, then, can be used to assess where such an approach is necessary or desirable in the first place. In this case, of course, the findings suggest that improving green space provision for the sake of decreasing loneliness levels is not necessary, as it would likely be ineffective.

Of course, these postulations require far greater empirical evidence, the absence of which can be related back to the lack of literature on interventions related to this topic. Moreover, it is important that various critiques of communicative planning theory have identified limits and shortcomings of its application in practice (e.g. McGuirk, 2001). Indeed, some of these issues were encountered in practice in the Norwegian example mentioned previously (Synnevåg et al., 2018). Yet I do feel it is necessary to better integrate knowledge on health and well-being into spatial planning, and for that this section is relevant to provide contextualisation.

As for how this relates to this thesis specifically, the finding that social and emotional loneliness are not or hardly impacted by access to urban green space reminds us that an increased provision of urban green space may not always lead to physical and mental health targets being met. In fact, given that making a neighbourhood greener can lead to gentrification (Wolch et al., 2014; Cole et al., 2017) and that gentrification-induced displacement is linked to negative health effects among the people that are displaced (Cole et al., 2017), it may be that making a neighbourhood greener will actually cause some people to become *more* lonely if no steps to prevent gentrification are taken. This shows how a focus on a singular goal can actually have an unintended, negative effect, which is exactly the kind of issue that collaborative planning is a response to. If green spaces are planned more collaboratively, the goals of the residents themselves may be better included in the process. If that means the new or improved green spaces suit the needs of the residents better and usage levels are increased, this may lead to increased health benefits. And even if health benefits are not produced, the fulfilment of other goals of the residents would still mean the provision of more green space had some benefits.

However, the main lesson of this thesis for spatial planning is that increasing green space provision is not a strategy that is likely to improve loneliness in the residents. It may lead to a lower level of social or emotional loneliness at the neighbourhood level if it causes lower-income households to be displaced, given that this thesis found that a lower percentage of low-income households is linked to lower levels of social and emotional loneliness, but such a reduction would then be attained by demographic change rather than addressing people's mental health issues. That, of course, is not an actual solution.

5.2.3 Future research possibilities

In additions to the lessons for practice identified above, this thesis leads to some pointers for future research. Firstly, the findings of this thesis underline the fact that the evidence on which factors influence social and emotional loneliness is mixed. There is, therefore, clearly scope for a paper that assesses to what extent the choice of methodology and assessed variables impacts findings in this regard, as this is not an explicit focus of existing meta-analyses either. Secondly, there remains a lack of understanding *why* the predictors of social and emotional loneliness differ in the way they do; this is especially the case for built environment factors like access to urban green space, as these studies have generally relied on quantitative methods, much like this thesis. Finally, it may be studied which types of other green space are the ones that impact emotional loneliness in a significant way, given that this catch-all category was rather broadly defined in this thesis.

As for research topics that pertain more strongly to spatial planning, there is – as noted by Lennon et al. (2017) – still a significant lack of research on how to incorporate physical and mental health targets into spatial planning. While the findings here suggest that such research does not need to focus on social and emotional loneliness, there is of course an array of health factors that *are* highly relevant. If planning is to be more collaborative, the integration of goals from outside the realm of spatial planning into the planning process is of great importance. The fact that there are so few studies on the interface between health and spatial planning suggests that there is still much work to be done on how to do so, and this complicates the use of the findings of papers such as this thesis in spatial planning. Hence, this can be seen as the most important direction of future research.

6. Reflection

To wrap up this thesis, I would like to dedicate a few words to reflecting on the research process. Overall, I am not satisfied by my own time management in this thesis, also because the combination of this and my erratic communication cannot have been ideal for my supervisor, Samira Ramezani. In spite of these issues, I do think the process was a success in other aspects. I completed this thesis in full without having to seek additional help outside of the allotted feedback moments, I think I successfully dealt with all feedback received, and ultimately I feel that the final product is quite convincing.

In hindsight, I wish I had realised that the high prevalence of autism in Eindhoven might have been relevant, although there is no neighbourhood-level data on the matter so it could not have been included in the regression analysis regardless. Aside from that, I still stand by the methodology as used here, as well as the results produced by it. These results are largely in line with what was to be expected from existing research, and it is only the strange discrepancy between the correlation and the regression outcome for the link between other green space and emotional loneliness that strikes me as odd in any way. Of course, it would have been more interesting had I found a greater impact of urban green space access on social and emotional loneliness, but it is only natural that, in research, sometimes no to little effect is found. That aside, the only things I wish I had done differently in hindsight is to either have found a way to be more motivated, or to be better at working around lapses in motivation, as this would have made the process as a whole smoother.

Finally, I would like to thank all attendants at the Graduate Research Day for their presence, and especially to those who asked questions as these helped illuminate potential weaknesses. I would also like to thank Samira Ramezani, in particular for her valuable feedback and her patience with the sometimes long gaps between the completion of intermediate products. Finally, given that this thesis represents the end of my master's studies and with it my time at the RUG, I would like to thank the faculty staff as a whole and the lecturers and other people directly involved with the various courses in particular, for making this degree possible, not least because both my bachelor's and my master's degree are the only of their kind in the Netherlands.

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Appendix 1: 11-item De Jong Gierveld Loneliness Scale

Source: De Jong Gierveld & Van Tilburg, 2006, p. 586).

Questions regarding emotional loneliness

1. I miss having a really close friend
2. I experience a general sense of emptiness
3. I miss the pleasure of the company of others
4. I find my circle of friends and acquaintances too limited
5. I miss having people around
6. I often feel rejected

Questions regarding social loneliness

1. There is always someone I can talk to about my day-to-day problems
2. There are plenty of people I can rely on when I have problems
3. There are many people I can trust completely
4. There are enough people I feel close to
5. I can call on my friends whenever I need them

Appendix 2: Multiple linear regression output: Coefficient tables for subsets of urban green space

Table 21 – Multiple linear regression output: Coefficients for distance decay-based indicator (large green space) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	28,912	5,432		5,322	< 0,001					
Distance decay-based indicator	0,077	0,194	0,018	0,394	0,694	-0,428	0,045	0,012	0,449	2,225
Residential density	> -0,001	< 0,001	-0,060	-1,092	0,278	0,295	-0,125	-0,034	0,324	3,089
Percentage single-family housing	-0,021	0,009	-0,127	-2,463	0,016	-0,350	-0,274	-0,077	0,364	2,748
Percentage aged 15-24	-0,018	0,036	-0,023	-0,511	0,611	0,275	-0,059	-0,016	0,477	2,098
Percentage aged 65 and over	0,105	0,023	0,191	4,606	< 0,001	-0,096	0,470	0,143	0,567	1,765
Percentage male	-0,105	0,088	-0,070	-1,194	0,236	0,241	-0,137	-0,037	0,284	3,522
Percentage higher educated	-0,065	0,016	-0,218	-4,021	< 0,001	-0,607	-0,421	-0,125	0,329	3,038
Percentage of households with a low income	0,331	0,057	0,323	5,849	< 0,001	0,760	0,560	0,182	0,318	3,141
Percentage of people with a western migration background	0,242	0,061	0,229	4,004	< 0,001	0,346	0,420	0,125	0,297	3,362
Percentage of people with a nonwestern migration background	0,249	0,019	0,588	13,426	< 0,001	0,839	0,840	0,418	0,506	1,976

Table 22 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with sport/play functions) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	30,579	4,896		6,245	< 0,001					

Distance decay-based indicator	-0,732	1,244	-0,020	-0,589	0,558	-0,139	-0,068	-0,018	0,853	1,172
Residential density	> -0,001	< 0,001	-0,078	-1,679	0,097	0,295	-0,190	-0,052	0,444	2,253
Percentage single-family housing	-0,021	0,009	-0,129	-2,495	0,015	-0,350	-0,277	-0,078	0,361	2,767
Percentage aged 15-24	-0,020	0,036	-0,025	-0,552	0,583	0,275	-0,064	-0,017	0,477	2,096
Percentage aged 65 and over	0,106	0,023	0,193	4,642	< 0,001	-0,096	0,472	0,144	0,558	1,791
Percentage male	-0,102	0,088	-0,068	-1,162	0,249	0,241	-0,133	-0,036	0,284	3,520
Percentage higher educated	-0,064	0,016	-0,215	-4,100	< 0,001	-0,607	-0,428	-0,128	0,353	2,832
Percentage of households with a low income	0,332	0,056	0,323	5,925	< 0,001	0,760	0,565	0,184	0,325	3,079
Percentage of people with a western migration background	0,243	0,060	0,229	4,019	< 0,001	0,346	0,421	0,125	0,297	3,364
Percentage of people with a nonwestern migration background	0,247	0,018	0,583	13,668	< 0,001	0,839	0,845	0,425	0,531	1,883

Table 23 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with nature function) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	29,368	5,146		5,706	< 0,001					
Distance decay-based indicator	0,073	0,248	0,013	0,296	0,768	-0,439	0,034	0,009	0,478	2,094
Residential density	> -0,001	< 0,001	-0,066	-1,334	0,186	0,295	-0,152	-0,042	0,397	2,522
Percentage single-family housing	-0,021	0,009	-0,130	-2,451	0,017	-0,350	-0,272	-0,076	0,348	2,877
Percentage aged 15-24	-0,021	0,036	-0,026	-0,573	0,569	0,275	-0,066	-0,018	0,464	2,154
Percentage aged 65 and over	0,104	0,023	0,189	4,515	< 0,001	-0,096	0,462	0,141	0,557	1,797

Percentage male	-0,106	0,088	-0,070	-1,198	0,235	0,241	-0,137	-0,037	0,283	3,536
Percentage higher educated	-0,065	0,017	-0,218	-3,909	< 0,001	-0,607	-0,411	-0,122	0,311	3,213
Percentage of households with a low income	0,332	0,057	0,324	5,863	< 0,001	0,760	0,561	0,183	0,318	3,141
Percentage of people with a western migration background	0,246	0,062	0,232	3,959	< 0,001	0,346	0,416	0,123	0,283	3,529
Percentage of people with a nonwestern migration background	0,248	0,018	0,585	13,623	< 0,001	0,839	0,844	0,424	0,526	1,902

Table 24 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with other function) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	34,351	7,663		4,483	< 0,001					
Distance decay-based indicator	-0,264	0,358	-0,028	-0,736	0,464	0,001	-0,085	-0,023	0,667	1,499
Residential density	> -0,001	< 0,001	-0,082	-1,735	0,087	0,295	-0,196	-0,054	0,427	2,340
Percentage single-family housing	-0,023	0,009	-0,138	-2,560	0,012	-0,350	-0,283	-0,080	0,330	3,033
Percentage aged 15-24	-0,025	0,037	-0,032	-0,689	0,493	0,275	-0,079	-0,021	0,452	2,214
Percentage aged 65 and over	0,106	0,023	0,193	4,656	< 0,001	-0,096	0,474	0,145	0,563	1,776
Percentage male	-0,117	0,089	-0,078	-1,306	0,195	0,241	-0,149	-0,041	0,273	3,665
Percentage higher educated	-0,066	0,016	-0,220	-4,140	< 0,001	-0,607	-0,431	-0,129	0,340	2,938
Percentage of households with a low income	0,330	0,056	0,322	5,890	< 0,001	0,760	0,562	0,183	0,323	3,093
Percentage of people with a western	0,247	0,061	0,233	4,065	< 0,001	0,346	0,425	0,126	0,293	3,415

migration background										
Percentage of people with a nonwestern migration background	0,248	0,018	0,585	13,724	< 0,001	0,839	0,846	0,426	0,531	1,883

Table 25 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (large green space) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	29,118	4,747		6,133	< 0,001					
Area in neighbourhood indicator	-0,028	0,019	-0,064	-1,471	0,146	-0,406	-0,167	-0,045	0,496	2,015
Residential density	> -0,001	< 0,001	-0,098	-2,031	0,046	0,295	-0,228	-0,062	0,407	2,454
Percentage single-family housing	-0,019	0,008	-0,117	-2,284	0,025	-0,350	-0,255	-0,070	0,360	2,781
Percentage aged 15-24	-0,017	0,036	-0,021	-0,468	0,641	0,275	-0,054	-0,014	0,477	2,098
Percentage aged 65 and over	0,117	0,024	0,214	4,876	< 0,001	-0,096	0,491	0,150	0,492	2,033
Percentage male	-0,082	0,088	-0,055	-0,934	0,353	0,241	-0,107	-0,029	0,276	3,617
Percentage higher educated	-0,060	0,016	-0,201	-3,863	< 0,001	-0,607	-0,407	-0,119	0,347	2,879
Percentage of households with a low income	0,328	0,055	0,320	5,941	< 0,001	0,760	0,566	0,183	0,326	3,071
Percentage of people with a western migration background	0,229	0,060	0,215	3,784	< 0,001	0,346	0,400	0,116	0,291	3,434
Percentage of people with a nonwestern migration background	0,248	0,018	0,585	13,874	< 0,001	0,839	0,848	0,426	0,531	1,882

Table 26 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with sport/play functions) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	30,150	4,776		6,313	< 0,001					

Area in neighbourhood indicator	-0,092	0,129	-0,025	-0,713	0,478	0,068	-0,082	-0,022	0,768	1,301
Residential density	> -0,001	< 0,001	-0,084	-1,737	0,087	0,295	-0,197	-0,054	0,408	2,450
Percentage single-family housing	-0,023	0,009	-0,138	-2,552	0,013	-0,350	-0,283	-0,079	0,329	3,042
Percentage aged 15-24	-0,022	0,036	-0,028	-0,616	0,540	0,275	-0,071	-0,019	0,471	2,125
Percentage aged 65 and over	0,106	0,023	0,193	4,657	< 0,001	-0,096	0,474	0,145	0,562	1,780
Percentage male	-0,099	0,088	-0,066	-1,128	0,263	0,241	-0,129	-0,035	0,283	3,535
Percentage higher educated	-0,065	0,016	-0,217	-4,131	< 0,001	-0,607	-0,431	-0,128	0,349	2,863
Percentage of households with a low income	0,334	0,056	0,325	5,995	< 0,001	0,760	0,569	0,186	0,328	3,052
Percentage of people with a western migration background	0,239	0,060	0,226	3,960	< 0,001	0,346	0,416	0,123	0,297	3,368
Percentage of people with a nonwestern migration background	0,248	0,018	0,585	13,722	< 0,001	0,839	0,846	0,426	0,531	1,885

Table 27 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with nature function) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	28,732	4,893		5,872	< 0,001					
Area in neighbourhood indicator	-0,031	0,030	-0,043	-1,020	0,311	-0,438	-0,117	-0,032	0,543	1,840
Residential density	> -0,001	< 0,001	-0,088	-1,838	0,070	0,295	-0,208	-0,057	0,420	2,382
Percentage single-family housing	-0,019	0,009	-0,116	-2,221	0,029	-0,350	-0,248	-0,069	0,352	2,844
Percentage aged 15-24	-0,014	0,036	-0,018	-0,398	0,691	0,275	-0,046	-0,012	0,470	2,128
Percentage aged 65 and over	0,112	0,024	0,203	4,720	< 0,001	-0,096	0,479	0,146	0,517	1,936
Percentage male	-0,080	0,090	-0,053	-0,880	0,381	0,241	-0,101	-0,027	0,265	3,772
Percentage higher educated	-0,059	0,016	-0,196	-3,595	0,001	-0,607	-0,383	-0,111	0,323	3,096
Percentage of households with a low income	0,338	0,056	0,330	6,089	< 0,001	0,760	0,575	0,188	0,327	3,060

Percentage of people with a western migration background	0,226	0,062	0,213	3,649	< 0,001	0,346	0,388	0,113	0,280	3,569
Percentage of people with a nonwestern migration background	0,247	0,018	0,583	13,717	< 0,001	0,839	0,846	0,425	0,531	1,883

Table 28 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with other function) and social loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	31,894	5,073		6,287	< 0,001					
Area in neighbourhood indicator	-0,024	0,022	-0,041	-1,094	0,278	-0,032	-0,125	-0,034	0,679	1,473
Residential density	> -0,001	< 0,001	-0,086	-1,835	0,071	0,295	-0,207	-0,057	0,434	2,304
Percentage single-family housing	-0,025	0,009	-0,152	-2,694	0,009	-0,350	-0,297	-0,083	0,299	3,342
Percentage aged 15-24	-0,023	0,036	-0,028	-0,633	0,528	0,275	-0,073	-0,020	0,474	2,111
Percentage aged 65 and over	0,105	0,023	0,191	4,653	< 0,001	-0,096	0,473	0,144	0,567	1,765
Percentage male	-0,121	0,089	-0,081	-1,369	0,175	0,241	-0,156	-0,042	0,275	3,640
Percentage higher educated	-0,065	0,016	-0,219	-4,191	< 0,001	-0,607	-0,436	-0,130	0,350	2,857
Percentage of households with a low income	0,327	0,056	0,319	5,855	< 0,001	0,760	0,560	0,181	0,323	3,100
Percentage of people with a western migration background	0,233	0,061	0,219	3,834	< 0,001	0,346	0,405	0,119	0,292	3,423
Percentage of people with a nonwestern migration background	0,249	0,018	0,589	13,807	< 0,001	0,839	0,847	0,427	0,526	1,900

Table 29 – Multiple linear regression output: Coefficients for distance decay-based indicator (large green space) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	36,740	8,007		4,589	< 0,001					

Distance decay-based indicator	0,082	0,286	0,014	0,287	0,775	-0,527	0,033	0,009	0,449	2,225
Residential density	> -0,001	< 0,001	0,005	0,087	0,931	0,531	0,010	0,003	0,324	3,089
Percentage single-family housing	-0,081	0,013	-0,344	-6,430	< 0,001	-0,636	-0,596	-0,208	0,364	2,748
Percentage aged 15-24	0,073	0,053	0,064	1,370	0,175	0,500	0,156	0,044	0,477	2,098
Percentage aged 65 and over	-0,013	0,034	-0,017	-0,392	0,696	-0,337	-0,045	-0,013	0,567	1,765
Percentage male	-0,254	0,130	-0,119	-1,964	0,053	0,503	-0,221	-0,063	0,284	3,522
Percentage higher educated	-0,035	0,024	-0,083	-1,476	0,144	-0,343	-0,168	-0,048	0,329	3,038
Percentage of households with a low income	0,466	0,083	0,319	5,580	< 0,001	0,690	0,542	0,180	0,318	3,141
Percentage of people with a western migration background	0,375	0,089	0,249	4,207	< 0,001	0,599	0,437	0,136	0,297	3,362
Percentage of people with a nonwestern migration background	0,249	0,027	0,415	9,136	< 0,001	0,800	0,726	0,295	0,506	1,976

Table 30 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with sport/play functions) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	39,421	7,184		5,488	< 0,001					
Distance decay-based indicator	-1,797	1,825	-0,034	-0,985	0,328	-0,219	-0,113	-0,032	0,853	1,172
Residential density	> -0,001	< 0,001	-0,016	-0,322	0,748	0,531	-0,037	-0,010	0,444	2,253
Percentage single-family housing	-0,082	0,013	-0,348	-6,527	< 0,001	-0,636	-0,602	-0,209	0,361	2,767
Percentage aged 15-24	0,070	0,053	0,062	1,329	0,188	0,500	0,152	0,043	0,477	2,096
Percentage aged 65 and over	-0,009	0,034	-0,012	-0,276	0,784	-0,337	-0,032	-0,009	0,558	1,791

Percentage male	-0,249	0,129	-0,116	-1,934	0,057	0,503	-0,218	-0,062	0,284	3,520
Percentage higher educated	-0,035	0,023	-0,082	-1,525	0,131	-0,343	-0,173	-0,049	0,353	2,832
Percentage of households with a low income	0,462	0,082	0,317	5,622	< 0,001	0,690	0,545	0,180	0,325	3,079
Percentage of people with a western migration background	0,378	0,089	0,251	4,260	< 0,001	0,599	0,441	0,137	0,297	3,364
Percentage of people with a nonwestern migration background	0,247	0,026	0,411	9,323	< 0,001	0,800	0,733	0,299	0,531	1,883

Table 31 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with nature function) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	36,308	7,571		4,796	< 0,001					
Distance decay-based indicator	0,198	0,365	0,025	0,544	0,588	-0,545	0,063	0,018	0,478	2,094
Residential density	> -0,001	< 0,001	0,007	0,134	0,894	0,531	0,015	0,004	0,397	2,522
Percentage single-family housing	-0,082	0,013	-0,350	-6,398	< 0,001	-0,636	-0,594	-0,206	0,348	2,877
Percentage aged 15-24	0,067	0,054	0,059	1,248	0,216	0,500	0,143	0,040	0,464	2,154
Percentage aged 65 and over	-0,016	0,034	-0,020	-0,468	0,641	-0,337	-0,054	-0,015	0,557	1,797
Percentage male	-0,258	0,130	-0,121	-1,992	0,050	0,503	-0,224	-0,064	0,283	3,536
Percentage higher educated	-0,038	0,025	-0,090	-1,553	0,125	-0,343	-0,176	-0,050	0,311	3,213
Percentage of households with a low income	0,462	0,083	0,317	5,545	< 0,001	0,690	0,539	0,179	0,318	3,141
Percentage of people with a western	0,386	0,091	0,256	4,222	< 0,001	0,599	0,438	0,136	0,283	3,529

migration background										
Percentage of people with a nonwestern migration background	0,249	0,027	0,414	9,319	< 0,001	0,800	0,733	0,300	0,526	1,902

Table 32 – Multiple linear regression output: Coefficients for distance decay-based indicator (green space with other function) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	58,203	10,924		5,328	< 0,001					
Distance decay-based indicator	-1,215	0,510	-0,091	-2,381	0,020	-0,187	-0,265	-0,074	0,667	1,499
Residential density	> -0,001	< 0,001	-0,039	-0,811	0,420	0,531	-0,093	-0,025	0,427	2,340
Percentage single-family housing	-0,090	0,013	-0,383	-7,069	< 0,001	-0,636	-0,632	-0,220	0,330	3,033
Percentage aged 15-24	0,043	0,053	0,038	0,812	0,419	0,500	0,093	0,025	0,452	2,214
Percentage aged 65 and over	-0,007	0,032	-0,009	-0,212	0,832	-0,337	-0,025	-0,007	0,563	1,776
Percentage male	-0,314	0,127	-0,147	-2,463	0,016	0,503	-0,274	-0,077	0,273	3,665
Percentage higher educated	-0,044	0,023	-0,104	-1,955	0,054	-0,343	-0,220	-0,061	0,340	2,938
Percentage of households with a low income	0,447	0,080	0,307	5,598	< 0,001	0,690	0,543	0,174	0,323	3,093
Percentage of people with a western migration background	0,401	0,087	0,266	4,623	< 0,001	0,599	0,471	0,144	0,293	3,415
Percentage of people with a nonwestern migration background	0,250	0,026	0,415	9,710	< 0,001	0,800	0,746	0,302	0,531	1,883

Table 33 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (large green space) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	36,889	7,032		5,246	< 0,001					
Area in neighbourhood indicator	-0,032	0,028	-0,052	-1,153	0,253	-0,552	-0,132	-0,037	0,496	2,015
Residential density	> -0,001	< 0,001	-0,025	-0,506	0,614	0,531	-0,058	-0,016	0,407	2,454
Percentage single-family housing	-0,079	0,013	-0,336	-6,292	< 0,001	-0,636	-0,588	-0,201	0,360	2,781
Percentage aged 15-24	0,075	0,053	0,066	1,422	0,159	0,500	0,162	0,046	0,477	2,098
Percentage aged 65 and over	0,002	0,036	0,002	0,045	0,964	-0,337	0,005	0,001	0,492	2,033
Percentage male	-0,228	0,130	-0,107	-1,752	0,084	0,503	-0,198	-0,056	0,276	3,617
Percentage higher educated	-0,030	0,023	-0,070	-1,283	0,204	-0,343	-0,146	-0,041	0,347	2,879
Percentage of households with a low income	0,462	0,082	0,317	5,645	< 0,001	0,690	0,546	0,181	0,326	3,071
Percentage of people with a western migration background	0,359	0,089	0,238	4,017	< 0,001	0,599	0,421	0,129	0,291	3,434
Percentage of people with a nonwestern migration background	0,248	0,026	0,413	9,393	< 0,001	0,800	0,735	0,301	0,531	1,882

Table 34 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with sport/play function) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	37,983	7,055		5,384	< 0,001					
Area in neighbourhood indicator	-0,063	0,190	-0,012	-0,330	0,742	-0,002	-0,038	-0,011	0,768	1,301
Residential density	> -0,001	< 0,001	-0,010	-0,203	0,840	0,531	-0,023	-0,007	0,408	2,450
Percentage single-family housing	-0,082	0,013	-0,349	-6,202	< 0,001	-0,636	-0,582	-0,200	0,329	3,042
Percentage aged 15-24	0,070	0,053	0,061	1,307	0,195	0,500	0,149	0,042	0,471	2,125
Percentage aged 65 and over	-0,012	0,034	-0,016	-0,365	0,716	-0,337	-0,042	-0,012	0,562	1,780
Percentage male	-0,250	0,130	-0,117	-1,926	0,058	0,503	-0,217	-0,062	0,283	3,535
Percentage higher educated	-0,034	0,023	-0,081	-1,482	0,142	-0,343	-0,169	-0,048	0,349	2,863
Percentage of households with a low income	0,469	0,082	0,322	5,702	< 0,001	0,690	0,550	0,184	0,328	3,052

Percentage of people with a western migration background	0,373	0,089	0,247	4,177	< 0,001	0,599	0,434	0,135	0,297	3,368
Percentage of people with a nonwestern migration background	0,248	0,027	0,412	9,307	< 0,001	0,800	0,732	0,300	0,531	1,885

Table 35 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with nature function) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	34,721	7,103		4,889	< 0,001					
Area in neighbourhood indicator	-0,080	0,044	-0,078	-1,824	0,072	-0,546	-0,206	-0,058	0,543	1,840
Residential density	> -0,001	< 0,001	-0,033	-0,685	0,495	0,531	-0,079	-0,022	0,420	2,382
Percentage single-family housing	-0,076	0,012	-0,325	-6,093	< 0,001	-0,636	-0,575	-0,193	0,352	2,844
Percentage aged 15-24	0,084	0,052	0,074	1,609	0,112	0,500	0,183	0,051	0,470	2,128
Percentage aged 65 and over	0,005	0,034	0,007	0,155	0,877	-0,337	0,018	0,005	0,517	1,936
Percentage male	-0,191	0,131	-0,089	-1,454	0,150	0,503	-0,166	-0,046	0,265	3,772
Percentage higher educated	-0,021	0,024	-0,048	-0,870	0,387	-0,343	-0,100	-0,027	0,323	3,096
Percentage of households with a low income	0,479	0,081	0,328	5,932	< 0,001	0,690	0,565	0,188	0,327	3,060
Percentage of people with a western migration background	0,335	0,090	0,222	3,718	< 0,001	0,599	0,395	0,118	0,280	3,569
Percentage of people with a nonwestern migration background	0,246	0,026	0,409	9,441	< 0,001	0,800	0,737	0,298	0,531	1,883

Table 36 – Multiple linear regression output: Coefficients for area in neighbourhood indicator (green space with other function) and emotional loneliness

Variable	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	43,953	7,263		6,052	< 0,001					

Area in neighbourhood indicator	-0,074	0,031	-0,090	-2,382	0,020	-0,158	-0,265	-0,074	0,679	1,473
Residential density	> -0,001	< 0,001	-0,036	-0,753	0,454	0,531	-0,087	-0,023	0,434	2,304
Percentage single-family housing	-0,094	0,013	-0,401	-7,040	< 0,001	-0,636	-0,631	-0,219	0,299	3,342
Percentage aged 15-24	0,061	0,051	0,053	1,180	0,242	0,500	0,135	0,037	0,474	2,111
Percentage aged 65 and over	-0,012	0,032	-0,015	-0,362	0,718	-0,337	-0,042	-0,011	0,567	1,765
Percentage male	-0,309	0,127	-0,144	-2,430	0,017	0,503	-0,270	-0,076	0,275	3,640
Percentage higher educated	-0,040	0,022	-0,093	-1,769	0,081	-0,343	-0,200	-0,055	0,350	2,857
Percentage of households with a low income	0,445	0,080	0,305	5,568	< 0,001	0,690	0,541	0,173	0,323	3,100
Percentage of people with a western migration background	0,346	0,087	0,230	3,986	< 0,001	0,599	0,418	0,124	0,292	3,423
Percentage of people with a nonwestern migration background	0,254	0,026	0,422	9,827	< 0,001	0,800	0,750	0,306	0,526	1,900