Healthy Connections

A (re)design for Hospital Gelderse Vallei Ede and its surroundings for countering age-related loneliness

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Preface

Before you lays the Bachelor thesis report ‘Healthy Connections: A (re) design for hospital ‘Ziekenhuis Gelderse Vallei’ and its surroundings for countering age-related loneliness’. This thesis concludes my bachelor studies BLP: Bsc Landscape architecture and Spatial planning at the Wageningen University and Research. This thesis confronts the current situation regarding social interaction possibilities for elderly people on and surrounding the premises of hospital Ziekenhuis Gelderse Vallei and aims to improve this by implementing certain design measures derived from case studies and literature research.

I want to dedicate this thesis research to my four grandparents, Angelien & Piet de Jong and Wies & Marie-Louise van Kampen, which I am proud to call my grandparents.

I want to thank my tutor, Agnes Patuano, for her support, understanding and creative input in these complex pandemic times. I also want to thank my peers Mar, Cipo and Venne for the feedback and help you provided. Lastly I want to thank all of my family and friends who have supported me every single day to make the most out of this thesis research. Thank you!

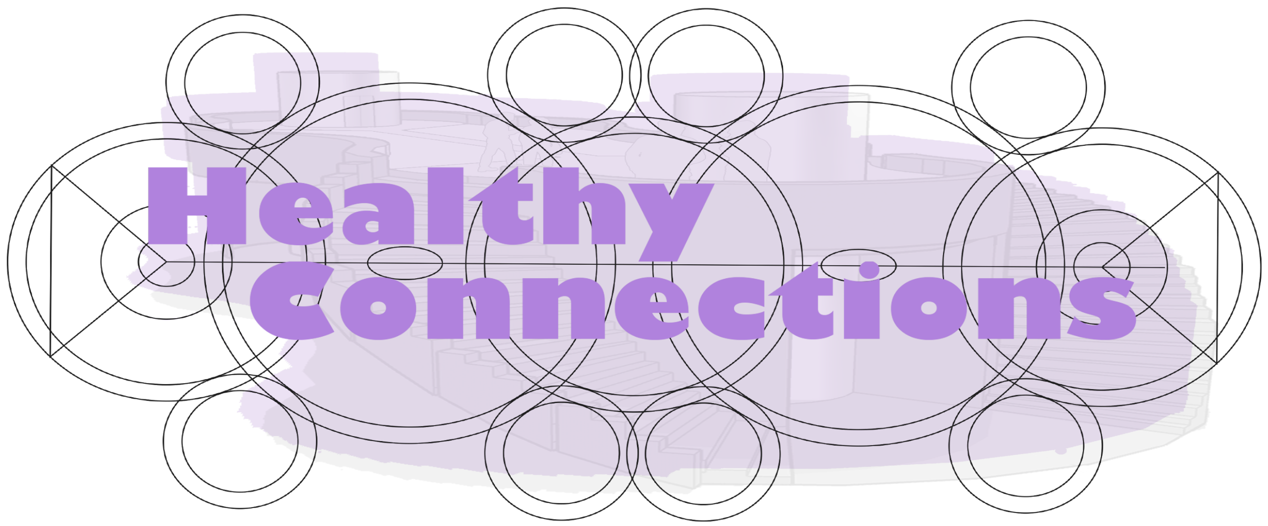
Rijn van Kampen

Abstract

Ageing is often accompanied by physical and mental health problems. Loneliness is one of those big mental health problems among elderly people. Loneliness can lead to more severe health problems like depression, hopelessness and worsening motor functions and is even associated with higher mortality rates. As loneliness among elderly people is becoming a growing societal problem in the Netherlands, it is up to municipalities to counteract against it. For countering loneliness, social cohesion and social interaction are vital factors.

As acting healthcare institution for approximately 260.000 residents of the provinces Gelderland and Utrecht, ‘Ziekenhuis Gelderse Vallei’ in Ede can take a leading role in countering loneliness among elderly people by providing social interaction locations (SIL) that are attractive, comfortable and reachable for elderly people. This would increase the social interaction possibilities for elderly people. To do so, a new spatial design of the public space surrounding the hospital facilities should be considered. The corresponding design questions is: What design interventions could improve the accessibility and thermal quality of SIL for elderly people, eventually increasing social interaction possibilities? This thesis research will endeavor to bridge the knowledge gap and thereby answer the design question by using research for and through design as research method.

In this research, several design implementations that could improve physical accessibility of SIL as well as implementations that could improve thermal comfort at SIL are derived from literature, case studies and site research. These are transformed into assessment criteria and design guidelines in order to make the knowledge applicable on the research site. All this comes together in a final masterplan for the hospital and its surroundings, called Healthy Connections Ede. In this masterplan, new design features like a pedestrian highway, a MiVaduct and new spatial organisations of the hospital premises form the base for a design that increases social interaction possibilities for elderly people. The knowledge found in this thesis research can be used by other landscape architects, urban designers and spatial planners when designing public spaces with the aim of countering loneliness among elderly people.



1. Introduction

The Netherlands is an aging country. The amount of Dutch people aged 65 years and older is estimated to almost double from 2010 and 2040, growing from 2,4 million to a whopping 4,6 million. (van Duin & Garssen, 2011). Ageing in most cases comes with an increase of physical- as well as mental health issues. This results in a lower quality of life for elderly people and also results in rising need for healthcare services and bigger societal costs. (European Commission, 2007). One of those mental health problems that can be the result of ageing is **loneliness** (Ministerie van Volksgezondheid, Welzijn en Sport). Loneliness is a common phenomenon experienced worldwide and occurs most often with people of older age (Honigh-de Vlaming, 2013). There is an important difference between 'being alone' and experiencing 'loneliness'. While the first is not a direct cause of negative emotions and in most cases the temporary state of not being around anybody, the latter can be defined as "*the unpleasant or inadmissible lack of the (quality of) certain relationships*" (Honigh-de Vlaming, 2013). Loneliness in old age is often a result of the loss of social relationships due to age-related events like the death of relatives or retirement from working (Honigh-de Vlaming, 2013). According to the RIVM (national institute for Public Health and Environment), recent studies from Amsterdam indicate that 31% of Dutch elderly people (65 years or older) faces loneliness, with 3% suffering from severe loneliness (RIVM, 2011).

A bad self-perceived state of health (physical and psychological), social interaction barriers (physical and psychological), restricted functional abilities like impairments and size of social network are all factors that influence the experienced loneliness (Honigh-de Vlaming, 2013). Loneliness can result in various, more severe mental health problems like depression, hopelessness, cognitive impairment and substance abuse. But loneliness can also have a negative influence on physical health by enlarging chances of malnutrition, high blood pressure (hypertension) and worsening motor functions (Lee et al., 2019). Loneliness has even been linked to higher mortality rates (Tilvis et al., 2010). These numerous negative health effects could be reduced by countering the problem of loneliness – improving the quality of life of people and saving society money by reducing healthcare costs.

Social interaction and social cohesion are vital in countering loneliness among elderly people. Societal participation and social cohesion can prevent loneliness by 1) improving the social network quality of lonely people and 2) improving social cohesion in a neighbourhood. The latter could also help the monitoring of lonely people (Honigh-de Vlaming, 2013). In the Netherlands, The Dutch Social Support Act (2007) makes local governments responsible for enhancing social cohesion, especially for vulnerable groups such as less mobile and elderly people, to counter loneliness. (Tjalma- den Oudsten et al., 2006).

As loneliness among less mobile and elderly people is a rapidly growing societal problem (Honigh-de Vlaming, 2013), it is of high importance for local governments to counteract against it. Hospital 'Ziekenhuis Gelderse Vallei' in Ede plays an important role in the agendas of elderly people as acting regional healthcare institution. Elderly people made up 38% of their total patient base in 2018 and 2019. (Looijen, 2020). Together with the municipality of Ede, who are responsible for enhancing social interaction for vulnerable groups, the hospital can take a leading role locally in countering loneliness in order to reduce mental health problems among pensioners in the region. This would benefit the hospital due to lower health care costs and of course benefit the quality of life for elderly people that make up a vast part of their patient base. In order to do so, the hospital should provide the possibility for elderly people to have encounters and social interactions with others as this lowers chances of being lonely. As most social interaction take place in outside (public) environments (Erell, Pearlmutter & Williamson, 2011), spatial organization, -elements and -design of public environments play a big role in facilitating services that promote social interactions. This is where landscape architecture comes into play. However, currently the places stimulating social interaction on and surrounding the hospital premises lack certain important design aspects like physical accessibility (walkability) from the hospital buildings, seating comfort and environmental comfort – especially for elderly people. Therefore, they can not function optimally for elderly people. This poses a local problem and with it many research- and design opportunities.

In this thesis I argue that the features promoting social interaction found on and surrounding the hospital premises are lacking a sufficient level of physical accessibility and thermal quality for less mobile and elderly people (figure 1). This research will endeavour to resolve the lack of accessible and thermally comfortable social interaction locations on and surrounding the premises of Hospital 'Ziekenhuis Gelderse Vallei' in order to stimulate social cohesion and social interaction possibilities for elderly people by using a research for and through design methodology. In the end, this could possibly enlarge social participation within the research site among the target group and with it improve their quality of life.

This research contributes to science by studying the barriers for elderly people to go outside and actually engage in social interaction, as well as summarizing multiple design interventions that could improve social interaction possibilities for elderly people by improving thermal comfort and physical accessibility of SIL. These implementations are represented by design guidelines which can be used by urban planners and landscape architects to increase social interaction possibilities for elderly people in public space designs or spatial plans.

1.1. Site introduction

The hospital 'Ziekenhuis Gelderse Vallei', with over 22.000 annual hospitalizations on average (CBS, 2019), is the major acting healthcare institution for a large part of the province of Gelderland and the east of the province of Utrecht. Their acting area covers multiple municipalities and serves around 260.000 of its residents (Ziekenhuis Gelderse Vallei, 2020). This means 1,5% of the Dutch population depends on the services of this hospital.

'Ziekenhuis Gelderse vallei' is located in the city of Ede and is enclosed by major traffic routes 'Laan der Verenigde Naties' on the north side and 'Dr. W. Dreeslaan' on the east side of the premises, making the hospital easily reachable regionally. Along the southern- and western borders the hospital is adjacent to the Rietkampen neighbourhood which consist mostly of apartment buildings and terraced houses. The hospital facilitates many parking spaces in their parking garage and the 3 bus stops located on the hospital site make the hospital well connected to the public transit network. North of the laan der Verenigde Naties, an urban park can be found with a big water feature in the middle. The park however is hard to reach due to the big traffic roads and crossing. The park, hospital premises, adjacent part of the neighbourhood and two previously named roads together form the research site for this thesis research, as shown in figure 2.

1.2. Report structure

This thesis report starts off with introducing the scope and problem of this research and providing the methods and materials used to conduct the research. the focus in chapter 2 is on the current situation at the research site regarding social interaction possibilities for elderly people, the barriers for elderly people to have social interaction in public spaces and how this could be improved by design interventions. Chapter 3 focuses on thermal comfort and its effect on social interaction possibilities on site as well as in general. From the knowledge found in chapter 2 and 3, design guidelines and assessment criteria will be drawn up in chapter 4. These will be used in chapter 5 which introduced 3 spatial concepts for improving the research site and assesses these to come to a final concept. In chapter 6, design choices will be validated by assessment, leading to the creating of a masterplan in chapter 7. This masterplan is elaborated on in chapter 7 by means of design details, cross sections and spherical impressions. Chapter 8 and 9 respectively conclude this research by a research discussion which will reflect on this research and last but not least end with a final conclusions that can be drawn from this research.

Figure 1: Collage of pictures made at Ziekenhuis Gelderse Vallei showing the insufficient quality of social interaction locations ragerding accessibility and and thermal comfort. Insufficient pedestrian routing makes it hard for (less mobile) pedestrians to reach facilities (picture 3 and 4) and resting places (picture 2). Picture 3 shows how the social interaction location (in this case a sheltered bench) design lacks multifunctionality; while the roof keeps dry in rainy weather, it has a greenhouse like effect in sunny weather making it uncomfortable in certain situations.

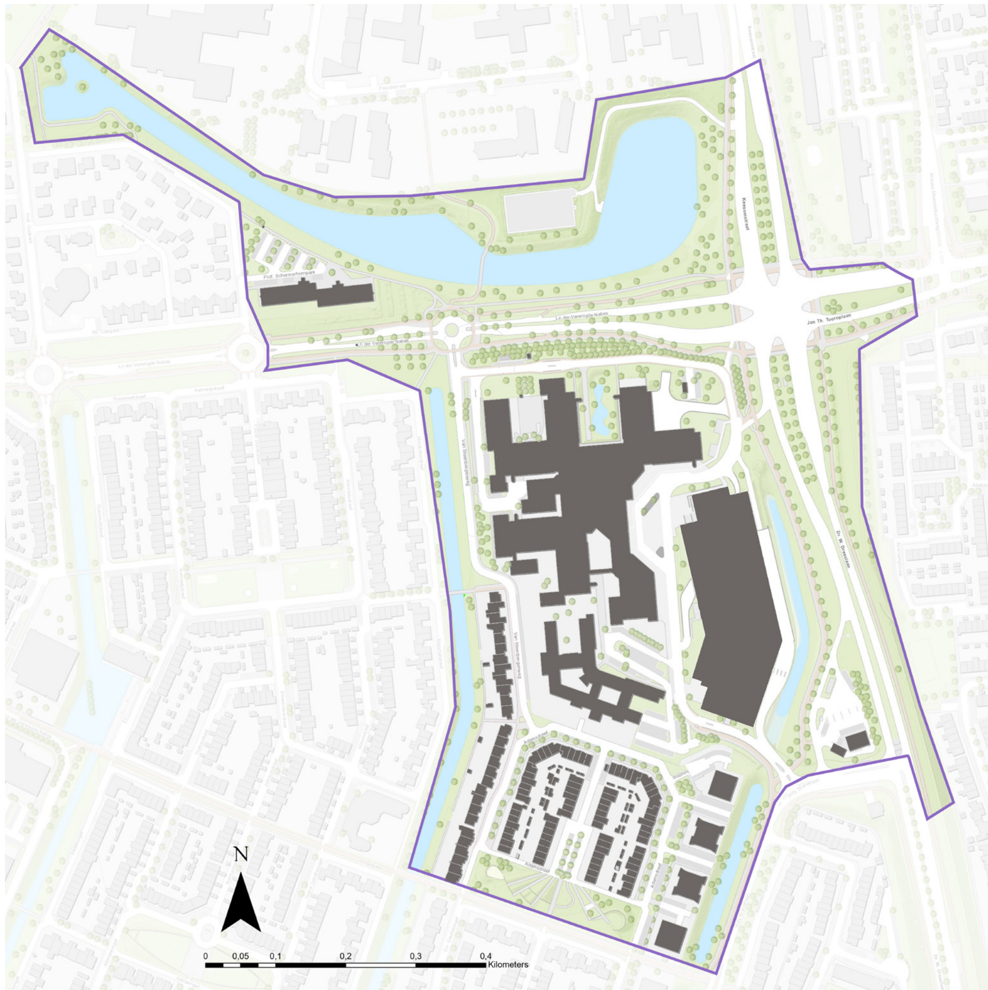


Figure 2: Map of the research site of this thesis research. The site includes the hospital premises in the middle, the van Steenbergenweg (west), part of the Rietkampen neighbourhood (south) and the park (north) and major traffic roads (east).

1.3. Thesis Statement

For this thesis, the stated problem is as follows:
"The hospital site and its surroundings should provide accessible and thermally comfortable social interaction locations for less mobile and elderly people to decrease loneliness among these people by providing social interaction possibilities. This results in a higher quality of life among the elderly."

The goal of this research is to improve the accessibility and thermal comfort of social interaction locations (SIL) on and surrounding the premises of 'Ziekenhuis Gelderse Vallei' to improve social interaction among elderly people, reducing loneliness among the target group.

As some frequently used concepts are still undefined, a definition is proposed:

- Social Interaction Locations in this thesis are defined as locations in public spaces including features that aim to stimulate social interaction for (un)related visitors. This concept is often shortened to SIL.

- Accessibility of SIL in this thesis can be regarded as the pedestrian walkability and walking comfort for the target group in order to reach SIL.

- Thermal Quality of SIL in this thesis can be regarded as the thermal comfort present at the SIL measured by exposure to solar radiation (sunlight) and perceived thermal comfort.

- Elderly people are intended in this thesis as research target group and consist of all people aged 65 and older, but also includes people with a physical disability that influences their mobility negatively.

- ZGV is an abbreviation for the name of the hospital which is used as case in this thesis study, which is 'Ziekenhuis Gelderse Vallei' in the municipality of Ede, the Netherlands.

1.3.1. Design Question

What design interventions could improve the accessibility and thermal quality of SIL for elderly people, eventually increasing social interaction possibilities?

To find an answer to this design question, knowledge has to be generated on multiple subjects like social interaction, accessibility and thermal comfort. This is the knowledge gap this thesis faces. In order to bridge this knowledge gap, sub research questions (or in this case sub design questions) are formulated. Each sub design question is aimed to be answered in the following chapters by performing research for and through design, in which as well literature studies as case studies of other designs will be used to find answers. The questions are separated into knowledge questions, for which research for design is applied, and design questions, for which research by designing is applied. The questions are as follows:

Knowledge Questions

These Sub research questions cover the current knowledge gap by doing research for design (RFD):

1) Where are the current locations providing social interaction possibilities for elderly people?

2) What is the current pedestrian routing quality from and towards these SIL?

3) What does the current elderly pedestrian behaviour look like around busy places and their SIL on the site?

4) What are barriers for less mobile elderly people to go outside and have social interaction?

5) What design implementations stimulate social interaction for elderly people?

6) What is the current microclimate situation regarding thermal comfort within the site premises?

7) What design implementations improve thermal comfort in different urban spaces?

Design Questions

These sub-research questions cover a design decision knowledge gap by doing research through design (RTD)

8) Where should (micro)climate adaptation measures be implemented to improve thermal comfort?

If all questions are answered, this thesis will endeavour to have main design question answered.

1.4. Methods & Materials

An overview table of the methods and materials for this research is given in Appendix 1 (table 12). By performing multiple site analysis studies, this research aims to generate a better understanding of the social interaction possibilities and behaviour of the current situation at the research site, exposing the weak spots regarding social interaction for elderly people in the design which provide opportunities for improvement. By studying relevant literature and case studies related to loneliness, social interaction in public spaces and social interaction barriers for elderly people, knowledge about the subject will be generated which will be translated to a set of design guidelines for designing a landscape that stimulates social interaction. Multiple concepts will be created according to the design guidelines and generated analysis maps. These concepts will all be assessed through a list of assessment criteria which are derived from literature study about thermal comfort and the relation between spatial configuration and perceived thermal comfort, to eventually come up with a design for the research site that could improve the accessibility and thermal quality of SIL for elderly people. This research process is visualised step-by-step in the following research model (figure 3):

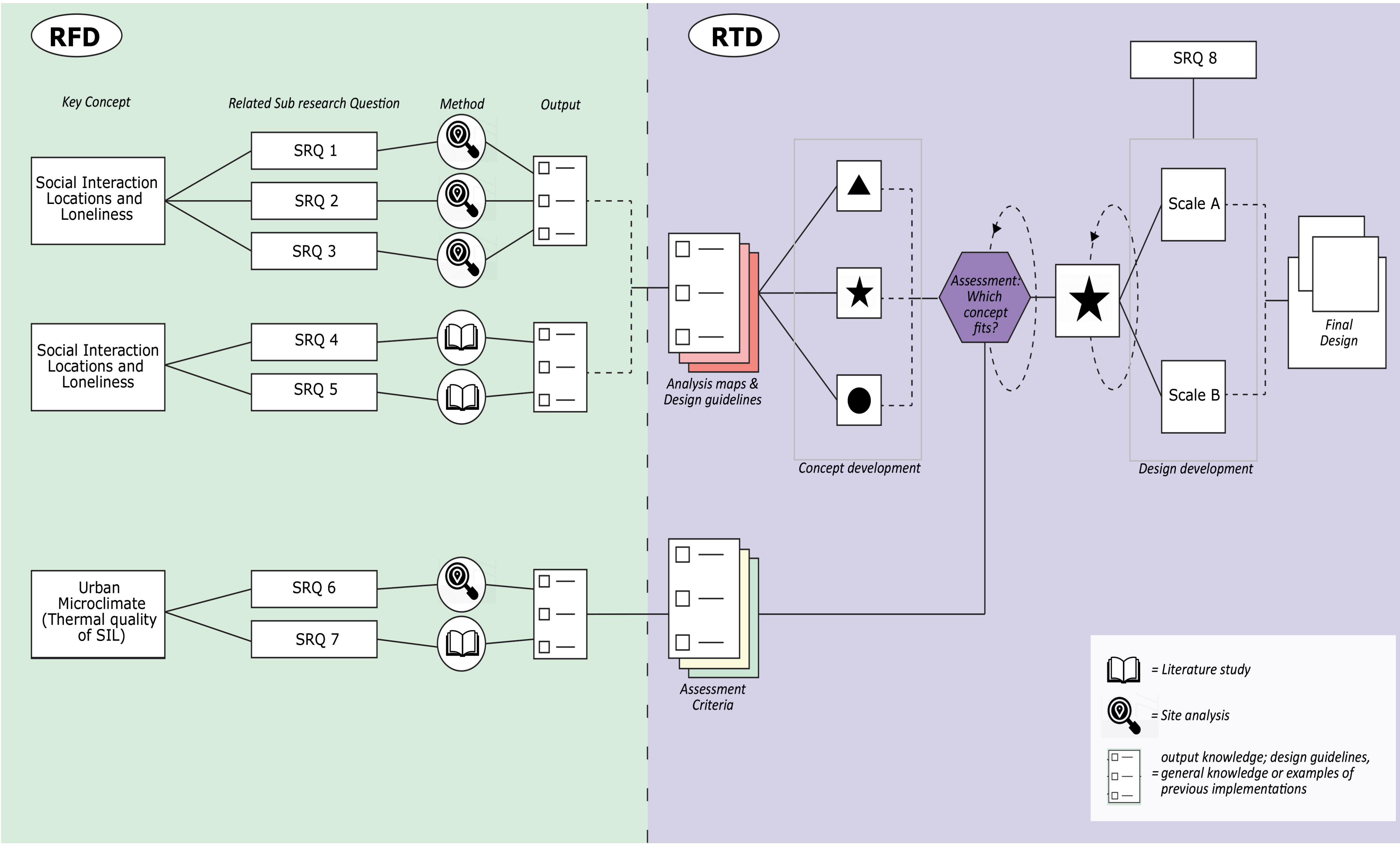


Figure 3: Research model for this thesis research. Based on the research model for design by van Etteger, 2017. By using Research for design first and research through design thereafter, a scientific approach for a site design is made.

2. Loneliness and social interaction

Loneliness among elderly people is a result of age-related events such as the death of a partner or relative, retirement and physical health issues like mobility impairments (Honigh-de Vlaming, 2013). Next to that, societal changes like the increase of single-family households, increased ageing and rapid traffic and network changes contribute to loneliness as well (Dykstra, 2009). Lastly, ageing results in the shrinking of the social network of elderly people. According to the disengagement theory by Cumming and Henry, this is part of natural ageing: as people get older, they become more conscious of death and therefore more self-focused. This result in more detachment towards social interaction (Heylen, 2010). Nevertheless, 31% of Dutch elderly experience loneliness (RIVM, 2011). Because loneliness can be the cause of multiple more severe physical and psychological conditions that negatively affect the quality of life for elderly people (Honigh-de Vlaming, 2013; Lee et al., 2019), loneliness is a problem that should be taken very seriously. Especially regarding (future) health care institutions. To counter loneliness, social participation and social cohesion are key. These enlarge the social interaction possibilities for people facing loneliness. Social interaction can prevent loneliness by improving the network size and quality of lonely people and improving social cohesion in a neighbourhood or community (Honigh-de Vlaming, 2013). This chapter will focus on loneliness and social interaction - how this is represented on the research site and in general by certain design aspects. First, an inventory of multiple design aspects influencing social interaction will be done (2.1.). Next, possible barriers for elderly people to actually go outside and participate in social activities is researched (2.2.). Lastly research is done on how social interaction possibilities could be improved by certain design implementations (2.3.).

2.1. Loneliness among elderly people at ZGV in Ede

To create a better understanding of the current situation at the research site regarding loneliness, behaviour of elderly people and social interaction possibilities, this section focusses on doing (site) research on several factors that influence social interaction like pedestrian routing, behaviour and SIL that are currently available.

2.1.1 Social interaction possibilities at research site

To enlarge social interaction possibilities, the hospital site needs to provide places that encourage visitors, patients and staff to interact with one another. Examples of these places are benches and similar resting spots, bus stops, coffee stands, refuge spots in nature, artworks and playgrounds (Erell, Pearlmutter & Williamson, 2011). This leads to the first research question:

1. Where are the current locations providing social interaction possibilities for elderly people?

By counting SIL during a site visit, all SIL could be located and put in a map (figure 4). Currently, Ziekenhuis Gelderse Vallei and its surroundings provide 28 locations that stimulate social interactions. Of these locations, 21 can be regarded as resting spots (bench or similar), 1 as landscape artwork, 3 playground areas, 2 bus stops and 1 as refuge place in nature (deck).

2.1.2. Pedestrian routing at research site

Accessibility to SIL is vital, especially for people with mobile restraints and elderly people, to enable social interaction. Ageing results in a decline of the activity range for elderly people. A smaller activity range enlarges the importance of pedestrian design (Tsai et al., 2016). According to research conducted by Tsai et al. on the 'space-time paths' of elderly people, their walking range differs per type of outdoor activity (being: social type activity, selection type activity and necessary type activity). The generated walking distance range (distance in meters / time in minutes) is more than double for social type outdoor activities like social interaction (675 meter / 12 minutes) as it is for necessary type activities like grocery shopping or public transit (145 meter / 6 minutes) (Tsai et al., 2016).

Figure 4: locations of the current available SIL within the research site

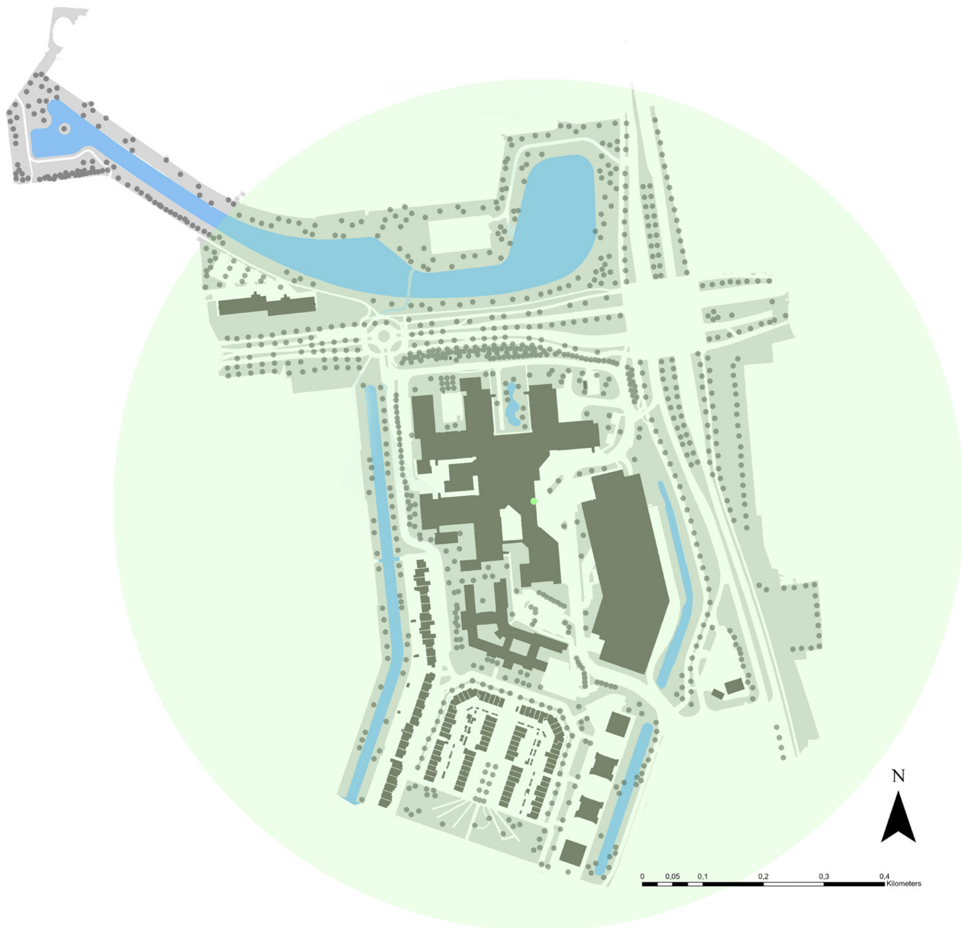


Figure 5: (absolute) walking range for elderly people from the hospital entrance according to Tsai et al. (2016).

From this, an (absolute) physical range from the hospital can be put in a site map, with the hospital entrance as starting point (figure 5). The green circle shows the maximum range (675 meter , in great circle distance, from the hospital entrance). All currently available SIL on the research site are within this physical range for elderly people, which makes them theoretically reachable. But are they in reality?

In order to reach the available SIL, sufficient pedestrian mobility facilities (sidewalks, curbs and crossing points) should be available for hospital visitors and designed to fit the needs of elderly people to enable good mobility services across the premises. Mobility products and assistive devices such as walking canes, wheelchairs, walkers and scooters should be taken into account (Rosenberg et al., 2012). This introduces the following research question:

2. What is the current pedestrian routing quality from and towards these SIL?

A site research on all pavements within the research site leads to the map shown in figure 6. The map shows the pedestrian network within the research site, with the different colours indicating the quality of the sidewalk. The quality is measured by the pavement material (smooth/rough), the slope (levelled/slope up or down), presence of curb ramps and crossing comfort/safety of subsequent crossing points. These assessment criteria for pavements are derived from the BEAMS study by Rosenberg et al. as they are regarded as important aspects for sidewalk comfort for elderly people (Rosenberg et al, 2012). A green routing means the pedestrian comfort is sufficient for elderly and less mobile people (see figure 7a on next page); orange routing means the sidewalk lacks certain components for elderly pedestrian comfort (see figure 7b); red routing means absence of pavement or insufficient pedestrian quality for elderly and less mobile people (see figure 7c). The purple circles imply an uncomfortable or obscure crossing point due to insufficient pedestrian comfort.

Figure 6: Pedestrian network structure within the research site. Different colours indicate different pavement quality in regard to elderly and less mobile users.

Figure 7a: three examples of 'green routing' on the research site. The Singelpad sidewalk (picture 1), the entrance square (picture 2) and the east side of the park north of the hospital (picture 3)

figure 7b: three examples of 'orange routing' on the research site. The crossing point between the steenbergen-weg and the Willy Brandtlaan (picture 4), the exit lane of the parking garage (picture 5) and the bridge crossing the water body of the northern park (picture 6)

figure 7c: three examples of 'red routing' on the research site. The sudden sidewalk stop on the east side of the entrance square (picture 7), the walking path in the northern park (picture 8) and the Willy Brandtlaan next to the parking garage (picture 9)

2.1.3. Pedestrian behaviour at research site

A useful means to address the usability of spatial configuration of a place is by creating a behavioural map (Ittelson et al., 1970). Behavioural maps are a tool for place analysis and design by simple observations. Behavioural mapping is therefore a more dynamic type of analysis compared to design templates or design models, because it is related to the specific design site (Marušić, 2012). A behavioural matrix is used to conduct field observations; the matrix should include different measurement moments on different times of the week (e.g. morning, evening and weekend observations) and different behavioural types (e.g. sitting, walking, jogging etcetera) that will be counted and classified per time slot (Marušić, 2012).

To understand the current degree of social interaction possibilities on the research site and how suitable and popular the current SIL are, the behavioural patterns of elderly pedestrians on the site was analysed by means of behavioural mapping, leading to the third research question:

3. What does the current elderly pedestrian behaviour look like around busy places and their SIL on the site?

To do so, 5 locations that contain a cluster of SIL were monitored: the park (right side) (1); the benches at the Willy Brandtlaan (2); the bus stop 'Ede Gelderse Vallei' (3); the entrance square (4) and the Radiotherapy group parking lot (5) (see figure 8). For all locations, a behavioural analysis was done on 3 different times of the week: on a working day in the morning (9:30 – 12:00); on a working day in the afternoon (15:30 – 18:00 PM) and in the weekend past noon (12:00 – 14:30). For each location, visitors within the target group (elderly people) were counted for exactly 30 minutes. They are classified according to their behaviour. The classes of behaviour are *transport walking** (1); *recreational walking* **(2); *Walking with a dog or child* (3); *Being moved (in a wheelschair or similar device)* (4); *Sitting on bench* (5); and *standing* (6). Also, the amount of nearby (visible) SIL were counted per location and weather conditions noted per measurement moment to keep track of factors that could influence the outcome of the research. The results were noted in a behavioural matrix for each location, which are shown in appendix 2.

The matrices reveal clear differences in usage pattern and density between the different analysed locations. There were no differences in weather conditions. For example, the entrance square has higher activity among elderly people (which means it is visited or used more frequently) as the Williy Brandtlaan up north. The matrices are translated to behavioural maps, one for each location. These maps give a more specific insight in which places within each location are (not) frequently used, and for what kind of behaviour. They also show major pedestrian walking fluxes and places that people avoid. The maps can be found in appendix 3.

* Transport walking in this thesis is regarded as the act of moving from A to B for necessary activities which are mandatory or necessary and therefore inevitable to move for.
** Recreational walking in this thesis is regarded as moving from A to B via a certain chosen routing purely for fun, activity and relaxation, as form of leisure activity.
(Tsai, Chen and Ning, 2015)

figure 8: Map showing the 5 locations that will be monitored during the behavioural mapping research: the park (right side) (1); the benches at the Willy Brandtlaan (2); the bus stop 'Ede Gelderse Vallei' (3); the entrance square (4) and the Radiotherapy group parking lot (5)

2.1.4. Results

The site analysis on different possible factors influencing social interaction possibilities has led to new information about the current state of the hospital premises and its surroundings regarding social interaction possibilities.

First off, a total of 28 SIL was counted for the research site. These include mostly benches and other resting spots but also some bus stops, playgrounds and natural areas or artworks. Secondly, an inventory of pavement quality according to a set of criteria based on the needs for elderly people to have sufficient walking comfort resulted in a map which accurately shows the pavement quality for each sidewalk in the present pedestrian network structure. When this map is combined with the map showing the locations of all available SIL it shows how multiple SIL are currently not or hardly reachable for elderly people (see figure 9). Of the 28 SIL available, only 10 are properly reachable by foot from the hospital entrance because of sufficient continuous pavement leads to these SIL. the other 18 are either unreachable (coloured red) or hardly reachable (coloured orange) because either the pavements surrounding it lack a sufficient quality level (1) or the pavement routing from the hospital entrance towards it stumbles upon a physical barrier like insufficient crossing or absence of sidewalk and there is therefore no direct sufficient routing to reach that particular SIL (2). From this can be concluded that 64% of all currently available SIL are not properly reachable for elderly and less mobile people and therefore do not or very little contributing to social interaction possibilities for these people.

From the behavioural analysis matrices, it can be concluded that most of the people within the target group that were observed practiced ‘transport walking’, which is a formal type of transport - going from A to B because it is necessary or mandatory for e.g. a check-up meeting in the hospital or picking up a relative. Transport walking is focussed on getting from A to B and leaves few space for social interaction. Informal activities, which in this case includes the behavioural activities ‘recreational walking’, ‘walking with a dog or child’ and ‘sitting on benches’ occurred to a lesser extent. It is these behavioural activities which are often linked to promoting social interaction (Honigh- de Vlaming, 2013). The current situation at the hospital site is thus mostly used for formal transport and not often for recreational and resting activities. The degree of social interaction possibilities in the current situation is therefore rather low.

From the information gathered in the behavioural analysis maps a general map showing the activity density of elderly people for all five analysed locations is created (figure 10). This activity density map gives insight in routing usage and which SIL are used most and which aren’t for the analysed areas. The map is generated from the amount of counted people in the target group for each location during the 30 minutes of measurement: green area’s indicate 0-30 people counted in 3 x 30 minutes, yellow areas indicate 30-60 people counted in 3 x 30 minutes and orange to red areas indicate over 60 people counted within 3 x 30 minutes. The places that have the highest activity density are used most frequently and therefore are most important to evaluate and improve where necessary regarding social interaction possibilities. In this case, these places are the main entrance, the square in the middle, the northern exit of the parking garage and the walking route from the entrance towards the bus stop and back.

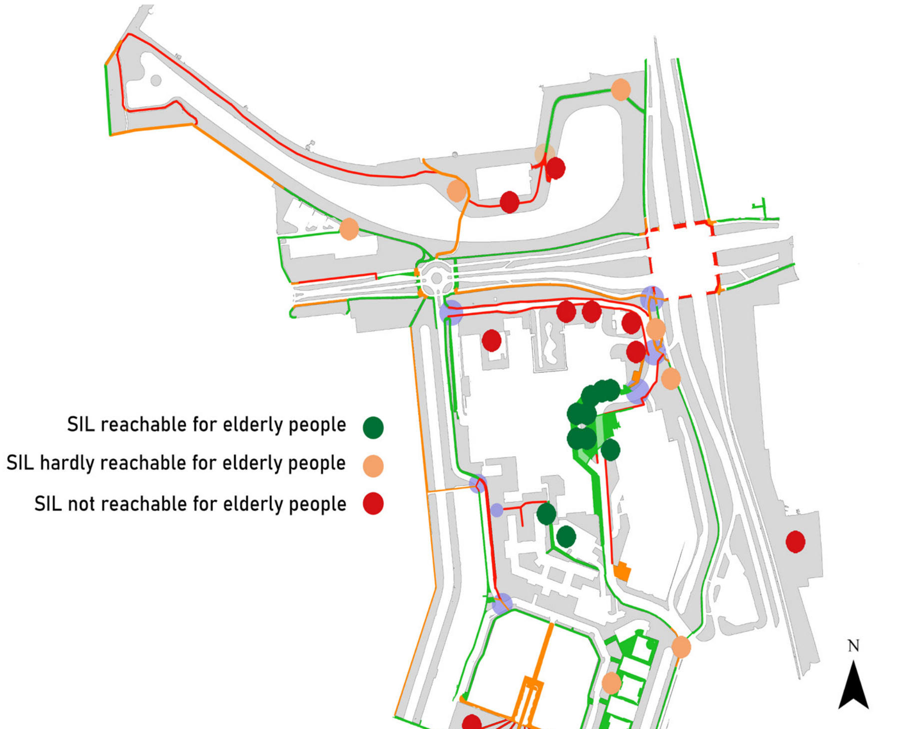


figure 9: Map showing reachability of existing SIL based on walkability and pavement quality

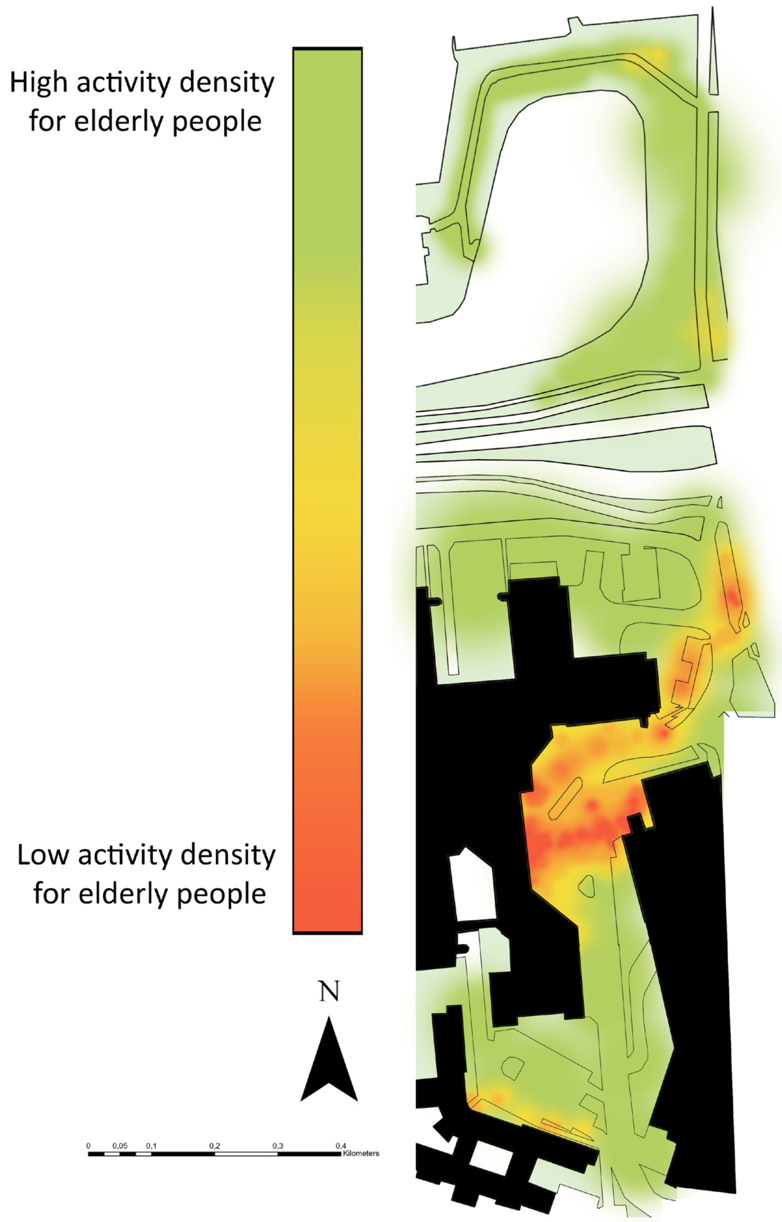


figure 10: Map showing the activity density of a part of the research site. Generated from knowledge found by behavioural research.

2.2. Barriers for social interaction

To understand more about the behaviour of elderly people regarding social interaction and why they would or would not participate in social interaction, it is important to understand the barriers they are facing to go outside/go to a SIL and actually engage in social interaction.

4. What are barriers for less mobile elderly people to go outside and have social interaction?

2.2.1. Physical barriers

During an interview study among elderly people, it was found that multiple age related health issues, such as physical impairments and visibility- or hearing disabilities were perceived by elderly people as barriers to go outside and interact with peers (Honigh-de Vlaming, 2013). Physical- and mobility impairments among elderly people directly leads to a lower physical activity average: only 37,7% of disabled elderly meet the activity guidelines of 150 minutes moderate intensity activity per week, compared to 49,4% for those without disabilities (Centres for Disease Control & Prevention, 2007). In general, neither of these groups (non-disabled elderly and disabled elderly) are close to meeting the recommended physical activity. Low activity increases the risk of developing more secondary impairments like physical pain, higher BMI and fatigues (Boslaugh & Andresen, 2006). Low activity also indicates fewer time spent outdoors, which means less options for social interaction (Sugiyama et al., 2008). The BEAMS study by Rosenberg et al. shows there are many physical barriers in the built environment that less mobile elderly people perceive as barriers and obstructions for going outside (Rosenberg et al., 2012). Lighting sources provide better visibility, especially important for elderly with visibility impairments. Good street lighting would also lower the barrier to go outside after sundown. Pedestrian comfort is perceived to be one of the most important barriers for going outside. Available sidewalks with smooth surfaces that are evenly levelled are important, especially for people walking with canes, walkers or in wheelchairs. Also, curb ramps are very important facilitators to access sidewalks. Insufficient curb ramp conditions can be real obstacles for elderly or impaired people. Another pedestrian barrier is the lack of crossing points in convenient locations, or dangerous crossings (f.e. due to low traffic visibility). According to the BEAMS study, elderly people often felt pressured to cross as quickly as possible which made them afraid of tripping and of drivers not noticing them crossing (Rosenberg et al., 2012). The latter is also defined as separate barrier; traffic in the area. Fast driving traffic and parked cars also frighten elderly and less mobile people to cross roads.

The weather also plays an important role in the decision to go out. Bad weather conditions such as hail, rain and intense heat or sun exposure frightened elderly people to either fall on slippery pavements (rain/hail), hypothermia (cold temperatures) or sun strokes and dehydration (hot temperatures). Amenities such as shaded resting places or rain shelters could improve this. Absence of resting places and public restrooms in general are perceived as barriers as well. Lastly, the aesthetic value of built environment and surroundings perceived by the elderly is also of relevance. Less concrete and more greenery (f.e. flowers, trees) in community gardens and play sites for children would stimulate elderly people to get outside and really enjoy their walk while also providing social interaction possibilities. (Rosenberg et al., 2012; van den Berg et al., 2020).

2.2.2. Psychological barriers

A study conducted by van den Berg et al. found that besides physical barriers, elderly people also experience psychological barriers preventing them to go outside and have social interaction (van den Berg et al., 2020). The most frequently stated psychological barrier is perceived (personal) safety – venturing outdoors alone makes elderly people feel vulnerable for crime, accidents and sudden health complications. Night-time safety in particular forms a barrier for elderly people to go out after dark. Perceived safety is particularly low in public open spaces such as community gardens, parks and squares. (Sugiyama & Ward Thompson, 2008).

Also, the presence of nuisance such as unattended dogs, youth hanging around and littering discourage people to go outside and take a walk. However, this can differ per perceiver due to personal character differences (Sugiyama & Thompson, 2008). Another psychological barrier is the ability of autonomy to go out. When elderly people perceive the built environment to be unsafe or uncomfortable to go out on their own, they will go out less. Outdoor spaces that are easy to navigate and move through enable elderly people to go out independently (van den Berg et al., 2020). Lastly, availability of social activities, or social interaction possibilities, is seen as promotor to go outside. Elderly people prefer environments that enable them to socialize with residents, friends or family. Organized events and activities like barbecues and picknicks could stimulate this as well. (Bengtsson & Carlsson, 2015; Tsai et al., 2016).

Multiple studies have shown various physical as well as psychological barriers for elderly people to go outside and participate in the community, have social interaction and be physically active. The listed physical and psychological barriers are included in the gathered design guidelines used later on in this research and presented in section 4.1.

2.3. Stimulating Social Interaction by Design

As the current situation regarding SIL on the research site and elderly pedestrian behaviour on site have been investigated and translated into analysis maps, a good understanding of social interaction possibilities and their popularity and accessibility on the research site is created. However, an understanding of the current situation is not enough to improve the current situation – for creating a design that promotes social interaction among elderly people it is vital to understand how to promote social interaction by implementing specific design characteristics. These characteristics often focus on providing a solution for physical or psychological barriers that are summarized in the previous chapter. This formed the interlude for the following research question:

5. What design implementations stimulate social interaction for elderly people?

To explore the different possibilities of design implementations, this section explores and combines multiple case studies that use design to promote social interaction.

In order to reach a social activity like interaction with a stranger or a relative, an 'encounter' is critical (Peters et al., 2009). Without encountering another individual, social interaction won't take place. In design, this means that creating places that stimulate encounters will enlarge the chances for social interaction. Another important thing to take in to account is the reputation of a place. Spaces acquire a reputation depending on the kind of activities that take place and feeling it generates among visitors (Holland, et al. 2007). This reputation has significant effects on the development and usage patterns of the place. A place which has a 'bad' reputation (e.g. high nuisance or unsafe environment) will be less attractive for visitors and thereby provide way less opportunities for social interaction.

"By creating areas where strangers can meet, urban design is able to counter some imbalances in the contemporary built environment... However, this is only possible when more attention is given to the design of … the spatial elements that enable it: edges, thresholds, paths, nodes and props. It is through these spatial elements that so many types of interactions among strangers occur in public space.'' -Aelbrecht, 2016 (P. 147)

A study by Aelbrecht argues that certain design aspects stimulate social mixing and interaction; edges, paths, thresholds, nodes and props like promenades, sitting structures, stairs and leaning edges provide a balance between comfort and openness, which stimulates social interaction (Aelbrecht, 2016).

Elderly people have different preferences for public spaces than for example young people have. According to Sugiyama & Ward Thompson, elderly people prefer recreational walking in public spaces, or neighbourhood open spaces, that provide a 'pleasant atmosphere' and a low level of 'nuisance' like rowdy young people, loose dogs and busy traffic (Sugiyama & Ward Thompson, 2008). Elderly people in general have the urge to avoid places that are highly used by young adults and children (Holland et al, 2007). Pleasantness of public spaces is derived from multiple factors. Firstly, good public facilities and amenities like resting spots or benches, public toilets and shelter are important. Also, there should be opportunities for children to play and for elderly people to have a chat (Sugiyama & Ward Thompson, 2008). Especially benches and resting places that provided 'something to look at' are popular among elderly people. (Holland et al, 2007). Having 'something to look at' is perceived as important factor for pleasant public space, as they encourage elderly people to stop and observe the surroundings and with it, provides opportunities for engagement. This could be activities related to other people, a viewpoint, a promenade or abundant wildlife scenery for example (Ward Thompson et al., 2007). This is also supported by Aelbrecht, who argues that designing spaces intended for 'people-watching' results in more inclusive spaces (Aelbrecht, 2016). Lastly, the public spaces that include water features like ponds, fountains or a brook as well as dense and quality greenspace are perceived to be more pleasant by elderly people (Sugiyama & Ward Thompson, 2008). The latter is supported by Dimitrova et al., who concluded that people who reside close to green spaces like parks and nature and spend a small amount of weekly time (> 1 hour) in this green space have a higher perceived social cohesion than people who did not spend time in the same greenspace (Dimitrova et al., 2017). Accessible greenspace thus contributes to stimulating social interaction. According to Peters et al, urban residents prefer urban parks over nature areas. They visit urban parks more often than nature parks (Peters et al. 2009).

A case study by Holland et al. found multiple design implementations that could stimulate social interaction and use of public spaces for elderly people similar to the findings of Sugiyama & Ward Thompson; good seating or resting spots, sufficient night lighting and available public amenities. They also concluded that the availability of parking lots stimulates social interaction. Car parking facilitates public space accessibility for less mobile people. However, parking lots should not be prominently present as this causes cars to overrule pedestrian traffic which lowers the amount of pedestrian visitors (Holland et al. 2007). Good public signage was also appointed as important factor for social interaction in public spaces, because it is informative and promotes way-finding towards public spaces (Holland et al. 2007).

2.3.1. Results

Multiple (case) studies have found certain design features that (de)stimulate social interaction in public spaces. The features that positively influence social interaction possibilities include creating leaning edges (1), thresholds, nodes and props (2) (Aelbrecht, 2016), pleasant atmosphere (achieved by including resting places, chatting places, night lighting, playgrounds and public amenities) (3) (Sugiyama & Ward Thompson, 2008), low nuisance levels (4) (Sugiyama & Ward Thompson, 2008), providing 'something to look at' (5) (Sugiyama & Ward Thompson, 2008; Aelbrecht, 2016), having water features (6) (Sugiyama & Ward Thompson, 2008), having dense and quality greenspace (preferably urban parks instead of rough nature) (7) (Sugiyama & Ward Thompson, 2008; Peters et al., 2009; Dimitrova et al., 2017), available, close by parking which is not prominently present (8) (Holland et al., 2007) and good signage (9) (Holland et al., 2007). These nine design features are listed and taken into account later on when setting up several design guidelines presented in section 4.1.

2.4. Conclusions

This chapter explored the properties of loneliness and social interaction possibilities on the research site, answering 5 of the 8 sub-design questions by doing literature research, examining case studies and doing site analysis. The results are summarized for each sub-design question in table 1 to give a clear overview of the results found in this chapter.

Table 1: Table showing all sub-design questions and the results for each one as found in chapter 2

Sub-design question	Results	Section
1. Where are the current locations providing social interaction possibilities for elderly people?	28 SIL are identified within the current research site, visualised in figure 4.	2.1
2. What is the current pedestrian routing quality from and towards these SIL?	3 types of pavement quality were defined and applied on all pavements in figure 6.	2.1
3. What does the current elderly pedestrian behaviour look like around busy places and their SIL on the site?	For 5 locations, behavioural analysis maps were made for 3 different times of the week, shown in appendix 2 and 3.	2.1
4. What are barriers for less mobile elderly people to go outside and have social interaction?	The physical barriers include *insufficient lighting; unsafe sidewalks; curbs and ramps; insufficient street crossings; fast moving traffic; availability of amenities; parking availability; weather conditions and aesthetics of the built environment* (Rosenberg et al., 2012; van den Berg et al., 2020). The psychological barriers include *perceived safety; lack of nuisance; perceived autonomy and availability of social activities* (Sugiyama & Thompson, 2008; Bengtsson & Carlsson, 2015; Tsai, Chen & Ning, 2016; van den Berg et al., 2020).	2.2
5. What design implementations stimulate social interaction for elderly people?	the design elements *leaning edges* (1), *thresholds, nodes and props* (2), *pleasant atmosphere* (3), *low nuisance levels* (4), *providing 'something to look at'* (5), *water features* (6), *dense and quality greenspace* (7), *close by parking* (8) and *good signage* (9) (Holland et al., 2007; Sugiyama & Ward Thompson, 2008; Peters et al., 2009; Aelbrecht, 2016; Dimitrova et al., 2017) all could contribute to improving social interaction	2.3

However, the spatial organisation of the physical environment is not the only factor influencing the usage patterns of SIL. The outside environment, or in this case **urban microclimate**, determines the response of people on the situation (Moonen et al., 2012). People constantly evaluate the weather and microclimate which influences for example their activity patterns and causes psychological adaption to the situation (Moonen et al., 2012). Bad microclimate conditions "*may distress people and lead them to avoid using these area"* (Nikolopoulou et al., 2003. P. 95). To understand, predict and thereafter manipulate urban microclimates gives humanity the power to improve our outside living climate to our advantage. Enhanced microclimates make the outdoor spaces, which we as humans depend on and spend time in every day, more comfortable and healthy to spend time in (Erell, Pearlmutter & Williamson, 2011). Healthy and comfortable outdoor spaces lead to less distress among people and therefore does not stimulate people to avoid these areas. This is especially important for resting places (like many SIL are), as they have a longer exposure time to a single microclimate environment due to longer stays (Nikolopoulou et al., 2003).

To elaborate on how the urban microclimate, especially (perceived) thermal comfort, influences social interaction and how thermal comfort could be improved, the next chapter will focus on researching such questions.

3. Urban microclimate: thermal comfort

"It is between the buildings that much social interaction takes place. Pedestrians passing in the street; people sitting on park seats, observing; a group waiting for a bus; a busker entertaining the shoppers; a couple sipping coffee on a café terrace; a fair with dodgem cars or a music festival: all are scenes that take place outside"

-Erell, Pearlmutter & Williamson, 2011 (P. 1)

Our experiences of the public environment, or 'outside', are largely influenced by urban microclimates (Moonen et al., 2012). Urban microclimate at the local scale is mainly affected by processes occurring in the atmosphere layers called the Urban Boundary Layer (UBL, from rooftops to the point where cities no longer affect atmosphere) and the Urban Canopy Layer (UCL, from the ground up to the tree- and rooftops: the "space where people live"). The processes in these atmospheric layers influence the perceived microclimate phenomena, which is mainly noticeable on street scale. Here, factors like sunlight, shade, ventilation (wind) influence the perceived urban microclimate (Erell, Pearlmutter & Williamson, 2011).

Thermal comfort is one of the physiological states regulating temperature in humans and other organisms. It is especially relevant for usage of outdoor spaces: "Thermal comfort forms an important factor for the usability and attractiveness of *outdoor places*" (Lenzholzer, 2010). Thermal comfort was described to be "*that condition of mind which expresses satisfaction with the thermal environment*" (American Society of Heating, Refrigeration and Air Conditioning (ASHRAE), 2010. P. 3). The definition indicates that thermal comfort is both formed by physical- and physiological factors as well as by psychological factors (Lenzholzer, 2010; Klemm, 2015). Therefore, design of the physical environment alone can not fully improve the thermal comfort of a location – thermal comfort is perceived differently per individual. However, research conducted by Lenzholzer found that some spatial configuration types (physical environment) are linked to certain indicators for specific microclimates (Lenzholzer, 2010).

Also, a design that does not take thermal comfort into account has a higher possibility of being unattractive to users because of a possible lower perceived thermal comfort (Nikolopoulou et al., 2003). Therefore, an attempt to find out about thermal comfort in the current microclimate of 'Ziekenhuis Gelderse Vallei' and how to improve this to increase user comfort will be done in this research. This will be done by creating a better understanding of how thermal comfort is perceived and what its indicators are. Secondly, research on the current thermal comfort at the research site will be done. This analysis will be translated to multiple design assessment criteria regarding thermal comfort of SIL, which will be used to assess the created concepts in chapter 6.

3.1. Thermal comfort indicators

So thermal comfort is dependent on physiological factors, physical factors and psychological factors (Lenzholzer, 2010). But what exactly are these factors? Physical indicators for perceived thermal comfort include air temperature (in degrees Celsius), air-movement conditions (wind), humidity and radiant temperature (emitted by surroundings). Physiological indicators for perceived thermal comfort include metabolism rates and clothing degrees, which differ per perceiver. Psychological factors also differ per perceiver and are influenced by the origin, birth place and cultural differences per person (Lenzhozer, 2010). Factors influencing thermal perception (psychological factors of thermal comfort) in outdoor spaces are width of public space, openness of public space and materialisation of public spaces (Lenzholzer, 2010). As stated, there is a direct correlation between the usability and attractiveness of outdoor spaces and thermal comfort (Lenzholzer 2010).

Similarly, section 2.2 about barriers for elderly people to go outside concluded that weather conditions such as too hot or too cold weather are perceived as significant barrier to actually go outside and go to a SIL (Rosenberg et al., 2012; van den Berg et al., 2020). Lastly, uncomfortable environmental temperatures can lead to thermal (heat) stress. (Epstein & Moran, 2006). Heat stress is the cause of direct physical health risks, especially for vulnerable groups like elderly people. Heat stress also causes thermal discomfort which affects activity and behaviour of people in urban environments (Klemm, 2018). To improve the quality of SIL, an inventory of the physical and psychological (perceived) thermal comfort at the research site can lead to insights and design assessment criteria for certain decisions regarding improving thermal comfort.

3.2. Thermal comfort at research site

Each urban microclimate has different thermal conditions because every place has a unique spatial variability. To understand the situational thermal conditions can prevent a "*careless site design which will rather worsen the thermal comfort than improve it* " (Klemm, 2015. P). To prevent this a site analysis is conducted according to the following question:

6. What is the current microclimate situation regarding thermal comfort within the site premises?

To answer this question, a site analysis for physical components of thermal comfort like shade and sunlight exposure, surface materialisation and vegetation structure will be done.

3.2.1. vegetation structure

The vegetation structure present on the research site is important because vegetation has a cooling effect (Shashua-Bar and Hoffman, 2000): vegetation often provides shading by blocking solar radiation, but also cools down ambient air temperature by evapotranspiration (Yang et al., 2017). Therefore, vegetation positively affects thermal comfort. The map in figure 11 shows the vegetation structure on the research site, with a distinction between low vegetation like grass and ground cover plants (soft green) and trees (bright green). This distinction is important because low vegetation has a lower evapotranspiration effect than trees (Stan et al., 2014).

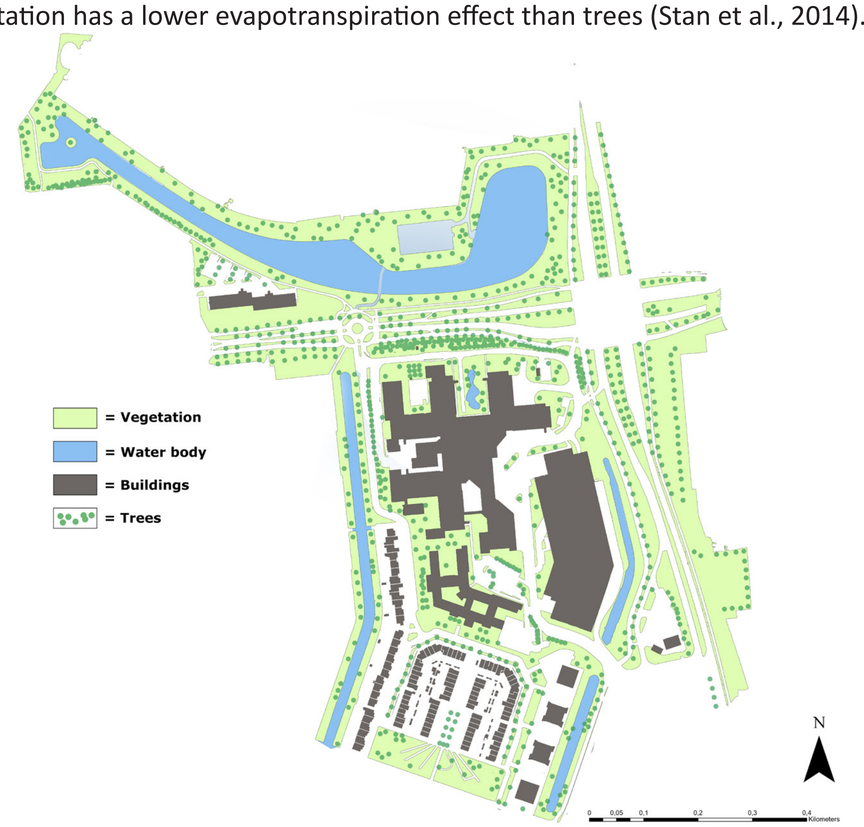


figure 11: a map showing vegetation structure within the research site, making a distinction between trees and low vegetation like lawns, public gardens or parks and bushes.

3.2.2. Surface materialisation

The materials of which the built environment consists largely influence the thermal storage of solar radiation. Every material has its own thermal properties depending on density, heat capacity and thermal diffusivity/admittance values (table 2) (Erell et al., 2011).

Table 2: Table of thermal properties of natural and man-made materials. The rows highlighted yellow represent the major surface groups present at the research site. Adopted from: Erell, Pearlmutter & Williamson. (2011). From: Oke (1987; tables 2.1 & 7.4).

Material	Remarks	ρ Density and (kg m^{-3})	c Specific heat and (J kg^{-1} K^{-1})	C Heat capacity and (kJ m^{-3} K^{-1})	k Thermal conductivity and (W m^{-1} K^{-1})	κ Thermal diffusivity and (m^2 s^{-1} × 10^{-6})	μ Thermal admittance and (J m^{-2} s$^{-1/2}$ K^{-1})
Natural soils:							
Sandy soil (40% pore space)	dry	1600	800	1280	0.30	0.24	620
	saturated	2000	1480	2960	2.20	0.74	2550
Clay soil (40% pore space)	dry	1600	890	1420	0.25	0.18	600
	saturated	2000	1550	3100	1.58	0.51	2210
Peat soil (80% pore space)	dry	300	1920	580	0.06	0.10	190
	saturated	1100	3650	4020	0.50	0.12	1420
Water	pure, at 4°C	1000	4180	4180	0.57	0.14	1545
Man-made construction materials:							
Asphalt		580	800	1940	0.75	0.38	1205
Building brick		1970	800	1370	0.83	0.61	1065
Concrete	dense	2300	650	2110	1.51	0.72	1785

In general, higher material masses result in larger heat storage and emission capacities. Thermal storage and emission effect surface temperatures and thereby also ambient air temperatures (Erell et al., 2011). The majority of the surface on and around the hospital premises is covered by streets and pavements, buildings or vegetation. The major soil type of the research site is "*vlakte van ten dele verspoelde dekzanden of loss*" (PDOK, 2020). This means the soil exist majorly of dry sand and loess particles. The major surface types of the research area are categorized and represented visually in a surface materialisation map (figure 12). The map makes a distinction between the natural surfaces *water and vegetation on soil* and man-made surfaces *asphalt, building bricks and concrete (pavement tiles)*. Buildings' roof surfaces are covered mostly in roof tiles, gravel or roofing felt.

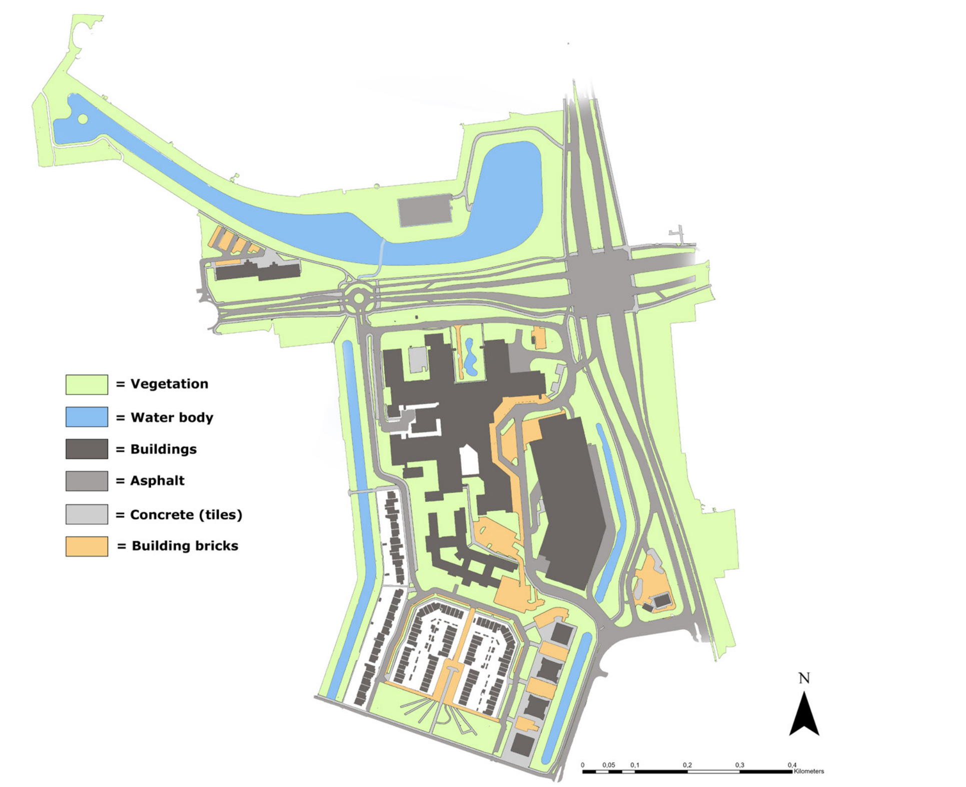


figure 12: a map showing the major types of surface materialisation within the research site. Private areas and patio's are not taken into account and left blanco

3.2.3. Shading and sunlight exposure

When structures provide shading, the surrounding surfaces (streets, walls, etc.) gain less temperature rise from solar heat. This reduces the thermal heat stored and radiated by buildings and surfaces (also called thermal storage) (Shashua-Bar and Hoffman, 2003; Erell, Pearlmutter & Williamson, 2011). Shading therefore provides a cooling effect on its environment. The coverage of the shade as result of the amount of penetrating solar radiation (sunlight) through the object determines the intensity of its cooling effect (Shashua-Bar and Hoffman, 2000).

To study shading patterns on the research site, a SketchUp model of the Hospital and its surrounding was made (figure 13). A simulation in this model showed accurate 3D visuals of the shading progression during average summer- and winter days.

From this model, several cross sections were made for locations in which multiple SIL are present (the same locations as the behavioural analysis was done for): the entrance square (A, fig. 14 & 15), the bus stop 'Ede- Gelderse Vallei' (B, fig. 14 & 15), the Radiotherapy group parking lot (C, fig. 14 & 15), and a long cross section from the Willy Brandtlaan (north of the hospital) all the way to the across the park north of the hospital (D, fig. 14 & 15). For each location, a cross section was made for summer- and winter days. This shows the seasonal differences for each location. The shading was recorded every two hours at four different times of the day, starting at 11:00 in the morning and ending at 17:00 in the afternoon. The cross sections provide three surface colours: red, orange and yellow. A red surface means high exposure to solar radiation. Surfaces coloured red are at no moment of daytime covered in shading. An orange surface means a moderate exposure to solar radiation. This means the surfaces coloured orange are covered in shade for less than 2 hours per day. Green surfaces represent a low exposure to solar radiation. These surfaces experience more than 2 hours of shading per day.

From the shadow analysis of multiple busy spots within the research site can be concluded that there are several "cool spots" and several "hot spots" on the research site. Cool spots are places which experience sufficient shading and therefore have a good thermal comfort due to low or mediocre solar radiation exposure. For the cross sections, these are surfaces coloured green. Hot spots are places with a low thermal comfort because they are too exposed to solar radiation during the day. For the cross sections, these are surfaces coloured red. The cool- and hot spots are different depending on the season.

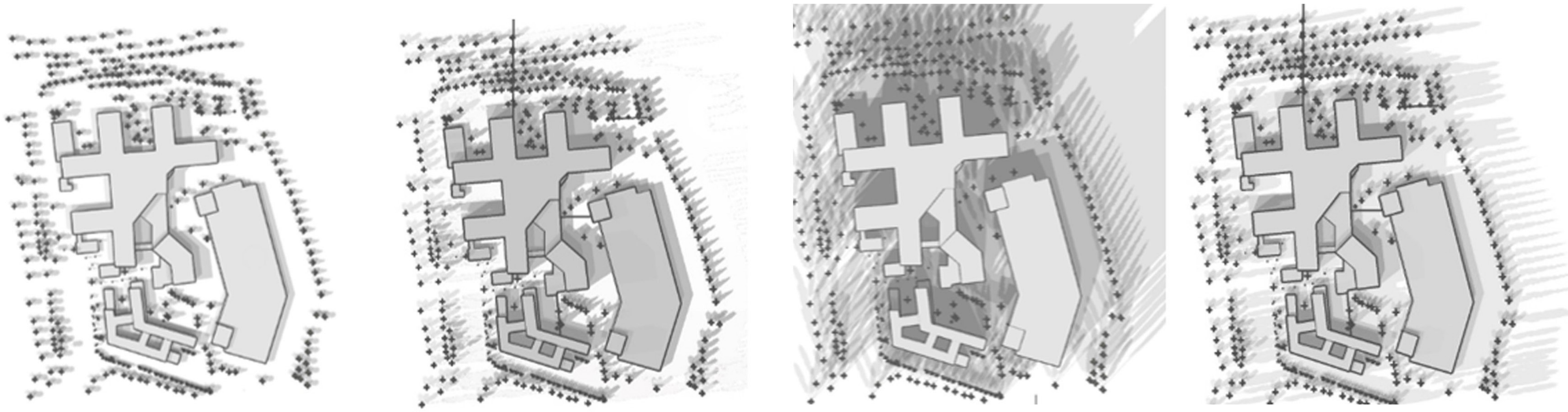


figure 13: the SketchUp model from above showing the shading progression for each season. From left to right: Summer, Autumn, Winter, Spring

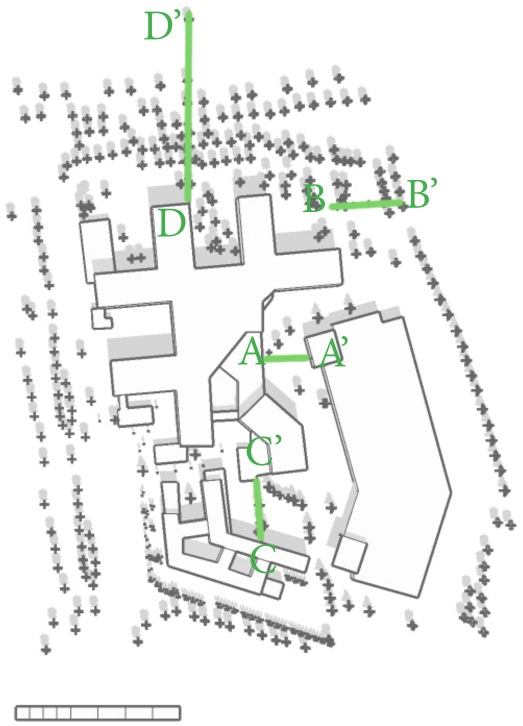


figure 14: SketchUp map showing all cross section locations (coloured green)

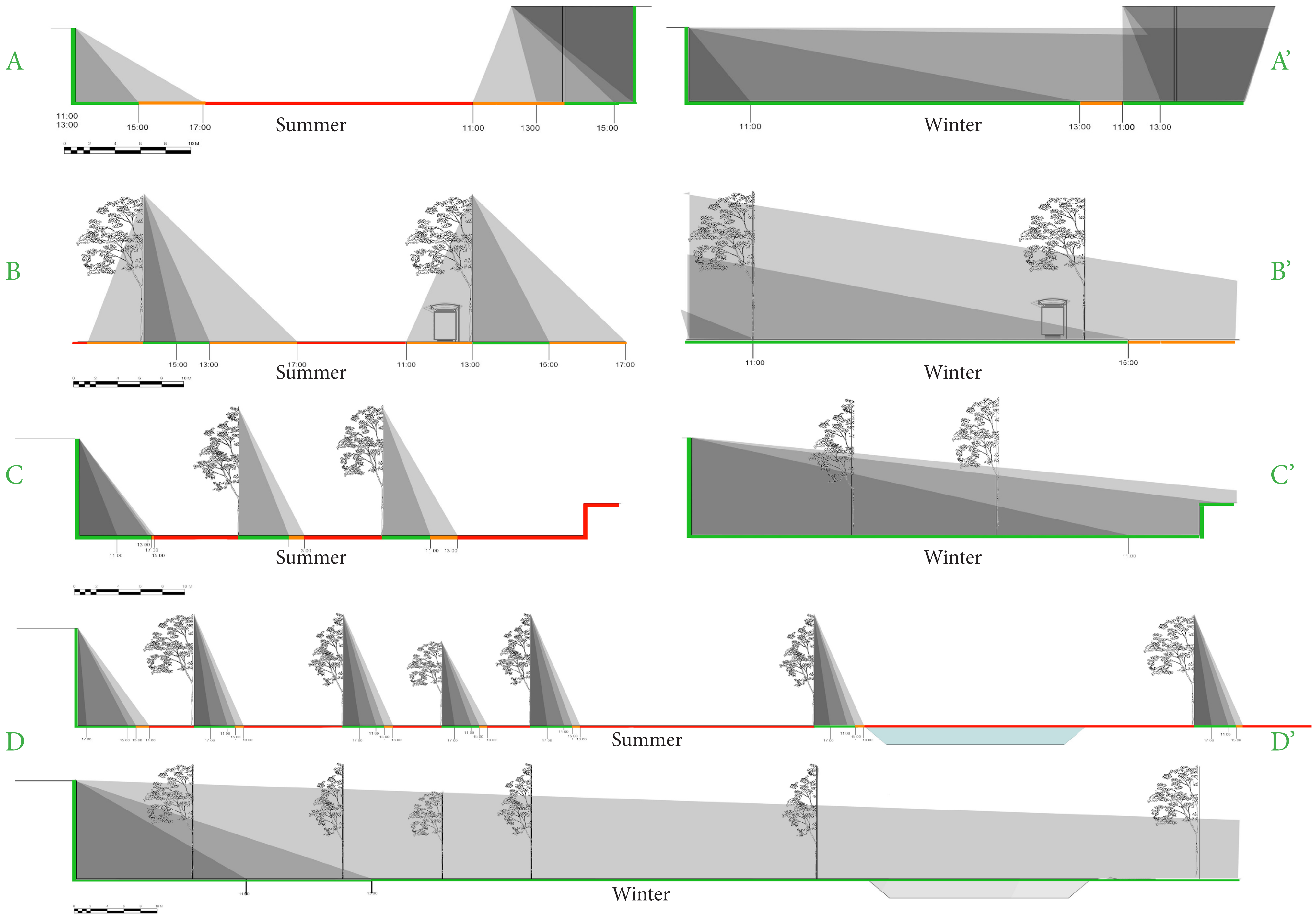


figure 15: summer- and wintertime cross sections of the four listed locations, showing the shading progression during daytime for both seasons and exposing 'hot spots' (red surfaces) and 'cool spots' (green surfaces) within these areas.

3.2.4. Results

From the analysis of physical components of thermal comfort shade and sunlight exposure, surface materialisation and vegetation structure a better understanding of thermal comfort on the research site is formed. To make a clear overview, a combination map is made which incorporates all three analysed physical components into one map for thermal comfort on site. As calculating exact values for every square meter is outside the scope of this research and this thesis does not possess the right quantitative data to do so, multiple assumptions are made to be able to easily combine the gathered knowledge into one map.

The first assumption in this thesis is regarding the effects of shading. As shade prevents solar radiation (which increases thermal storage), this thesis assumes that the less shading a specific location experiences during daytime, the higher the exposure is to solar radiation, which leads to a higher thermal storage and emission. More shading thus results in a positive effect on thermal heat.

Another assumption is done regarding different materialisations of surfaces. Different surface materials lead to differences in thermal storage per material. According to the properties given in table 1, concrete has the highest thermal admittance (measure for absorption and emission of heat for materials) and therefore has the highest negative influence on thermal comfort regarding materialisation. Concrete is followed by water, but due to water's high evaporation rates and low albedo effect (which gives water a high heat absorption capacity) it rather absorbs heat than emit heat – however, water does not have direct cooling effects on the direct environment, but due to the openness of water bodies provides more shading opportunities and improves ventilation which do cool down the ambient temperature (Jacobs, Klok et al., 2020). So in second place come building bricks instead, then asphalt, followed by water surfaces. Last but not least, the soil covered by vegetation has the lowest negative impact on thermal heat.

The last educated guess assumed in this thesis is that the shading and evapotranspiration caused by vegetation leads to cooling of surface- and air temperature and therefore has a positive effect on thermal heat.

With these assumptions, all gathered knowledge can be combined in the map shown in figure 16. The thermal heat map indicates the amount of thermal admittance and solar radiation for the specific location, based on evapotranspiration, thermal storage and sunlight exposure. The brighter the orange colour, the higher the thermal discomfort is. The deeper colour blue means a more comfortable thermal environment.

If this map is combined with the map showing SIL (figure 17), it can be concluded that 13 of the 28 current SIL on the research site are situated on a location where thermal discomfort is experienced. These are coloured bright red. SIL situated on a location with sufficient thermal comfort are coloured bright blue. It is remarkable that most of the SIL with bad thermal comfort are within the hospital premises and close to the entrance – all 8 SIL situated on the entrance square are coloured red. These are also the SIL that are used most (see SIL reachability map and activity density map (figure 9 and 10) in sub-section 2.1.4) despite the present urban climate conditions (low thermal comfort). This is a weak spot in the current design that should be improved to make the place more attractive and suitable for social interaction.

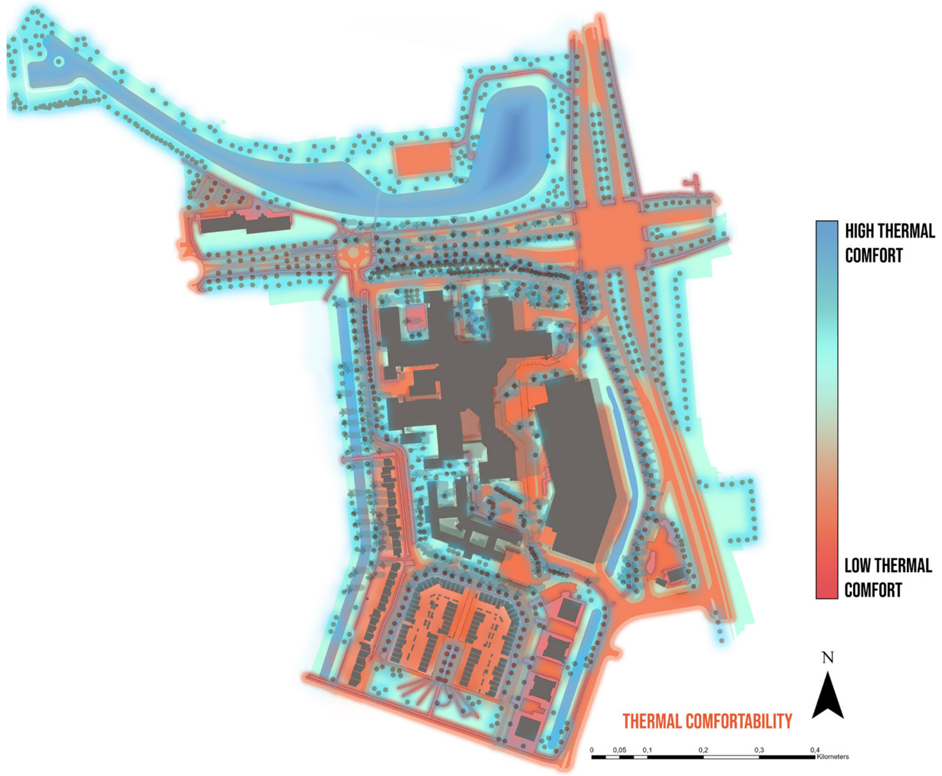


figure 16: general thermal comfort map, showing which locations experience high thermal comfort (blue) and low thermal comfort (red) as result of all physical components of thermal comfort

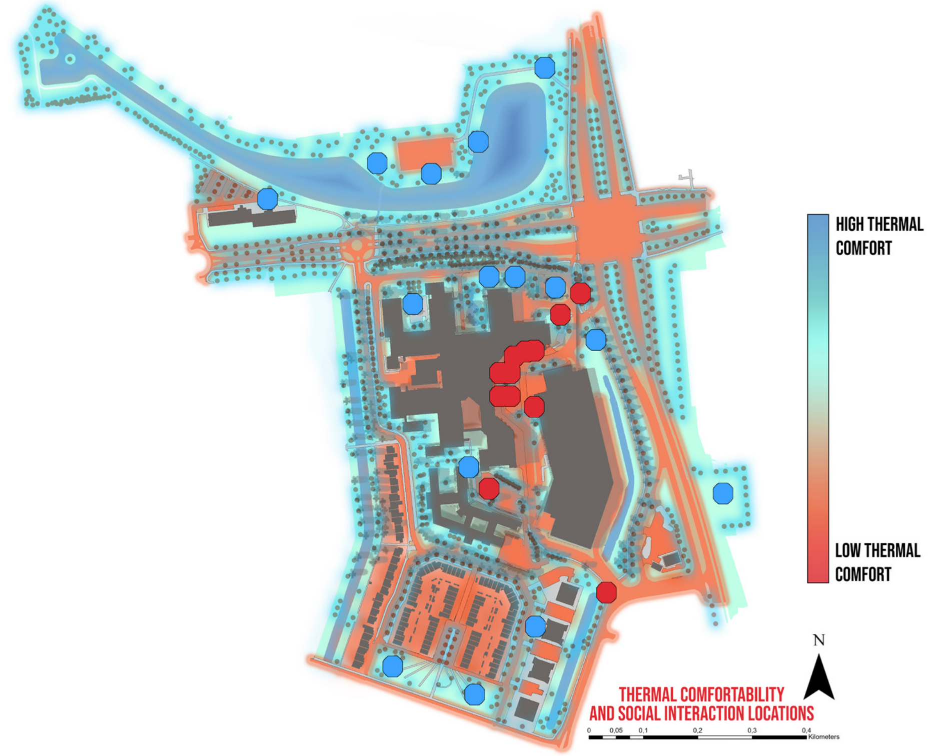


figure 17: map showing the current SIL within the thermal environment. Red dots mean SIL experiencing insufficient thermal comfort, blue dots mean SIL within places with a sufficient thermal comfort.

3.3. Improving thermal comfort

As the thermal comfort indicators on site have been investigated and translated into multiple maps, a better understanding of the specific hot- and cool spots within the research site is achieved. This led to the conclusion that 13 of the 28 current SIL are located in places with uncomfortable urban microclimates due to thermal discomfort. To improve the thermal conditions on these locations, an understanding of the design implementations that could possibly improve the current situation – by creating a design that provides sufficient thermal comfort and thereby makes the SIL located within the design more attractive and of higher quality for elderly people.

"Therefore, next to situational knowledge, landscape architects need general knowledge on how to improve the urban microclimate and residents' thermal perception"

- Klemm, 2018 (P. 16)

This will be done in this section, according to the following research question:

7. What design implementations improve thermal comfort in different urban spaces?

By examining multiple case studies on thermal comfort improvement by landscape design implementations, an answer for this question will be sought. As stated earlier, variety in spatial configuration largely influences the urban microclimate (in this case thermal comfort) (Lenzholzer, 2010; Klemm, 2018) and therefore also the implementation that affects thermal comfort per space. This research makes a distinction between three types of urban spaces in order to do a more specific investigation on design implementations for each type of urban space.

The three types are *Urban squares (1), Urban greenspaces (2) and Urban street canyons (3)*. Urban squares are defined as vast, open, public squares or plazas which are dominantly covered in hard materials like pavements or asphalt. Urban greenspaces are defined as urban green infrastructure within public spaces aimed to serve multiple purposes for the public like parks, tree lanes, green playgrounds and public gardens. Urban street canyons are defined as narrow public space mainly intended for living and transport that are in between multiple-storey buildings. Definitions are based on definitions used in research by Lenzholzer (2010) and Klemm (2018).

3.3.1. Design implementations for urban squares

Urban squares are often large open spaces, often called a 'void' by big architects and urban designers (Lenzholzer, 2010). This void of squares often comes with a high thermal discomfort. The vast openness offers few shading, few shelter from precipitation and wind and a low spatial variety, causing few different urban microclimate options. The openness also creates sudden options for wind fluxes bringing heat from urban street canyons to the squares (Lenzholzer, 2010). Squares are often covered in hard, impermeable surfaces like concrete, stone and metals. These surfaces have a high heat capacity and high thermal storage (Erell, Pearlmutter & Williamson, 2011). In combination with the high exposure to solar radiation, squares often have harsh microclimates with high thermal discomfort (Lenzholzer, 2010). This asks for design adaptions to improve thermal comfort in urban square environments. In a study conducted by Lenzholzer, multiple design implementation recommendations to improve urban thermal climate for squares are suggested, such as: spatial objects to break the openness of big squares and create more diversity and less 'void' on squares. (e.g. by planting trees, sculptures, furniture and shading structures) (1); Breaking the openness of squares can also resolve the low thermal comfortability if the breaking objects also reduce solar radiating by providing shade, vegetation or water features like fountains or ponds (2); The various created microclimate situations should also provide resting places like benches or seating, so people can stay longer if desired (3); The materialisation of the urban square should also be thought of; use of more 'warm' materials (low albedo & high heat conductivity) like wood, textile and vegetation will result in higher perceived thermal comfort (4) (Lenzholzer, 2010).

3.3.2. Design implementations for urban greenspaces

Urban greenspaces in general are linked to multiple solutions for environmental challenges like urban heat islands, air pollution and water regulation (Klemm, 2018). Greenspaces improve thermal comfort because the vast amount of vegetation and water surfaces present provide shading and evapotranspiration, making urban greenspaces popular cool spots. The cooling effect of urban greenspaces is highly depending on the spatial configuration patterns of vegetation and water features (Li, Zhou, 2019). In a case study by Klemm (2018), multiple design guidelines for spatial configuration of urban greenspaces regarding improving thermal comfort suggest creating a *"variety of solar exposure conditions"* (Klemm, 2018. P. 88) to improve perceived and physical thermal comfort (1). By creating a shading ratio for a park were 40% of the locations are shaded, 20% partially shaded and 40% of locations is sunny, this variety can be achieved. The shaded, partially and sunny spots should be alternately scattered within the urban greenspace, creating a 'patchwork pattern' of sun and shaded spots (2). This can be done for example by creating edges or height differences. Opting autonomy in creating own thermal comfort (3) is also advised, by creating multi-functional spaces and rather empty spaces like terraces or lawns (Klemm, 2018).

3.3.3. Design implementations for urban street canyons

Urban street canyons are a common phenomena in cities experiencing urban heat problems. Relatively narrow streets enclosed between multiple story buildings create a 'canyon-structure' which contribute to urban thermal discomfort because street canyons have a high thermal storage due to the large sum of hard surfaces (streets and walls), have a smaller sky-view factor due to their narrowness (figure 18) which reduces the heat release during night-time and lastly reduce ventilation options by blocking air fluxes (Kusaka & Kimura, 2004; Erell, Pearlmutter et al. 2011). Urban heat in street canyons is also influenced by the street orientations, amount of anthropogenic activity (anthropogenic heat flux) and height-to-width ratios (Hotkevica, 2013).

Urban canyons therefore ask for design implementations that improve one of these factors to reduce thermal discomfort. Street greenery can have a positive impact in urban street canyons because they provide shade and evapotranspiration which increases air humidity and decreases ambient temperatures. Street greenery also improves the perceived thermal comfort on short term (Klemm, 2018). Examples of street greenery at multiple height levels and their climate benefits: (high) trees provide shade/ reduce solar radiation and lower ambient air temperature by evapotranspiration.

Especially deciduous trees with high canopies enlarge thermal comfort as well in summer- as winter time because they lose their leaves during the cold seasons and block less wind fluxes than coniferous tree species; vines and climbing plants provide shading, reduce solar radiation reflection and provide insulation effects; plants next to buildings lower air temperatures next to the building walls, reducing thermal storage and humidity of the walls; ground cover plants reduce solar radiation reflection and thermal storage of surfaces (Hotkevica, 2013; Klemm, 2018). Creating diverse microclimate situations in streets can also enhance peoples autonomy to choose their preferred environment (shade or sunlight) (Klemm, 2018).

Next to reducing solar radiation and reflection effects, ventilation should also be considered. Good ventilation of street canyons can reduce vertical mixture of atmosphere layers and sweep out particulate matter emitted by anthropogenic activity (Hotkevica, 2013). However, trees and vegetation as well as street orientation and H/W ration block ventilation up to 60% of the possible wind speed. To stimulate ventilation, a sufficient distance between trees can prevent blockage of wind. But this goes at cost of the amount of trees and thus shading in the canyon (Hotkevica, 2013). A good balance between tree frequency and climate effects should be considered for designing thermally comfortable streets and urban canyons.

Lastly, the usage of permeable surfaces such as gravel and sand rather than asphalt (impermeable) where possible could also positively affect thermal comfort in street canyons as water is able to cool down the surface by dripping through the pores (Chen et al., 2019).

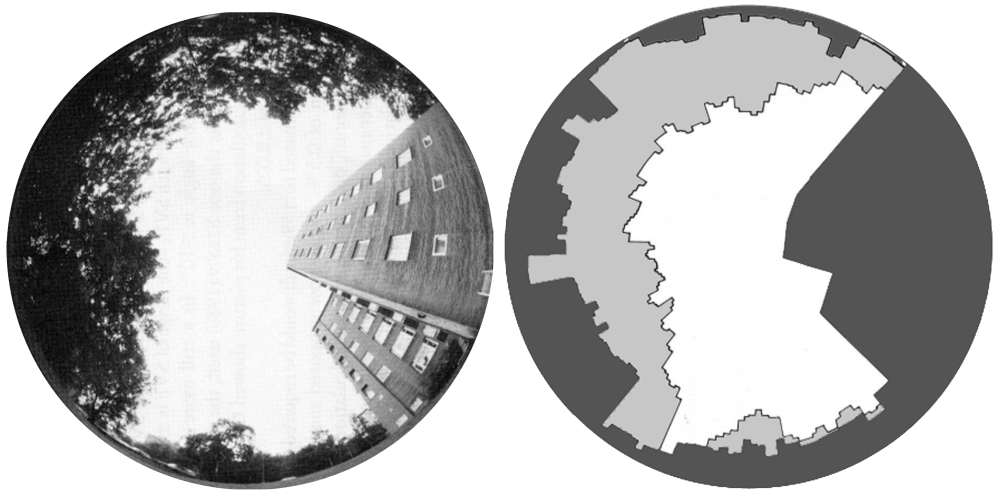


figure 18: An example of a sky-view in a street. The higher the buildings and the more narrow a street, or the higher a Height-Width ratio, the lower the sky view factor. This means a lower heat release during night time and thus higher temperatures in the related street canyon. Adopted from Holmer (1992).

Previous research done on this subject has resulted in multiple design implementations that could improve thermal comfort in different urban spaces like urban squares, urban greenspaces and urban street canyons. Many implementations suggest adding and ordering specific types of greenspace, materialisation types for surfaces (walls and floors) and certain design patterns that improve thermal comfort. These suggested design implementations will be translated to design assessment criteria in chapter 4.

3.4. Conclusions

Chapter 3 has focussed on how (perceived) thermal comfort influences social interaction and how thermal comfort could be improved, answering sub-design questions 6 and 7. First, the indicators for thermal comfort and perceived thermal comfort were listed in section 3.1. In the next section (3.2) a broad site research was done on different physical aspects of thermal comfort, as design mainly focusses on the physical realms of the (built) environment. In section 3.3, design implementations for improving thermal comfort in different types of urban spaces were sought after. Multiple were found. All found results are summarized: for each sub-design question in table 3 to give a clear overview of the results found in this chapter.

The knowledge aqcuired in this chapter provides answers for sub-design question 6 and 7. This concludes the knowledge questions and with it, the research for design phase of this thesis research. A large part of the knowledge gap to answer the design question is bridged.

However, multiple question still remain unanswered. Thats why the second part of this thesis is going to focus on answering these questions by means of reserach through designing. The generated knowledge will be translated to some design guidelines and assessment criteria sets in chapter 4. With these, this thesis aims to turn spatial concepts into a new (re)design for the research site where the generated knowledges is applied in landscape architecture. In this way, the knowledge can be applied after being generated which will help answering the main design question of this research.

Table 3: Table showing all sub-design questions and the results for each one as found in chapter 3

Sub-design question	Results	Section
6. What is the current microclimate situation regarding thermal comfort within the site premises?	Multiple physical factors influencing thermal comfort were found and analysed on the research site, resulting in maps on vegetation structure, materialisation type and shading progress. This led to a map for general thermal comfort on site.	3.2
7. What design implementations improve thermal comfort in different urban spaces?	Design implementations for improvement of thermal comfort in urban squares include: *spatial objects to break the openness* (1); *Include shading features, vegetation or water features* (2); *provide resting places* (3); *use of more 'warm' materials like wood, textile and vegetation* (4) (Lenzholzer, 2010). Design implementations for improvement of thermal comfort in urban greenspaces include: *creating a variety of solar exposure conditions by applying a shading ratio (40% shaded - 20% partially shaded - 40% sunny)* (1); *creating a 'patchwork pattern' of sun and shaded spots* (2); *opting autonomy by creating multi-functional spaces* (3) (Klemm, 2018). Design implementations for improvement of thermal comfort in urban canyons include: *having street greenery at multiple levels (as well vertically as horizontally)* (1); *consider a good balance between tree frequency and climate effects* (2); *Usage of permeable surfaces* (3) (Hotkevica, 2013; Klemm, 2018; Chen et al., 2019).	3.3

4. Design guidelines & Assessment criteria

In the previous chapters, the relation between SIL, loneliness and thermal environment were explained, elaborated on and applied on site research by means of research for design (the first phase of this thesis research). All this gathered knowledge will be categorized in two groups which will both be crucial in the second phase of this thesis research; research through design. The two categories are 1) Design guidelines and 2) Assessment criteria. In this thesis, the knowledge generated in chapter two (Loneliness and social Interaction) is translated to design guidelines, which will be leading in forming different design choices and solutions in chapter 6 and design details in the final design. The knowledge generated in chapter three (Urban microclimate – thermal comfort) is translated to assessment criteria. The latter will be used to assess concepts and design choices. A distinction is made between concept assessment criteria (1), which are more general criteria and go less into detail, and design assessment criteria (2) which are more focussed on design details and features. With concept assessment the aim is to pick the concept that fits best in line with the research goal: **to improve the accessibility and thermal comfort of SIL on and surrounding the premises of 'Ziekenhuis Gelderse Vallei' to improve social participation among elderly people, possibly reducing loneliness among the target group.** This will be done in chapter 6. To create a clear overview of all generated design guidelines and Assessment criteria, this chapter focusses on listing them in a logical, manageable and applicable order.

4.1 Design guidelines

The design guidelines are created from the knowledge gathered in chapter two. The design guidelines will combine some specific design implementations proposed in chapter two that serve similar purposes. In order to reorganise the gathered data, first all data is listed and linked to the section in which the knowledge was gathered:

Sub-section 2.2.1 Physical barriers for Elderly people:

- *insufficient lighting*
- *unsafe (narrow, rough and/or sloped) sidewalks*
- *absence of pavement curb ramps*
- *insufficient street crossing safety due to lack of traffic visibility or traffic lights or crossing time*
- *fast moving traffic nearby*
- *availability of amenities like shelter, resting spots, toilets and drinking fountains*
- *parking availability*
- *weather conditions*
- *insufficient aesthetical appeal of the built environment (no water features or well maintained greenspaces)*

Sub-section 2.2.2 Psychological barriers for Elderly people:

- *perceived (night-time) safety*
- *lack of nuisance*
- *perceived autonomy*
- *availability of social activities.*

Section 2.3 Stimulating social interaction by design

- *creating leaning edges*
- *creating space for thresholds, nodes and props*
- *acquire a pleasant atmosphere (achieved by including resting places, chatting places, night lighting, playgrounds and public amenities)*
- *providing low nuisance levels*
- *providing 'something to look at'*
- *having water features*
- *having dense and quality greenspace (preferrably urban parks > rough nature)*
- *providing available, close by parking spaces which are not prominently present*
- *providing good signage*

All this knowledge is combined into 6 design guidelines. They are summarized below and an explanation and matching icon are provided for each design guideline. Where possible, features improving the thermal comfort will also be taken into account in these design guidelines. A design which improves the accessibility and thermal comfort of SIL on and surrounding the hospital premises to improve social interaction possibilities for elderly people should:

1. Provide a suitable pedestrian network structure for elderly people

The hospital buildings should be connected to the SIL by a network of broad, levelled and smooth surfaced sidewalk network that includes curb ramps and clear crossing places where needed in order to get elderly and less mobile people from the hospital to SIL and back. Where possible, big (motorized) traffic fluxes should be avoided and the amount of big crossing points minimalized. This should increase the walkability (accessibility) of SIL for elderly people. Where possible, permeable surfaces should be used to contribute to improving thermal comfort. See figure 19a.

figure 19a: Icon representing the suitable pedestrian network for elderly people.

2. Provide public services and amenities

The design should have amenities and social features that increase the services for visitors and therefore increase visitor comfort. Places that provide shelter for extreme weather conditions, public toilets, trash bins and drinking fountains (water points) should be incorporated in the design. Also, services for accompanying children and dogs like playgrounds and DogDepot trash bins should be taken into account. Close by parking spots should be available and connected to the pedestrian network structure. See figure 19b.

figure 19b: Icon representing public services and amenities.

3. Promote organised social interaction and autonomy

The design should provide options for having organised events for the community aiming to increase social cohesion and interaction like neighbourhood barbecues, picknicks, outdoor workshops and outdoor concerts or readings. Follies or open fields or stages could provide spaces for this. Also, clear signage should be provided at nodes and crossing points to increase elderly autonomy. See figure 19c.

figure 19c: Icon representing organised events and autonomy among elderly.

4. Provide various attractive and reachable SIL

The design should provide a high variety of types of SIL in different locations and thermal environments. Variation in type and environment give elderly people the autonomy to pick their preferred SIL environment and location. This could be resting places like benches, sitting stones and edges, but the design should also create space for certain nodes, props and thresholds as they also contribute to social interaction. Design features like stairs, leaning edges, promenades and sighting points could provide this. The SIL should be located close to the pedestrian network structure to maximize their reachability. Where possible , the use of porous and warm materials like wood should be used to increase thermal comfort. See figure 19d.

figure 19d: Icon representing various attractive SIL.

5. Help increase perceived (nighttime) safety

Design features like continuous night lighting along the pedestrian network structure and absence of fast moving traffic and complex crossing points should increase the perceived safety experienced by elderly people. Also, minimising chances for impoverishment and nuisance by e.g. hanging youth contributes to increased perceived safety, which can be done by avoiding spaces that are visually closed off and provide lighting on meeting places and sport fields. See figure 19e.

figure 19e: Icon representing perceived (nighttime) safety.

6. Provide an aesthetically appealing environment

The design should incorporate well maintained and attractive outside environment features like water features, fountains, dense (park -like) greenspaces and flowers. Also, providing 'something to look at' contributes to the likes of elderly people as it provides amusement and a common subject of conversation. Where possible, different types and heights of vegetation should be considered as it contributes to good thermal comfort. See figure 19f.

figure 19f: Icon representing an aesthetically appealing environment.

These design guidelines will be leading in making design choices in chapter 6, creating a new design for the research site and will be aimed to all be incorporated in the final masterplan (chapter 7) to ensure an improvement regarding social interaction possibilities for elderly people on the research site. The next section will focus on defining design- and concept assessment criteria from the gathered knowledge in chapter 2 and 3.

4.2 Assessment criteria

This thesis divides the assessment part in two phases. In phase one, multiple assessment criteria derived from important findings in the analysis (chapter 2 & 3) are used to assess the concepts in chapter 5. In phase two, more specific assessment criteria which are derived from the analysis on thermal comfort are used to assess design choices made in chapter 6.

4.2.1 Concept model assessment criteria

For assessing concept models, a set of relatively broad assessment criteria is needed as concept models do not provide design choices yet. Concepts are merely a framework in which the design is created. Therefore, this thesis utilizes seven criteria which have been highlighted as important factor for creating a site design that stimulates social interaction among elderly people earlier throughout this research (in chapter 2 and/or 3). These seven concept model assessment criteria are:

- *Walkability (physical accessibility)*
- *Thermal environmental variation*
- *Physical environmental variation*
- *High user density*
- *Thermally comfortable locations*
- *Low nuisance levels*
- *High feasibility*

These assessment criteria are measured according to the analysis results and by expert judgement. To give more insight in why these assessment criteria are chosen and how they are measured, a more in-depth explanation per criteria is provided:

1). The walkability is the physical accessibility for elderly people to be able to reach the SIL from the hospital exits and also return without struggling to cross a road or walk, get on or off a pavement. A good walkability lowers the barriers to go from and towards SIL's. This includes having proper pavement structures built for elderly and less mobile people as found in sub-section 2.1.3 (Rosenberg et al., 2012; van den berg et al., 2020). This will be measured by the quality of current pavements in the area. However, This is alterable later on in the design phase. Because this is regarded as one of the most vital criteria, it is counted double (x2) in the phase 1 assessment matrix (see table 2).

2). The thermal environmental variation is a mixed or patched pattern of shading, half-shade and sunny spots, which creates places with differences in thermal comfort (Klemm, 2018). This variation is important because it allows people too chose their preferred microclimate environment, as found in section 3.3. This is measured by the degree of variation in shading during summer- and wintertime (figure 13 & 15). Because this is regarded as one of the most vital criteria, it is counted double (x2) in the phase 1 assessment matrix (table 2). This is alterable later on in the design phase.

3). The physical environmental variation is the degree of variety in physical structures in the surroundings like urban canyons or squares, neighbourhood area's or greenspaces. They are measured by the presence of different types of physical environment.

4). A high user density in places improves the chances of an encounter occurring between users of the space, which is vital for having social interaction (as found in section 2.3). This is measured by looking at the behavioural maps for certain locations.

5). To have thermally comfortable locations means to provide a higher attractiveness and comfortable urban microclimate, which lowers barriers for elderly people to visit the SIL and stimulate longer stays (as found in section 3.3) (Lenzholzer, 2010; Klemm, 2018). This is measured according to the overall map for thermal comfort (figure 16). Thermal comfort is alterable later on in the design phase.

6). Low levels of nuisance also lower another barrier for elderly people to visit SIL's and therefore stimulate social interaction among them, as found in section 2.2 (Rosenberg et al., 2012; van den berg et al., 2020). Nuisance is measured by looking at the chances of hanging youth, developing deserted, impoverished places and loose dogs walking there.

7). A high feasibility is important actually carry out design plans. Feasibility is measured in this thesis by the degree of design implementations; a concept with few/smaller necessary changes is regarded more feasible than a concept which implies many/heavy necessary design implementations to achieve success. Because this is regarded as one of the most vital criteria, it is counted double (x2) in the phase 1 assessment matrix.

The concepts will be assessed according to the concept assessment matrix (table 4). The grading systems works as follows: for each criterium, a score is given ranging from -2 to +2. -2 is the lowest score (the criteria is not represented in the concept model), whilst +2 is the highest score (the criteria is optimally represented in the concept model). A score of 0 means a neutral score, e.g. the concept is represented but does not influence the concept model. (x2) for a criteria means the criteria is counted double for the final score as the criteria is regarded to have a bigger impact and importance. The concept with the highest total score fits best to achieve the design goal of this thesis according to the criteria. This concept will then be worked out further in detail in the design phase.

Table 4: concept assessment matrix showing the 7 assessment criteria and their weight for the final score. Every concept model will receive X amount of points for every category. All points will be added up at the end to determine the final score for each concept.

Model X					
Assessment Criterium:	Points				
	-2	-1	0	+1	+2
Walkability (physical accessibility) (x2)					
Thermal environmental variation (x2)					
Physical environmental variation (x1)					
High user density (x1)					
Thermally comfortable locations (x1)					
Low nuisance levels (x1)					
High feasibility (x2)					
Total score					

4.2.2 Design assessment criteria

The second phase serves to assess design choices made for the final design. As the design should already have incorporated all design guidelines on improving social interaction possibilities, these criteria purely focus on assessing thermal comfort of certain design choices to ensure a good thermally comfortable environment is maintained or created if not yet present.

In chapter 3, the relation between social interaction and (perceived) thermal comfort was explained, elaborated on and applied on site research. This resulted in multiple seasonal bound cross sections of shading patterns for 4 relevant site locations, shading pattern maps (3.1.1); analysis maps for the major surface materialisation within the research site (3.1.2) and a map showing the vegetation structures and its effects on thermal comfort (3.1.3). The gathered site-specific knowledge was combined to an overall map for thermal comfort on site (3.1.4). Also, design implementations that could improve (perceived) thermal comfort on physical and psychological perspective were summarized and listed (3.2). All this information is combined to 4 general assessment criteria for thermal comfort within design choices. Also, a fifth criteria is added, which is different depending on the type of urban space in which the design implementation is located (criteria 5A, 5B and 5C). An elucidation is provided for each assessment criteria. As most design solutions for improving thermal comfort are relatively small design implementations, feasibility is not taken into account here.

To assess the design choices made in chapter 7, the design concepts should meet the following criteria regarding thermal comfort of the urban microclimate:

1). The design solution should incorporate street greenery on multiple height levels and as well horizontal as vertically to reduce thermal storage and increase shading, material humidity and evapotranspiration.

2). The design solution should incorporate multiple resting spots/ furniture made out of 'warm' materials to improve thermal comfort and promote longer stays.

3). The design solution should provide both sunny and shaded spots according to the shading ratio (40% shaded, 20% half-shaded, 40% sunny) and a patchwork pattern to optimize (perceived) thermal comfort within the urban greenspace.

4). The design solution should make use of permeable surfaces where possible to reduce stored and emitted heat in canyons

5A). The design solution should provide spatial objects that provide some shading and break the openness and wind fluxes of the square, creating diversity in urban microclimates. (specifically for Urban squares)

5B). The design solution should leave room for open and multi-functional spaces for people to autonomously create their own thermal comfort. (specifically for Urban greenspaces).

5C). The design solution should consider a good balance between tree planting frequency and climate effects like shading and wind blockage. Trees used should be deciduous trees with high canopies to optimise thermal comfort. (specifically for Urban canyons).

The design assessment criteria will be applied according to the design assessment matrix (table 5). The fifth criteria has double the weight (x2) in the assessment as it is specific for that type of urban space and therefore is more important to incorporate than the 4 general assessment criteria, which weigh as (x1). For each solution, a score is given per criteria. This can be '-' (negative (= criteria not met)), '0' (neutral) 'or '+' (positive (= criteria is met)). The solution with the highest score at the end, or most '+', is the solution that fits best and the one that will be used in the final masterplan in chapter 7.

Table 5: design assessment matrix showing the 5 assessment criteria and their weight for the final score for each solution. (x2) means the criteria is counted double for the final score as the criteria is regarded to have a bigger impact and importance.

Location X (type of urban space)	Scores (+/-)		
Design assessment criteria	Solution 1:	Solution 2:	Solution 3:
1. Incorporate different levels of greenery (x1)			
2. Include resting spots made of 'warm materials' (x1)			
3. Provides sunny/shading spots in a patchwork pattern (x1)			
4. Uses permeable surfaces where possible (x1)			
5A/B/C. specific to type of urban space (x2)			
Total score			

In this chapter, six design guidelines and two sets (one for assessment phase 1 and one for assessment phase 2) of multiple assessment criteria were derived from knowledge generated in chapter 2 and 3 of this thesis research. The assessment criteria are listed in assessment matrices (table 4 & 5). In the next chapter, three different spatial concepts will be made for the research site. These concepts will be assessed according to the concept model assessment criteria to pick the concept that is most suitable to solve the problem stated at the start of this research.

5. Conceptualisation phase

To improve the social interaction possibilities for elderly people, a better connection between SIL and the target group (elderly people) should be established. Therefore, SIL distribution and access routing are very important and should be leading in forming different spatial concepts.

5.1 Concept building

To explore the different opportunities for SIL distribution and routing, three concepts models are created with various distribution patterns: a scattered SIL model (1); a clustered SIL model (2) and a SIL routing model (3).

5.1.1. Scattered SIL concept model

This model (figure 20) has a widespread and evenly distribution of different SIL over the whole research site area. It looks a bit similar to the current SIL distribution. In this way, the highest environmental variation (as well physical as thermally) can be reached. It also stimulates autonomy among elderly people by giving them many choices in which SIL they want to go to and which routing they use to go there. A possible problem in this model will be properly connecting all SIL to the hospital buildings without negatively influencing current mobility services for traffic. This is also a big design implementation which lowers the feasibility.

5.1.2. Clustered SIL concept model

Fairly opposite to the scattered SIL model, the clustered SIL model (figure 21) proposes to create one or several clusters of SIL somewhere in the centre of the research site. By doing so, the SIL are very easily reachable because they are close to the hospital buildings and sufficient pedestrian routing is present already. It also creates an even larger user density than is already present. This will enlarge encounter chances. However, too high density can also cause chaos and nuisance for elderly people. A possible problem this model could be facing is improving the current thermal comfort present in the central area of the research site, without negatively influencing current mobility services for traffic – bus lines, taxi's and ambulances can not be avoided.

5.1.3. SIL routing concept model

Kind of a hybrid form between the previous two concept models, the SIL routing model (figure 22) focusses on creating a walking route specifically designed for elderly and less mobile people, which is surrounded by various types of SIL. In this way, a relatively high environmental variation is maintained whilst also increasing accessibility by prioritizing pedestrian movement above other traffic forms. The route will surround the main hospital building and also cross to the park up north. A possible problem this model could be facing is creating an efficient connection between the hospital premises and the park up north, without negatively influencing current mobility services for traffic (mainly the 'Laan der Verenigde Naties').

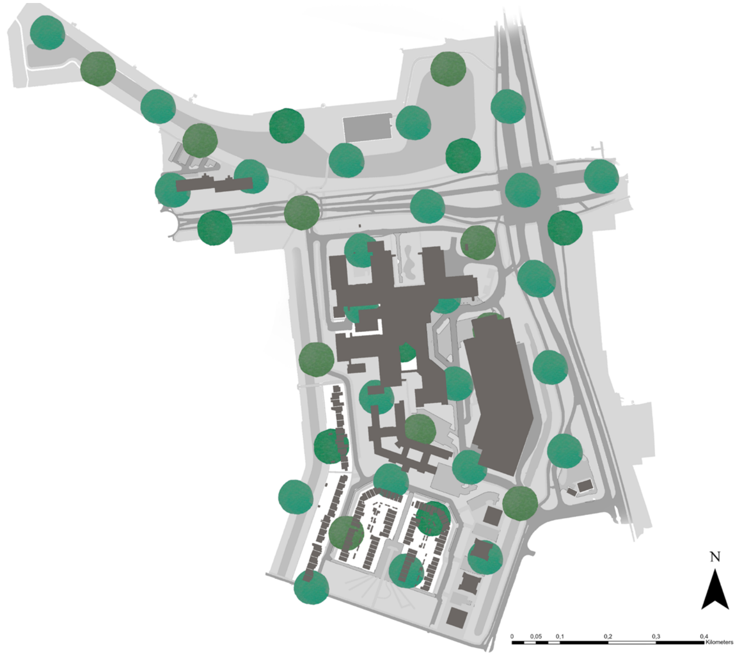


figure 20: concept map for the scattered SIL model. The green dots represent SIL.

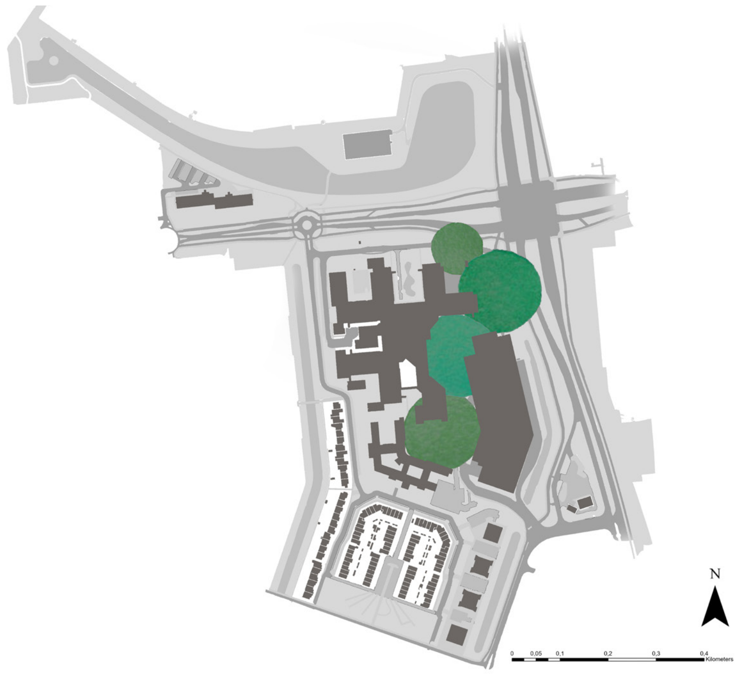


figure 21: concept map for the clustered SIL model. The green dots represent SIL.

figure 22: concept map for the SIL routing model. The green dots represent SIL.

5.2 Concept assessment

For assessing the three generated concepts, the concept model assessment criteria are put in an assessment matrix (table 2) which will be used to compare the three concepts. A score will be given for each criteria based on the analysis results and expert judgement, which will lead to a total score for every concept model. The concept model with the highest total score in the end shall be the concepts that suits the site best regarding improving the quality of life for elderly people regarding social interaction possibilities.

5.2.1. Scattered SIL model

By scattering SIL all over the research site (figure 20), the highest variation in physical environment and thermally comfortable locations can be reached. However, this poses problems for accessibility (walkability). To ensure that all SIL are reachable, a vast network of sufficient pavements needs to be installed. Without pedestrian infrastructure, the SIL will be of no use for elderly people. This model also creates lower user density because of the widespread SIL and many SIL options. Nuisance in this model is very dependant on the location. Some (f.e. close to roads) experience high nuisance levels and some (f.e. in the park) experience low nuisance levels. The same applies to the thermally comfortable locations. Lastly, the feasibility is rather low in this model. This is because a high amount of changes is needed to achieve this model; many pedestrian routing structures have to be improved or even created, and many SIL have to be added. Due to low user density, the results could be less effective as other models while having a relatively low feasibility. This results in the assessment matrix found in appendix 4.

5.2.2. Clustered SIL model

By clustering SIL in a central part of the research area close to the hospital buildings (figure 21), the walkability (physical accessibility) of the SIL is optimized. Few pedestrian walking facility upgrades are needed as the current pavement quality is already very sufficient there. Clustering creates a high user density because of the small surface and high service provisions. However, by clustering the environmental variation declines as the surroundings are all within the centre of the hospital premises. Most places are currently thermally uncomfortable, however this could be altered by designing. The model has a high level of nuisance due to the clustering and high density being very close to inevitable traffic fluxes like taxi's, bus lines and ambulance emergency routes. Because the design implementations that are needed are rather small (creating better urban comfort and better SIL), the feasibility for this model is very high. This results in the assessment matrix found in appendix 4.

5.2.3. SIL routing model

This model (figure 22) combines aspects of both previously assessed models. By creating a major walking route surrounded by SIL, the walkability will be relatively high. The walking distances are dependant on the SIL people choose to go to. Because the route crosses the park as well as the hospital premises, a moderate physical environmental variation (park and urban facilities) is maintained. The park also makes the environmental thermal variety higher on average as the park majorly holds shading spots and higher perceived thermal comfort and the hospital site majorly has sunny spots and lower perceived thermal comfort. However, the park area is bigger and therefore this model has quite good thermally comfortable locations overall. To reach the park, a crossing has to be designed to link the hospital premises and park. This creates high nuisance levels, which is also the case in the centre of the hospital premises. Because changing the mobility network without negatively influencing other traffic fluxes is a big design implementation as it probably requires a pedestrian bridge or tunnel, the feasibility of this model is quite low. Altogether this results in the assessment matrix found in appendix 4.

5.2.4. Chosen concept model

The final scores for each concept model are -3 points for the scattered SIL model, +1 points for the Clustered SIL model and +3 points for the SIL routing model. The concept assessment reveals that the **SIL routing model scores the highest**, with a total of +3 points. This means the SIL routing concept is most likely to achieve the design goal when designed according to the design guidelines. The SIL routing concept will thus be the leading concept further on in this thesis.

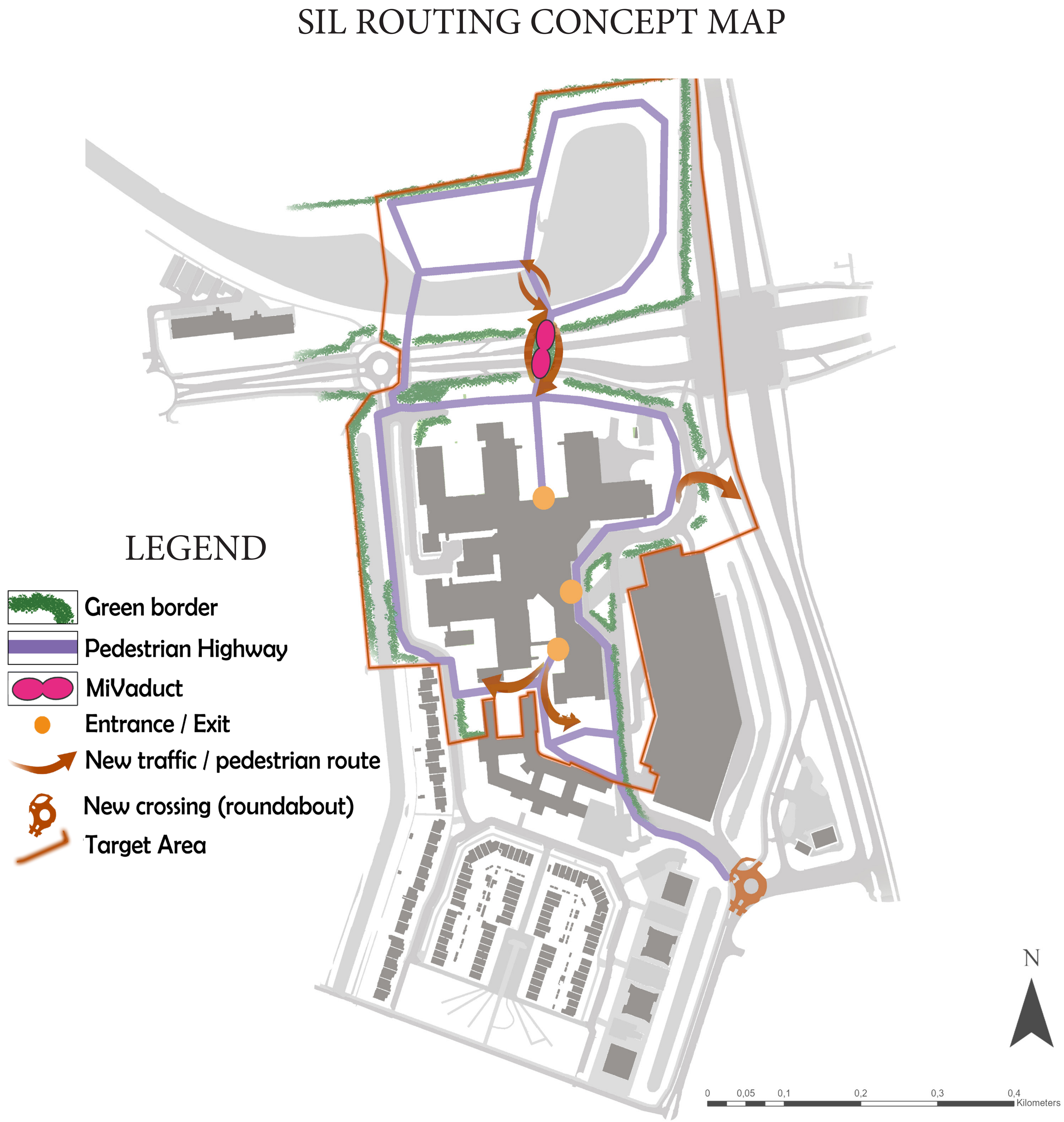


figure 23: Final concept map for the SIL routing concept model. It provides more detail on how the concept is constructed and indicates the main target area for design implementations, the new routing on site (pedestrian highway) and the new MiVaDuct to cross the Laan der Verenigde Naties.

5.3. Final concept

For the SIL routing concept, a more specific concept map (figure 23) is created which provides more detail to understand which area will be focussed on in design (target area), the new walking route and the new traffic links established on site. An important part of the new route is the MiVaDuct, a pedestrian bridge crossing the Laan der Verenigde Naties.

In this concept, a pedestrian-exclusive route is prioritized; the so-called 'pedestrian highway'. This route connects all available SIL in the area to the hospital buildings by broad and levelled roads which provide sufficient pedestrian comfort for elderly and less mobile people - having clear crossings, smooth (concrete) surfaces and avoiding the big traffic crossings. Lighting along this route increases night time safety and counters nuisance and impoverishment (Rosenberg et al., 2012; van den Berg et al., 2020).

The concept aims to improve the quality, user comfort and aesthetic appeal of the park up north and link it to the north side of the hospital premises by creating a pedestrian passage (MiVaduct) in the middle of the Laan der Verenigde Naties to avoid the busy crossing point in the north-east corner of the research site and the roundabout on the north-west side. The northern part of the Willy Brandtlaan will be removed to create a more open space exclusively for pedestrian users. This road currently serves as exit route for cars that either drop off people on the kiss & ride (entrance square) or park in the parking garage. To provide a new exit route, a new road should be created directly at the entrance of the parking garage which leads to the Dr. W. Dreeslaan. The roundabout that is created on the south side of the hospital premises will provide options for car traffic to go north- and southwards after exiting the premises. Green borders surrounding the SIL spaces almost everywhere separate the busy roads (Laan der Verenigde Naties & Dr. W. Dreeslaan) and peaceful garden- or park like SIL spaces. This lowers nuisance and improves perceived safety (Rosenberg et al., 2012; van den Berg et al., 2020) and aesthetic appeal (Sugiyama & Ward Thompson, 2008). Lastly, the outdated parking lot next to the radiotherapy group building is to be redesigned as the parking garage provides enough (close by) parking space. This provides opportunities for improving thermal comfort and creating a pedestrian exclusive garden like space which can play an important role as link in the pedestrian SIL route. Two currently small entrances are transformed to more general entrances/exits which directly lead into pedestrian exclusive spaces, stimulating pedestrian movement and giving pedestrians the opportunity to avoid the busy entrance square.

By accompanying the pedestrian exclusive route with a variety of different and high quality SIL like benches, edges, nodes and props, promenades and artworks, the routing creates the opportunity to significantly improve social interaction possibilities for elderly people.

Now that the final concept has been established, it is time to start working this out further. However, there is still a part of the knowledge gap unanswered. There is no knowledge yet about what locations are most suitable for placing SIL and neither is there on where climate adaption measures need to be implemented. The next chapter will focus on answering these questions by means of research through designing.

6. Designing phase

The concept map provides some general information and forms the base for a new site (re)design that stimulates social interaction for elderly people at hospital 'Ziekenhuis Gelderse Vallei'. However, the map does not provide information on where specific design choices should be made and which choices should be made. To find out about this, this chapter utilizes research through designing. Research through designing is a method which provides knowledge on efficient design choices and placement of certain design aspects by assessing different design solutions that could solve identified design problems. Currently, there still is a knowledge gap on where to implement design measures for improving thermal comfort, and where SIL and pedestrian routing should exactly be placed to achieve optimal social interaction possibilities for elderly people. To explore and solve these questions, research questions are aimed to be answered by doing research through designing.

6.1. Improving thermal comfort in design

Exploring where changes should be made to improve thermal comfort leads to this question:

8. Where should (micro)climate adaptation measures be implemented to improve thermal comfort?

The current hot and cool spots locations that provide either thermal comfort or thermal discomfort are known. These are visualised in the thermal comfort map (figure 17). When this map is compared to the concept map, 5 locations that are located inside the 'target area' (see final concept map in figure 26) aimed to be used for SIL which currently have a low (perceived) thermal comfort come forth. These locations are numbered 1 to 5 and are shown in figure 24.

figure 24: Map showing 5 locations in the target area where a thermally uncomfortable environment is present. The areas are found by combining the thermal comfort map and final concept map.

For each location, a quick problem identification is done. If the problem is known, multiple solutions can be thought of by applying the knowledge on thermal comfort that was found in chapter 3. By identifying the problem, multiple solutions can be thought of and worked out in a simple design. These design solutions are then assessed according to the design assessment criteria (as defined in sub-section 4.2.2) to determine which of the solutions has the highest score and thus is most suitable to improve thermal comfort a choice can be made on what design implementation fits best or is most feasible for optimizing the final design. The design assessment matrix (table 3) is filled in for each location and a score is given per solution per criteria. This can be '-' (negative (= criteria not met)), '0' (neutral) 'or '+' (positive (= criteria is met)). The solution with the highest score at the end, or most '+', is the solution that fits best and the one that will bge used in the final masterplan in chapter 7.

6.1.1. Location 1

This is an unidentified, closed off and deepened square covered in asphalt and concrete. The trees surrounding it provide some shade but sunlight still reaches the hard surfaces, causing thermal storage and material heating (Erell et al., 2011) which makes this location thermally uncomfortable. The main problem here is the type of materialisation. Solutions are (figure 25A):

1). Removing the hard surfaces and covering the location in forest/park space will reduce thermal storage and increase shading and aesthetic appeal of the park if designed right (Erell et al., 2011)
2). Filling the concrete 'tub' with water will reduce thermal storage and provide recreational options (Jacobs, Klok et al., 2020).
3). Creating a sports field or playground with permeable surfaces will reduce thermal storage and provide a recreational option (Chen et al., 2019).

The solutions are assessed in the matrix shown in table 6. This location can be regarded as an urban square. From the final total scores can be concluded that for location 1, solution 3 (transforming it into a sports-/play area with permeable surfaces) has the highest score and is therefore the most suitable solution to improve thermal comfort on the location.

Table 6: design assessment matrix for thermally uncomfortable location 1

Location 1 (Urban square)	Scores (+/0/-)		
Design assessment criteria	**Solution 1: Turn into park**	**Solution 2: Fill with water**	**Solution 3: Turn into sports area**
1. Incorporate different levels of greenery (x1)	+	-	+
2. Include resting spots made of 'warm materials' (x1)	0	-	+
3. Provides sunny/shading spots in a patchwork pattern (x1)	+	-	+
4. Uses permeable surfaces where possible (x1)	+	+	+
5A. spatial objects break void & provide shade (x2)	++	--	++
Total score	++++	- - -	+++++

figure 25A: design solutions for the problems regarding thermal comfort for location 1

6.1.2. Location 2

This is a part of the northern side of the Willy Brandtlaan. Due to insufficient shading by trees or hospital buildings, the asphalt street and concrete pavements are exposed to solar radiation, causing the same main problem as in location 1 (thermal storage) (Erell et al., 2011). The main problem here is the type of materialisation. Solutions are (figure 25B):

1). Removing the hard surfaces and covering the location in forest/park space will reduce thermal storage and increase shading and aesthetic appeal of the hospital site if designed right (Erell et al., 2011).
2). By transforming the road surface to permeable surface thermal storage would decrease (Chen et al., 2019) whilst not having to change the current functionality.

The solutions are assessed in the matrix shown in table 7. This location can be regarded as urban greenspace. From the final total scores can be concluded that for location 1, solution 1 (removing the Willy Brandtlaan party and turning it into a park) has the highest score and is therefore the most suitable solution to improve thermal comfort on the location. In order to prevent mobility issues, a new exit route for cars has to be found in the design with the Willy Brandtlaan gone.

Table 7: design assessment matrix for thermally uncomfortable location 2

Location 2 (Urban greenspace)	Scores (+/0/-)		
Design assessment criteria	**Solution 1: turn in to park**	**Solution 2: permeable road**	**Solution 3: n/a**
1. Incorporate different levels of greenery (x1)	+	+	n/a
2. Include resting spots made of 'warm materials' (x1)	+	-	n/a
3. Provides sunny/shading spots in a patchwork pattern (x1)	+	+	n/a
4. Uses permeable surfaces where possible (x1)	+	+	n/a
5B leave room for multifunctionality / open spaces (x2)	++	--	n/a
Total score	++++++	0	n/a

figure 25B: design solutions for the problems regarding thermal comfort for location 2

6.1.3. Location 3

This is a concrete basketball field which is a little deserted. It is very similar to location 1: a concrete surface causes thermal storage and material heating (Erell et al., 2011) making the location thermally uncomfortable. The main problem here is the type of materialisation. Solutions are (figure 25C):

1). Removing the hard surfaces and covering the location in forest/park space will reduce thermal storage (Erell et al., 2011) and increase shading and aesthetic appeal of the hospital site if designed right.
2). Creating shade by planting trees/ building shading structures around the basketball field reduces the solar radiation reaching the surface and increases evapotranspiration (Klemm, 2018).
3). Transforming the surface to permeable surfaces will reduce thermal storage (Chen et al., 2019) whilst not having to change the current functionality.

The solutions are assessed in the matrix shown in table 8. This location can be regarded as urban square. From the final total scores can be concluded that for location 1, solution 1 (removing the basketball field and turning it into a park) has the highest score and is therefore the most suitable solution to improve thermal comfort on the location.

table 8: design assessment matrix for thermally uncomfortable location 3

Location 3 (Urban square)	**Scores (+/0/-)**		
Design assessment criteria	**Solution 1: Turn in to park**	**Solution 2: Surround with trees**	**Solution 3: create permeable field**
1. Incorporate different levels of greenery (x1)	+	+	-
2. Include resting spots made of 'warm materials' (x1)	0	0	+
3. Provides sunny/shading spots in a patchwork pattern (x1)	+	+	-
4. Uses permeable surfaces where possible (x1)	+	-	+
5A. spatial objects break void & provide shade (x2)	++	++	--
Total score	+++++	+++	--

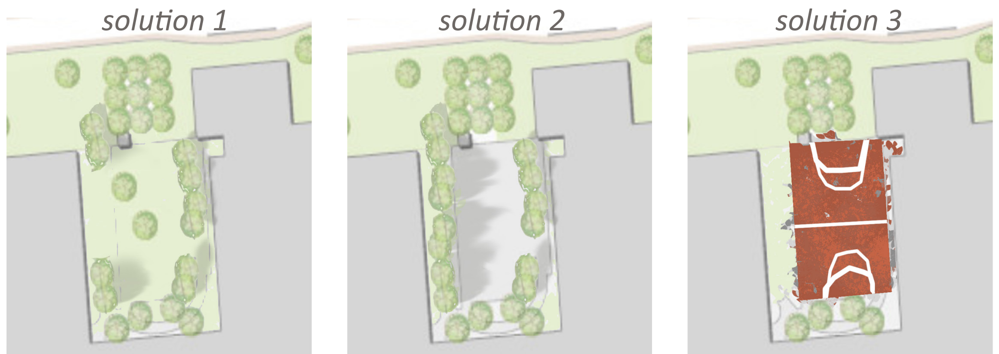


figure 25C: design solutions for the problems regarding thermal comfort for location 3

6.1.4. Location 4

This area consist of the central entrance square of the hospital, bicycle racks and pavements alongside the Willy Brandtlaan and the bus stop located next to it. Here, multiple factors influence thermal comfort. All places have very few shading, causing a lot of sun exposure hours during daytime (Klemm, 2018). The majority is made of hard surfaces which causing surface heating (Erell et al., 2011). Lastly, a high activity pattern of pedestrian people and traffic all moving criss-cross through this space generates a lot of anthropogenic heat (Erell et al., 2011) and also increases perceived thermal discomfort. The main problems are: solar radiation exposure, materialisation and anthropogenic heat fluxes. Solutions are (figure 25D):

1). Creating shade by planting vegetation (trees) and building shading structures around the hot surfaces where possible to reduce solar radiation and improve evapotranspiration (Klemm, 2018).
2). Transforming the pavements to permeable surfaces can decrease the thermal storage (Chen et al., 2019).
3). Redirect visitor, staff- and patient transport movement fluxes by improving other exits/entrances and roads surrounding the hospital to change the traffic pattern and thereby decrease anthropogenic heat (Erell et al., 2011).

The solutions are assessed in the matrix shown in table 9 . This is an urban square type of space. From the final total scores can be concluded that for location 4, solution 1 (placing more trees and other shading structures) has the highest score and is therefore the most suitable solution to improve thermal comfort on the location. As solution 3 was not an assessable design solution because it does not provide certain spatial properties, it has the end score 0. Nevertheless, adding entrances would increase the reachability of many SIL and also relieve the main entrance of the high activity density it is currently experiencing. Lowering visitor and traffic fluxes at the main entrance by creating more entrance/exits for visitors would reduce the generated anthropogenic heat on the main entrance square and reduce traffic fluxes, immproving (perceived) thermal comfort. Thus, in this case, a combination of solution 1 and 3 is the most optimal situation and both solutions will be implemented as they are not conflicting implementations but rather complementary.

Table 9: design assessment matrix for thermally uncomfortable location 4

Location 4 (Urban square)	**Scores (+/0/-)**		
Design assessment criteria	**Solution 1: Trees and shading structures**	**Solution 2: Permeable walking surfaces**	**Solution 3: More entrances**
1. Incorporate different levels of greenery (x1)	-	-	0
2. Include resting spots made of 'warm materials' (x1)	+	0	0
3. Provides sunny/shading spots in a patchwork pattern (x1)	+	-	0
4. Uses permeable surfaces where possible (x1)	-	+	0
5A. spatial objects break void & provide shade (x2)	++	--	0
Total score	++	---	0

figure 25D: design solutions for the problems regarding thermal comfort for location 4

6.1.5. Location 5

Location 5 is mostly the parking lot of the radiotherapy group building, which is partly shaded and covered in hard surfaces. The parts exposed to sunlight warm up very quickly and the hard surfaces store this heat (Erell et al., 2011). Metal cars also store and reflect a lot of heat. The main problems here are surface materialisation and presence of cars. Solutions for this are (figure 25E):

1). Transforming the parking lot surface to permeable surfaces which decrease thermal storage (Chen et al., 2019) and keep the current functionality.
2). Removing the parking lot and replacing it with park or garden will reduce thermal storage (Erell et al., 2011), increase aesthetic appeal (Sugiyama & Ward Thompson, 2008) and evapotranspiration (Klemm, 2018) and remove cars.

The solutions are assessed in the matrix shown in table 10. This is an urban square type of space. From the final total scores can be concluded that for location 4, solution 2 (replacing the parking lot by park spaces or gardens) has the highest score and is therefore the most suitable solution to improve thermal comfort on the location.

Table 10: design assessment matrix for thermally uncomfortable location 5

Location 5 (Urban square)	**Scores (+/0/-)**		
Design assessment criteria	**Solution 1:**	**Solution 2:**	**Solution 3: n/a**
1. Incorporate different levels of greenery (x1)	-	+	n/a
2. Include resting spots made of 'warm materials' (x1)	0	+	n/a
3. Provides sunny/shading spots in a patchwork pattern (x1)	-	+	n/a
4. Uses permeable surfaces where possible (x1)	+	+	n/a
5A. spatial objects break void & provide shade (x2)	--	++	n/a
Total score	---	++++++	n/a

figure 25E: design solutions for the problems regarding thermal comfort for location 5

6.1.6 Results

The results show the 5 most fitting design interventions to improve thermal comfort on within the target area. These include creating a permeable sports field in the park up north and turning hard surfaces on the north- (Willy Brandtlaan; basketball field) and south- (Parking lot) side of the hospital premises in to pedestrian exclusive park like area's. The centre of the hospital site is upgraded with trees and shading structures that improve thermal comfort (Klemm, 2018) without disturbing the current traffic flows. Extra entrances should take density pressure and toff the main entrance, improving the traffic pattern and decreasing anthropogenic heat (Erell et al., 2011) and at the same time providing quick passage to the SIL routing network.

These design solutions will be incorporated in the (re)design of the research site to optimize thermally comfortable locations on and surrounding the hospital premises.

6.2. Locations suitable for SIL in design

To know where (not) to put SIL in the final design, suitable locations for SIL should be identified. To do so, the set of generated design guidelines is used to assess different locations within the concept 'target area' (consisting of most of the hospital site and the park up north; see final concept map in figure 23). To do so, the target area is divided into 5 sub-areas: The park (1), the north side of the hospital premises (2), the van Steenbergenweg and surroundings (3), the bus stops, main entrance square and surroundings (4) and the former parking lot and park of the radiotherapy group (5) (see figure 26).

For each area is checked if all design guidelines are incorporated in that specific area. If a design guideline is represented in the sub-area, the icon linked to the specific design guideline (figure 19a-19f) will be added to the area it applies to. If all design guidelines are included in a sub-area it will be marked 'sufficient' for placing SIL. If one or multiple design guidelines are not present or lack certain quality, they will be marked 'insufficient' for placing SIL. If areas turn up to be insufficient for placing SIL, a problem identification is done to thereafter come up with solutions by expert judgement to solve the stated problem. The aim of this is to maximise the amount of locations within the target area that are suitable for placing SIL by conducting research through design. The solutions are provided in appendix 5. The 5 sub-areas and linked design guidelines (icons) are visualised in figure 26.

As figure 26 shows, 3 out of 5 sub-areas have all six design guidelines represented in the design concept and are therefore considered to already be sufficient for placing SIL. The two that do not represent all design guidelines are sub-area 1 (the park) and sub-area 3 (the van Steenbergenweg and its surroundings). To ensure these locations could also be used in the final design for placing SIL, improvements or solutions for current absent factors are provided in appendix 6 and the best solution is chosen by expert judgement and incorporated in the final masterplan that is presented in the next chapter.

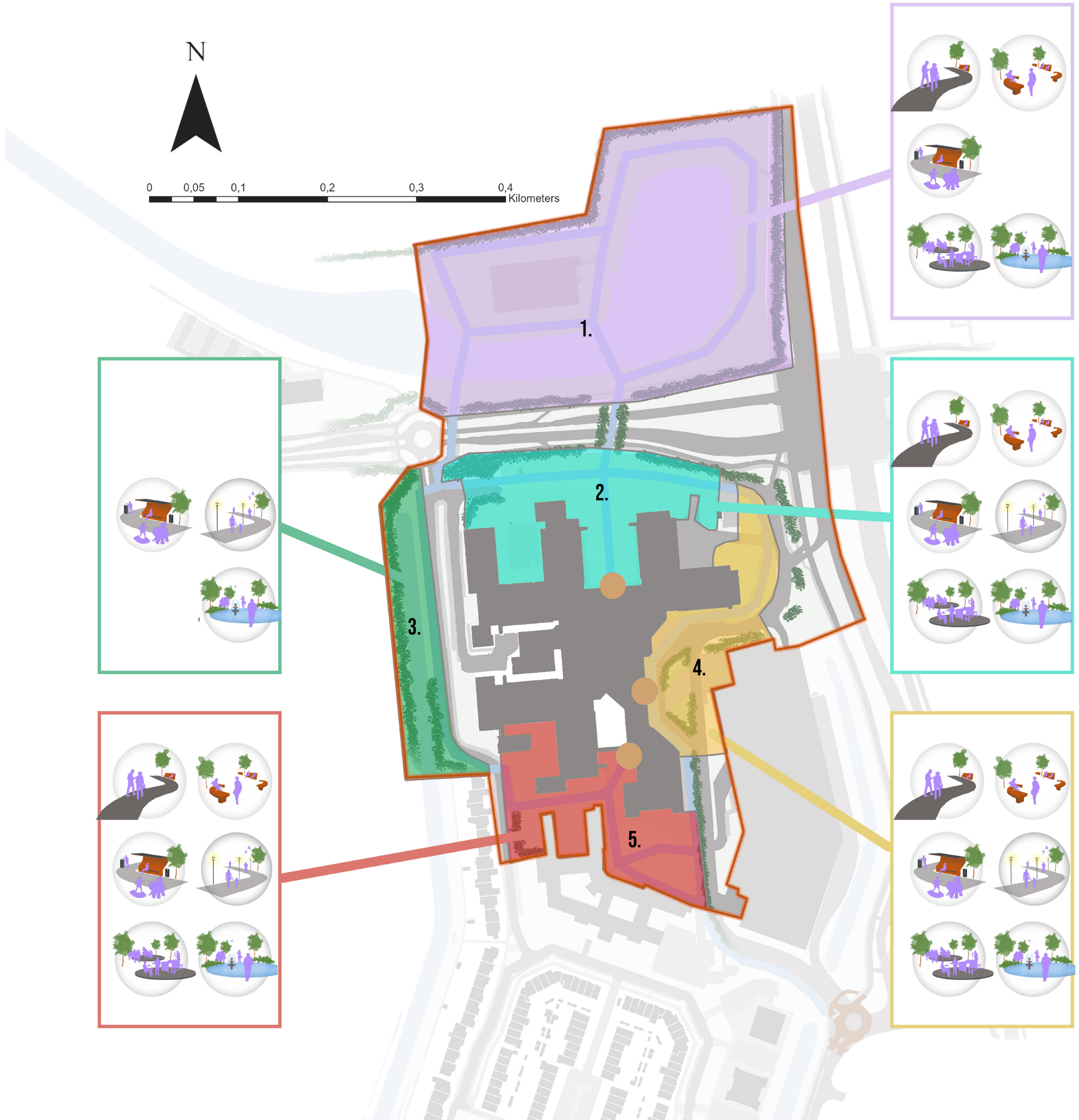


figure 26: SIL suitability map, showing the 5 different sub-areas and the amount of design guidelines represented for each sub-area in the current concept situation

7. MASTERPLAN | HEALTHY CONNECTIONS EDE

The masterplan visualised in the map in figure 27 is the result of combining all design implementations generated in chapter 6 with the six design guidelines that were drawn up in chapter 4. The masterplan builds on the final concept defined earlier in this research: the SIL routing concept. In this masterplan, the hospital facilities are connected to various SIL placed all over the target area by a circular pedestrian-exclusive walking route; the so-called pedestrian highway (coloured purple). This is a broad and levelled path made from white concrete and is accompanied by street lighting everywhere. It connects the main- and new entrances/exits to the park-like surroundings. To explain the masterplan into detail, several highlights are pointed out and emphasised. The design guidelines represented by them are also named per highlight.

For a more elaborate explanation of the masterplan, see appendix 6.

Lowered soccer court improves thermal comfort due to its permeable surface, facilitates a playing area and provides something to look at. Includes a concrete sitting stairs down from the running path and borders to the concrete platform south of it.

1. Provide a suitable pedestrian network structure for elderly people
4. Provide various attractive and reachable SIL

Improved van Steenbergenweg has more space for walking and resting or social interaction due to switching the sidewalk and road. Concrete platforms lean over the sloped lawn. Includes picnic benches.

1. Provide a suitable pedestrian network structure for elderly people
4. Provide various attractive and reachable SIL

LEGEND

- Existing greenspace
- Trees
- Buildings
- Water features
- Existing roads
- Existing pavements
- Bicycle roads
- Pedestrian Highway
- Sloped recreational lawn
- Running path
- Entrance/exit
- Picnic bench
- Straight bench
- Curved bench
- Bio-based noise wall
- Water plant border
- MiVaduct
- Bus stops
- Football court
- Shading structure
- Fountain
- Gazebo
- Pond fountain
- Flower (picking) fields
- Wooden promenade
- Playground
- Water tap point

figure 27: Masterplan for the final design showing the new pedestrian highway and all other design implementations explained on this page.

- **The pedestrian highway** is accompanied by a separate running path here to prevent conflict between user groups and increase perceived safety among the target group.
  1. Provide a suitable pedestrian network structure for elderly people
  2. Provide public services and amenities
  5. Help increase perceived (night time) safety

- **A recreational lawn slope** cleared of vegetation offers a wide open space for recreation or organised events.
  3. Promote organised social interaction and autonomy
  6. Provide an aesthetically appealing environment

- **Wooden walking promenades** at the waterfront provide sublime resting locations along the pedestrian highway. Combined with the concrete platforms many social interaction affordances are created like seating spots and leaning edges.
  4. Provide various attractive and reachable SIL
  6. Provide an aesthetically appealing environment

- **A new walking bridge** across the pond. Its broadness creates space for a walking part and a 'resting' part, which is made out of wood and facilitates multiple benches. It optimizes walking route options and time. it is accompanied by small fountains on both sides.
  4. Provide various attractive and reachable SIL
  6. Provide an aesthetically appealing environment

- **The MiVaduct** connects hospital site to the park up north by a concrete structure for pedestrians exclusively. Has broad Cor-ten steel stairs on both sides and two stainless steel elevator shafts with elevators. Its broad design lends itself for a park-like design with trees, hanging plants and benches on the upper level. A public toilet sits partly under- and next to the right stairs on the park side.
  1. Provide a suitable pedestrian network structure for elderly people
  2. Provide public services and amenities
  4. Provide various attractive and reachable SIL
  5. Help increase perceived (night time) safety

- **Northern hospital gardens** replace the northern Willy Brandtlaan and basketball field into a garden as pedestrian exclusive zone. It is connected to two new entrances. It includes a playground, flower (picking) fields, water tap points, a fountain and multiple seating structures
  1. Provide a suitable pedestrian network structure for elderly people
  2. Provide public services and amenities
  4. Provide various attractive and reachable SIL
  5. Help increase perceived (night time) safety
  6. Provide an aesthetically appealing environment

- **The improved entrance square** provides a higher thermal comfort by shading structures and extra trees. Includes new seating structures. Traffic situation stays unchanged.
  1. Provide a suitable pedestrian network structure for elderly people
  2. Provide public services and amenities
  4. Provide various attractive and reachable SIL

- **Southern hospital gardens** connect the van Steenbergenweg to the Willy Brandtlaan and a new entrance. A pedestrian exclusive zone. Includes shading structures, flower (picking) fields, water tap points, a small planted hill, an open gazebo and multiple seating structures
  1. Provide a suitable pedestrian network structure for elderly people
  2. Provide public services and amenities
  3. Promote organised social interaction and autonomy
  4. Provide various attractive and reachable SIL
  5. Help increase perceived (night time) safety
  6. Provide an aesthetically appealing environment

Healthy Connections

7.1 MASTERPLAN ǁ AT NIGHT

As stated in the masterplan description, the pedestrian routing or 'highway' is accompanied by night lighting everywhere to ensure a higher perceived night time safety, lower the barrier for elderly people to go out after dark and counter possible nuisance and impoverishment like hanging youth and homeless people. The map shown in figure 28 shows the lighting plan in detail for the whole routing. The map only shows new lights that are added to the already existing lighting network in the area.

LEGEND

- Big street lights
- Small street lights
- Low lighting poles
- LED strip lighting
- Flower art lamp

figure 28: Lighting plan for the final design showing all the new lights that are placed along the pedestrian highway

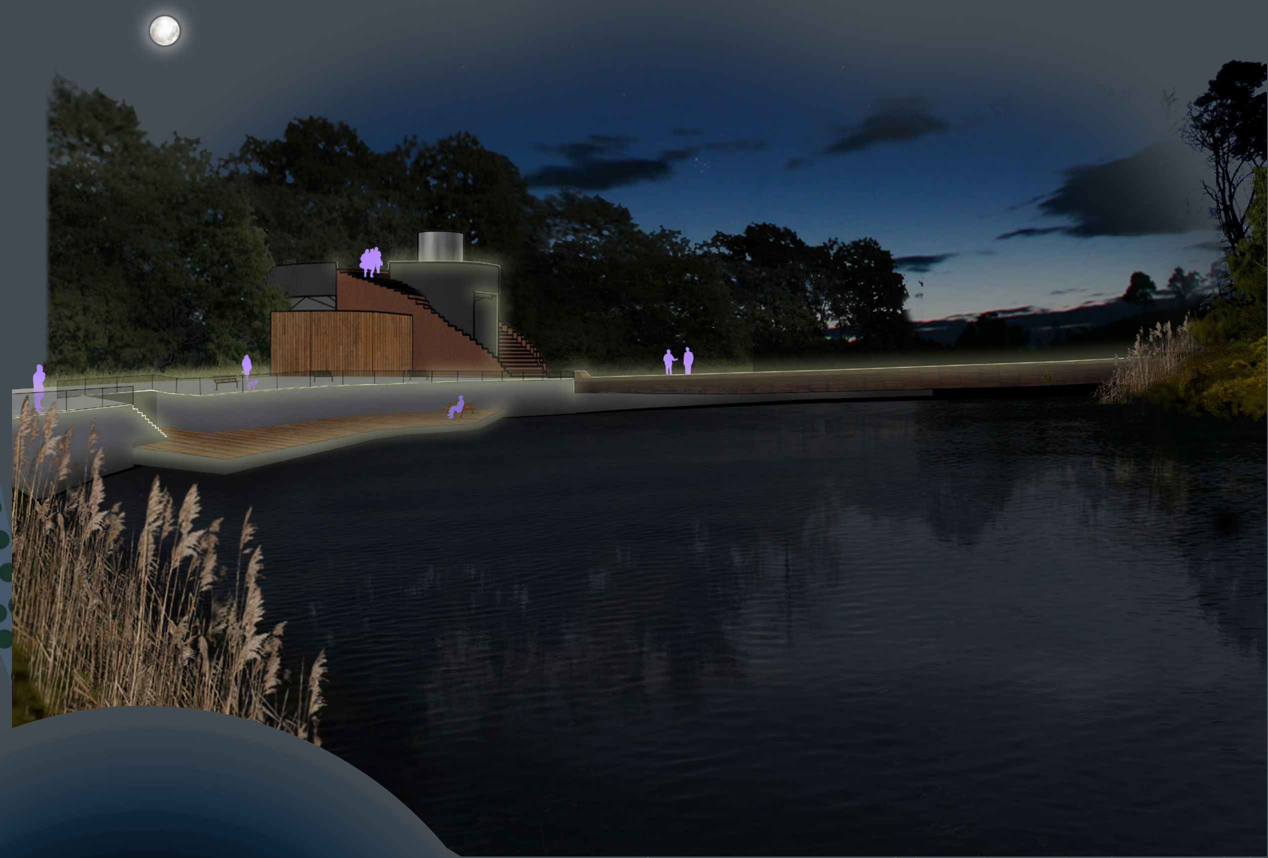


figure 29: Impression of the park at night, showing enlightened bridge and promenade close to the MiVaduct entrance. Next to the MiVaduct, the public toilets are located.

figure 30: Detailed impression of some ground lighting design on the hospital premises, flower shaped lamps which will be placed in flower fields on the norhtern - and southern gardens of the premises.

Healthy Connections

7.2. MATERIALISATION AND SPHERICAL IMPRESSIONS

Materialisation of design

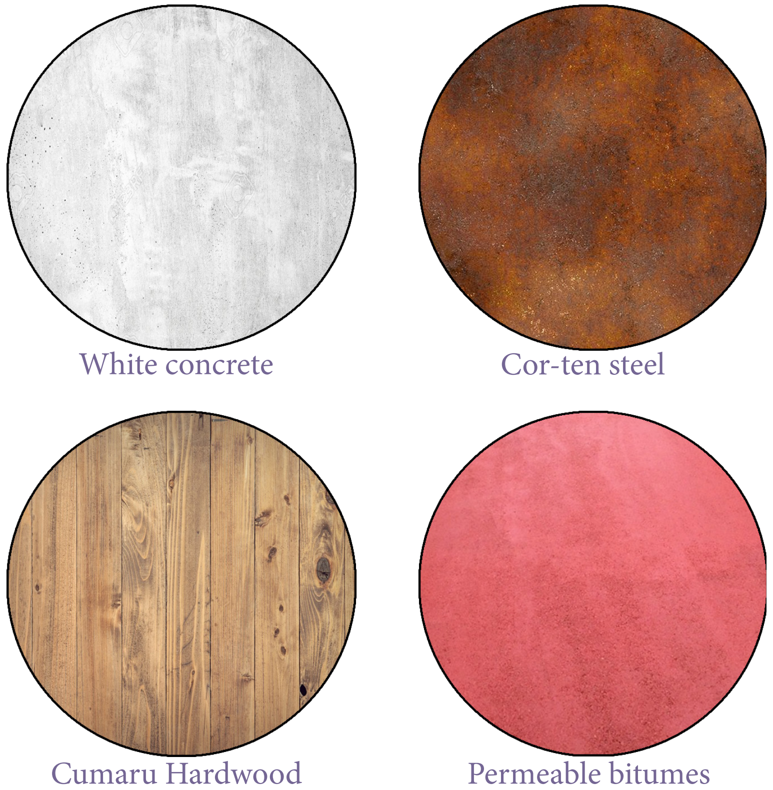


figure 31: main material types used in the Masterplan: white concrete, cor-ten steel. Cumaru Hardwood and permeable sporting bitumes

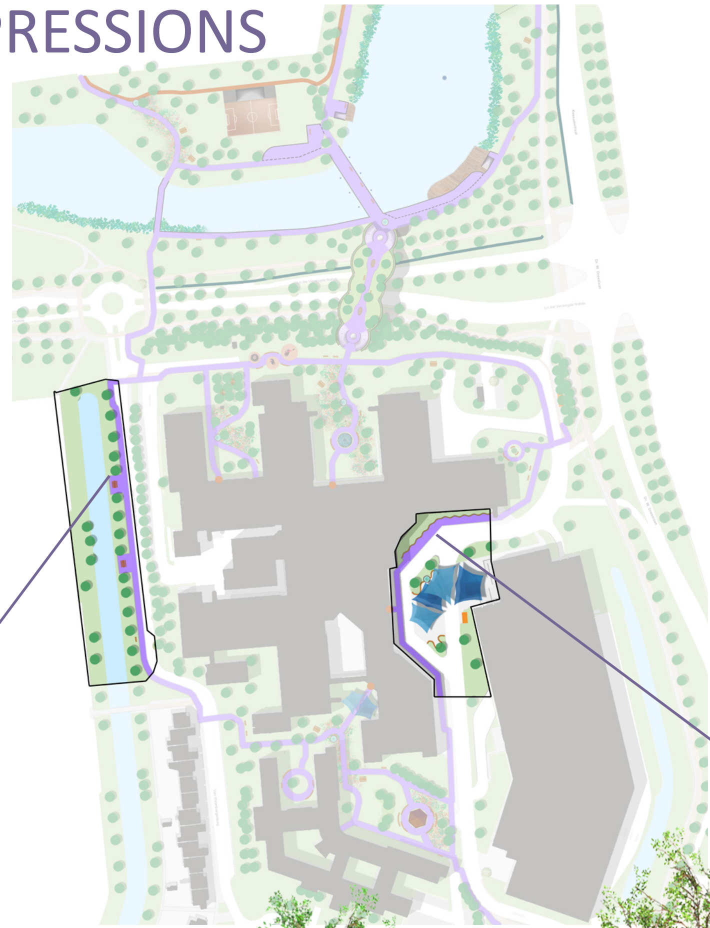


figure 32: spherical impression of the new situation in the van Steenbergenlaan

figure 33: spherical impression of the new situation on the entrance square of the hospital premises

7.3. DETAIL 1: MIVADUCT AND NORTHERN HOSPITAL GARDEN

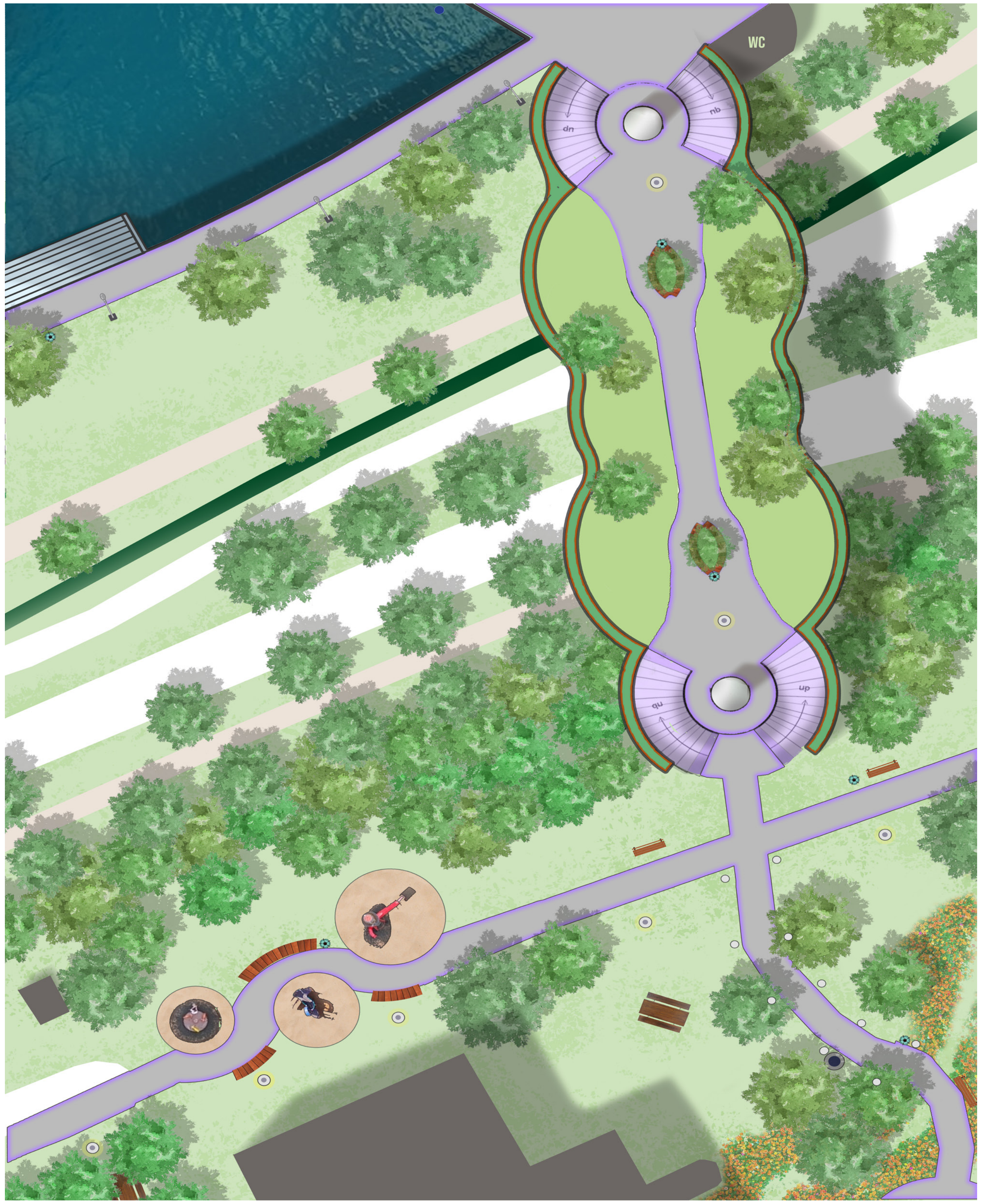


figure 34: Detail map for the MiVaduct and a part of the northern hospital garden

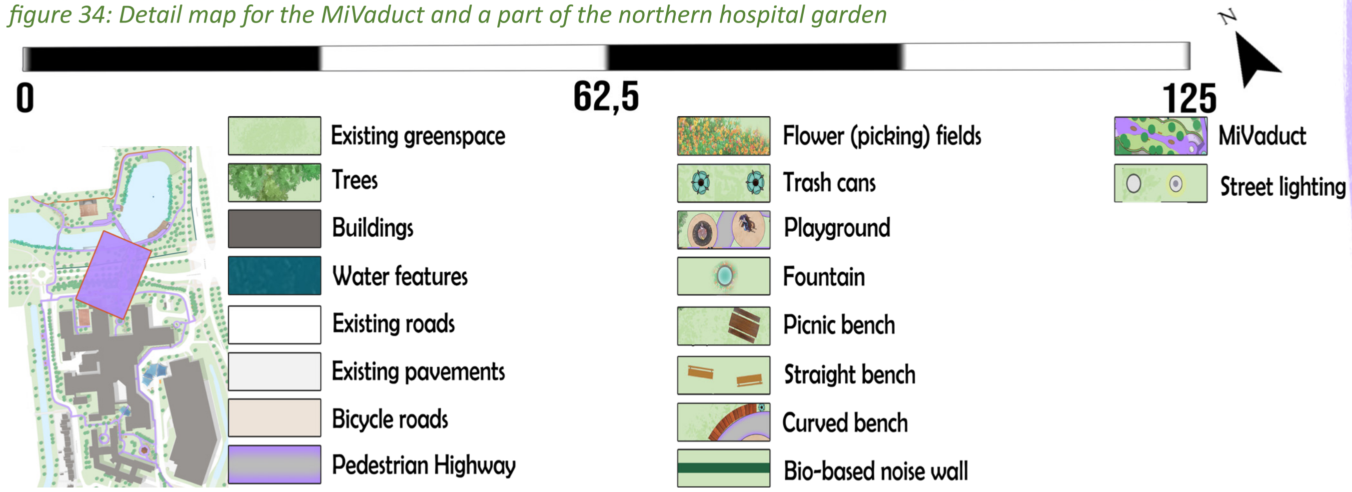
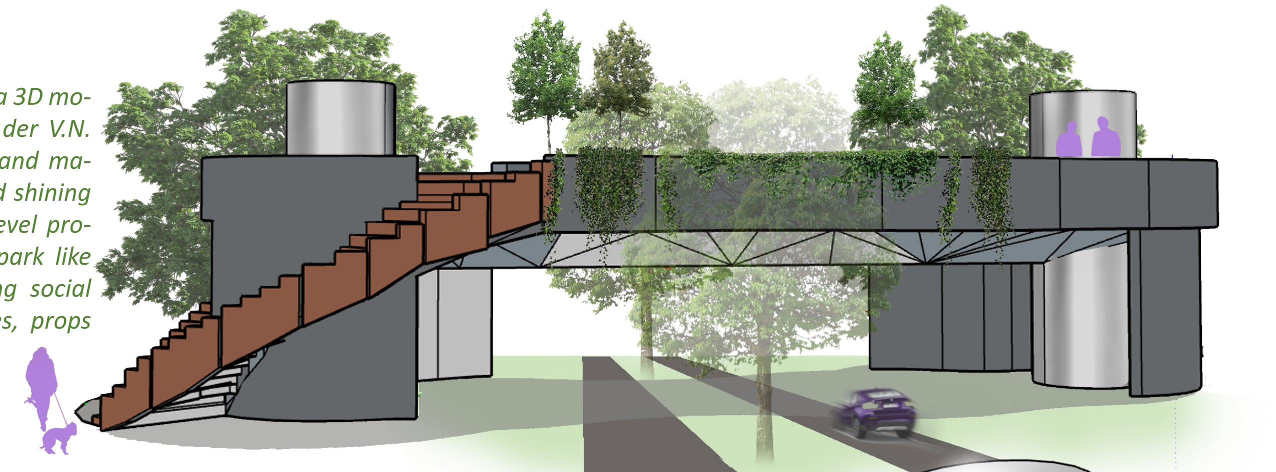


figure 35: Three reprocessed visuals of a 3D model of the MiVaDuct across the Laan der V.N. showing its positioning, curvy design and materialisation: corten steel, concrete and shining stainless steel. The stairs and upper level provide room for vegetation creating a park like scenery on top, whilst also promoting social interaction features like leaning edges, props (stairs/elevator) and benches.



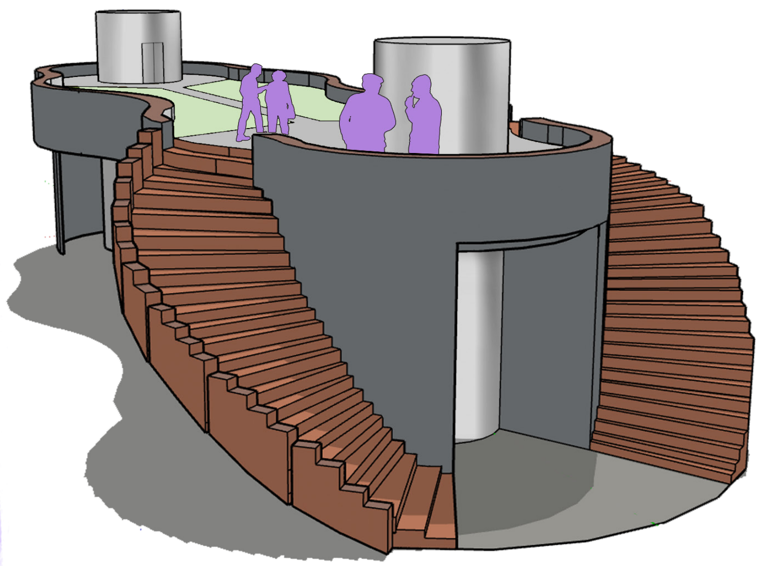


figure 36: spherical impression of the playground and pedestrian highway on the former Willy Brandtlaan north of the hospital

7.4.DETAIL 2: PARK WITH PROMENADES AND BRIDGE

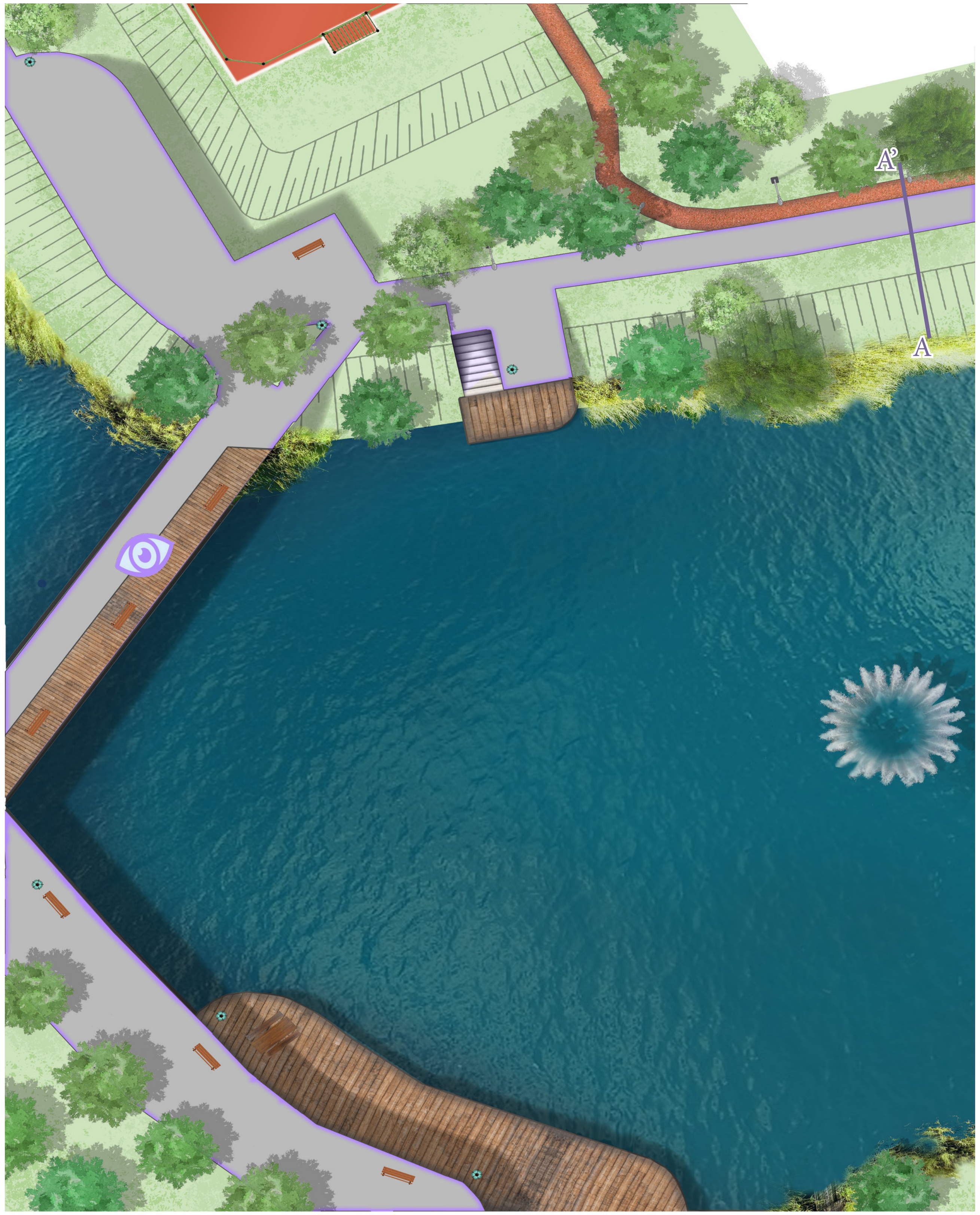
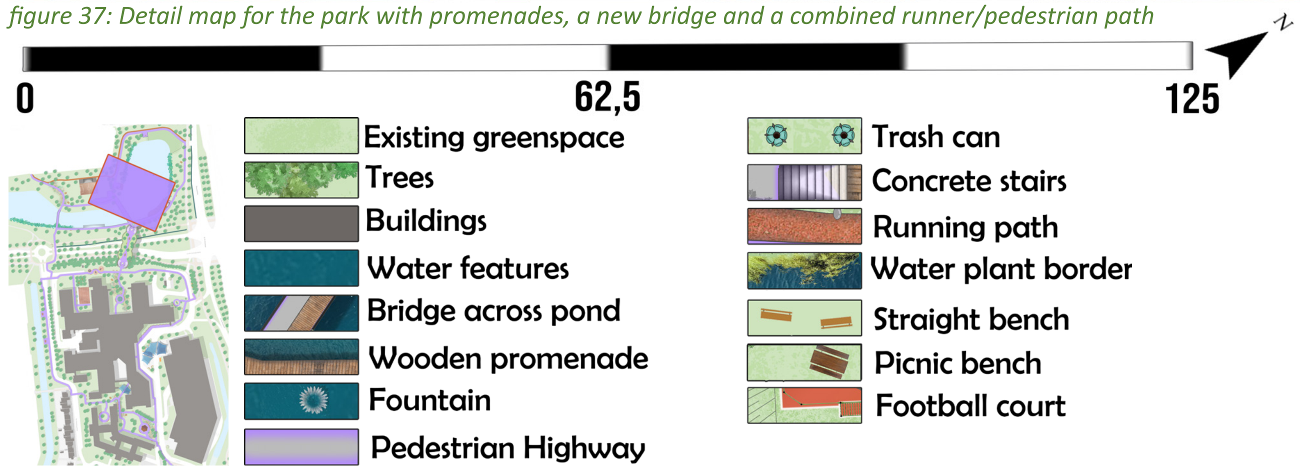


figure 37: Detail map for the park with promenades, a new bridge and a combined runner/pedestrian path



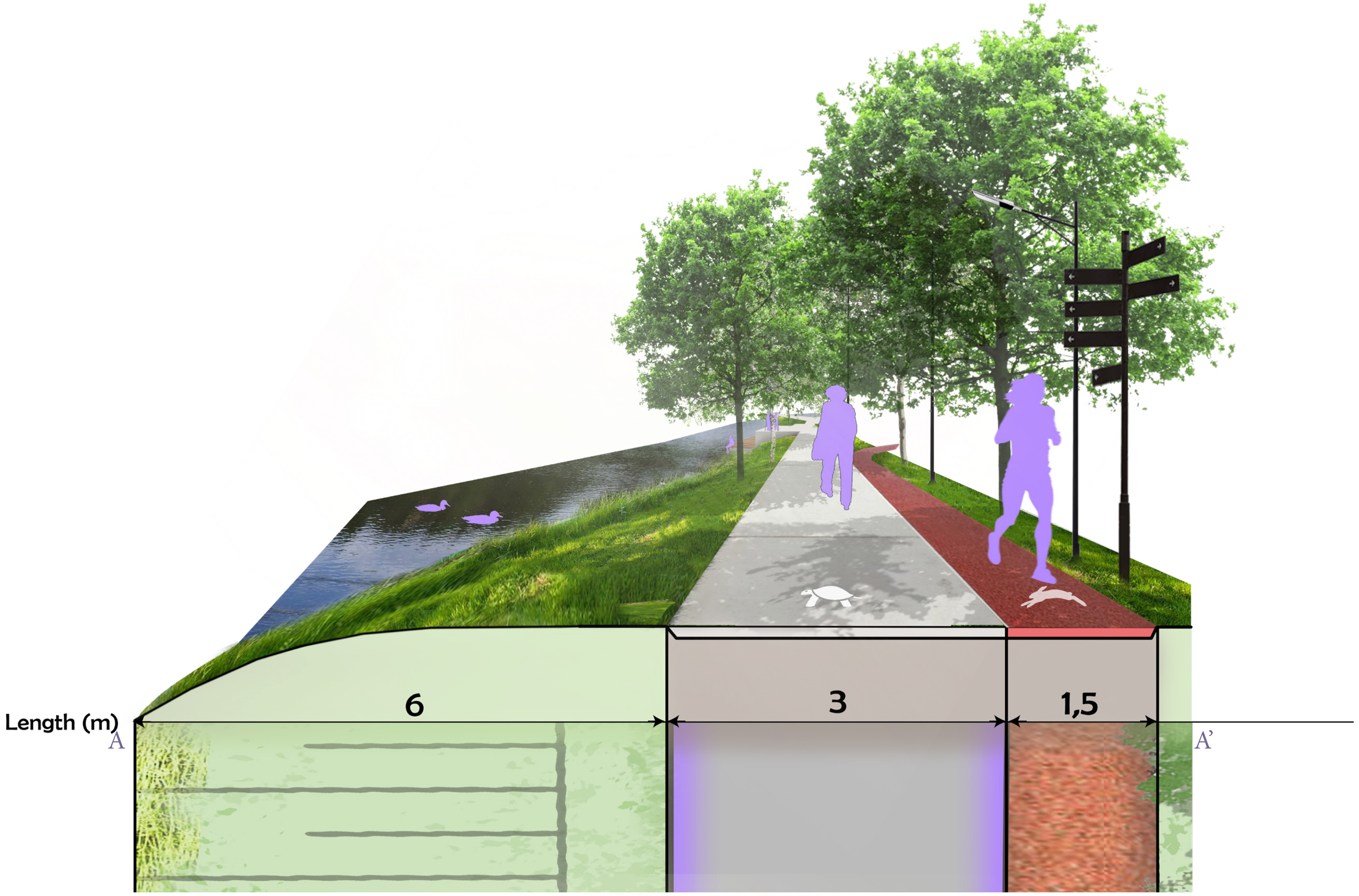


figure 38: cross section of the combined running path and pedestrian highway in the north part of the park. This eliminates possible user conflict. Good signage contributes to way finding in the park.

figure 39: spherical impression of the park as seen from the new bridge. The bridge provides spae for walking as well as space with resting affordances. The bridge connects the norhtern- and southern part of the park creating shorter and more routing combinations.

7.5. DETAIL 3: SOUTHERN HOSPITAL GARDEN

figure 40: Detail map for the southern hospital garden with a gazebo, grass hill and new entrance/exit

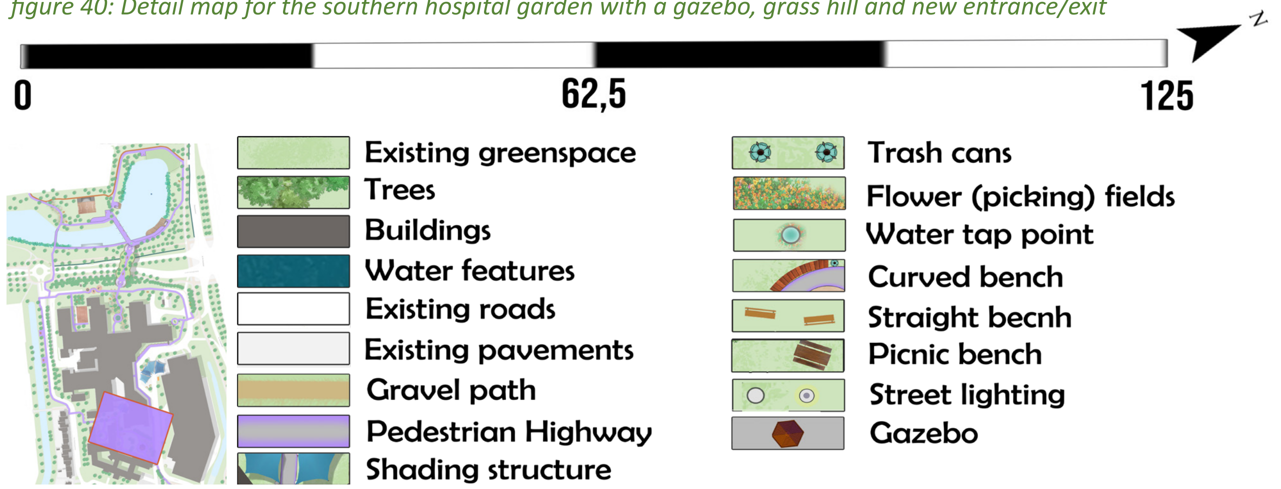


figure 41: Detailed impression of new trash bins created to match the spatial design. Corten steel and copper.

figure 42: spherical impression of the new entrance/exit route leading right into the southern hospital garden, exclusively for pedestrians.

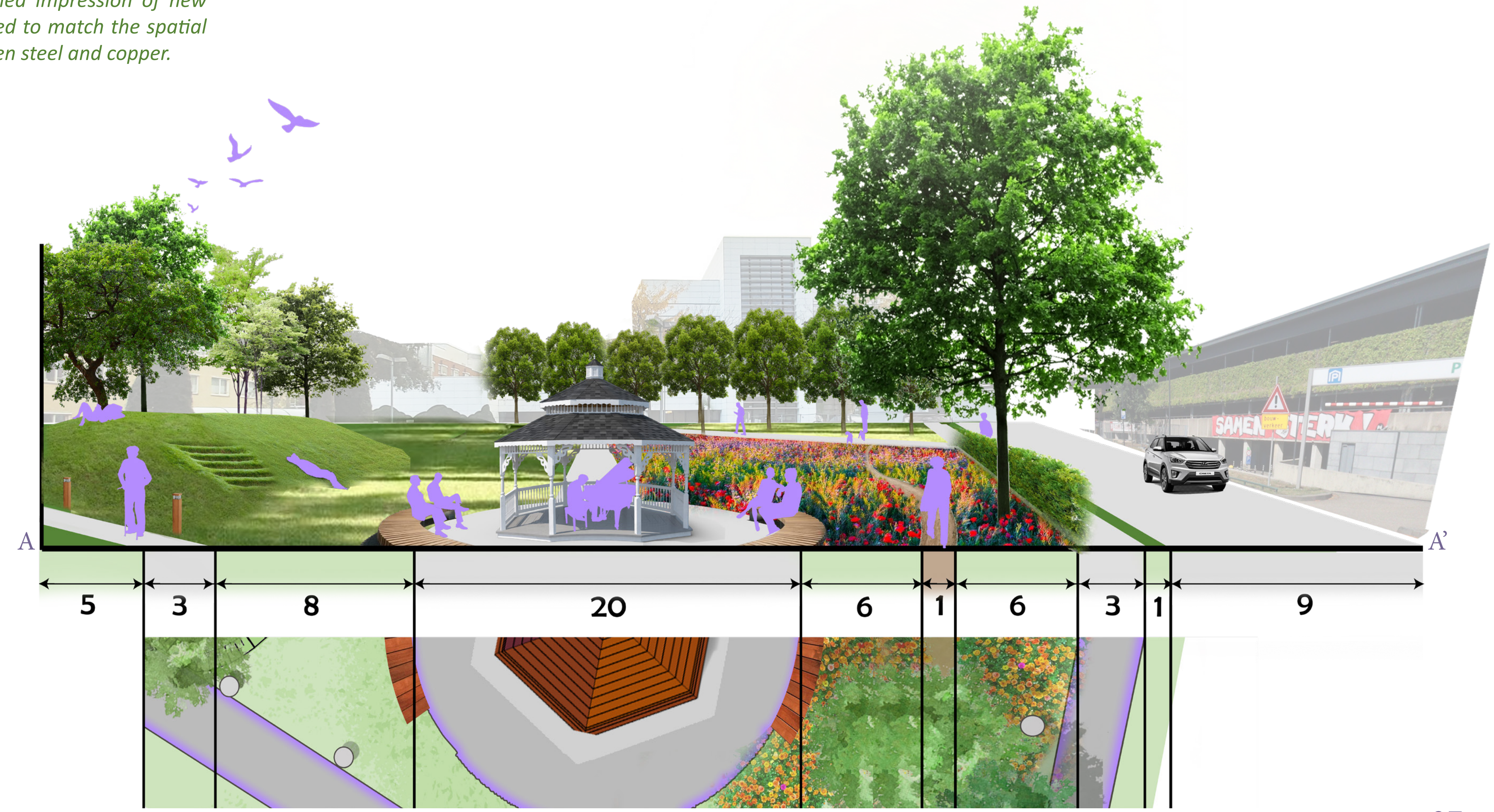


figure 43: Cross section of Southern hospital garden, showing the structure and feautures of southern part of the garden

8. Discussion

This section will look back critically on the literature research as well as the final design that has resulted out of combining the gathered knowledge and assessment. The design should meet criteria for a good physical connection between hospital facilities and SIL for pedestrian elderly people, as well as meet criteria implying a sufficient level of thermal comfort on these SIL. Let's start off with looking at the weaknesses in my literature research (chapter 1, 2 and 3)

During site research in section 2.1, several SIL available on sight are appointed, however this is purely based on theoretical affordances of design features (Erell et al., 2011). This does not cover all location that in reality provide social interaction for elderly people. In order to get more accurate knowledge on which locations on the research site serve as SIL, a long term behavioural analysis and research surveys should be conducted among visitors, patients and staff that are 65 years and older. Section 2.1 also assesses the pavements according to a set of criteria adapted from the BEAMS study (Rosenberg et al., 2012). However, it is short-sighted to assume that all elderly people have the same degree of difficulty for moving from a to b by foot. Whilst one might be in a wheelchair or have mobility impairments, and therefore has a lot of difficulties with for example sloped sidewalks, another elderly person could be physically unharmed and have no problems with the same sidewalk. The analysis of pavement quality is purely theoretical and therefore could be considered biased. Lastly, the behavioural mapping of the visitors in section 2.1 did not include questioning which means that the assigned 'type of behaviour' per person can never be confirmed. Type of behaviour is purely based on observation and judgement of one individual (myself) and therefore can be rather unreliable and vulnerable to misinterpretation or double-counting of the same individual. This decreases the credibility and accuracy of the statistics taken from the behavioural matrices (appendix 2). As a result, the behavioural maps (appendix 3) and activity density map (figure 10) also become less accurate.

In section 2.2 the educated assumption is made that to stimulate elderly people to go outside by lowering their barriers means to increase social interaction possibilities as most social interaction takes place in the outdoor environment (Erell et al., 2011). This is not necessarily true, and is strongly depending on the individual preferences and characteristics of each individual elderly person. Also, some barriers probably are left out as I did not find the literature stating them. Similarly, section 2.3 sought after design implementations that could stimulate social interactions. Several are found, however this is adapted from the knowledge that I found. Due to time limitations, not all academic work has been sought through which means there are probably more design implementations affecting social interaction that remain unnamed here.

In chapter 3, the aspect of urban microclimate, mainly thermal comfort, is included as factor affecting social interaction possibilities. This is based on the assumption that because thermal comfort influences usage of spaces, a low thermal comfort will result in a lower usage of certain locations. This could be doubted as each individual has his or her own thermal preferences. Perceived thermal comfort is therefore very subjective and also hard to conduct general research on. Whilst one person may find a bench in the sun very uncomfortable due to solar radiation and increased (perceived) heat, another might find it very attractive and would like to take a break on that specific bench. I tried to take this all into account as much as possible in my design and supported this with knowledge on shading/sunlight patterns (Klemm, 2018). By maximising the autonomy of people to pick their own preferred thermal environment (having shaded, half-shaded and sunny spots in a patchwork pattern).

Section 3.2.3 provides a shading analysis based on a SketchUp model. As surrounding buildings and the different heights and types of trees are not incorporated in the 3D-model, this may affect the outcome of the shading patterns (figure 13). Nevertheless, the majority of shading pattern will be accurate enough to properly define hot and cool spots on the research site and therefore this does not really affect the outcome of the general thermal comfort map (figure 16). When seeking after design implementations that improve thermal comfort in different urban spaces in section 3.3., only two case studies (Lenzholzer, 2010 & Klemm, 2018) are used. As these two authors are also colleagues and peer researchers which both reviewed each others work, this knowledge might be biased. There is no knowledge found proposing a different view on thermal comfort in different urban spaces. However, the research conducted by Lenzholzer (2010) and by Klemm (2018) have lots of peer reviews and are both very broad researches, going in to detail on a lot of aspects influencing thermal comfort in urban microclimates.

Next up, the weaknesses in the final design that resulted from the generated knowledge. Most design choices are validated by doing research through designing. This is however a very difficult design method as it always has a part expert judgement in it, making it not purely scientific. There often is an application gap between a specific site with its own unique spatial organisation, climate and usage patterns and the general assessment criteria derived from for example a case study conducted in a totally different environment. Using such assessment criteria makes validating design choices easier, but simultaneously makes it harder to know if the outcome will have effect in your own design and if it will work in the research site. This brings in a lot of uncertainty and a negative downside to design choices if they do not work out like they are intended to.

In section 6.1, five locations with a low thermal comfort are aimed to be improved. The solutions provided for each location are assessed in the assessment matrix by expert judgement from me. Here it could be possible that when calculating exact values of each solution, it might result in a different solution coming out as 'the best'. Due to time limits and the lack of the right knowledge and information, these calculations are not made. It would be a good thing to include these in a follow-up research.As for the masterplan, all design guidelines and the design implementations are incorporated and combined with my own design choices. For example, the northern part of the Willy Brandtlaan is removed and replaced with the northern hospital garden. While this improves the available greenspace and SIL, and creates the opportunity for a pedestrian exclusive space that can connect the park to the hospital premises, it could also create grave mobility issues. In order to minimise this, a new exit road was created next to the exit of the parking garage. If this solves the possible problem is not known. A new exit could also pose more problems for e.g. bus routes and ambulance routes. Therefore, a suitable solution for this possible mobility problem should be researched in a follow-up research.

Incorporating new entrance/exit routes will take off the density pressure of the main entrance square, improving perceived thermal comfort and increasing attractiveness promoting longer stays. However, more entrances/exits also create a control problem. Now, all in- and outcoming people are registered at the service desk and less security is needed. When 3 extra entrance/exit combination are added, this asks for a ingenious control systems and way more employees working on security, mobility and registration. A possible solution could be to only allow people with a special patient- or employee card to go in and out via the new entrances/exits. To explore the opportunities and threats of adding entrances/exits, a follow-up research should dive deeper into the consequences it has for the security and administration for the hospital.

Lastly, the design has incorporated new night lighting everywhere alongside the pedestrian highway as it would increase autonomy to go outside after dark and perceived safety. This could have an opposite effect: the night lighting could improve the situation for people walking dogs at night, rowdy young people hanging around there and homeless people gathering there. This would decrease the perceived safety and increase nuisance levels in the area, also lowering its reputation. This all negatively affects social interaction possibilities. It is a risky design choice, which if executed right could be fruitful but also has high chances of failure. Therefore this should carefully be reconsidered and sought out more in detail.

9. Conclusion

This thesis research focussed on how spatial design could help prevent the global problem of loneliness among elderly people by means of providing (better) SIL. The design question that arises to do so was: 'What design interventions could improve the accessibility and thermal quality of social interaction locations for elderly people, eventually increasing social interaction possibilities?'

By doing literature- and case studies as well as site specific research on hospital 'Ziekenhuis Gelderse Vallei' and its surroundings, multiple design interventions that could improve the physical accessibility (walkability) (chapter 2) and thermal comfort of social interaction locations (chapter 3) were found. Also, some design implementations that could improve the quality and attractiveness of social interaction possibilities for elderly people in general was generated (chapter 2 and 3). The design interventions are summarized and listed in table 11. As these design interventions are aimed at elderly people (aged 65 and older), they do not certainly apply in general.

By applying these design implementations in future landscape designs, the (physical) accessibility and thermal quality as well as the quality and attractiveness of SIL for elderly people could be improved to an extent in which they improve social interaction possibilities for elderly people. This contributes to countering the growing global problem of loneliness among elderly people on a local scale. With it, it can improve the quality of life for elderly people. In order to easily apply the knowledge found in this research, it was transformed into six general design guidelines for improving social interaction possibilities for elderly people. These are:

1. The design should provide a suitable pedestrian network structure for elderly people
2. The design should provide public services and amenities
3. The design should promote organised social interaction and autonomy
4. The design should provide various attractive and reachable SIL
5. The design should help increase perceived (night-time) safety
6. The design should provide an aesthetically appealing environment

These guidelines can be used in other design processes focussing on improving social interaction possibilities for elderly people.

By projecting these design guidelines on the research site and validating design choices with design assessment criteria derived from the generated knowledge, a masterplan for the redesign of the current site could be made that would improve the accessibility and thermal quality of social interaction locations for elderly people at Ziekenhuis Gelderse Vallei.

For improving accessibility at the research site, a 'pedestrian highway' routing was installed: a pedestrian-exclusive route connecting hospital facilities and garden- or park-like surroundings via a broad, levelled and smooth concrete path. The path is accompanied by night lighting and sufficient signage to improve perceived safety and autonomy for elderly people, and provides multiple types of SIL at various suitable locations on the research site. A major link is established by creating a MiVaduct (pedestrian bridge) over the Laan der Verenigde Naties and a new bridge across the pond in the park.

For improving thermal comfort at the research site, multiple design interventions are executed in places currently experiencing low thermal comfort. These include placing shading structures, planting more trees, replacing hard surfaces with permeable surfaces like vegetation and bitumen and adding extra entrance/exit combinations to the hospital facilities.

Altogether, these implementations form the new (re)design for hospital Ziekenhuis Gelderse Vallei and its surroundings, which contributes to countering loneliness by increasing the social interaction possibilities. Therefore, this thesis has suggested multiple substantial and effective design implementations for improving accessibility and thermal comfort of social interaction locations for elderly people.

Table 11: All gathered design interventions for improving SIL accessibility, thermal comfort at SIL (for three different urban spaces) and SIL in gereneral. For each implementation, the source it was adopted from is added and the chapter or section in which this was introduced are named.

Design interventions that could improve SIL accessibility:	**Source**	**Section**
1. Broad, levelled sidewalks with smooth surface and curb ramps	Rosenberg et al., 2012; van den Berg et al., 2020	*2.3*
2. Clear road crossings with visible traffic		
3. Avoid busy roads and fast driving traffic		
4. Available amenities and services like shelter, toilets and resting spots along access routes		
5. Parking availability close by, but not in direct sight (not prominently present)	Holland et al., 2007	
6. Provide good signage along routes		
Design interventions that could improve thermal comfort present at SIL: Urban Squares	**Source**	**Section**
1. Spatial objects to break the openness	Lenzholzer, 2010	*3.3*
2. Include shading features, vegetation or water features		
3. Provide resting places		
4. Use of more 'warm' materials like wood, textile and vegetation		
Design interventions that could improve thermal comfort present at SIL: Urban Greenspaces	**Source**	**Section**
1. Creating a variety of solar exposure conditions by applying a shading ratio (40% shaded - 20% partially shaded - 40% sunny)	Klemm, 2018	3.3
2. Creating a 'patchwork pattern' of sun and shaded spots		
3. Opting autonomy by creating multi-functional spaces		
Design interventions that could improve thermal comfort present at SIL: Urban Canyons	**Source**	**Section**
1. Having street greenery at multiple levels (as well vertically as horizontally)	Hotkevica, 2013; Klemm, 2018	3.3
2. Consider a good balance between tree frequency and climate effects	Hotkevica, 2013	
3. Usage of permeable surfaces	Chen et al., 2019	
Design interventions that could improve social interaction possibilities in general	**Source**	**Section**
1. Increase perceived (night-time) safety	Sugiyama & Ward Thompson, 2008; van den Berg et al., 2020	*2.3*
2. Smart use of 'fourth places' by creating nodes, props and thresholds	Aelbrecht, 2016	
3. Increase the aesthetic appeal of the outside environment	Sugiyama & Ward Thompson, 2008; Peters et al., 2009	
4. Having facilities for other user groups like playgrounds and sports facilities	Sugiyama & Ward Thompson, 2008	
5. Provide 'something to look at'		
6. Acquire a pleasant atmosphere by including a variety of resting places (benches) and amenities		

10. Reflection

Designing for human health and wellbeing by means of landscape architecture is a particularly difficult discipline as it tries to connect psychological mechanisms and general preferences to physical spatial organisations. Recent substantial research about the general links between human health and physical environment has shun more light on the problematics, challenges and opportunities within this discipline. Being such an unexplored field which so recently gained substantial evidence and yet is so relevant for modern day society, I immediately was enthusiastic when this topic was introduced for writing a thesis. During this thesis research, I learned a lot more about the actual factors of the physical world that influence our day-to-day health. In addition, I also learned about the complexity of this subject and the difficulties there are in decision making when a spatial concept is translated to a final design. I realised that even with most design implementations validated by research, there could possibly be a negative downside if the design turned out different than expected. This gave me a new insight on what landscape architecture as discipline could mean for society in general, especially in a future where global health problematics and mass urbanisation are becoming more and more evident.
In this thesis research I started off with several personal goals to reach during the development of my research. In this section I will reflect on my personal performance from the past 9 weeks. What did I do well? What could have been done better? Where was I slacking?

Overall, I think I did a good job during this thesis research. My main learning objective was to improve my academic skills and write a full research on my own. As the Landsacape Architecture bachelor studies does mainly focus on the overall designprocess from scratch to design details and learning to present, visualise and argument your ideas, very few time is spent actually practicing doing academic research. This made me a little nervous about starting my bachelor thesis as I had the feeling I may not be up for the task with the knowledge I gathered during the past three years of bachelor studying. However, when I eventually got the hang of it, it went quite well. With the right vision and research structure in mind and useful feedback I think my research skills have improved a lot and I actually am able to conduct research on my own. If this is sufficient for publishing is another story, however I am confident that the general design guidelines and suggestions made in this thesis research could be used in beneficial ways by landscape architects, urban planners and spatial organisers. Looking through this report I am confident about the academic level of this research and proud of the end product.

Another learning objective was to narrow my scope to one or two problems, as I often tend to enlarge my scope at the start of a design studio (as learned from previous experiences). This often leads to a chaos, superfluous work and makes t harder to come to specific decision making. Eventually, I think I succeeded in doing so, but at first I still broadened my research to much. This resulted in a knowledge gap too big to bridge, eventually leaving me to skip some sub-design questions and rewriting parts of my research. I could have done better at the start by being more realistic and less ambitious when defining my design problem, questions and knowledge gap. However, in the end I think I managed to restore a decent narrow scope by rewriting and leaving aspects out.

Learning to manage working breaks and holding on to time schedules was my third and maybe most important learning objective. I often get caught up in working, losing sight of time and working late or forgetting breaks. This eventually resulted in RSI and stress problematics with which I have struggled previously forcing me to stop studying for a while. This was something I definitely did not want to reoccur during writing my thesis. I had a strict break schedule and set a maximum hours of work per day. Sometimes I did not always hold on to this as I am usually more productive during evening hours. However, overall I think I prioritized well during the past 9 weeks, taking breaks regularly and contacting my tutor and examiner when a negative development on personal front took up a lot of my energy and focus. I am happy to say that I see how I have improved on this front and could finish this thesis without the previously named problematics reoccurring.

Lastly, the fourth learning objective was to make a design and visualisations that are coherent and in the same style. In previous design studios I often got comments on irregularities of different work styles and material choices. I used a specific colour palette for making all visualisations and developed a style up front, which really helped me to create more coherence between my different design visuals. For me, the presented design is more coherent than all previous works I have made, and therefore I consider this objective has been reached successfully.

This thesis research learned me a lot about a for me unknown field of landscape architecture which I now find one of the most interesting. It also learned me more about myself; how I manage my time properly, when to start and when to stop working and last but not least that I actually enjoy doing academic research more than I thought up front. Perhaps this thesis research one day stimulates the hospital Ziekenhuis Gelderse Vallei or other healthcare institutions to critically look at their public spaces outdoors and motivates them to choose for a (re)design with interventions to counter loneliness among elderly people in mind.

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12. Appendices

the appendices provide additional information and figures related to this research.

12.1. Appendix 1: Methods & Materials table

Table 12: a table for the methods and materials (section 1.5) that shows a clear overview of the Sub research questions, to which concept they belong and by what means or method they are aimed to be solved. When literature is involved, the literature is listed under materials/sources.

Key concept(s)	Related SRQ(s)	Research Method	Materials/Sources
Social Interaction Locations (SIL) and loneliness *(Location and accessibility of SIL)*	1. Where are the current locations providing social interaction possibilities for elderly people?	**RFD:** Site analysis	Site visit, mapping all SIL on the research site. Making pictures. 1. Tsai et al. (2016)
	2. What is the current pedestrian routing quality from and towards these SIL?	**RFD:** Site analysis & literature research	Site visit, mapping all pedestrian roads from and towards SIL on the research site. Making pictures. Based on criteria derived from literature. 1. Rosenberg et al. (2012)
	3. What does the current elderly pedestrian behaviour look like around busy places and their SIL on the site?	**RFD:** Site analysis	Site visit, counting people in target group according to behavioural types on 5 chosen locations to eventually create behavioural maps for 3 different times of the week. 1. Itterson et al. (1970) 2. Marušić (2012)
	4. What are barriers for less mobile elderly people to go outside and have social interaction?	**RFD:** Literature study	1. Honigh-de Vlaming (2013) 2. Boslaugh & Andresen (2006) 3. van den Berg et al. (2020) 4. Rosenberg et al. (2012) 5. Sugiyama & Ward Thompson (2008) 6. Bengtsson & Carlsson (2015) 7. Tsai et al. (2016)
	5. What design implementations stimulate social interaction for elderly people?	**RFD:** Literature study	*1* Peters et al. (2009) 2. Holland et al. (2007) 3. Aelbrecht (2016) 4. Sugiyama & Ward Thompson (2008) 5. Dimitrova et al. (2007).
	9. What are the best suitable locations for Social Interaction Locations for elderly people within the site premises?	**RTD:** concept phase	Analysis, problem identification and solution proposals based on found knowledge (chapter 2). Assessing multiple solutions by means of design assessment criteria to determine the best solution.
Urban Microclimate: thermal comfort *(Thermal Quality of SIL)*	6. What is the current microclimate situation regarding *thermal comfort* within the site premises?	**RFD:** site analysis & literature study	SketchUp 3D model simulation, ARCgis Pro maps analysis and conversion. 1. Shashua-Bar and Hoffman (2000); (2003) 2. Yang et al. (2017) 3. Stan et al. (2014) 4. Erell et al (2011) 5. Jacobs et al. (2020)
	7. What design implementations improve thermal comfort in different urban spaces?	**RFD**: Literature study	1. Klemm et al. (2018) 2. Lenzholzer (2010) 3.. Erell et al.. (2011) 4. Li et al. (2019) 5. Kusaka & Kimura. (2004) 6. Hotkevica (2013) 7. Chen et al. (2019)
	8. Where should climate adaptation measures be implemented?	**RTD:** concept phase	Analysis, problem identification and solution proposals based on found knowledge (chapter 3). Assessing multiple solutions by means of design assessment criteria to determine the best solution.

12.2. Appendix 2

Table 13: behavioural analysis matrix for counting different behavioural types for each of the examined locations in the behavioural research. The six behavioural types include transport walking (1); recreational walking (2); walking with dog or child (3); being moved in a wheelchair (4); sitting on a bench (5); waiting (standing) (6). Factors like weather and amount of SIL are also noted.

Location:	**Amount of visible SIL:**	**Type of SIL:**	
T(C):	**Weather:**		
	Date:		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 12:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*		0	
Recreational Walking**			
Walking with dog or child			
Being moved (wheelchair or similar)			
Sitting on bench			
Waiting (standing)			
Total amount of elderly & less mobile visitors per 30 minutes			

Table 14: behavioural analysis matrix for the Bus stop in the Wily Brandtlaan: Éde, Gelderse Vallei' showing the amount of counted behavioural types per category per time of the week.

Location: Bus stop Willy brandtlaan 'Ede, Gelderse Vallei'	**Amount of visible SIL:** 3	**Type of SIL:** bus stop, 2 curved benches on grass	
T(C): 20°C – 23°C	**Weather:** Clear sky, sunny		
	Date: 16 – 9 – 2020		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 12:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*	4	10	13
Recreational Walking**	4	3	6
Walking with dog or child	0	1	0
Being moved (wheelchair or similar)	1	1	2
Sitting on bench	2	4	7
Waiting (standing)	1	1	3
Total amount of elderly & less mobile visitors per 30 minutes	**12**	**20**	31

Table 15: behavioural analysis matrix for the Parking lot in front of the radiotherapy group showing the amount of counted behavioural types per category per time of the week.

Location: Parking lot in front of Radiotherapy group	**Amount of visible SIL:** 2	**Type of SIL:** iron benches with backrests, bench with transparent roof	
T(C): 20°C – 23°C	**Weather:** Clear sky, sunny		
	Date: 16 – 9 – 2020		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 12:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*	7	11	6
Recreational Walking**	1	2	5
Walking with dog or child	0	0	0
Being moved (wheelchair or similar)	0	1	1
Sitting on bench	2	6	4
Waiting (standing)	1	1	0
Total amount of elderly & less mobile visitors per 30 minutes	**11**	**21**	**16**

Table 16: behavioural analysis matrix for the Entrance square of the hospital showing the amount of counted behavioural types per category per time of the week.

Location: Entrance Square Ziekenhuis Gelderse Vallei	**Amount of visible SIL:** 10	**Type of SIL:** wooden benches, bench with transparent roof, bus stop	
T(C): 20°C – 23°C	**Weather:** Clear sky, sunny		
	Date: 16 – 9 – 2020		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 10:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*	82	86	75
Recreational Walking**	1	0	4
Walking with dog or child	1	1	2
Being moved (wheelchair or similar)	11	23	17
Sitting on bench	13	13	16
Waiting (standing)	12	6	4
Total amount of elderly & less mobile visitors per 30 minutes	**120**	**130**	**118**

Table 17: behavioural analysis matrix for the Wily Brandtlaan on the north side of the hospital premises showing the amount of counted behavioural types per category per time of the week.

Location: Willy brandtlaan, North side of Hospital premises	**Amount of visible SIL:** 2	**Type of SIL:** 2 curved benches on grass	
T(C): 20°C – 23°C	**Weather:** Clear sky, sunny		
	Date: 16 – 9 – 2020		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 12:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*	3	0	2
Recreational Walking**	2	1	2
Walking with dog or child	0	0	0
Being moved (wheelchair or similar)	0	1	1
Sitting on bench	0	0	1
Waiting (standing)	1	0	0
Total amount of elderly & less mobile visitors per 30 minutes	**6**	**2**	**6**

Table 18: behavioural analysis matrix for the park north of the hospital (west of the pond) showing the amount of counted behavioural types per category per time of the week.

Location: Park north of hospital, west side next to the big pond	**Amount of visible SIL:** 2	**Type of SIL:** : iron bench with backrest, wooden deck at the waterfront	
T(C): 20°C – 23°C	**Weather:** Clear sky, sunny		
	Date: 16 – 9 – 2020		**Date:**
Activity of observed pedestrian senior	**working day (morning: 9:30 – 12:00)**	**working day (afternoon: 15:30 – 18:00)**	**weekend day (afternoon: 12:00 – 14:30)**
Transport Walking*	0	1	0
Recreational Walking**	2	6	12
Walking with dog or child	0	1	1
Being moved (wheelchair or similar)	0	0	0
Sitting on bench	1	1	1
Waiting (standing)	0	0	0
Total amount of elderly & less mobile visitors per 30 minutes	**3**	**9**	**14**

12.3. Appendix 3: behavioural maps

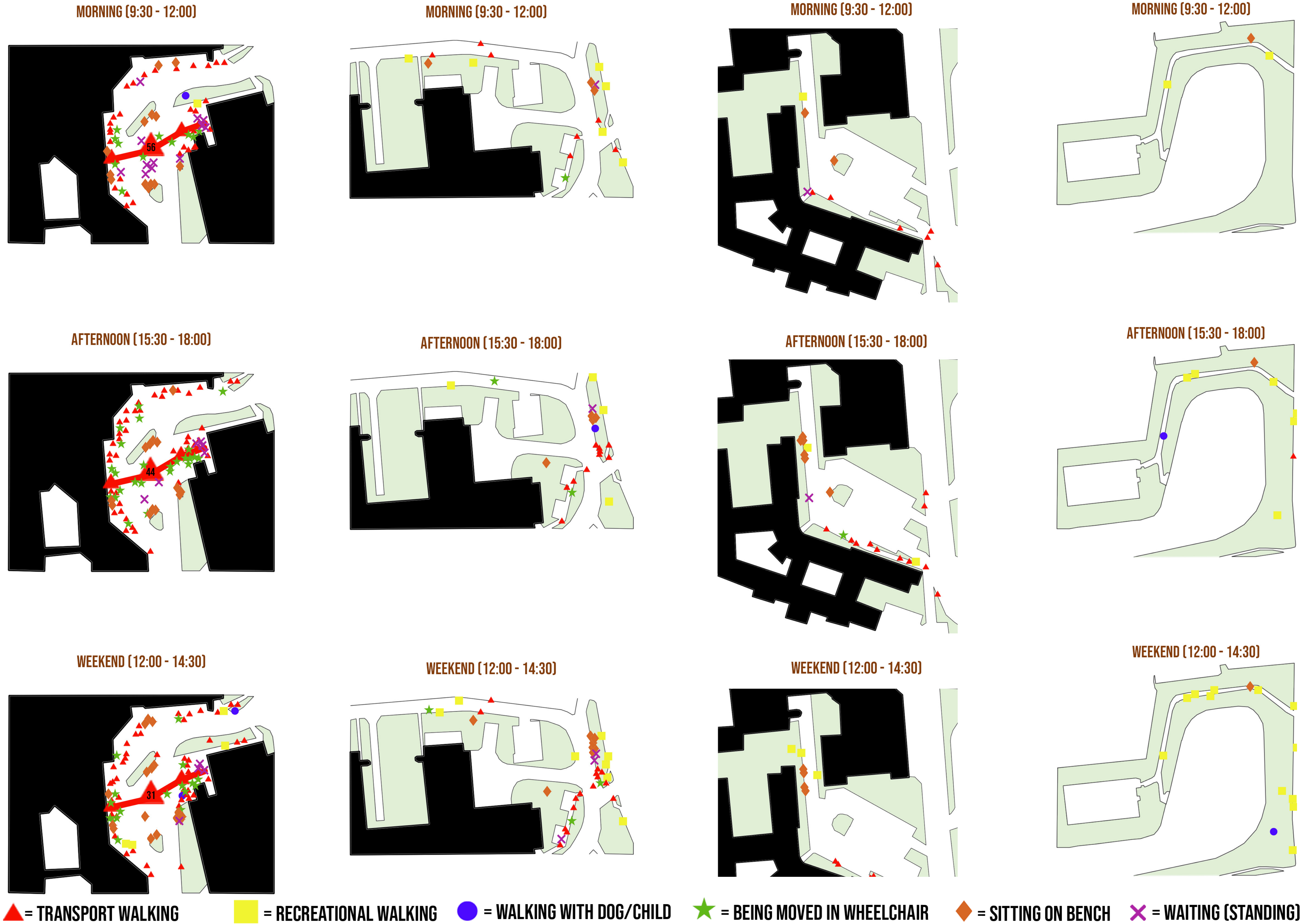

Figure 44: Behavioural maps for each examined location during behavioural analysis. The analysis for the bus stop and Willy Brandtlaan (north) are combined into one map. Each icon resembles a specific type of behaviour and resembles 1 person in the target group (65 and older) doing so within the examined location. The locations of the icon placement are the place where the behaviour occurred when examining. Figures from left to right: Entrrance square; Willy ***Brandtlaan + Bus stop; parking lot; park.***

12.4. Appendix 4: Concept assessment matrices

this appendix shows the filled in concept assessment matrixes for all three concept models poresented in chapter 5 and assessed in chapter 6. The SIL Routing concept model at the end has the highest total score, making it the most suitable spatial concept for improving social interaction among elderly people on the research site.

5.2.1. Scattered SIL model

By scattering SIL all over the research site, the highest variation in physical environment and thermally comfortable locations can be reached. However, this poses problems for accessibility (walkability). To ensure that all SIL are reachable, a vast network of sufficient pavements needs to be installed. Without pedestrian infrastructure, the SIL will be of no use for elderly people. This model also creates lower user density because of the widespread SIL and many SIL options. Nuisance in this model is very dependant on the location. Some (f.e. close to roads) experience high nuisance levels and some (f.e. in the park) experience low nuisance levels. The same applies to the thermally comfortable locations. Lastly, the feasibility is rather low in this model. This is because a high amount of changes is needed to achieve this model; many pedestrian routing structures have to be improved or even created, and many SIL have to be added. Due to low user density, the results could be less effective as other models while having a relatively low feasibility. This results in the following assessment matrix (table 19)

Scattered SIL model					
Assessment Criterium:	**Points**				
	-2	-1	0	+1	+2
Walkability (physical accessibility) (x2)	x				
Thermal environmental variation (x2)					x
Physical environmental variation (x1)					x
High user density (x1)		x			
Thermally comfortable locations (x1)				x	
Low nuisance levels (x1)		x			
High feasibility (x2)	x				
Total score	-3				

5.2.2. Clustered SIL model

By clustering SIL in a central part of the research area close to the hospital buildings, the walkability (physical accessibility) of the SIL is optimized. Few pedestrian walking facility upgrades are needed as the current pavement quality is already very sufficient there. Clustering creates a high user density because of the small surface and high service provisions. However, by clustering the environmental variation declines as the surroundings are all within the centre of the hospital premises. Most places are currently thermally uncomfortable, however this could be altered by designing. The model has a high level of nuisance due to the clustering and high density being very close to inevitable traffic fluxes like taxi's, bus lines and ambulance emergency routes.Because the design implementations that are needed are rather small (creating better urban comfort and better SIL), the feasibility for this model is very high. This leads to the following assessment matrix (table 20)

Clustered SIL model					
Assessment Criterium:	**Points**				
	-2	-1	0	+1	+2
Walkability (physical accessibility) (x2)					x
Thermal environmental variation (x2)		x			
Physical environmental variation (x1)	x				
High user density (x1)					x
Thermally comfortable locations (x1)		x			
Low nuisance levels (x1)	x				
High feasibility (x2)					x
Total score	-1				

5.2.3. SIL routing model

This model combines aspects of both previously assessed models. By creating a major walking route surrounded by SIL, the walkability will be relatively high. The walking distances are dependant on the SIL people choose to go to. Because the route crosses the park as well as the hospital premises, a moderate physical environmental variation (park and urban facilities) is maintained. The park also makes the environmental thermal variety higher on average as the park majorly holds shading spots and higher perceived thermal comfort and the hospital site majorly has sunny spots and lower perceived thermal comfort. However, the park area is bigger and therefore this model has quite good thermally comfortable locations overall. To reach the park, a crossing has to be designed to link the hospital premises and park. This creates high nuisance levels, which is also the case in the centre of the hospital premises. Because changing the mobility network without negatively influencing other traffic fluxes is a big design implementation as it probably requires a pedestrian bridge or tunnel, the feasibility of this model is quite low. Altogether this results in the assessment matrix shown in table 21.

Clustered SIL model					
Assessment Criterium:	**Points**				
	-2	-1	0	+1	+2
Walkability (physical accessibility) (x2)				x	
Thermal environmental variation (x2)					x
Physical environmental variation (x1)				x	
High user density (x1)			x		
Thermally comfortable locations (x1)				x	
Low nuisance levels (x1)		x			
High feasibility (x2)	x				
Total score	+3				

Table 19 (upper), 20 (middle) and 21 (lower): concept assessment matrices for each spatial concept model: Scattered SIL model (upper table); Clustered SIL model (middle table); SIL routing model (lower table). The accessory text is shown on the right side of each assessment matrix

12.5. Appendix 5: designing for SIL Suitability

Sub-area 1: the park

As seen in figure 26, the park has 5 out of 6 design guidelines represented in the final concept. The one that is missing, is design guideline 5: Help increase perceived (nighttime) safety. This design guideline deals with nuisance and lack of night lighting. The concept map includes night lighting everywhere alongside the 'pedestrian highway' routing (figure 23), making night lighting not the problem for this sub-area. Noise however is a problem because of the big traffic roads along the southern- and eastern borders of the park. These are too close and therefore cause a highlevel of perceived nuisance when inside the park due to the sight and sound of passing traffic. The big crossing connecting the roads also generates extra noise and pollution levels due to cars slowing to stop and accelerating afterwards (Raza et al., 2018). A solution for this problem is to place a barrier between the park and road that blocks noise, particulate matter and covers the roads from sight. By applying research through designing, this sub-section will explore which barrier and material suits the site best.

Noise barriers can be made out of multiple materials. According to a report by NSW which set guidelines for noise barrier design, the wall shoudl 1). be at least 1.5 meters in height, 2). be located as close to the road (source of noise) as possible. 3). be consistent in material and height (monotonous) to be of least distraction to automobilists, 4). should integrate the residential/built environment and vegetation present to 'fit in' with them. Also, certain relief in the building material could mute sounds even more due to multiple reflection. (NSW Government, 2016).

There are three main types of noise barrier materials: stone or concrete (1); acrylic and other synthetic materials (2) and timber or foam grown with plants also called "bio-barriers" (3) (NSW Government, 2016). A spherical impression showing a noise wall made out of each material is made to compare these and find out which of the three noise barriers fits best with its surroundings.

Figure 45A shows the 'Laan der Verenigde Naties' north of the hospital site with a concrete noise barrier. A pro of this materialisation is that the relief on the walls improves muting the noise even more (NSW Government, 2016) and the concrete matches with the built environment (viaduct). Cons are that concrete has high thermal storage (Erell et al., 2011) and is less safe than the other materials regarding car- or other traffic accidents.

Figure 45B shows the 'Laan der Verenigde Naties' with a synthetic noise barrier. Pro's of synthetic noise barriers are low thermal storage (Erell et al., 2011) and a high variation in design options. Also, they are easy to install and relatively cheap. However, Synthetic barriers have few relief possibilities and often have reflective properties which could be dangerous for road users (NSW Government, 2016). Also, in this case, synthetic materialisation does not match the physical environment.

Figure 45C shows the 'Laan der Verenigde Naties' with a bio-based noise barrier. The barriers has a low thermal storage and absorbs noise very well due to the foam on which the plants grow and the 'relief' created by the plants (NSW Government, 2016). The natural design blends in very well with its surroundings and is also more safe for car crashes and accidents. A con for this design is that a living noise barriers requires maintainance and could fail to grow or die due to weather circumstances.

figure 45A: spherical impression of a concrete noise barrier alongside the Laan der Verenigde Naties

figure 45B: spherical impression of a synthetic noise barrier alongside the Laan der Verenigde Naties

figure 45C: spherical impression of a bio-based noise barrier alongside the Laan der Verenigde Naties

Sub-area 3: the van Steenbergenweg and surroundings

For sub-area 3, the van Steenbergenweg and its surroundings, only 3 out of 6 design guidelines are represented in the current concept (see figure X). Design guidelines 1 (Provide a suitable pedestrian network structure for elderly people); 3 (promote organised social interaction and autonomy) and 4 (provide various attractive and reachable SIL) are missing. These all have one cause: the area has too few space. Besides the road and sidewalk, the area only offers a small lawn strip that is mostly sloped towards a ditch for social interaction. This is insufficient for as well walking spaces (design guideline 1), events or community gatherings (design guideline 3) and attractive, varied SIL (design guideline 4). To solve the problem of narrowness and little space for social interaction, creative shifts in spatial organisation have to be made. Figure 46A and figure 46B show two solutions for creating more space in the van Steenbergenweg to have more opportunities to place SIL.

In figure 46A, the sidewalk and car road are swapped so that the sidewalk is now on the waterfront side. At multiple places, a platform with railing is made which leans over the lawn slope. this provide easily accessible locations next to the walking routes to place benches or other resting places. The implementation leaves most of the current greenspace intact.

Figure 46B has a somewhat bigger design intervention. In this situation, the road and sidewalk are also swapped. However, the sidewalk is transformed to a walking promenade which encloses the trees to broaden the path. A railing provides safety. the broadened sidewalk provides space for resting places or benches and for people to stop walking and lean against the railing. The design intervention does reduce the amount of greenspace.

figure 46A: spherical impression of a solution on how to create more space in the van Steenbergenweg by implementing small terraces that lean over the lawn slope.

figure 46B: spherical impression of a solution on how to create more space in the van Steenbergenweg by implementing a broad wooden walking promenade alongside the road.

For sub-area one (the noise barrier), the best option is the bio-based barrier, as it has the highest coherence with the surroundings and seems to have the fewest negative aspects. The other noise barrier options do not have pro's the bio-based barrier does not have. Therefore, the noise barriers that will be included in the final design will be bio-based noise barriers as shown in figure 45C.

For sub-area three (creating more space for walking and social interaction), the best option is the implementation of the small terraces. This solution leaves more space for the existing greenspace and is a way smaller design intervention. This increases its feasibility. This solution also creates separate spaces for wakling (the new sidewalk) and resting or social interaction (the terraces) whereas for the other solution these are blended. Therefore, the van Steenbergenweg will be redesigned according to the first solution, as shown in figure 46A.

12.6. Appendix 6: Description final masterplan

this appendix includes a broader description of the master plan for the (re)design of hospital Ziekenhuis Gelderse Vallei and its surroundings - Healthy Connections Ede.

The masterplan visualised in the map in figure 27 is the result of combining all design implementations generated in chapter 6 with the six design guidelines that were drawn up in chapter 4. The masterplan builds on the final concept defined earlier in this research: the SIL routing concept.

In this masterplan, the hospital facilities are connected to various SIL placed all over the target area by a circular pedestrian-exclusive walking route; the so-called pedestrian highway (coloured purple). This is a broad and levelled path made from white concrete and is accompanied by street lighting everywhere. It connects the main- and new entrances/exits to the park-like surroundings. On the hospital premises this route establishes a new link between the van Steenbergenweg and Willy Brandtlaan on two locations (north- and south of hospital building). The route avoids big crossing points and traffic fluxes by the major new link that will be established between the hospital premises and the park: the MiVaduct. This is a pedestrian walking bridge or viaduct across the Laan der V.N. which is designed specifically to serve people travelling by foot. The MiVaduct (short for 'Minder valide'-duct, a dutch term for elderly and less mobile people) construction is mainly built out of concrete and provides broad, corten steel stairs and elevators in stainless steel 'cocoon' casings on both sides. Its broad upper level provides space for a park like design including trees and hanging plants. Curved benches in the middle provide a resting spot along the lineair path across the MiVaduct.

The redesign of the park combines mobility with recreation resulting in a high variety of (types of) SIL such as a big and small wooden waterfront promenade, four elevated platforms hanging over the slopes providing viewpoints and leaning edges, a football court accompanied by seating stairs. Smart placement of the platforms and promenades results in views that always (partly) show another platform or promenade, which enlarges the attractivity of the places as all of them provide 'something to look at'. The elevated platforms are used similarly in the van Steenbergweg to create more space and SIL. A new, broad bridge connects the northern side of the park directly to the MiVaduct, optimising routing possibilities and travel time from and towards the hospital facilities. The bridge has a walking part and a part that provides resting affordances like benches and leaning edges to take a break. As the park is currently used by runners also, a running path made of permeable bitumen next to the pedestrian highway in the north side of the park should prevent conflicts between different user groups. This also contributes to perceived safety and promotes sports and activity for other hospital clients. The slope in the northeast corner of the park is cleared to create a sloped lawn which can be used multifunctionally for resting and recreation. On the eastern- and southern edge of the park, a bio-based noise barrier separates the traffic roads from the park and existing cycle roads to block the sight of passing cars and prevent the mojority of the noise and exhaust gases to reach the park.

On the hospital premises, both the northern Willy Brandtlaan and parking lot of the Radiotherapy group building are replaced by small park spaces that are exclusive walking spaces. To prevent mobility issues as a result, a new exit lane from the Willy Brandtlaan (east side) to the Dr. W. Dreeslaan is created which enables leaving traffic to get on the major traffic routes straight away. As the parking garage provides enough parking space for the hospital (bron) , redesigning the parking lot to a park poses no parking issues. The small park areas created between the buildings serve as community gardens that provide place for organised activities and community gatherings as well as various types of seating places like benches and picnic benches. Tap water stations and shelter options are also incorporated.

The main entrance square is enrichted with some sun screens covering the major walking routes to create more thermal comfort. Extra trees and low vegetation also contribute to higher (perceived) thermal comfort and to more aesthetic appeal. New benches and a tap water station should enlarge seating comfort and encourage a more comfortable stay. Because of the extra entrance/exit options, the activity density pressure of the main square will be lowered.

This design provides all properties needed for stimulating social interaction as defined in the six design guidelines, especially improving the current situation for the elderly and less mobile people whilst also improving pedestrian network structure and -quality and contributes to a more thermally comfortable environment. This is done without negatively affecting private traffic fluxes and public transit, nor negatively affecting other user groups. Healthy Connections: by connecting SIL and hospital facilities, elderly people can connect with one another.