BLOWING OFF STEAM

TOWARDS THERMALLY COMFORTABLE AND RESTORATIVE HOSPITAL OUTDOOR SPACES AT HOSPITAL GELDERSE VALLEI EDE

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ABSTRACT

Noli turbare circulos meos! Do not disturb my circles! – *Archimedes*

For a healthy population, a healthy hospital staff is a prerequisite. However, their long and intensive working days can cause or contribute to attentional fatigue, which interferes with their work performance. Any opportunity to revitalise during a shift should be taken on with both hands, meaning staff needs the opportunity to blow off some steam occasionally. This thesis explores how hospital outdoor spaces can contribute to attention restoration of staff, within a framework of thermal comfort. Hospital Gelderse Vallei Ede provides the context for this research. Design principles based on Attention Restoration Theory and heat stress are identified, and a site-analysis is executed to give direction to design guidelines. Zones were identified to better decompose the underlying causes of the problems at the site. The design guidelines are used to draft design concept variations, which in turn are evaluated by criteria for thermal comfort. One zone is redesigned in detail, and evaluated by criteria for attention restoration. Both the design guidelines and criteria are based on literature, which results in evidence-based designs, meaning that the redesigns of Hospital Gelderse Vallei are credible for their restorative and heat-mitigative potential. This thesis advocates that more attention should be paid to human-environment relationships at hospital outdoor spaces and shows an example of how wellbeing of hospital staff can be improved, offering inspiration for future heat-mitigation projects of hospital sites that simultaneously try to improve restorativeness.

Preface

Thank you for taking the time to read my bachelor thesis on thermally comfortable and restorative spaces at Hospital Gelderse Vallei Ede. It is the epitome of the skills I have gained during my bachelor Landscape Architecture at Wageningen University and Research. The design that was created is evidence-based and is represented by both digital and hand-drawn work.

Wellbeing and health has been a personal issue for me this past year, as I was confronted with myself and my working habits, and had to alter my lifestyle accordingly. The only challenge I had given myself was to finish my thesis within the set time, and make it through healthily. This experience has made me more conscious of how mental and physical health interact, which motivated me to explore how I could make a design to improve mental health in relation to an environment.

I could not have done this without my supervisor, Agnès Patuano, who not only made the time to tutor me, but also helped me shape my research by asking the right questions and setting realistic expectations. Every tutor session she started out with asking not how the project was going, but how I was doing, which reminded me of what is important: health. Her compassionate yet critical attitude kept me motivated, for which I am very grateful.

I would also like to thank Elly van Duijn, Sabine Humblé, and Stijn Doelman for taking the time to help me organise my thoughts when I had too many, and helping me move forward with my design process. Furthermore, I want to thank my housemates, for offering different perspectives and making me laugh, and Kevin, for being my rock.

Wageningen, May 21st 2021

TABLE OF CONTENTS

1. INTRODUCTION

The healthcare profession is known for its high work pressure and history with mental fatigue and other mental health-related problems (Abdul Shukor et al., 2012; Blasche et al., 2017). Mental fatigue occurs when a person finds themselves deeply focussed for a prolonged time (Kaplan, 1995). This does not affect mental wellbeing altogether, merely the capacity to direct attention (Szolosi, 2011). To avoid confusion, in this thesis mental fatigue will be referred to as directed attention fatigue (DAF), as this is the mechanism that will be focused upon.

Restoring attention deficit is essential for hospital workers to stay functional (Blasche et al., 2017). Once fatigued, the faintest distraction can intervene with their resilience, focus and therefore effectiveness in doing their job (Abdul Shukor et al., 2012; Szolosi, 2011). Wellbeing and health of staff is extremely important, not only for their own good, but health of other people relies on the functioning of hospital staff. A malfunctioning staff may lead to a degradation in quality and availability of healthcare. Therefore, hospital staff is targeted in this research.

Design of hospital outdoor spaces (HOS) has been relying on a limited budget for a long time, resulting in a disregard of their restorative potential (Djukanović et al., 2017; Nedučin et al., 2010). This resulted in functionally designed, grey areas that require little maintenance.

Grey area is related to heat stress, whose effects will intensify due to climate change (Lenzholzer, 2015). In turn, heat stress negatively affects attention restoration (AR) (Taylor et al., 2015), making it an additional cause, beside work-related pressures, that feeds attentional fatigue.

By removing environmental stressors from and adding vegetation to HOS, hospital staff gets the opportunity to restore (Abdul Shukor et al., 2012; Marangos et al., 2020; WHO, 2017). HOS is used by staff, patients and visitors. These users have conflicting needs that should be taken into account with regard to attention restoration.

The challenge is to find balance within a vibrant site that simultaneously tackles heat stress and DAF: a healthy staff is a focussed staff that is less prone to making errors.

THESIS STATEMENT

The aim of this bachelor thesis is to develop evidence-based (EB) design guidelines that improve restorative capacity and decrease climatologic vulnerability of HOS. Hospital Gelderse Vallei Ede (HGV) provides the context for this thesis.

RESEARCH QUESTIONS

How can outdoor spaces surrounding HGV be redesigned to decrease directed attention fatigue and enhance thermal comfort for hospital staff?

SRQ1: What landscape elements are additional causes of DAF?

SRQ2: What design principles can help replenish attentional capacity?

SRQ3: What is the microclimate of the designated area?

SRQ4: What design principles can enhance thermal comfort?

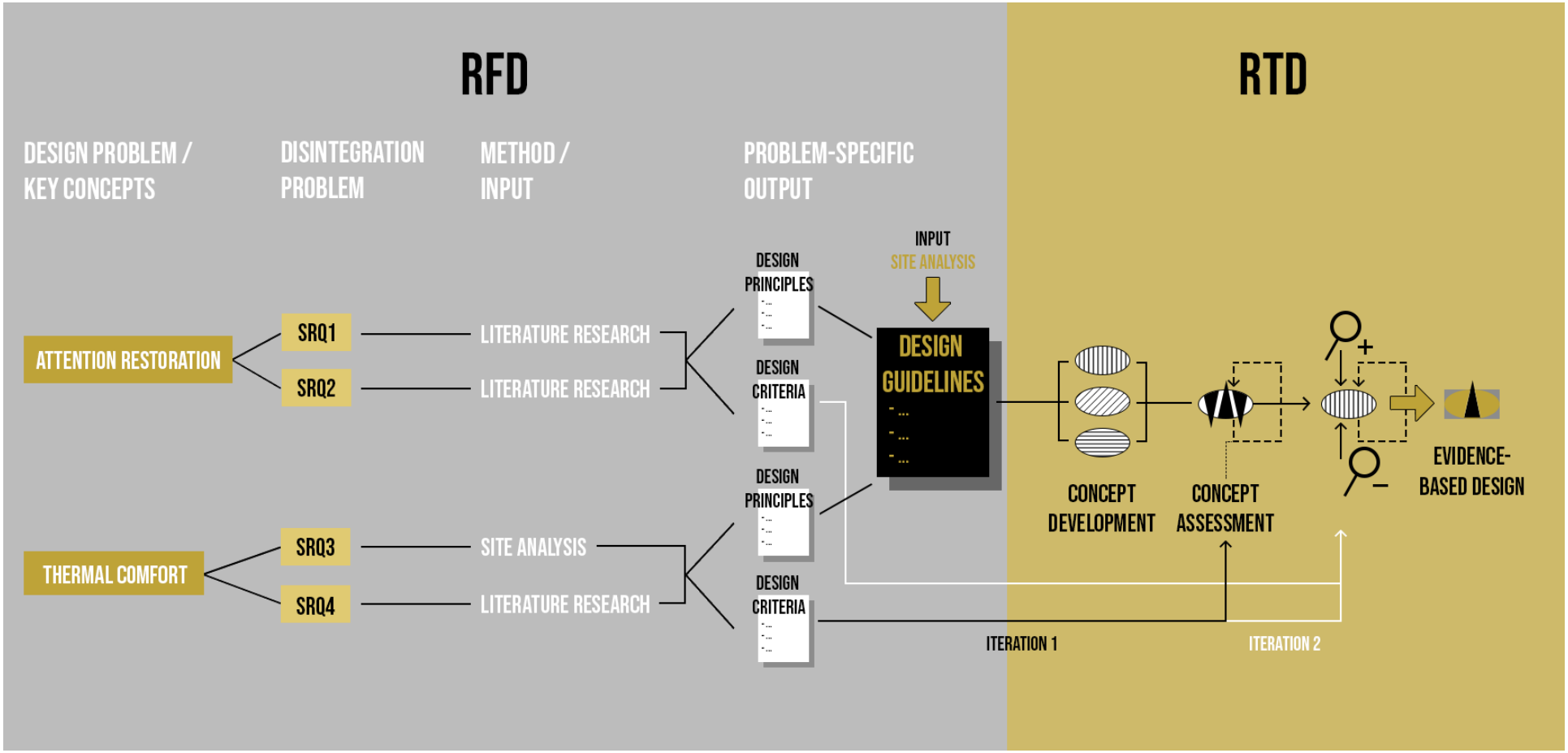


Figure 1 Methodology

Research for design (RfD) and research through design (RtD) are the predominant methods used (*figure 1*). These methods infuse the design with evidence, enhancing its credibility (Lenzholzer et al., 2013). The methodology is inspired by analytical models that use ingredients for an evidence-based design (EBD; Milburn & Brown, 2003). The SRQs helped answering the MRQ. With substantiated answers from literature reviews, case studies and cartographic and on-site analysis, design principles were drafted, i.e. a list of values that functions as a guide. The principles from the two concepts form design guidelines. From this, conceptual models were created and tested, based on knowledge-infused criteria, that function as standards the design should meet. The first iteration is based on thermal comfort, to find which variation best mitigates heat. Afterwards, a second iteration takes place for a smaller sub-area, testing it for its restorative capacity in scales from 1:2000 and smaller, to choose the most effective design.

3. THEORETICAL FRAMEWORKS (FROM THEORY TO DESIGN PRINCIPLES)

Design principles should be infused with knowledge from literature research (*figure 1*) for an EBD to be realised. This chapter is dedicated to put out a body of knowledge, from which substantiated principles can be derived. Attention Restoration Theory (ART) and the foundations of heat stress are used to find answers and develop these principles.

3.1 ATTENTION RESTORATION THEORY

Attention Restoration Theory is used to explain human capacity to focus and solve problems, speculating why and how this capacity fluctuates.

There are two types of attention. The first, directed attention (DA), is a voluntary form of attention that uses cognition and is essential in problem-solving and human effectiveness (Kaplan, 1995; Szolosi, 2011; Taylor et al., 2015). However, it needs effort, and for that reason is sensitive to fatigue (*ibid.*). Prolonged effort can lead to DAF (Kaplan, 1995). An example is a doctor performing an operation, wherefore focus is essential. DAF can arise even when someone enjoys an activity, as the psychobiological system regulating attention gets more susceptible to stimuli when fatigued (Varkovetski, 2015). DA is the type of attention that needs restoration.
The second type is fascination. Fascination is effortless and tireless (Kaplan, 1995), and can be called upon by elements that are inherently fascinating to mankind, forming a basis for restoring attentional reserves (Hartig et al., 2014; Szolosi, 2011), yet is not the only feature that should be available in a restorative environment.

ART claims that immersing oneself in natural or other restorative environments will help restore the attention deficit (Kaplan & Kaplan, 1989). This is because natural environments are most often preferred and are likely to consist of all four key features that allow attention restoration: being away (psychological detachment of the work setting); extent (familiarity and coherence encourage immersing oneself in the environment); soft fascination (effortless attention instead of DA, through elements e.g. water, species richness, wildlife and other interesting elements); and compatibility (matching the needs of target group) (*ibid.*).

By removing elements in that increase the attention deficit, and encouraging attention restoration through design interventions, micro-restorative experiences can be improved. In this thesis, micro-restorative experiences are defined as restorative experiences that occur within a short timeframe, and function as a quick boost to attentional capacity.

(NON-)RESTORATIVE ENVIRONMENTS

To design an environment that promotes AR, it is useful to identify what restorative and non-restorative environments consists of. This way, additional causes to DAF can be filtered out, minimising the presence of fatiguing elements. It can be thought that anything that is not linked to a key feature is non-restorative. This is too general, as use of restorative elements is very context-dependent. For example, planting a tree on the traffic plateau at the main entrance will not make it a restorative environment, even though trees can be restorative elements. Placement could already determine restorative impact of an element. For this reason, the components of an environment that are positively linked to AR (*table 1*) should enrichen a context together, while negative components should be avoided, which is how table 1 should be interpreted.

Table 1 Several environmental components linked to AR-features based on 1. Faris et al. (2012); 2. Grahn and Stigsdotter (2010); 3. Kaplan (2001); 4. Nedučin et al. (2010); 5. Ode Sang et al. (2016); 6. Szolosi (2011); 7. Taylor et al. (2015); 8. Ulrich (1986); 9. Van den Berg et al. (2014); 10. Varkovetski (2015); 11. White & Shah (2019); 12. WHO (2016)

Attention restoration	Positive relation	Negative relation
Being away	Water (1, 8, 10); bird sounds (1, 2, 12)	Reminders of the daily routine (3)
Extent	Coherence (3); scope (3); openness (8, 9)	Too much wilderness (9)
Soft fascination	Water (1, 8, 10); species richness (2); view of nature (1, 4, 11); bird sounds (1, 2, 12)	Too busy (luminance, motion) (11); complexity (3); abstract and interpretative designs (4); forceful stimuli (like ambulance) (10)
Compatibility	Water (1, 8, 10); scattered trees (8); utilities (2); variety in opportunities (being social/not, sitting/walking, shadow/sun, etc.) (2, 4); cleanliness (5); aesthetics (5); safety (5); accessibility (5); familiarity (4); isolation from patients (1); peacefulness/serenity (2); (window) view of nature (1, 4, 11)	Too busy (2); heat (7); bad maintenance (5); smoking (1); too much information (4); distraction (3); lack of information (3); duty (3); deception (3); difficulty (3); danger (3); unfamiliarity (6)

LANDSCAPE PREFERENCE

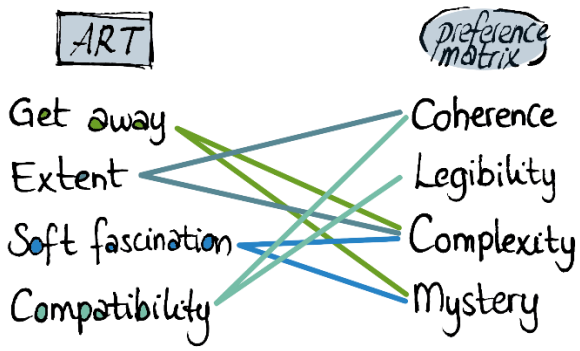


Figure 2 Attention Restoration Theory linked to the preference matrix

Table 2 Preference matrix (Kaplan & Kaplan, 1989)

	Make sense	*Involvement*
Immediate	Coherence	Complexity
Predicted	Legibility	Mystery

Preference suggests the presence of an actual or illusional choice between alternatives, enabling a person to choose a compatible environment (Grahn & Stigsdotter, 2010; Kaplan & Kaplan, 1989). The preference matrix (*table 2*) indicates what is generally preferred in landscapes, which should not be confused with elements that are inherently fascinating or restorative. However, the matrix can be linked to ART (*figure 2*). Complexity and mystery relate to aspects that evoke soft fascination, such as (species) richness (Grahn & Stigsdotter, 2010), and experience of nature (Faris et al., 2012; Kaplan & Kaplan, 1989). Moreover, for the environment to suggest an extent, it should be both coherent and complex (Kaplan, 1995). Coherent and legible landscapes make sense, for which they are compatible, and lastly, engaging environments can pose a great getaway. Hence, landscape preference can be used as a tool to assess which environmental quality people tend to choose for.

WATER

This passage is about the restorative value of water, as water is a curious design element in terms of restorativeness. A variety of literature mentions that the presence of water in an environment is appreciated (Faris et al., 2012; Ulrich, 1986; Varkovetski, 2015), which is supported by the empirical research of White et al. (2010). It is confirmed that presence of blue structures, be it in natural or built areas, is preferred, and that the perceived restorativeness of environments is greater in those with water (*ibid.*). The question why water is restorative is left unanswered, yet heavily speculated upon. Theorised explanations are, amongst others, that auditory and visual stimuli could be fascinating (White et al. 2010), such as the sound of moving water or its reflective capabilities, or that the association of water with the possibility to physically immerse oneself in it may replicate the positive associations held with the action itself (*ibid.*). Humans may also have an innate preference for blue environments from an evolutionary perspective, as it increased chances of survival (Szolosi, 2011). Regardless the explanation, water is a useful design element as it will often improve the restorativeness of an environment.

DESIGN PRINCIPLES

To allow for AR to take place, the design should have elements that allow

- a sense of being away
- extent
- soft fascination
- compatibility

whilst they simultaneously

- are accessible
- block negative intrusions.

3.2 HEAT STRESS

On a hot summer's day, thermal comfort, or the microclimatic experience, will be low in direct sunlight. A high humidity also decreases thermal comfort, as sweat is unable to evaporate into the air (Lenzholzer, 2015). Other physical factors that influence the experience of temperature are thermal radiation, reflection, shadow, wind, evaporation, and individual circumstances (*ibid.*). Thermal comfort can also be experienced on a psychological level, through ambience. Wind, radiation and ambience of surroundings can be anticipated upon through small-scale design (Lenzholzer, 2015).

To mitigate heat stress in summer at HGV, elements that decrease thermal comfort should be removed, and small-scale design interventions will allow improvement of microclimatic experiences.

HEATING UP AND COOLING DOWN

Elements that cause the environment to heat up should be avoided and replaced where possible. An overview of such elements and their properties is shown below. Design solutions to heat stress are given as well.

Vegetation and nature
Natural elements have a considerable cooling capacity, and their absence negatively affects the temperature (Ragheb et al., 2016; Stewart & Oke, 2012). Research has shown that thermal differences are largely determined by building configuration and coverage (Stewart & Oke, 2012), emphasising the impact of natural elements.

Plants leak water, and use heat to evaporate this into the air, which cools the direct environment around the plant (Shahmohamadi et al., 2011). This process is called evapotranspiration (ET). Together with an often high albedo of leaves and the shade canopy of a plant, it cools down the environment (Ragheb et al., 2016; Shahmohamadi et al., 2011). Another cooling characteristic of vegetation is its texture. The leaf coverage and roughness have a negative relation with the temperature (Ahmadi Venhari et al., 2017), so more dense coverage and rougher plants will lead to a cooler environment. As species differ in ET-rate and phenotype, a mix of species may lead to a more comfortable temperature.

Water bodies wider than fifty metres also cool down the air temperature, through evaporation and heat absorption (Lenzholzer, 2015; Ragheb et al., 2016). Especially when combined with vegetation, water elements may be an interesting tool for additional thermal comfort.

Surfaces and materials
The type of material used greatly influences heat stress. Sealed surfaces like roads, pavements, roofs and walls often have less favourable reflective, emissive and conductive properties. These properties determine the material's reflectivity and absorptivity of thermal radiation (Lenzholzer, 2015), and therefore, how warm the material and its environment can become. Sealed surfaces are often made from dark asphalt, concrete or bricks, which absorb more radiation, heat up, and emit this heat back into the environment (Ragheb et al., 2016). Another problem of sealed surfaces is their impermeability. This prevents evaporation, and with that contributes to heating up the air temperature (Shahmohamadi et al., 2011).
Another cause of heat stress may, paradoxically, be a high albedo. Reflective materials in small spaces may reflect heat onto people, decreasing their thermal comfort (Lenzholzer, 2015). Hence, use of materials with a high albedo is especially favoured when it is possible for the radiation to go above the buildings, for example on roofs. Alternatively, materials that store relatively little heat can be used, which are generally lightweight and porous items such as gravel or wood (Lenzholzer, 2015).

Moreover, thermal comfort can be influenced through the psychological dimension, also known as the ambience of a place (Lenzholzer, 2015). The actual microclimate is not changed, but the microclimatic experience is. A cool ambience can be manipulated through materials. For example, wood and bricks are often regarded as "warm", inviting materials, whilst "cool" materials, such as concrete, steel or glass may set a more distant ambience (*ibid.*). Colours may also contribute to a cool ambience. Where metallic, light and cool colours, such as whites, greys and blues, may suggest coolness, a warm ambience in western culture is often expressed in darker and warmer colours, such as reds or browns. Associations with warmth and coolness can be very culture-dependent (Lenzholzer, 2015), which is important to consider in design. Cool and warm materials should be strategically used, also with regard to seasonal variations: even though a steel bench may be associated with a cool ambience, the material conducts heat easily (*ibid.*), which is physically uncomfortable in summer.

Sun and shade

Direct sunlight significantly decreases thermal comfort. Heat that radiates (in-)directly onto people is unpleasantly hot in summer (Lenzholzer, 2015). A lack of shadow opportunities will on one hand cause for the exposed surface to warm up considerably, and on the other hand is experienced as much warmer than shaded areas, as previously mentioned (*ibid.*). This may result in people clustering in the shade canopy, with additional (thermal) discomfort from the mass. For this reason, shadow opportunities should be provided.

Ventilation

A lack of wind can potentially trap heat. A skimming air flow develops at densely built areas with a height/width-ratio (H/W-ratio) over 0.7 (Lenzholzer, 2015). This wind remains above buildings, whereafter heat accumulates (*ibid.*). Heat accumulation intensifies with the use of "hot" materials and closed building structures (*ibid.*). It is important that these areas heat up as little as possible, which can be achieved through design interventions as mentioned above. Other wind behaviours are wake interference flows, where the H/W-ratio lays between 0.3-0.7 and the ground is only reached through eddies (wind circulations), whereas isolated roughness flows occur at H/W-ratios under 0.3 and acts almost as if there are no barriers (*ibid.*).
Areas that are exposed to wind can be considered uncomfortable for a variety of reasons. Firstly, the wind speed can be too powerful, especially at areas with a low H/W-ratio. Wind with speeds exceeding eighteen kilometres per hour is experienced as unpleasant (Stathopoulos, 2009), and should be slowed down. Secondly, building configuration with an unfortunate wind direction may have a channelling effect (Lenzholzer, 2015), where wind is accelerated into a tunnel. This should be avoided (Stathopoulos, 2009). Lastly, the wind direction influences the microclimate (Redactie Weeronline, 2021).
A slight, cool breeze on a hot summer's day is more desirable than direct exposure to a warm, harsh wind. To achieve this, wind can be fragmented by natural elements such as semi-open shrubs that both cool and slow wind down.

In conclusion, to mitigate heat stress, HGV can be enhanced by removing design elements that negatively influence evaporation and reflectivity, and instead use those that allow more evaporation, have a higher albedo, provide shade, fragment wind, cool the area and generally use are more natural solutions for a cool ambience. An indication of such elements is shown in *table 3*.

Table 3 Heat mitigation strategies based on Atelier GROENBLAUW (n.d.); Lenzholzer (2015)

Strategies	**Design elements**
Vegetation	Green noise barriers; select drought-resistant plants; greener car parks; vary species and types; urban green; green roofs; extensively managed green areas; more natural traffic spaces; green ponds; de-paving
Improving surfaces (albedo and evaporation)	Reducing pavements and improving the ground; porous or cool paving material (low density and porous surfacing); improve outer building shell (enlarged albedo or smaller heat storage by using porous and lightweight material); green facades/roofs; water elements; cool furniture (high or low albedo)
Provision of shade	Shade provided by vegetation (planted pergolas, espaliers, green facades or screens, trees, shrubs, perennials, green demarcation elements, etc.); urban shadow facilities (arcades, loggias, louvres, constructed blinds, pavilions, shadow roofs, demarcation elements, etc.)
Wind fragmentation and ventilation	Open vegetation at street level; dense vegetation at street level; urban ventilation; preventing horizontal eddies/strengthen vertical eddies ; "stepped" wind flow; reduce channelling effect; control and cool airflows

DESIGN PRINCIPLES

To encourage cooling of the area and enhance thermal comfort, the design should have

- Natural elements
- Cool sealed surfaces
- Shadow elements
- Elements that guide wind

4. ANALYSIS HOSPITAL GELDERSE VALLEI

To eventually draft design guidelines, site-specific information is essential (*figure 1*). HOS, like HGV, are urban spaces with very specific demands and characteristics. HGV (*figure 3*) is designed functionally, to optimise the flow of people throughout the area. The site has an extreme need for accessibility, which is expressed in a need for parking space, clear routing and high mobility. Site-specific issues that will be focussed upon are those that demand attentional capacity and those that cause heat stress. These issues behave differently throughout the area, and several zones can be distinguished with their own problems, but also opportunities. Therefore, a zoning plan is used to study the issues more closely.

Figure 3 Grey entrance of HGV with an open square and confusing paving

DEMANDING ELEMENTS

HGV is a concrete island that is a separate entity within its context. The area is surrounded by elements that are particularly draining for already fatigued users, as was mentioned in *table 1*. Such elements are, amongst others, heat stress and a lack of coherent, peaceful and well-maintained HOS (Djukanović et al., 2017; Faris et al., 2012; Nedučin et al., 2010). This is expressed in the excessive variety and quantity of paving and grey elements (*figure 3*), the lack of (shadow) opportunities (*figure 3*), problems with wayfinding and orientation, the continuous flow of people and vehicles, messiness (*figure 4*), and noise levels from the surrounding roads that exceed the preferred norm of 48 dB (Gemeente Ede, 2011). This also means that the extreme need of accessibility of the site that was mentioned earlier, is not completely fulfilled. In *figure 10* in paragraph 4.1, the demanding elements are attached to a location at HGV.

Figure 4 Chaotic green structures and lack of maintenance

HEAT ANALYSIS OF THE AREA

HGV forms an urban heat island (UHI) and is plagued by an uncomfortable wind chill (*figures 5, 6*). Not only does this high temperature increase physical discomfort, heat also negatively impacts the ability to focus (*Table 1*; Taylor et al., 2015). The main problems regarding heat stress are discussed below, to determine the microclimate of the site.

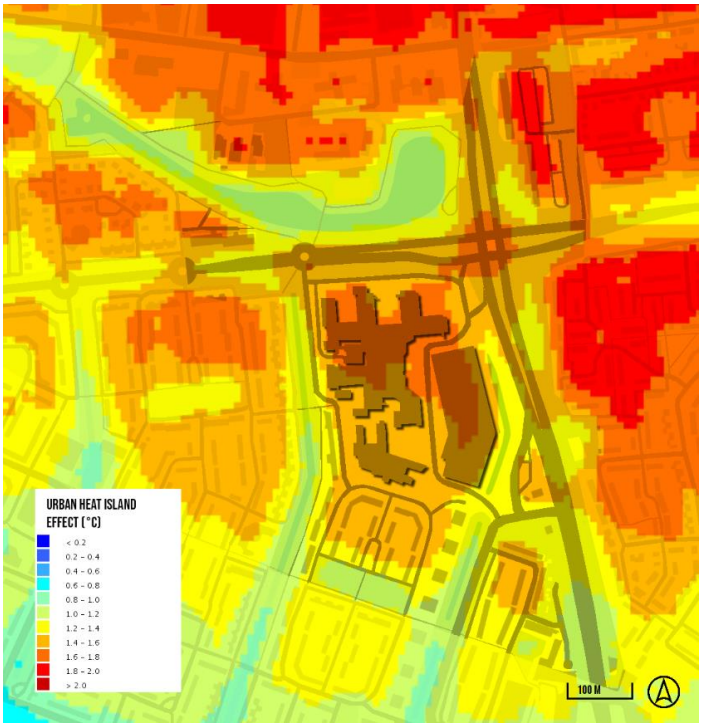


Figure 5 UHI at HGV based on Atlas Leefomgeving (n.d.)

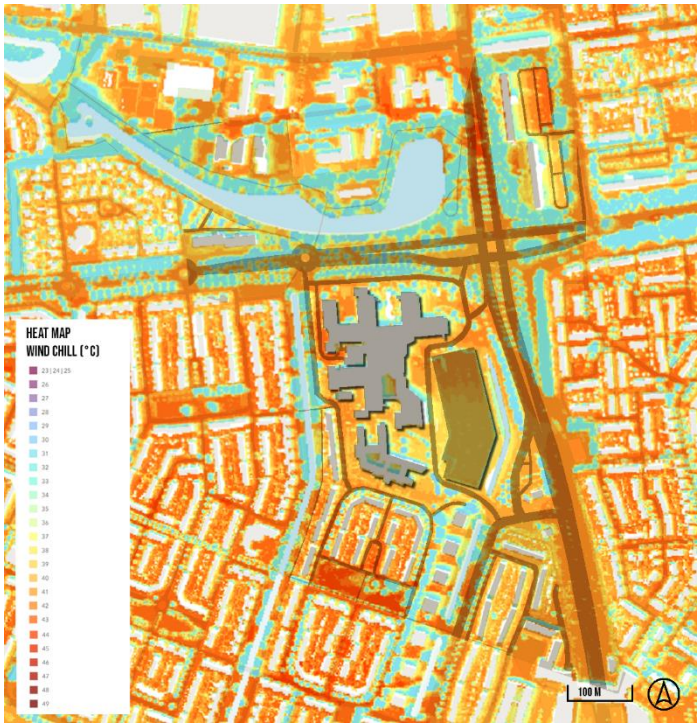


Figure 6 Wind chill at HGV - the cooling effect of trees

Vegetation is a problem at HGV, or rather the lack of it (*figure 3*). As was discussed in *chapter 3.2*, heat stress relatively aggravates with the absence of green, for its cooling capacities. Furthermore, the quality of the existing green is not great either. The bare spots in the lawn (*figure 4*) e.g. reduce the evaporative capacity of the surface, negatively influencing thermal comfort.

Moreover, the **vast amount of sealed surfaces** at HGV contribute to the UHI-effect at the site. Even though the use of clinkers at the main entrance and at the entrance of Riethorst (the building south of the main building) could be considered sub-optimal, with its open-paving method and relatively light bricks, the substantial quantity of grey material in the area will cause for the surface to always be relatively warm.

Shadow opportunities are scarce. As can be seen in a shadow analysis of the site (*figure 7*), several locations are completely exposed to the sun all year. While this exposure can offer some comfort in winter, in summer it will lead to thermal discomfort. As priorly mentioned in *chapter 3.2*, direct thermal radiation is unpleasant, negatively affecting the microclimatic experience of these locations. Areas with a lower, more comfortable, wind chill (*figure 6*) are located mainly in the shade canopy of trees and in that of the large buildings.

Figure 7 Shadow analysis HGV of December 21st 11 AM; 1 PM; 3 PM & June 21st 11 AM; 1 PM; 3 PM; 5 PM

Ventilation is unfortunate at the site. HGV mainly has a southwestern wind (Meteoblue, 2021), which is a warm wind with a humid character (Redactie Weeronline, 2021), therefore not optimal for thermal comfort. Wind flow potentially explains a substantial part of the UHI-effect at HGV. Wind is blocked by the large buildings (*figure 8*), creating a skimming air flow, as the H/W-ratio exceeds 0.7. In combination with the unfortunate use of materials and direct impact of sun, a heat trap arises.

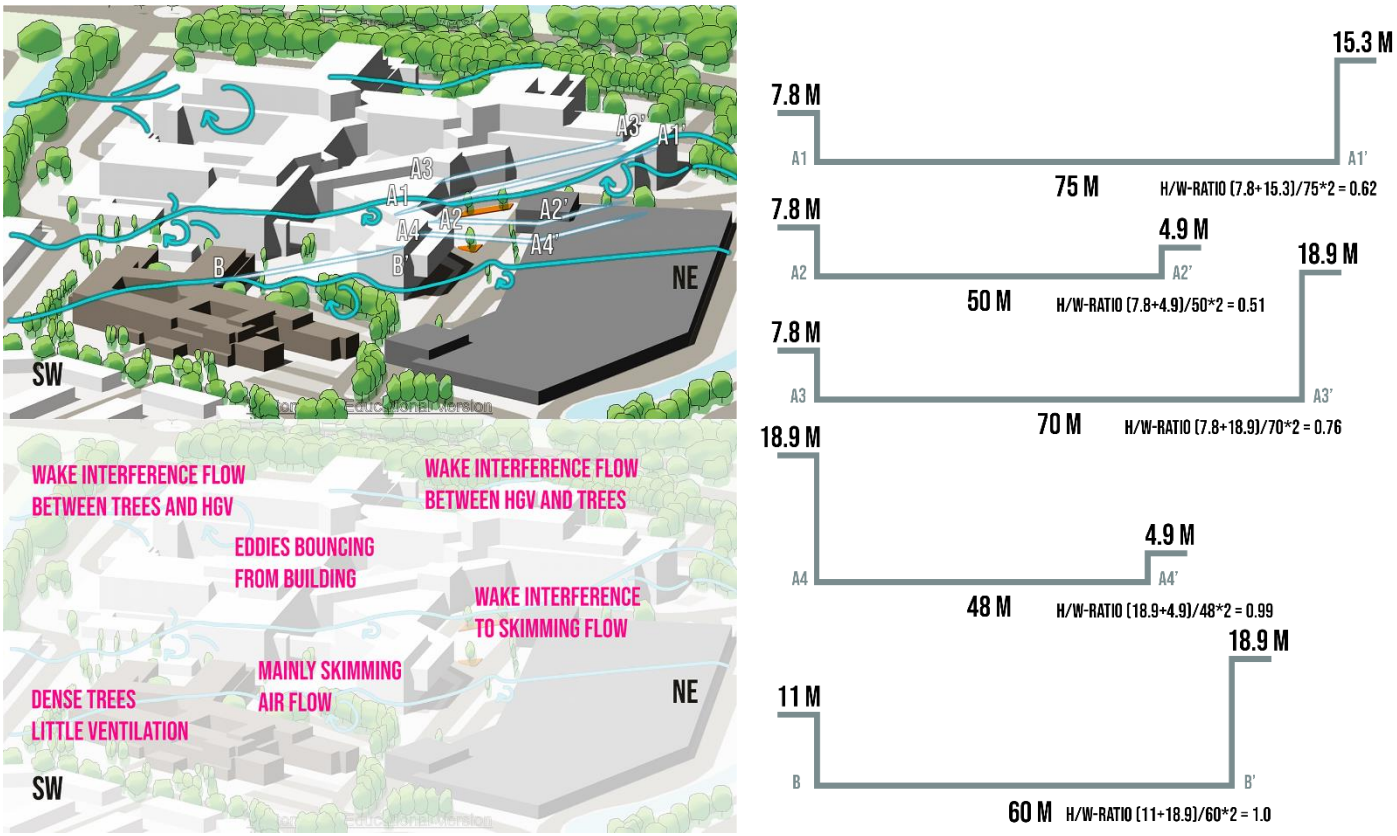


Figure 8 Estimated wind flow HGV and examples of calculations of the H/W-ratio at the main entrance (A) and small parking lot (B)

In conclusion, thermal comfort at HGV is low, except for at the park, which is a cool pocket compared to its surroundings (*figure 9*). Even though this hospital climate does not entirely match the climate zones as defined by Stewart and Oke (2012), the cool- and hotspots can be linked to a combination of zones.

The microclimate of the compact midrise building structure with few or no trees is in stark contrast with the waterbody and scattered trees at the park, which roughly corresponds with local climate zones 2D/E (compact midrise with low plants and paved area) and B+G (scattered trees and water).

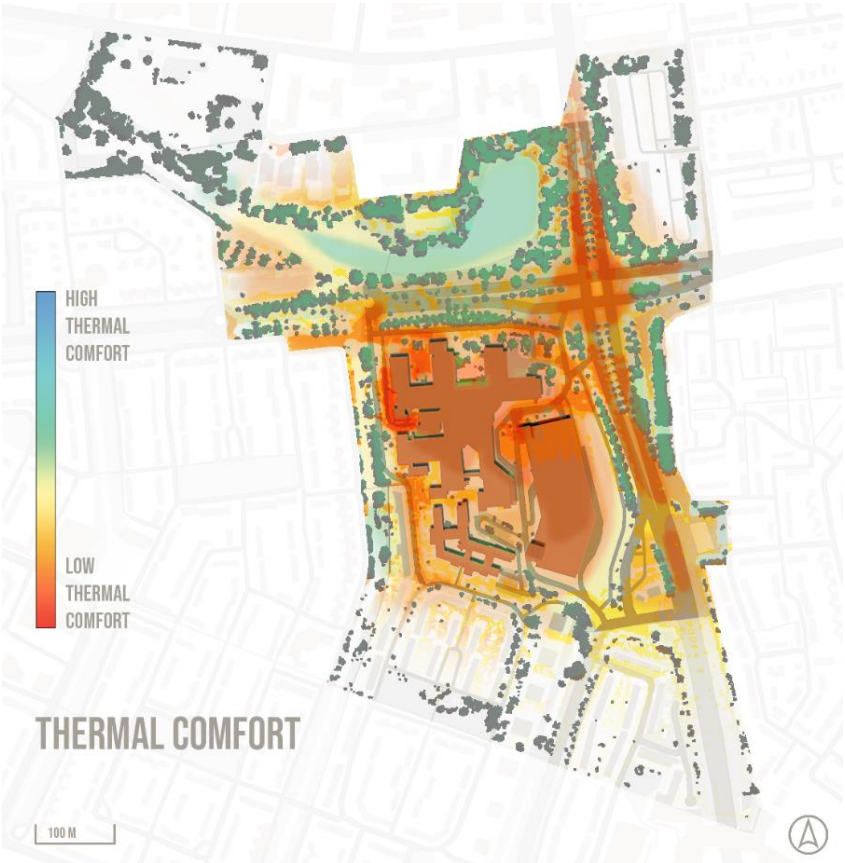


Figure 9 Experienced heat analysis based on UHI (Atlas Leefomgeving, n.d.), wind chill (ArcGIS Storymaps, 2020), estimated wind flow and (Van Kampen, 2020)

4.1 ZONING HOSPITAL GELDERSE VALLEI

The main fatiguing elements and problems at HGV (*figures 3-9*) were layered, from which zones were identified (*figure 10*). The zoning plan is used to analyse the needs and opportunities of the zones with the greatest range of issues.

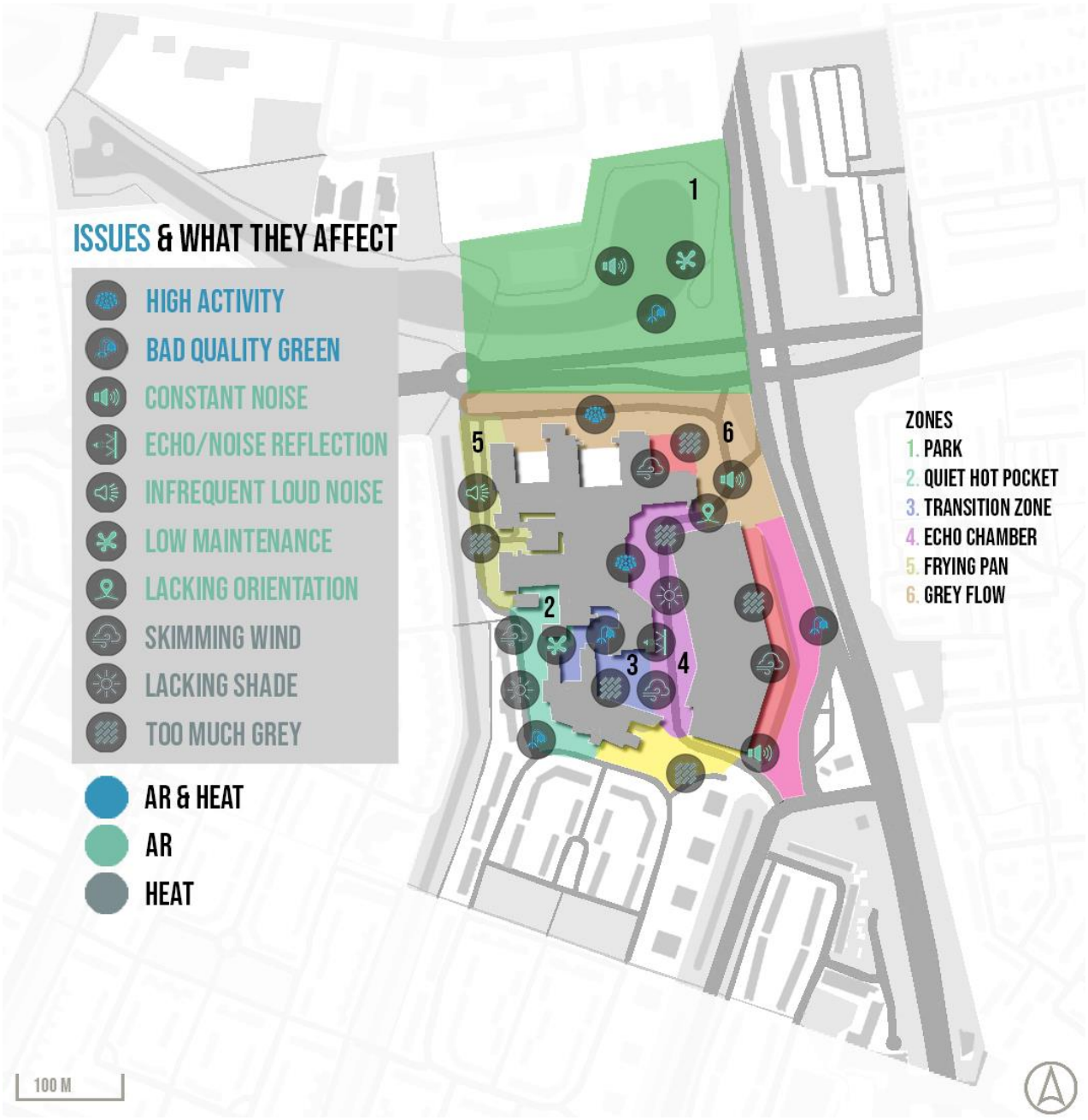


Figure 10 Zoning the problems of HGV

Park

Needs: muted or masked continuous noise from the road; improved accessibility of paths; renewed planting scheme and more bins for improved maintenance; more seating opportunities

Opportunities: cooling effect water can be improved through an island, simultaneously providing an interesting getaway; cool pocket that is physically away from working space (retreat)

Quiet hot pocket

Needs: more wind fragmentation and cooling of wind; more shadow opportunities; improved routing to avoid bare spots; enrichened planting scheme; more seating opportunities

Opportunities: peaceful and private seating area for staff (already relatively quiet, away from the flow); close to the working environment, thus accessible

Transition zone
Needs: lessened amount and intensity of hot-spots and heat accumulation by de-paving, greening, ventilating where possible and adding shadow opportunities; improved routing to avoid bare spots; enrichen planting scheme; more coherent organisation; muted or masked sound from echoing cars; more cool materials
Opportunities: relatively little noise disturbance except for an echo from cars; transition between staff bubble and social flow (no harsh transition needed); use parking lot to green the area; close to the working environment, thus accessible

Echo chamber
Needs: lessened intensity of heat accumulation by de-paving, greening, ventilating where possible and adding shadow opportunities; muted or masked sound from echoing cars between buildings and continuous noise from road; improved wayfinding by logical and apparent routes, clear use of material and signs; more cool materials
Opportunities: a restorative seating area with a social ambience for the less fatigued; improved flow of people

Frying pan
Needs: lessened intensity of hot-spots and heat accumulation by de-paving, greening, ventilating where possible and adding shadow opportunities; muted or masked infrequent noise from ambulances
Opportunities: isolated route from and towards the park

Grey flow
Needs: lessened intensity of hot-spots and heat accumulation by de-paving, greening, ventilating where possible and adding shadow opportunities; muted or masked continuous road from the road
Opportunities: busier route from and towards the park and bus stop

4.2 HOSPITAL STAFF

Staff has additional demands from HOS than patients and visitors. Literature research is used to find general needs of hospital staff, as time is a limiting factor in this research. There is insufficient time to let HGV staff participate. Besides, it is hard to ethically justify disturbing those already lacking time. Especially now, in the COVID-pandemic, when regular healthcare is postponed and staff is moved to other departments to provide the additional hands needed (EenVandaag, 2021), it is unacceptable to demand more of them than what they are already doing for society.

HOS should be accessible, and therefore close to the working environment (Faris et al., 2012). They are mainly used around noon, within a limited time frame (*ibid.*). It has been found that the main activities in breaks consist of having lunch; smoking; getting away; chatting; sitting and talking; and perambulating, each enduring five to ten minutes (Faris et al., 2012; Sherman et al., 2005; Whitehouse et al., 2001). *Figure 11* shows which area can be covered within this time frame (WHO, 2016).

The target group therefore needs a peaceful environment with as little fatiguing elements as possible, that is easily accessible and away from patients and visitors, thereby increasing the amount of micro-restorative experiences.

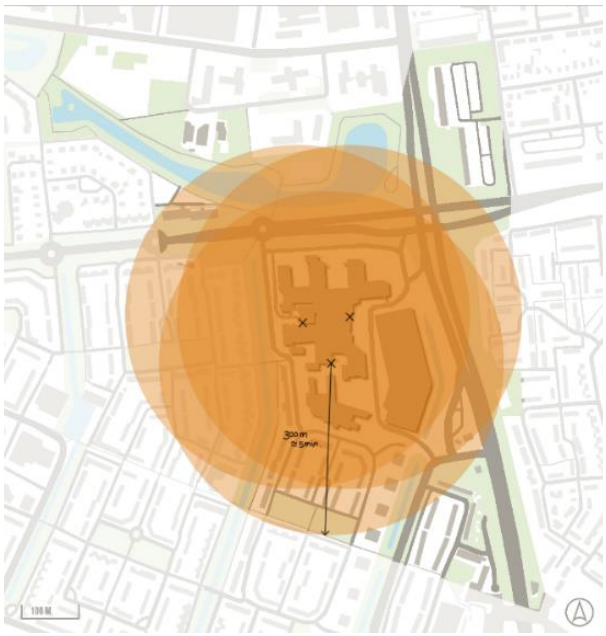


Figure 11 Five minutes translated to coverable distance

5. DESIGN GUIDELINES

By combining the design principles for restoration of attention capacity and enhancement of thermal comfort with the site analysis and demands for the target group, it is possible to develop design guidelines (*figure 1*). These have been assigned to the key concept they influence, which is shown in *figure 12*. To support the design guidelines, visualisations were made (*figure 13*).

1. **Nature-based solutions** are preferred over built solutions
2. Use of **water elements** is applauded

To provide shelter from both sun and wind, natural elements are preferred, for their additional positive impact on temperature. Natural elements can simultaneously have a positive effect on attention-depleted users, for they are inherently fascinating (Hartig et al., 2014; Kaplan & Kaplan, 1989; WHO, 2017). Water is a popular element that may cause psychological detachment, evoke fascination and concurrently have a cooling effect and mask noise (Kaplan & Kaplan, 1989; Landscaping Network, 2016). Rough natural elements could also be deployed to mute or mask acoustic intrusions and to cool the environment down (Ahmadi Venhari et al., 2017; Landscaping Network, 2016; Nilsson et al., 2013).

3. **Sealed surfaces** should be present **only where absolutely necessary**, and consist of **cool materials** that allow evaporation, have a high albedo, or be covered by natural elements
4. **Sealed surfaces** should also be **easily accessible** to its users and for their intended purposes
5. The shape of the surface may express its functionality: **straight roads where necessary**, curves where possible
6. **Wayfinding** should be made easier, **no unnecessary tasks** within the area: clear and logical **routes** that are **safe** and **accessible** to vehicles and pedestrians

Thermal impact of sealed surfaces should be minimised, so cool materials are favoured where they are necessary. Using less sealed surfaces could increase the fascination a site evokes, as natural options are often more textured. Curved roads hold more fascination than straight ones (Szolosi, 2011), however, functionality is important in this area, so if one is ought to get from point A to B as fast as possible, that should be prioritised. One should also easily and safely find their way, to avoid additional fatigue.

7. Users should be offered **a choice** by being given multiple options regarding **routes** and **seating opportunities**, and with that the degree of **solitude** as well
8. **Richness** in natural species and built elements is highly encouraged
9. Design elements are preferably **low-maintenance**
10. **Repetition** can be used as a tool to ensure that the bigger picture is **coherent**
11. **Site-specific solutions** should be applied, to respond to the **main problems and opportunities** of each zone in a coherent manner

The design should be compatible with its users. As there is a variety of individual preference, there should be multiple options, such as being alone or together, in the sun or shadow, in or out of the wind, et cetera. The extent of the site is enlarged by coherent and rich use of materials, which are restorative properties.

In conclusion, grey should be used only where necessary, and green should be implemented where possible, in a logical and coherent manner.

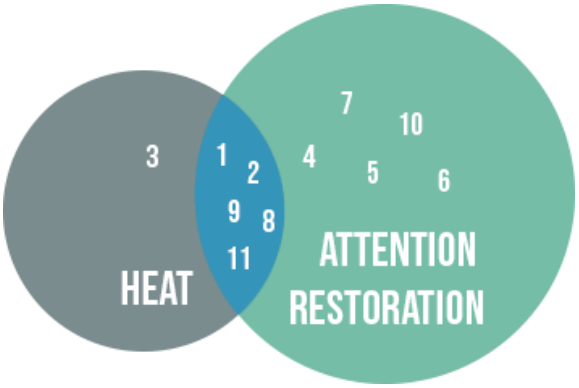


Figure 12 Linking the design guidelines with the key concepts

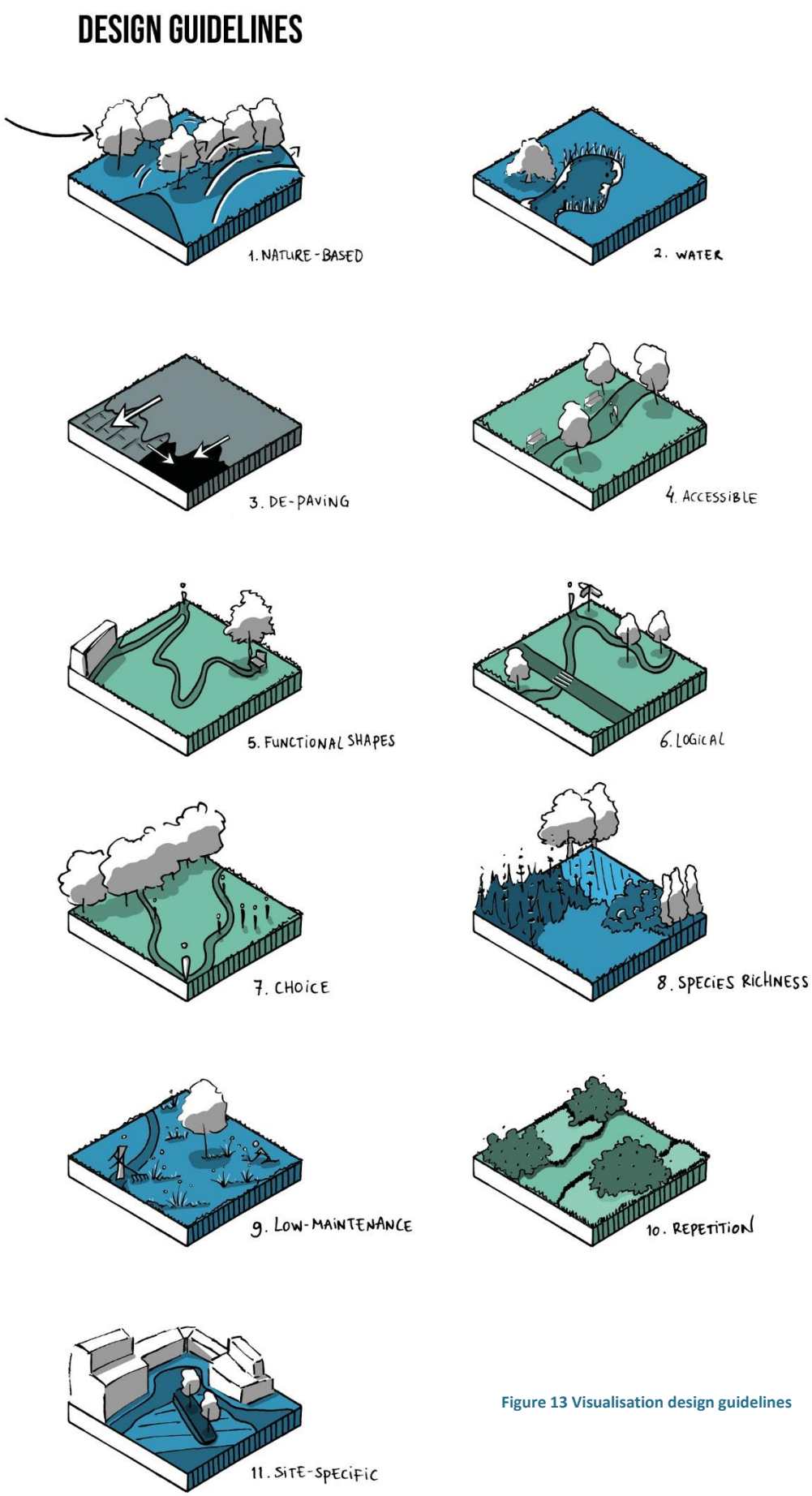


Figure 13 Visualisation design guidelines

The zones are ascribed certain qualities that elaborate on potentials and presumably solve issues, with the guidelines taken into account (*figure 14*). These qualities are based on a combination of literature research and creative input. An evaluation with EB-criteria should tell which concept variation likely enhances thermal comfort (*figure 1*). Variations are a necessity, as the credibility of the final design is bigger when it is the product of considerate deliberations. Due to limiting time, only two variations were drafted per zone.

6.1 DESIGN CRITERIA FOR THERMAL COMFORT

The criteria used to assess the concept variations are explained below.

Shadow
Shaded places are more thermally comfortable compared to those exposed to direct sunlight. The more shadow opportunities there are, the more favourable a concept is. Clustered and closed vegetation results in more intensely shaded area, and is preferred over scattered and open vegetation.

(Semi-)sealed surfaces
The more permeable a surface is, the better it is for evaporation, the cooler the material, and in accordance with the design guidelines, it is preferable to use grey where necessary, and replace it with green where possible. It is therefore essential to look at both the quantity and quality of surfaces. This means, the area is evaluated based on how much of the concept consists of sealed surfaces, and on the type of these surfaces.

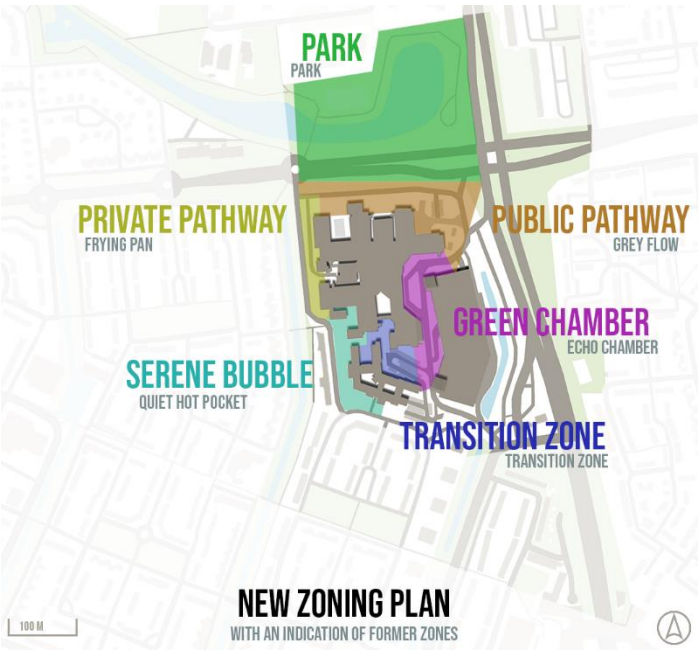


Figure 14 New zoning plan HGV

Cooling capacity of green
Plant types differ in effect on thermal comfort for the same covered area. For this reason, vegetation should undergo a weighted assessment based on the cooling capacity per type of green. Trees are most effective at cooling the environment, followed by shrubs, herbaceous plants, and lawn (Balany et al., 2020). The rougher the plant surface, the greater the cooling effect, and the greater the leaf area, the more thermal comfort (Ahmadi Venhari et al., 2017). Based on this knowledge, an estimation was made on the cooling capacity of the proportion of green in each concept.

Accessibility
A precondition for the site is its accessibility, making it a necessary criterion. Concepts were evaluated based on the amount of options users would have with routes and the possibilities to diverge from the standard routes. Furthermore, the sealed surfaces have been taken into account, as the material and amount affect the mobility of its users.

Functionality
How well does the design respond to the main issues and opportunities of each zone? This criterion varies slightly per area to which it is applied, but will show which concept best fits the needs of each zone. A need in all zones is low maintenance, whilst criteria like variety in species or muting noise are not necessary everywhere. It is possible that functional criteria overlap with the ones named above, like shadow opportunities. This way, extra weight is added to fulfil the needs of the area.

6.2 CONCEPT VARIATIONS AND EVALUATION

The zones that were identified at HGV are renamed to reflect their intended ambience (*figure 14*), whose names will be used to refer to the different zones. Below, the variations to each zone are explained. The concept variations for the masterplan were not drawn in scale, but can be used as a rough overview of the design elements and their placement within the design variation. This way the variations can be evaluated for their thermal comfort. *Table 4* explains how the iterations should be interpreted.

Table 4 Reading guide iterations

Criterion	Coloured variant best adheres to criterion	White variant scores lower than coloured one

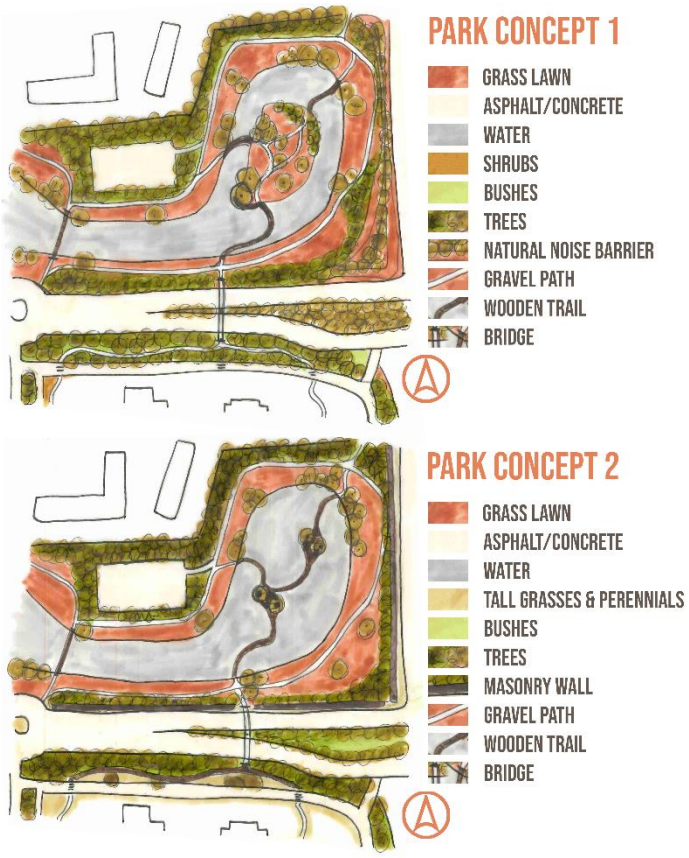
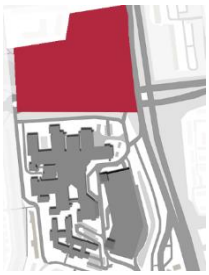


Figure 15 Concept variations park

PARK



In the renewed design of the HGV and its context, the park (*figure 15*) functions as an accessible getaway, as part of the restorative journey.

Concept 1 has an improved accessibility through a bridge that allows safe and rapid crossing of the road. A natural sound barrier consisting of trees and bushes is used south of the park. The heavier traffic on the westside is muted by another sound barrier (a hill with trees on top of it). The island is a cooling, alluring element that offers additional recreational opportunities. A mix of wooden trails over water and gravel on land is used for pedestrians, both cooler paving materials.

Concept 2 also has improved accessibility by a bridge. Comparatively, more area is covered with wooden trails, as these are also present on land. Moving towards the HGV, tall grasses and perennials are used to separate the road from the footpath. Wooden trails give multiple routing options. Masonry walls are used to mute the sound coming from the road, and lower vegetation is used along the road

Table 5 Evaluation concept variations park

	Concept 1 (C1)	Concept 2 (C2)
Shadow	More trees and larger shaded area	Fewer trees and smaller shaded area
(Semi-) sealed surfaces	Additional surface (island), which is permeable, green surface → proportionally more permeable surface	Use of cool sealed surfaces
Cooling capacity green	Additional cool surfaces enhance the cooling capacity of the park; thereby C1 enjoys more trees and green noise barriers	Taller, more structured grasses have a higher cooling capacity than the lawn used in C1, yet don't weigh up against all the additional trees and other vegetation in C1
Accessibility	Offers more options route-wise compared to C2); improved access by bridge over road; option to wander off the fixed path (lawn is relatively accessible); gravel is multifunctional for users (walking, running)	Less options (routing); improved access by bridge over road; one cannot diverge from the path (trails and taller grasses); gravel used is multifunctional
Functionality	*Noise control* Muted noise (by vegetated hill) *Low maintenance* Gravel: average-high maintenance; vegetation: average-maintenance *Accessibility* C1>C2	*Noise control* Very effectively muted noise (by masonry walls combined with vegetation) *Low maintenance* Trails: average-maintenance; vegetation: low-maintenance *Accessibility* C1>C2
Final judgement with eventual amendments: concept 1 with additional rougher green elements		

In *table 5*, the two variations are compared to another using the criteria in *chapter 6.1*, with C1 being the winner. The design guidelines provide that de-paving and using more natural and accessible options are preferable. Therefore, the small loss in functionality of noise barriers is accepted. Adding rougher vegetation to C1 will improve thermal comfort and noise control.

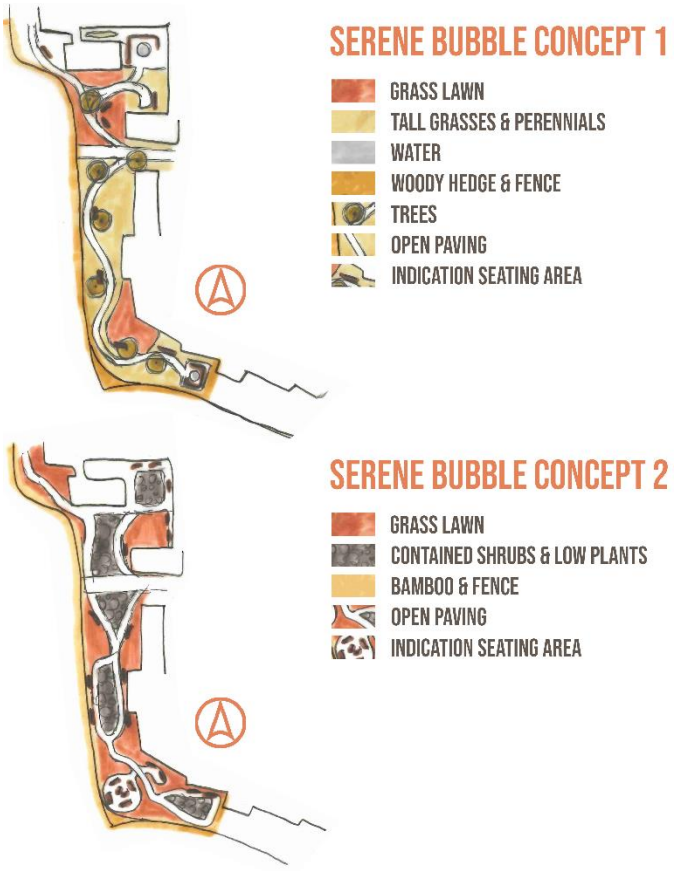


Figure 16 Concept variations serene bubble

SERENE BUBBLE

The serene bubble (SB, *figure 16*) is a private pocket where hospital staff can retreat in peace.

Concept 1 has a winding path that is mainly surrounded by tall grasses and perennials. The path is paved with light, permeable material. Scattered trees provide shadow opportunities, and water elements pose fascinating cooling elements. The area is secluded from the road next to it by a woody hedge (and fence for safety). Seating opportunities are mainly spread.

Concept 2 also has a permeable path, but is mainly surrounded by lawn. Areas with contained shrubs and low plants divide the path, adding more route-variety. The area is secluded from the road by bamboo and a fence. Seating opportunities are both clustered and spread.

The design variations are evaluated in *table 6*. C1 best adheres to the design criteria. C2 has more grey, which is reflected in its superior accessibility and inferior thermal comfort. To improve the accessibility of C1, additional (seating) opportunities should be added. For the final design of any zone, it is good to keep in mind that bamboo is fairly high-maintenance, to prevent it from taking over, so use should weigh up against the maintenance.

Table 6 Evaluation concept variations serene bubble

	Concept 1	Concept 2
Shadow	Trees have a great cooling capacity and broad range for casting shadows; tall grasses (herbaceous); hedge (woody)	Contained shrubs; movable screens; bamboo (woody)
(Semi-) sealed surfaces	Proportionally less sealed surface; open paving (porous)	Proportionally more sealed surface (both contained plants and more pathways); open paving (porous)
Cooling capacity green	Trees, tall grasses, hedge and lawn (2 woody and 2 herbaceous elements) – relatively equivalent to C2; proportion of green C1>C2	Shrubs, bamboo, lawn (2 woody and 1 herbaceous elements) – relatively equivalent to C1; proportion of green C1>C2
Accessibility	Fewer options (one path; little variation of seating opportunities); open paving	More options (multiple pathways leading to the same destination; variation of seating opportunities); open paving
Functionality	*Shadow* C1>C2 *Low maintenance* Tall grasses (extensively kept): very low-maintenance; less paths and lawn; hedge and trees: low-maintenance; water elements: high-maintenance *Species richness* C1>C2 (trees, hedge, lawn, tall grasses)	*Shadow* C1>C2 *Low maintenance* Bamboo: high-maintenance (spreads easily, hard to rid once settled); contained shrubs, more lawn and paths: average-maintenance *Species richness* C1>C2 (bamboo, lawn, contained shrubs) *variety tall grasses ≈ contained shrubs
Final judgement with eventual amendments: concept 1 with an improved the accessibility (more choices)		

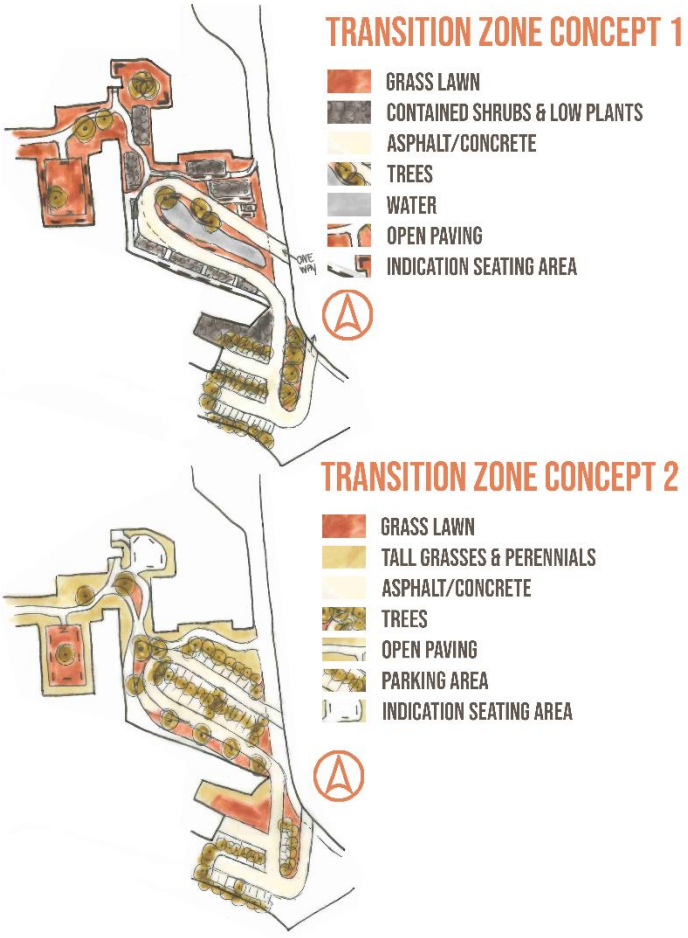


Figure 17 Concept variations transition zone

TRANSITION ZONE

The transition zone (TZ, *figure 17*) forms a gradual change in activity and greenness between the serene bubble and the green chamber.

Concept 1 is surrounded with mainly lawn, yet the further one moves towards the green chamber, the more contained shrubs and plants can be found. The biggest change is however, the removal of part of the parking lot, and replacing it with a body of water. The remaining parking area is also paved with open-grid structures. Open paving is applied to footpaths, and roads are made from asphalt.

Concept 2 has a greened parking lot with trees, and open-grid pavers with grass. Footpaths consist of open paving as well, contrary to the road for motorised vehicles, which is more sealed. Extensively kept grasses and perennials surround the premises, alternated with small lawns.

Based on the evaluation of the concepts in *table 7* can be said that the (sub-)criteria where C2 is superior, the tall grasses are the decisive factor. For this reason, C1 should be used as a basis, with added grasses and perennials.

Table 7 Evaluation concept variations transition zone

	Concept 1	Concept 2
Shadow	Few clustered trees; many scattered trees; contained shrubs (semi-open)	Many clustered trees; few scattered trees; tall grass (semi-open)
(Semi-) sealed surfaces	Less parking area (permeable grass concrete pavers); contained planting (green element)	More parking area (permeable grass concrete pavers) → proportionally more grey surface; parked cars as additional heat source (less evaporation, heating up and reflection)
Cooling capacity green	Few clustered trees; many scattered trees; shrubs (woody); lawn; water(-plants); proportion of green surface C1>C2	Many clustered trees; few clustered trees; tall grass (herbaceous); lawn; proportion of green surface C1>C2
Accessibility	More options than C2 (more walking routes; lawn can be walked upon; scattered trees offer more individual shadow opportunities); less parking area lowers access per vehicle	Fewer options than C1 (tall grasses cannot be surpassed – fixed route; clustered trees offer fewer individual shadow opportunities); more parking area enlarges access per vehicle
Functionality	*Noise control* C1>C2 (trees; shrubs); water may mask noise *Low maintenance* Road, trees and lawn: low-maintenance; shrubs and water element: average-high-maintenance *Shadow* C1<C2 *Species richness* Trees; shrubs; lawn; water plants *Greening* Removal of part of parking area	*Noise control* C1>C2 (trees; tall grasses) *Low maintenance* Tall grasses: very low-maintenance; road, trees and lawn: low-maintenance *Shadow* C1<C2 *Species richness* Trees; tall grasses; lawn *Greening* Leaving in the parking area
Final judgement with eventual amendments: concept 1 with additional tall grasses		

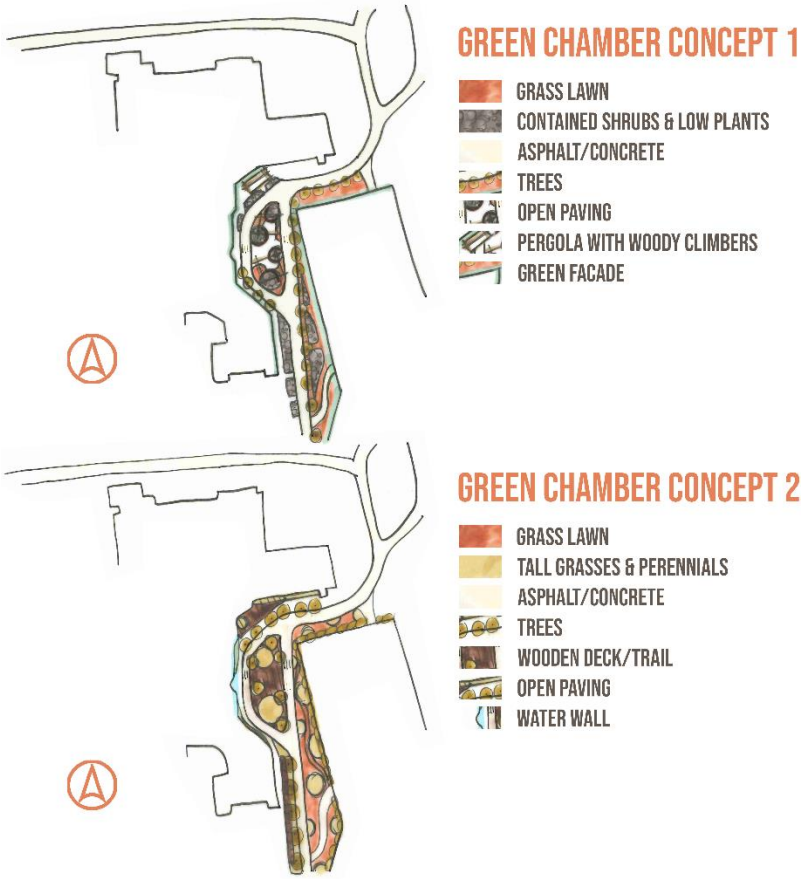


Figure 18 Concept variations green chamber

GREEN CHAMBER

The green chamber (GC, *figure 18*) is a welcoming, greened area with a functional flow of people, which is lead towards the main entrance.

Concept 1 adds green facades to the main building and parking garage. Together with pergolas with woody climbers, contained shrubs with plants and trees, the echo is addressed, and probably muted. The parking garage is connected with the entrance by marked crossings, and footpaths are porous. The road is made from asphalt. Lawn fills up spaces that are not necessarily paved.

Concept 2 has an entrance with a water wall. Tall grasses and perennials are scattered throughout the area, and trees form green lines. Footpaths are partly made from wooden constructions, in stark contrast with the road from asphalt. Pedestrians will also set foot on open-paved paths.

Table 8 Evaluation concept variations green chamber

	Concept 1	Concept 2
Shadow	Variety of shadow elements and proportionally shaded area C1>C2 (trees; vegetated pergolas; contained shrubs)	Variety of shadow elements and proportionally shaded area C1>C2 (trees; tall grasses)
(Semi-) sealed surfaces	Proportionally less sealed surface; open paving (porous)	Proportionally more sealed surface; wooden decks have more (semi-)sealed surface underneath and are therefore less porous
Cooling capacity green	Fewer trees; pergolas with woody climbers; lawn; shrubs; green facade	More trees; tall grasses; lawn; water wall
Accessibility	Fewer options than C2 (no additional paths); the open paving is well-accessible to all users	More options than C1 (additional path across the road); wooden decks may not be optimally accessible for less mobile people (possibly slippery and elevation may be unfavourable)
Functionality	*Noise control* C1>C2 (trees; shrubs; green facade; vegetated pergolas) *Low maintenance* Road, trees, facade and lawn: low-maintenance; shrubs and vegetated pergolas: average-maintenance *Accessibility* Fewer options, favourable material *Greening* Proportion of green C1>C2	*Noise control* C1>C2 (trees; tall grasses); water and tall grasses may mask noise *Low maintenance* Road, trees and lawn: low-maintenance; tall grasses: very low-maintenance; water element: high-maintenance *Accessibility* More options, less favourable material *Greening* Proportion of green C1>C2
Final judgement with eventual amendments: concept 1 with more options (roads, for safety of bicyclists/cars)		

From the concept evaluation of the GC (*table 8*) can be concluded that the rough natural elements add to the thermal comfort and noise control of the area. It could however be improved by increasing the amount of options, which can be done by altering the roads, e.g. separating lanes for bicyclists and motorised vehicles.

6.3 MASTERPLAN

Based on the results of the first iteration, the masterplan was put together (*figure 1*). The concept variations were made bearing the design guidelines in mind, meaning that the design elements that are ultimately used in the master plan should be enhancing the site's restorative capacity and thermal comfort, even though not all zones are tested for both key concepts. Hence, the masterplan (*figure 19*) is an EBD, with a higher credibility for its positive influence on heat stress, compared to its effect on AR, with an exception of the SB (*figure 16*), as this zone is improved and re-evaluated for its restorative capacity in the next chapter. The design does not focus on it, but roofs should either be high in albedo to reflect the thermal radiation, or be greened, to minimise heat emission from the buildings.

Figure 19 Masterplan HGV

CONGRUENCE OF DESIGN SOLUTIONS WITH THE DESIGN GUIDELINES

In this paragraph, it will be briefly explained how the design solutions cohere with some of the design guidelines. In *figure 20* can be seen exactly what guidelines were used to develop the design of each zone.

1. Nature-based solutions
Using nature to lessen the intensity of issues at the site can mainly be seen in the large amount of woody plants that is included, that absorb sound and are superior at cooling down the environment, compared to smoother (green) surfaces, which means they are deployed to enhance both AR-capacity and thermal comfort at a site. An example can be seen in the GC, where pergolas, shrubs, green facades and trees are likely to mute the echo and create a cool pocket (*figure 19*).

2. Water elements
Water is also an element that can be used for AR and heat mitigation. It is used in the parking lot in the TZ mainly to cool down the pocket, as wind is unable to cool down the tiny square (*figure 8*), and its positive effect on AR is more of a bonus, whereas at the SB, the small water elements mainly affect the ambience and restorativeness of the environment.

3. De-paving
Sealed surfaces were only used where necessary, which also means that additional sealed surfaces were added if this was needed for e.g. improved accessibility. This was the case at for example the private pathway, to connect the SB with the park, and at the park, to give an alternative, shorter, walking route (*figure 19*). At the GC, however, the total amount of sealed surfaces is lessened, as the road from 8.5 metres in width is split in a road from 4 metres and a bicycle path from 2.5 metres (*figure 19*). For roads directly on the premises of HGV clinkers are used, and permeable surfaces for foot- and bicycle paths are used throughout the entire plan.

4. Accessibility
Open paving is well-accessible to all vehicles and pedestrians. The wooden trails may get slippery, which can be fixed by e.g. skid resistant strips. Furthermore, the bridge (*figure 19*) enhances accessibility from and towards the park, as there are no additional dangers from traffic to reckon with. The SB and private path are not accessible to all users, marked by signs.

5. Functional shapes
The TZ, SB and park have mainly curved paths, contrary to the GC, where, even though there is a resting area present, the main function of the path is still to support the flow. The private path is straight, for there is limited space near the road for ambulances, which is prioritised over a walking route.

6. Logical
Dividing the road in the GC helps structuring the area and enhances safety, and the tall grasses form a guiding barrier towards the main entrance. Bicyclists have a priority over vehicles at the premises, which is indicated by road markings. Other road markings are crossings for pedestrians (*figure 19*), as they have priority over all traffic, at the appointed spots. It is necessary to provide better directional signs as well. Points of interest for these are near the bus stop, the parking garage, and at Riethorst.

7. A choice
With regard to choosing your own path, the park is the best example, as it provides the most routes (*figure 19*). The SB forms a great examples of a variety in opportunities for shelter, as it is possible to seek shelter from wind, sun and people, by secluding oneself in pockets and behind vegetation, but it is also possible to gather and sit in the sun or in a little breeze.

8. (Species) richness
The perennial- and grass mixes consist of plentiful species, and a large variety of natural elements is used throughout the design. Even though there are different kinds of ambiences in each zone, it is important that the different built elements are coherent. For this reason, the shape of the container for shrubs (*figure 19*) is the same throughout the plan, but its contents can vary.

9. Low-maintenance
The perennial- and grass mix is meant to be kept extensively, meaning that the vegetation is cut back in early spring only. Lawn should be regularly mowed to keep it accessible, and paths should be kept clear and tidy. The water elements (*figure 19*) should be checked regularly for water bloom, and the water quality should be safeguarded, making it somewhat higher in maintenance. Trees, shrubs and hedges should be kept neatly, and will need maintenance approximately once or twice a year.

10. Repetition

As was said earlier, the contained shrubs have similar, coherent shapes. Species of trees, shrubs, perennials and grasses should be repeatedly planted as well, and come back in a logical sequence, as is done at the SB, where trees are planted next to the path in a zig-zag pattern (*figure 19*). Besides shapes and sequencing of species, repeated use of material also enhances the coherence of the bigger picture, as is seen at the park, where the water is crossed via wooden trails, and land is crossed via gravel paths (*figure 19*). Furthermore, one kind of paving is used to indicate a function, such as footpath or parking, and the same kind of material should be used for seating and bins throughout the premises.

11. Site-specific solutions

This design guideline was applied everywhere, as the design to each zone specifically responds to the issues and opportunities at each site. An example of a site-specific solution is the creation of an island at the park (*figure 19*), to enhance the cooling capacity of that specific spot, and to enhance the accessibility of the park within its context.

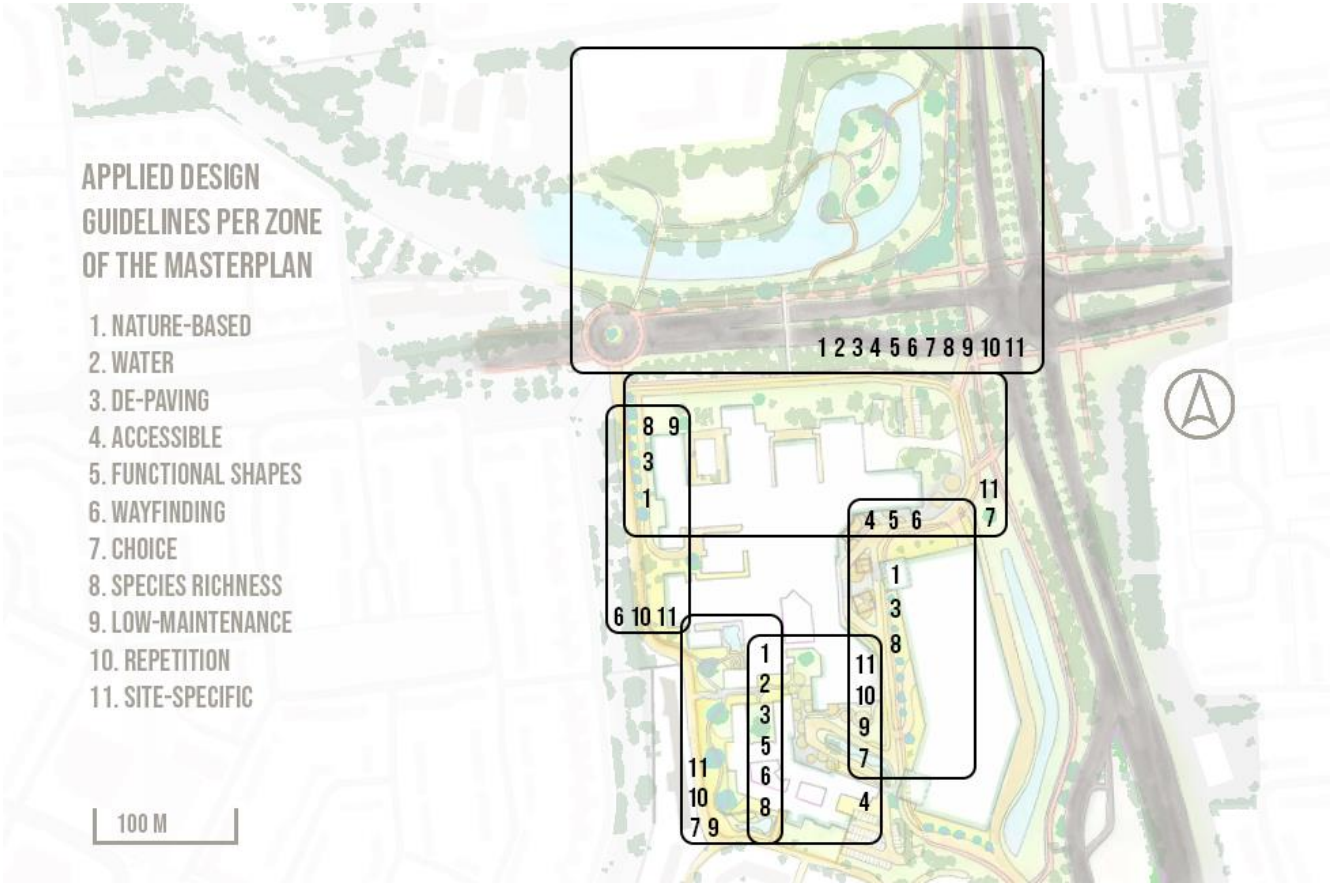


Figure 20 Indication of what design guidelines are used to redesign each zone in the masterplan

7. DETAIL PLAN: THE SERENE BUBBLE

Besides trying to improve thermal comfort, the intention of this design thesis is to enhance attention restoration of hospital staff. The SB may have the greatest potential for this, as this zone is already relatively quiet, lays out of the main flow of the area, yet is still proximate. Two concepts were drafted for a detail plan, with differences in shelter, seating and planting, and will be tested for their AR-capacity. Conforming to the design guidelines, some recommendations were drafted for the detail plan.

ZOOMING IN

Zooming in means more attention should be paid to detail. For this reason, the design guidelines in (*figure 13*) need extra substantiation, for the conceptualisation of the design to get sufficient direction. Additions are worked out below.

Coherent site-specific solutions, offering a choice and low-maintenance nature-based solutions
To avoid thermal discomfort and to anticipate to individual compatibility, several options for shelter from sun, wind and people should be offered. This can be done through strategic placement of plants and seating areas.
Species placement should be compatible with the sun- and soil circumstances, and its hardiness (Gardenia, n.d.-c; PlantMaps, n.d.). Compatible species were found using Gardenia, Shoot and FineGardening (Gardenia, n.d.-a, n.d.-b; Shoot, n.d.; Small, 2020), to find existing plant combinations, that are preferably low in maintenance.

The design should be rich of species, with repeated elements and should make sense
For the planting construction to enable AR, it should offer species richness (soft fascination); a clear and coherent structure (extent); plants that retain interest for a long time (soft fascination); aesthetically pleasing plants (compatibility); peacefulness (compatibility); and scattered trees (compatibility). Based on these properties, planting instructions were made. These are inspired by Piet Oudolf, who mastered to retain fascination throughout the year with his planting schemes (Slatalla, 2018).

Structuring
Species should be planted in a maximum of two to three layers, for the construction to be comprehensive (Slatalla, 2018). Repetition is a tool that creates a rhythmic contrast between airy and stiff structures, resulting in coherence and peacefulness (*ibid.*). Oudolf recommends using 70 percent of structure plants and 30 percent of filler plants (Slatalla, 2018). Structure plants are grasses, long-season perennials and blooming plants with distinct shapes that remain interesting throughout the seasons, while fillers are used for their flowers or colours and become shapeless after mid-summer (*ibid.*).

Interest and aesthetic
Species should offer foliage, structure, or seed heads for at least nine months (long-season plants) or three months (all plants, including flowers) (Shoot, n.d.). Aesthetics is found beyond the flowering state, for structure offers interest too (Slatalla, 2018).

7.1 DESIGN CRITERIA FOR ATTENTION RESTORATION

The criteria used to assess the concept variations are explained below.

Landscape preference
The preference matrix (*table 9*) forms a criterium to assess how compatible, fascinating and restorative each concept is. The indicators are operationalised into assessable concepts, such as repetition and organisation to evaluate the coherence.

Table 9 Preference matrix with assessable concepts based on Kaplan & Kaplan (1989)

	Make sense	*Involvement*
Immediate	Coherence (organisation and repetition of design elements)	Complexity (species richness and number of different objects)
Predicted	Legibility (openness and structuredness)	Mystery (obscuring yet promising for more information)

Compatibility
Besides the coherence and legibility of a landscape that the preference matrix accounts for, the concepts should be assessed on peacefulness (refuge options, openness and privacy), accessibility (shelter and surface type), to choose for an optimal environment for the staff.

Functionality
Lastly, the design must comply with the zones' main needs, which are low maintenance, thermal comfort (shadow opportunities), and species richness.

7.2 CONCEPT VARIATIONS AND EVALUATION

The SB variations are based on the outcome of the first iteration (*table 6)*, meaning the basis of the design is a secluded area with a winding path, water elements, tall grasses, perennials, scattered trees, and lawn pockets. In an attempt to design in favour of AR, the structure of planting, naturalness of water elements and seating opportunities were varied.

Figure 21 Concept variations serene bubble

DETAIL CONCEPT 1: TUNNEL-VISION

The first concept variation (*figure 21*) has structured the grasses and perennials as a tunnel path, and has pockets with scattered benches, and natural-looking water elements. Smaller trees, such as the Italian alder, pose as a suitable wind break (RHS, n.d.), whilst also providing shadow. The tall grasses and perennials also scatter the wind and provide some shadow. A fence is included for security, separating the HGV premises from its direct surrounding. An impression of how this works together is given in *figure 22*, where it can be seen that the tunnel engulfs the user, with the intention to enlarge the sense of extent. The mix of grasses and perennials should be chosen carefully, for species have to work together, and the tunnel smoothly declines towards the path from plants of 2.40 metres to 0.3 metres.

DETAIL CONCEPT 2: OVERVIEW

Contrary to concept 1, concept variation 2 (*figure 21*) offers an overview of the SB, as species of tall grasses and perennials will reach a maximum height of 1.50 metres. It is a textured structure, as plants are alternating in height. Furthermore, benches are long, connected and follow the path. More modern water elements are used, with unnatural shapes and relatively cleared out water. Large trees, such as the European ash, ensure a large shadow canopy. The border is demarcated by a cornelian cherry hedge. Cornelian cherry is a species that would grow well in this environment and does not compete with surrounding perennials (tuinenstruinen.org, 2016), and has positive qualities to form a proper windbreak (RHS, n.d.). The common ash is also suitable as a windbreak (RHS, n.d.) How these elements work together can be seen in the cross-section in *figure 22*.

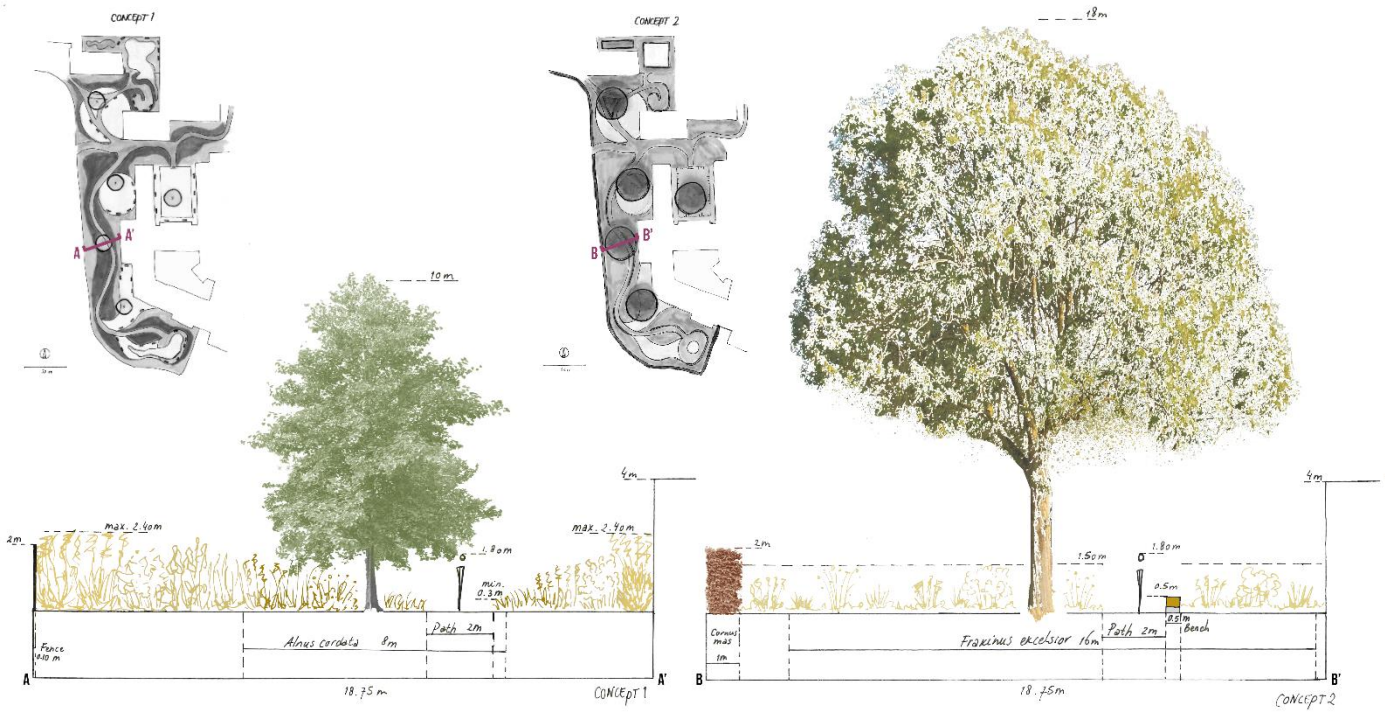


Figure 22 Cross-sections of concept variations of the serene bubble

EVALUATION OF THE DETAILED DESIGN VARIATIONS

The two concepts for the SB are evaluated based upon the criteria mentioned above, as can be found in *table 10*, resulting in the conclusion that C2 will more positively affect AR than C1 would. However, the coherence, legibility, maintenance, complexity and peacefulness can be improved by using elements of C1. Firstly, the water elements of C1 would enhance coherence and legibility of the design, as their natural shapes may be more similar to each other, thus more predictable. The softer transition it forms amidst the planting scheme may improve the structuredness. The lower maintenance is also preferable.
Secondly, the tunnel-effect may be boring and lacking prospect if it is applied everywhere, but may be alluring if there actually is a prospect and an end of the tunnel. A tunnel also adds to the legibility of the design, as the transition of species is much smoother, whilst also offering more peacefulness, as the tunnel functions as a hideout. Thermal comfort improves too, as the tunnel adds more shadow opportunities. The variety in structure therefore could be a useful implementation.
Thirdly, if the benches would be reorganised, more different objects would be present in the design, making it more complex, and there would be more opportunities to retreat. This is all taken into consideration with the finalisation of the detail design.

Table 10 evaluation detailed design serene bubble

	Concept 1: Tunnel-vision	Concept 2: Overview
	Landscape preference	
Coherence	*Organisation* Tunnel-effect by planting from **high to low(er) towards path**, smooth transition *Repetition* (Shape of) perennials and grasses, trees, lawn (shape), **similar water elements**	*Organisation* Deliberate textured planting in smooth, hazy swaths alternately with structure plants, **varying in height** *Repetition* Perennials, grasses, trees, lawn (shape)
Legibility	*Openness* Tall/tunnel vegetation **blocks view**; few small trees *Structuredness* **Smooth** structure from high to low, clear and predictable	*Openness* Vegetation can be **overlooked**; few large trees hiding viewscapes *Structuredness* Hazy swaths alternated with structure plants with various heights, **less structured** than C1
Complexity	*Roughness* Smooth *Species richness* Grasses (incl. grass block), perennials, tree, lawn, **more water plants** *Nr. of different objects* **Separate** benches, water(-**plants**), grass block, grasses, perennials, lawn, path, trees	*Roughness* Textured *Species richness* Grasses, perennials, **hedge**, tree, lawn, **green block** (with e.g. Hydrangea), fewer water plants (due to maintenance) *Nr. of different objects* **Fewer** (and long) benches, water(-plants), green block, grasses, perennials, lawn, path, trees, **hedge**
Mystery	*Obscuring yet promising* Obscuring, but not promising (no prospect)	*Obscuring yet promising* Obscuring and promising (trees as screens with hidden lawn pockets behind them)
	Compatibility	
Accessibility	Seating only semi-accessible (no sealed surface); tall grasses offer wind protection and some shadow	Seating very easily accessible; large trees offer protection from sun and wind; hedge mainly offers additional wind protection
Peacefulness	*Refuge* Separate benches (solitude possible); seating in pockets (**more secluded**) *Prospect* Relatively **little overview** due to vegetation *Privacy* When grasses need pruning (early spring) there is no privacy from the road	*Refuge* Connected benches ("sitting alone together", **less secluded**, as it is located along path) *Prospect* **Great overview** past vegetation, sometimes blocked by trees *Privacy* Semi-open hedge in winter, with grasses in front of it; at the beginning of spring the hedge offers **more privacy** whilst grasses are pruned
	Functionality	
Low maintenance	Low maintenance vegetation and design elements	Little more maintenance due to clean-cut look of water element
Thermal comfort	Smaller trees cast less shadow; tall grass blocks sun	Large trees cast a lot of shadow; hedge blocks and medium-height grasses block sun
Species richness	Grasses (incl. grass block), perennials, tree, lawn, **more water plants**	Grasses, perennials, **hedge**, tree, lawn, **green block** (with e.g. Hydrangea), fewer water plants (due to maintenance)
Final judgement with amendments: *Concept 2* with **1. Water elements of C1 (improves coherence, legibility and maintenance);** **2. Part with C1 planting structure (improves peacefulness, legibility and thermal comfort);** **3. Reorganisation of benches (enhances complexity and peacefulness)**		

7.3 DETAIL PLAN

Based upon the iteration of the concept variations, a detail plan was made for the SB (*figure 23*). It contains several amendments that were considered after testing the initial concepts, for the design to work even better, as was explained in the previous section.

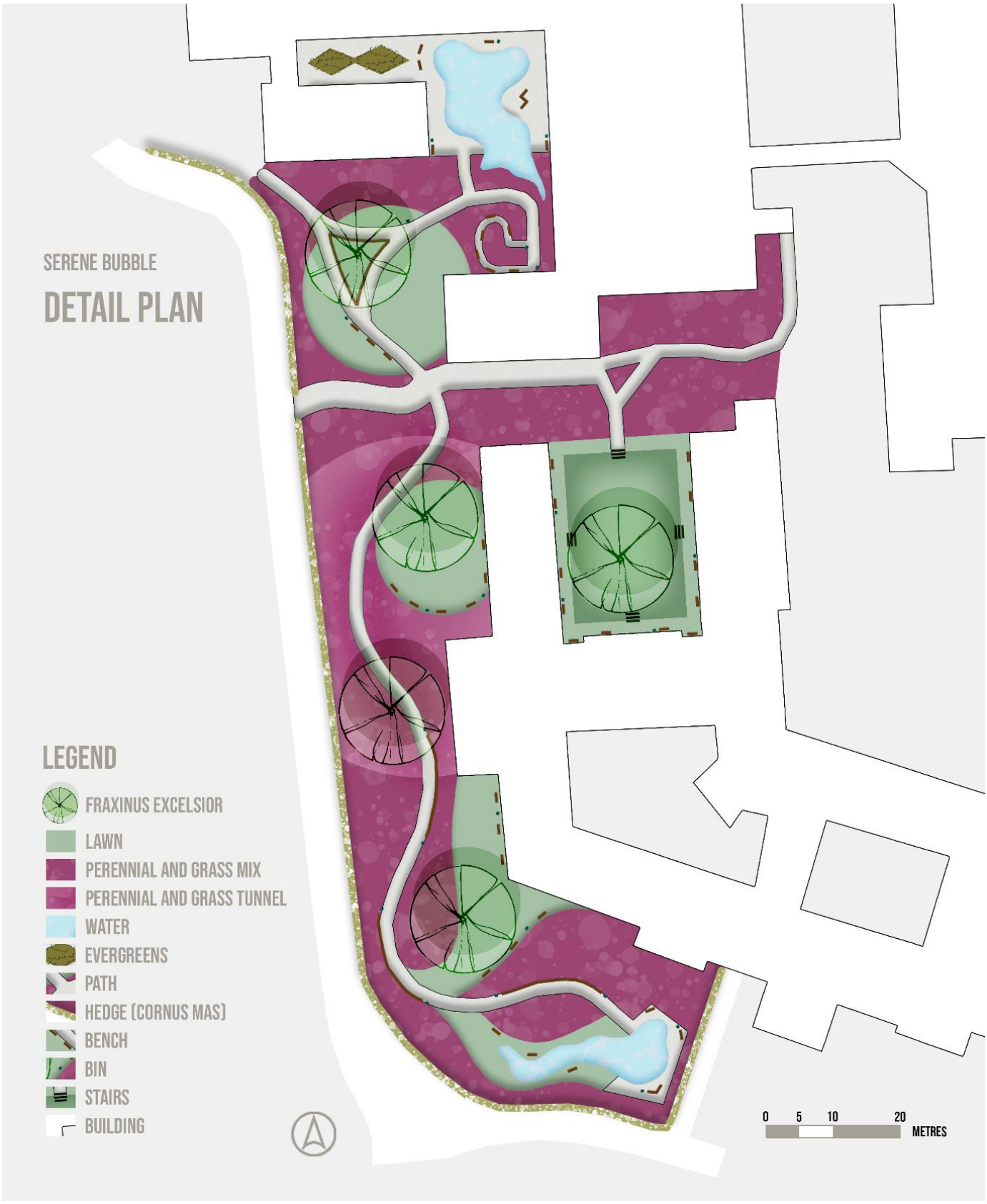


Figure 23 Detail plan serene bubble

ATTENTION RESTORATION

Perennials and tall grasses are planted in different constellations. As was discussed in the evaluation of the SB (*table 10*), a part of the redesign includes plants with a tunnel structure. The placement of this tunnel (*figure 22, 23*) is at a spot that is relatively public. Consequently, it offers more opportunity for refuge, and may lure people to see what is beyond the tunnel (prospect). The planting is carefully chosen and constructed, for a coherent picture and for good conditions for the plants themselves. In *table 11*, an overview of species is given with their characteristics.

Table 11 Indication planting scheme and their characteristics (after a few years) within the design

Species	What & where	Height (m)	Maintenance	Season(s) of interest	Blooming
Fraxinus excelsior	Tree, scattered	15-25	Average	Mid spring-autumn	April-May
Cornus mas	Hedge, edge	2	Low	Early spring, mid-summer-winter	Feb-April
Allium 'Globemaster'	Bulb, middle border	0.6-0.9	Low	Late spring-winter	May
Echinacea purpurea	Long-season perennial, middle border	0.6-1.5	Low	Mid spring-winter	June-August
Eupatorium maculatum	Long-season perennial, back of border	1.5-2.4	Low	Mid-summer-winter	July-Sept
Geranium 'Rozanne'	Filler, front/middle border	0.3-0.6	Low	Late spring-autumn	May-July
Miscanthus sinensis 'Silberfeder'	Ornamental grass, back border	1.8-2.4	Low	Late summer-winter	July-Feb
Phlomis tuberosa	Long-season perennial, front/middle border	0.9-1.5	Low	Late spring-winter	May-July
Salvia x sylvestris 'Tanzerin'	Medium-season perennial, front/middle border	0.6-0.9	Low	Summer-winter	June-August
Sedum 'Herbstfreude'	Long-season sedum, front/middle border	0.3-0.6	Low	Mid-summer-winter	Sept-Oct
Stipa tenuissima	Long-season grass, front/middle border	0.3-0.6	Low	Late spring-winter	July-August
Veronicastrum virginicum 'Album'	Long-season perennial, middle border	1.2-1.8	Low	Mid-summer-winter	June-August

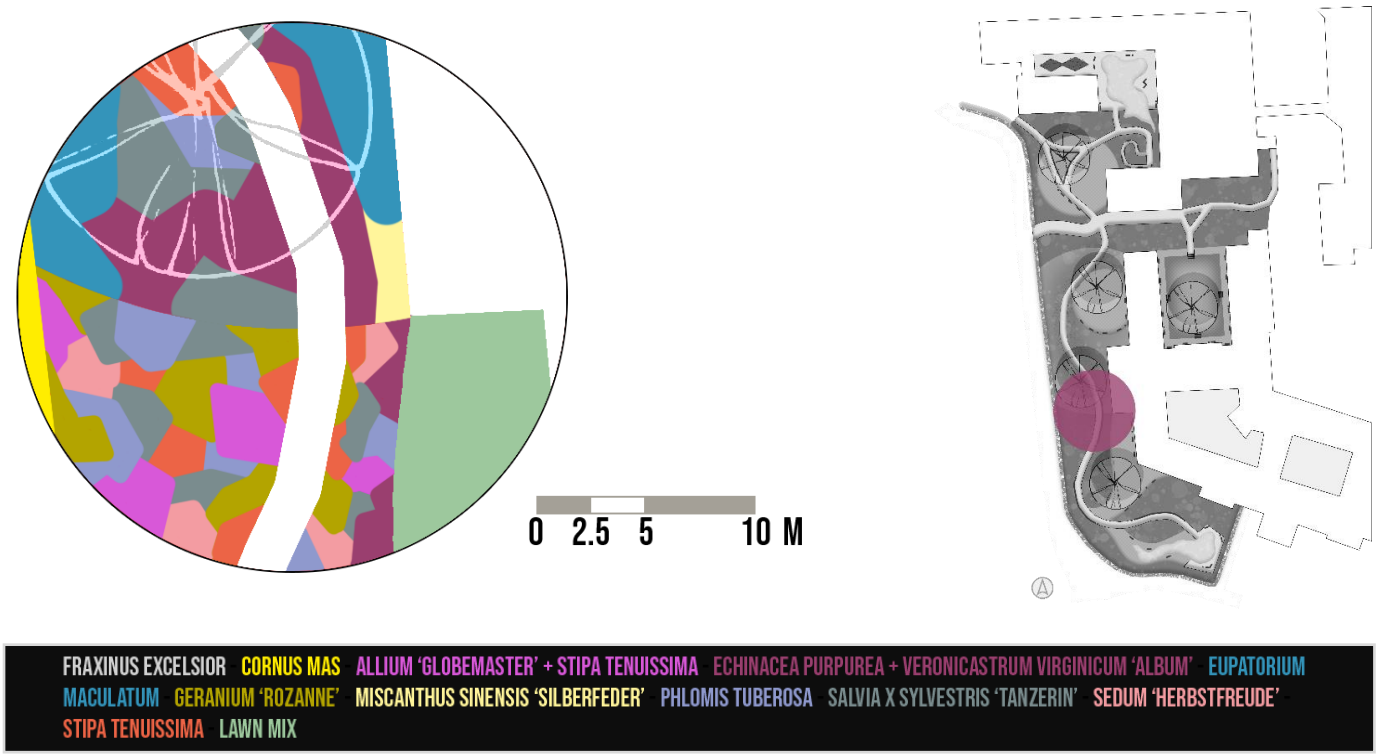


Figure 24 Extract proposed planting scheme

The height of plants is a determining factor for their place in the planting scheme (*figure 24*). Other species may be added, as the planting scheme functions as an indication of what could create the intended atmosphere, on the condition that they adhere to the design guidelines and are coherent within the bigger picture. In *figure 25*, the trees are drawn in context of the buildings, as both are large, vertical elements within the design. It shows the large impact the ash trees have, and how they manage to act as landmarks as well as pose as shelter.

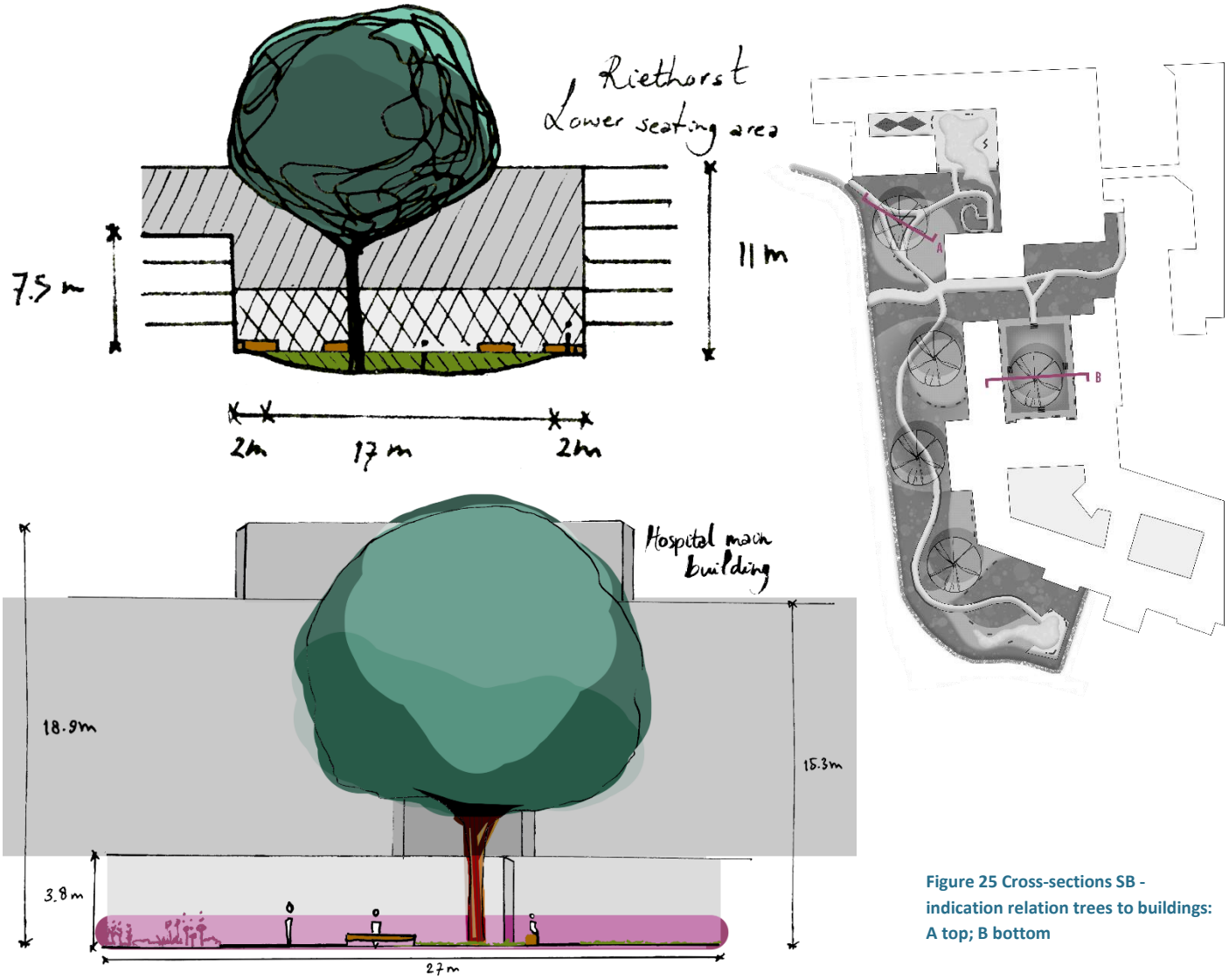


Figure 25 Cross-sections SB - indication relation trees to buildings: A top; B bottom

The grasses and perennials were not only chosen based on their height or growing conditions, but also for their colour and fascination throughout the seasons, as colour can influence the ambience and coherence of the planting structure. In summer, the SB will light up in romantic greens, whites and pinks (*figure 26*). Cultivars do come in other colours, but there will be greater legibility with use of similar colours, mainly because the alternating heights in combination with too many colours may make the design too incoherent and complex, overwhelming the user and making the design a less restorative environment. The planting scheme consists of hazy swaths alternated with structured vertical lines, offering an interesting variation between smooth and rough elements, to stir both complexity and legibility.

In winter, the perennials lose their leaves, but their fascinating seed heads remain, which retains their restorative benefits. Grasses and perennials change colours, shifting the colour pattern to browns, yellows and darker magenta undertones (*figure 27*). These warmer tones may have their benefits in winter for thermal comfort, but also contribute to coherence of the area.

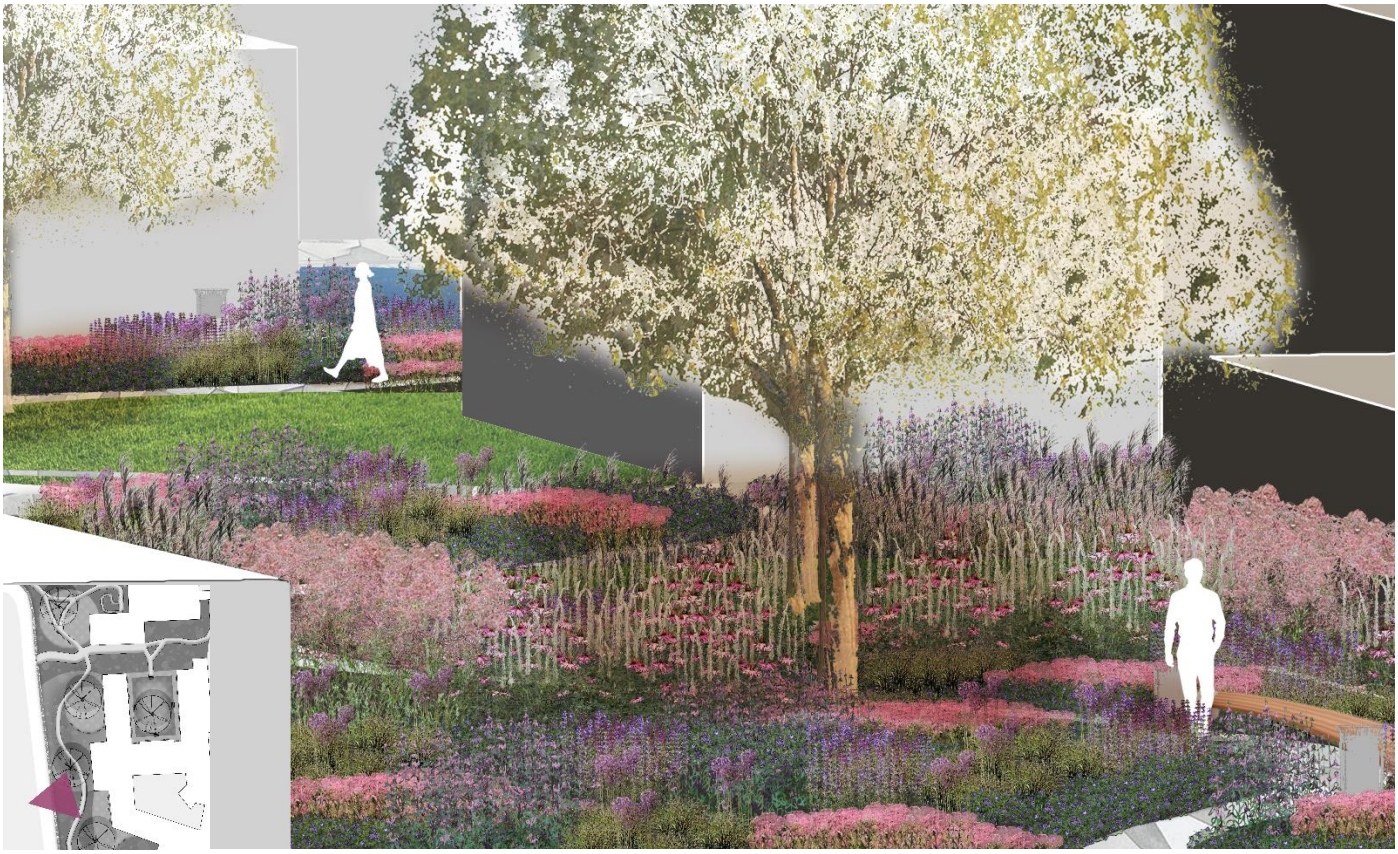
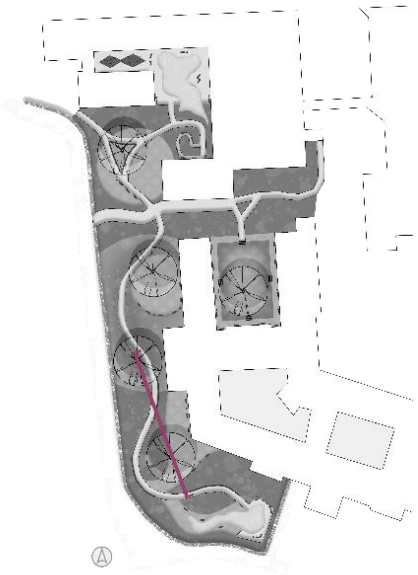


Figure 26 Artist impression SB in summer

Figure 27 Artist impression SB in winter

The European ash (*table 11*) that is used in this design usually grows up to 25 or 30 metres, meaning it still has a large potential impact in summer. To calculate how large the shade canopy of the European ash exactly is, the solar elevation angle was used at the 21st of June and December. It must be accounted for that ash trees carry no leaves in winter, so the shade canopy will be more scattered than is visualised. Based on this analysis (*figure 28*), the trees will have a shadow canopy of at least 11.3 metres in summer around lunchtime (SunCalc.org, n.d.), which leaves relatively much space for people to recreate, as people prefer to be between 0.9 and 1.35 metres apart (Sorokowska et al., 2017), leaving space for approximately eight to nine people per tree.

The large shade canopy in winter (*figure 28*) lowers the wind chill, so a warmer ambience is desirable, to change the microclimatic experience. The Cornelian cherry (*table 11*) is useful here. It blooms with yellow flowers from February to April, a warm colour that could positively affect thermal comfort in the cold.



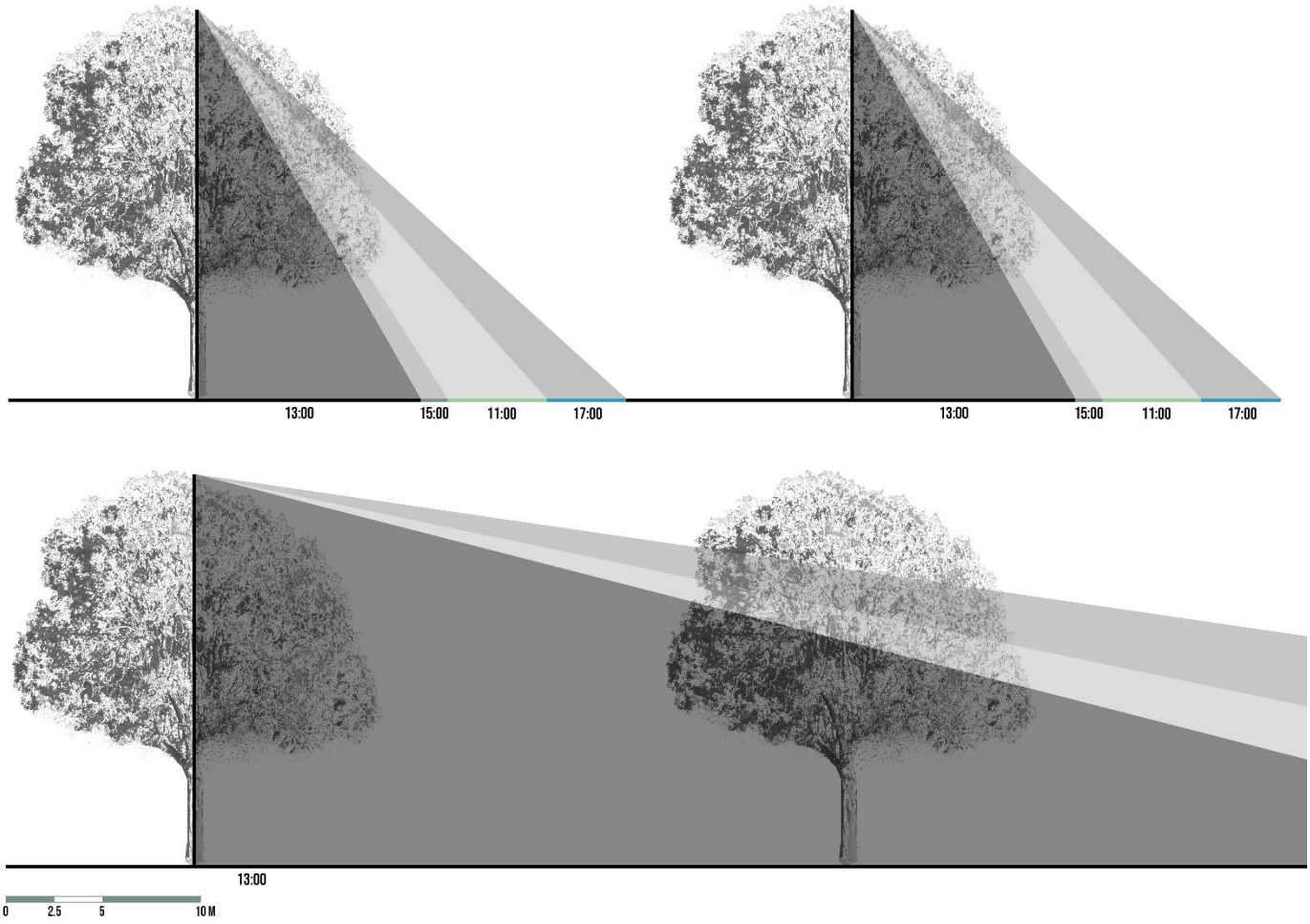


Figure 28 Shadow analysis European ash (20m) summer (top) and winter (bottom)

8. DISCUSSION

The results of this thesis are two designs and a set of design guidelines which respond to the needs and opportunities at HGV. These show that certain design solutions can be employed to solve multiple issues at once, with regard to AR and heat stress. Green elements form a common thread throughout the design, and provide a great example of multifaceted use.

Designing suitable outdoor environments for hospital staff is vital for their functioning (Blasche et al., 2017), and from the site analysis can be concluded that the HGV HOS are not suitable. It is not the only hospital with neglected outdoor spaces (Djukanović et al., 2017), which underlines the importance of this research. For a healthy population, wellbeing of all hospital staff is a prerequisite, meaning that HOS that negatively impact wellbeing ought to be improved. This thesis advocates that more attention should be paid to human-environment relationships at HOS and shows an example of how wellbeing of hospital staff can be improved, offering inspiration for future heat-mitigation projects of hospital sites that simultaneously try to improve restorativeness. It can however not be used as a blueprint for future design projects or, as the design guidelines are site-specific. The needs and opportunities should always be assessed for each context, and underlying problems should be considered.

With regard to the time frame, design solutions for thermal comfort in both summer and winter, and actual preferences for a restorative environment at the site were not analysed. A variety of options should account for differences in preference, so users would have to be included to optimise the designs, would they be further developed.

As the design is not executed, its actual thermal comfort and restorativeness will not be confirmed or rejected. The basis of evidence relies on assumptions, especially for AR. One of the greatest remaining questions in ART is – *where do we draw the line*? This line is expressed in e.g. the optimal amount of water in an environment (White et al., 2010) or in the amount of wilderness that is considered too little or too much (Van den Berg et al., 2014). When is something too complex, too busy or too dull? This line is not fixed yet, making it possible that the designs crossed this line. It can be tested through e.g. reaction to 3D visualisations. In a model, the effect on the microclimate of cooling elements and their configuration can be run, which is unfortunately not my expertise, but it would show the effectiveness for heat mitigation.

Furthermore, *table 1* is very likely to be incomplete, showing only a brief overview of certain elements that interact with restorativeness of the environment. It can also be said that using landscape preference as a criterion to assess the restorative capacity of an environment is a generalisation of theories that should not be made, as landscape preference and ART are two different models that concentrate on other facets of the relationship between people and their environment (Joye & Van den Berg, 2019). I agree that they are different models, but as their components show overlap (*figure 2*), using landscape preference as indicator for restorativeness can be defended. It can still be argued that this means that the designs show more elements that are preferred rather than restorative. The preference matrix (*table 2*) explains why people choose for the environment they feel good in, and it is not ruled out that this is not a restorative environment, especially as the assessable concepts that were used within the preference matrix (*table 9*) are also restorative elements (*table 1*). This makes it plausible that the designs in fact would enhance restorativeness compared to the current situation.

9. CONCLUSION

Outdoor spaces at Hospital Gelderse Vallei Ede are climatologically vulnerable and have a low restorative capacity, as there are too many demanding elements for fatigued users, such as hospital staff, and the area is subjected to heat stress. In this thesis, it was attempted to provide an answer to the research question *how can outdoor spaces surrounding HGV be redesigned to decrease directed attention fatigue and enhance thermal comfort for hospital staff?* Sub-research questions were used as a guide through the research process, and are briefly answered below.

SRQ1: WHAT LANDSCAPE ELEMENTS ARE ADDITIONAL CAUSES OF DAF?

Landscape elements that are negatively linked with restoration, and are therefore additional causes of DAF are, amongst others, reminders of the daily routine (Kaplan, 2001); too much wilderness (Van den Berg et al., 2014); too busy/many stimuli (White & Shah, 2019); complexity (Kaplan, 2001); abstract and interpretative elements (Nedučin et al., 2010); forceful stimuli (Varkovetski, 2015); heat (Taylor et al., 2015); bad maintenance (Ode Sang et al., 2016); smoking (Faris et al., 2012); information overload (Nedučin et al., 2010); distractions, lacking information, duty, deception, difficulty, danger (Kaplan's six categories of incompatibility; Kaplan, 2001); and unfamiliarity (Szolosi, 2011).

Knowledge of fatiguing elements makes it easier to locate them and avoid them -*know thy enemy*.

SRQ2: WHAT DESIGN PRINCIPLES CAN HELP REPLENISH ATTENTIONAL CAPACITY?

To allow for AR to take place, the design should have elements that allow a sense of being away, an extent, soft fascination, and compatibility, whilst they simultaneously are accessible and block negative intrusions.

SRQ3: WHAT IS THE MICROCLIMATE OF THE DESIGNATED AREA?

Thermal comfort is the experienced microclimate, which is low at HGV, except for at the park, which is a cool pocket compared to its surroundings (*figure 9*). Even though this hospital climate does not entirely match the climate zones as defined by Stewart and Oke (2012), the cool- and hotspots can be linked to a combination of zones. Trees largely contribute to the experienced temperature at cool spots throughout the area.

The physical microclimate of the compact midrise building structure with few or no trees is in stark contrast with the waterbody and scattered trees at the park, which roughly corresponds with local climate zones 2D/E (compact midrise with low plants and paved area) and B+G (scattered trees and water). This means that ventilation by the southwestern wind is minimal, and that there is little vegetation to cool down the environment, while the vast quantity of grey accelerates the heating process.

SRQ4: WHAT DESIGN PRINCIPLES CAN ENHANCE THERMAL COMFORT?

To encourage cooling of the area and enhance thermal comfort, the design should have natural elements, cool sealed surfaces, shadow elements, and elements that guide wind.

It was useful to identify zones in the area, to be able to look at site-specific issues and their underlying causes more closely, as this helped applying adequate design solutions to each zone. The answers to the sub-research questions helped to shape the design guidelines (*figure 13*), which in turn provided a basis for the conceptualisation of the masterplan and detail plan. Multifunctional solutions can be implemented to let hospital staff blow off some steam, whilst also cooling the environment. It is plausible that the design solutions that were applied in the designs actually enhance thermal comfort and decrease DAF relative to the current situation, for they are infused with a substantiated body of knowledge and were evaluated based on knowledge-infused criteria.

RECOMMENDATIONS FOR FUTURE RESEARCH

As was mentioned in the discussion, there is no clear answer as to where to draw the line in restorativeness of design elements and -properties like water, wilderness or complexity. It would therefore be necessary to have an improved and enlarged empirical body of evidence on AR-capacity of certain elements or properties, and explore the boundaries of their restorativeness. Moreover, the micro-restorative potential of environments should be studied more closely, as the ability to quickly revitalise people is overlooked, and may offer a solution for the short-lived moments hospital staff has to spend outside.

It can be concluded that more research and action is necessary to optimise the outdoor working environment for hospital staff.

10. REFLECTION

Writing this thesis has been an interesting journey. The more I immersed myself in the subject of my thesis, landscapes for human wellbeing and health, the more interesting it became to me. There are many unexplored corners and concepts within ART, which is challenging when trying to find empirical evidence. This is why it really helped me to have very specific research questions, and with that a framework that brought me clarity amidst an overwhelming amount of research papers.

Halfway my thesis my RSI situation worsened, but I could not figure out why. By redefining my planning and specifying what products I intended to produce, my mind could breathe again, and so could my body. I learned that creating order in my mind and my surroundings really helped me to release tension in my body, and function properly. I believe that this, and that proving to myself that even when taking breaks, I can finish my work, are the most important lessons I have learned along the way.

Having said this, it was not easy to take breaks. It was not superfluous to have Workpace installed, which kept reminding me to take small breaks, and have my housemates ask me to have lunch. There is still a learning curve of knowing when to stop, and knowing when something is enough, also with regard to design and gathering information. It did not occur once that I redrew the same design several times because something could be improved, like it was the case for the masterplan (*figure 29*). I started out on the computer, but had to remind myself that this would not be the sensible thing to do, regarding my physical state, and switched back-and-forth from my computer to the drawing table, as the scribbly lines of my shaky hand would not suffice for a master plan, I convinced myself. However, at some point I recognised this pattern, and tried to break through it, which is personal progress compared to earlier design studios. For example, I made the final version of the masterplan on paper (*figure 29*), and retouched it in Photoshop, provided that the map should communicate the design well.

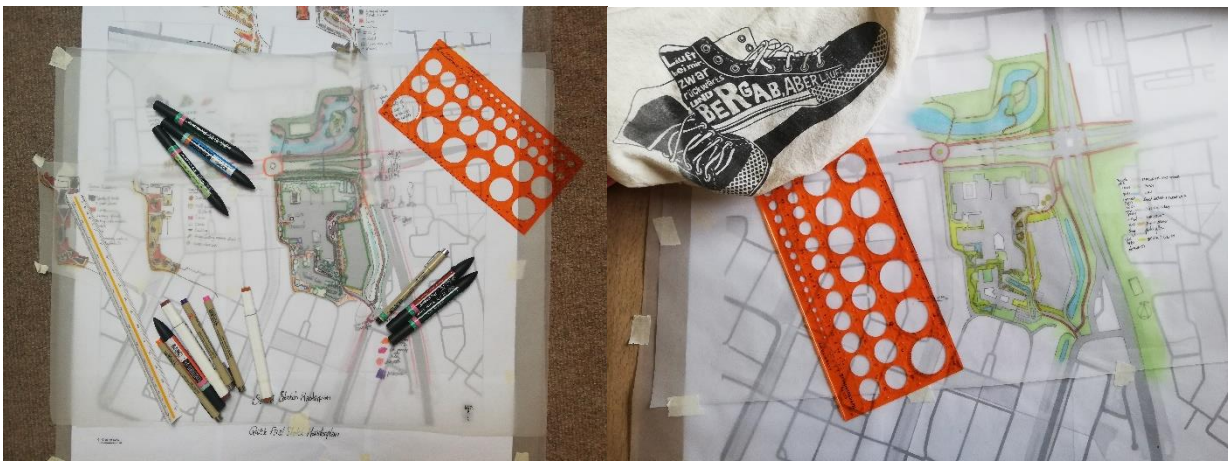


Figure 29 An example of the many layers and attempts during my design process

Furthermore, for the first few weeks, I was able to stick to the proposed planning fairly well. Halfway, my organisation was lacking, and I tried to work around it by making a new planning, as mentioned earlier. It gave me an indication of what products I still needed, and what time I gave myself to spend on each product. Working along the lines of this planning was great, it made me work very goal-oriented and efficiently. For future projects, it would be good to get a grasp of more realistic time expectations for certain products, to optimise time management.

My last learning goal was to know when to ask for help and when to work individually. I know that I need a fair amount of reassurance, and that I naturally ask a lot of questions to receive this reassurance. Despite this tendency, I believe I managed to limit the questions to the scheduled tutoring moments, with a few exceptions. The moment I had some technical issues that I could overcome by working around it, I wanted to know how to properly do it, and reached out to a former teacher. I believe that asking (these kind of) questions help me to learn and develop my skills. I also reached out to some fellow students/friends for help a few times, to brainstorm together about the many ideas I had, and for them to help me organise my thoughts. I believe that working on a project alone is possible, but I could not have done it without the critical questions my supervisor asked me, or without the brainstorm sessions with my friends and housemates. Feedback and criticism will only help strengthening your case, and I think that a studio-environment is more inviting for students to engage in discussions than a secluded bedroom, which was a disadvantage I overcame by reaching out. A future challenge for myself is to be more confident in my abilities, and to be content with imperfection.

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