Facilitators and barriers of creating heat-adaptive schoolyards in Rotterdam: a comparative case study.




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Preface

Writing this thesis on heat-adaptive measures at schoolyards has been a rich learning experience for me. After finishing my bachelor Health and Society at Wageningen University, I discovered that human behaviour, the influence of the environment on health and especially the role that greenery can play in this highly interested me. After finishing the course Settings for Health Promotion and the Academic Consultancy Training on reasons why consumers green their gardens or not, I knew that I wanted to specialise in the application of green in relation to health. Starting with the topic of climate adaptation and health connected well to this aim, together with the upcoming internship with Rijksinstituut voor Gezondheid en Milieu (RIVM) about applying a healthy, green living environment program in practice.

This thesis is meant for everyone that works or is interested in the field of heat-adaptive measures in urban areas or specifically at schoolyards. The thesis also elaborates on the points of interest when involving different stakeholders and how a renovation program comes to being. The report finishes with a practical advice for all parties that are interested in continuing with similar projects.

During the research process I developed myself in cutting the Gordian knots when collecting and analysing data. I was stimulated to revise my work again and again, coming back to the core of the work and adjusting the report to that. Overall, I learned a lot about differentiating between main and side points and choosing the best fitting ways (professionally and personally) to present these outcomes. From the start of the thesis process, my supervisors Dr. Ir. Lenneke Vaandrager and Yvette Buist (MSc) have guided me very well. The academic insights that they provided me to improve my own work are already a valuable addition to my professional skills. I want to thank them for the close and transparent assistance, and I look forward to further develop my gained academic capacities during my upcoming internship and future career.

Abstract

Background: Climate change affects people's living environment and their health, amongst others through heat waves and urban heat islands (UHIs). Although the focus has often been on elderly, children are also prone to suffer from heat stress. The aim of this research was therefore to unravel why some schools have implemented heat-adaptive measures at their schoolyard, and others have not. The main research question focussed on finding the factors that influence the development and implementation of these heat-adaptive measures at Rotterdam schoolyards and the drivers behind these factors.

Methods: A systematic literature review was conducted to gain insight in the heat-adaptive measures that have been applied in urban areas around Europe. Semi-structured interviews with school team members, schoolyard greening initiatives and the municipality were performed to clarify the involved stakeholders, their motives and the required capacities and skills in the renovation process.

Results: Green cover and an increased albedo level are heat-adaptive measures that successfully lower UHIs. Green roofs and green façades only lower the very local temperature. Sun sails also contribute to lower heat stress, but trees have better performances in providing shade. The school team, the students, their parents, the neighbourhood, the municipality, and the schoolyard greening initiatives are the most closely involved stakeholders in the schoolyard context. Creating a feeling of ownership through clear communication, having a vision on the usage purposes of the schoolyard, performing project management, and applying knowledge and skills are necessary skills to succeed a heat-adaption renovation. Barriers in this process are amongst others vandalism, problems around maintenance and resistance from other stakeholders. While schools have a lot of motives to green their schoolyard such as the connection to their education, adapting to the environment and financial considerations, the effects on the climate were mostly seen as a positive side-effect rather than being the main goal.

Discussion: Even though not all stakeholders were included in this research due to the research timing and corona effects, an in-depth insight about the schoolyard context was gained regarding heat-adaptation. In future research, the motives of architects behind the schoolyards should be investigated, as well as the efficiency amongst teachers to include nature in their curriculum. Moreover, investigating the correlation between vandalism and greenery is needed to take away fear amongst the school team. When implementing green it should be considered whether schoolyards are the most effective level. Besides, heat-adaptive measures should always be placed with taking the physical context into account.

Conclusion: Adding green cover is a promising measure that could help mitigating heat at schoolyards. To make this application successful, organisational and social skills are required from the stakeholders. When the schoolyard is considered as a holistic, interconnecting system, different considerations can be included. Potential barriers of resistance, misunderstanding or loiterers can be overcome through communication and early involvement.

Keywords: Heat adaptation, Schoolyards, Rotterdam, Facilitators, Barriers, Capacities, Skills
Word count: 25919

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1. Introduction

1.1 Heat waves and health

Climate change is a worldwide problem that affects communities through many different pathways (Rohat et al., 2021). It is assumed that the increase in frequency of occurring extreme weather events (EWEs) such as episodes of unusual heat, is related to climate change (Martinez Garcia & Sheehan, 2016). The definition of a heatwave is rarely comprehensive on a global level, as the extent of acclimatisation and adaptation by a population differs per climate and region. In order to determine the health risks of heatwaves, the duration and intensity of hot days are mostly used to define a heatwave (Yang et al., 2019). Since this thesis focuses on the Dutch city of Rotterdam, the following definition by KNMI (n.d.) is used: "A *heatwave* is a sequence of at least 5 summer days in De Bilt (maximum temperature 25.0°C or higher), of which at least 3 days are tropical (maximum temperature 30.0°C or higher)". Such events of extreme heat are a driver behind the worldwide weather-related mortality (Rohat et al., 2021). Heat does not only lead to death in the worst cases, but also leads to other health problems like fatigue, concentration problems, dehydration and allergies (Kuypers et al., n.d.). These symptoms are an utterance of the concept '*heat stress*', which describes the difficulties the body has when getting rid of excess heat. To cool down, the body temperature rises and the heart rate increases. The ongoing process of trying to store heat can sometimes cause health problems as described above (IOWA University, n.d.).

When cities grow and develop, green space is often compromised. Less vegetation decreases the capability of evaporative cooling, which paves the way for urban heat islands (Chakraborty et al., 2019). *Urban heat island (UHI)* effects describe the phenomenon in which urban areas often have a higher temperature than its surrounding rural regions. This temperature difference is mainly caused by the higher absorption of heat in cities than they can release during nighttime, amongst others because of the present high walls, poor air flow and presence of dark and paved surfaces (Kuypers et al., n.d.; Van Roekel, 2014). Besides, commercial activities, mobility and the associated air pollution also play a role in retaining the heat (Kuypers et al., n.d.). An UHI is considered to be the most evident climate-related manifestation of the current urbanisation processes. Figure 1 shows that an increase of a few degrees in temperature (especially above 30°C) in cities like London can lead to a substantial increased mortality risk (Rydin et al., 2012).

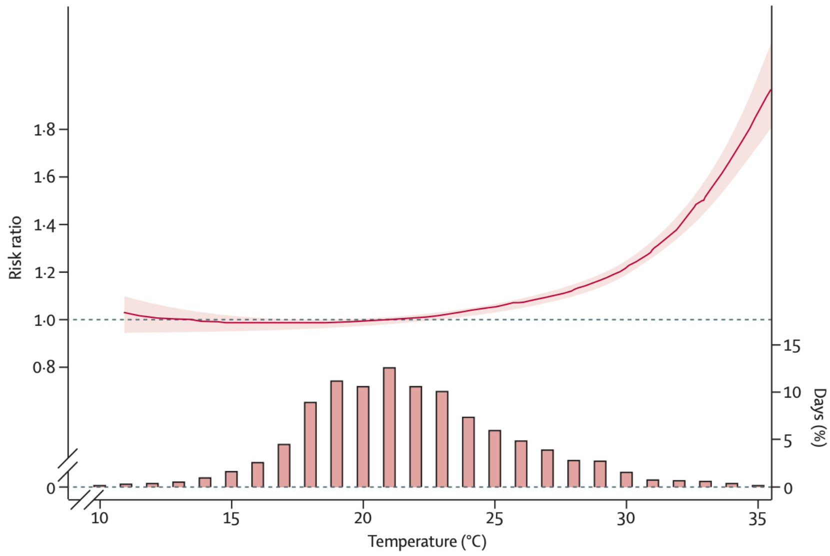

Figure 1. The association between temperature and mortality in London.
Temperatures are 2-day maximum temperatures after adjustment for potential confounders.
The shaded area shows the 95% CIs. Reprinted from Rydin et al. (2012).

When looking at the Netherlands, urban areas in cities like Rotterdam can reach temperatures of over 7°C higher than in surrounding rural areas, as shown in Figure 2. Despite the health effects of heat, this EWE often receives inadequate attention from Dutch municipalities compared to other EWEs like floods. This might be caused by the fact that, especially in the Netherlands, heat and drought are quite recently emerging problems; flooding on the other hand has been a problem for centuries and is easier to recognise the direct impact from, such as flooded basements (Hofgärtner & Zijlstra, 2018). At the same time, UHIs form an increasing health risk as cities such as Rotterdam are becoming increasingly densified and more paved (Gemeentewerken Rotterdam, 2011).

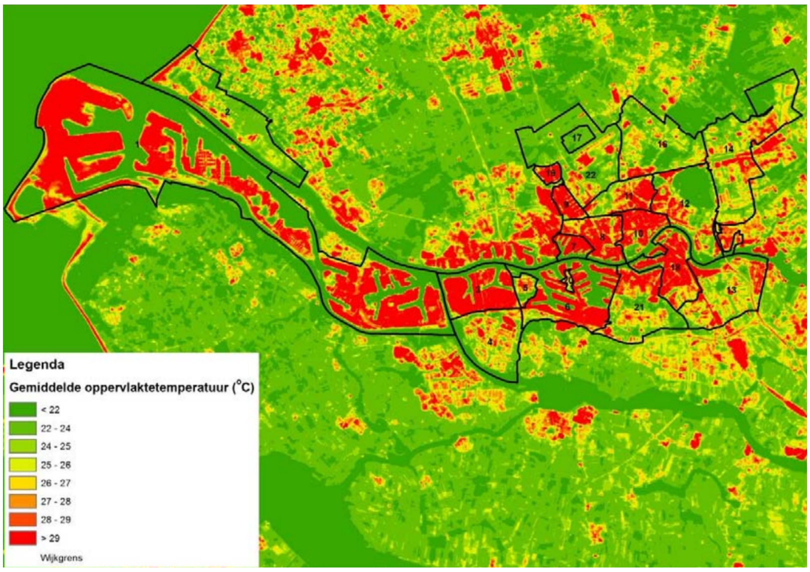

Figure 2. Average surface temperatures (°C) in Rotterdam and surroundings, measured in 2011. Colours range from <22°C (dark green) up till >29°C (bright red). Reprinted from Gemeentewerken Rotterdam (2011).

1.2 Vulnerable groups

Not all population groups are impacted equally by the effects of extreme heat. Groups from low-income communities, ethnic minorities, elderly, socially isolated people, those with pre-existing medical problems and people without access to air conditioning are generally more vulnerable to extreme heat exposure (Rohat et al., 2021). A thoroughly researched concept that relates to the determinants of vulnerability is *socioeconomic status (SES)*. Mueller and Parcel as cited in Shavers (2007) defined this concept as "the relative position of a family or individual on a hierarchical social structure, based on their access to or control over wealth, prestige and power". SES is generally related to one's health status, which can give an indication about the access of an individual or group to basic resources that are needed for good health. SES itself is mostly measured by occupation, education, or income. For example, being unemployed can be a predictor of decreased health compared to being employed. A lower SES often results in a higher exposure to risk factors, such as physical risks at work or living in poor housing circumstances (Adler & Newman, 2002).

For children, SES has an influence on multiple levels of their well-being. Children from low-SES families often experience more severe consequences of health problems than children from higher-SES environments. This can also be of influence on how children are able to deal with heat. Especially children under 14 years old are more susceptible during heat waves (Xiao et al., 2017).

Considering these characteristics of vulnerable groups, amongst Dutch cities Rotterdam seems to stand out in terms of the proportion of vulnerable people living in the city. When looking at the 20 poorest postcode areas of the Netherlands, 9 of them are located in Rotterdam (SCP/CBS, 2014). In 2014, Rotterdam was even reported to be leading the poverty ranking in the Netherlands as it has relatively high levels of unemployment, low property prices and poor households (Tersteeg et al., 2017). This common status of disadvantage also affects children: 1 in 4 children living in Rotterdam grow up in poverty (Warm Rotterdam, n.d.). As income is a rather accurate predictor of vulnerability (inverse relationship), this poverty rate has important implications for risks of heat exposure. Vulnerable groups are often less able to adapt their behaviour or their living situation to heat, amongst others because lower-income neighbourhoods are further away from (natural) cooling features than higher-income neighbourhoods (Platform 31, n.d.). Moreover, several studies have shown an association between a lower SES, exposure to UHIs and the corresponding negative health outcomes (Chakraborty et al., 2019; Hsiang et al., 2017; Jenerette et al., 2007; Nayak et al., 2018).

1.3 Children and heat effects

School environments play a big role in the daily life activities of children. When being at school, children spend about 30% of their time at the schoolyard (Antoniadis et al., 2017). A comfortable microclimate at the schoolyard and other characteristics of the built environment can have a positive influence on children's physical and social activities, and therefore on their health. Nevertheless, when children face thermal conditions that are too hot for their bodies, this positive correlation decreases; children can suffer from heat exhaustion, fatigue or dehydration, which limits their cognitive ability (Vanos, 2015). Compared to adults, children have limited abilities to deal with heat stress.

First, children often still depend on their caretakers to protect them from dangers, for example to provide them sun protection. Children are also less capable of effectively communicating their needs in terms of thermal comfort, calorie intake or hydration. Furthermore, due to their higher body surface area-to-mass ratio, they have a greater temperature transfer with their environment than adults. Besides, children have a higher metabolic rate and are thus more sensitive to temperature. Activity-wise they are often more active than adults when being outdoors (Martinez Garcia & Sheehan, 2016). Moreover, children up to the age of eighteen are more sensitive to UV radiation exposure coming from the sun than adults, which increases the risk of skin cancer in case of overexposure. Even though children are often taught how to protect themselves from the sun by measures like sunscreen and wearing hats, these efforts have turned out to be inadequate (McWilliam et al., 2020). This indicates that other measures are needed to protect children in times of heat.

1.4 What are schoolyards

Heatwaves are becoming a more common problem on Dutch schoolyards, especially during the summer months. While staying inside can protect children from heat and harmful solar radiation, physical activity is restrained (Boldemann et al., 2011). This is a worrisome effect, as 80 percent of the Dutch youth already performs too little physical exercise (RIVM, 2013). At the same time, Dutch schoolyards are still 62,8% paved on average. These paved surfaces can reach temperatures over 30 degrees Celsius (Van Dijk, 2020). A schoolyard is considered to be the area or playground around the school building, that is used by students and/or school staff in their free time (Stadler-Altmann, 2021; Van de Grint, 2014). According to Jantje Beton (n.d.) ,the most important values when designing a schoolyard are that children feel free to move, learn, play, discover and relax. The schoolyard should also provide protection to children, but at the same time it should offer them space to discover their own borders and to stimulate facing new challenges. Regarding the playing safety, the school should take the possibilities of supervision with different schoolyard set-ups into account to guarantee safety. For example, natural elements that come in different levels and sizes require a certain design and strategic placement (Schoolpleinen Brabant, 2018). Besides, the school plays a role in evaluating what schoolyard elements fit to the children’s capacities and what their parents prefer in terms of safety, getting dirty and playing outside the school terrain. In conclusion, next to playing practicalities, there are many other factors to take into account when choosing a certain schoolyard design (Jantje Beton, n.d.).

While schoolyards used to be seen as a tiled square with some playground equipment to entertain children during breaks, nowadays a schoolyard is considered much more (Van de Grint, 2014). Schoolyards are seen as playing a social, multifunctional role in a community or neighbourhood (BOERplay, n.d.). For example, after school hours the schoolyard can function as a public space, especially in urban areas where public spaces are often in a deficient state (Dessì, 2020). Public spaces can have an important social function and attract many people, irrespective of their social status (Tersteeg et al., 2017). Moreover, when some measures are taken to improve the microclimatic adaptation of the schoolyard, the environmental resilience of the neighbourhood also benefits from this (Dessì, 2020). The latter point touches upon a considerable knowledge gap. Most studies that have investigated the thermal environments of schools have focused on the indoor environments. This means that there is still a lot to learn about the interaction between the outdoor thermal environment and children's well-being (Shih et al., 2017; Zhang et al., 2017). Moreover, it can be suggested that schoolyards which are set up more like a park in terms of green structures can also cool their nearby environment down at nighttime, which would be especially beneficial for highly paved neighbourhoods. Research even suggests that repetition of green spaces has more effect on the environment than creating one big park with the same surface size, meaning that intervening at schoolyard level can have important benefits for the local UHIs (Kuypers et al., n.d.).

1.5 Schoolyards in vulnerable neighbourhoods

Little research seems to be done about what schoolyards in vulnerable neighbourhoods look like, what design elements they have and how they differ from less vulnerable neighbourhoods. This indicates that schoolyards are still an underrepresented topic when it comes to doing broader research on the causes, differences, and consequences of different types of schoolyards in different urban areas. Nevertheless, Dutch news websites increasingly highlight the importance of greening schoolyards or to use the schoolyards for multiple (educational) purposes, such as for outside lessons (Croes, 2021; Omroep West, 2021). However, this approach already focuses on the 'end' of the cause-and-effect chain, by reflecting on the benefits of the use of greenery. Less attention is paid to the 'start' of this chain, leaving questions like 'Why are some schoolyards greener than others?' or 'What is the problem of a paved schoolyard for the direct and indirect environment?' open. It is therefore important to create a fuller picture of what is really happening at those schoolyards, what the reasons are behind current schoolyard designs and how the schoolyard users deal with periods of heat. It is likely that the current corona pandemic increases the attention for other potential uses of the schoolyard like outside education, as safety measures against the virus emphasise the importance of ventilation. This raises the question why schoolyards are not used for such purposes yet (Croes, 2021). The most important motivator behind greening schoolyards seems to be the positive influence that nature has on the development, physical activity, and social interactions of school children. Disadvantages or barriers to transform schoolyards are amongst others a limited budget (Laconi, 2019).

1.6 Design of schoolyards

Ever since the 80's, the authority of deciding about the size and the design of Dutch schoolyards has not been with the Ministry of Education anymore, but with the local municipalities (Speelruimte, n.d.). Moreover, in 2015 there has been a legislative change, in which the full responsibility and the budget for the maintenance of public schoolyards have been put in the hands of the school boards themselves. Before, these decisions were a teamwise responsibility of the school, the schoolyard users and the municipality (Buiten Spelen, 2014). On the one hand, these extra demands can form an extra pressure for school boards as they are not used to prioritising and performing the management and maintenance of (the budget of) their schoolyard. On the other hand, this local responsibility offers opportunities to improve their schoolyards tailored to the needs and wishes of their own students (Buiten Spelen, 2014; Stad en Groen, 2014).

Even though there is an increasing focus amongst schools and educators to green their schoolyards (Flax et al., 2020), not many scientific studies can be found on the contribution that schoolyards can offer to climate adaptation. For example, when the search term 'contribut* AND schoolyard* AND climate AND adapt*' was inserted on the database Scopus (in April 2021), no results were found. This either indicates that the knowledge on the advantages of heat resilient schoolyards is still scattered, or that the focus has been more on other parts of cities instead of schoolyards. This is however a missed opportunity for urban heat adaptation, as urban schoolyards cover a large part of the open spaces in city areas. In the case of creating more heat resilient schoolyards, the surrounding community can also benefit from it (Flax et al., 2020). Especially when the children or the community members are involved in making the school heat resilient and letting the school function as a 'community hub', parents can also become more aware of the effects of heat (C40 Cities, n.d.; Flax et al., 2020). The process of greening schoolyards is an evident way of addressing climate change, especially regarding the increase of heat periods. Amongst others a green schoolyard can absorb more rainwater and can counteract the heat island effect. Depending on the choice of species, the amount of grass and trees coverage and the size of the schoolyard, the increased evaporation by the vegetation, their own transpiration, their offered shading, and their air movements contribute to creating a 'cooling island' instead. Besides these environmental benefits, children also experience a positive influence on their health and brain development when playing in natural environments (Flax et al., 2020). Despite all this knowledge about advantages of greenery, in Rotterdam alone only 12 primary schools can currently be labelled as 'green' (Cobra Groeninzicht, n.d.), while Rotterdam counted 217 primary schools in 2021 (AlleCijfers, 2021). This raises the question why so little schools have applied heat-adaptive measures to their schoolyards yet.

2. Theoretical framework

2.1 The Poland framework

Health problems do not arise in a vacuum; becoming sick or healthy always happens within a certain setting. Settings in which people play, work and live, in which behaviour happens and in which interactions take place between circumstances and people (Poland et al., 2009). Similarly, if an intervention is to be implemented to influence this health setting, it is conducive for the likelihood of success if attention is paid to the local context. For example: who are the stakeholders, what does the psychosocial and physical environment look like, what role does the broader socio-political context play in the problem (and solution)? Using this technique in setting up an intervention is what Poland et al. (2009) call a 'settings approach'. To form a rich picture of the particular health setting, a threefold framework was set up.

In the case of studying the facilitators and barriers of heat-adaptive schoolyards, the use of the Poland framework allows the researcher(s) to gain multiple perspectives about the reasons for the current schoolyard designs, which stakeholders (such as local agencies) are involved in renewing a schoolyard and how the main schoolyard users think about possible heat-adaptive measures to adjust the schoolyard with. As students spend a big part of their day at the schoolyard, this place is considered a health setting too.

In Table 1, the first part of the framework is shown. In this table, questions are formulated that help clarifying different aspects of the health setting that are considered during the planning and implementation of an intervention program. The sections 'Stakeholders and interests' and 'Power, influence and social change' were used as a fundament for the topic list of the semi-structured interviews with all three interviewed parties. These questions clarify which parties are usually involved in greening the schoolyard and what power each of these players have in the renovation process. This gives researchers an indication of how to work within this complex health environment.

Table 1

Understanding settings: fundaments for the topic lists. Adapted from Poland et al. (2009).

Stakeholders and interests
8. Who are the primary stakeholders in this setting or affecting this setting?
9. What are their agendas, their stake in change or the status quo, access to resources?
10. What are the functions of this setting for different stakeholders?
11. Who is absent from this setting? Why?
12. What is the meaning of health from different stakeholder perspectives and its salience to them?
13. How widely are the determinants of health as they are experienced in this setting understood and acted on?
Power, influence, and social change
14. How do power relations come into play in this setting?
15. What is the relative power of stakeholders? How is power exerted?
16. Who controls access to this setting?
17. Who sets the agenda in this setting?

18. Who participates in decision making? On what basis? On whose conditions?
19. Who has a voice? What is the relative role and power of experts and of the lay public in agenda setting, problem definition, intervention planning, implementation, and evaluation?
20. What – or who – drives (or blocks) change in this setting?

To get more insight in the skills that are required from each involved stakeholder, the section Capacity from Table 2 in Poland et al. (2009) was used in the topic list of the interviews as well. If the local situation is outlined from the perspective of the most important stakeholders, understanding what they need and what skills they can bring, a more systematic analysis about the setting is created. Having this analysis clear offers opportunities for capacity building and empowerment. This study aims to provide a better overview of the schoolyard setting in order to overcome barriers and make use of facilitators to develop and implement more heat-adaptive schoolyards in the future.

Table 2
Changing settings: fundaments for the topic lists. Adapted from Poland et al. (2009).

Capacity
5. What capacities are required among professionals for this setting to promote health effectively?
6. What capacities are required within local communities to make this setting effective?
7. What capacities are required among local agencies for this setting to be effective?
8. What capacities are required among governments for this setting to be effective in promoting health?

The third set of questions from the Poland framework focuses on the identification of knowledge gaps about the health setting and its settings approach, as well as the connection between knowledge and practice (Poland et al., 2009). The questions on this aspect are particularly useful when evaluating the appliance of knowledge in practice. As this thesis mainly focuses on filling the knowledge gap on heat-resistant schoolyards and not necessarily on creating an intervention to beat this heat, less attention was paid to this third part of the Poland framework.

2.2 The Socio-Ecological Model

As can be noticed from the depth that the Poland framework searches in every unique and complex health (intervention) situation, change does not occur in a vacuum. One individual or organisation acts within its direct and indirect environment, in which different stakeholders play a role. Bronfenbrenner (cited in Kilanowski, 2017) illustrates this by using nested circles, as can be seen in Figure 3. This life context is especially important for children, as they are constantly developing themselves. The way in which this development occurs depends on the mutual influence of the child and its social environment (Van Oijen, 2010). However, the health of children these days is at risk. The number of children with behavioural and concentration problems increases, as does the number of children that does not perform moderate-intensity exercise enough. Moreover, children seem to lose contact with nature more (Hovinga, n.d.). Connecting these health effects to heat, children can feel unfocused, tired or short of breath when air temperatures rise (GGD Amsterdam, 2016). This is where the schoolyard comes into play. A primary school is located in a certain neighbourhood, considered as part of the mesosystem, according to the socio-ecological model (Kilanowski, 2017). This system is just beyond the immediate interactions that the individuals (students, teachers) have, but it still directly influences them. Connecting this to greenery, when the school is located in the middle of the city centre where everything is paved, this will directly influence the schoolyard's local climate which in turn influences the children's thermal comfort. Looking a bit further, the community context and the existing social networks around the school are of indirect influence on the children. For example, when the community is involved in taking care of the schoolyard, chances are higher that a greening project succeeds. On a higher level, cultural influences of what interests and bothers people can also influence what happens on the individual level. Then, on the chronosystem level, governmental policy can influence the decisions that are made regarding the schoolyard. What can be concluded from this, is that all stakeholders are interconnected, not only in their interdependent interests, but also because their different 'locations' within the bigger system influence each other. The socio-ecological model (SEM) thus connects the situation sketch of the rich schoolyard setting with the different levels that interact that all contain stakeholders with certain capacities and interests.

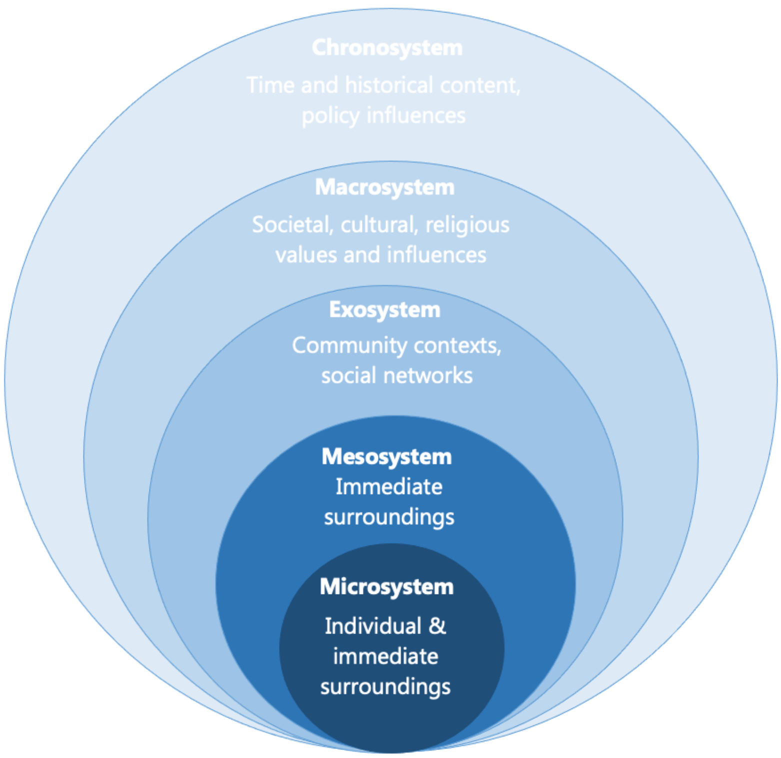

Figure 3. Socio-ecological model by Bronfenbrenner, adjusted from Henderson and Baffour (2015); Kilanowski (2017).

The aim of this study is to integrate the SEM with the settings analysis based on Poland et al. (2009). As such, an overview is created of all the actors within the schoolyard setting, as well as what is currently done with Rotterdam schoolyards and the motives behind this. As the field of schoolyard settings still appears to be understudied, the outcomes can offer a valuable addition to the knowledge base about facilitators and barriers of heat-adaptive schoolyards.

3. Research questions

3.1 Main question

Even though a lot of scattered pieces of theory already exist on the effects of heatwaves, urban areas and heat adaptation and the benefits of urban green, many primary schools in especially vulnerable neighbourhoods still lack a heat-adaptive schoolyard. As schoolyards can exacerbate the surrounding heat or cool the direct environment, it is necessary to look deeper into the current situation of heat adaptation at schoolyards of primary schools in Rotterdam. Therefore, the following research question was formulated:

"Which factors influence the development and implementation of heat-adaptive measures at schoolyards in Rotterdam and what are the drivers behind these factors?"

3.2 Sub questions

To be able to answer the main research question, a set of sub questions was set up. These questions will provide the essential background of the underlying factors regarding heat-adaptive measures at schoolyards. The questions were based on Table 1 and 2 from the Poland framework, more specifically the section about stakeholders and interests and capacities. The purpose of these research questions was to clarify which facilitators and barriers are experienced by the stakeholders when creating a heat-adaptive schoolyard. The sub questions were divided in two parts, connecting to the two studies that were performed in this thesis. First, a literature study was done to answer the question:

1. Which heat-adaptive measures have been applied in urban areas around Europe and what effects did they yield, according to the literature?

Second, semi-structured interviews were performed. In these interviews, the following sub questions were central:

2. Who are the stakeholders involved in the creation of heat-adaptive schoolyards?
3. What capacities and skills are required amongst the closely involved stakeholders to create a heat-adaptive schoolyard in Rotterdam?
4. What are the motives behind the current implementation of schoolyard elements, according to the closely involved stakeholders?

4. Methods

4.1 Systematic literature review

Building on the information from the introduction, a systematic literature review was done to evaluate the different interventions that make an urban area more heat adaptive. As schoolyards are still underrepresented in heat-adaptive studies, the main focus was on urban areas in general. This systematic literature review covers the first part of the thesis, by answering the sub research question:

1. 'Which heat-adaptive measures have been applied in urban areas around Europe and what effects did they yield, according to the literature?'.

The scope of Europe was chosen as the databases provided scattered results from all over the world. Filtering per country became too messy when using two different databases, but by filtering for Europe still a broad range of heat-adaptive opportunities was derived from an area with a relatively internal comparable climate. To search for relevant literature in a systematic way, a table was created with all search terms that could be used in the databases Scopus and GreenFILE (from EBSCOhost). Based on the results of both databases, irrelevant study topics were filtered out using the search terms NOT (Scopus) or AND NOT (GreenFILE). Together with the table of search terms, the search question that was used in each database can be seen in Appendix A. Additional filters in each database were used to specify the search and reduce the number of irrelevant hits. The detailed filters for both databases can be found in Appendix B. All articles that were considered useful were downloaded as a full APA citation in the program EndNote.

After the literature research itself, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to select articles from the research to include in the study. In systematic literature research, PRISMA is particularly useful to evaluate interventions (PRISMA, 2021). PRISMA developed a checklist for this to report a systematic review in a transparent way (Appendix C). Besides, PRISMA consists of a flow diagram with 4 phases to go through which can be used to record the systematic research process for each single research question. The research process for sub research question 1 can be found in Appendix D.

4.1.1 Inclusion criteria

To be able to select the articles that were most relevant for the study, a set of selection criteria was used: 1) The described measures were located in urban areas; 2) The described measures had a focus on the extreme weather event of heat; 3) The described measures should be applicable in existing urban areas, not in newly-built quarters as the study is about already built schoolyards; 4) the study describes concrete heat-adaptive measures; 5) The included studies were written in Dutch or English. Studies that described a toolbox or an action plan for designing heat-adaptive measures or to evaluate such interventions were excluded, as well as articles that were a book chapter and not a scientific review.

To determine the time range of which articles would be included, Dutch statistics of the history of heatwaves were consulted. After a period of 7 years without an official heatwave from 2006, from the year 2013 on hotter and more frequent heatwaves occur in the Netherlands (KNMI, 2021; Voskuil, 2020). As heatwaves have become a more common phenomenon since 2013, the publication years of the selected articles had to be between 2013 and 2021.

4.1.2 Quality assessment articles

To appropriately evaluate the quality of all included articles, two types of assessment tools were used. First, the TAPUPAS framework by Pawson et al. (2003) was used to assess the included quantitative studies. This framework included 10 criteria which can be seen in Appendix E. During the rating process it was found that almost all quantitative articles had modelling or environmental simulations as main methods, which did not include the involvement of real participants. 2 of the criteria (about appropriate sample size and sound sampling) were therefore left out of the analysis because of irrelevance. Each article was checked for all the other 8 criteria. If the article met a criterion, it received 1 point. If not, it was scored as 0. Articles with 2 points or less were qualified as 'poor'. Articles with 3 to 5 points were qualified as 'moderate'. Articles that scored 6 points or higher were qualified as 'strong' (Brombacher, 2019; Super et al., 2017; Van Dillen et al., 2013). Furthermore, qualitative studies which carried out a (systematic) literature review or a meta-analysis were assessed through the checklist of the Critical Appraisal of a Meta-Analysis or Systematic Review (CEBMa, 2014). This checklist contains 12 questions which could all be answered by 'yes', 'no' or 'unclear'. The answer that each article scored also had different ratings: 'yes' received 2 points per question, 'no' received 0 points and each 'unclear' received 1 point. Articles that scored 0-11 points were qualified as 'poor'. Articles scoring 12-17 points qualified as 'moderate'. Articles between 18-24 points were qualified as 'strong' (Brombacher, 2019; CEBMa, 2014). The full checklist can be seen in Appendix F.

All articles that came up after entering the search term in Scopus or GreenFILE, that checked the inclusion criteria and those that were also available and relevant were included in the quality assessment. The score of each article (marked as 'moderate', or 'strong') was added as a column in the complete table of literature as seen in Appendix P. Articles that were labelled as 'poor' were left out of the systematic review. The results of all the quality assessments are depicted in Appendix G.

Another part of the quality assessment consisted of checking for potential biases. Next to the most important biases from Verkooijen (2021), the method of reporting biases as in the overview from Drucker et al. (2016) was used as a fundament to form a table with all the relevant biases checked for in each article. Each study was examined for the listed biases, rating them with a high, unclear, or low risk for each bias. Only the biases that had a high risk of existing in each study were elaborated upon in the results table as shown in Appendix H.

4.1.3 Analysis of the literature

After gathering the literature in Table 5 and Appendix P and assessing each study's quality, the literature was analysed. This was done by grouping the different types of heat adaptive measures that came up in the studies, including the effect size and potential side effects of each intervention. For each category, a summary was created of the most important effects and implications as shown in the results section.

4.2 Selection of primary schools

The second study of this thesis contained a series of semi-structured interviews. These interviews aimed to answer the following sub research questions:

2. *Who are the stakeholders involved in the creation of heat-adaptive schoolyards?*
3. *What capacities and skills are required amongst the closely involved stakeholders to create a heat-adaptive schoolyard in Rotterdam?*
4. *What are the motives behind the current implementation of schoolyard elements, according to the closely involved stakeholders?*

Based on the literature studies from the introduction, it can be concluded that groups that are already disadvantaged are also at higher risk of being negatively influenced by EWEs like heatwaves. The first step was thus to create an image of which Rotterdam city districts are most often exposed to heat, as well as which of these areas can be categorised in the lower SES category. As this combination is likely to create extra vulnerability for the inhabitants, most profit on the field of heat resistance can be made at schoolyards in those areas. To create a rich picture for the area selection, several sources were used, as shown in Table 3.

Table 3
Selection of Rotterdam districts. Own table.

Measured element	Source
Highest percentages of measured poverty, poorest postal codes	SCP/CBS (2014);Van Hulst and Hoff (2019)
Lowest average personal incomes (amongst citizens in their 30's)	Kansenkaart (n.d.)
Safety and social indexes	Gemeente Rotterdam (2020)
Interactive maps of most petrificated areas, UHIs, heat stress caused by hot nights, areas with many tropical days, areas with lowest amount of greenery.	Klimaateffectatlas (n.d.)

The counts that each district occurred amongst Rotterdam neighbourhoods in the list of factors is shown in Appendix J. In this table, only the most significant districts were included; districts that did not show up in the lists of these factors were kept out.

In total, 4 districts were included. The location of these districts can be seen in Figure 4.

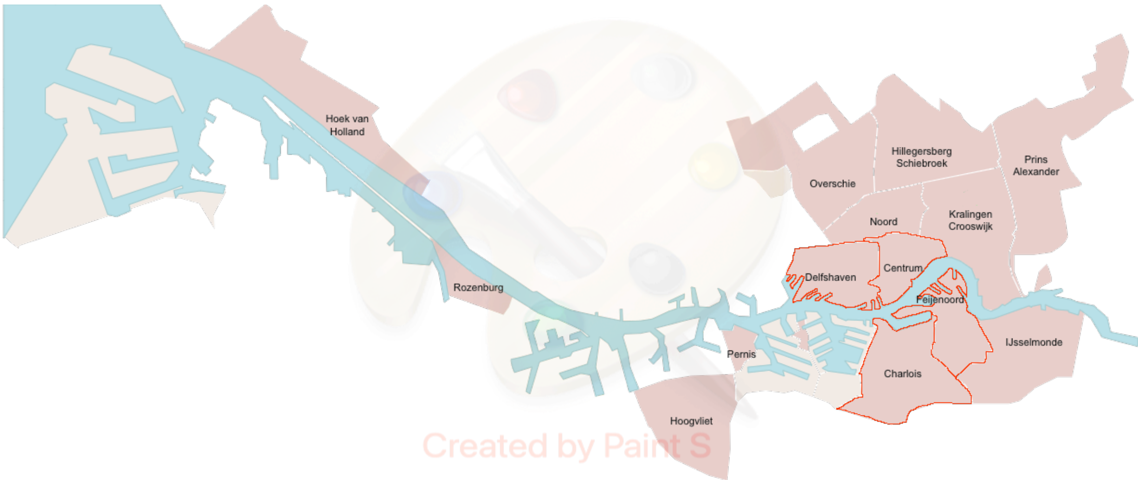

Figure 4. Map of Rotterdam with the selected districts of Centrum, Feijenoord, Delfshaven and Charlois. Adapted from Gemeente Rotterdam (2020).

The data collection consisted of two phases. In the first phase, the first two selected districts were taken to contact schools from, as derived from the maps of Cobra Groeninzicht (n.d.). These maps showed all registered primary schools, including their score in percentages of greenery in the public space, the distance to a small forest fragment ("postzegelbosjes"), the amount of greenery in a radius of 100 meters around the school and the amount of green in playgrounds. In an interview with senior advisor Dirk Voets from Cobra Groeninzicht, it became clear that the percentage of public greenery and the amount of greenery in a 100m radius were the most representative measures of the real-life situation. While first it was intended to only contact the most petrificated schools, after a period of low response rates all schools within the selected districts were contacted. The schools were emailed and called to request participation. All contact moments and discussed details were kept track of in a Microsoft Excel sheet. In the second phase, two additional districts were included to contact primary schools from as not enough participants had replied yet.

To be able to include the greenest schools in Rotterdam that were assumed to be the most heat-adaptive too, the same map from Cobra Groeninzicht (n.d.) was used. The inclusion criteria for this category were: located in Rotterdam and a greenery score labelled as 'good' by the organisation. Cobra Groeninzicht (n.d.) used 3 different labels to describe the amount of measured green, being 'good', 'average' and 'below average'. The green schools were selected from all over Rotterdam, as the proportion of 'green' labelled schools in the specified districts was too low to gain representative results. Moreover, it was aimed to include a similar amount of paved and green schools to compare these two categories in terms of motives and capacities and skills.

After 9 weeks of data collection, this research phase had come to an end. In total, 9 schools were interviewed. 1 interview was left out of the analysis because it was too short, the information was superficial and it was the only interview that was held through telephone, making an in-depth interaction harder. Besides, this school did not meet the selection criteria regarding the selected districts.

4.3 Interviews with closely involved stakeholders of the schoolyard

4.3.1 Semi-structured interviews with school team members

The school team members were approached through e-mail with the request to participate in an online interview through Microsoft Teams. Beforehand, a topic list with questions that was based on the health settings questions by Poland et al. (2009) was created and adjusted during the process when necessary. The topic list can be found in Appendix K. During the interviews, the questions were asked in an open way, to make the interviewee feel free to elaborate on the parts that they considered important. The goals of the interviews were to unravel facilitators and barriers that the schools experienced in creating a heat-adaptive schoolyard, while also clarifying which motives were behind current and future planned schoolyard designs. Besides, questions about the involved stakeholders were asked to find out who was involved and how much power every stakeholder had in the renovation process. When the interviewer needed more clarification on an answer, questions such as 'Why do you think that?' or 'Why do you find this important?' were asked to stimulate the participant providing more in-depth information. After all topics had been discussed, the interview finished. All interviews were recorded – after permission from the participant – and transcribed.

After the interview the participants were e-mailed with the question to send some photos of their schoolyard. These photos were not systematically analysed but rather functioned as a visual addition to the results. The photos that were send by schools with permission to share them can be found in Appendix L. Besides, the photos were used as a source to determine the characteristics of each included schoolyard. Putting the physical characteristics of each schoolyard in a table, a comparison was made to indicate which schools were more petrificated and which were more green. This table can be seen in Appendix M. The names of the schools were kept anonymous in this report.

4.3.2 Semi-structured interviews with schoolyard greening initiatives

In the beginning of the data collection period, an orientation meeting was held with the organisation Natuurlijk Schoolplein to gain more information about heat-adaptive elements at schoolyards. As this meeting was not intended as an official interview yet, it was not recorded but taken minutes of. This interview clarified that such schoolyard greening initiatives (SGIs) have a rich body of knowledge on the schoolyard renovation processes. When the response rate of schools remained low during the first data collection period, it was decided to include more SGIs to carry out semi-structured interviews with. These SGIs were contacted through their website; others were referred to by other interviewees, which created a rich network of different involved parties. It should be noted that not all SGIs are mainly focussed on greenery when renovating a schoolyard, but as the included ones did a lot with natural elements and heat-adaptation, they are all labelled as a greening initiative in this study. All interviews were done with the guidance of a topic list (shown in Appendix N) and were held through Microsoft Teams. When transcribing the interviews, the written transcript of the first interview was included as well. All the other interviews were transcribed through audio recordings. An overview of these organisations is shown in Table 4.

Table 4
Participating schoolyard greening initiatives and spokespersons. Own table.

Schoolyard greening initiative	*Background / field of work*
Natuurlijk Schoolplein Dorine Epping	Supporting schools in the process of greening their schoolyard
Schoolpleinvergroeners Pam Post and Tjitske Westra	Supporting schools in the process of greening their schoolyard
Jantje Beton Marlies Bouman	Charity that is committed to create more challenging playing spaces and playing opportunities
Speelnatuur Suzanne van Ginneken	Supporting schools in and providing information about the process of greening their schoolyard
IVN Natuureducatie Ian Mostert	Organises activities and projects to connect people with nature

4.3.3 Semi-structured interview with the municipality of Rotterdam

In the second half of the data collection period, it became clear that the municipality of Rotterdam was almost always involved in the greening of schoolyards, either through providing the subsidy or through renovating the public schoolyard space themselves. As mapping the stakeholders is an important part of the research questions, it was decided to also contact the municipality of Rotterdam, requesting a meeting with a specialist on the field of greenery subsidies for schools and/or urban green projects in the city. The interview with advisor and project manager of City Management Mr. Bes was done through Microsoft Teams, again by means of a semi-structured topic list (Appendix O). The interview was recorded and transcribed afterwards.

4.3.4 Analysis of the interviews

In total, 14 interviews were held and transcribed, containing the interviews of 8 schools, 5 SGIs and 1 member of the municipality of Rotterdam. All transcripts were stored and uploaded in the program Atlas.ti for qualitative analysis. A code list was created in an inductive iterative way. The researcher started with setting up a primary code list which was expected to be found in the transcripts. During the analysis, the code list was constantly compared and adjusted to the main themes in the texts. The codes were firstly divided into the different sub research questions, namely motives, and capacities and skills that were recognised. Next, more detailed subcategories were created that summarised the most frequently mentioned answers. When the code list was saturated, a mind map was created to make sense of the interconnections between all the different categories and visually represent the code list (Figure 7). Then, each of the categories were described according to their most important features coming from the analysis. Furthermore, the most important relations between the categories were described. These results are shown in the next chapter.

5. Results

5.1 Included studies literature research

To answer the research question and its sub questions, 14 studies were used in the systematic literature research. All of these studies carried out a quantitative simulation or modelling (case) study. This means that they used models or a simulation program to measure effects of potential urban green interventions. In Table 5, the most important findings per study are shown. Some studies also included a quality assessment or evaluation of their simulation or modelling methods, but these results were not incorporated in the table as this is not the focus of the current research.

Table 5

Included studies RQ 1.1: 'Which heat-adaptive measures have been applied in urban areas around Europe and what effects do they yield, according to the literature?'

Authors, year	**Title**	**Country, year data collection**	**Summary outcomes**
(Baryła et al., 2019)	Surface temperature analysis of conventional roof and different use forms of the green roof	Poland, 2015	The average and maximum temperature of green roofs remained significantly lower than those of the bitumen (conventional) roofs in summertime. In September, those differences were small.
(Emmanuel & Loconsole, 2015)	Green infrastructure as an adaptation approach to tackling urban overheating in the Glasgow Clyde Valley Region, UK	United Kingdom, 2011	Green infrastructure can contribute significantly to mitigating urban overheating and could also reduce surface temperature (up to 2ºC) Additional cooling strategies like increasing the building cover can improve air temperature patterns and thermal comfort.
(Fallmann et al., 2013)	Mitigation of urban heat stress -a modelling case study for the area of Stuttgart	Germany, 2003	Changing the albedo offered the most promising results to lower the temperature difference between rural and urban areas (almost 2ºC). Not clear if one big green park or multiple smaller green parks would be better for city planners.
(Kántor et al., 2018)	Human-biometeorological significance of shading in urban public spaces—Summertime measurements in Pécs, Hungary	Hungary, 2016	Radiation conditions play a big role in thermal comfort. Thermal characteristics of surfaces and overhead shading solutions influence this. Trees provide more comprehensive shading and heat stress reduction than artificial devices. High-hanging and large sun sails or big trees and a dense canopy are more beneficial for heat stress reduction than their smaller or lower types.
(Kleerekoper et al., 2015)	Climate adaptation strategies: Achieving insight in microclimate effects of redevelopment options	The Netherlands, 1950-2011	On block and neighbour-hood level, measures that contribute to cooling are higher roof albedo, increasing building height and adding vegetation. The shadow by higher buildings and more solar radiation reflection contribute the most to this. Measures leading to heat are lower roof albedo and adding pavement.

			Whether trees provide cooling depends on their placement context. Tipping point of albedo need to be researched to avoid extra heating.
(Knaus & Haase, 2020)	Green roof effects on daytime heat in a prefabricated residential neighbourhood in Berlin, Germany	Germany, 2018	The cooling effect of green roofs at street level are negligible. This is likely caused by the dampening effect of building height. Rooftop greening is thus no replacement for ground green but rather complementary, as they do heat up less than bare roofs. At roof level, green roofs increase the thermal comfort. If used as recreational space, these roofs can provide extra benefits for health and environment.
(Macintyre & Heaviside, 2019)	Potential benefits of cool roofs in reducing heat-related mortality during heatwaves in a European city	United Kingdom, 2003 & 2006	Applying cool roofs to commercial buildings has the largest influence on ambient temperatures because commercial areas are the most densely built. Urban areas that had reflective roofs showed lower maximum temperatures than when those areas had vegetation on all surfaces. This indicates the efficiency of shading by urban infrastructure. Cool roofs can reduce heat-related mortality during a heatwave up to 8% of which maximally 25% can be attributed to UHI.
(Maggiotto et al., 2021)	Heat waves and adaptation strategies in a Mediterranean urban context	Italy, 2019	Urban forestry seems a more effective adaptation strategy than cool surfaces. The downside of urban forestry is that it increases the moisture rates which can increase citizens' thermal discomfort.
(Noro & Lazzarin, 2015)	Urban heat island in Padua, Italy: Simulation analysis and mitigation strategies	Italy, 2012	Planting trees and grass ('Green ground') decreases UHI 1°C (nighttime) to 2°C (daytime), which is mainly caused by the trees' shadowing effect. This can have negative effects at night when the foliage is too dense. Applying the 'Cool pavements' strategy of replacing traditional asphalt and concrete of pavements and roads with higher albedo and emissivity materials ('cool materials') decreased UHI 1.5°C (nighttime) up till 4°C (daytime). This is mainly caused by the increased albedo and the connected lower surface temperature.
(Skelhorn et al., 2014)	The impact of vegetation types on air and surface temperatures in a temperate city: A fine scale assessment in Manchester, UK	United Kingdom, 2010	No significant relationship was found between canopy cover and air temperature. Additional greening also did not significantly change the air temperature. Green roofs decreased air temperature up to 0.17°C at the downwind side and at roof level. Greenspace did lower surface temperatures with 1°C when 5% more mature trees were added. Besides, adding 5% new trees or hedges could lower the surface temperature with 0.5°C. There was a clear relationship between total leaf area and surface temperature.

(Taher et al., 2019)	The influence of urban green systems on the urban heat island effect in London	United Kingdom, 2018 & partly unknown	Placing more trees can increase thermal comfort, followed by a living façade. High albedo pavement (HAP) had the lowest effect on thermal comfort. Trees have more effect in areas with higher solar radiance and challenging street orientations because they offer shading. They also more directly influence pedestrians than living façades do. Living façades and trees increase relative humidity levels.
(Tiwari et al., 2021)	The impacts of existing and hypothetical green infrastructure scenarios on urban heat island formation	United Kingdom, 2015	Vegetation cover (approx. 78%) reduced maximum temperature with 0.7°C (nighttime) and minimum temperature with 0.3°C (daytime) compared to no green cover. This is caused by increased albedo and increased surface roughness. This surface is also less resistant to evaporation and thermal admittance. The small area that was equipped with green roofs didn't change the temperature at urban scale, but they did lower the temperature with 0.1°C at neighbourhood scale. Tree covered land lowers temperature perturbation more than grass. The UHI intensity that appears on different landforms is influenced by the intensity and/or the number of anthropogenic heat sources, the surface roughness, the distance from GI space, and the percentage of land covered by GI.
(Vojvodikova et al., 2020)	Land use changes and effects on heat islands in the city	Czech Republic, unknown	In two scenarios where the current greenery was changed or removed and where trees of different sizes (diameter of 3 or 7 meters) were planted, no significant improvements were found in changing heat stress.
(Zölch et al., 2016)	Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale	Germany, 2002 (current) & 2058 (future)	The application of UGI has the potential to lower heat stress of pedestrians. Green roofs had a negligible contribution, green façades improved the thermal comfort by 5-10% and trees did this by 10-13%. The most important functions of UGI are respectively shading, evapotranspiration and ventilation. Trees thus have a higher influence on thermal comfort than green façades or roofs as the latter can't provide shadow. The minimal increase of green share is 10% to counteract the impacts of climate change. It is also important to place vegetation in a strategic way to increase the mitigating effects and to lower the need for extra green cover. UGI has multiple benefits, like regulate rainwater, benefitting biodiversity, air quality, climate change and health.

5.1.2 Literature results: urban green interventions and their effects

In this section, an overview is given of every type of intervention that was studied in the literature, to see to what extent they yielded a positive result regarding the impact on UHIs, air temperature, surface temperatures or alike. A summary and integration with the interview findings can be found in the discussion These results answer the sub research question:

1. *Which heat-adaptive measures have been applied in urban areas around Europe and what effects did they yield, according to the literature?*

5.1.2.1 Green roofs

In five greening intervention studies, green roofs were an evaluated component, mostly through testing their cooling effect in a simulation (Baryła et al., 2019; Knaus & Haase, 2020; Skelhorn et al., 2014; Tiwari et al., 2021; Zölch et al., 2016). In the most cases, green roofs only had a very little or an unsignificant effect on the air temperature. For example, in the study by Tiwari et al. (2021), the temperature at neighbourhood scale only decreased with 0.142°C . In Skelhorn et al. (2014), the air temperature at roof level decreased with 0.17°C. This change is likely to be even lower at street level, as Knaus and Haase (2020) found that green roofs have a negligible cooling effect at this level, especially when green roofs were placed at buildings higher than 10 meters. Baryła et al. (2019) found a relatively big effect on the average surface temperature, with green roofs having an average of 3.6°C lower in May and 31.1°C in June/July compared to bitumen roofs. These cooling effects were largest in the summer months June, July, and August. In short, the results of green roofs are mixed. When the effect on the air temperature was measured, insignificant changes were found. When measuring the effect on the surface temperature and comparing this to conventional (bitumen) roofs, larger effects in temperature decrease were found.

5.1.2.2 Green cover

Another intensely investigated greening intervention are several types of green covers. Starting with trees, their effect on thermal comfort is mostly moderate (Emmanuel & Loconsole, 2015; Kleerekoper et al., 2015; Maggiotto et al., 2021; Taher et al., 2019; Tiwari et al., 2021; Vojvodikova et al., 2020; Zölch et al., 2016). Trees are natural elements that offer shading and evapotranspiration, which can lead to substantial temperature decreases. However, the increased humidity coming from urban forestry can again lead to thermal discomfort (Maggiotto et al., 2021). Taher et al. (2019) added to this by showing no changes in thermal comfort by placing extra trees. In similar terms, planting smaller (3 meters diameter) or bigger (7 meters diameter) trees showed no significant improvement regarding heat stress in the study by Vojvodikova et al. (2020). Kleerekoper et al. (2015) warned that placing trees does not always cool the environment, as their effects depend on the surroundings. For example, if trees are placed in a particular way they can block heat reflection and cooling airflows. While Emmanuel and Loconsole (2015) did not distinguish their green cover increase in terms of greenery types, they found that increasing the urban green cover by 20%, the local surface temperature could be lowered up to 2°C . This urban green cover increase can potentially eliminate 33-50% of the expected extra urban heat island effect in 2050. Regarding the trees, Tiwari et al. (2021) found that these work better in reducing temperature disruption compared to grass. Zölch et al. (2016) also compared different green infrastructure possibilities, with trees having the greatest potential to reduce thermal discomfort during warm days.

In the same study by Zölch et al. (2016), green façades on walls were investigated. They were found to reduce some local heat and the amount of solar reflection, but this effect was only noticeable in their direct proximity (within 2 meters). Related to increasing urban green cover, Noro and Lazzarin (2015) and Skelhorn et al. (2014) modelled different greenspace scenarios in which the amount of greenery in an urban area was increased. Noro and Lazzarin (2015) halved the asphalt surface and doubled the surface with green and plants, leading to a 1.4°C decrease at nighttime air temperature and to 3°C at daytime temperature. This effect was mainly caused by the provision of shadow. Skelhorn et al. (2014) added 5% mature trees or new trees and hedges in their simulation. This intervention lowered the surface temperature with 1°C and 0.5°C respectively. However, when looking over the whole study area, this cooling effect was neglectable. Fallmann et al. (2013) performed a similar study, by replacing urban surfaces with natural vegetation, which was done by placing one big park area or multiple small parks. This intervention decreased the UHI effect by about 1°C.

5.1.2.3 Increased albedo

Next to placing more green in urban areas, there were also studies that increased the albedo level of the surrounding materials. Most of these intervention types yielded positive results, meaning that they were often able to lower the air or surface temperature. Continuing with the study by Fallmann et al. (2013), changing the albedo of the roof and wall surfaces decreased the UHI intensity by almost 2°C. This impact was the most visible around the solar noon. Macintyre and Heaviside (2019) showed a similar effect by letting cool roofs with a relatively high albedo cooling down the environmental temperature during daytime. While this effect seems effective during daytime, it should be kept in mind that UHI is usually the greatest at night. Kleerekoper et al. (2015) also measured the effects of albedo roofs and concluded that the surrounding area can be cooled down. However, they also noted that it matters in what area the albedo façades are placed. If they reflect heat to other places that hold heat, the reflected heat becomes latent heat. On the other hand, if the reflected heat ends up around trees, it is converted to growing energy and evaporated water. Similar to placing trees, changing the albedo of (roof) materials should always be done with an awareness of the surrounding context. Another type of increased albedo was carried out through using higher albedo surfaces for pavements, like Taher et al. (2019) did in London. That these higher albedo pavements did increase the thermal comfort because of a lower surface temperature. However, the mean radiant temperature increased. Maggiotto et al. (2021) substituted asphalt for concrete pavement light, but in this intervention no effective lowering of air temperature was measured. This type of heat-adaptive measurement appears to be more variable in the yielded results. Contradictory to the mixed results from above, Maggiotto et al. (2021) found that increasing the albedo of impervious horizontal surfaces lowered the nighttime air temperature with 1.8°C and with 4°C at daytime. This was done by changing all the traditional concrete and asphalt of pavements and roads with a higher emissivity and albedo. The air became less heated because less solar radiation was absorbed. Potential negative side-effects from the albedo enhancement such as glare were not considered.

5.1.2.4 Shading

Small shading mechanisms, such as a single tree with little canopy or some low-hanging sun sails, are capable to reduce heat stress levels by minimally one PET-category in the summer. PET describes how the human body is affected by the thermal environment, for which the temperature range in °C is connected to different levels of thermal stress, as can be seen in Table 6 (Kántor et al., 2018). Comparing artificial shading mechanisms such as sun sails to natural shading mechanisms such as trees, the first ones are less effective. Sun sails are more transmissive for short-wave radiation than tree canopies. When placing sun sails, large and high-placed ones are more effective than low-placed ones. For trees, dense, mature trees with an extensive canopy can provide the most effective shading compared to smaller trees. Another way in which shade can be created is by high buildings. Kleerekoper et al. (2015) found that higher buildings can cool down the neighbourhood. However, while buildings can delay the temperature increase around noon, they can increase the temperature up to 1°C in the evening (21h) in some cases.

Table 6

PET-ranges connected to different degrees of thermo-physiological stress according to Matzarakis and Mayer (cited in Kántor et al., 2018)

PET range [°C]	Level of thermal stress
41 <	extreme heat stress
35 – 41	strong heat stress
29 – 35	moderate heat stress
23 – 29	slight heat stress
18 – 23	no thermal stress
13 – 18	slight cold stress
8 – 13	moderate cold stress
4 – 8	strong cold stress
< 4	extreme cold stress

5.2 Semi-structured interviews

5.2.1 Involved stakeholders

The first goal of the interviews was to trace a map of all stakeholders that are involved in the process of creating a heat-adaptive schoolyard, so a more holistic view on the process was created. Moreover, the capacities and skills that are required from these stakeholders were investigated. As such, in this section the following sub research questions are answered:

2. Who are the stakeholders involved in the creation of heat-adaptive schoolyards?
3. What capacities and skills are required amongst the closely involved stakeholders to create a heat-adaptive schoolyard in Rotterdam?

There are two categories of stakeholders considered in this study. The first category contains the stakeholders that appeared to be directly involved in the schoolyard renovation process towards heat-adaptive schoolyards. These stakeholders were often mentioned by the interviewed participants. In this study, this group is referred to as 'closely involved stakeholders'. An overview of these stakeholders is displayed in Figure 5.

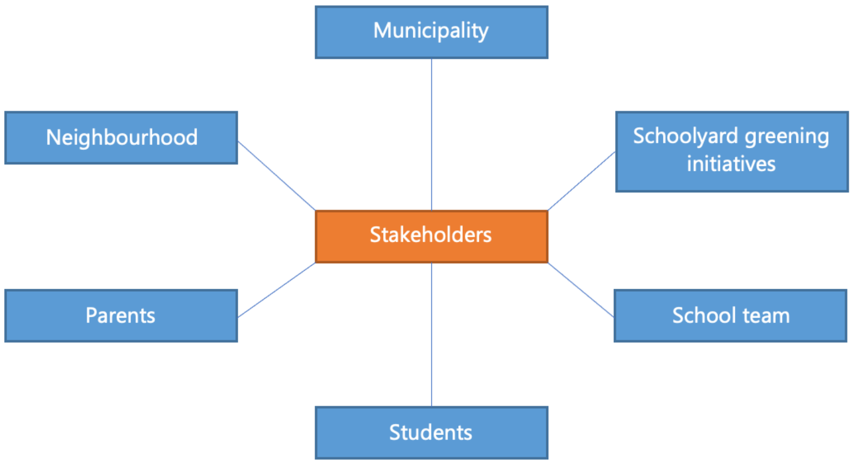

Figure 5. Closely involved stakeholders. Retrieved from semi-structured interviews.

The second group contains all stakeholders that are related to the renovation process. These are amongst others parties that fulfil a background role such as the government or umbrella school foundations, or parties that are not always involved in schoolyard renovations, such as contractors or architects. Furthermore, the closely involved stakeholders who play a central role in the process are covered. The SEM was used as a fundament to interpret the position of the stakeholders. Not only does every stakeholder have an influence on the process because of its amount of power and point of view, all stakeholders also interconnect. Together they create a unique and complex health intervention situation, as already described by Poland et al. (2009). Through placing this web of interconnected stakeholders in the life context with different system levels from the SEM, a clearer picture is created of the context in which the schoolyards exist and how all these different levels eventually affect children's health by means of thermal comfort. An overview of this network is shown in Figure 6.

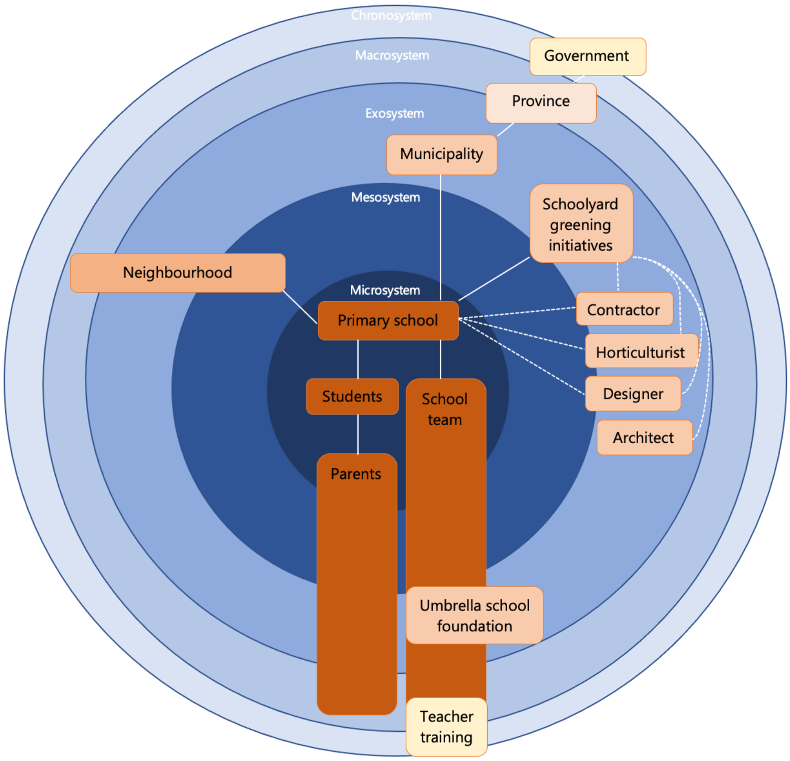

Figure 6. Stakeholders involved in the development and implementation of a heat-adaptive schoolyard. An integration with the Socio-Ecological Model.

5.2.2 Roles and required capacities and skills from stakeholders

In this section, the category of closely involved stakeholders is elaborated upon. First, some background information is provided about the context of the stakeholder and their role within the schoolyard context and the stakeholder network. In addition, the capacities and skills that are required from each stakeholder to facilitate the process of creating a heat-adaptive schoolyard are clarified. Often, a certain capacity or skill has two sides of the coin: if a stakeholder possesses a required capacity, this can significantly stimulate the process of heat-adaptation. At the same time, when a stakeholder lacks a required capacity, the process can be hindered. The most important experiences about each capacity (either the facilitating or the hindering side) are elaborated upon.

5.2.2.1 School team

Background and role

The school team is always involved to a greater or lesser extent, because they are one of the main schoolyard users. The principal is often involved as he/she also often controls the school's budget. When a working group is created within a school team, often a couple of teachers participate in it. One school had the employee on parental involvement as the central driving force in the project development, who collaborated with a few parents from the activities committee. While Rotterdam schools are often part of an umbrella school foundation, the latter were decided to leave out of the group of closely involved stakeholders, as they fulfilled a more background role in the interviews.

Capacities and skills

Connected to the working group mentioned above, the skill of **creating ownership** amongst the involved stakeholders is important to increase the chance of making the new schoolyard sustainable for long-term use. For example, when the school team involves the neighbourhood in the brainstorming process, the residents tend to feel ownership which increases the chance that they take care of the schoolyard or keep an eye on the visitors. Next to residents, parents are also important to create ownership amongst because they can help with executive tasks. Especially because many schools have a limited budget, involving stakeholders to help in the process can save some money. Involving stakeholders to create ownership is best done by clear **communication** so that concerns or objections about topics such as hygiene and vandalism can be early detected and resolved.

Regarding the school's budget, it is important to **have a vision about the distribution of the money and how priorities are set**. If a school managed to save own money for the renovation project, the process is likely to develop faster as applying for subsidy can slow down the process. However, schools often don't have money saved for outdoor maintenance. Marlies Bouman explains that schools tend to underestimate the actual costs of a renovation, partly because there are always additional costs to realise the natural elements (such as hiring an excavator) and because subsidies only contribute to the final price for a small part. Besides, schools do not always have a clear vision about their education and how they want to connect their schoolyard to this, said Suzanne van Ginneken.

Regarding **project management skills**, it is important that the school keeps an eye on the order of actions, to keep control over what is happening and involving people to help. For example, the renovation of the schoolyard should be planned around important test periods and the plants require to be planted in specific seasons. Dorine Epping suggested that schools and municipalities would profit from collaborating with regional supervisors, to allow heat-adaptive schoolyard renovations to happen on a bigger scale. Besides, one school expressed their wish for having a designated expert to handle the process steps. They explained that having to do it all by themselves while such projects have been done before feels like reinventing the wheel. This can be too time consuming when they also want to focus on education. This lack of time regarding the project management was also discussed with Ian Mostert. He reacted:

> "That immediately says that they [the schools] see the schoolyard as a glorified release point, where you allow children to run after they have done serious things that are important, such as learning. While if you have a different vision [...], you should see the outdoor space as a learning environment where children can develop."

These two viewpoints show that schools and SGIs can have different perceptions about priority setting regarding the schoolyard, which also connects to the vision that stakeholders have on the project.

Managing the orientation phase of the project development is an important skill to possess for a school. Marlies Bouman explains that schools are inclined to request a catalogue from playground equipment suppliers and choose some elements based on their budget and the students' preferences, while this does not necessarily connect to the school's vision on education. Instead, diving into the vision and true playing preferences of children could yield a more valuable result.

Another aspect that Pam Post and Tjitske Westra considered important to tackle at the start, is creating a realistic *time investment plan*. In this way, infeasible plans such as tiny children's farms are tackled before the development. Other expectations such as different views and preferences regarding heat-adaptive elements are best to express in the beginning, according to Marlies Bouman.

In **managing the development and implementation phase**, involving stakeholders is a key part to make everyone a part of the process. One tip that was given by Marlies Bouman about this development phase was that schools can also start with implementing changes in phases, instead of renovation the whole schoolyard at once. In this way they can experience how the new elements at the schoolyards are used and when this is successful, schools are more likely to implement more of it.

When **managing the aftercare and evaluation phase**, having a vision is again important to make the project work for the long term. Not only maintaining and managing the new schoolyard is important, also using the schoolyard within the educational program should be thought through beforehand.

5.2.2.2 Municipality

Background and role

Many schoolyard properties belong to the municipality. It depends on the specific policy rules who (the school or the municipality) is financially responsible in case of schoolyard renovations. If the schoolyard itself belongs to the school but the adjacent area belongs to the municipality, often consultation is done if the municipality also plans to perform maintenance there. Besides, schools can apply for municipality subsidy programs to green their schoolyard. If the schoolyard is mainly the municipality's property, schools don't always receive subsidy to organise a greening renovation themselves. The spokesman of the municipality explained that some schools that applied for subsidy had a public schoolyard with an according public function, of which the municipality decided to not provide them subsidy but let them participate in an organised "outdoor space trajectory". In such cases, the municipality organises a working group in which the school team also participates. These trajectories follow a municipal planning process, containing a schedule of requirements, a concept and final design amongst others. It can thus be concluded that the municipality is, to a greater or lesser extent, always involved in a schoolyard renovation process.

Capacities and skills

In deciding which schools receive subsidy for a schoolyard renovation, the municipality has to **select participants**.

The selection is done by a diverse program team, composed of different disciplines, such as climate, urban development, management consultancy and education. Mr. Bes from the municipality of Rotterdam explained the selection criteria for schools as follows:

> "We don't just give a bag of money. We really try to guide those schools, because as far as we are concerned, it goes further than: you do something fun with your schoolyard and then it's done. It is really about the longer term too, which you have to arrange properly. You have to have support within your school, among the local residents, and of course you have to think carefully about the design. What are the current functions of the schoolyard, et cetera. So there is a lot to consider. How do you plan to use it in you education program? These are all things that we also ask in advance before we grant a subsidy."

For the municipality, an important part of **managing the orientation phase** is checking the boundary conditions and policy requirements for the public space. For example, in some cases schoolyards are bound by certain design elements and material requirements belonging to the unifying 'Rotterdamse Stijl'. Besides, the municipality considers the amount of required maintenance for each type of material and schoolyard design. In this phase, **stakeholders have to be involved** too. Similar to the school team's skills, this is best be done through clear **communication**. Moreover, in **managing the development and implementation phase**, a dialogue is maintained with the school about which heat-adaptive measures are possible. Other capacities that the municipality has in the field of schoolyard renovations is **managing the policy and financial flows** around newly built school properties.

5.2.2.3 SGIs

Background and role

There are many SGIs on the market that offer help to schools in their greening or heat adaptation trajectory. While it can happen that umbrella school foundations decide to make some big schoolyard changes, schools mostly get in touch with SGIs themselves. This happens from different phases. As Suzanne van Ginneken explains, many schools are still in the orienting phase with a current 'bare' schoolyard, while others have already tried some changes such as vegetable gardens, but don't manage to continue the process. Other schools are already green but struggle with the effects of natural elements at the schoolyard, such as mud. Besides there are some schools that are engaged in a new building project with a corresponding new schoolyard. SGIs often take on a counselling role.

When counselling a school, the project starts with an orientation phase, assessing what a green schoolyard is and what options are feasible for the school. Then, all stakeholders are involved to go through the schoolyard renovation plan. In the following phases, a function layout is designed, and the financial trajectory is run through. The intensity of interference by a SGI differs, depending on the school's request.

Capacities and skills

SGIs offer additional capacities that schools don't always have by themselves. Firstly, SGIs **indicate whether a school is suited** for a schoolyard renovation before they start, by means of a 'go or no-go talk' as Ian Mostert illustrated. He explained that he first wants to know what will happen at the schoolyard after school, whether the school is planning to use the schoolyard for lessons, as his SGI doesn't want to invest public money in a "pimped break space". Some SGIs offer starting kits to help the school team in this process. Secondly, SGIs have experience on the field of plant species and where they should be placed so they have a low chance of being destroyed by children. When schools make a misjudgement about the elements they want to use, they can be discouraged to keep developing it. This can withhold schools to become more heat adaptive. SGIs often have done many evaluations of schools that implemented green schoolyard elements, causing them to **have wider knowledge** about strong elements and potential pitfalls. An elaboration on these strengths and pitfalls in heat adaptive elements is provided in Appendix Q. The practical experience of SGIs also applies in **guiding the teachers**. Some teachers have shared their fear about green schoolyards towards SGIs, because they think the greenery worsens the overview at the schoolyard or that the children will break down all the materials. SGIs can resolve this fear by explaining how the process works and what positive effects greenery has. Moreover, when SGIs start the orientation phase with the school team, they know how to ask the right questions to let the teachers make a realistic estimation of their available time to use for schoolyard maintenance. They thus have extra knowledge on the **planning and time investment** field.

Before implementing a new schoolyard, SGIs **design** the new layout as a conceptual design. After feedback from the stakeholders is derived, the final design is established. Also from the position of SGIs it is thus important to **involve stakeholders** in the process.

5.2.2.4 Neighbourhood

Background and role

The neighbourhood is to some extent always involved in the renovation process of a schoolyard. First of all, the students from a primary school often live nearby, together with their parents. The stakeholder neighbourhood thus partly overlaps with the stakeholders students and parents. From the interviews it resulted that most subsidies require schools to open their schoolyard, so it becomes accessible for all children in the neighbourhood after school time. By creating such an open space, the schoolyard gets a societal function. In such cases it is extra important to involve the local residents in the design plan of the schoolyard so that their preferences and needs are included in the design.

Youth are a part of the neighbourhood that is often considered by a school team with mixed feelings. One school illustrated that they placed a fence around the schoolyard a few years ago, because they experienced a lot of nuisance from loiterers. Another school that suffered from this tried to design a spot at the schoolyard where loiterers could gather so that they would cause less nuisance. Suzanne van Ginneken had a more optimistic view on this group; she stated that vandalism doesn't increase once the schoolyard becomes greener.

> "What helps the most, is talking with the guys. [...] The camera helps well and having the local police officer come by, have good contact with them. And it [the vandalism] is often temporary, because often it is one group that does it. [...] But it is also a matter of a pretty design, because if something is pretty, it is destroyed less quickly."

In short, the youth that is primarily known to loiter around the schoolyard is often considered a barrier. For some schools, this means that they give up on requesting subsidy for a green schoolyard. For other schools, it stimulates them to get creative in the schoolyard design. In the next section, the capacities and skills that go along with these ways of acting are discussed.

Capacities and skills

The neighbourhood plays a more dependent role in the connection with other stakeholders, such as the primary schools. While the neighbourhood doesn't have a lot of influence in whether they are being involved or not, once they are involved they can contribute to the renovation process. First, local residents can help **maintaining** the schoolyard and perform some **social control** over the after-schooltime-usage. Ian Mostert suggested that once a sense of ownership has been created amongst the loiterers -who often also live in the neighbourhood –, they are more likely to take care of the schoolyard. A barrier that can exist in the neighbourhood that withholds the residents from getting involved is poverty. When people have problems at home, their energy might be fully consumed by this, withholding them to also invest energy into other things such as the local schoolyard.

5.2.2.5 Parents

Background and role

Parents are often mentioned as the driving force behind setting up a schoolyard renovation project. Through collaborating in a working group, parents brainstorm about the options and help with the maintenance. However, it differs per neighbourhood how intensely parents are involved. Marlies Bouman and Suzanne van Ginneken suggested that poverty and certain cultural backgrounds can influence the extent to which parents feel the need to be involved in school projects.

Capacities and skills

Being involved and having a **sense of ownership** is essential in upholding the schoolyard renovation. As the school team often feels that they don't have enough time to participate in other tasks than teaching, parents can fill this gap. Also, it can save schools money if parents are able to **apply their knowledge and skills** from fields such as gardening, designing and architecture. Suzanne van Ginneken added that **fund raising** is another task that is the best to be done by parents, as it is too much work to be done by the school team. Through **communication** via the school's newsletter, parents can share their positive experiences from working in a maintenance group to attract new parents to this (social) opportunity.

5.2.2.6 Students

Background and role

In most interviews it was mentioned that children were involved in the brainstorm process about the design of the new schoolyard, as they are the main schoolyard users. Marlies Bouman illustrated a remarkable phenomenon when involving children in the brainstorming sessions. In the beginning the children often mentioned playing football as their preferred activity at the schoolyard. Afterwards they were taken to De Speeldernis, a natural playground and knowledge centre in Rotterdam which they had really enjoyed. In the week after, they brainstormed again. Now, new ideas such as building huts and playing with water came up. This indicated that students were unfamiliar to these activities before, but by trying it out they formed new playing preferences. This is an important result when involving children in the process, as they are tended to mention what they are familiar with from their frame of reference. Especially in cities this 'loop' is easily maintained: when children don't know nature, they won't bring it up either. Pam Post and Tjitske Westra further explained that there are different playing types of children, all having different needs when it comes to the schoolyard. Often, not all types of children are represented in a schoolyard design. Another school didn't agree with this viewpoint. They stated that there are no playing types of children. Instead, children discover their playing preferences according to what is offered to them at the playground. Even though there are different opinions on the origin of the students' playing preferences, it can be concluded that a higher variety of playing materials is beneficial for how children can develop their playing behaviour.

Capacities and skills

While children often can't have a direct influence on the extent to which they are involved in the process, there are many ways in which they can contribute to the **brainstorming** process. Schools gave examples of involving children through making a rap, building a scale model, participating in a drawing competition or through discussing in a student council.

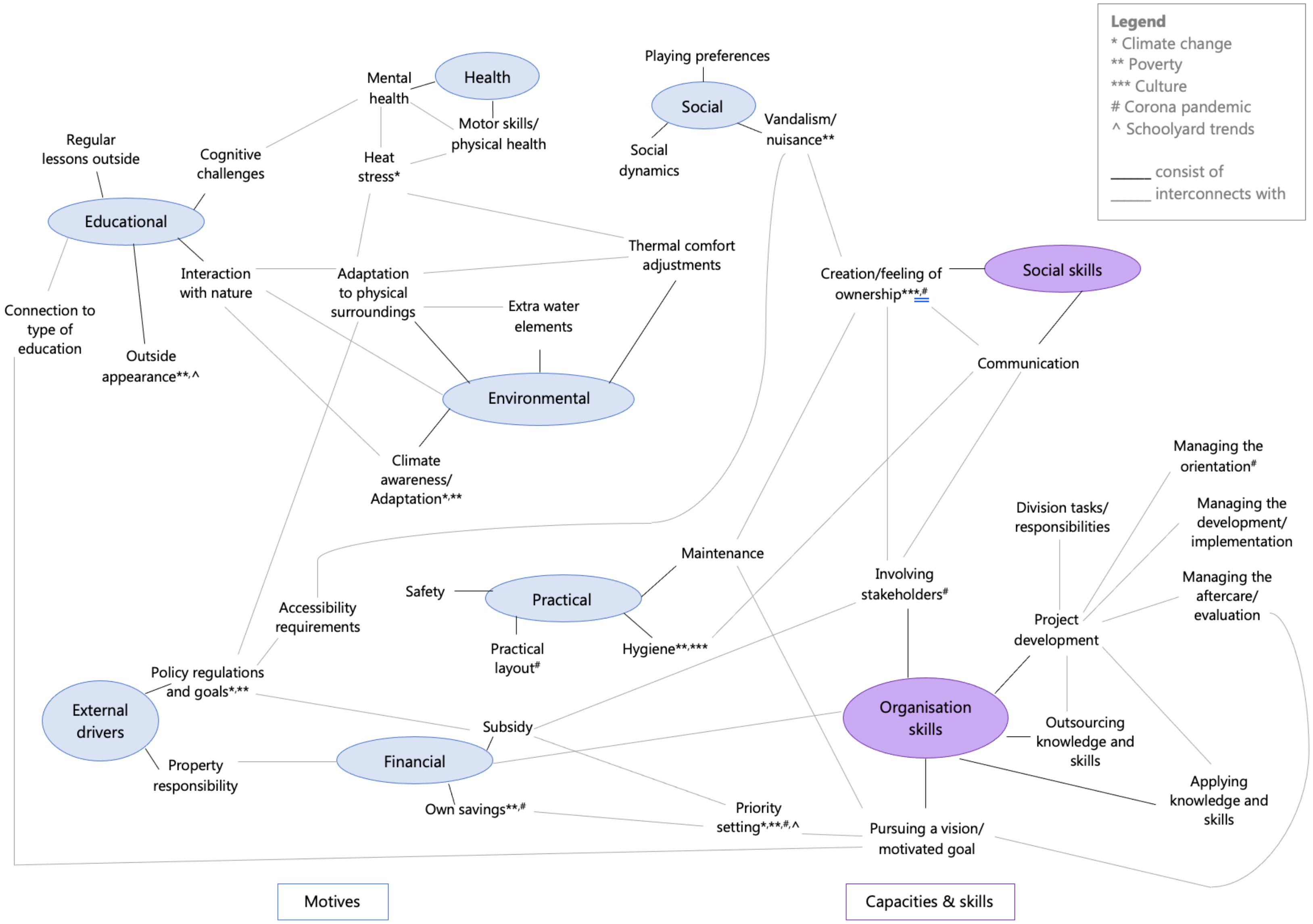

Figure 7. A network overview of the connections between the different motives and the required capacities and skills amongst the closely involved stakeholders.

5.2.4 Motives behind schoolyard designs by closely involved stakeholders

In this section, the motives that stakeholders mentioned for their current or preferred schoolyard design are explained to answer the sub research question:

3. What are the motives behind the current implementation of schoolyard elements, according to the closely involved stakeholders?

These motives are considered the drivers behind the choices to implement certain types of schoolyard elements and are here called considerations. Based on the findings from the different coding phases, umbrella categories were created that summarise the different types of considerations. As the considerations often applied to multiple stakeholders, the most important approaches of each consideration are explained. In Figure 7, a graphic representation of the most important connections between the different motives and the different required capacities and skills is shown. This image is not fully comprehensive but indicates how the different elements relate to each other.

5.2.4.1 Educational considerations

Educational considerations are all factors that have to do with the education type and curriculum of a school, with learning goals for students and a school's important values, vision, and policies. Especially the outside appearance was important for schools, as one of them explained: "We are in an environment of low social, economic class, for the most part. Then you want the outside in particular to look neat, to be cared for, so that the poverty is not seen or noticed." Next to this appearance, following the trend of greening schoolyards is a driver for schools. Ian Mostert, Pam Post and Tjitske Westra explained that 'greening' is sometimes used as a marketing and communication strategy, rather than a tool for heat-adaptation.

For many subsidy programs, it is required that schools have a vision on how to integrate the new schoolyard in their curriculum. While one of the schools had already included nature in their program, many other schools don't have a clear view on how they want to apply the natural elements in their daily lessons. This is striking as many schools expressed their wish to let children interact with nature more, so they gain more knowledge about nature and sustainability. Besides, the health benefits of being in nature were mentioned by schools.

5.2.4.2 Environmental considerations

Environmental considerations are all factors that relate to the physical environment at and around the schoolyard and more broadly considering the general climate. Especially adjustments to increase thermal comfort at schoolyards were frequently mentioned as a motive by schools. This relates to the direct surroundings of a school and the experienced heat stress that comes from the degree of petrification. It should be noted that this heat awareness was only present if the school team or students already suffered from heat. When schools felt like they had enough greenery or shade around the schoolyard they were less likely to feel the urge to adapt the schoolyard to heat.

A climate change effect that is more visible at schoolyards is waterlogging. Several schools complained about flooded schoolyards after heavy rainfall, which is again related to the degree of petrification. An intervention that is often a subsidy requirement for green schoolyards that also helps to battle the water is disconnecting the rainwater drainage. While the climate doesn't appear to be a main driver for schools, adding green to the often "concrete jungle" around them was considered important to increase the accessibility to green for the students. Nevertheless, not all schools consider the environment when discussing the schoolyard. One school from a deprived neighbourhood indicated that they felt it was more important to focus on the development and support of the children than to prioritise climate change.

5.2.4.3 External considerations

External considerations are the drivers that are beyond the direct influence of the stakeholder itself, but they still affect the opportunities to create a heat-adaptive schoolyard. The most important category that belongs to external considerations are the policy regulations and goals, set by the municipality. One of the main policy requirements for receiving greening subsidy is an open, accessible schoolyard so that the neighbourhood can benefit from it too. This can be a barrier for schools that experience vandalism. In addition, Mr. Bes from the municipality of Rotterdam elaborated upon other policy criteria. Related to environmental considerations, one criterion covers factors as heat stress, petrification and waterlogging to select which schools would benefit most from additional green. Second, social factors such as the social status of the neighbourhood and the school's motivation are considered when distributing subsidy. A second type of external considerations is to whom the school property belongs. If the municipality is responsible for (parts of) the schoolyard, the maintenance is usually also performed by them.

5.2.4.4 Financial considerations

Financial considerations are all factors that relate to the access to money and managing finances, which appear to play a big role in planning a schoolyard renovation. Money can either stimulate the process when schools have access to subsidy or own savings, or hinder the process when lacking this access. At the start, the effort that is required for the subsidy application process can demotivate schools to apply. When coming to the development and implementation, the main expenses are the execution process itself, purchasing playing elements and arranging inspection or replacement of playing equipment. An external factor that influences the financial flexibility of schools is poverty. In lower SES areas, parents sometimes pay less or no parental contribution. Moreover, the corona pandemic has forced schools to invest in extra (home) studying materials.

5.2.4.5 Health considerations

Health considerations are all factors that are connected to the well-being of the students, which contain 3 main perspectives. First, schools emphasised that they wanted to stimulate children's motor skills, partly because the current digitalising time can negatively influence these aspects. The municipality highlighted to also consider the amount of overweight in a neighbourhood when selecting schools. Some SGIs added that especially girls become less sedentary when playing at green schoolyards. Besides, greenery can benefit the concentration of students when being in class. In addition, their mental health in general (such as feeling good in one's own skin) increased with nature around them. Furthermore, some schools talked about behaviour that protected children from heat stress, amongst others drinking enough water and applying sunscreen.

5.2.4.6 Practical considerations

Practical considerations are all factors that are related to the practical side of a schoolyard renovation, especially when talking about the new playing equipment and the use of natural elements. First of all, maintenance should be considered in terms of labour and costs. In collaboration with the municipality, schools can sometimes arrange sharing these tasks. Besides, safety is a multi-faceted practical component. The playing equipment needs to be safe to play with. If the equipment comes from an official supplier, there are often clear guidelines to secure safety. In contrast, natural materials often have to be assessed individually, for example regarding sharp edges or falling height. Another safety threat can come from loiterers, especially when they leave waste behind at the schoolyard. Furthermore, hygiene is a concern that predominates amongst parents and teachers, especially when having natural elements at the schoolyard. While communication can partly solve this problem, it was also suggested that it differs per culture how this problem is perceived. Besides, the aim for hygiene relates to poverty when schools want to have a 'clean' look at their schoolyard to cover deprivation problems. Lastly, the practical layout is a point of consideration when connecting the design to the children's playing preferences and the usage intensity of different schoolyard elements. Since the corona pandemic, having enough space is also covered by this motive.

5.2.4.7 Social considerations

Social considerations are all factors that relate to the influences that a heat-adaptive or green schoolyard has on the social dynamics of the stakeholders, of which mainly the students and the neighbourhood are affected. Children are the main schoolyard users, so their playing behaviour is directly affected by the available materials. For example, many schools aimed for a diversity of challenging playing equipment so children are stimulated to discover, play, and learn. Many children expressed their playing preferences of having a football area, on which some schools had already acted upon as shown in Figure 8. Besides, some stakeholders just mentioned 'more green' as a playing preference to have at the schoolyard. As children were reported to play differently when being around greenery, their social dynamics are also of interest when deciding about the new schoolyard design. Children that play in a natural environment show more prosocial behaviour, according to Pam Post and Tjitske Westra. The representatives from De Schoolpleinvergroeners explained how green can be combined with all the different playing preferences:

> "As far as we are concerned, it is not an either-or situation. Green in does not mean all tiles out, and sustainable use does not just mean plants. It is a combination of real green to play with, to play in, combined with playing material that is perhaps more demarcated, but where also has to be space for certain children, and is above all vandal-proof."

Besides, having several (sporty) playing materials causes children to play nicer together. Moreover, one school highlighted that they wanted to avoid hiding spots as this would facilitate bullying behaviour. Lastly, vandalism is considered when choosing which elements to place at the schoolyard, so that people are less tended to destroy what is around them.

Figure 8. Football area at a schoolyard. Private photo from primary school.

6. Discussion

6.1 Integrated findings

Implementing heat-adaptive measures can be done in different ways. From the literature it resulted that adding green cover in urban areas is most effective in lowering the UHI. Especially trees can lower the air temperature through performing evaporation and offering shade. However, professor Sanda Lenzholzer, specialist in landscape architecture and spatial planning (in Arnhem Klimaatbestendig, 2021) stated that trees can also lower wind speeds or block airflow when placed in the wrong position. Green façades and green roofs only reduce the air temperature within their near proximity. Furthermore, sun sails offer some temperature reduction but not as well as trees. In all cases it is necessary to pay attention to the context, so the chance of negative side effects is lowered.

When renovating a schoolyard, multiple stakeholders are involved, of which the school team, the students, the parents, the neighbourhood, the municipality and the SGIs are the most closely involved. Involving stakeholders is considered as one of the main skills for the renovation initiators to possess, as this allows to bundle knowledge and supports the longer-term maintenance. As such, it is important that the initiator performs clear communication with the other parties to create a sense of ownership amongst them. For the executive parties such as the school team, having a vision on the purpose of the new schoolyard is essential to let the design plan succeed, but also to integrate the greenery in the school's curriculum. During the development and implementation, a project management approach is needed to let the renovation develop professionally, amongst others by dividing the tasks and pursuing a motivated goal. Applying knowledge and skills about the execution of the renovation, such as designing or gardening, can fasten the process and save money. If necessary, SGIs can offer guidance in a renovation process and take over some of the organisational tasks.

The interviewed stakeholders expressed different categories of considerations when adapting their schoolyard. First, educational considerations were mentioned by schools talking about the connection to their type of education, aiming for a certain outside appearance, wishing to move some lessons outside, facilitating interaction with nature for students and cognitively challenging them. The latter relates to health considerations that were made about mental and physical health, but also about heat protective behaviours. Managing heat connects to considerations about the environment, containing motives as adding green to the petrificated neighbourhood and solving waterlogging problems. Whether these adjustments are possible is influenced by external factors, such as policy regulations around the provision of subsidy. In these regulations, requirements such as an openly accessible schoolyard are recorded. This forms a barrier for schools that suffer from vandalism. Besides it depends on the amount of subsidy and own savings that a school has what kind of renovation is possible. Social considerations are the effects on the social dynamics of children and what playing preferences they have. Heat-adaptive elements such as greenery were reported to increase children's prosocial behaviour. The schoolyard should also meet practical considerations such as feasible maintenance and safety.

Based on the interviews, almost all natural elements were reported to be applicable at a schoolyard for heat reduction, as long as they are placed strategically in terms of local climate effects and usage intensity. Only grass and willow huts were not recommended as they erode too quickly at schoolyards. These findings are in line with the literature, in which green cover was found to be the most effective in reducing UHIs. This means that a wide range of green applications such as trees and bushes is possible at schoolyards.

The use of the health setting questions by Poland et al. (2009) led to the creation of an in-depth investigation in what stakeholders perceive to be facilitators and barriers in creating a heat-adaptive schoolyard. The questions stimulated the researcher to gain different perspectives from different levels of stakeholders, enabling her to compare the outcomes and integrate them into an overview of required motives, capacities and skills. The Socio-Ecological Model by Bronfenbrenner (cited in Kilanowski, 2017) then offered a format to interpret these findings with (Figure 3), showing the interconnections and the different levels that form the context in which the stakeholders interact. This holistic view forms a valuable addition in bundling the knowledge that is available about adapting schoolyards to heat.

6.2 Interpretation and in-depth discussion

The local environment of primary schools influences the goals and priorities that schools have in different ways. First, the amount of nature that is present around the schoolyard can influence the experienced urgency to make the schoolyard more heat adaptive. For example, one school explained that they don't really suffer from heat, which makes heat adaptation less of an action point. Another school was located in a richly green environment, making them organise lessons there. On the one hand, it can be suggested that this demotivates schools to adjust their own schoolyards as their environment is already heat-adaptive. On the other hand, a schoolyard is a relatively small part of a neighbourhood. If the latter is already green, priorities could be focussed on more paved areas instead.

Different stakeholders reported that creating a green or natural schoolyard is a contemporary trend amongst schools. As schools frequently reported that the outside appearance was an important consideration for them, it can be stated that this trend is a bigger driver for schools than the benefits for the local climate. This was confirmed by schools who described that they were only focussing on adapting to the hottest spots on the schoolyard if children experienced heat stress. Lowering the UHI is therefore more of a positive side-effect. In her graduation research, Mijnarends (2017) also found that green schoolyards are an upcoming trend, mostly because more attention is currently paid to stimulating a child's development. According to this research, greenery would stimulate a child's physical and mental health. As such, having other motivations than climate adaptation currently results in schoolyards becoming greener.

This study focussed on heat at the schoolyard level. While creating smaller green areas can decrease the UHI up to 1°C, this is only one perspective. Fallmann et al. (2013)

performed a series of simulation studies that focused on a more regional urban scale, where the city is evaluated as a whole system that interacts with its environment. In this sense it can be questioned whether focusing on this local level is effective if whole areas need to be cooled down. Dorine Epping argued that a special team should be assigned to function as an extra organisational 'layer' between schools and subsidy regulations, so a higher effectiveness can be reached in greening schoolyards. It could be argued that a team is more effective at neighbourhood level than at the level of single schools. Schools often reported to feel hindered by vandalism in implementing greenery, even though the study by Van Dijk-Wesselius et al. (2021) doesn't show any differences between the frequency of vandalism at green and paved schoolyards. When the focus would shift to neighbourhood heat adaptation instead of individual schoolyards, these kinds of barriers could be dealt with from a higher level.

While one of the SGIs aimed to make a schoolyard "as green as possible and place as many trees as possible" to benefit the thermal comfort, the execution should be performed more nuanced according to Klemm et al. (2018). When implementing a climate adaptive design, situational knowledge about the urban microclimate and generic knowledge about how the new schoolyard elements are used is necessary to achieve the aimed climate effects (Klemm et al., 2018). When greenery is placed everywhere without considering the context, the modifications can create an adverse effect on the local climate, such as holding heat. While greenery is a common solution in heat adaptation, other implementations such as vaporising water (Arnhem Klimaatbestendig, 2021) or increasing albedo levels (Cheela et al., 2021) are also possible. Nevertheless, next to positive effects on the climate, greenery also benefits health (Shanahan et al., 2015).

6.3 Strengths and limitations

During the data collection period, the corona pandemic still influenced most of the living and working environments. When contacting the schools for participation at the end of the schoolyear (around July 2021), many schools reported that they had to catch up with the backlogs in their curriculum caused by corona and were therefore not available for extra activities. Besides, as primary schools often have testing periods at the end of the schoolyear, even less schools were available for interviews. Nevertheless, 8 schools were able to participate in the end. While interviews on location – without corona restrictions – might have created a more facilitating setting for open conversations and bigger group interviews, the on average 30-minute online interviews still yielded rich results.

Another limitation in contacting the schools was that most schools that participated already added greenery or were motivated to green their schoolyard. This means that the most petrificated schools were underrepresented in this study, forming a limitation to the generalisability of the results. On the other hand, Rotterdam is a frontrunner when it comes to urban heat adaptation and greening interventions, according to Dorine Epping. This fact is likely to have offered richer and more in-depth information about the processes around heat-adaptive schoolyards than in cities were less experienced is present on this topic.

While many stakeholders are closely involved in a schoolyard renovation process, not all of them could be interviewed within the research period of this thesis. This means that not all perspectives were taken into account from the source itself. Nevertheless, this research was still able to interview stakeholders from different levels of the Socio-Ecological Model by Bronfenbrenner (cited in Kilanowski, 2017), creating a broad picture of the schoolyard context. As Poland et al. (2009) also considered it important to gain rich perspectives from multiple stakeholders, this is one of the study's strengths.

6.4 Future research

For future research, three main points are recommended. First, investigating the motives of architects when designing newly built schools and schoolyards can give more insight into choices of schoolyard positioning, budgets, and space usage. Currently, stakeholders reported that the incoming sunlight or available shadow was often insufficient at the schoolyards. Moreover, when no budget is left for the schoolyard in the building process, schools have to invest in this themselves which is often a barrier when renovating. Gaining insight into the drivers behind these choices opens up possibilities to increase attention for the schoolyard design. As municipalities also play a role in budgeting for new constructions, their role in the budget division should also be included.

Secondly, it is recommendable to research the effectivity of including nature in the curriculum by teachers. In this study, teachers were reported to be scared to include nature in their educational programs, as they have never learned how to deal with these elements. Researching how this can be done more effectively tackles this problem at the spring of the daily education. In turn, inclusion of nature and climate awareness in the lessons can be improved.

Thirdly, the correlation between vandalism and greenery appeared in this research, without showing how these factors relate to each other. A couple of schools reported to be held back from creating a more natural schoolyard, as they were scared to provoke vandalism. Nevertheless, an often-stated requirement to receive subsidy for green schoolyards is to make the schoolyard accessible for everyone. On the other hand, some SGIs claimed that creating a natural schoolyard doesn't make the amount of vandalism worse; in the best-case scenario, loiterers that feel a sense of ownership would even become more careful with the new playing elements. To clarify how this interaction works, more research should be conducted. This knowledge can then take away some of these fears amongst school team members which in turn can facilitate the creation of heat-adaptive schoolyards.

6.5 Advice for heat-adaptation at schoolyards

For this thesis, multiple stakeholders were interviewed. In these interviews, many tips, tricks, facilitators, and barriers about creating a heat-adaptive schoolyard came to the surface. In this study it was aimed to bundle this knowledge into a concise overview that forms a practical advice for stakeholders that will work with greening schoolyards in the future.

Practical advice

- Involve all relevant stakeholders
- Create shared ownership as the fundament of the process
- Assign responsible persons & delegate tasks
- Include the context of the schoolyard before implementing greenery
- All greenery works with strategical placement, except grass and willow huts

Figure 9. Practical advice for future schoolyard heat adaptation renovations.

A short explanation of each point of advice from Figure 9 is given in this section. First, it is important that the main player can build on the stakeholders that are involved from the beginning of the process. The most important example is the effect of a sense of ownership, which stimulates people to support the process. When the required stakeholders are involved, assign some persons to be responsible for several tasks, such as finances, planning and designing. Then tasks can be delegated to release some pressure from the school team members. Eligible people can often be found amongst parents, local residents and SGIs. When designing a schoolyard design, it is important to take a holistic view on the physical environment. Consider what effects are aimed at in terms of shadow, cooling, sunlight, and playing opportunities so the greenery or artificial cooling elements are placed in an effective way, minimalizing negative side-effects such as a blocked airflow or increased humidity. Lastly, almost all natural elements can work at a schoolyard, so heat-adaptive elements can be chosen as wished. Whether the greenery survives is mainly influenced by the strategic positioning regarding the local climate and erosion. The only elements that are less recommended are grass and willow huts. Enjoy the process of development and collaboration and strive to achieve your schoolyard vision!

7. Conclusion

Trees and other types of green cover are the most effective in reducing the UHI. Less effective heat-adaptive elements are green roofs and green façades. Artificial interventions such as increasing the albedo, installing sun sails, or increasing building height can also lower some daytime heat. The most closely involved parties are the school team, the students and their parents, the municipality, the neighbourhood, and the schoolyard greening initiatives (SGIs). The capacities and skills that are required from these stakeholders are firstly organisation skills. Involving stakeholders, carrying out the project development, applying knowledge and skills and pursuing a vision or motivated goal are the most important elements. Besides, the social skills of creating or feeling a sense of ownership and communication are facilitators of the renovation process.

The closely involved stakeholders had many different motives for their schoolyard choices. These considerations were categorised in different themes, being educational, environmental, health, social, external, practical, and financial considerations. Of these considerations, reasons such as letting children interact with nature, having access to subsidy and adapting the schoolyard to the physical surroundings were frequently mentioned.

In summary, early involvement of stakeholders, clear communication and organisation skills are facilitators in the process of schoolyard renovation which can overcome barriers such as vandalism, maintenance problems and resistance from other stakeholders. While the climate or heat waves are not yet the driver of most schools to renovate their schoolyard, other considerations currently stimulate schools to green up their place.

Integrating the findings that originated from the health settings questions as offered by Poland et al. (2009) and placing these in the socio-ecological context of Bronfenbrenner (cited in Kilanowski, 2017), it became clear that a primary school is part of a complex setting with different stakeholders who all influence the development of heat-adaptive measures at a schoolyard. While schools often don't have climate adaptation as priority when designing their schoolyard, they currently follow a trend of green schoolyards which is beneficial for local UHIs, as long as the greenery is placed adequately. The question remains whether it is recommendable to continue greening schoolyards, or that a different level of heat adaptation should be approached. Moreover, other interventions apart from greenery that lower heat should remain considered as an option.

Within the school domain, more research is required on motives from architects to design the schoolyards in a certain way, to create opportunities for heat-adaptation. Besides, the skills from teachers to integrate nature in their curriculum still lacks efficiency, which also requires attention. To understand how vandalism correlates with heat-adaptive or green schoolyards, more studies are to be done on this topic.

What can be concluded from this research is that schools have many opportunities to implement heat-adaptive measures at their schoolyards, as long as the complex health context is taken into account.

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Appendices

Appendix A: Search terms and search question databases

Search terms

Concept 'Heat-adaptive'	Concept 'measures'	Concept 'urban areas'	Concept 'schoolyards'
"Heat adapt*"	Measure*	"urban area*"	Schoolyard*
"Heat-adapt*"	Maatregel*	Cit*	"School playground*"
"Hitte-adaptie*"	Chang*		Playground*
"Hitte adaptie*"	Aanpass*		Schoolplein*
"Heat-resilien*"	Solution*		Speelplein*
"Heat resilien*"	Oploss*		
"Climate adapt*"	Element*		
Klimaatadaptie*			
"Climate sensitiv*"			
Klimaatsensitie*			
"Klimaat sensitie*"			
"Green-blue"			
"Green blue"			
Groenblauw*			
Green*			
Groen*			
Natur*			
Natuur*			

Search question databases

1a. Which heat-adaptive measures have been applied in urban areas and schoolyards around Europe and how are they evaluated?	
Database	**Search question**
Scopus	Heat* OR "heat wave*" OR "*heat island*" OR "heat event*" OR "heat stress" OR climate OR green* OR natur* AND adapt* OR measure* OR solution* AND "urban area*" OR schoolyard* OR "school playground*" OR playground* OR cit* AND NOT energy AND NOT solar AND NOT pollut* AND NOT pregnan* AND NOT fertilit* AND NOT carbon* AND NOT drain* AND NOT river* AND NOT sea* AND NOT coast* AND NOT soil* AND NOT flood* AND NOT *water* AND NOT China AND NOT emission* AND NOT traffic AND NOT depress*
GreenFILE	Heat* OR "heat wave*" OR "*heat island*" OR "heat event*" OR "heat stress" OR "thermal stress" OR climate OR green* OR natur* AND adapt* OR measure* OR solution* AND "urban area*" OR schoolyard* OR "school playground*" OR playground* OR cit* NOT energy NOT solar NOT pollut* NOT pregnan* NOT fertilit* NOT carbon* NOT drain* NOT river* NOT sea* NOT coast* NOT soil* NOT flood* NOT *water* NOT China NOT emission* NOT traffic NOT depress*

Appendix B: Literature search filters in databases

	Scopus	GreenFILE
Years	2013-2021	2013-2021
Language	English	English
Subject areas	<u>Selection 1</u> - Environmental Science - Earth and Planetary Sciences - Social Sciences	<u>Selection 1</u> - Cities & towns - Urban planning - Heat transfer - Heat storage - Urbanization - Climate change mitigation - Heat - Thermal comfort - Solar radiation - Urban heat islands <u>Selection 2</u> - Climate change - Metropolitan areas - Environmental policy - Green infrastructure - Temperature - Land surface temperature - Urban plants - Heat waves (meteorology) - Europe - Urban trees <u>Selection 3</u> - Urban climatology - Urban forestry - Public spaces - Urban ecology (sociology) - Government policy - Great Britain - Green roofs - Cities & towns – environmental conditions - Ecological resilience - Sustainable urban development - Paris (France) - Urban health - Weather - Climate change prevention - European Union - Global temperature changes - Surface temperature - Environmental exposure - Climate change & health - Climatic extremes - High temperatures

		- Urban parks
Countries or regions	Germany, UK, NL, Italy, Switzerland, Sweden, Austria, Czech Republic, France, Spain, Belgium, Hungary, Poland, Portugal, Greece, Serbia, Cyprus, Denmark, Finland, Ireland, Romania, Bosnia and Herzegovina, Norway, Slovakia, Slovenia, Ukraine (countries only partly in Europe not counted)	Europe, GB, Paris (France)

Appendix C: PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	

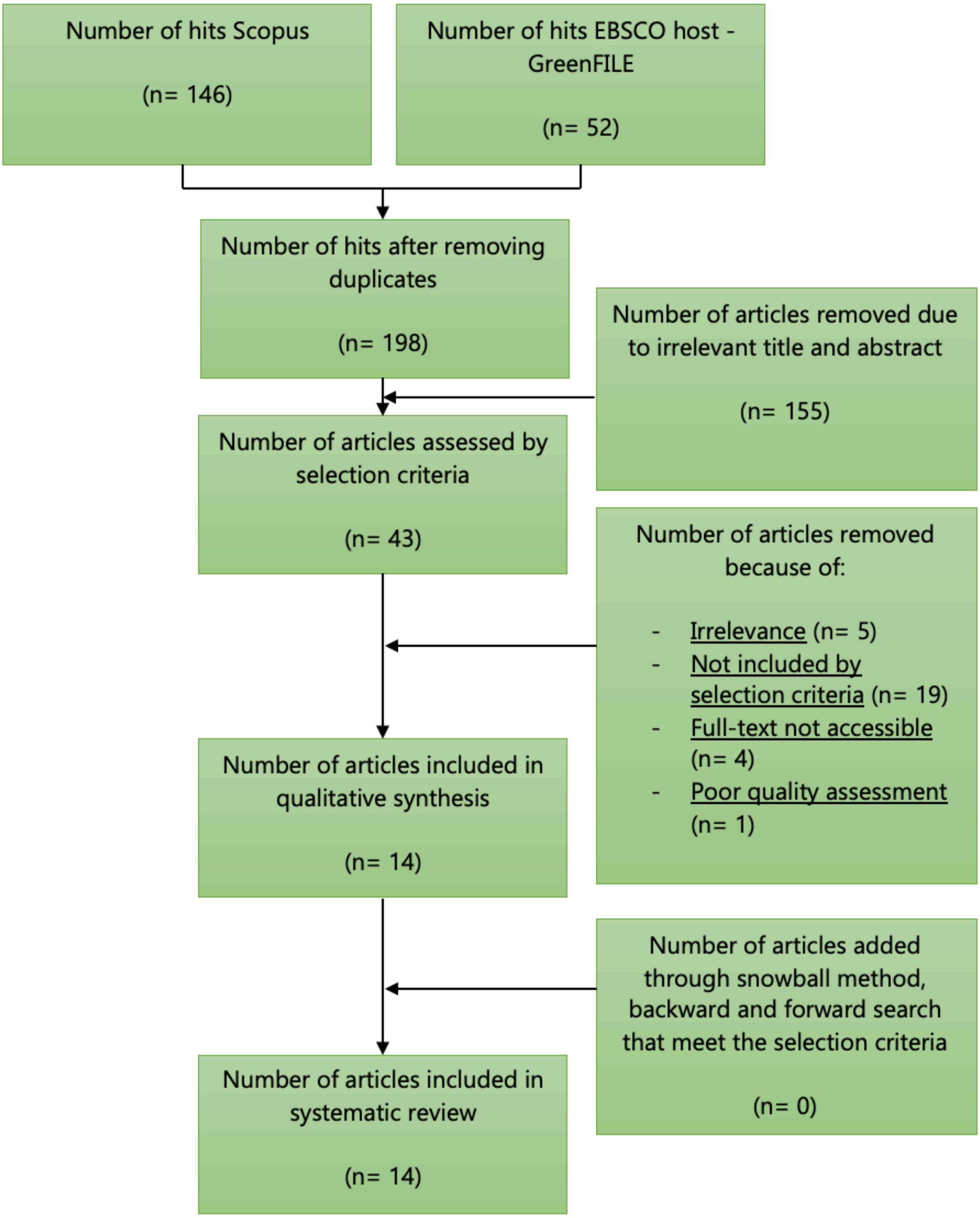
Section and Topic	Item #	Checklist item	Location where item is reported
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	
	23b	Discuss any limitations of the evidence included in the review.	
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	

Section and Topic	Item #	Checklist item	Location where item is reported
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Appendix D: PRISMA flowchart



Appendix E: TAPUPAS framework

Generic standards

- Transparency
- Accuracy
- Purposivity
- Utility
- Propriety
- Accessibility
- Specificity

Criteria

1. Clear description of study aim
2. Appropriate size of sample
3. Sound selection/sampling of sample
4. Appropriate description of the context of the study and of the study participants
5. Conclusions supported by the data
6. Sound description of limitations
7. Sound data
8. Appropriate analysis to answer the research question
9. Logical, traceable, and clear documentation of the research process
10. Sound extrapolation of conclusions to the theoretical population

Appendix F: Checklist of the Critical Appraisal of a Meta-Analysis or Systematic Review

CEBMa
center for
Evidence-Based Management

Critical Appraisal of a Meta-analysis or Systematic Review

Appraisal questions	Yes	Unclear	No	
1. *Did the study address a clearly focused question?*				
2. *Was a comprehensive literature search conducted using relevant research databases (i.e. ABI/INFORM, Business Source Premier, PsycINFO, Web of Science, etc.).*				
3. *Is the search systematic and reproducible (e.g. were searched information sources listed, were search terms provided)?*				
4. *Has publication bias been prevented as far as possible (e.g. were attempts made at collecting unpublished data)?*				
5. *Are the inclusion and exclusion criteria clearly defined (e.g. population, outcomes of interest, study design)*				
6. *Was the methodological quality of each study assessed using predetermined quality criteria?*				
7. *Are the key features (population, sample size, study design, outcome measures, effect sizes, limitations) of the included studies described?*				
8. *Has the meta-analysis been conducted correctly?*				not applicable
9. *Were the results similar from study to study?*				
10. *Is the effect size practical relevant?*				not applicable
11. *How precise is the estimate of the effect? Were confidence intervals given?*				
12. *Can the results be applied to your organization?*				

Adapted from Crombie, The Pocket Guide to Critical Appraisal; the critical appraisal approach used by the Oxford Centre for Evidence Medicine, checklists of the Cochrane Centre, BMJ editor's checklists and the checklists of the EPPI Centre.

Appendix G: Quality assessment articles

RQ1 – Quantitative studies: TAPUPAS framework

	Study aim	Clear context description	Supports conclusions	Sound limitations	Sound data	Appropriate analysis	Clear research process	Sound extra-polation	Total	Qualification
(Baryła et al., 2019)	1	1	1	0	1	1	1	1	7	Strong
(Emmanuel & Loconsole, 2015)	1	1	1	0	1	1	1	1	7	Strong
(Fallmann et al., 2013)	1	1	1	0	1	1	1	0	6	Strong
(Kántor et al., 2018)	1	1	1	1	1	1	1	1	8	Strong
(Kleerekoper et al., 2015)	1	1	1	1	1	1	0	1	7	Strong
(Knaus & Haase, 2020)	1	1	1	1	1	1	1	1	8	Strong
(Macintyre & Heaviside, 2019)	1	0	1	1	1	1	1	1	7	Strong
(Maggiotto et al., 2021)	1	1	1	0	1	1	1	1	7	Strong
(Noro & Lazzarin, 2015)	1	1	1	1	1	1	1	1	8	Strong
(Skelhorn et al., 2014)	1	1	1	1	1	1	1	1	8	Strong
(Taher et al., 2019)	1	1	1	0	1	1	1	1	7	Moderate

(Tiwari et al., 2021)	1	1	1	0	1	1	1	1	7	Strong
(Vojvodikova et al., 2020)	1	1	1	0	0	1	0	1	5	Moderate
(Zölch et al., 2016)	1	1	1	0	1	1	1	1	7	Strong

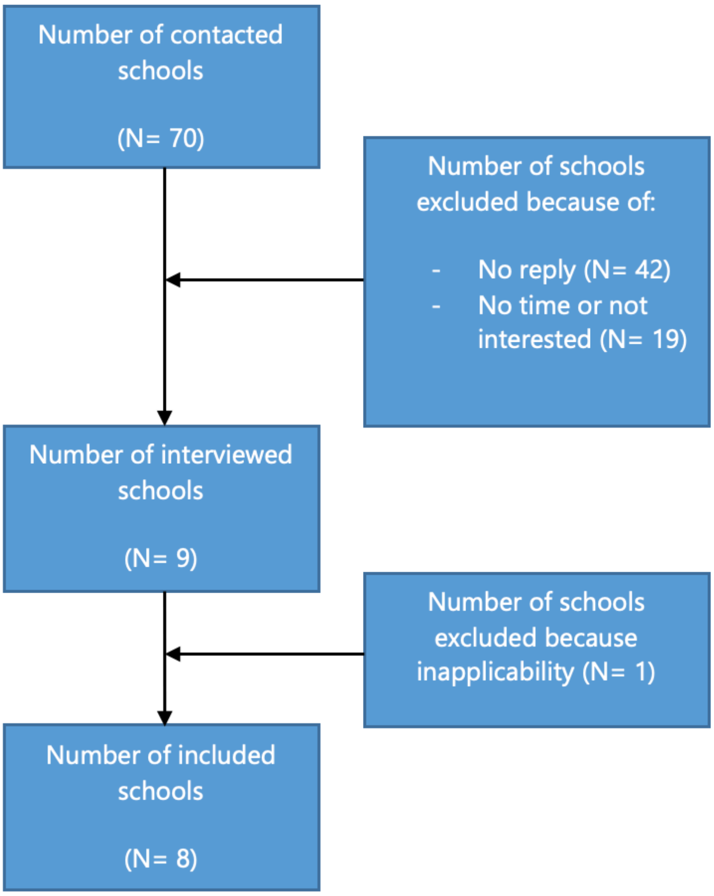
RQ1 – Qualitative studies: CEBMa Critical Appraisal of a Meta-Analysis

	Clear research question	Appro-priate literature search	Systematic and repro-ducible	Prevention public-cation bias	Clear criteria	Appropriate assess-ment study qualities	Description key features	Correct meta-analysis	Similar results	Effect size	Effect estimate	Applic-ability	Total	Qualifi-cation
(Koch et al., 2020)	1	1	1	0	1	0	1	1	1	1	1	0	9	Poor

Appendix H: Risk of bias in included studies of the systematic literature review

	Researcher bias	Design bias	Measurement bias	Publication bias	Confirmation bias	Reporting bias	Confounding
Baryła et al. (2019)	Low	Low	Low	High	High	Low	Low
Emmanuel and Loconsole (2015)	Low	Low	Low	High	Unclear	Low	Unclear
Fallmann et al. (2013)	Low	Low	Low	High	Unclear	Low	Low
Kántor et al. (2018)	Low	Low	Low	High	Low	Low	Unclear
Kleerekoper et al. (2015)	Low	Low	Low	Low	Low	Low	Low
Knaus and Haase (2020)	Low	Low	Low	Low	Low	Low	Unclear
Macintyre and Heaviside (2019)	Low	Low	Low	High	Low	Low	Low
Maggiotto et al. (2021)	Unclear	Low	Low	Unclear	Low	High	Unclear
Noro and Lazzarin (2015)	Low	Low	Low	High	Low	Low	Low
Skelhorn et al. (2014)	Low	Low	Low	Low	Low	Low	Low
Taher et al. (2019)	Low	Low	Low	Low	High	Low	Low
Tiwari et al. (2021)	Low	Low	Low	High	High	Low	Unclear
Vojvodikova et al. (2020)	High	Unclear	High	Low	Low	High	Unclear
Zölch et al. (2016)	Low	Low	High	Unclear	Low	Low	Low

Appendix I: Selection of primary schools in Rotterdam



Appendix J: District selection Rotterdam based on vulnerability factors

		Factors						Total occurrences
		Highest poverty	Lowest personal incomes	Lowest physical, safety and social indexes	Highly paved	Most effects from heat (UHIs, hot nights, tropical days)	Lowest amount of greenery	
Districts	Feijenoord	2	0	3	2	5	1	13
	Centrum	1	1	1	2	4	1	10
	Delfshaven	2	2	1	0	0	1	6
	Charlois	1	0	3	1	0	0	5
	Noord	1	0	0	0	3	0	4
	IJsselmonde	0	0	1	0	1	0	2
	Kralingen-Crooswijk	1	0	0	0	0	0	1

Appendix K: Semi-structured interview questions school team (Dutch)

1. **1.** Wat zijn de belangrijkste redenen voor de manier waarop het schoolplein momenteel is ingericht?
   - **a.** Wat beschouwt deze school als belangrijke elementen op het plein?

2. **2.** Is het schoolplein ooit van inrichting veranderd?
   - **a.** Zo ja: wanneer?
   - **b.** Zo ja: waarom?

3. **3.** Zijn er dingen die jullie momenteel zelf aan het schoolplein zouden willen aanpassen?
   - **a.** Zo ja: wat en waarom?
   - **b.** Zijn er plannen aanwezig voor een aanpassing/renovatie van het schoolplein?
   - **c.** Heeft jullie school een bepaald imago/visitekaartje dat jullie (hiermee) graag willen uitstralen? Waar komt dat door?

4. **4.** Wie zijn er verantwoordelijk voor de inrichting van het schoolplein?
   - **a.** Is er een verschil in de mate waarin deze personen hier uiteindelijk invloed op hebben?
   - **b.** Wat is er nodig aan inspanning vanuit het schoolteam om zo'n verandering mogelijk te maken?
   - **c.** Zijn er partijen van buiten de school betrokken bij de aanpassing van het plein?
     - **i.** Zo ja: welke partijen zijn dat? Hoeveel invloed hebben zij?

5. **5.** Stel, iemand heeft een idee om het schoolplein aan te passen. Wat is dan de procedure?
   - **a.** Welke factoren kunnen zo'n aanpassing/renovatie bevorderen?
   - **b.** Welke factoren kunnen zo'n aanpassing/renovatie belemmeren?

6. **6.** Door het veranderende klimaat krijgt Nederland steeds vaker te maken met hittegolven. Doet de school hier iets mee?
   - **a.** Zo ja: wat en waarom?
   - **b.** Zo nee: waarom niet?

7. **7.** Stel dat jullie school het advies krijgt om meer natuur op het schoolplein aan te brengen. Hoe staan jullie hier dan tegenover?
   - **a.** Zijn er elementen waar jullie voorkeur aan zouden geven? Waarom?
   - **b.** Zijn er elementen die jullie liever niet op het schoolplein hebben? Waarom?

Appendix L: Photos from included primary schools

School 1

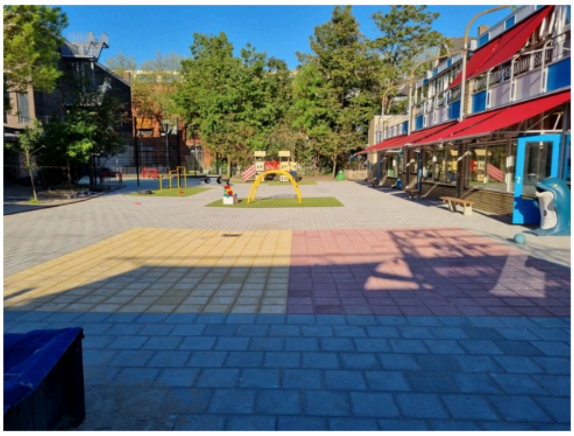




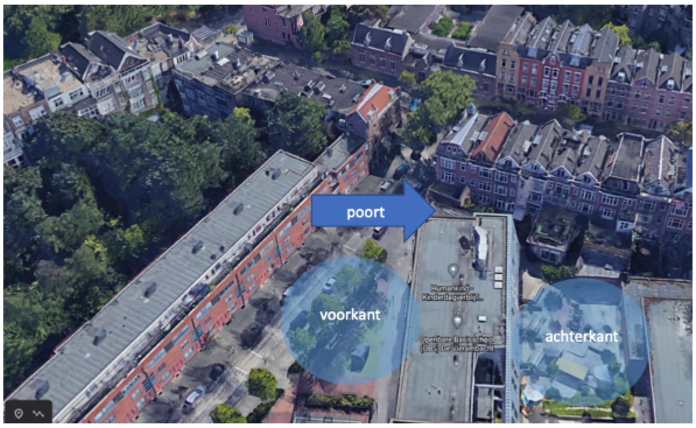
School 3



School 4



School 5



School 7




School 8


Appendix M: Comparison of heat-adaptive characterstics schools

			District							
			Feijenoord		Delfshaven			IJsselmonde	Prins Alexander	
		School number	1	2	3	4	5	6	7	8
Physical characteristics	**Green score public space**		8%	20%	2%	11%	29%	32%	35%	35%
	Green score 100m radius		16%	13%	22%	31%	26%	53%	45%	65%
	Recently renovated		Yes	Yes	Partially	Yes	-	-	-	Yes
	Fenced/ enclosed schoolyard		Yes	Yes	Yes	Yes	Yes (backside)	Yes	Yes	Yes
	Wind direction schoolyard		South	Unknown	Unknown	South	Northeast, Southwest	South, West	All directions	All directions
Present elements	**Natural ground cover**	At schoolyard	Yes	-	-	-	-	-	-	Yes
		Neigh-bouring	-	-	-	-	-	-	-	-
	Lower green (grass, flowers)	At schoolyard	Yes	-	-	-	-	Yes	-	-
		Neigh-bouring	-	Yes	-	-	-	Yes	-	Yes
	Bushes	At schoolyard	-	-	-	Un-clear	Yes	-	Yes	Unclear
		Neigh-bouring	-	-	-	Yes	Yes	Yes	Yes	Yes

Trees	At schoolyard	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes
	Neigh-bouring	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes
(Vegetable) garden	At schoolyard	Yes	-	-	Yes	-	-	-	-
	Neigh-bouring	-	-	-	-	-	-	-	Yes
Water elements	At schoolyard	-	-	-	-	-	-	-	-
	Neigh-bouring	Yes	-	-	-	-	-	-	Yes
Tiles/concrete	At schoolyard	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Neigh-bouring	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Natural playing elements/ materials	At schoolyard	Yes	Yes	-	-	-	-	-	Yes
	Neigh-bouring	-	-	-	-	-	-	-	-
Artificial playing elements/ materials	At schoolyard	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Neigh-bouring	Yes	-	-	-	-	-	-	-
Places of shadow	At schoolyard	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes
	Neigh-bouring	-	Yes	Unclear	Yes	Unclear	-	Yes	Yes

Appendix N: Semi-structured interview questions schoolyard greening initiatives (Dutch)

1. Kunt u uitleggen hoe het proces gaat als jullie met een nieuwe school een project aan gaan?
    a. Komt het initiatief meestal vanuit jullie of vanuit de school?

2. Werken jullie zelf ook nog met andere partijen samen in zo'n project?
    a. Wat hebben jullie van deze partijen nodig?
    b. Zijn er bepaalde partijen die meer invloed hebben dan andere? Hoe komt dat?
    c. In welke mate moeten/houden jullie rekening met de wensen van deze partijen?

3. Welke capaciteiten hebben jullie als organisatie van de school nodig om een project te laten slagen?

4. Welke capaciteiten voegen jullie als organisatie toe in het proces als aanvulling op wat een school zelf kan?
    a. In hoeverre laten jullie de school meebepalen en in hoeverre nemen jullie zelf de regie?

5. Welke factoren kunnen een pleinrenovatie bevorderen?

6. Welke factoren kunnen een pleinrenovatie belemmeren?
    a. Gebeurt het ook wel eens dat de samenwerking met een school uiteindelijk staakt/niet lukt? Waar ligt dat dan aan?

7. Wat merken jullie van bewustzijn rondom hitte vanuit scholen?

8. Doet jullie organisatie ook iets met het veranderende klimaat en de bijbehorende hittegolven? Op welke manier?
    a. Welke elementen worden het vaakst toegepast op scholen als het gaat om hitte-aanpassing?
    b. Welke elementen worden het minst vaak toegepast of zijn het minst gewenst als het gaat om hitte-aanpassing?

9. Welke natuurlijke elementen achten jullie zelf het best toepasbaar op schoolpleinen? En welke zijn het minst handig?

Appendix O: Semi-structured interview questions municipality of Rotterdam (Dutch)

1. Kunt u iets vertellen over uw ervaringen op schoolpleinen in Rotterdam?

2. Heeft u een beeld van het proces dat plaatsvindt als scholen contact leggen en/of subsidie hiervoor aanvragen bij de gemeente?
    a. Wat zijn hierin valkuilen en stimulerende factoren?

3. Zijn er wijken met bepaalde kenmerken waar de vergroening van een schoolplein juist makkelijker of moeilijker gaat?

4. Wat denkt u dat voor scholen de meest voorkomende drijfveren zijn om een groen schoolplein te nemen?

5. In hoeverre speelt hitte-adaptatie een rol in het aanleggen van schoolpleinen?
    a. Waarom denkt u dat dit (g)een rol speelt?

Appendix P: Additional information literature results

Authors, year	Title	Country, year data collection	Study design	Study aim	Input and output	Potential biases	Quality
(Baryła et al., 2019)	Surface temperature analysis of conventional roof and different use forms of the green roof	Poland, 2015	Quantitative comparative measurement study	"The analysis of temperature changes of different roof surfaces"	<u>Intervention</u> Different roof surfaces: board, conventional roof; substrate covered with plants (shrubs, gravel); intensive roof substrate without plant cover <u>Outcome variables</u> Temperature changes	Publication bias (study shows positive outcomes of the researched interventions, which might make this article more likely to be publicised than studies that don't show these effects) Confirmation bias (in the introduction only confirmative information towards the study aim is given. Besides, in the results and conclusion the message is a bit repetitive; mainly the temperature difference between general green roofs and conventional roofs is given, without addressing critical notes for implementation)	Strong
(Emmanuel & Loconsole, 2015)	Green infrastructure as an adaptation approach to tackling urban overheating in the Glasgow Clyde Valley Region, UK	United Kingdom, 2011	Quantitative comparative simulation study	"Explore the role of green cover in areas of different urban density within the GCV Region in the central belt of Scotland."	<u>Intervention</u> Impermeable surfaces; impermeable surfaces from which all stormwater is infiltrated on property; non-vegetated, semi-permeable surfaces, green façades; extensive green roofs, intensive green roofs and areas underlain by shallow subterranean structures, vegetated areas	Publication bias (study shows positive outcomes of the researched interventions which high potential effects like eliminating 1/3 up to 1/2 of the expected extra urban heat island effect, which might make this article more likely to be publicised than studies that don't show these effects)	Strong

					Outcome variables Local warming attributes (air temperature effects, surface temperature effects, thermal comfort)		
(Fallmann et al., 2013)	Mitigation of urban heat stress -a modelling case study for the area of Stuttgart	Germany, 2003	Modelling case study	"To analyse the urban climate on a regional scale [...] to offer support to local authorities for a sustainable urban development and contribute to climate research through improved models dealing with urban environments."	Intervention 4 scenarios: changed albedo for roofs and walls; modified proportion street width/building height; greening scenario 1 (big park); greening scenario 2 (number of smaller parks) Outcome variables Potential temperatures; development of UHI intensity	Publication bias (study shows positive outcomes of the researched interventions, which might make this article more likely to be publicised than studies that don't show these effects. Besides this study aims to offer decision support and improved models which they have managed to. It might be less likely to be published if they did not manage the latter two goals.)	Strong
(Kántor et al., 2018)	Human-biometeorological significance of shading in urban public spaces—Summertime measurements in Pécs, Hungary	Hungary, 2016	Quantitative comparative measurement study	"To assess the human-biometeorological impact of shading in a Central-European city during summer daytime and to compare the effectiveness of different types of	Intervention Shading (trees, sun sails) Outcome variables Human-biometeorological measurements (radiant flux densities,	Publication bias (study shows positive outcomes of the researched interventions, which might make this article more likely to be publicised than studies that don't show these effects)	Strong

				shading [...] in reducing heat stress in different urban settings."	air temperature, wind speed, humidity)		
(Kleerekoper et al., 2015)	Climate adaptation strategies: Achieving insight in microclimate effects of redevelopment options	The Netherlands, 1950-2011	Quantitative comparative simulation study	"Identifying what design measures and typologies that are most effective in certain neighbourhoods, thus to contribute to the broader question: 'How to apply climate adaptation measures in specific neighbourhood typologies in The Netherlands?'"	<u>Intervention</u> Street trees; grass fields; pavement materials roof and façade colours; building height. <u>Outcome variables</u> Temperature; comfort levels	No high risks found	Strong
(Knaus & Haase, 2020)	Green roof effects on daytime heat in a prefabricated residential neighbourhood in Berlin, Germany	Germany, 2018	Quantitative comparative simulation study	"Investigating the effectiveness of rooftop greening as nature-based solution to the increasing heat challenge in central Berlin. The objective is thus to understand whether green roof implementation on these large-scale building structures can improve the local thermal situation	<u>Intervention</u> Roof greening <u>Outcome variables</u> Meteorological forcing data (i.e. air temperature, wind speed, wind direction); interactions between vegetation, substrate layer and fixation materials on façades or roofs; human thermal comfort (HTC)	No high risks found	Strong

				during intensified summer heat in central Berlin."			
(Macintyre & Heaviside, 2019)	Potential benefits of cool roofs in reducing heat-related mortality during heatwaves in a European city	United Kingdom, 2003 & 2006	Quantitative comparative simulation study	"Quantify what proportion of heat related deaths which have been attributed to the UHI could potentially be avoided by implementation of cool roofs across the West Midlands region."	Intervention Cool roofs Outcome variables Local ambient temperatures in rural and urban land cover areas with quantified UHI intensity (summertime), heat-related mortality	Publication bias (study shows positive outcomes of the researched interventions, which might make this article more likely to be publicised than studies that don't show these effects)	Strong
(Maggiotto et al., 2021)	Heat waves and adaptation strategies in a Mediterranean urban context	Italy, 2019	Quantitative comparative simulation study	"To evaluate the effectiveness of two adaptation strategies (cool surfaces and urban forestry) in lowering urban temperatures and improving thermal comfort for citizens."	Intervention Cool surface case (asphalt replaced by concrete pavement light); urban forestry case (base case plus trees placed) Outcome variables Temperature; relative humidity	Reporting bias (focus of the study is evaluating to heat adaptation strategies, but the discussion only contains information from literature about more general effects of heat and possible adaptation strategies on health, plus only a few lines in the conclusion are about the findings of this study. Highly likely that more complete conclusions are left out.)	Strong
(Noro & Lazzarin, 2015)	Urban heat island in Padua, Italy: Simulation analysis and mitigation strategies	Italy, 2012	Quantitative comparative simulation study	"To evaluate the presence of the UHI phenomenon and to investigate the effect of possible mitigation strategies in a representative site of the city."	Intervention Greenery; water Outcome variables Air temperature	Publication bias (study shows positive outcomes of the researched interventions, which might make this article more likely to be publicised than studies that don't show these effects)	Strong

(Skelhorn et al., 2014)	The impact of vegetation types on air and surface temperatures in a temperate city: A fine scale assessment in Manchester, UK	United Kingdom, 2010	Quantitative comparative simulation study	"To present the results of an investigation into the relative effect of different greenspace types within a temperate northern UK city neighbourhood and to assess the utility of ENVI-met for fine scale assessment of the impacts of vegetation type on urban temperatures."	Intervention Types of greenspace: No greenspace; all existing greenspace replaced with grass; base + 5% newly planted trees; base + 5% mature trees; base + 5% shrubs/hedges; base +largest building fitted with green roof) Outcome variables Air and surface temperatures; wind; shading	No high risks found	Strong
(Taher et al., 2019)	The influence of urban green systems on the urban heat island effect in London	United Kingdom, 2018 & partly unknown	Quantitative comparative simulation study	"To investigate the extent to which urban green systems (UGS) may play an effective role in the mitigation of the UHI, in the current and future climate scenarios using Oxford Street in London as the case study."	Intervention Trees; living façade (LF); pavement albedo Outcome variables UHI; Physiological Equivalent Temperature (PET); Air temperature (Ta); Radiant Temperature (Tmrt); Predicted Mean Vote (PMV)	Confirmation bias (in the causes of the research is mentioned that the researchers are looking for effective and heat mitigating UGS, for which they selected a few types without explaining why those types were chosen. Might point to existing expectations)	Moderate
(Tiwari et al., 2021)	The impacts of existing and hypothetical green infrastructure scenarios on urban heat island formation	United Kingdom, 2015	Quantitative comparative simulation study	"To quantify the impact of different green infrastructure (GI) planning on temperature	Intervention Types of GI: green roofs, grass cover, trees cover; urban landform	Publication bias (study yields significant results which are comparable to other studies with similar outcomes, which might make this article more likely to be publicised than studies that don't show this effect)	Strong

				perturbations using scenario modelling.”	Outcome variables Temperature perturbations	Confirmation bias (in the result section there is often referred to other studies that yielded comparable outcomes. If the researchers knew this before the data collection and analysis started this may have biased them)	
(Vojvodikova et al., 2020)	Land use changes and effects on heat islands in the city	Czech Republic, unknown	Quantitative comparative simulation study	“To show the possibilities of a variant solution in relation to the creation or reduction of heat islands.”	Intervention (Changes of) land use (greenery, parking areas) and land cover Outcome variables Heat stress level; spatial distribution of heat stress in urban areas	Researcher bias (assumption without proper reference made that municipality is not capable of properly illustrating and evaluating impact of planning decisions, which can steer the method and/or outcomes) Measurement bias (model was applied at a location requested by the municipality, which could be a less representative area than when objectively chosen based on maps) Reporting bias (research process was not clearly elaborated upon, so important details could be kept away)	Moderate
(Zölch et al., 2016)	Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale	Germany, 2002 (current) & 2058 (future)	Quantitative comparative simulation study	“Quantifying the effectiveness of three types of urban green infrastructure (UGI) in increasing outdoor thermal comfort in a comparative analysis.”	Intervention Types of UGI: trees, green roofs, green façades Outcome variables Outdoor thermal comfort: physiological equivalent temperature (PET); thermal sensation for pedestrians	Measurement bias (most favourable diurnal cycles chosen to prove heat effects, might not be average)	Strong

Appendix Q: Experiences with implemented heat-adaptive elements

Throughout the interviews, multiple types of heat-adaptive elements were mentioned and evaluated in terms of whether they work at schoolyards or not. The most important evaluations are shortly described in this section.

A common natural element at newly renovated schoolyards are **willow huts**. As children are tempted to climb on the branches, these huts are easily destroyed. Pam Post and Tjitske Westra reported that they have not found one schoolyard at which a willow hut worked. Ian Mostert did suggest that when building the hut with vertical stakes instead of horizontal ones, so children can't climb on it. Another element that was advised against was **grass**, as it becomes overrun easily. Dorine Epping added that **vegetable gardens** are also less recommendable, as these tend to be "barren and desiccated" after the summer holiday. As discussed before, Epping explained that this option only works if the maintenance of it is "in the school's DNA".

Epping continued explaining some of her recommendations when it comes to heat-adaptive schoolyards. She reported: "I am not a fan of big football fields for example, they are way to dominant. Place a panna field in the corner or go to the park. Create the schoolyard with **natural materials**, **height differences**, **wooden elements**, and **(stepping) stones**". She further added that successful elements aren't necessarily the standard elements such as climbing frames, but rather creative elements. While **water elements** can sometimes cause complaints from parents, choosing forms that are more controlled were also suggested by Epping. She used wadis with water that contain water for maximally 24 hours, water tanks, water playing objects or water pumps that are only opened in the summer period as examples.

Suzanne van Ginneken described how important it is to place the right materials at strategic spots, so that they do not get overrun easily. Van Ginneken continued that in general, **all natural materials** can work, as long as it is well designed. Two last elements that were recommended by her were **espaliers** and **pergolas**. When placed in front of classrooms outside they can filter the sunlight when coming in and provide some shadow.