SPATIAL DESIGN AS A TOOL TO PREVENT PLUVIAL FLOODING: A ROTTERDAM CASE STUDY

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Abstract

Due to climate change, the intensity of both draughts and rainstorms will increase (KNMI 2014). This, together with soil sealing will cause pluvial flooding in urban areas to occur more often in the future. As a solution, temporary water storage, both above and below ground, is being implemented as a measure against flooding. The city Rotterdam is one of the leading players in the world of making the city climate-proof (Afeworki et al. 2017). In this report, 3 cases of temporary water storage are analysed and compared based on 3 different elements: Effectivity of the measure, functionality and the design of the measure. In these cases, to decrease the problem of pluvial flooding, underground storage can be considered to be most efficient. However, above ground water storage in combination with public participation at the start of process management, can lead to making better places.

Inhoud

1. Introduction

1.1. Background

In the past few years, especially since 2018, there have been several very dry periods in the Netherlands, alternated by heavy rain showers. Rain is essential for maintaining the groundwater levels for agriculture, dike preservation and drinking water. However, these rains and storms have also lead to flooded streets and overflown sewers, particularly in urban areas. According to the ‘Klimaatscenario’s’ by the KNMI (2014), the rain intensity will continue to increase by 2050. This means that these kind of heavy rains will occur more often throughout the years, causing the streets to be flooded more often as well. Especially within urban areas, where the sewers are the main carrier of the rainwater, this can cause problems and discomfort to its citizens. According to Carter et al. (2015) “pluvial flooding is predominantly caused by short duration intense rainfall occurring locally, and results from rainfall-generated overland flow and ponding prior to associated runoff entering any watercourse, drainage system or sewer.”
Apart from that, due to urbanization, urban areas also flood more frequently and longer, because there is less chance of infiltration into the earth (Gallo et al., 2012). This is because areas that used to have the function of greenery or agriculture, are now being transformed for purposes of housing traffic and economy, also known as soil sealing (Nestroy 2013). This means that the soil is covered by materials with a low permeability such as asphalt and other road pavements (Nestroy 2013).

One of the cities that is currently dealing with these problems is Rotterdam. Rotterdam has a long history of both working with and against water. The name itself has its origin in water management: The dam in the river Rotte. Currently the city is still one of the most active cities concerning climate adaptation in the Netherlands, and has a large, long-term programme on climate-proofing the city (Afeworki et al. 2017). The aim of the climate adaptation programme is connecting water with opportunities, and not just see water as a risk (Climate Proof Initiative 2014).
Since the start of the programme in 2008, dozens of projects have been realized including green roofs, floating house developments, underground water storage, and water plazas. According to Afeworki et al. (2017), Rotterdam takes a rare approach to climate adaptation within the city: A policy approach where multiple levels of government, including national, regional and municipal governments, have a direct influence on Rotterdam’s decisions on climate adaptation. For example, the national ministry sets the policy agenda for climate adaptation. However, the initiatives are all set up from a municipal or community level. Taking into account the national adaptation plans, visions and political mandates, Rotterdam has created a framework which enables faster implementations of new measures (Afeworki, 2017). A clear example of this is the implementation of green roofs in Rotterdam. Through communication and showing the possibilities, local inhabitants are convinced of the advantages of green roofs (Wienese, 2017). The same strategy is used for water retention areas. Thus, when looking at climate mitigation for storms, Rotterdam is one of the leading players in the world (Afeworki, 2017). Consequently it is also a very interesting city for a case study on urban flood adaptation measures.

To make sure that the streets are flooded less frequently because of extreme rain, the water management infrastructure in cities needs to change. Therefore the topic of this paper is focused on increasing the resilience to pluvial flooding in urban areas..

1.2. Research problem

Since finishing the construction of the first water plaza of the Netherlands in 2012 at Bellamyplein in Rotterdam, water storage areas are considered to be a large part of the solution to increase resilience to pluvial flooding. Although academic literature discusses water retention measures such as green and blue roofs and water retention (add refs) there is a gap in the literature how to design specifically

water plazas for water retention. This report can help fill this gap by combining both effectivity and design of different water retention measures.
This report will address this gap through a case study on 3 different water plazas in the city of Rotterdam.
This is societally relevant as other cities might learn from these experiences and how to include such measure in their urban policies. Through this study, insight can be provided into how spatial design of water retention in urban areas, and more specifically: water plazas, can help to decrease pluvial urban flooding. To further understand this, the following question will be answered:

"How can pluvial flood resilience be achieved through spatial design of water retention areas?"

The main question is divided in the following sub-questions

- What are the existing measures on pluvial flood resilience in Rotterdam?
- Which measures work best?
- how can water retention areas be used for multiple urban functions
- Which lessons can be drawn from the measures taken in Rotterdam?

Figure 1.1 further represents this problem through a conceptual model of this research. Climate change requires resilience to urban flooding. This model shows that this can be done through spatial planning and technical interventions. Water retention areas combine these two interventions through different aspects of efficiency, functionality and design.

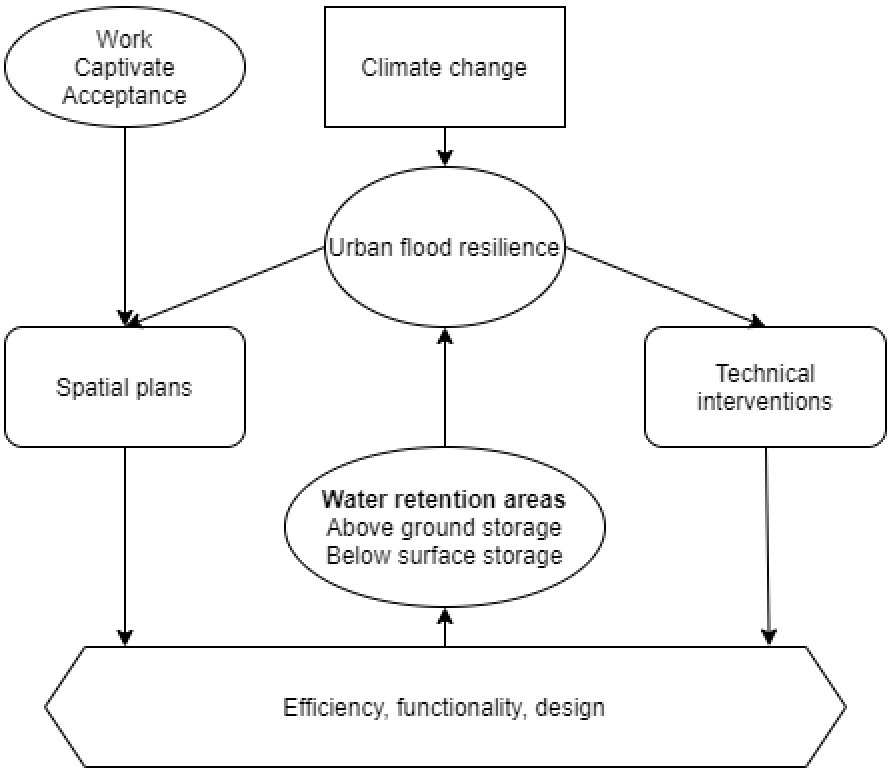

Figure 1.1: conceptual model

1.3. Structure

Following the introduction in the previous paragraphs, a theoretical framework will be established in the next chapter, including a conceptual framework. This is followed by the methodology, in which the method of data collection is further explained, as well as the selection process for the 3 different cases. After this, the results will be discussed through a comparison of the different cases, followed by a discussion in which the findings will be highlighted and further interpreted. Finally, a conclusion will be drawn together with recommendations for other cities based on the report.

2. Theory

One of the main concepts addressed in figure 1 is resilience. Resilience can be defined as the elasticity of a system to disruption, and how fast it can return and/or improve to its previous state (Derickson & MacKinnon, 2012). In this report the resilience of a city to extreme pluvial flooding can thus be how fast an excess of rainwater can be handled by the city's sewer and water system.

Staddon et al. (2017) states that there are 4 factors to increase resilience: 1. Why it is done to resolve the issue? 2. How? Whether it can resolve more than the appointed issue. 3. Who are involved? 4. What the intervention is itself. Especially the why and what refer to the technical aspect of the intervention. Why was this intervention needed and what was solved? However, the 2nd factor implies that there is more than just the technical intervention needed to increase resilience. Spatial design works together with people and space to create better space.

This supports the idea that the management of stormwater with multiple functions, is essential to improve the overall resilience in urban areas, as it not only requires a design and engineering dimension, but also a more social approach (Staddon et al., 2018). This can be done in two ways: an area that has been designed to be functional and aesthetically pleasing, but still being able to store water. Or a plaza that has been designed to store water, can still be used as a playground or meeting place. Not only for resilience, but also for spatial design in general, solutions are based on what functions are needed from the user's perspective, and to acquire this, the design of a space often needs to be adapted (Van Dijk et al. 2019). There is a need for pluvial flood management, but also to enjoy space.

According to Van Dijk et al. (2019), a spatial plan needs to captivate, find acceptance, and work before it can be made reality. Only when a plan has been realized or very carefully analysed it can be determined whether a plan works. In the Nota Ruimte (Rijksoverheid, 2005), 7 criteria are provided to further evaluate spatial quality in the Netherlands:

- Spatial diversity: Preserving and enhancing the character of the space.
- Economic and social functionality: All functions must work well together and enhance each other.
- Cultural diversity: There is a possibility to develop a variety of cultures
- Social justice: Everyone has the same opportunities to enjoy the space and have a healthy life within the space developed.
- Sustainability: The space is safe and decreases environmental problems.
- Attractiveness: The beauty of the space must be preserved.
- Human scale: The needs and experiences of citizens are taken into account within the design of the space.

Van Dijk et al. (2019) describe these design criteria as a tool to physically observe the result of a design. However, they argue that within the planning process more is needed. Because when the spatial design matches all criteria for spatial quality, there is still a good story required to market it.

Going back to the technical side of an intervention of stormwater mitigation measures, two main types of water storage can be distinguished: Above ground water storage and below ground water storage. Above ground water storages are mainly implemented in the form of open water, and water plazas of which the Bellamyplein and the Benthemplein are the most famous examples. These plazas fill up with rain water in cases of extreme precipitation, and are emptied once the pressure on the sewers has decreased. For this report, only the water plazas will be discussed.

For below ground water storage there are several different options for implementation. One option is to use the underground water storage as overflow basin. In case of the river or sewer reaching a certain height, water will automatically flow into the storage. Once the sewers have enough capacity to receive more water, the water is pumped out. A second option is through infiltration. Underneath or nearby green space infiltration crates are placed. During a storm, rainwater will infiltrate the ground, after which it reaches reservoir where the water will be stored. In these cases, the water is often not pumped out once the storm has cleared, but it is preserved inside the reservoir to help water the green space in case of draughts.

Staddon et al. (2018) established 6 monitoring criteria to evaluate the effectiveness and success of stormwater mitigation measures in general: water ecology, water environment, sponge facilities, water safety, system construction and visibility. This demonstrates that for a measure to be successful, it needs more than efficiency. When looking at water ecology and environment, an example can be that above ground stormwater storage can provide breeding grounds for bugs such as mosquitos, and often require more maintenance and cleaning (Wong and Jim 2017).
Problems like this can be prevented, through the principles of 'Good Governance', as described by Van Dijk et al. (2019):

- The duty of care
- The obligation to state reasons
- The principle of fair play
- The prohibition of misuse of powers
- The prohibition of arbitrary action
- The principle of equality
- The principle of protection of legitimate reasons

In this case the duty of care can make sure that the deciding government has done the necessary research to be able to make the right decision. Furthermore, the implementation of principles of 'good governance' can often help raise acceptance of a project (Van Dijk et al. 2019). Especially the prohibition of arbitrary action ensures that the interests and needs of various stakeholders are included to arrive at an acceptable plan. 'Good governance' is mainly supported within project management, compared to process management. According to Harmsen and Lamers (2013), "in project management, the focus is mainly on the internal manageability, with less attention towards the stakeholders". Within process management, interaction with stakeholders from the beginning on is essential. The aim of process management is to find a goal, and then work towards it, instead of working together to reach a pre-set goal. Whereas process management might reach a higher acceptability, its effectiveness is still under debate. However, open dialogue with stakeholders at the start of, and during projects remains essential (Harmsen & Lamers, 2013).

Another method to reduce risks, and decrease the possibility of pluvial flooding is diversity measures. By using a variety of measures the load and negative external effects are spread. In the case of preventing pluvial flooding, redundancy measures provide backup capacity during an extreme rainfall event (Bollinger et al., 2013).
The architects of the Benthemplein amongst others, offer the diversity measures as a solution in the city of Rotterdam. According to them, both large-scale and local measures can together help decrease pluvial flooding, in which redundancy measures can also be applied (Urbanisten, 2010). The importance is highlighted by the municipality of Rotterdam, as it has calculated that it will need over 100 million litres of overflow capacity to be able to keep the streets from flooding (Witman, 2014).
A framework for the governance of climate adaptation, which includes the relationships between the environment, social system, and technical system is provided by Bollinger et al. (2013). The technical system can be divided between components, links, and networks. Environmental factors have a direct influence on the components, which can spread to the network level. An example that can be fitted within this report is a part of a street that has been flooded because of a rainstorm. The rainstorm is the environmental factor directly impacting the component: a street. Because of this, the node, which is in this case the entire transport corridor of the street, its accessibility might be reduced, causing other parts of the network to receive an overload in traffic. The framework offers a method of analysis for possible obstructions and

adaptation measures at different levels within the technical system. Identifying the different affected aspects of the system, and its relationships can provide a basis for highly effective pluvial flood adaptation measures.

3. Methodology

The research strategy of this paper is the combination of secondary data collection and a comparative case study. The data is collected from official government websites, such as the Hoogheemraadschap Schieland en de Krimpenerwaard, books, reports, and academic articles. The databases used were Google, Google Scholar, and SmartCat.

Before conducting this research, several other methods of research were considered such as primary data gathering through short interviews or surveys with locals around the selected cases, and interviews with experts on the subject of urban retention measures or water plazas. The interviews with the locals would offer additional information on their perspective on the spatial design of water retention measures. However, because of the COVID-19 virus, it was not safe to go to the required locations. An interview with an expert could provide fresh insights on the subject, with possible new information. However, this topic of research has not been researched enough to find an expert on this particular subject. Several experts on similar topics were contacted via email. However, their topic of expertise was not sufficiently directed at the spatial design of water retention measures to be able to provide the required information.

As mentioned in the introduction, the city of Rotterdam has a long history of working with water, and is one of the most active cities in the world concerning climate adaptation. Because of this, the city is well-known for its climate adaptation measures. These were the main consideration for choosing Rotterdam as the setting for this research.
Within Rotterdam, 3 separate cases of water retention measures were chosen based on difference in size, functions and design. Based on desk research, a list was comprised of multiple existing water retention measures in Rotterdam, with information on how much water could be stored, what other functions were present apart from water storage, and whether it was above ground, below ground, or storing water through infiltration. To be able to form an advice for future water retention measures, there were as many differences included between the cases as possible. Research done before the selection of cases also indicated the significance of different types of measures to reduce risks of implementation (Bollinger et al., 2013).

Based on this information, 3 cases were selected that were all different considering size, functions and design. Further details on these cases are discussed later in this report.
The 3 cases are analysed individually to identify their strengths and weaknesses. By means of an evaluation tool specifically for spatial design as a pluvial flood measure. The lessons learned from the comparison of the three cases form the basis of an advice for future pluvial flood measures in Rotterdam and other cities. The objective of this advice is to decrease pluvial flooding in urban areas in the future.
This resulted in the following 3 cases that were selected for this report: The Benthemplein, the Museumparkgarage, and the ZoHo Regentuin.

Benthemplein

As mentioned before, the water plaza at the Benthemplein is one of the most famous measures of pluvial flood management in Rotterdam. The plaza consists of 3 levels which all have a different function during dry periods. Figure 3.1 shows the top view of the design of the Benthemplein. It offers opportunities for playing sports like basketball and roller-skating and it has a theatre in which people can socialize. During and directly after a rainstorm, the water plaza has a capacity to store 1700 cubic metres of water. This is collected from the rain that directly falls onto the square, but also from the roofs of surrounding buildings. Figures 3.2 to 3.4 show this with more detail on the collection points for the separate basins. The KNMI (2014) predicts that by 2050 the maximum amount of rain will be 44 millimetres per day. The area of the water plaza is 1800m2, which means that this plaza can store the rain of an area over 23 times the size of the water plaza in a rainstorm of 44 millimetres.

The Benthemplein measure has as main function the temporary storage of water. At the same time, there are possibilities for skating, basketball and relaxation. The buildings surrounding the square mostly have educational and living purposes. The people visiting the Benthemplein are therefore most likely interested in its functions. The functions therefore work well together. People are tempted to stay longer in the area, therefore making it more lively outside of working hours as well. However, when the basins are filled, the amount of functions of the plaza are decreased: the basketball court and the theatre are temporarily inaccessible. This is the case until the water is released into the sewers.

This liveliness also refers to the people involved. The design invites to use the space for more than getting to your destination. The materials used are similar to the surrounding buildings, and together with its functions, this enhances the character of the space. The design of this water plaza is made for the experience of the citizens, therefore meeting the requirements for the human scale.

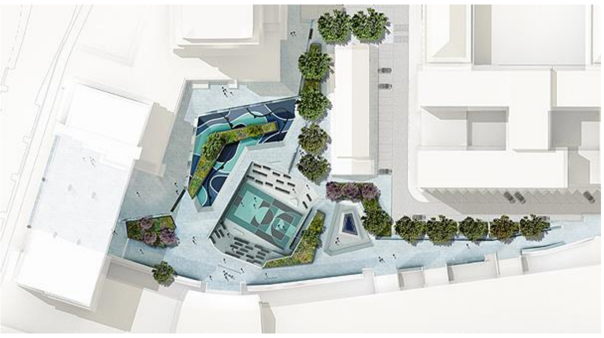

Figure 3.1: Benthemplein top view

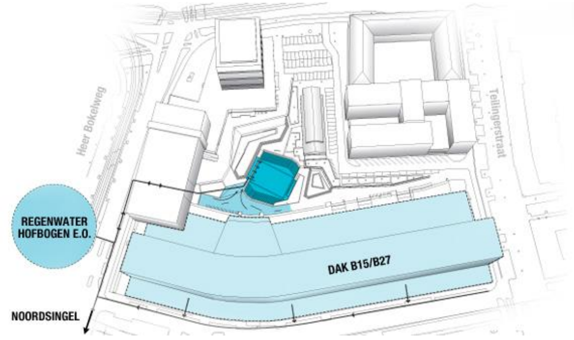

Figure 3.2: Water collection main basin

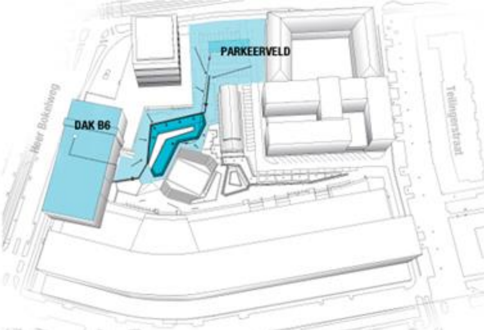

Figure 3.3: Water collection secondary basin

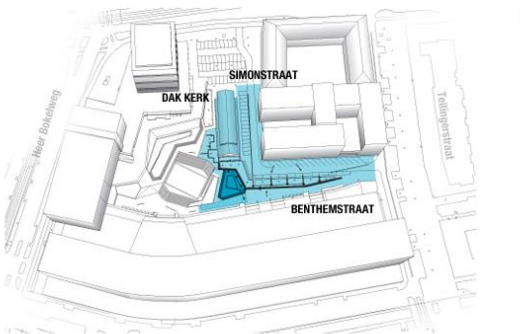

Figure 3.4: Water collection minor basin

Source: De Urbanisten (2013)

Museumparkgarage

The Museumparkgarage has the largest underground water storage in Rotterdam. Once the water level of the sewers reaches a certain height, the rainwater is let into the compartments underneath the entrance of the garage. The compartments can be filled with up to 10000 cubic metres of rainwater. In terms of space, the water storage has an area of 1800m2, meaning that it can store water from an area of nearly 140 times that size. However, because the storage receives the water from the sewers, and not directly from the storm, this is less relevant.

As the name suggests, this water storage facility is also a parking garage. The water storage is located beneath the entrance of the parking garage, as shown in figure 3.5. Apart from this, there are no apparent functions for this type of water storage. The water storage makes sure that the space underneath the garage is most optimally used.

The design of the Museumparkgarage is rather subtle. It has been integrated into the design of the parking garage, therefore not influencing the main surroundings of the garage. In terms of spatial diversity, the measure does preserve the character of the space, but not further enhance it. The parking garage caters to the needs of the citizens, as most visitors of this area are often not inhabitants of Rotterdam, and therefore

need to come by car. In this area, the invisibility of the water storage measure keeps the attractiveness of the area intact.
Once it has stopped raining, the water is pumped back into the sewers. When the compartments are filled up with water, the parking garage is still completely accessible.

Figure 3.5: Underground water storage Museumparkgarage (Municipality Rotterdam)

Regentuin ZoHo

This garden is located in a run-down neighbourhood of Rotterdam where a bottom-up organisation is trying to revitalize the area through several projects such as the “ZoHo Regentuin”, which translates to ZoHo Raingarden. In this garden, during a storm, water is collected from the roof of the ‘Hofbogen’, as demonstrated in figure 3.6. The ‘Hofbogen’ used to be an old railway viaduct, but has been re-purposed for several new functions. After the water is captured, it is pumped into four large letters that spell ZoHo. In terms of water storage capacity, the Regentuin is rather small compared to the other cases. Only 3 cubic metres of water can be stored in the garden. The area from which the rainwater is collected, will however provide 22 times more rainwater than can be stored inside of the garden.
In the letters the water is stored and regulated. In case of more expected precipitation, the rainwater is pumped out during a dry period of time to make room for more water. If there is a draught expected, the water remains in the reservoirs, and will be let go into the ground to water the nearby plants. Both when the sun is shining and during periods with excess water, citizens can still enjoy the garden.
Apart from that, the storage facility is meant as a piece of art, and the plaza itself has relaxation as main purpose. From a human perspective, the functions do not enhance each other. However, from the sustainability perspective, the water storage for dry periods can together improve the local water balance.
ZoHo is an organisation that is improving the Zomerhofkwartier in Rotterdam through culture, architecture, food, sustainability, etc. Because of its structure, nearly all projects are done bottom-up or as a local initiative, and the citizens have a say in what they want and need in the area. The design of the water storage is made to stand out and bring attention to what is being done in this neighbourhood. In this case, the attractiveness is improved through art, and the measures are implemented by using the existing historical buildings.

Figure 3.6: ZOHO raingarden water storage system (Studio Bas Sala, 2015)

4. Results and comparative analysis

Both Staddon et al. (2018) and the Dutch government provide evaluation tools for determining spatial quality and water storage measures individually. However, as previously discussed, both are required to evaluate the effectiveness within space. For evaluation and comparison of the three different cases, a new tool is needed to combine the existing tools that evaluate the successfulness of a plan.
Based on the literature in the theory chapter, 3 most important elements to evaluate pluvial flood measures in urban areas are distinguished: efficiency, functionality and design.
Efficiency can be defined as ‘producing the results you want without waste (Cambridge dictionary)’. It considers how well the measure solves the problem, with the least amount of resources. In this case, space is the main resource. Efficiency mostly refers to the previously mentioned monitoring criteria for effectiveness and success, as proposed by Staddon et al. (2017).
Functionality looks at how well it works within the space. It considers the economic and social functionality as mentioned in the Nota Ruimte (Rijksoverheid 2005), but also whether the measure resolves more than just the appointed issue. As mentioned before, according to Staddon et al. (2017), one of the factors to increase resilience is whether it can solve more than the appointed issue. Functionality refers back to the different functions a pluvial flood measure can have.
Lastly, the design of the measure is essential to prevent devaluation of the area. Since these measures are often in urban areas, spatial diversity, attractiveness, human scale and safety are essential for the acceptance of the measures. This is mostly directed at who are involved with the project, as these factors are creating support for the plan. An increased sustainability for the projects is the eventual goal. The design is essential to be able to captivate people in order to realize the plan, and also influences its acceptance. According to van Dijk et al. (2019), these are 2 out of 3 factors that are required before being able to make a plan reality.
In other words, most of the criteria of Staddon et al. (2017) and the Rijksoverheid (2005) can be divided amongst the three proposed criteria as follows:

- Efficiency of the measure: What it solves, the intervention itself.
- Functionality: Resolving more than the appointed issue, economic and social functionality
- Design: People involved, spatial diversity, attractiveness, and human scale.

Figure 4.1 shows the rating of the cases based on these 3 elements. This is followed by a description of why the cases received the rating that is provided.

4.1. Comparison

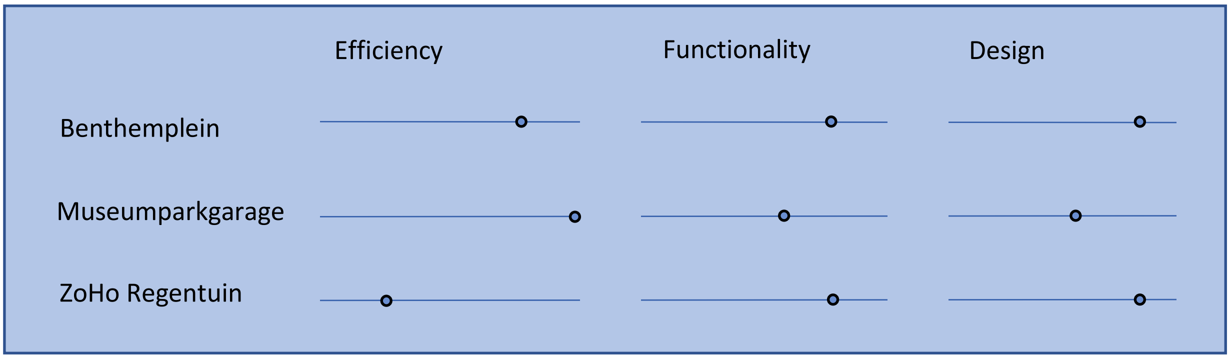

Figure 4.1: Evaluation of existing measures.

Because the Museumparkgarage is underground it uses the least amount of space considering the use of space. Apart from that, the amount of water that can be stored, is the most in comparison with the total land area. Therefore it can be said that the Museumparkgarage water storage is most efficient when looking at solving the pluvial flooding problem. The above ground water storage of the Benthemplein has the second-to-highest efficiency because of the large amount that can be stored here as well. However, where the total area of land used is the same, the total possible amount of water storage is a lot less: 10,000 cubic metres versus 1,800 cubic metres.
On the other hand, whereas the ZoHo raingarden can store a lot less rain water, it does have a built-in water store and release system. Therefore this can sometimes help to solve problems caused by long draughts. When looking at the total sustainability of the project, the ZoHo raingarden is slightly more effective. However, the effectivity to the appointed problem can be considered to be a lot less.
This has a very strong link to functionality as well. As this solves more problems than just pluvial flooding, even if it's on a small scale. Apart from water storage and watering plants, it also offers the function of relaxation because of its green surroundings, and the structure being a piece of art. The Benthemplein also offers a variety of functions, making it a place that is more lively and used more often than before the measure was implemented. In comparison to this, the Museumparkgarage offers a lot less functions: it only acts as water storage and a parking garage. It can therefore be considered to have a lower functionality as a spatial measure.
The design of the Benthemplein causes the people to be involved with the area. It is apparent that the human scale was a strong factor in the design of the plaza. Because of the interaction with its surroundings, it enhances the character of the space. As mentioned before, the collected rainwater to store in the ZoHo letters, comes from the roof of the 'Hofbogen'. Therefore the project is using what is already there and improving the area through the measure. Thus using both the spatial diversity and local attractiveness to improve the space. For the Museumparkgarage, design of the pluvial flood measure was barely used to improve the spatial quality. The need for parking space and water storage is met, but the measure does not improve the attractiveness and character of the space. The overall design of the measure within space is therefore rated less than the Benthemplein and the ZoHo Regentuin.

5. Discussion

The data suggests that when there is a large-scale need for water storage, water storage as implemented in the ZoHo Regentuin, is very unrealistic. Projects which only cater for 3 cubic metres of water storage, will not be enough if a city requires over 100,000 cubic metres as overflow capacity. However, considering that a system like this also waters the local greenery, it can be a very local solution for draught and as an inspiration for other cities to store excess water, and using it during dry periods of time. Furthermore, these types of projects bring attention to local organisations that try to

improve their neighbourhoods. The ZoHo raingarden might not be very efficient as a pluvial flood measure and work very well, but it does sell a story. Furthermore, the smart systems within water storage to be able to use the measure for watering greenery, can also be used on a larger scale.
The Museumparkgarage is on the opposite side of this. The project is highly efficient at solving the pluvial flood problem, because it offers a very large water storage area. However, because of its invisibility, it is harder to market because it does not improve the local spatial quality from the human perspective, or as an attractive spatial measure.
When looking at the intervention as a whole, the Benthemplein meets all points for evaluation. It has a relatively high effectiveness, and improves the spatial quality through enhancing what is already there, and using the citizens to create a place that accommodates social activity and sports. However, it has a decrease in functionality after a rainstorm because of the flooded basins, which can no longer be used for skating or basketball.

According to the definition of resilience provided in the theory, resilience is how fast a component is able to return to its previous state after a disruption (Derickson & MacKinnon, 2012). It can be said that all discussed measures have an influence on the resilience to pluvial flooding in Rotterdam, though some more than others. This is supported by the results based on the 4 factors to improve resilience, as proposed by Staddon et al. (2017). The measures all have a clear link to the issue, they can resolve more than the appointed issue, the stakeholders have been involved, and the interventions work to resolve the issue.

Based on the 3 discussed cases, Rotterdam faces climate adaptation through a method similar to the previously discussed framework by Bollinger et al. (2013). A thorough analysis of possible extreme environmental events and its effects on different networks and components within a city, have led to a diversity of measures, all meant to solve pluvial flooding. Particularly the relationships between the components can identify the measure best suited to the area. Diversity measures have been applied through differences in size, but also in method of providing water storage capacity: directly storing the water and capacity for overflow. At the same time, these measures are also a type of redundancy measures.

Going back to the theory by Van Dijk et al. (2019), a plan needs to captivate, find acceptance and work. Only then it can be made reality. Within this research, information on the acceptance of the plans for the 3 types of water plazas is insufficient to draw any conclusions on. The methods for this research were limited because of temporary travelling restrictions in the Netherlands because of the COVID-19 virus. The impact of a more thorough inclusion of citizens through process management on the acceptability might thus require more research in the future, to be able to provide advice on participation of citizens.
However, studied literature suggests that through process management might improve the spatial quality because it can take into account the wishes of the citizens more accurately (Harmsen & Lamers, 2013). This can be particularly important in cases similar to the Benthemplein, where the different functions are a large part of the successfulness of the measure.

6. Conclusion

A plan might work in one place, but maybe not in the other because of different cultural values, but also because of different technical aspects and needs. All cases discussed in this report have been made reality, but what lessons can be drawn from these projects to help implementation in other areas and cities?
The research question *“How can pluvial flood resilience be achieved through spatial design of water retention areas?”* was answered by analysing three different cases of pluvial flood measures in Rotterdam, and applying a comparative analysis.

The results indicate that in case of high pluvial flood risks, on an individual level, the implementation of underground water storage can be recommended the most, because generally speaking, the capacity for water storage is much larger. However, as this report shows, above ground water storage can also be very effective as a measure for temporary water storage. At the same time, it offers more opportunities for combining functions. Therefore it can enable citizens to use the water plaza for more than solving the problem of pluvial flooding: namely improving the spatial quality. When looking at the city as a whole, a combination of both types is preferred, to be able to spread external effects.

Altogether, it can be concluded that by applying the framework for supporting governance within climate adaptation, the most suitable measures can be selected. Apart from that, using different measures can help focus on the issue at hand: pluvial flooding.. To solve pluvial flooding, an efficient measure is underground water storage. However, above ground water storage also offers enough space to reduce the impact of extreme rainfall events on the sewers. But because of multiple functions fit for usage by citizens, and public participation or local initiatives to successfully achieve this, at the same time it can make places better.

This means that to be able to plan new pluvial flood measures, municipalities will need to invest time in researching the needs of citizens. This might result in a high variety of different measures, and more individual spaces in cities, giving neighbourhoods an individual character.

The report shows the advantage of different functions within pluvial flood measures, but as mentioned before, it also raises questions on how local governments can use this to raise acceptability. Future research can help elaborate on the process of establishing these measures.

Because this subject is still rather new in academic spheres, we did not succeed in including interviews with experts on the subject. This means this paper might be slightly biased from the author’s point of view. By conducting interviews with people using the area surrounding the cases on their views on pluvial flood measures, the outcomes can be checked. However, because of the circumstances along the duration of the research concerning the COVID-19 virus, this was not possible to do within this research. Therefore another suggestion for future research is to conduct quantitative research to be able to provide more thorough guidelines for planning pluvial flood measures from the perspective of the inhabitants.

7. References

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