Evaluation of climate adaptation strategies in Maastricht

Assessing to what extent climate adaptation is addressed

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Abstract

Climate adaptation is needed to prevent any damage and harm against extreme weather events caused by climate change. An increase in the number of cities having integrated strategies towards climate change is therefore needed, which is a reason that the assessment of this is necessary. The city of Maastricht in South-Limburg is an example where a lot of damage has been done recently by extreme weather events, which is why this is an important city to check to what extent climate adaptation is addressed in the current strategies of this city. To assess this, several criteria have been formed regarding climate adaptive measures in different sectors, such as agriculture, industry, and direct flooding protection. The methodology for this research is for this reason a detailed content analysis. Multiple documents of Maastricht are analysed to get a full overview of all climate adaptation measures. The most quotations referring to climate adaptation are found for the criteria of public space, healthcare, and communication and coordination of stakeholders. This indicates that Maastricht's main type of adaptation has a focus on the safety of the inhabitants in terms of flooding safety and health. A few criteria lacked quotations, for example on social safety nets, public transport, and industry, but also hard engineering and agriculture lacked. Agriculture and social safety nets are important elements of an integrated adaptation strategy, which means Maastricht's one is not as integrated as it should be. The lacking criteria in the end got a score of 0 or 1 and on these elements recommendations are given to the strategy developers and the municipality of Maastricht on how to improve on these. The strengths and weaknesses of Maastricht's strategy should be an important lesson for other cities. More research on climate adaptation in strategy documents can be done by assessing a specific element of climate adaptation in more detail.

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Introduction

Background

As climate change has caused a lot of trouble until now, most studies agree that it will play a big role in the future as well (de Bruin et al., 2009). According to de Bruin et al (2009), mitigation strategies will not be enough to outweigh all the effects of climate change. Climate adaptation in strategies is therefore needed to assist climate mitigation and to control climate change effects in the future. Climate change adaptation is context dependent, which means strategies of countries and cities need to prioritize the sector where adaptation is more needed than another sector (de Bruin et al., 2009). According to the Sustainable Development Goal (SDG) 11.b it is a goal to increase the number of cities with integrated strategies towards climate change adaptation (Klopp and Petretta, 2017). An integrated multi-sectoral approach is key in a climate adaptation strategy in order to make cities more resilient for climate change effects and is in that way sustainable (Cord et al., 2008; SDG Nederland, n.d.). Assessing a strategy document is therefore important to evaluate to what extent climate adaptation is addressed in these strategies and in how far they use an integrated and multi-sectoral approach.

By making integrated strategies for climate adaptation it is possible to adapt for multiple sectors and combining climate adaptation goals with other projects in the city to minimize the trade-offs between sectors (Petit-Boix et al., 2017). An example of further research on the assessment of climate adaptation strategies is assessing more case studies of cities addressing climate adaptation in the strategy documents (Grafakos et al., 2020, p. 12). An example of a case study, where strategy documents on climate adaptation need to be assessed to check on SDG 11.b, is in the southern region of the province of Limburg in the Netherlands. In July 2021 south-Limburg and big parts of Belgium and Germany were struck by extreme rainfall and river flooding of the Maas and Rijn caused by the effects of climate change (Task Force Fact Finding hoogwater 2021, 2021). A lot of financial damage has been done to housing and infrastructure in the areas, as well as societal and emotional damage (Task Force Fact Finding hoogwater 2021, 2021). This even costed a few people's lives. The TU Delft has done an evaluation on how this major flooding could have happened and what damages it has caused to the area. It is important to evaluate future climate adaptation strategies to be more prepared for these kinds of extreme weather events in the future.

Assessing the current strategy documents of Maastricht on climate adaptation can give an insight to what extent climate adaptation is addressed in the strategies. The conclusions of this evaluation might be useful for cities in Belgium and Germany in the affected region of flooding in 2021, but for other Dutch cities along rivers too. It is useful for those Dutch cities, because the events in 2021 caused river flooding.

Research problem

As stated in the background of this research more evaluation is needed on the assessment of climate adaptation in strategy documents. The aim of the research will be to assess the

strategies around climate adaptation of the city of Maastricht and give recommendations in the end after the evaluation. It is important to know how climate adaptation is addressed in Maastricht's strategy. Especially because of the damage that has already been done by the effects of climate change in 2021 in the region, this should be a priority. Based on this the following research question will be answered: To what extent is climate adaptation addressed in the current strategies of the city of Maastricht?

To assess the climate adaptation strategies in more detail and give recommendations for improvement of the climate adaptation strategies of Maastricht, the following sub-questions will be:

- What is the definition of climate adaptation?
- How do the climate adaptation strategies of Maastricht comply with the criteria of the assessment?
- What could be recommendations for the climate adaptation strategies of Maastricht?

Theoretical framework

Concepts and criteria

Before assessing the strategy documents of Maastricht and giving recommendations it is important to understand the main concept: climate adaptation. Climate adaptation are measures that (will) adjust to current and future negative climate change effects (Janetos, 2020). These are also measures that minimize the risk of damage of extreme weather events as much as possible, such as heat waves and extreme precipitation events (Janetos, 2020). Climate adaptation is about minimizing the risk as close to a 100% as possible, because of unforeseen events in the unpredictable and complicated future it could never be fully leakproof (Janetos, 2020).

In order to evaluate to what extent climate adaptation is addressed in current strategies of Maastricht, criteria for assessment are needed. Below is an overview (table 1) of all criteria of the assessment. These criteria are based on the building blocks of how an integrated adaptation strategy should look like. Integrated adaptation consists of three elements (figure 1), which each overarch multiple sectors and components: protection, resilience and risk management (Cord et al., 2008). The first element is protection, which is about infrastructural elements or other measures to directly prevent flooding, protect vulnerable areas, and reduce possible damage (Cord et al., 2008; de Bruin et al., 2009). These elements of protection or security can be in the form of dikes and levees, which are examples of hard engineering structures to prevent an area from being flooded (Scheres and Schüttrumpf, 2019). A second possibility for protection is making room for the river, which is more flexible and is a soft engineering strategy (Zevenbergen et al., 2015). Instead of reinforcing and increasing dikes and levees, more space is given to the river to flow through to prevent flooding (Rijkswaterstaat, n.d.). Therefore it is needed for Maastricht to have measures like this in either form. The criteria of ‘hard engineering’ and ‘soft engineering’ for the element of ‘protection’ are in the overview (table 1) below and include some detail.

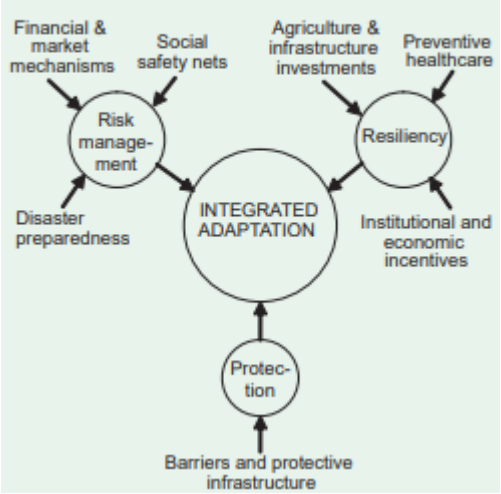

Figure 1: The main elements of an integrated adaptation strategy (Cord et al., 2008).

The second element is resilience, which consists of climate adaptation measures to the agricultural, infrastructural, industrial, ecological, and health sector (Cord et al., 2008). Adaptation to the agricultural sector is about investments and measures in climate change resisting agriculture against extreme weather events (de Bruin et al., 2009). For the infrastructural sector climate adaptation is about public utilities such as electricity, sewage and (drink)water, but also about public transport and public space that are climate adaptive and are prepared for extreme weather events (de Bruin et al., 2009). Public space is a big part of a city's infrastructure and they can play a major role in weathering climate change (Peinhardt, 2021). The meaning of public space in this research is that it is accessible for everyone, for example parks and squares, but also sidewalks, bike paths and (car)roads count as public space (Peinhardt, 2021). This means the criteria around public space will contain climate adaptive measures around these features. At last there is also private infrastructure, like the inhabitant's own property that can contribute to the climate adaptivity of a city as well. This means that in the sector of infrastructure, there are four separate criteria: public utilities, public transport, public space, and private infrastructure.

Companies in the industrial sector in chemistry, petrol, and energy that are risk prone, should be resilient for possible calamities whenever extreme weather events occur (de Bruin et al., 2009). Then there is the ecological sector, which is about the protection of species and strengthening and conservation of nature, for example the National Ecology Network against climate change (de Bruin et al., 2009). At last there is the healthcare sector, which should be addressed in climate adaptation strategies, regarding problems such as heat stress, increase of diseases, and increase of toxic algae (de Bruin et al., 2009). These problems occur due to climate change.The criteria for these five sectors of 'resilience' are in the overview below (table 1) .

The last element of an integrated adaptation strategy is risk management, which is about disaster preparedness and social safety nets (Cord et al., 2008). Disaster preparedness is about safety/evacuation plans and routes, while social safety nets are about the social security and aftercare of households and companies including insurance and compensation, especially for vulnerable and poor people after extreme weather events (de Bruin et al., 2009; Cord et al., 2008). The criteria for risk management are in the overview below (table 1)

A final element for the assessment of climate adaptation strategies is about the communication and coordination of stakeholders such as the national government, provinces, municipalities and other relevant stakeholders (de Bruin et al., 2009). There needs to be a clear division who has which task and what the responsibilities are of each stakeholder in climate adaptation measures. This makes it more clear who has which role, and this will result in better coordination and communication between the stakeholders (de Bruin et al., 2009). This criteria also includes for example the involvement of inhabitants in climate adaptation by the government and municipality. The criteria for communication and coordination of stakeholders are in the overview below (table 1).

Table 1: Criteria of the assessment for the climate adaptation strategies.

Element of integrated strategy and its variables	**Main criteria**	**Details**
Protection (Hard engineering)	Infrastructural hard engineering structures as dikes and levees are added and/or improved to prevent direct flooding	Especially for protection of vulnerable areas and direct prevention of (river) flooding
Protection (Soft engineering)	More space is given to the river to flow to prevent direct flooding	Especially for the protection of vulnerable areas and direct prevention of river flooding
Resilience (Agriculture)	Investments and measures on climate adaptive agriculture are referred to	To adapt to these extreme weather events caused by climate change
Resilience (Infrastructure/Public utilities)	Investments and measures in climate adaptive public utilities are referred to	This indicates electricity, sewage and (drink)water
Resilience (Infrastructure/Public transport)	Investments and measures in climate adaptive public transport are referred to	For example railways and stations
Resilience (Infrastructure/Public space)	Investments and measures in climate adaptive public space are referred to	For example highways, bike paths and sidewalks, but also squares and parks
Resilience (Infrastructure/Private infrastructure)	Investments and measures in climate adaptive private infrastructure are referred to	This indicates inhabitant's own property
Resilience (Industry)	Measures for the resilience of risk prone companies are referred to	For example in chemistry, petrol and energy or any other risk prone company
Resilience (Ecology)	Climate resilience of nature areas is referred to in terms of flora (plants) and fauna (animals)	Protection of species and strengthening and conservation of nature, for example the National Ecology Network (Natura 2000 in Netherlands)
Resilience (Healthcare)	Measures for preventive healthcare to climate change is referred to	Regarding problems of heat stress, diseases, and toxic algae
Risk management (Social safety nets)	Measures for social security and aftercare of households and companies (including insurance and compensation) are referred	Especially for vulnerable and poor people; After extreme weather events

	to	
Risk management (Disaster preparedness)	Safety/evacuation plans and routes are referred to	For the occurrence of extreme weather events
Communication and coordination of stakeholders	Clear division of tasks and responsibilities of the different stakeholders is referred to	Examples of stakeholders in terms of climate adaptation are water boards, provinces, municipalities, companies, etc., but also involvement of inhabitants

Conceptual model

The conceptual model in figure 2 below will visualize how the research will be conducted. The model starts with the academic and social relevance from which a research question with subquestions will be formed. To answer the research question a theoretical framework is needed which explains the main concept of climate adaptation. In this theoretical framework the methodology will be explained in more detail with the criteria for the assessment of the strategy documents. With these criteria the strategy documents will be fully analyzed in detail. After the assessment the recommendations will be given to the developers of the strategy documents.

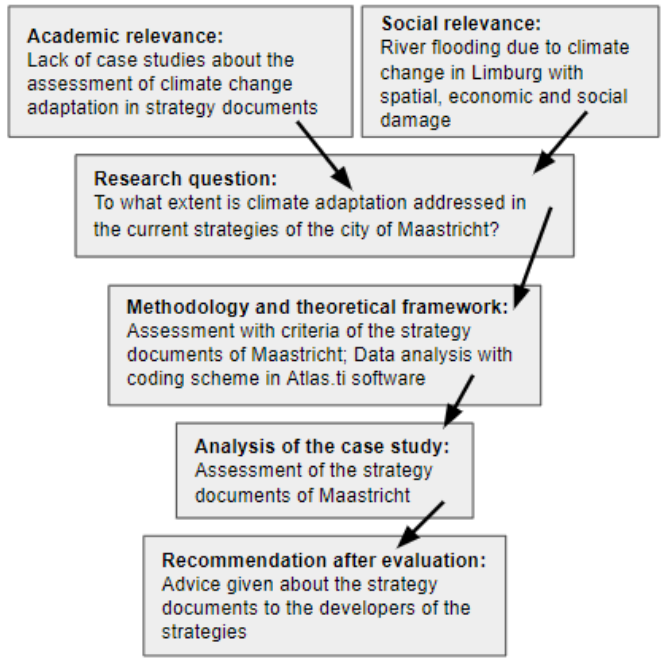

Figure 2: The conceptual model of the research.

Methodology

Why an evaluation and why for Maastricht?

To reflect whether or not these climate adaptation strategies are resilient for the future, doing an evaluation on these is crucial (Uitto et al., 2017). Evaluation of strategy documents helps with learning about the complex challenges that we are facing due to climate change in the future and make cities more resilient. With the outcomes after the assessment of these strategies we can increase the effectiveness by making strategies more integrated and by minimizing the trade-offs (Uitto et al., 2017). In this evaluation there will be a case study assessment, which is a detailed content analysis of a strategy document or in this case multiple documents to get a full overview of climate adaptation measures.

The case for this research is the city of Maastricht with the main focus on climate adaptation measures in its strategy documents. For this city there is societal relevance to check to what extent climate adaptation is addressed in its strategy, because in July 2021 south-Limburg was hit by extreme rainfall and river flooding of the Maas (Task Force Fact Finding hoogwater 2021, 2021). In Maastricht itself 10.000 inhabitants were preventively evacuated, which shows Maastricht was not ready enough to handle these events. Assessing the current strategy documents around climate adaptation of Maastricht, might give an insight if the city is dealing enough with this theme and is as close to a 100% prepared as possible for climate change events in the future. As stated in the background section before, the conclusions of this evaluation are not only useful for Maastricht itself, but also for German and Belgian cities affected by the events of 2021 and Dutch cities along a river.

Which data will be used?

In order to answer the research question, which is ‘To what extent is climate adaptation addressed in the current strategies of the city of Maastricht?’, the strategy documents about climate adaptation of the city Maastricht need to be analysed. This data is primary data and in the research the following documents will be analysed: Omgevingsvisie 2040 Maastricht deel 1 & 2, Waterprogramma Maastricht 2023-2027 and Klimaatadaptatie strategie Maastricht 2023-2027. These documents should contain most information about the climate adaptation measures of Maastricht. All these documents are strategy plans and more detailed productions of these strategy plans, which are intended for the municipality of Maastricht and the region of the Maas.

At first there is the Omgevingsvisie 2040, which is a document on how the physical living environment of Maastricht should be developed until 2040 and is not completely about climate change (adaptation). An Omgevingsvisie is an official plan document, in which a municipality establishes its ambitions and policies for the physical living environment for the upcoming years (Informatiepunt Leefomgeving, n.d.). This is an integrated vision in which all different sectors of the living environment are discussed, for example water, nature, infrastructure, traffic, and cultural heritage (Gemeente Maastricht, 2020). In this document the different aspects are interconnected with each other to form an integrated strategy. In part one of the Omgevingsvisie the vision itself is discussed, while in the second part all policy goals are discussed per sector connected to the vision in part one. This document has been solely made by the municipality of Maastricht, but the document has been formed together with representatives of several involved companies and a few involved citizens (Gemeente Maastricht, 2020). The creation of this vision has been done with an open dialogue approach.

The second document is the Waterprogramma Maastricht 2023-2027, in which all municipal tasks around water are established. The program is about the duties of the municipalities towards wastewater, rainwater and groundwater (Nelen & Schuurmans, 2022b). These duties also affect other themes and activities like climate adaptation, which is the reason why it is included in the evaluation to get a full overview of all climate adaptation measures.

Before the establishment of the Waterprogramma, the common goals and actions of all stakeholders of the partnership of Maas en Mergelland had been written down in the Waterketenplan (Nelen & Schuurmans, 2022). In the water program these goals and actions were worked out to measures on a municipal level of Maastricht. All goals and actions of the Omgevingsvisie 2040 and Waterprogramma Maastricht 2023-2027 are further developed in climate adaptation strategies (Nelen & Schuurmans, 2022a). This strategy on the municipal level is called the Klimaatadaptatiestrategie Maastricht 2023-2027. This last document is focusing on climate change adaptation only in the municipality. It describes how the municipality wants to prepare for climate change and its extreme weather events (Nelen & Schuurmans, 2022a). This document is composed with different departments of the municipality and partnerships outside the municipality. All three documents are assessed as total and not individually.

Variables

In this research the city of Maastricht and especially the strategy documents towards climate adaptation are the case. To assess the strategy documents in detail, multiple variables with sometimes multiple criteria will be analyzed in this research. The variables are mostly based on different sectors and the criteria on the measures of these sectors towards climate adaptation. The following variables will be analyzed: protection, agriculture, infrastructure, industry, ecology, healthcare, social safety nets, disaster preparedness, and communication and coordination of stakeholders. The variables will be translated into different criteria, sometimes multiple per variable. All variables are summed up in the coding tree below (figure 3) to show which criteria are used for the research. These variables and criteria are stated in table 1 under the section about the theoretical framework.

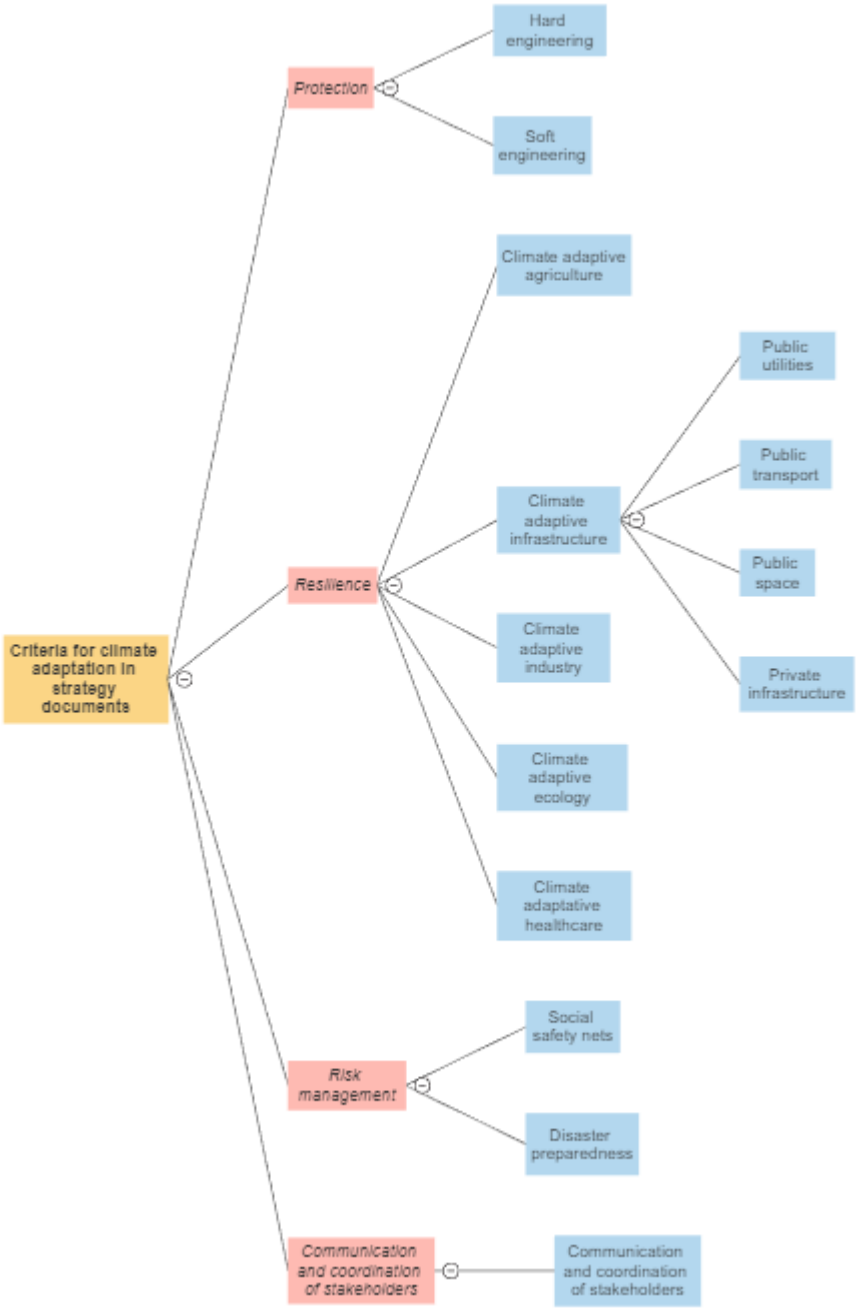

Figure 3: Coding tree for the different criteria on climate adaptation

Scoring system

To measure to what extent certain criteria of climate adaptation are addressed, a scoring system is used (Preston et al., 2011). Preston et al (2011) use the scores 0, 1, and 2, which are explained in table 2 below. In this research the criteria will be scored too with numbers 0, 1, and 2 to find out to what extent climate adaptation is addressed for each criteria. The conditions of the scoring system, which are from an article of Preston et al. (2010), have been redesigned, but the scoring numbers stay the same. A score of '0' for a criterion means that there is "No evidence or consideration for a particular criterion was apparent" in the document, which suggests the criterion was neglected in the climate adaptation strategy (Preston et al., 2010, p. 419). A score of '1' for a criterion means that "Evidence exists of

consideration of a particular criterion", which means the criterion or a goal for the criterion is referred to without any added implementation details or an explanation of further action (Preston et al., 2010, p. 419). A score of '2' for a criterion means that "Evidence exists of consideration of a particular criterion" with more detail, which means the criterion is referred to with added implementation details or an explanation of further action (Preston et al., 2010, p. 419). A score of '1' or '2' determines to what extent a variable is included, while a score of '0' means a variable is excluded. If in a case there are multiple measures for a criterion, from which one has added implementation details or explanation of further action, and the other one has not, it is weighed which measure is most important to give a final score. With the scores of criteria it is easier to see what is excluded or what criterion needs to have more detail in the strategies. By scoring these criteria it is possible to give recommendations about the strategies to the developers.

Table 2: Scoring system for the extent of consideration of a criterion (Preston et al., 2010, p. 419).

Score	**The extent of consideration of a criterion**
0	"No evidence or consideration for a particular criterion was apparent".
1	"Evidence exists of consideration of a particular criterion", which means the criterion or a goal for the criterion is referred to without any added implementation details or an explanation of further action.
2	"Evidence exists of consideration of a particular criterion" with more detail, which means the criterion is referred to with added implementation details or an explanation of further action.

Analysis steps

The first step in the analysis of data is to transfer the three strategy documents in a coding program named Atlas.ti. In this program all criteria of the assessment will be placed too, which are based on the variables. The next step is reading in detail the documents and manually linking all relevant quotations to a related criterion. These quotations contain elements of climate adaptation measures or are referred to the criterion. Of course there is a possibility of human error when linking these quotations manually. When some quotations are missing, this can influence the outcomes of the assessment. After the coding of all documents is done, all quotations linked to a criterion will be read again to see which quotations are useful for the scoring and to what extent certain criteria are addressed. All criteria will then be scored with 0,1, or 2, this depends on what the quotations are about and what scores these quotations get the most. After the scoring is done, it is clear which criteria are addressed (enough) and which are excluded in the strategy documents of Maastricht. Based on these scores a recommendation is given to the developers and the municipality of Maastricht and general lessons can be formed for other cities.

Ethics

With the recommendation for the developers in mind at last there is an ethical consideration in this research, which is about making this evaluation public without consent of the developers of the strategy, the municipality of Maastricht and other involved stakeholders. As stated in the strategy document itself, it is not allowed to use and share any information without consent (Nelen & Schuurmans, 2022b). As this research is done by an outsider from the institutions which developed these strategies, the recommendations will only be shared with the institutions itself after the assessment and will not be made public to prevent any harm to the institution's and Maastricht's image.

Results

At first in the results section will the quotations per criterion be quantified in table 3 below. In this table all 13 criteria and the total number of quotations per criterion will be listed. A notable remark is that it is possible that some quotations are used for multiple criteria. Another remark is that it is possible that some quotations from the strategy documents are not marked, because these were exactly the same or it was not clear enough if a quotation was referring to climate adaptation. After the quantification of the quotations each criterion will be separately discussed in this section.

Table 3: Quantification of the total number of quotes used for the scoring of each criterion

Criterion name	**Total number of quotations for a criterion**
Protection (Hard engineering)	4 quotations
Protection (Soft engineering)	12 quotations
Resilience (Agriculture)	4 quotations
Resilience (Infrastructure/Public utilities)	13 quotations
Resilience (Infrastructure/Public transport)	1 quotation
Resilience (Infrastructure/Public space)	46 quotations
Resilience (Infrastructure/Private infrastructure)	11 quotations
Resilience (Industry)	2 quotations
Resilience (Ecology)	11 quotations
Resilience (Healthcare)	33 quotations
Risk management (Social safety nets)	0 quotations
Risk management (Disaster preparedness)	7 quotations
Communication and coordination of stakeholders	27 quotations

Hard engineering

The protection criterion of hard engineering indicates the addition or improvement of dikes or levees as a direct prevention of flooding in the strategy documents. Three of the total four quotes were all the same form of a principle in combination with a soft engineering measure. This principle is “Ruimte waar het kan en dijken waar het moet”, which means giving more room for the river to flow through where it is possible and adding dikes or levees where it is necessary (Gemeente Maastricht, 2020, pp. 66,93; Nelen & Schuurmans, 2022a, p. 22).

Soft engineering

The protection criterion of soft engineering indicates that more space is given to the river to flow through as a direct prevention of flooding in the strategy documents. Three of the total twelve quotes relate to the same principle as stated in the paragraph about hard engineering. Eight other quotes relate to measures to give more space to the river of the Maas, from which five give specific parts or locations along the Maas where these river widening measures need to be implemented. The specific locations are along the eastside of the river at the height of the inner city until three kilometers towards the north and south of the inner city in the ‘Zuidelijk Maasdal’. The last quotation left is not a measure itself, but indicates several specific locations where potential soft engineering measures should be explored further, for example the deepening of the summerbed of the river (Gemeente Maastricht, 2020, pp. 93-94).

Agriculture

The criterion for climate adaptive agriculture indicates investments or measures on climate adaptive agriculture. Two of the four quotes describe the problem that climate change causes extreme drought, which led in the past and might lead in the future to huge damage to the harvest. One quotation describes that agricultural land should be used as sustainable as possible (Gemeente Maastricht, 2022, p. 110). The last quote, which is in the Klimaatadaptatiestrategie Maastricht 2023-2027, describes that agricultural lands are going to be transformed continuously to biological or nature inclusive agricultural lands or to nature towards 2040 with focus on a few specific areas around Maastricht (Nelen & Schuurmans, 2022a, p. 32).

Public utilities

The criterion for public utilities indicates investments or measures on climate adaptive public utilities as electricity, sewage and (drink)water). All thirteen quotes are related to the sewage system and especially focused on the disconnection of rainwater from the wastewater to prevent flooding. Two quotes specify locations where this is needed, because these are flooding nuisance locations, for example the Vroenhovenweg and adjacent neighbourhoods of the Tuinen van Maastricht (Gemeente Maastricht, 2020, p. 78; Nelen & Schuurmans, 2022b, p. 17). Three other quotes describe a continuous process of disconnection of rain water from the sewage system in the upcoming years in combination with (re)developments and infrastructural activities. One quotation describes a principle that underground pipes for rainwater only are constructed when there is a lack of space in an area (Gemeente Maastricht, 2020, p. 91). A last quotation describes the extra problem when too much rainwater is discharged through the sewage system, because then wastewater overflows in a water environment of flora and fauna, which is toxic for them (Gemeente Maastricht, 2020, p. 91).

Public transport

The criterion for public transport indicates investments or measures on climate adaptive public transport. There was only one quotation for the scoring of the criterion in the strategy documents. In the Omgevingsvisie Maastricht 2040 is stated that there is the ambition to develop the central station to a bigger station (Gemeente Maastricht, 2020, p. 50).

Public space

The criterion for public space indicates investments or measures climate adaptive public space as squares and parks, but also roads, bikepaths and sidewalks. All 46 quotes relate to the problem of flooding nuisance or heat stress, from which the effects can be lowered by different types of measures. Of these quotes were 34 related to an increase, improvement or conservation of different forms of greening on different scales and locations in the city of Maastricht. For 11 quotes this greening should be done in combination with infrastructural activities or other (re)developments of the public space. Seven quotes specify the need for more greening in neighbourhoods itself, for example Malmberg where a green buffer element will be added to reduce flooding nuisance (Gemeente Maastricht, 2020, p. 13). While another seven quotes relate a reversed solution, which is less petrification. Three quotes specifically regard the greening of playing grounds or squares. Then there are also a few measures on climate adaptive public space in specific locations. Examples are redirecting the Franciscus Romanusweg, creating a new crossing across the Maas and redirecting rain water from the Via Regia roundabout (Gemeente Maastricht, 2020, pp. 16,74,76). These three measures are all related to lower (the risk of) flooding nuisance. Another measure is that research will be done to a disfunctioning water buffer along the Willem Alexanderweg during the event of 2021 to let it function properly again (Nelen & Schuurmans, 2022a, p. 23). Another possible measure that will be researched, is to use a past water connection (the Jekerkanaal) to buffer extreme weather events and use the canal of the Lage Fronten to delay peak discharge into the Maas and other channels (Gemeente Maastricht, 2020, p. 79). A last measure is that with the building of new high rise the public space around it should have high quality with focus on heat stress and flooding nuisance, which means greening (Gemeente Maastricht, 2020, p. 174).

Private infrastructure

The criterion for private infrastructure indicates investments or measures on climate adaptation on inhabitant's own property. In essence are all eleven quotes related to the problem of heatstress or rainwater infiltration, but with measures on private properties. All measures want to stimulate more greening, some specify more greening on roofs. Other quotes relate to less petrification of front yards, which also means more greening to lower heat stress and increase the buffer capacity of rain water on private property. Two quotes describe that new buildings should mandatorily have water buffers in advance on private properties (Nelen & Schuurmans, 2022b, pp. 15-16). Another quote relates to campaigns of the municipality to stimulate more greening on people's own property (Gemeente Maastricht, 2020, p. 78). At last there is a quote about a priority for measures on inhabitants' initiative which increase water infiltration, for example green roofs (Nelen & Schuurmans, 2022a, p. 26).

Industry

The criterion for industry indicates measures on climate resilience of risk prone companies, for example chemistry, petrol and energy. In total there are two quotes used for the scoring of the industry criterion. Both quotes related to the fact that there is permanent attention for external safety of these types of companies (Gemeente Maastricht, 2020, p. 106).

Ecology

The criterion for ecology indicates measures for climate resilience of nature areas in terms of protection and conservation of flora and fauna. Four of the eleven quotes relate to development or improvement of nature along the Maas shore or other water bodies if it increases the buffer capacity to improve flooding safety. Another three quotes describe an opportunity to conserve or increase biodiversity in combination with climate adaptation measures, for example creating amphibian friendly water buffers in stream valleys to stimulate exchange between different toad populations (Gemeente Maastricht, 2020, p. 74). At last four quotes notice the problem that nature will be harmed in different ways due to climate change.

Healthcare

The criterion for healthcare indicates measures for preventive healthcare to climate change regarding problems of heat stress, increase in diseases and toxic algae. Five quotes relate to the problem of heat stress and indicate which type of area and which specific area have the most heat stress nuisance. Specific neighbourhoods named in the strategy documents are Limmel, Nazareth, Daalhof, Wolder and Biesland, which are in the south-west of Maastricht. In the Omgevingsvisie Maastricht 2040 a map is shown with prioritized areas that suffer the most from heat stress (Gemeente Maastricht, 2020, p. 81). 21 quotes contain the measure of increasing greening or blue structures for cooling against heat stress in the whole city, of which two describing this should be done in combination with (re)developments in the upcoming years. Three quotes regard a specific measure for green roofs on buildings against heat stress. One quotation about a possible, but expensive measure is to remove certain petrifications to lower heat stress as a last resource (Nelen & Schuurmans, 2022a, p. 26). Another quote regards a cooling element of rain water elements to prevent heat islands in the city (Gemeente Maastricht, 2020, p. 91). A last quote is to use historical blue and green structures as cooling elements against heat stress (Gemeente Maastricht, 2020, p. 189).

Social safety nets

The criterion for social safety nets indicates measures for social security and aftercare of households and companies (including insurance and compensation) after extreme weather events. In the three researched strategy documents zero quotations were found for this criteria.

Disaster preparedness

The criterion for disaster preparedness indicates safety or evacuation plans and routes for the occurrence of extreme weather events. One quote explains that more research will be done to find a fitting calamity plan for flooding safety, while two other quotes explain that more research will be done if a regional heat protocol is necessary, or even more local on city scale (Nelen & Schuurmans, 2022a, p. 16,26,33). Another quote describes that the safety region already has a calamity plan and the municipality of Maastricht already has a flooding guide. Both the plan and guide are partially up to date, but will possibly be adjusted after current evaluations. The last quote regards a general goal of the

Klimaatadaptatiestrategie Maastricht 2023-2027 to have a clear calamity control plan to minimize possible damage (Nelen & Schuurmans, 2022a).

Communication and coordination of stakeholders

The criterion of communication and coordination of stakeholders indicates a clear division of tasks and responsibilities of the different stakeholders, but also involvement of inhabitants. Nine quotes relate to better cooperation in the future with different institutions within or outside the city to come up with climate adaptation measures. Another nine quotes relate to the fact that the municipality wants to involve the inhabitants, companies, and society more and make it a permanent part in making climate adaptation policy choices. A measure for this is for example awareness campaigns about climate adaptation for inhabitants. Thereby wants the municipality to have a collective agenda where the inhabitants' wishes and the government's ambitions are connected, which can be done through dialogue with inhabitants and other stakeholders (Gemeente Maastricht, 2020, p. 119). Two other quotes describe a clear division of responsibilities about flooding safety. The province and water board are responsible for the realisation and reinforcement of dikes, while the national government and water board are responsible for measures against river flooding of the Maas (Nelen & Schuurmans, 2022b, p. 4; Nelen & Schuurmans, 2022a, p. 10). The partnership Maas and Mergelland is carried on, but will be improved in terms of more regular meetings, knowledge exchange, and making clear responsibilities for each stakeholder within the cooperation to make climate adaptation more effective and efficient (Nelen & Schuurmans, 2022a, p. 17). Maastricht will play an active role in the improvement of this cooperation, because these measures have a big influence on Maastricht itself (Nelen & Schuurmans, 2022a, p. 17). At last there are three quotes regarding better cooperation with the water board for flooding safety, with agricultural and nature conservation institutions to see to what extent they can buffer more water and with housing corporations to decrease flooding nuisance from the sewage system.

Overlapping criteria

In the previous sections all important outcomes of the quotations of the different criteria have been described. Thereby there were also a lot of quotations which overlapped with multiple criteria and might tell something about the integration of climate adaptation in the strategies. The biggest overlap in criteria are measures regarding the reducement of heat stress (healthcare) in the public space. These sixteen quotes all indicate cooling or greening measures to reduce this problem in as well the inner city as neighbourhoods. Besides that, there are three quotations concerning private infrastructure and heat stress, where measures are described to implement cooling or greening elements on private property. Another important overlap are three quotes about public utilities and ecology. These quotes concern measures to make a climate adaptive sewage system to prevent flooding nuisance and overflow of toxic waste in nature. At last there is an overlap of three quotes about hard and soft engineering, which is an ambition to implement room for the river measures as much as possible, but implement dikes if really needed.

Conclusion

Conclusion and final scoring of the criteria

In the results section all important quotations of all three strategy documents are briefly discussed, which are going to be assessed to give a total score for each criterion. After the scoring of each criterion, the main research question “To what extent is climate adaptation addressed in the current strategies of the city of Maastricht?” can be answered. All final scores of the different criteria are summarized in table 4 below. The hard engineering criterion gets a score of 1, while the soft engineering criterion gets a score of 2. In both criteria the principle of “Ruimte waar het kan en dijken waar het moet” is marked, but this is only a general rule that the municipality of Maastricht wants to apply. While no clear measures with any details are found for hard engineering, there are a lot of clear measures with implementation details for the soft engineering criterion. The next criterion for climate adaptive agriculture gets a final score of 0. The quotes found only give detail on the problem that climate change causes for agriculture, but no measures or clear goals are given. Investments in agriculture are an important element of an integrated climate adaptation strategy (Cord et al., 2008). The strategy of Maastricht lacks this element according to the theoretical model. There is no clear cause why this is not included, because the problem of agriculture is addressed in the documents.

The criterion for public utilities gets a score of 2, because there is a clear climate adaptation measure to disconnect rain water from the sewage system. There is a clear explanation of further action that in the upcoming years it will continuously be disconnected, but also with a few examples of places which need priority due to flooding nuisance. The disconnection does not only tackle a flooding nuisance problem, but also prevent harm to nature due to an overflow of toxic waste. Measures for climate adaptive public utilities are therefore also an integrated measure in the strategy documents. A score of 0 is given to the criterion of public transport, because nothing related to climate adaptation is referred to in the strategy at all. The public space criterion gets a score of 2, because a lot is discussed in the strategies about more greening and less petrification to tackle flooding nuisance and heat stress in the public space. Thereby are often implementation details of specific locations or areas referred to, which are important to improve or is there a clear explanation of further action to increase greening in public space in combination with infrastructural activities or (re)developments. For climate adaptivity measures in public space there is a lot of overlap with healthcare in reducing heat stress. This indicates a clear integration of the two sectors to tackle problems and goals more integrative. A good indication of an integrated adaptation strategy. Next does the criterion for private infrastructure also get a score of 2, because clear measures or regulations are referred to to make inhabitant’s own property more climate adaptive. New buildings should have water buffers mandatory and awareness campaigns with priority to climate adaptive measures on citizen’s own initiative are examples of these. These measures for private infrastructure are also linked to heath stress and are in that sense a more integrated measure.

The criterion of industry gets a score of 0, because no quotes relate to climate resilience of industry, only that there is attention to external safety in general. A score of 0 is given to the criterion for ecology. In most quotes only the problems caused by climate change to nature or chances to link climate adaptation measures to increase biodiversity are addressed. Other

quotes relate to expansion of nature only if it increases the buffer capacity and flooding safety, but these measures are clear enough or contain enough details to get a score of 1 or 2. The criterion for preventive healthcare against climate adaptation gets a score of 2, because there is a clear overall measure to lower heat stress with an increase in greening and decrease in petrification in the whole city. Thereby have some quotes a clear explanation for further action on where and how to use these measures against heat stress.

A score of 0 is given to the criterion for social safety nets, because nothing has been referred to in the documents about this. Social safety nets are also an important element of the theoretical model of Cord et al. (2009), which is lacking in the strategy of Maastricht. On the other hand the criterion for disaster preparedness gets a score of 1, because more research will be done on calamity plans, guides for flooding and regional heat protocols to minimize damage during extreme weather conditions, but no further details on what is in these plans. Disaster preparedness is also an important element in the theoretical model of Cord et al. (2009). The last criterion for the coordination and communication of stakeholders gets a score of 1. There is a lot of emphasis on improvement of cooperation with other involved stakeholders with climate adaptation, more citizen involvement and an improvement of the partnership of Maas and Mergelland. Although not a lot is said about responsibilities and tasks of stakeholders for specific implementation of climate adaptive sectoral measures.

After the completion of the scores of all criteria, the research question can be answered. It can be concluded from this research that the current strategies around climate adaptation of Maastricht lack in measures, goals and investments about hard engineering, agriculture, public transport, industry, ecology, social safety nets, disaster preparedness, and communication and coordination of stakeholders. The criteria of soft engineering, public utilities, public space, private infrastructure and healthcare got a score of two, which indicated they are addressed enough in these strategies.

These qualities and limitations of Maastricht’s climate adaptation strategy can be a lesson for other cities in the region or cities along a river. Maastricht's main type of adaptation was about the safety of inhabitants regarding flooding safety and health, which resulted in scores of 2 in the criteria for public/private infrastructure and healthcare. It is important to focus on climate adaptive public space and direct protection in climate adaptation strategies like Maastricht did to protect the inhabitants. On the other hand Maastricht had a lot less focus on elements of an integrated climate adaptation strategy from Cord et al. (2009) like climate adaptive agriculture and social safety nets. These elements are neglected or forgotten in the climate adaptation strategy of Maastricht, which made the strategy not as integrated as it should be. Other cities should take both the strengths and limitations of Maastricht’s strategy into account for their own strategies. A general lesson for other cities from the assessment of Maastricht strategy is that there should be a clear division of the importance of all different aspects around climate adaptation, but none should be neglected or be made non- or less important.

Table 4: Overview of the final scores for each criterion

Criterion name	**Final score for each criterion**

Protection (Hard engineering)	Score of 1
Protection (Soft engineering)	Score of 2
Resilience (Agriculture)	Score of 0
Resilience (Infrastructure/Public utilities)	Score of 2
Resilience (Infrastructure/Public transport)	Score of 0
Resilience (Infrastructure/Public space)	Score of 2
Resilience (Infrastructure/Private infrastructure)	Score of 2
Resilience (Industry)	Score of 0
Resilience (Ecology)	Score of 0
Resilience (Healthcare)	Score of 2
Risk management (Social safety nets)	Score of 0
Risk management (Disaster preparedness)	Score of 1
Communication and coordination of stakeholders	Score of 1

Discussion

The biggest strength of this evaluation is that the scoring system for the criteria is simplistic and thereby easy to understand. This results in a clear separation of lacking, medium and good addressed criteria in the strategy documents. This system on the other hand is also a limitation, because the criteria can only result in three types of scores: 0, 1 and 2. With this system no real nuances can be made for criteria, but the simplistic scoring system creates clarity and gives a good impression of which criteria are lacking and which are fairly good. Another weakness of this evaluation is that it is not focused enough on a specific element of climate adaptation. This means the research lacks a detailed analysis of specific elements, but gives a clear overview of what is lacking in general around climate adaptation goals and measures in the strategy documents. Further research on climate adaptation in strategy documents (of Maastricht) could be done by focusing completely on one element of climate adaptation. This can result in a more focused analysis on the specific measures of a certain element. For such research a more extensive scoring system is needed to evaluate each measure individually to find out to what extent they contribute to climate adaptation. While for a general impression of all climate adaptation measures this simplistic scoring system is a fit choice. At last another evaluation of the same criteria of this research should be done every few years. This is to check whether the criteria with a score of 2 are still addressed enough and whether criteria with a score of 0 or 1 have improved in future strategy documents of Maastricht.

Recommendations

The recommendations for the developers of the strategy documents and the municipality of Maastricht will be on the criteria with a score of 0 or 1. This means the criteria with a score of 2 are good, but should be evaluated again every few years to keep up with climate change. When using a principle like “Ruimte waar het kan en dijken waar het moet” (translated in the results about hard engineering), it would be useful to name specific areas which are more vulnerable and need additional or improved dikes, to reduce damage to these and other areas (de Bruin et al., 2009). For agriculture it would be useful to name clear measures or goals against the named problems in the strategy documents. In the documents the problem is specifically named that climate change causes drought, which causes damage to agricultural lands or harvest, but no measures are given for this (Nelen & Schuurmans, 2022a, p. 11). Examples of possible measures are crop variation and improvement of the irrigation systems to spread the risk of possible harvest loss (de Bruin et al., 2009). It is important for Maastricht to make progress in this to comply with the theoretical model of Cord et al. (2009).

Another criteria lacking in the strategy documents was public transport. In the Omgevingsvisie Maastricht is named that the central station will be developed into a bigger station, but nothing else for this development is named regarding climate adaptation (Gemeente Maastricht, 2020, p. 50). While it could happen that extreme weather events can cause damage here or disturb the public transport. Measures to reduce damage or distribution would be needed to protect public transport and especially a new main station (de Bruin et al., 2009). For ecology it would be recommended to form clear measures regarding the protection and conservation of flora and fauna in nature against climate change, especially because the problem itself is named that damage is done and can be done by climate change (de Bruin et al., 2009; Nelen & Schuurmans, 2022a, p. 11; Gemeente Maastricht, 2020, p. 91). Another recommendation would be for more clear measures to climate resilience industry, especially for risk prone companies (de Bruin et al., 2009, p. 38).

Another recommendation is that there needs to be more clarification in climate adaptation documents on social security and aftercare of households and companies after extreme weather events related to climate change. Maastricht should also make more progress in including this in the following strategies, because it is an important element in reassuring the inhabitants’ safety. Thereby should these documents contain more details of the improved content of calamity or other safety plans (de Bruin et al., 2009). At last would be recommended to specify more often who has which responsibility and task on clear specified climate adaptation measures. It is important to improve coordination and communication between different governmental bodies (national, regional and local) to successfully implement climate adaptation measures (de Bruin et al., 2009).

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