Climate Risks Vulnerability Assessment for Built Heritage: Investigation in Gorinchem, the Netherlands

Xiaoling Wei

Research Paper | MSc Architecture, Urbanism and Building Sciences
Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands

Research Tutor: **Wido Quist**

Abstract

In the context of rapid climate change, heritage buildings are potentially affected by climate hazards, but the susceptibility varies. This study investigates the value and climate vulnerability of 15 national monuments and 15 municipal monuments in Gorinchem. By analyzing five value dimensions of the research objects: age, social, functional, memorial, and aesthetic; and the assets' vulnerability to flooding, drought, and overheating, six buildings were identified as highly at risk of value loss. The methodology includes qualitative and quantitative approach, analyzing the sites based on the value matrix and climate-risk mappings.

Keywords

Heritage, Architecture, Value Assessment, Vulnerability, Climate Risk, Mapping, Gorinchem

1. Introduction

Climate-related disasters such as rising sea levels, floods and drought are affecting the sensitive delta areas in the Netherlands significantly. In the basin area between the rivers Lek, Merwede, and Noord, a flood-prone region called the Alblasserwaard-Vijfheerenlanden (A5H) has been recorded victim of flooding at least 33 times since the dikes were built in 1277. (Schakel, M.W, 1977) In the last few decades, the global climate change increasingly affects the built structures and human living environment. Cultural heritage sites, such as historic buildings and landscape, are especially at risk. (Arrighi, 2021) In 2019, a research was conducted into the consequences of extreme weather on the Alblasserwaard-Vijfheerenlanden region. It was found that heat and rainwater flooding are the primary climate effects. (Klimaatadaptatie, n.d.)

In the year 1995, Gorinchem, one of the riverine cities in this region, barely escaped a disaster caused by constantly high water levels, lots of precipitation, strong winds and insufficiently reinforced dikes. (De Stad Gorinchem, 2015) (Fig. 1.1) (Fig. 1.2)

Fig.1.1. High water in 2015, twenty years after the flooding in 1995. ©GP-photo

Fig.1.2. Screenshots of a Video Taken in 1995, Showing the Degradation of Building Due to Excessive Water. ©Jan Boshoven.

Gorinchem is the meeting point of four provinces, as well as the intersection point of Old Holland Water Line (Dutch: Oude Hollandse Waterlinie) and the extension of Water Triangle (Dutch: Waterdriehoek), which are two Cultural Heritage Lines (Dutch: Cultureel Erfgoed) proposed by the South Holland Province. (Fig. 1.3) It holds great significance geographically and strategically in climate actions.

Moreover, Gorinchem possesses extremely rich historical and cultural heritage that spans different periods of time. The city dates back to around 1000 A.D. as a settlement of fishermen and farmers, then developed into a fortified medieval city, (Fortified City Gorinchem, n.d.), and had been home to a vast steel industry from 1881 to 1976. (Gorinchem, n.d.) Currently there are 215 national and 260 municipal heritage objects in total listed for protection. (Rijksdienst Voor Het Cultureel Erfgoed, n.d.) (Gemeentelijke Monumenten, n.d.) (Fig. 1.4) Those objects include both architectural and non-architectural elements, ranging from houses, factories, mills, and water tower to dikes, boundary stones, defensive walls, etc. Many efforts have been made to protect these listed buildings by governments, academics, and local initiatives focusing on some specific heritage buildings, such as the heritage foundation of De Vries Robbe (Dutch: Stichting Erfgoed De Vries Robbe) and the SIMAV mill conservation foundation (Dutch: Molenstichting SIMAV).

While the number of heritage sites is vast, their importance and susceptibility to climate risks can vary greatly. Therefore, this research aims to investigate the value and vulnerability of Gorinchem's listed heritage sites in relation to climate risks, both qualitatively and quantitatively. By categorizing and

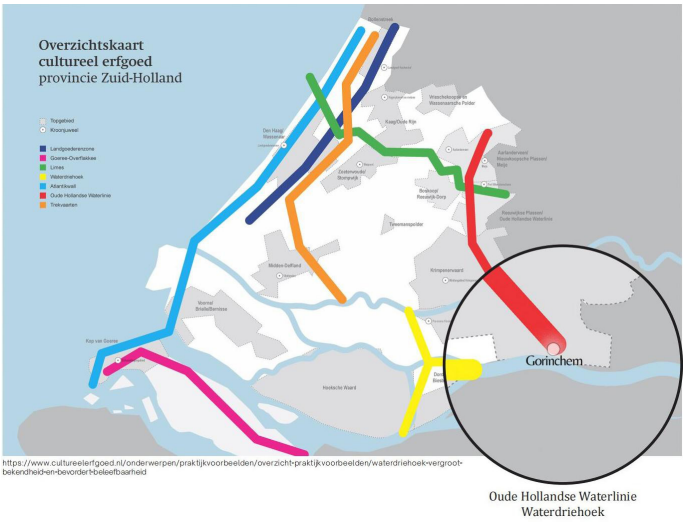

Fig.1.3. Gorinchem and Cultural Heritage Lines. ©Provincie Zuid-Holland

assessing the vulnerability and significance of each selected site, the study seeks to identify the most at-risk locations, for which specific administrative measures should be taken for better protection actions. While for other sites that are in a relatively safe status, the possibility for redevelopment or redesign is with less limitations and constrains.

While the primary focus is on listed buildings, the methodology developed in this research, including the value assessment and climate vulnerability analysis, can be adapted and applied to non-listed buildings as well. This broader application is intended to benefit the wider scope of Gorinchem's architectural heritage, particularly those not yet covered by existing protective measures. The findings will directly support the ongoing redesign of a post-industrial site in Gorinchem, providing strategic insights for protecting Gorinchem's heritage in the face of climate change.

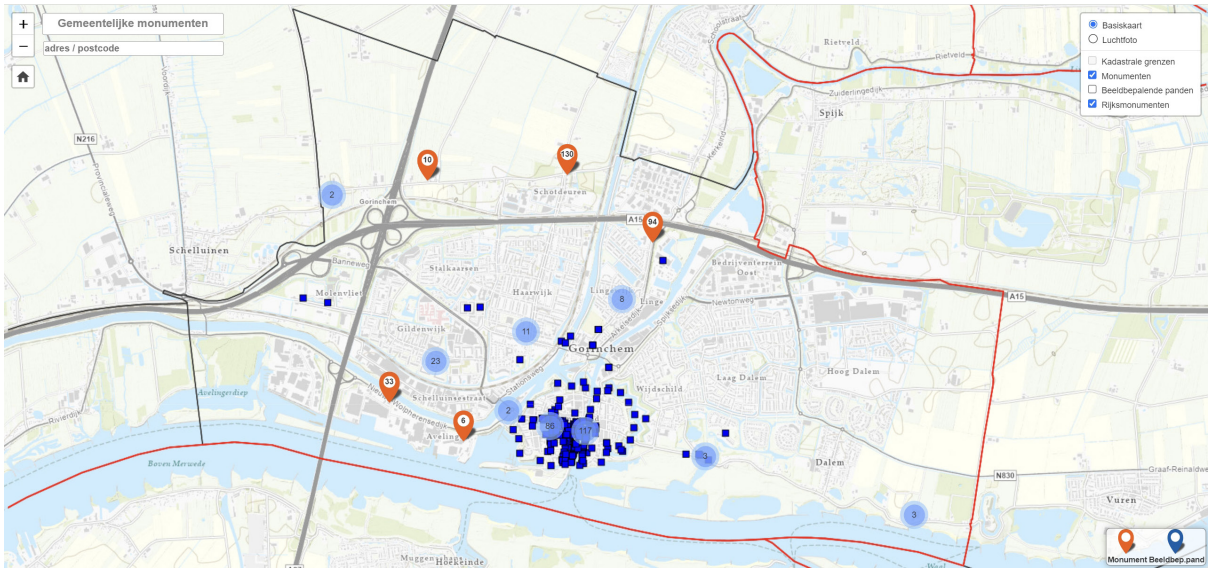

Fig.1.4. National and Municipal Cultural Heritage Sites in Gorinchem. ©Gemeente Gorinchem

2. Literature Review

There are a lot of existing research on relavent topic, presenting models and approaches to assess the vulnerability of architectural heritage to climate risks. Among them, two key methods constitutes main references for this paper.

2.1. A Qualitative Approach - Method by Brokerhof et al. (2023)

In 2023, a study conducted in Dordrecht, a municipality near Gorinchem and also part of the Waterdriehoek Area, Brokerhof et al. (2023) proposed the Quick Flood Risk Scan Method. This method is a simplified approach to assess the vulnerability of cultural heritage assets to flood risks, focusing on three components: Value, Vulnerability, and Exposure. (Fig. 2.1.1)

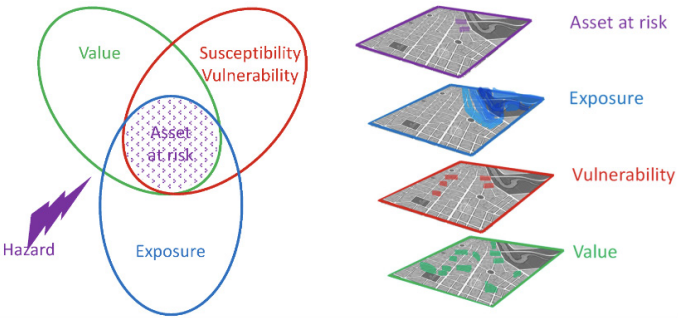

Fig. 2.1.1. Principle of the Quick Flood Risk Scan Method. ©Brokerhof et al.

The value of researched objects are classified into three categories - low, medium, and high according to their footprint, height, function, and significance. Vulnerability assesses the physical susceptibility of a building to water damage, excluding factors like adaptive capacity and social-economic aspects, also classified into three levels. Based on the outcome of the evaluation, a three-by-three matrix was generated and each researched object have its own position in this matrix that reflect potential value loss. (Fig. 2.1.2) Finally, dots presenting the researched objects on a flood hazard map are colored to correspond with the matrix, providing a risk map that visually illustrates potential losses without using numerical values. (Fig. 2.1.3)

This system is a qualitative approach to present the at-risk building assets under flood risk. Its simplicity makes it understandable to non-professionals, such as residents and other stakeholders. However, the rough classification of "low-medium-high" system is considered disadvantageous in preciseness because it is general and dismissed differences between case and case. For example, two sites both being highly valuable and vulnerable and both exposed, are not necessarily equal in potential loss. It's likely that the value of one building is high because of its structure and function, which is tangible; while for the other built structure the value embedded is more intangible, such as the atmosphere and sense of identity the place can give to its users, as brought forward by Christian Norberg-Schulz in his publication Genius Loci. (Norberg-Schulz, 1980) Thus the intangible value in this case is less subjected to physical loss. Despite the disadvantages in preciseness, this method is worth referring to due to its conciseness and straightforwardness. Its application in a relevant geographical location adds value to this research paper and enhances comparability.

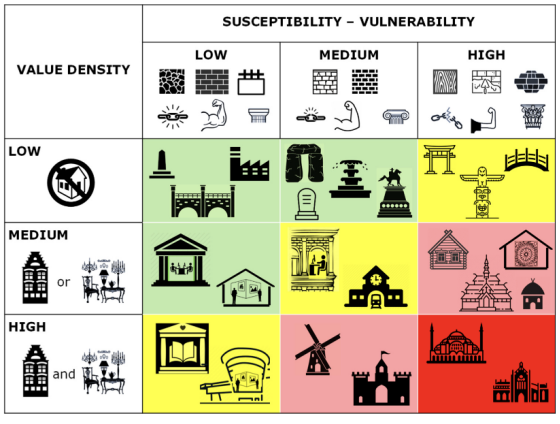

Fig. 2.1.2. Vulnerability-Value Matrix. ©Brokerhof et al.

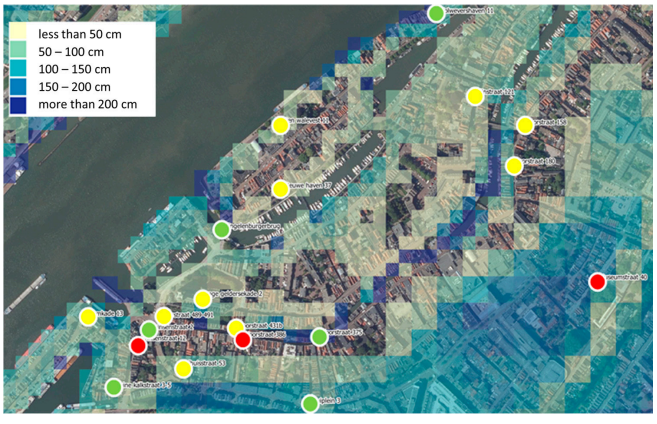

Fig. 2.1.3. Mapping of Research Objects on Hazard Map. ©Brokerhof et al.

2.2. A Quantitative Approach - Method by Stephenson and D'Ayala (2022)

Another relevant study provided a more quantitative approach to assess the flood vulnerability for built heritage. Stephenson and D'Ayala (2022) carried out flood risk assessment for a total of 600 buildings in three cities: Tewkesbury, Winchester, and York in the UK. The authors introduced seven descriptive parameters for vulnerability: age, listed status, use, footprint, number of storeys, materials and structure, and condition. The age and listed status indicate the cultural asset's value, while the building's usage reflects its revenue potential. The footprint and number of storeys assess the asset's risk exposure. Additionally, the materials and structural system reveal susceptibility to flood damage, while overall condition evaluates resilience against flooding hazards.

For each parameter, a set of attributes ranging from 3 to 5 was established through calculations to determine the maximum possible responses. These attributes were then assigned a vulnerability rating (VR) on a scale from 10 to 100. (Table 2.2)

The initial assessment of the data examines each parameter individually, analyzing how variations in responses contribute to the relative vulnerability of different building typologies across various sites. Then combining these parameters to create an overall vulnerability index (VI) for each building.

This system proved its validity identifying both individual building and site-wide vulnerability. Also, the numeric values assigned via mathematical calculation reduced the subjectivity in research and makes it more rational. However, the independence between all the seven parameters are open to debate. For example, age is a very important factor when putting a building into listed status in most of the cases; while the footprint, number of storeys and materials and structure are relatable to some extend. Additionally, when applying the method in a wider range, complication arise, due to the fact that the listing criteria for different local authorities are similar but not always completely consistent. This complexity is even enlarged when applying to locations in different countries.

Descriptor	Response	VR
Age	Medieval/Tudor	100
	Jacobean	77.5
	Georgian	55
	Victorian	32.5
	Modern	10
Listed status	Grade I	100
	Grade II*	70
	Grade II	40
	Not listed	10
Storeys	4	100
	3	70
	2	40
	1	10
Construction	Earth	100
	Timber frame	70
	Brick masonry	40
	Stone masonry	10
Condition	Poor	100
	Good	55
	Excellent	10

Table. 2.2. Vulnerability Descriptor Ratings. ©V. Stephenson and D. D'Ayala

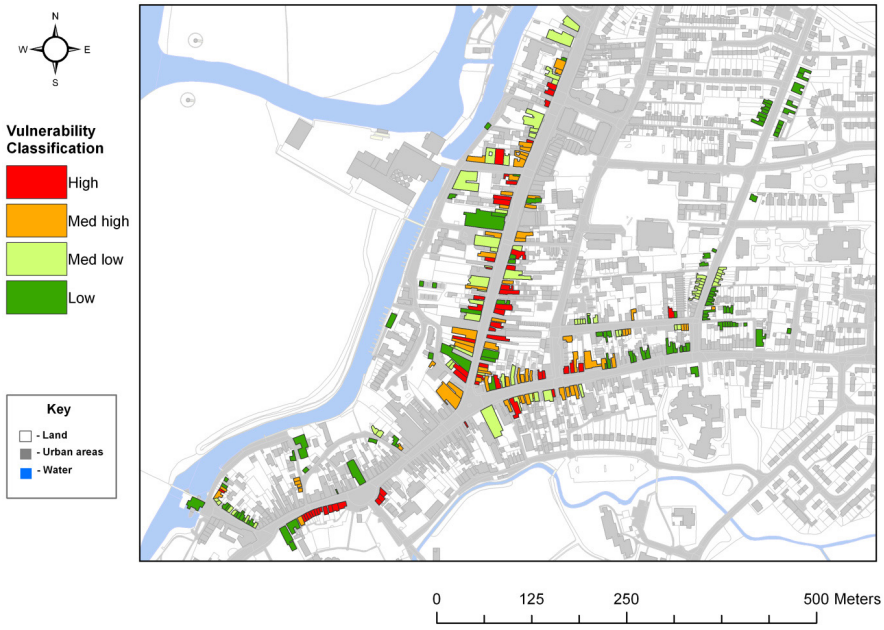

Fig. 2.2. Vulnerability Map of Tewkesbury. ©V. Stephenson and D. D'Ayala

3. Methodology

In reference to the above-mentioned two methods, a combination approach has been developed for this research, including value and vulnerability assessments.

3.1. Value Assessment Criteria

The assessment of value is based on five dimensions: age value, social value, functional value, memorial value, and aesthetic value. Each dimension is graded across four levels: ++ (highest), +(medium), 0 (neutral), and - (lowest). After assigning scores to each building for every value dimension, the scores are converted into numerical values. Specifically, "++" is assigned a value of +2, "+" a value of +1, "0" a value of 0, and "-" a value of -1. The Value Index (VI) is then calculated as the sum of all numerical scores across the dimensions. This value assessment system of five dimensions is derived from the two main literature references. Its simplicity allows straightforward comparisons between sites and provides a clear hierarchy of value. Also, it allows subjective dimensions (such as aesthetic value) and objective dimensions (such as age value) to be quantitatively evaluated on a comparable scale.

Age value, according to Alois Riegl in his publication The Modern Cult of Monuments: Its Character and Origin (1903), is testimony to the endless cycle of life and decay. (Lamprakos, 2014) In this research, the age value considers the origin and authenticity of the buildings, with the grading criteria: 1. buildings that are completely authentic, and was constructed from the medieval time to the 18th century are rated as (++); 2. buildings constructed from the 18th to the 19th century, and / or have been partly altered or rebuilt are rated as (+); 3. buildings constructed from the 19th to the 20th century, and /or with majority of alternation as (0); 4. buildings constructed from the 20th century onwards, or have been altered completely after so are rated as (-).

Social value of cultural heritage is embedded in space, as the space functions as a place for people to meet and to build a sense of belonging, developing a community's collective identity. In this way places contribute to community bonds. In this research, social value is determined by the publicness and significance of the building to the society. Public buildings that people would feel strongly connected to, such as major religious buildings and educational facilities are rated as (++), while those public buildings with less sense of social connection are rated as (+) or (0) accordingly, and the private buildings like residential houses are rated as (-).

Functional value in architecture is to fulfill the practical needs of a building's users. It is the primary goal for buildings, varying by architectural typology, user group, and design intentions. Functional value is determined by whether the building is still in use (+) or not functional (-).

Memorial spaces can evoke common memories of a family, a community or a nation, such as memorial halls, monuments, cemeteries, and family ancestral houses. Memorial value is graded high (+) to buildings that evoke local or family common memories or have been used for public memorial activities, while those that do not are rated as low (-).

Aesthetic value in architectural heritage is associated with the visual components that made up a property, including material, colour, shape, proportion, morphology, pattern, texture, craftsmanship, consistency, contrast, etc. A combination of these aspects enhance the building's appeal and provide psychological comfort to users and can affect people's mood, behavior, and well-being. Based on the above-mentioned factors, scores for each research objects' appearance are graded into very high(++), high (+), medium (0), and low (-).

3.2. Vulnerability Assessment Criteria

As in the report of the regional governmental regional study, Flood, Drought and Heat are the primary climate effects in the A5H area, including Gorinchem. (Klimaatadaptatie, n.d.) Therefore, they are the key aspects to analyze for the vulnerability. Specifically, each asset is analyzed by its location on the following climate mappings, which sourced from Atlas of Living Environment (Kaarten | Atlas Leefomgeving, n.d.): 1. Risk of Flooding from the Sea, Lake or River; 2. Maximum Water Depth in the Event of a Dike Breach; 3. Areas with Vulnerable Foundations Due to Drought; and 4. Urban Heat Island Effect index(UHI). Each mapping set enables a parallel comparison among the 30 research objects, and a bar chart is drawn to represent each object's vulnerability to a specific climate threat. With four mappings, each building has four bar charts, collectively indicating its overall vulnerability: buildings with two or more red bars are highly vulnerable, those with one red bar and/ or two or more yellow bars, are moderately vulnerable, and others are low vulnerable. With those information, a Risk-Exposure map is developed to show and compare the vulnerability for all the 30 objects.

The result of value assessment and vulnerability assessment for each building are then compared in overlapping, to identify the building asset that is facing most potential loss, which are those scores over 5 in Value Index (VI) and being highly vulnerable. These buildings are in need of specific measures for better conservation. On the other hand, a building asset that is not facing urgent threats, means that more flexible alternation or redevelopment is possible.

4. Value and Vulnerability Assessment

4.1. Research Objects Selection

In a previously done collective research (AR3AH115 Studio Work, 2024), 20 buildings of 9 typologies, which are water towers, religious buildings, energy buildings, factories, wind/water mills, barns, shipyards, dike houses, and offices in the Waterdriehoek area were selected and studied on spatial relations between water and land, and their social link and relationship with the urban context and human activities. (Fig. 4.1.1) Being one of the towns in this landscape and historical context, Gorinchem possesses rich variety and great amount of architecture heritage, with all the above-mentioned nine presented.

In this research, 15 national monuments and 15 municipal monuments in Gorinchem are selected as the objects for analysis. (Fig. 4.1.2) (Table. 4.1) The typologies vary from windmills and water tower that date back to the middle ages to more contemporary industrial heritage and residential buildings, reflecting the town's diverse architectural evolution across centuries. These buildings were chosen for their historical significance, architectural diversity, and representative role in Gorinchem's urban and social development. By including buildings of varying time periods and functions, this study seeks to prove the validity of the method across all kinds of buildings, and its potential to be expanded to include other types of buildings, such as unlisted ones.

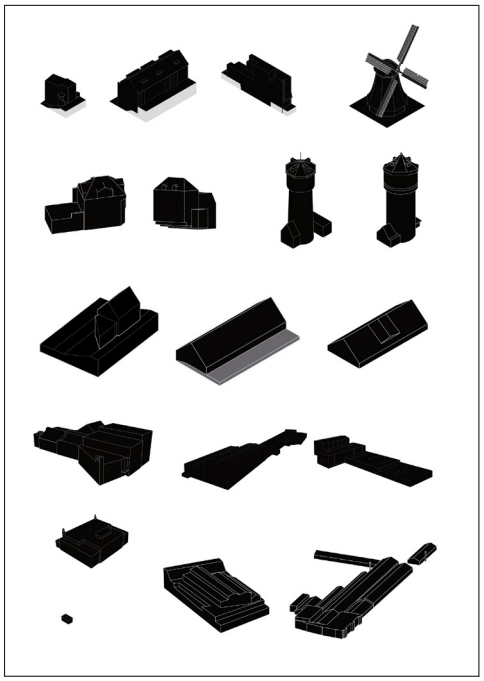

Fig. 4.1.1. Typology Research. ©AR3AH115 Studio Work

Fig. 4.1.2. Set of Photos of Research Objects.

Reference Number	Building Address	Typology	Listed Status
1	Spijksedijk 8, 4207 GN, Gorinchem	Industrial - Service Building	National
2	Arkelsedijk 46, 4206 AC	Industrial - Factory	National
3	Boogschutterstraat 2 A, 4205 JC	Residential Building	National
4	St. Jorisplein 1, 4205 JA	Residential Building	National
5	Grote Kerk Gorinchem, Groenmarkt 7, 4201 EE	Religious Building	National
6	Merwededijk 5-6, 4207 AJ	Religious Building	National
7	Zusterstraat 29, 4201 EK	Educational Building	National
8	Boerenstraat 44, 4201 GB	Military/Defence Building - Arsenal	National
9	"De Hoop", Dalemwal 21, 4201 BS	Windmill	National
10	"Nooit volmaakt", Bagijnenwal 38, 4201 JJ	Windmill	National
11	"Oostmolen", Grote Schelluinsekade 2, 4204 TX	Polder Mill	National
12	"Westmolen", Grote Schelluinsekade 18, 4204 TX	Polder Mill	National
13	Haarstraat 101, 4201 JB	Healthcare Facility	National
14	Eind 3, 4201 CP	Service/Residential Building	National
15	Kriekenmarkt 21, 23, 25, 4201 AN	Residential Building	National
16	Nieuwe Wolpherensedijk 33h	Industrial - Power Station	Municipal
17	Krinkelwinkel 6-8	Industrial - Factory	Municipal
18	St. Martinuskerk, Wijnkoperstraat 4	Religious Building	Municipal
19	Rond de watertoren 2-18	Residential Building (previous water tower)	Municipal
20	"Metropole", Melkpad 3/ Melkheul 2	Hotel	Municipal
21	Herman de Ruyterstraat 32	Educational Building	Municipal
22	Herman de Ruyterstraat 30	Educational Building	Municipal
23	Chapel, Arkelse Onderweg 43	Religious Building	Municipal
24	"Het Loo", Haarweg 93	Farm House	Municipal
25	Kleine Haarsekade 130	Farm House	Municipal
26	"'t Hoekje", Kalkhaven 53	Office/Residential Building	Municipal
27	Burgstraat 61	Mix - Cigar Factory/ Residential Building	Municipal
28	Plantsoen 13	Residential Building	Municipal
29	Nieuwe Hoven 43	Residential Building	Municipal
30	Haarstraat 25	Religious/Residential - Rectory	Municipal

Table. 4.1. List of Research Objects, Typology and Listed Status.

* The detail information of the assets is in the appendix. The information is sourced from the database of Cultural Heritage Agency of the Netherlands and Municipal Monuments of Gorinchem. (Rijksdienst Voor Het Cultureel Erfgoed, n.d.) (Gemeentelijke Monumenten, n.d.)

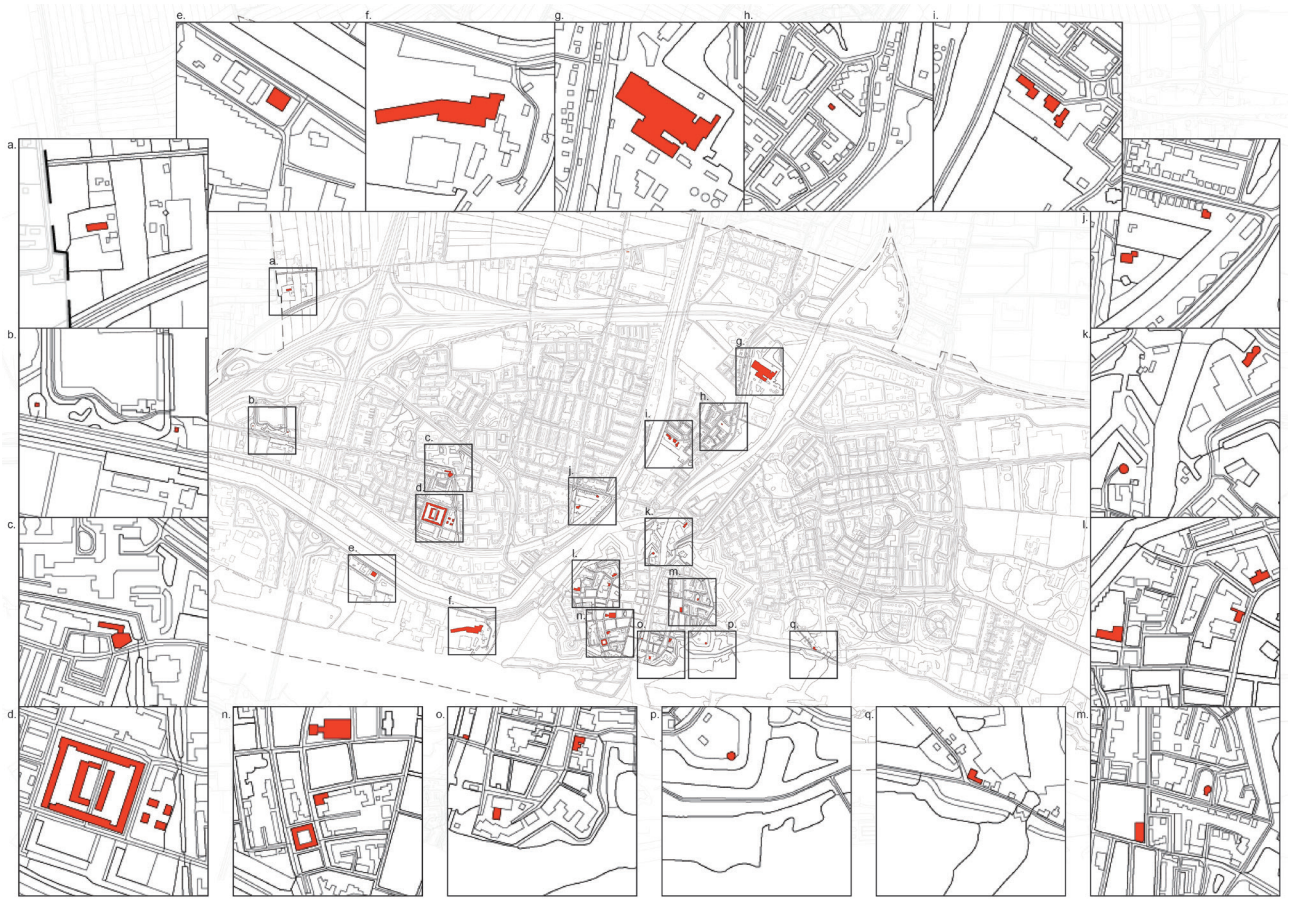

Fig. 4.1.3. Research Objects Location Overview.

4.2. Value Assessment

Based on the criteria outlined in the methodology section, the value assessment was conducted, and the results are presented in the table 4.2. The building with the highest value is Building 5, the great church Gorinchem. This stands to reason that it is the most significant public building of the city, being highly historical, functional, and memorial. Following this is Building 19, a residential building repurposed from a water tower.

The analysis reveals that, in general, national monuments tend to have a higher Value Index (VI) than municipal monuments, as the five criteria often align with the standards for listed status designation. However, exceptions exist. For instance, Building 19, which is not recognized as a national monument, is considered to have a high value in this study (VI = 7) due to its innovative redesign, which shows social, functional, and aesthetic values. On the other hand, buildings 14 and 15, although designated as national monuments, are assessed as having relatively low VI. Both are private residences that are no longer in use, resulting in lower scores for functional and social value. These findings suggest that the evaluation framework in this study shares similarity but also focuses on aspects different from those in official monument listing criteria.

Reference Number	Value Assessment					Value Index (VI)
	Age Value	Social Value	Functional Value	Memorial Value	Aesthetic Value	
1	o	o	+	+	++	4
2	+	o	-	++	+	3
3	o	++	++	+	+	6
4	o	++	++	+	+	6
5	++	++	++	++	++	10
6	+	++	++	+	o	6
7	o	++	++	o	+	5
8	++	+	o	++	+	6
9	++	+	-	++	++	6
10	++	+	-	++	++	6
11	+	+	-	++	++	5
12	+	+	-	++	++	5
13	+	++	++	o	+	6
14	+	o	-	+	++	3
15	+	o	-	o	++	2
16	o	+	+	o	+	3
17	+	o	++	++	o	5
18	o	++	++	+	o	5
19	+	+	++	+	++	7
20	+	o	++	+	+	5
21	+	++	+	o	o	4
22	+	++	+	o	o	4
23	+	+	-	o	+	2
24	+	-	o	+	+	2
25	+	-	o	+	o	1
26	+	-	+	o	+	2
27	+	-	o	+	+	2
28	+	-	+	o	+	2
29	+	+	++	o	+	5
30	+	o	+	+	o	3

Table. 4.2. Value Assessment Overview of the Research Objects.

4.3. Vulnerability Assessment

4.3.1. Risk of Flooding from the Sea, Lake or River (Fig. 4.3.1)
In this mapping, flood risk is determined by the anticipated frequency of flooding. The color scale ranges from light yellow, indicating no chance of flooding, to dark purple, representing a one-in-ten-year flood event. The darker the color, the higher the flood risk.
According to their geographical locations on the map, it turns out that buildings 3, 11, 12, 23, and 25 are at high risk, with most of their volume exposed to a 1-in-10-year or 1-in-100-year flood event. While eight buildings are at medium risk, that are 13, 17, 18, 20, 21, 22, 28, and 29. They are potentially facing the flood event once per 1000 years. As for the rest 17 buildings, they are facing almost no flood risk or only once per 100 000 year, which can be disregarded.

4.3.2. Maximum Water Depth in the Event of a Dike Breach (Fig. 4.3.2)
Another method to assess flood risks for buildings is by measuring the maximum water depth in the event of a dike breach. Although this is a rare event, it can cause significant disasters. We need to identify the most at-risk assets in this worst-case scenario.
Define risk levels as: low (water depth below 1.0 meter), medium (water depth between 1.0 to 2.0 meters), and high (water depth over 2.0 meters). 14 buildings are in high risk (1, 3, 4, 5, 7, 8, 11, 12, 13, 18, 20, 21, 22, 30); 7 buildings are in medium risk (14, 15, 19, 23, 25, 28, 29); and 9 buildings are in low risk (2, 6, 9, 10, 16, 17, 24, 26, 27)

4.3.3. Areas with Vulnerable Foundations Due to Drought (Fig. 4.3.3)
To the other extreme, too little water can also be risky to the structural integrity of buildings, particularly affecting their foundations. When there is a prolonged period of drought, the soil around a building's foundation can dry out and shrink, leading to gaps and potential instability.
In this mapping, level of vulnerability is determined in percentage: low (0-40%), medium (40-80%), and high (over 80%). 7 buildings are in high risk (3, 7, 9, 10, 26, 27, 29); 7 buildings in medium risk (4, 5, 8, 13, 14, 15, 30); while 16 buildings are in low risk (1, 2, 6, 11, 12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 28)

4.3.4. Urban Heat Island Effect Index (UHI) (Fig. 4.3.4)
Drought can result from overheating, which can also affect the air and living environment, known as the Urban Heat Island Effect (UHI). This phenomenon is common in city centers with many buildings and little green space, raising temperatures by several degrees and impacting the ecology and well-being of people.
For the UHI impact on the building and its environment, the following criteria is taken: a temperature increase of less than 0.8 degree means a low impact, 0.8 to 1.4 degree meaning medium, and over 1.4 degree meaning a high impact.
5 buildings are strongly influenced by the UHI effect (18, 21, 22, 23, 29); 5 buildings have a medium impact (1, 3, 13, 20, 30); and the remaining 20 buildings are with low impact.

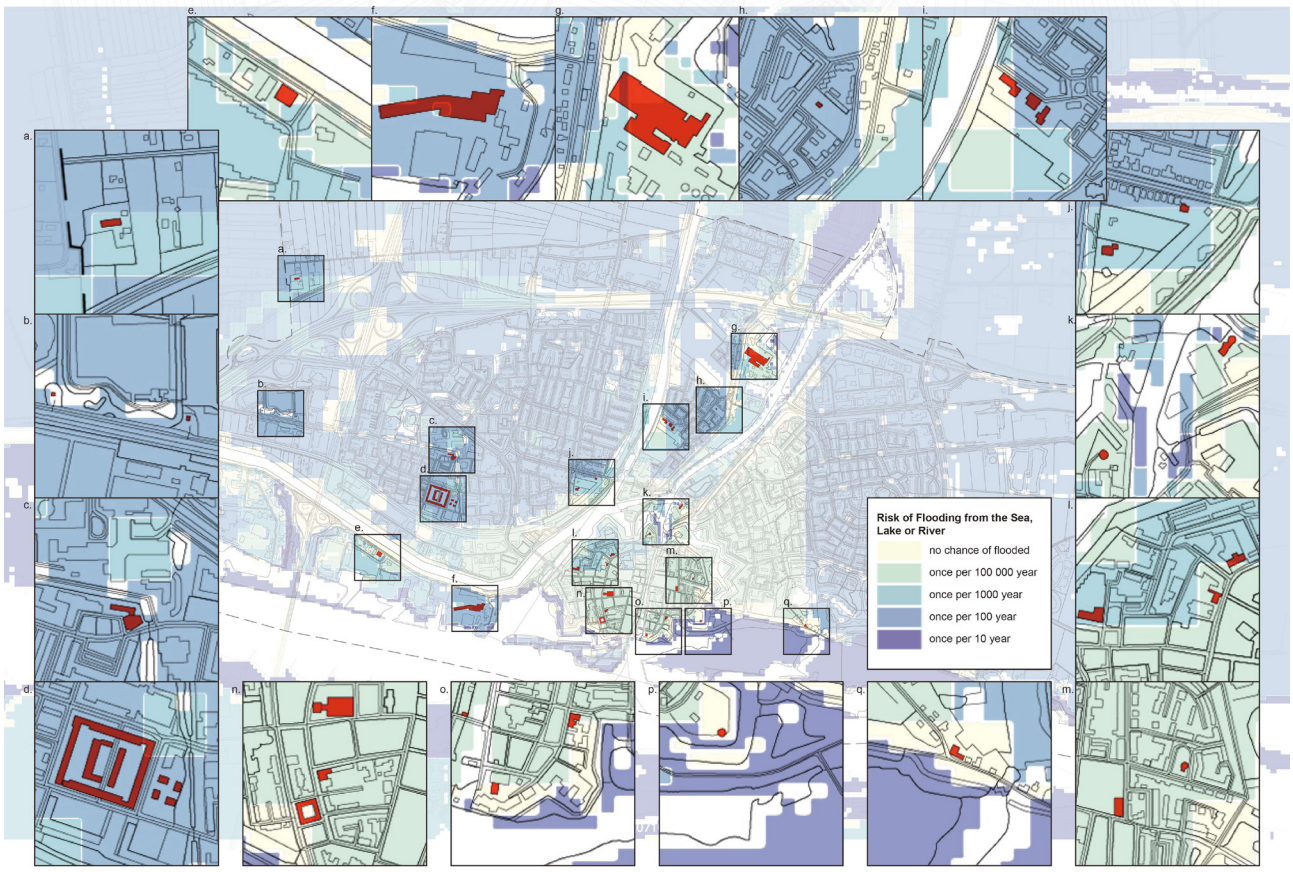

Fig. 4.3.1. Risk of Flooding from the Sea, Lake or River.

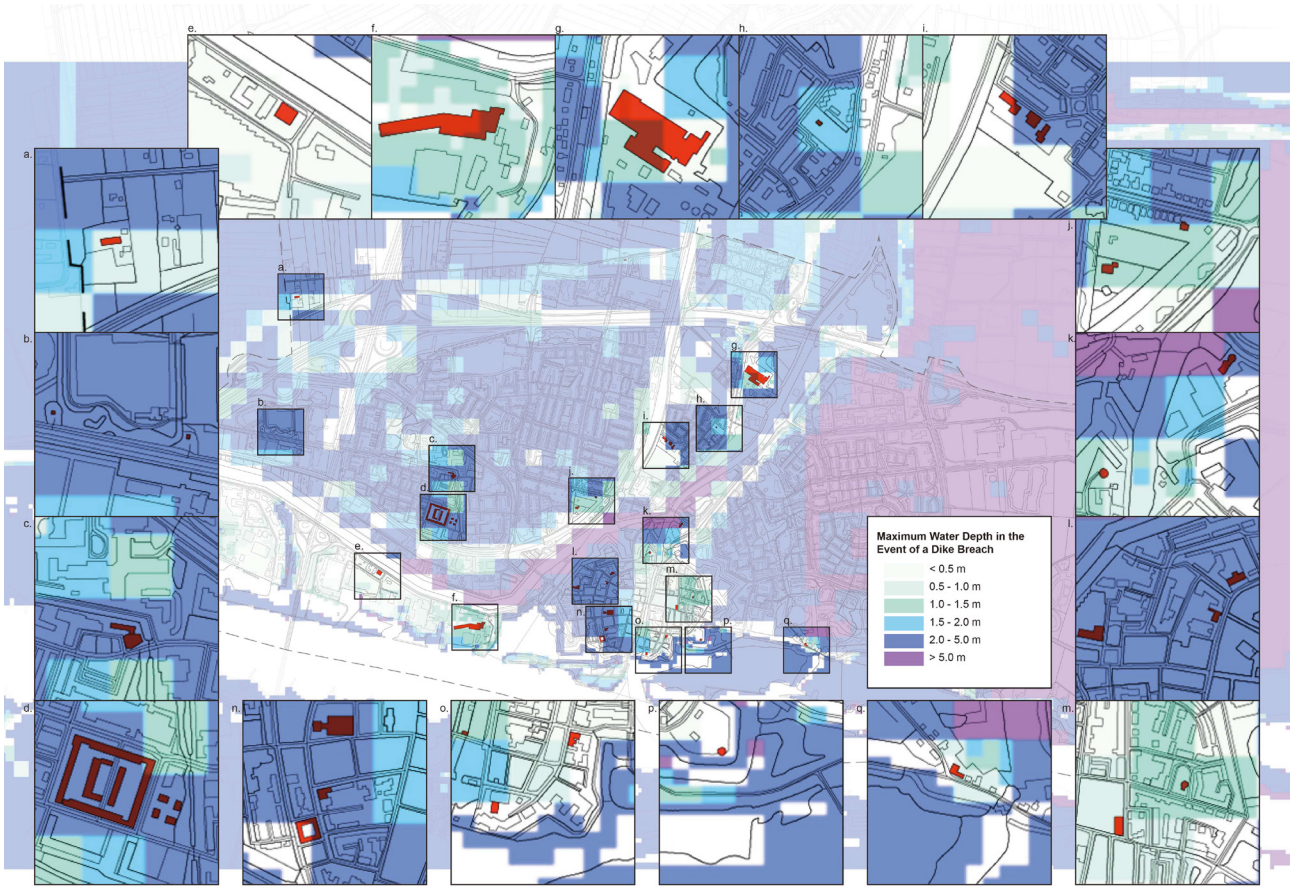

Fig. 4.3.2. Maximum Water Depth in the Event of a Dike Breach.

* These maps are sourced from Atlas Leefomgeving and were created by the author.

Fig. 4.3.3. Areas with Vulnerable Foundations Due to Drought.

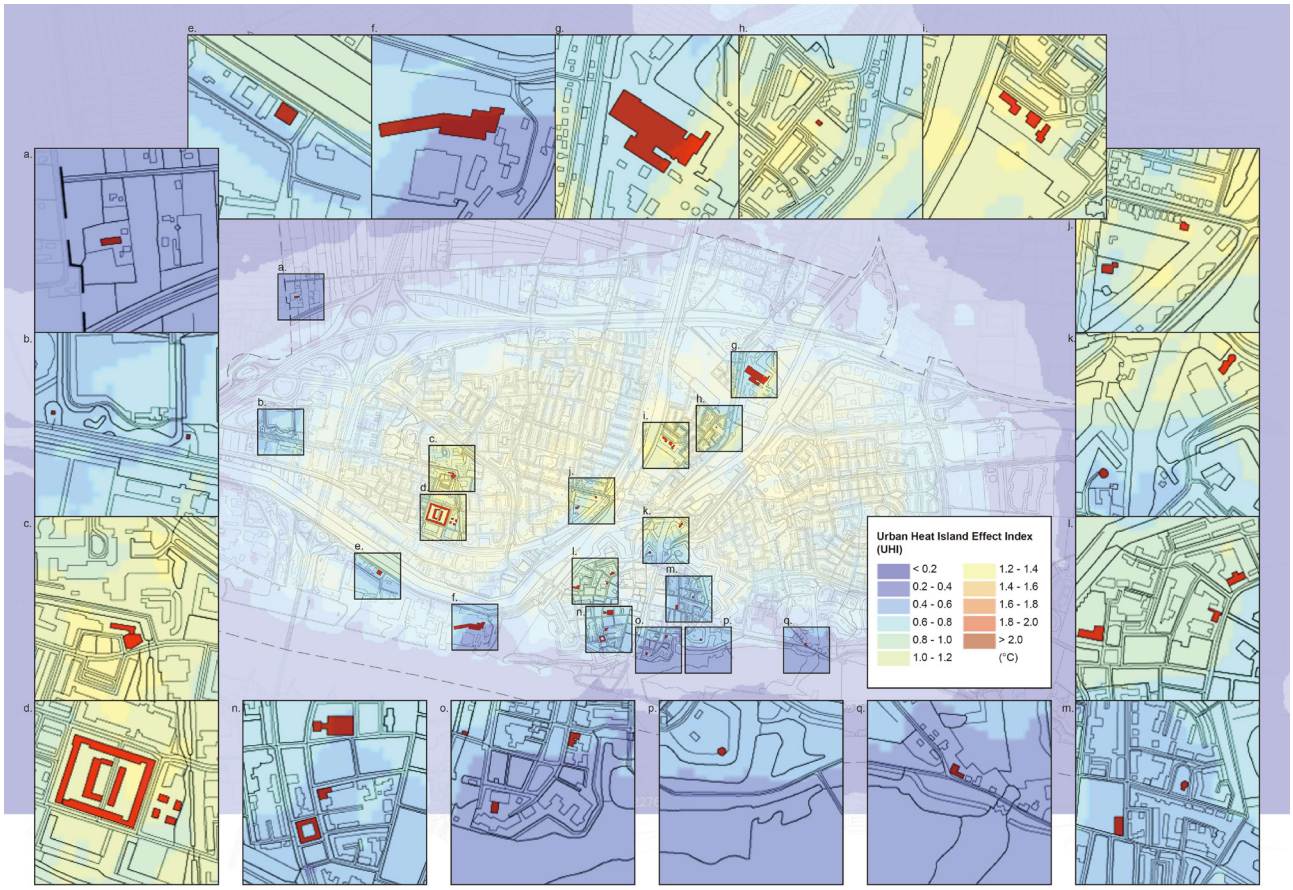

Fig. 4.3.4. Urban Heat Island Effect Index (UHI).

* These maps are sourced from Atlas Leefomgeving and were created by the author.

Reference Number	Climate Vulnerability Assessment				Overall Vulnerability (OV)
	Flooding		Drought	Heat	
	1. Risk ... *	2. Maximum ... *	3. Areas ... *	4. ... UHI *	
1	low	high	low	medium	**moderate**
2	low	low	low	low	**low**
3	high	high	high	medium	**high**
4	low	high	medium	low	**moderate**
5	low	high	medium	low	**moderate**
6	low	low	low	low	**low**
7	low	high	high	low	**high**
8	low	high	medium	low	**moderate**
9	low	low	high	low	**moderate**
10	low	low	high	low	**moderate**
11	high	high	low	low	**high**
12	high	high	low	low	**high**
13	medium	high	medium	medium	**moderate**
14	low	medium	medium	low	**moderate**
15	low	medium	medium	low	**moderate**
16	low	low	low	low	**low**
17	medium	low	low	low	**low**
18	medium	high	low	high	**high**
19	low	medium	low	low	**low**
20	medium	high	low	medium	**moderate**
21	medium	high	low	high	**high**
22	medium	high	low	high	**high**
23	high	medium	low	high	**high**
24	low	low	low	low	**low**
25	high	medium	low	low	**moderate**
26	low	low	high	low	**moderate**
27	low	low	high	low	**moderate**
28	medium	medium	low	low	**moderate**
29	medium	medium	high	high	**high**
30	low	high	medium	medium	**moderate**

Table 4.3. Climate Vulnerability Overview of the Research Objects.

* In this table, the complete header is as follows: 1. Risk of Flooding from the Sea, Lake or River; 2. Maximum Water Depth in the Event of a Dike Breach; 3. Areas with Vulnerable Foundations Due to Drought; and 4. Urban Heat Island Effect index(UHI).

5. Findings and Discussion

The identification of structures that are at the highest risk of potential value loss due to climate-related hazards is done by overlapping their value and vulnerability assessment results. (Fig. 5.1)

Combining the Value Index (VI) and the Overall Vulnerability (OV) of each building, it is defined that buildings with VI >= 5, and high OV are highly susceptible and threaten from climate risks. (Fig. 5.2)

Among all the 30 research object, there are 6 of them: 3. Housing Complex "Het Kremlin-1", 7. Educational Building, Zusterstraat, 11. Polder Mill "Oostmolen", 12. Polder Mill "Westmolen", 18. Religious Building, St. Martinuskerk, Wijnkoperstraat, and 29. GP/ Residential Building, Nieuwe Hoven. (Fig. 5.3)

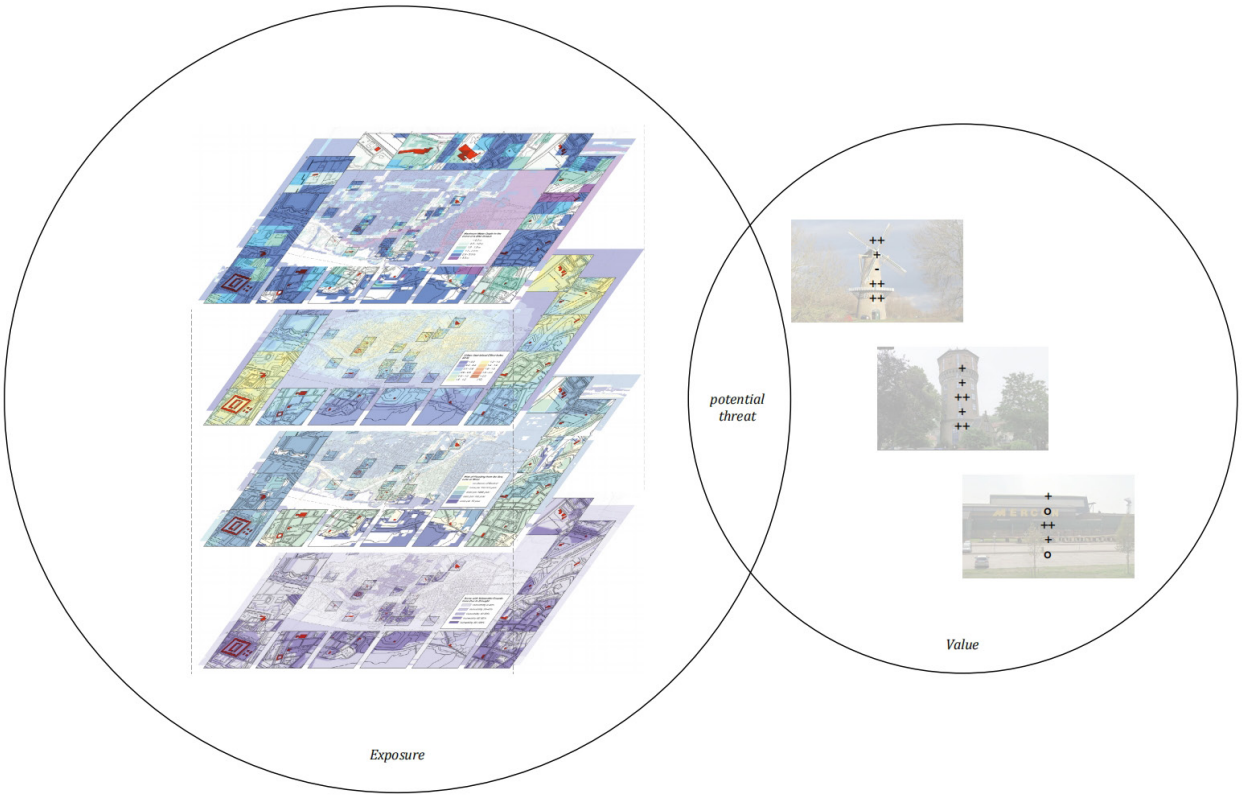

Fig. 5.1. Principle of Overlapping Analysis of Value and Vulnerability.

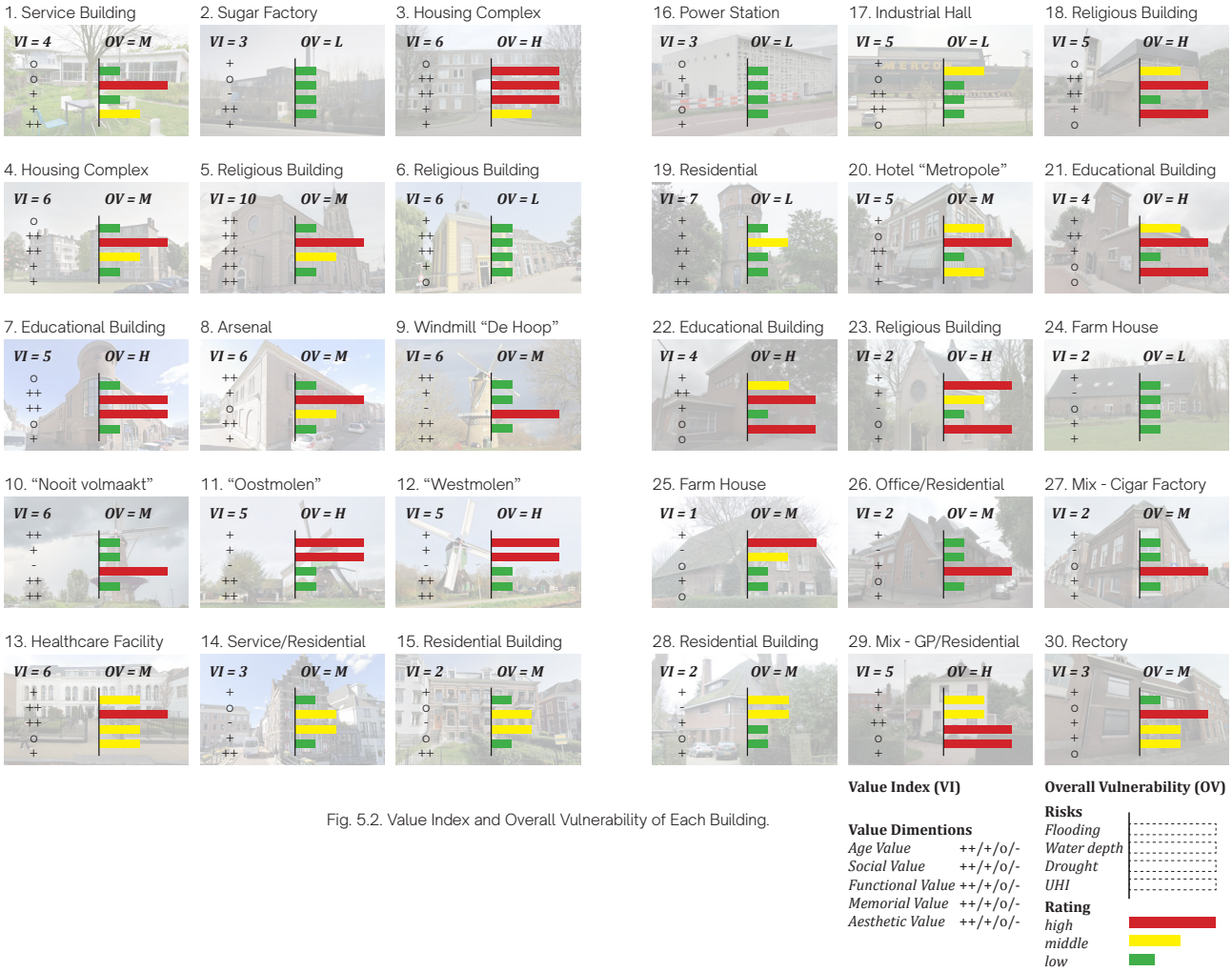

Fig. 5.2. Value Index and Overall Vulnerability of Each Building.

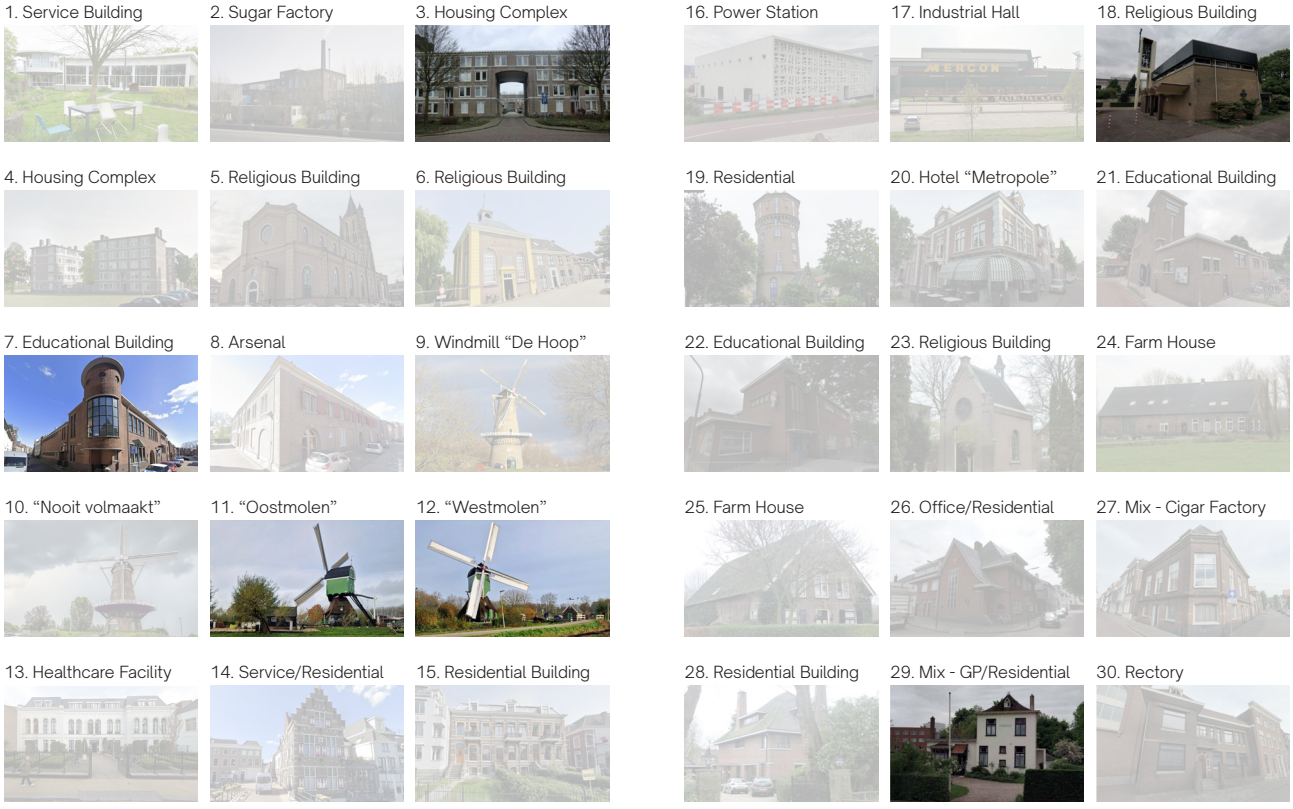

Fig. 5.3. Results: Buildings with the Most Potential Value Loss Due to Climate Risks.

It is noticeable that some pairs of objects are either both present or absent in the final result. In this research, pairs of objects, such as the windmills "Oostmolen" and "Westmolen", share similar geographical and historical contexts, as well as comparable valuation ratings and climate risk positions. This explains their simultaneous presence or absence in the final results.

Value serve as a fundamental determinant for the results, as an object without value would not face value loss. The assessment framework in this study has similarities to the official monument listing criteria, but the focus is also different. For example, in this research, functional value and other values are given the same weight, meaning that a building that is no longer in use is a "dead monument" and considered less valuable. Buildings that have been repurposed and revitalized would receive points for this evaluation. Therefore, a way to increase the value of abandoned architectural sites is to reuse and revitalize them.

The most important significance of this study is to identify the buildings most vulnerable to value loss caused by climate disasters from the huge national and municipal monument databases, so that protection measures can be more targeted. For Gorinchem, a city with a large cultural heritage but relatively small size and limited resources, this is very precious. In addition, although similar studies have been carried out in other larger cities in the province of South Holland (such as the study in Dordrecht in 2023), Gorinchem has never conducted a similar academic study on a large scale before. This paper is a pioneer for the local and can contribute to more academic research thereafter. Although only 30 listed buildings were studied, Gorinchem has many more listed or non-listed buildings, which can also be analyzed using the same framework.

However, there are certain shortcomings in this method. As the level of detail in the database varies across buildings, some value assessments were inevitably influenced by subjective judgment. To mitigate this, thorough investigations have been conducted to minimize bias, though it cannot be entirely eliminated.

As for the vulnerability assessment, sourcing from the climate maps, it only considered the natural impacts based on geographical location, but disregarded the strength of the buildings and their materials. If more information were accessible, or with the participation of civil engineering equipment and specialists, the vulnerability assessment could also incorporate non-natural factors and be conducted more quantitatively.

6. Conclusion

This research aims to identify the value and vulnerability to climate risks of 30 listed buildings in Gorinchem. Based on a qualitative and quantitative analysis of value in five dimensions - age value, social value, functional value, memorial value, and aesthetic value, and vulnerability to three categories of climate impacts - flood, drought, and overheating, it can be concluded that 6 buildings out of them are highly susceptible to value loss. It indicates that for the most at-risk locations, specific administrative measures should be taken for better protection actions. While for other sites that are in a relatively safe status, the possibility for redevelopment or redesign is with less limitations and constrains.

Besides that, the methodology developed based on the two main literature references has proved its validity in Gorinchem, and showed potential to be applied as a tool to other locations in further research. While there is still room for improvement, this framework provides a starting point for integrating cultural value and vulnerability into heritage conservation strategies.

References

Arrighi, C. (2021). A Global scale analysis of river flood risk of UNESCO World Heritage Sites. Frontiers in Water, 3. https://doi.org/10.3389/frwa.2021.764459

Assessing climate change risks and vulnerabilities. (n.d.). https://climate-adapt.eea.europa.eu/en/mission/knowledge-and-data/regional-adaptation-support-tool/step-2-assessing-climate-change-risks-and-vulnerabilities

Atlas Leefomgeving | Atlas Leefomgeving. (n.d.). https://www.atlasleefomgeving.nl/kaarten

Brokerhof, A. W., Van Leijen, R., & Gersonius, B. (2023). Protecting Built Heritage against Flood: Mapping Value Density on Flood Hazard Maps. Water, 15(16), 2950. https://doi.org/10.3390/w15162950

DickAanen. (2024, February 5). 1995: Een spannende week van extreem hoog water. Dick Aanen Journalistieke Producties. https://www.dickaanen.nl/1995-een-spannende-week-van-extreem-hoog-water/

Fortified city Gorinchem. (n.d.). Mooi Gorinchem. https://www.mooigorinchem.nl/en

Gemeentelijke monumenten. (n.d.). https://geoportaal.gorinchem.nl/geoapps/monumenten/index.html

Gorinchem. (n.d.). Gorinchem. https://brievb.wordpress.com/

Gorinchem op z'n kop tijdens bijna-ramp in 1995; duizenden Gorcumers verlaten huis en haard. (2020, January 31). De Stad Gorinchem. https://www.destadgorinchem.nl/lokaal/historie/317062/gorinchem-op-zn-kop-tijdens-bijna-ramp-1995-duizenden-gorcumers-verlaten-huis-en

Homepage - Regionaal Archief Gorinchem. (2022, June 23). Regionaal Archief Gorinchem. https://www.regionaalarchiefgorinchem.nl/

Jan Boshoven. (2022, January 5). 1995 Hoog Water Gorinchem [Video]. YouTube. https://www.youtube.com/watch?v=DJ6oTOje5s4

Joint Research Centre Data Catalogue - River Flood Hazard Maps at European and Global SCA. . . - European Commission. (2024, March 20). https://data.jrc.ec.europa.eu/collection/id-0054

Klimaatadaptatie. (n.d.). Gemeente Gorinchem. https://www.gorinchem.nl/gorinchem-duurzaam/klimaatakkoord/klimaatadaptatie

Lamprakos, M. (2014). Riegl's "Modern Cult of Monuments" and the Problem of value. Change Over Time, 4(2), 418–435. https://doi.org/10.1353/cot.2014.0011

Ministerie van Onderwijs, Cultuur en Wetenschap. (2021, February 8). Waterdriehoek vergroot bekendheid en bevordert beleefbaarheid. Praktijkvoorbeelden | Rijksdienst Voor Het Cultureel Erfgoed. https://www.cultureelerfgoed.nl/onderwerpen/praktijkvoorbeelden/overzicht-praktijkvoorbeelden/waterdriehoek-vergroot-bekendheid-en-bevordert-beleefbaarheid

Molenstichting SIMAV. (2024, December 5). Stichting tot Instandhouding van Molens in de Alblasserwaard en de Vijfheerenlanden. https://www.simav.nl/

Norberg-Schulz, C. (1979). Genius Loci: Towards a Phenomenology of Architecture. https://ci.nii.ac.jp/ncid/BA00446954

Schakel, M. W. (1977). De waterwolf slaat toe: Watervloeden in de Alblasserwaard.

Stephenson, V., & D'Ayala, D. (2014). A new approach to flood vulnerability assessment for historic buildings in England. Natural Hazards and Earth System Sciences, 14(5), 1035–1048. https://doi.org/10.5194/nhess-14-1035-2014

Stichting Erfgoed De Vries-Robbe | FIEN. (n.d.). https://www.industrieel-erfgoed.nl/stichting-erfgoed-vries-robbe

UNESCO World Heritage Centre. (n.d.). Mill Network at Kinderdijk-Elshout. https://whc.unesco.org/en/list/818/

Wei, X., Kourchine, A., Shen, B., O'Regan, B., Zirkzee, F., Tirion, L., Maessen, S., Mulder, T., & Roersma, T. (2024). Typology Research Report: Waterfront building typologies: Spatial relations between water and land in the Waterdriehoek. In AR3AH115 Marintime Heritage Studio. Delft University of Technology.

Zoeken in het Rijksmonumentenregister | Rijksdienst voor het Cultureel Erfgoed. (n.d.). https://monumentenregister.cultureelerfgoed.nl/

Appendix. Research Objects Description and Source of Information

1. Service Building, Spijksedijk 8, 4207 GN

The building was originally constructed in 1940 as the reception building of a local steel production company De Vries Robbé & Co. N.V. It was designed by architects B. Merkelbach and Ch.J.F. Karsten. Initially located on the north bank of the Linge River, its demolition was scheduled for 1996 to make way for Gorinchem's new fire department building. However, thanks to the efforts of the De Vries-Robbe Heritage Foundation, the building was relocated and reconstructed at its present site at Spijksedij 8, on the south bank of the Linge River. Currently it holds a gallery and an office for the municipality architects.

The round reception building is built on a hexagonal base, consisting of two floors and a single-storey, rectangular extension. Originally, the slightly curved dining room of one floor was connected to this. The reception building, like the dining room, consists of a steel skeleton, the substructure of which is filled with half-brick walls of yellow brick, the superstructure has large windows surrounded by a balcony that rests on steel columns. The flat, concrete roof extends to the width of the balcony, whose steel balustrade is filled with wire glass.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/525102?MonumentId=525102

2. Sugar Factory, Arkelsedijk 46, 4206 AC

The sugar factory with associated boiler house was built in 1871. It is constructed in a sober traditional brick construction that is characteristic of early Dutch factory architecture. Striking details are the richly designed facade ending: frieze, composed of a series of blind niches and the cast-iron windows with characteristic keel arch tracing. In the interior, the cast iron and steel riveted columns in particular contribute to the monumentality of the complex.

During the transformation of the company into a chemical factory in the last century, most of the original buildings were preserved intact. The characteristic features of the 19th-century sugar factory - a long, narrow brick front building with arched windows and behind it a boiler house, machinery hall, lime kiln, and workshops (among other things, see the reports of Oud Gastel and Sas van Gent) - are still clearly recognizable. It has been a protected national monument since 2006, and recent restoration work has ensured that its structural condition is good. They, together with the remaining halls of De Vries Robbe steel structure company located on the Arkelse Dijk, remind people of the industrial history of the Linge region.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/525118?MonumentId=525118
https://fabriekofiel.com/gorinchem/
https://www.monumenten.nl/monument/525118
https://www.resnovamonumenten.nl/projecten-1/suikerfabriek-gorinchem/

3. Housing Complex "Het Kremlin-1", Boogschutterstraat 2 A, 4205 JC

This is the higher-rise part of a housing complex with 236 living units. Designed by the architects A. Evers and G.J.M. Sarlemijn, and built in 1955-1956, the complex was built under the strict control of the city government to ease the housing shortage, which represents the social situation at that time.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/530956?MonumentId=530956

4. Housing Complex "Het Kremlin-2", St. Jorisplein 1, 4205 JA

The low-rise building of the complex consists of 20 single-family homes, shops and studios. Its social, functional, and historic value are identical to the above-mentioned complex.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/530955?MonumentId=530955

5. Religious Building, Grote Kerk Gorinchem, Groenmarkt 7, 4201 EE

The neoclassical building is a defining feature of the city centre of Gorinchem. On the same site there was previously a Gothic church, the Sint Maartenskerk, which was consecrated in 1263. A major restoration of the tower was carried out between 1941 and 1950.

Information:
https://grotekerkgorinchem.nl/kerkgebouw
https://nl.wikipedia.org/wiki/Grote_Kerk_(Gorinchem)
https://monumentenregister.cultureelerfgoed.nl/monumenten/16634?MonumentId=16634

6. Religious Building, Reformed Church, Merwededijk 5-6, 4207 AJ

The Reformed Church, which dates from 1801 according to a foundation stone, is a brick hall church on a rectangular plan, covered by a surrounding hipped roof and crowned by a wooden bell tower, the spire of which consists of a domed roof, on which an obelisk.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/38176?MonumentId=38176
https://monumentenregister.cultureelerfgoed.nl/monumenten/38175?MonumentId=38175

7. Educational Building, Zusterstraat 29, 4201 EK

This is a school designed by Gerardus Johannes Geijtenbeek and built in 1938. Built in a traditional style (Delft School), it is located on the corner of Zusterstraat and Broerenstraat and is part of the closed facade walls on both streets. The school was put into use in 1996 as a music school and cultural centre. Renovations were carried out on the interior for this purpose. Large parts of the floor plan and some former classrooms are still recognizable.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/525134

8. Arsenal, Boerenstraat 44, 4201 GB

This arsenal is part of the Gorinchem fortification complex. It is a stone building with a storey and a roof covered with tiles, and dating back to 1755. It is built on an almost square foundation around a courtyard.

As one of the many defensive and military facilities built in Gorinchem in the 18th century, this building holds great significance for the cultural and historical value. It reflects the history of a typical Dutch fortified city at the time.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/365903

9. Windmill "De Hoop", Dalemwal 21, 4201 BS

The windmill named "De Hoop" was built in 1764. It was used for grinding grain, which is no longer in operation now. It is a particularly large and dominant feature in an open landscape near a wide river.

Information:
https://www.molendatabase.nl/molens/ten-bruggencate-nr-00841
https://monumentenregister.cultureelerfgoed.nl/monumenten/16691
https://hansbrongers.nl/2022/03/10/molen-de-hoop-gorinchem/

10. Windmill "Nooit volmaakt", Bagijnenwal 38, 4201 JJ

The windmill "Nooit Volmaakt" is a round stone tower mill on one of the bastions in the fortress. This corn mill was built in 1718 on the site where a mill had been destroyed by a storm. Later, the mill was raised and provided with a tower. The mill was restored in 1996-1997 and opened in 1997. Since then, the mill has been in operation again for grinding grains. Now the mill also functions as a tourist point where people can visit and buy grain and flour products and mill bread.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/16690
https://www.molendatabase.nl/molens/ten-bruggencate-nr-00840

11. Polder Mill "Oostmolen", Grote Schelluinsekade 2, 4204 TX

The Oostmolen, built in 1817, served as a polder mill, just like the Westmolen. Their predecessors were set on fire by French troops and it was hoped that one mill would be enough later. This turned out not to be the case, which is why the Oostmolen was also rebuilt in 1817. In 1973, the municipality of Gorinchem became the owner, until transferred to a foundation SIMAV in 2017.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/16692
https://www.molendatabase.nl/molens/ten-bruggencate-nr-00839
https://www.simav.nl/molens/oostmolen/

12. Polder Mill "Westmolen", Grote Schelluinsekade 18, 4204 TX

The mill Westmolen was built in 1814. Like the Oostmolen, the mill was owned by a foundation called Binnen Molenstichting SIMAV since 2017 and is not open to tourists. The hollow post mill was completely restored in 2021 and has also been given new sails.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/16693
https://www.molendatabase.nl/molens/ten-bruggencate-nr-00838
https://www.simav.nl/molens/westmolen/

13. Healthcare Facility, Haarstraat 101, 4201 JB

This is a hospital built in 1866-1867, with white-plastered facade in the eclectic style influenced by national architect W.N. Rose. It features elongated facade with projecting corner sections, round-arched windows in the mezzanine, corner pilasters and a round-arched frieze under the eaves, and cast-iron gates on the street.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/16601

14. Service/Residential Building, Eind 3, 4201 CP

It was built in 1910 as a residence for bridge and lock personnel at the Oude Merwedesluis in the Lingehaven. The design is in Neo-Renaissance style. The building is located on the western side of the Lingehaven, directly on the water, next to the bridge and forms the end of a closed facade wall.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/525122

15. Residential Building, Kriekenmarkt 21, 23, 25, 4201 AN

This building group consists of a row of three houses built in 1890 in Neo-Renaissance style, designed by architect Jan Kraai from Gorinchem. House number 21 received a new conservatory in 1930 based on a design by Bauke van der Zijpp from Gorinchem. In the same year, the rear facade of number 23 was renovated.

Information:
https://monumentenregister.cultureelerfgoed.nl/monumenten/525127

16. Utility Building, Nieuwe Wolpherensedijk 33h

This is a former electricity distribution station that assured the daily functioning of the city. It locates at the Nieuwe Wolpherensedijk on the corner with the Ambonstraat, in an industrial area of Gorinchem. Elements of the facade dates back to 1968, while other cladding, frames, doors and interior are recent new construction

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Nieuwe%20Wolpherensedijk%2033h.pdf

17. Industrial Hall, Mercon, Krinkelwinkel 6-8

The industrial hall of the company Mercon was built in 1930 in functionalism style. The hall forms an industrial ensemble together with a few other factory halls and two cranes. This ensemble is iconic for this part of Gorinchem. Its value embedded in its function as a company hall, and as a reminder of the industrial history of Gorinchem.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Krinkelwinkel%206.pdf

18. Religious Building, St. Martinuskerk, Wijnkoperstraat 4

This is a small church serving the local community. It was reconstructed in 1967 as a typical post-war church in eclecticism style. It has an irregular hexagonal plan of one storey high with a flat roof, connecting a green square with shrubs, paths, and parking facilities.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Wijnkoperstraat%204.pdf

19. Residential Watertower, Rond de watertoren 2-18

The water tower was built in 1886 and designed by architect Jan Schotel in neo-Renaissance style. It is 31 meters high, with a maximum width of 10 meters and a water reservoir of 300 m^3. In 1910, the water company was taken over by the municipality. The tower was renovated in 1985 and now contains nine residential units.

Information:
https://www.watertorens.nl/watertorens/67-gorinchem-1886
https://www.watertorens.eu/torens/Gorinchem/Visserlaan/index.html
https://www.watertorens.eu/torens/Gorinchem/Visserlaan/Beschrijving%20monument.html

20. Hotel "Metropole", Melkpad 3/ Melkheul 2

The major volume of the building dates back to 1878, while the minor part was built in 1892 and the facade was renewed in 1916. It is a two storey high building with rectangular plan. The location at the corner and the public service function adds vitality to the city.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Melkheul%202a.pdf

21. Educational Building, Gymnastic School, Herman de Ruyterstraat 32

This is a gymnastic school as well as a community center, dating back to 1931 and was designed in expressionism style. It benefits the local users with functional space for interaction and social activities. It is also valuable in the urban setting.

22. Educational Building, Primary School, Herman de Ruyterstraat 30

This is a small christian primary school named "School met den Bijbel", reads the bricked-up texts in the facade. Built in 1937, it has been a collective childhood memory for the people from the neighbourhood. Nowadays it is one of the various educational facilities for kids locating at the same street, which are essential to the local community.

Information:
https://henk50.wordpress.com/tag/school-met-den-bijbel-gorinchem/

23. Religious Building, Chapel, Arkelse Onderweg 43

This is a chapel with burial vault for deceased priests dating back to 1882. The building was designed in eclecticism style, on a rectangular plan, single storey high with an attic, and a high saddle roof. Decorations are applied on the brick facade.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Arkelse%20Onderweg%2043.pdf

24. Farm House "Het Loo", Haarweg 93

The farm complex "Het Loo" locates in an original medieval sloping landscape on a river ridge. It was built in approx. 1850-1880. It is a rectangular barn, one storey high, with attic under saddle roof, and posts on either side of the driveway in Art Deco style. It is a reminder of Gorinchem's agricultural past.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Haarweg%2093.pdf

25. Farm House, Haarhoeve Farm Complex, Kleine Haarsekade 130

The Haarhoeve farm complex dates back to 1895. Like "Het Loo", it is also a clue and reminder of the agricultural past of Gorinchem, therefore it is valuable in historic and memorial value. It is also part of the river landscape and local rural life.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Kleine%20Haarsekade%20130.pdf

26. Office/Residential Building, "'t Hoekje", Kalkhaven 53

Locating at the street corner, the building "'t Hoekje" is an important urban facade. It is a traditional Dutch house with brick facade and saddle roof. It was built in 1936 in expressionism style, holding commercial and residential functions.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Kalkhaven%2053.pdf

27. Cigar Factory/Residential Building, Burgstraat 61

The mix-use building was built around 2nd half of the 19th century in Neo-Renaissance style. It formerly functioned as a cigar factory, reminding people of tobacco production history in Gorinchem. The combination of residential use and small handicraft workshops / family factories showed the commerce and production tradition of the time.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Burgstraat%2061.pdf

28. Residential Building, Plantsoen 13

This residential house built in 1930 is associated with the De Vries Robbé family, owners of the Gorinchem steel construction company. It is a typical Dutch detached house on a rectangular plan with two storeys high and an attic under a hipped roof.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Plantsoen%2013.pdf

29. GP/Residential Building, Nieuwe Hoven 43

The building consists of two parts, with General practitioner office and residential functions inside. It was first built in approx. 1880, being the residence of beer magnate Van Ravenswaay at the time. He was the biggest local beer brewer until 1918.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Nieuwe%20Hoven%2043.pdf

30. Rectory, Haarstraat 25

Constructed in 1931, this rectory building itself is a combination of residential use and office for the priest. Together with the adjacent church, KERK van Onze Lieve Vrouw Onbevlekt Ontvangen en de Martelaren van Gorkum, the religious building complex is an important urban place for the locals.

Information:
https://geoportaal.gorinchem.nl/geoapps/monumenten/pdf/Haarstraat%2025.pdf