6 Reflection Tingwei Du TU Delft

In this project, I aim to develop a visualization tool designed to intuitively and efficiently illustrate the extent of damage to building components caused by flooding induced by extreme compound flood. This tool will not only account for the impacts of such flooding but also precisely identify damage to building elements, enabling designers to assess building robustness early in the design stage. It will assist engineers in planning critical structural reinforcements before the structural design phase and help operators implement precautionary measures to protect vulnerable parts of the building before a disaster strikes. By catering to multiple stakeholders, this tool seeks to provide a cost-effective solution to minimize the loss of life and property.

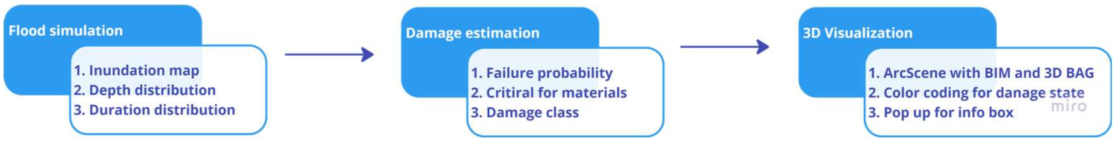


Figure 53: A brief workflow for implementation

Compound Flood simulation

The product design process is illustrated in the figure above. (Fig.53) The first step involves deriving the flood base parameters required for hydraulic model simulation, such as base level, rainfall, and flow speed, based on compound flood events that have occurred in the Netherlands. The second step is to quantitatively analyze the impact of the flood on the building element (with various materials) and to rate the level of damage based on the obtained fragile curves. The third step was to visualize the data results using ArcGIS Pro and mark the damage rating with colors.

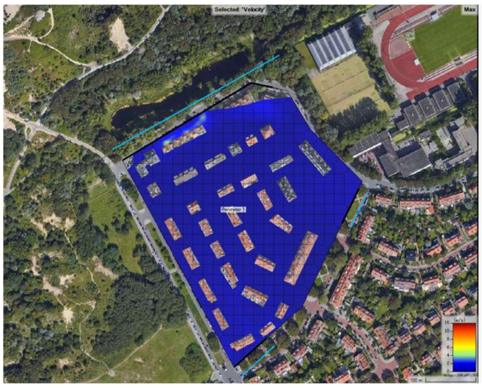


Figure 54. Interface of hydrodynamic simulation results in Hec Ras

Compound Flood simulation

The first step involved using hydraulic modeling to simulate inundation scenarios under real extreme flood conditions. This step aimed to generate maps of urban building inundation. Utilizing parameters for extreme weather conditions ensures comprehensive coverage of all possible flood scenarios. These parameters were sourced from literature (van den Hurk et al., 2015), which documents the most similar composite event to a flood hazard that has occurred in the Netherlands in recent years.

Given that water depth and velocity in urban centers can be influenced by surrounding buildings, simulating community-scale flooding scenarios allows for both the consideration of these influences and achieving sufficient accuracy in analyzing building component levels.

The focus of this phase was on using specialized hydrodynamic software to obtain maps showing the geographic distribution of water depth. (Fig.44) At the project's outset, a thesis study was conducted to select appropriate software. This involved reviewing and analyzing ten papers that summarized various hydrodynamic software, models, and their parameters. Additionally, the study organized information on formula methods, open sources, and the input and output parameters of twenty different hydraulic engineering software currently in use. Ultimately, two software packages were selected for this project: MIKE FLOOD and HEC-RAS.

The project process involved researching and studying both MIKE FLOOD and HEC-RAS software separately, followed by conducting simulation tests. Ultimately, HEC-RAS was chosen as the simulation software for several reasons:

MIKE FLOOD:

1. Specialization and Input Parameters: MIKE FLOOD requires many specialized input parameters, such as details of the underground pipe network and land permeability, which were not readily available. The absence of these parameters made the simulation challenging to execute.

2. Complexity and Sub-packages: The MIKE series includes a wide range of sub-packages, and coupling the models of several subsystems (like MIKE21 1D/2D and MIKE FLOOD) during the simulation increases both the complexity and the difficulty of adjustments.

3. Licensing Issues: The API port of MIKE FLOOD is commercially licensed, requiring substantial fees. Although initial software selection considered open-source options, the practical application revealed prohibitive costs associated with the API.

HEC-RAS:

1. Balance of Professionalism and Ease of Use: HEC-RAS strikes a good balance between professionalism and user-friendliness. It supports composite flood drivers, such as rainfall, runoff, and water levels, and is highly compatible with various data formats.

2. Visualization Capabilities: HEC-RAS offers a high degree of visualization, allowing intuitive viewing of results in different layers. Users can also directly modify data geometry within the view, facilitating easier debugging.

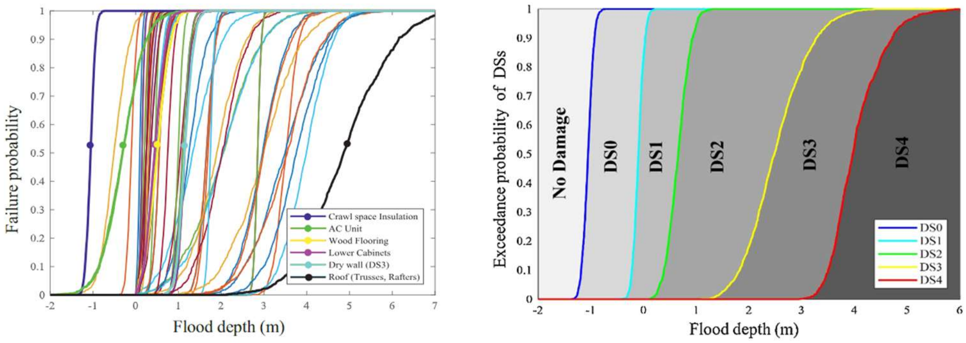
3. Direct Export to Raster Map File: HEC-RAS can export results directly to raster map files without requiring additional conversion, making it a straightforward source for subsequent spatial data analysis.

Ultimately, HEC-RAS features its own open-source API port (HEC-RAS Controller), which can be accessed using Python code to automate running the software and outputting results. And also stands out for its' flexibility (allowing for easier adjustment of model sets with hydraulic data).

During the testing process, Simona is responsible for ensuring the rigor and reliability of the simulation. To accurately reproduce recent extreme compound disasters, she suggested using rainfall and runoff parameters from the peak hours of these extreme events as model inputs. Utilizing known parameters from actual composite events provides a more realistic simulation compared to using extreme theoretical values.

Azarakhsh guided the project's digitalization efforts, placing significant emphasis on the feasibility of API integration. She recommended creating an API request demo to evaluate the interface response time. This suggestion is very sufficient, highlighting that it was unnecessary to wait until all simulation modeling is complete to perform this step. By testing the API call with a completed example early in the process, potential issues with the API could be identified and addressed promptly, allowing for quick adoption of alternatives if needed.

Damage quantification and classification



(a) Components fragility curves

(b) Fragility classification

Fig.45: Identification damage levels (Nofal et al., 2020)

The second step is damage assessment. This involves translating the simulation results, specifically the water depth, into damage levels for building components and then grading this damage. This step is crucial for transitioning from an urban scale to a building scale, aiming to derive a practical assessment system and criteria. The primary contribution of this work is the development of flood vulnerability curves for buildings without relying on empirical field data.

In our literature review, we used keywords such as "vulnerability analysis," "fragile analysis," "damage assessment," and "risk map," which led us to 17 relevant articles. These articles helped us organize widely used assessment methods, formula models, and parameters. Faced with the choice between performing a finite element analysis of a building structure and defining damage in five levels of severity through the Monte Carlo framework, I conducted separate tests for each approach.

Finite Element Analysis (FEA):

1. Software Requirements: This method required using specialized ANSYS software.

2. Data Transfer: The process involved transferring simulation data from HEC-RAS to ANSYS.

3. Visualization: The results then needed to be visualized in ArcGIS Pro.

4. Complexity and Time Consumption: The data transfer between these platforms was complex and time-consuming, adding significant overhead to the process.

Monte Carlo Framework:

1. Damage Assessment Method: This approach defines damage in five levels of severity using a Monte Carlo framework.

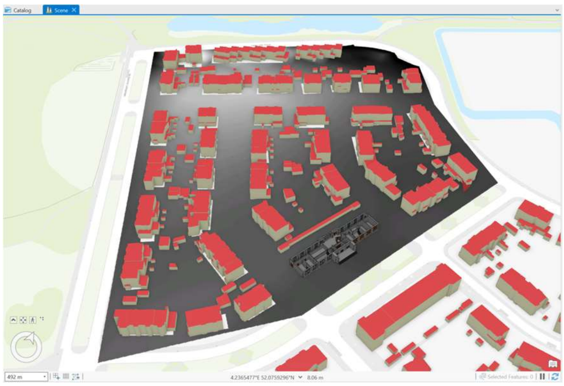
2. Component-based Analysis: The framework divides the building into separate components, assigning each to one of five predefined damage states.

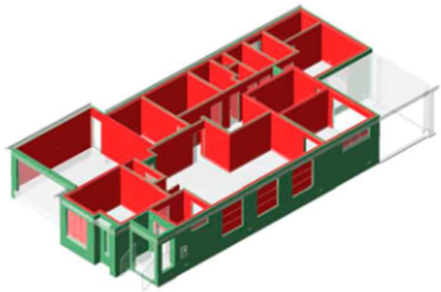
3. Efficiency: This method utilizes expert-based data obtained from online sources, making it more straightforward and less time-consuming compared to the FEA process.

Based on these tests, the Monte Carlo framework proved to be more efficient and feasible for the project, given the complexity and time constraints associated with the finite element analysis approach.

After thorough analysis and comparison, Simona suggested employing the univariate and multivariate component flood vulnerability method.(Nofal et al., 2020) This method uses expert-based data sourced from online resources and applies them within a Monte Carlo framework. It divides the building into separate components, assigning each to one of five predefined damage states that collectively characterize the damage to the entire building. (Fig.45)

3D Visualization





(a) BIM-GIS Integration in ArcGIS (b) color coding elements(Amirebrahimi et al., 2016)

Fig.46: Visualization of data results

The last step involves using FDA (Flood Damage Assessment) alongside ArcGIS Pro and Scene visualization to create a comprehensive framework for BIM-GIS integrated 3D visualization. This framework is designed to depict a building's unique behavior against floods. To achieve this, it combines two essential types of information:

Building Information: Complete building information is represented through Building Information Modeling (BIM). BIM provides detailed, accurate, and comprehensive data about the building's components, materials, and structural characteristics. (fig.46)

Flood Information: Flood-related data, typically managed by hydrodynamic software, is outputted to a Geographic Information System (GIS). GIS manages spatial data and provides a platform for visualizing flood extents, depths, and other hydrodynamic results. (fig.46)

The integration of BIM and GIS is crucial because neither can independently fulfill the project's requirements. BIM excels in detailed building information, while GIS specializes in spatial and flood data management. By integrating these systems, the framework can effectively visualize and assess flood damage in a 3D environment, offering a holistic view of the building's vulnerability and behavior during flood events.

However, in the initial stages, my aim was to develop a fully open-source web-based platform utilizing a B/S architecture for 3D geospatial data visualization, enabling dynamic and high-performance renderings of geographic data within a web browser. But, despite my architectural background, diving into web GIS proved challenging.

1. **Extensive computer background to acquire and apply**. While my undergraduate studies provided me with skills in Python editing through Grasshopper's interface and exposure to basic smart navigation projects using Python for data analysis during graduate school, the scope of this project demanded a deeper understanding of front-end visualization and back-end simulation, necessitating proficiency in Python, JavaScript, JSON, CesiumJS, Vue, Flask, and API requests. Despite investing significant time and effort in expanding my knowledge base, I encountered substantial hurdles during implementation. Even basic tasks, such as importing a BIM model into the Cesium platform, proved time-consuming and arduous, taking nearly half a month to accomplish.

2. **Api for simulation software.** The requirement for open-source simulation software posed additional challenges, particularly with the HEC-RAS controller, which, although open-source, differed significantly in its API call methods, resulting in further delays.

3. **Build a fully functional front-end framework**. Despite substantial progress in exporting hydrodynamic simulation results using the HEC-RAS controller and integrating detailed 3D representations of buildings and addresses from the 3D BAG dataset into Cesium, challenges persisted in developing a fully functional front-end framework using Vue and Flask, particularly in introducing clickable BIM models of each component. Consequently, despite diligent efforts, the intended fully functional B/S system remains unrealized. As it stands, the achieved milestones include exporting hydrodynamic simulation results, importing 3D BAG data into Cesium, and constructing the front-end framework using Vue.

The challenging journey of this project was made manageable and ultimately successful thanks to the unwavering patience and invaluable support of my mentor, Azarakhsh. From the outset, she played a crucial role in helping me organize the pipeline for integrating simulation data into Cesium, providing guidance and encouragement every step of the way. Recognizing the importance of practical feasibility, she wisely advised me to create a small demo to test the viability of our approach, setting a solid foundation for subsequent development.

When I encountered obstacles, particularly in loading city model data, Azarakhsh's resourcefulness shone through. She directed me to consult the 3D BAG documentation and facilitated a productive meeting with Ping Mao, a fellow GIS student who had faced similar challenges. Their collaborative efforts and shared experiences proved invaluable, enabling me to overcome hurdles and successfully load the model.

Throughout the project, Azarakhsh's unwavering support extended beyond technical assistance. She consistently demonstrated patience and understanding, even during moments of frustration or anxiety stemming from my limited coding skills. Her calm demeanor and empathetic approach not only alleviated my concerns but also inspired me to explore alternative solutions and persevere through challenges.

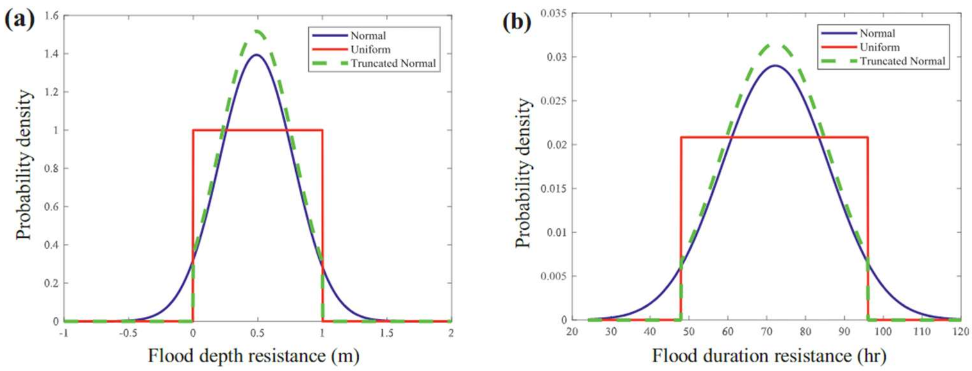
When I sought her opinion on alternative approaches after extensive research and contemplation, she graciously affirmed my considerations and offered insightful suggestions for implementation. This enabled me to pivot swiftly and confidently realign my project direction. Her encouragement and guidance were instrumental in fostering a sense of empowerment and motivation, ultimately contributing to the project's progress and success.

Above all, both of my mentors' mentorship has left a lasting impact, prompting me to reflect on the power of patience, collaboration, and resilience in overcoming obstacles. Her guidance has not only enriched my technical skills but also fostered a deeper appreciation for the importance of mentorship and support in navigating complex endeavors.

For the final phase of the project, the following objectives have been outlined:

1. Simulation of Composite Flooding Events: Expand the simulation scope to include various levels of composite flooding, requiring an increased number of samples for simulation and hierarchical display of exported results in ArcGIS. Utilizing filters, the damage grading can be visualized separately for each event.

2. Incorporating Duration in Damage Assessment: Explore the impact of both water depth and duration on building components' damage. This entails creating a graph to illustrate the resistance of different materials to duration and correlating it with the damage grading based on the water depth approach.(Fig.47)



(a) Resistance to water depth (b) Resistance to flood duration

Figure 55: Flood resistance for specific material (Nofal et al., 2020)

3. Integration of Cesium and ArcGIS: Investigate methods to connect Cesium and ArcGIS, enabling the visualization of results through the web interface. This involves exploring ArcGIS documentation to understand its API capabilities and learning the requirements of the Cesium call interface to facilitate seamless communication between the two platforms.

1. What is the relation between your graduation project topic, your master track (A, U, BT, LA,

MBE), and your master programme (MSc AUBS)?

The topic of this project is "A Design Tool to Analyze and Visualize the Risk of Building Structures under Compound Flood Hazards." Digital tools to aid in decision-making are among the most crucial concerns in the building technology profession.

This tool is designed not only for optimizing building design during the early stages but also for use in civil engineering by combining hydraulic and structural aspects to measure and mitigate the risk of building structures under compound flood hazards. Moreover, it can contribute to structural optimization, making it a versatile and valuable resource across various stages of building and infrastructure development. This idea is in line with the concept of building technology to make up for building and civil engineering technology.

2. How did your research influence your design/recommendations and how did the

design/recommendations influence your research?

My research influenced the final design in three key ways: through a comparative study of hydraulic models, a dissertation study of evaluation systems, and a study of visualization systems. These studies provided robust arguments for data reliability, methodological rigor, and application feasibility.

My design identified problems that arise when synthesizing and applying research from different fields. For instance, when quantifying damage, calculating the bending moment and shear force of the structure using finite element analysis posed a challenge because the analysis software could not be effectively linked with ArcGIS. Although finite element analysis offers specialized and accurate assessments of vulnerability, its incompatibility with the overall framework necessitated a change in the research strategy.

3. How do you assess the value of your way of working (your approach, your used methods, used

methodology)?

To assess the value of my approach, methods, and methodology, I consider several key factors:

1. Effectiveness in Meeting Objectives: My approach was designed to meet specific project objectives, such as integrating hydraulic simulations with structural analysis and visualizing flood risks in a user-friendly manner. By evaluating how well these objectives were met, I can determine the effectiveness of my methods.

2. Interdisciplinary Integration: The value of my methodology lies in its ability to integrate insights from different disciplines, such as civil engineering, hydraulic modeling, and geospatial analysis. This interdisciplinary approach ensures a comprehensive assessment of building vulnerabilities to compound flood hazards.

3. Stakeholder Engagement and Feedback: Regular engagement with mentors, peers, and other stakeholders provided valuable feedback that informed and improved my methodology. This iterative process of refinement ensured that the final design was aligned with the needs and expectations of its users.

By evaluating these factors, I can confidently assess that my approach, methods, and methodology were valuable and effective in achieving the project's goals and providing practical, reliable solutions for assessing building vulnerabilities to compound flood hazards.

4. How do you assess the academic and societal value, scope and implication of your graduation

project, including ethical aspects?

The social relevance of this modeling approach lies in its potential to significantly enhance community resilience and safety in the face of climate change-induced flood hazards. By accurately assessing flood vulnerability at both the structural and component levels, the approach enables proactive measures to be taken to reinforce buildings and infrastructure, thereby reducing the risk of damage and loss of life during flooding events.

Furthermore, the utilization of a web-based interface for data visualization promotes greater accessibility and transparency, allowing for widespread dissemination of critical information to stakeholders, including community members, local authorities, and emergency responders. This empowers communities to make informed decisions, develop effective evacuation plans, and allocate resources efficiently in preparation for flood events.

Overall, by addressing the pressing issue of flood risk management with advanced modeling techniques and accessible data visualization tools, this approach contributes to building more resilient and adaptive communities, ultimately enhancing societal well-being and safety.

5. How do you assess the value of the transferability of your project results?

From a scientific perspective, this modeling approach contributes to advancing our understanding of the complex dynamics of flood hazards in the context of climate change. By incorporating comprehensive assessments of flood hazard triggers and probabilities, the approach provides valuable insights into the multifaceted factors influencing flood risk.

Moreover, the integration of precise component-level analyses represents a significant advancement in flood vulnerability assessment methodologies. This detailed examination allows for a more nuanced understanding of structural vulnerabilities and the potential effectiveness of mitigation measures, thereby informing future research and engineering practices aimed at enhancing resilience to flood hazards.

Additionally, the utilization of a web-based ArcGIS Pro interface for data visualization not only facilitates collaboration among stakeholders but also presents opportunities for further scientific inquiry. The accessibility of data through such platforms enables researchers to explore new avenues of analysis, validate modeling assumptions, and refine predictive models, ultimately advancing the state of the art in flood risk assessment and management.

Overall, this modeling approach contributes to the scientific community by expanding our knowledge of flood risk dynamics, improving the accuracy of vulnerability assessments, and providing tools for collaborative research and decision-making in the field of flood hazard mitigation and adaptation.

6. How could the tools I used in the project be further developed?

1. **Integration with More Data Sources**: Future iterations could integrate additional data sources, such as real-time weather data, to enhance the accuracy and timeliness of flood risk assessments. This integration could enable more proactive and responsive planning and decision-making.

2. **Advanced Analytical Tools**: Incorporating advanced analytical tools and machine learning algorithms could further refine the damage assessment process. These tools could analyze patterns and predict vulnerabilities more accurately, providing deeper insights into flood risks.

7. what strategies did you employ to overcome these obstacles, and how did this experience shape your approach to interdisciplinary collaboration in future projects?

1. **Regular group exchanges:** Simona arrange group meeting each month. In these exchanges, cross-cutting topics serve as conduits for sharing literature, data sources, and tools, enriching our collective understanding. Moreover, exposure to diverse topics inspires fresh ideas, encourages thinking outside conventional boundaries, and fosters a deeper appreciation for varied research methods. By leveraging this interdisciplinary synergy, we not only enhance our individual projects but also cultivate a collaborative environment that propels innovative research forward.

2. **Flexibility and Adaptability**: Remaining flexible and adaptable to changing circumstances and unforeseen challenges was key. Being open to alternative approaches and willing to adjust strategies as needed allowed for more effective problem-solving.

3. **Learning from Mistakes**: Going fast, failing fast, and learning fast from bad experiences is the most useful thing I've learned. Because ignorance of other fields is sure to be accompanied by misinterpretation, the fastest way to correct it is to learn from the experience of trying and to refine your knowledge of other subjects even more.