Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Tingwei Du
Student number	5808138

Studio		
Name / Theme	Digital design tool for climate resilient structures	
Main mentor	Simona Bianchi	Structural Design (Structural Design & Mechanics)
Second mentor	Azarakhsh Rafiee	Computational Design (Urban resilient & Digital twin)
Argumentation of choice of the studio	When faced with multi-hazard scenarios, building structure level performance is an important indicator of building resilience evaluation. In the context of global climate change, I am committed to digitally realizing this goal and helping designers make decisions intuitively.	

Graduation project	
Title of the graduation project	A Design Tool to Analyze and Visualize the Risk of Building Structures under Compound Flood Hazards
Goal	
Location:	Noorderzijlvest, Netherlands
The posed problem	At present, when dealing with compound flood disasters, the neglect of the joint effect between multiple hazards often leads to an underestimation of the flood hazard level, which in turn leads to an overestimation of the resilience of the building, and how to accurately predict the resilience of the building's full life cycle is an important means of assisting in the decision-making of the building or its operation and maintenance. In addition, in order to reduce the cost of losses, the assessment scale is clarified to the level of structural components, which can more accurately determine the location of building components that need to make improvements, and maximize the overall building resilience. Currently, most disaster assessments are still in the qualitative stage, with limited applicability of the system, high uncertainty, and indices expressing the degree of hazard becoming difficult.

research questions and	The main research question is: "How We Built an Open Source System to Quantify the Risk of Structures Over Long Design Lives When Facing Compound Flooding Scenarios" The main research question can be divided into: The following sub-questions will have to be answered to be able to answer the main question: - How to assess multi-hazards risk for compound flooding in quantitative manner in urban scale, to consider of hazard inter-dependency? - How to model structure system for simulation, to develop a BIM-GIS integration approach to predict building structure performance? - What intensity indexes and performance indicators should be used to analyze failure behavior of structure over a long design lives. - How to integrate simulation models in a web viewer for their efficient performance on building structures, to interactively display the hazard index of each component?
design assignment in which these result.	The purpose of the research is to improve the compound hazard resistance of structures and to assist designers in making structural design decisions. The risk of building structures is evaluated under the compound flood scenarios, and the loss of components at each position is identified to determine which parts should be strengthened or maintained, in order to improve the building's resilience to hazards in a more efficient manner. As a result of this study, a "structural risk identification system for flooding" is proposed. The intensity and probability of individual hazards are the input parameters, and the risk curves (including frequency, vulnerability, and exposure) of structural components are the output variables.

The final design tool results need to meet the following requirements:

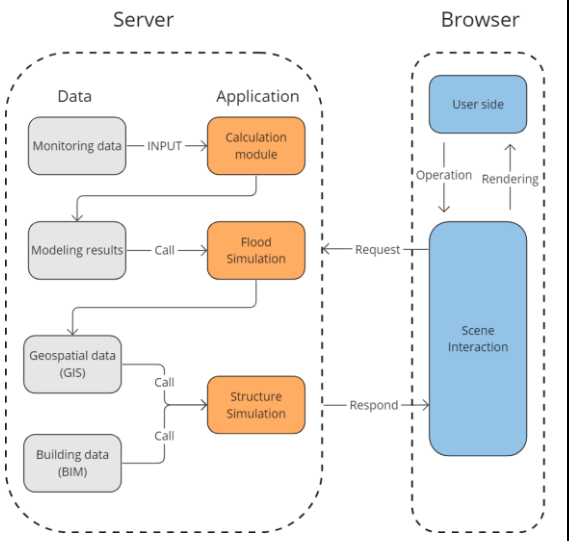
1. get the CityGML model with the BIM model and import it into Cesium
2. load predicted climate data and get inundation maps based on city-scale flood predictions and derive hazard maps (depth of inundation-return period) for target buildings
3. analyze the vulnerability and exposure of the structural elements of the BIM models
4. synthesize the hazard frequency, vulnerability and exposure to obtain hazard curves for each component
5. visualize the structural hazard curves with heat maps using Cesium's interactive function

Process

Method description

This thesis aims to design a digital tool to help architects quantitatively assess the risk index of structural elements in case of compound flooding. So that reinforcement measures can be targeted. These results were quantified by plotting vulnerability curves of structure level performance to the vulnerability parameters considered. The methodology of the thesis follows the process of a digital tool development, including the following steps:

Aspect	Subject	Detail	Method	Output
Source Estimation	Climate change	Projecting future climate change in the Netherlands based on historical KNMI data	regional climate model simulations (van den Hurk et al., 2015)	Probability distribution curves for precipitation and storm surge
	Compound flood	Analyzing the compounding occurrence of heavy precipitation and storm surge conditions in a Dutch coastal polder area	Bivariate copula model(Santos et al., 2021)	Joint probability distribution curves (hazard curve) for compound floods
Risk Quantification	Vulnerability analysis	Hydrostatic action computation	*Research:* Kelman2002 and Spence 2004 *Software:* Finite Element Analysis *Criteria:* Ultimate- and Serviceability-Limit States	Load duration, magnitude on each component -- loads and resistance -- damage
	Exposure analysis	Water contact damage	CLASSIFICATION: FEMA (2008) HNFMSC (2006)	Classification of magnitude according to the materials, immersion duration and ratio of immersion in water
	Risk analysis	Damage with different probability of occurrence can provide a overview of building over a whole design life	Probability of hazard X Consequences	Risk curve

3D Visualization	Data Layer (server)	Monitoring data: Terrain, Flood, Building, Utility, Valuation, Material Domain package	
	Application Layer (server)	Simulation module: Flooding simulation (MIKE21/ SIMSCALE/ DELFT-FLAT) Structure simulation: FEA	
	Display Layer (Browser)	User side: Web viewer (Cesium / ArcScene) Scene interaction: Pop up with risk curve	

Literature and general practical references

Hatzikyriakou, A., Lin, N., Gong, J., Xian, S., Hu, X., & Kennedy, A. (2016). Component-based vulnerability analysis for residential structures subjected to storm surge impact from hurricane sandy. *Natural Hazards Review*, *17*(1). https://doi.org/10.1061/(asce)nh.1527-6996.0000205

Klerk, W. J., Winsemius, H. C., van Verseveld, W. J., Bakker, A. M. R., & Diermanse, F. L. M. (2015). The co-incidence of storm surges and extreme discharges within the rhine–meuse delta. *Environmental Research Letters*, *10*(3), 035005. https://doi.org/10.1088/1748-9326/10/3/035005

Kumar, P. (2022). An ogc 3 d tiling technique based user interactive platform for digital twins in a virtual reality environment. ..

Leal, M., Reis, E., Pereira, S., & Santos, P. P. (2021). Physical vulnerability assessment to flash floods using an indicator-based methodology based on building properties and flow parameters. *Journal of Flood Risk Management*, *14*(3). https://doi.org/10.1111/jfr3.12712

Mitu, M. F., Sofia, G., Shen, X., & Anagnostou, E. N. (2023). Assessing the compound flood risk in coastal areas: framework formulation and demonstration. *Journal of Hydrology*, *626*, 130278. https://doi.org/10.1016/j.jhydrol.2023.130278

Santos, V. M., Casas-Prat, M., Poschlod, B., Ragno, E., van den Hurk, B., Hao, Z., Kalmár, T., Zhu, L., & Najafi, H. (2021). Statistical modelling and climate variability of compound surge and precipitation events in a managed water system: a case study in the netherlands. *Hydrology and Earth System Sciences*, *25*(6), 3595–3615. https://doi.org/10.5194/hess-25-3595-2021

Sun, Q., Fang, J., & Liu, M. (2023, May 15). *Simulation and assessment of compound flooding in coastal cities under climate change*. Copernicus GmbH. https://doi.org/10.5194/egusphere-egu23-9259

Thakur, P. K., Maiti, S., Kingma, N. C., Hari Prasad, V., Aggarwal, S. P., & Bhardwaj, A. (2011). Estimation of structural vulnerability for flooding using geospatial tools in the rural area of orissa, india. *Natural Hazards*, *61*(2), 501–520. https://doi.org/10.1007/s11069-011-9932-3

Database resource:

Urban LOD Model: 3D BAG

https://3dbag.nl/en/viewer?rdx=68755.76155396842&rdy=443935.96029131283&ox=125.86108289746335&oy=140.9409318175455&oz=-72.23769729454943&lod=lod22

Surge storm, precipitation, discharge historic observation data:

https://waterinfo.rws.nl/#/publiek/waterhoogte

https://cds.climate.copernicus.eu/cdsapp#!/software/app-extreme-precipitation-statistics-europe-explorer?tab=app

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

   a. Resilience: Understanding and assessing potential flood damage is crucial in designing structures that can resist or recover from compound flood, contributing to overall climate resilience.
   b. Digitalization: The BIM-GIS integration enables the tool to use real-time or historical data for flood modelling and assessment, allowing for dynamic adaptation strategies based on future climate patterns.
   c. It empowers stakeholders to make informed decisions during the design and planning stages, leading to structures that can better withstand and adapt to the impacts of climate change, particularly those related to flooding.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The modeling approach proposed takes into account not only the changes in flood hazard triggers due to climate change but also the probability of occurrence between indicators. Thus, the structural performance of the whole building cycle can be regarded.
In addition, this study surpasses the urban scale analysis of hazard vulnerability by precise to components, which allows designers and engineers to reinforce structures with high risk more accurately.
Finally, visualizing the data results with a web-based end is clearer, lighter, and faster for collaborative design, engineering, and other stakeholders.