

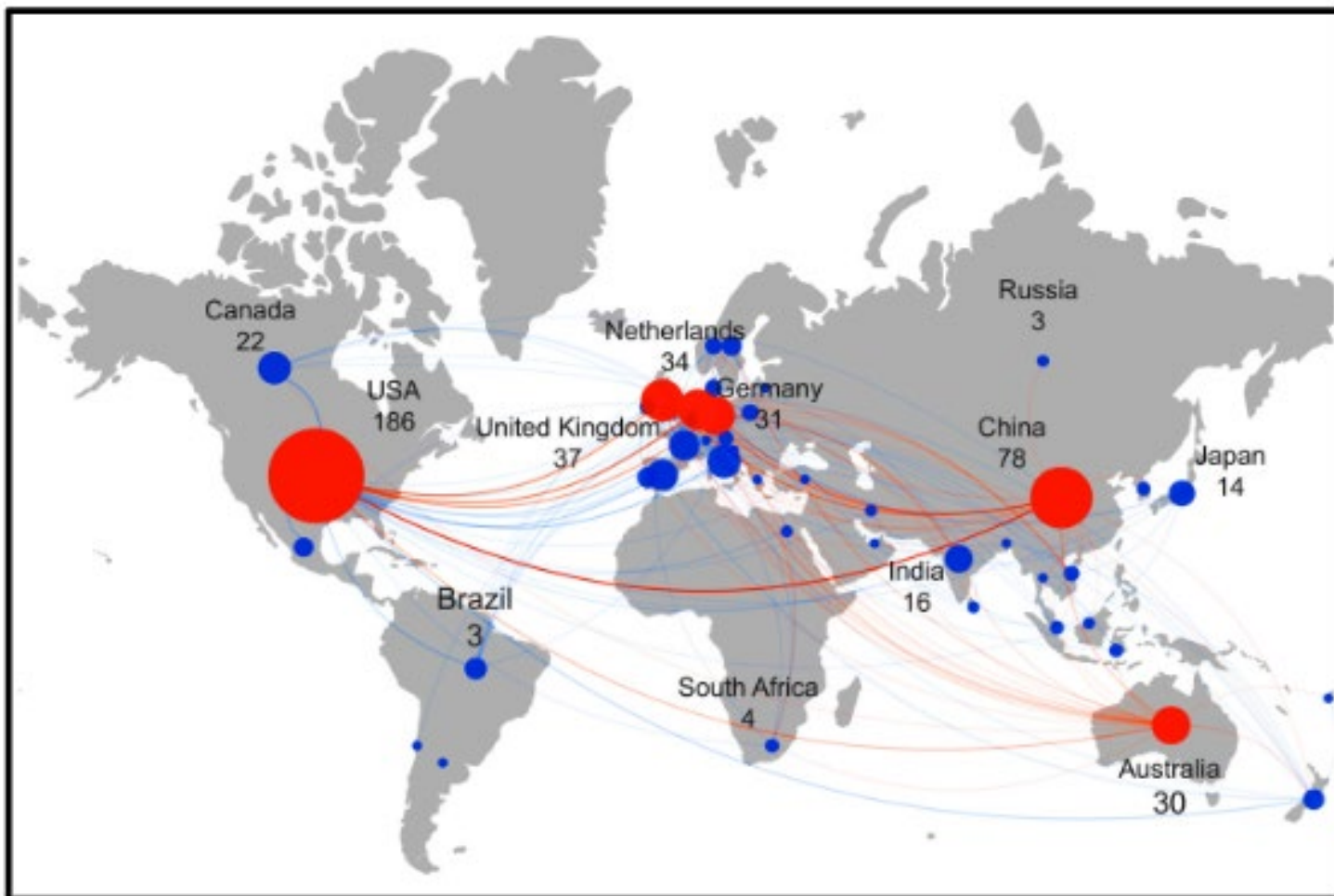
A Digital Tool to Analyze and Visualize the Risk of Structures under Compound Flood Hazards

Building Technology Graduation Project
Tingwei Du | 5808138

Simona Bianchi , Resilient Structural & Climate Design
Azarakhsh Rafiee , Computational Design & Digital twin

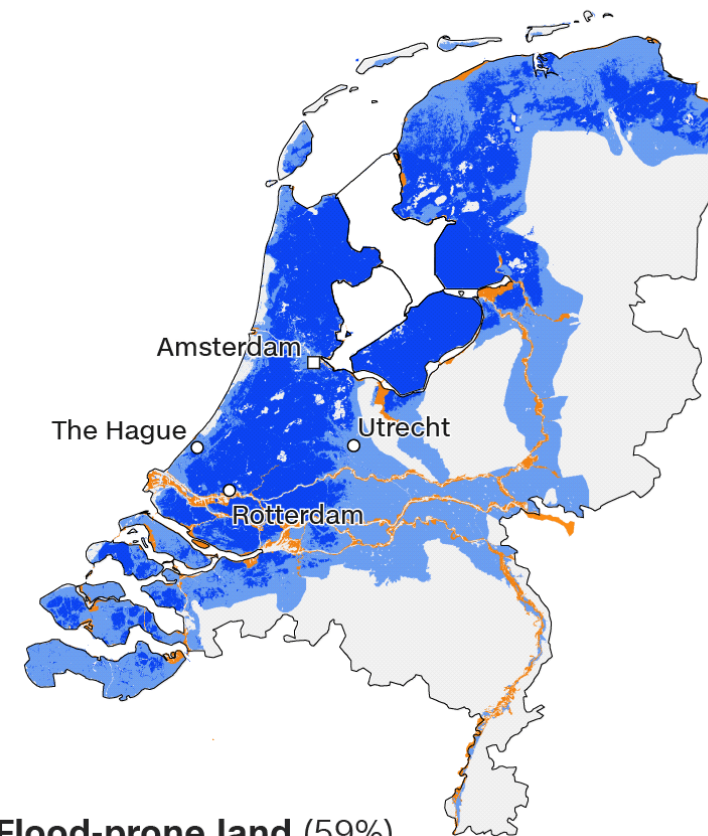
Delegate Examiner:
Marc Schoonderbeek





2014-2022

More than half of the Netherlands is located on flood-prone land



Flood-prone land (59%)



"NOW FOR FUTURE"

IN 2100



Sea level

100 cm



Flood-prone area

125%



Inundation depth

2.5 m



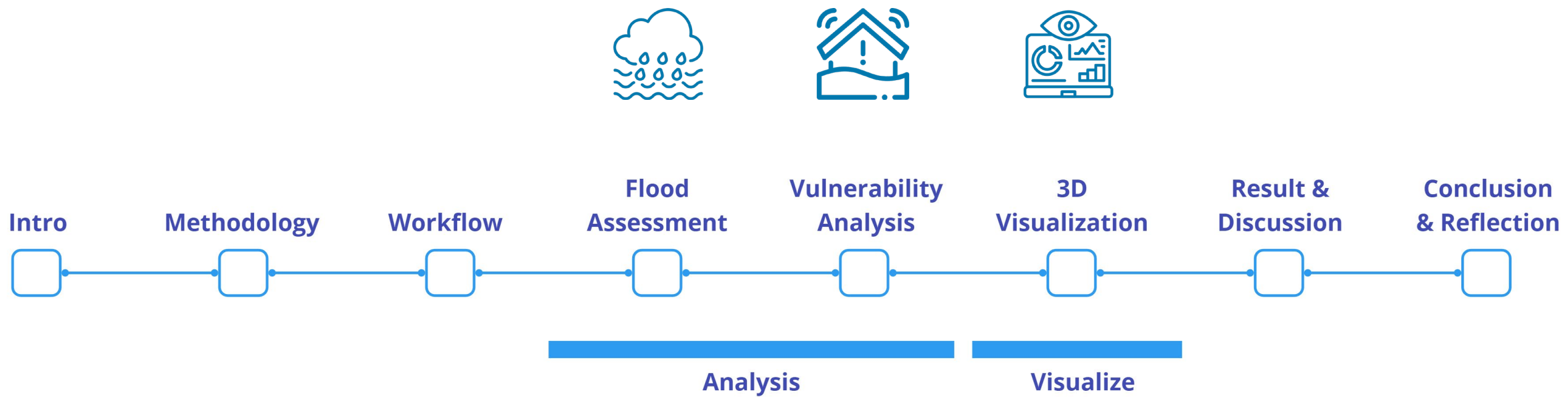
“NOW FOR FUTURE”



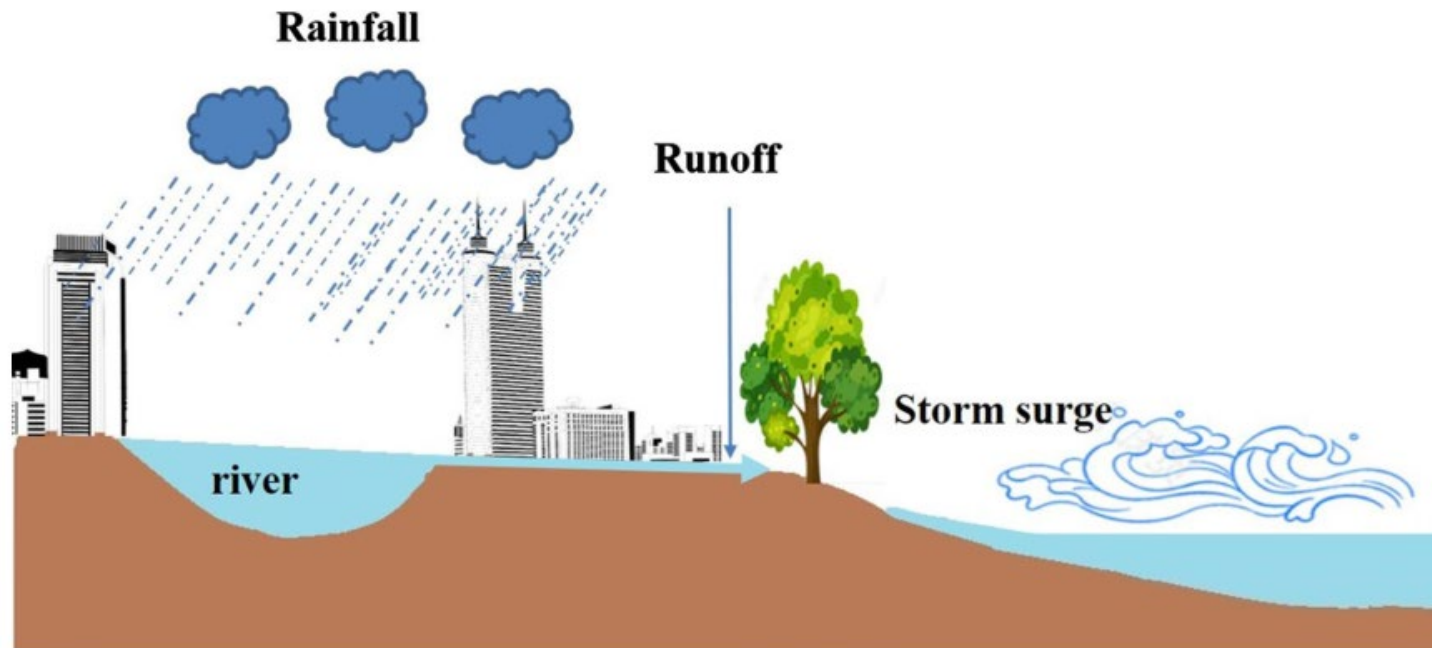
- Flood risk management
- Fresh water
- Spatial Adaptation

TOPIC

A Digital Tool to **Analyze** and **Visualize**
the Risk of Structures
under Compound Flood Hazards

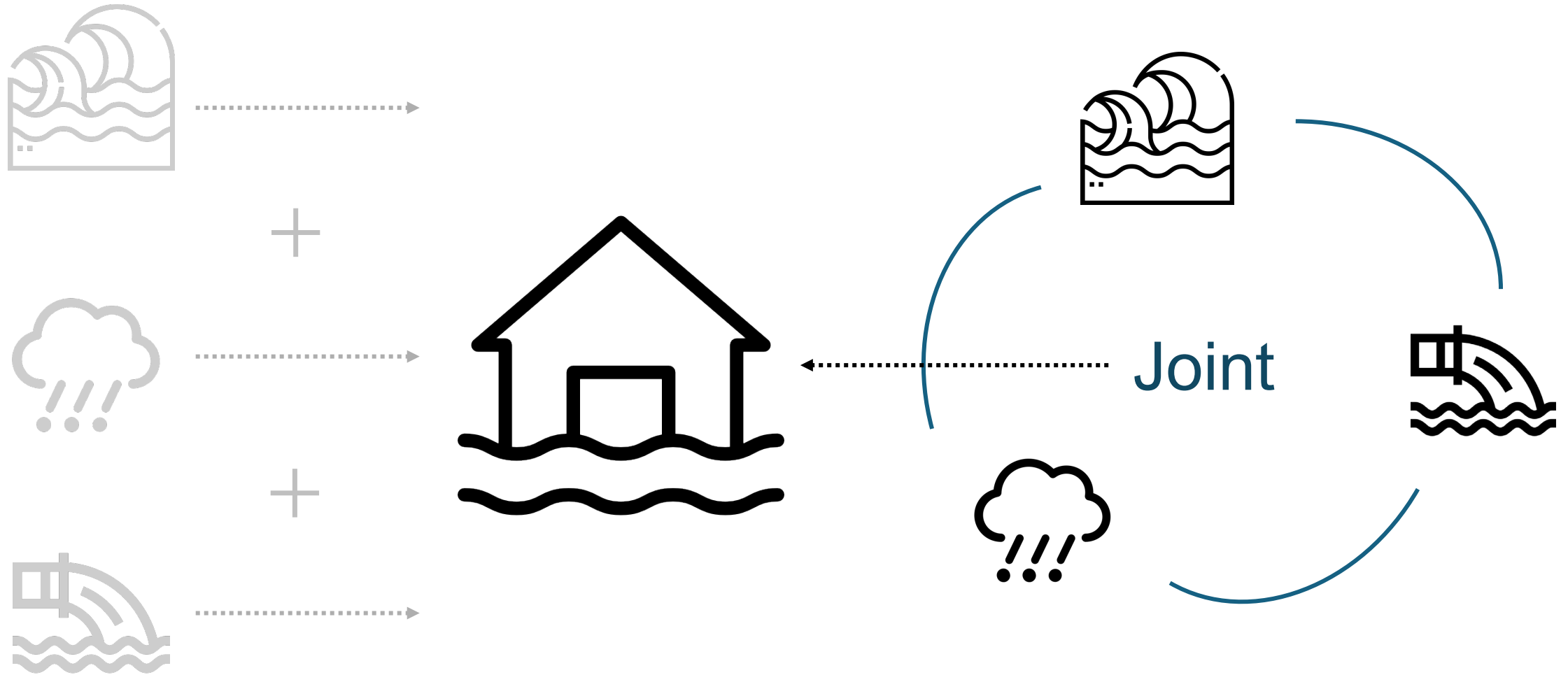


Key Flood Indicators

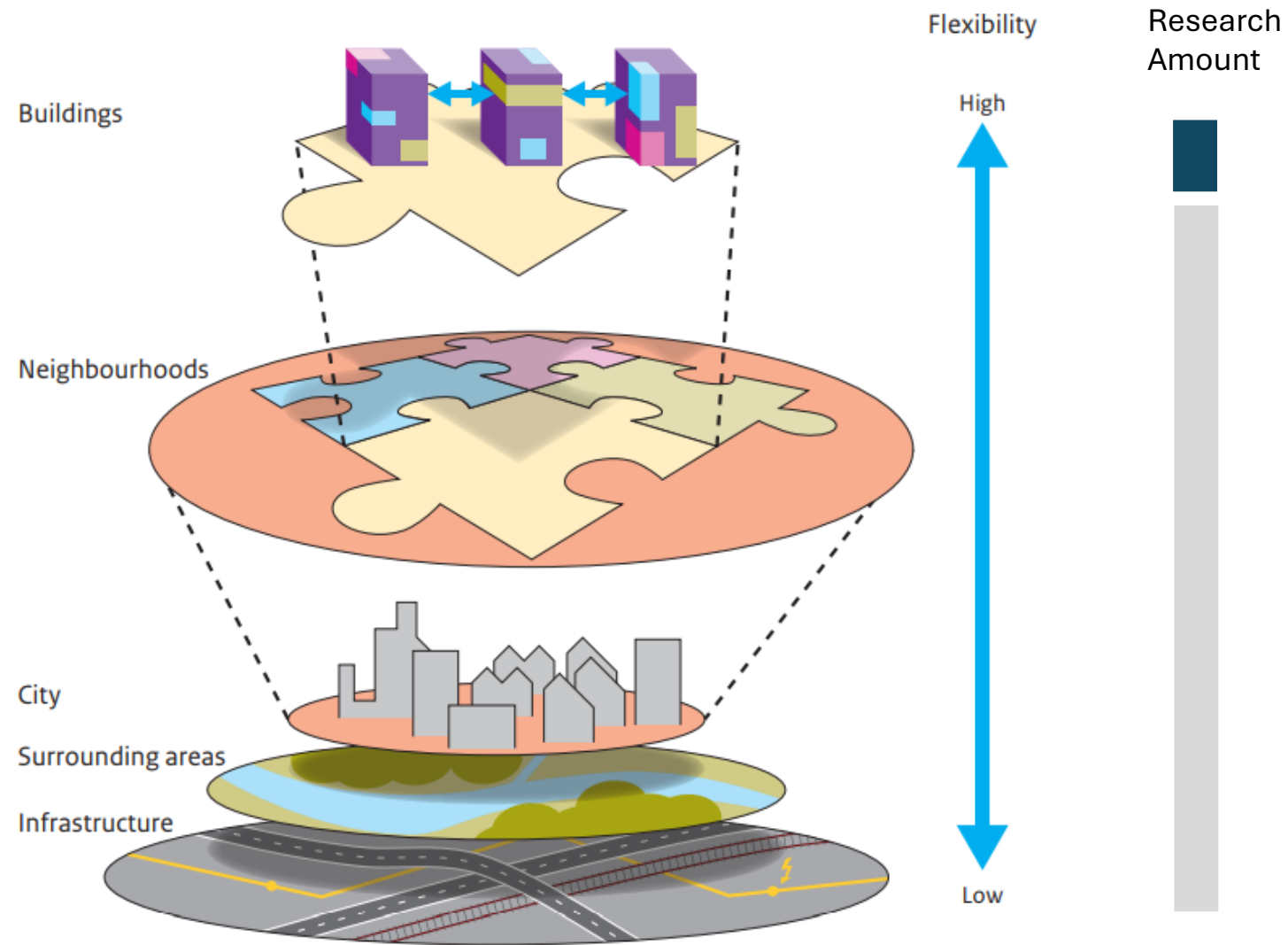


- Storm surge
- Precipitation
- River discharge

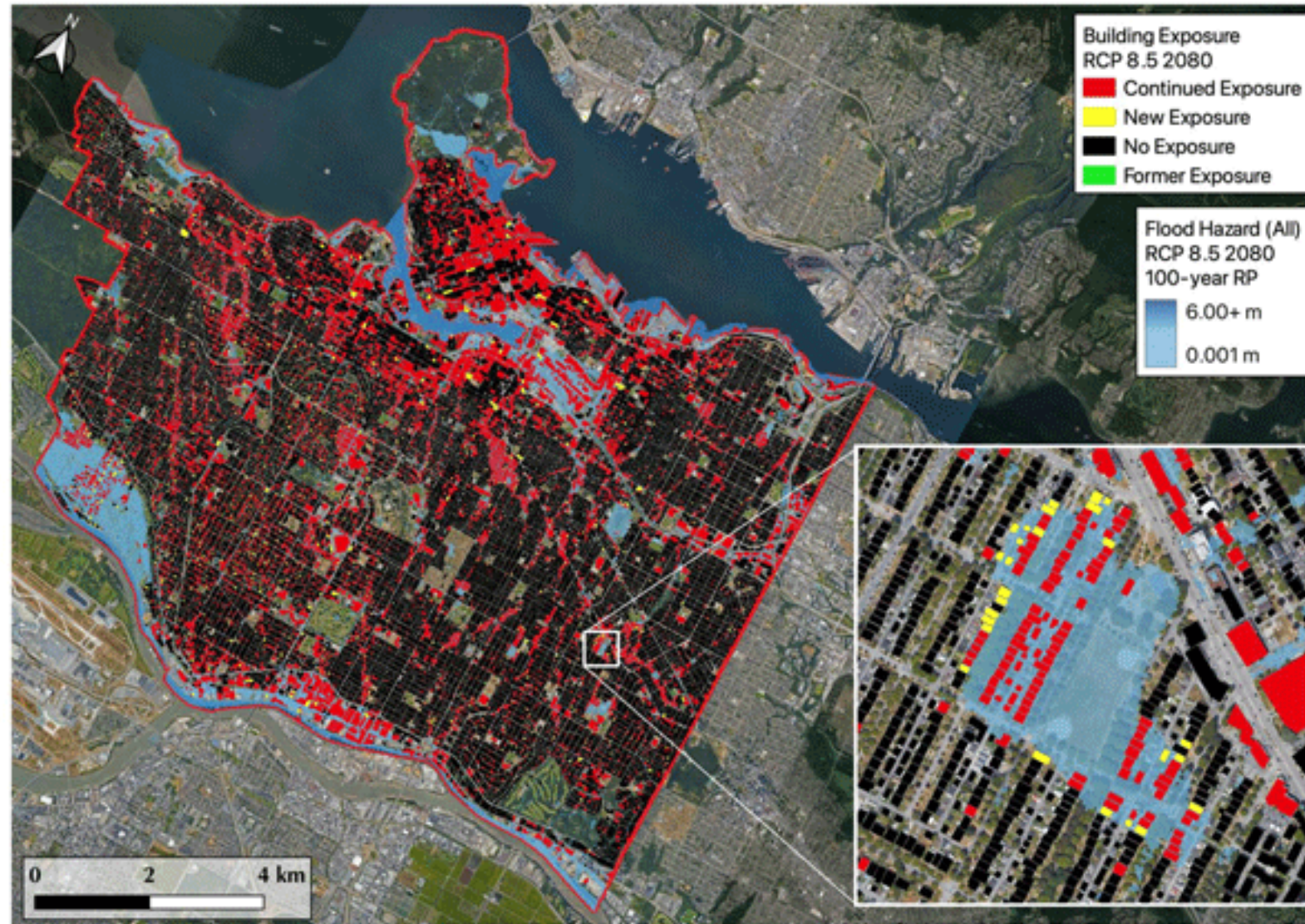
Combination Effect



A Digital Tool to Analyze and Visualize the Risk of **Structures** under Compound Flood Hazards



Risk map in community level



Intro



Optimization in building element level

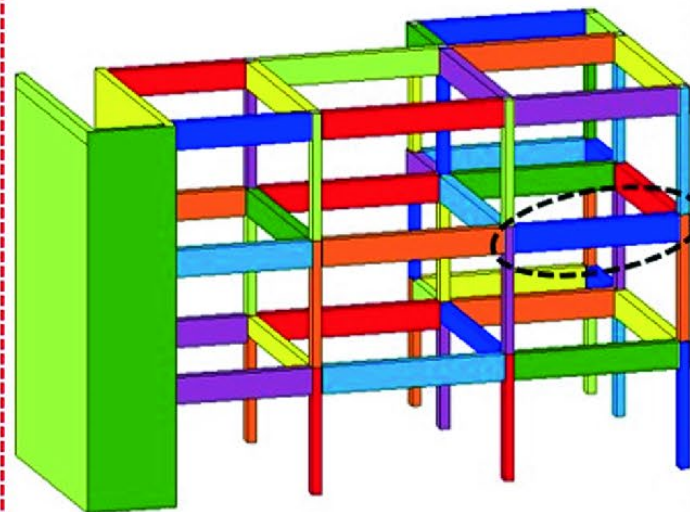


Identify the damage state of elements

Initial BIM Model



Color Coded BIM Model



Severity Indices:



Tag on Individual Element

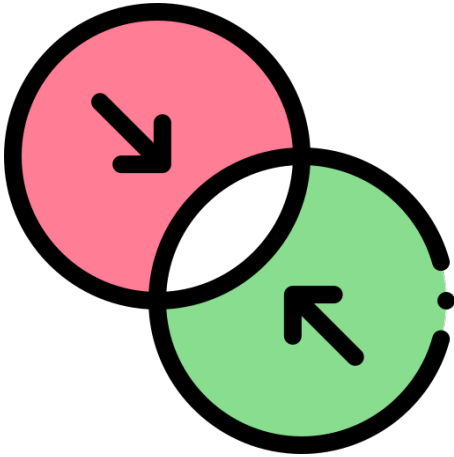


Element Severity = 5

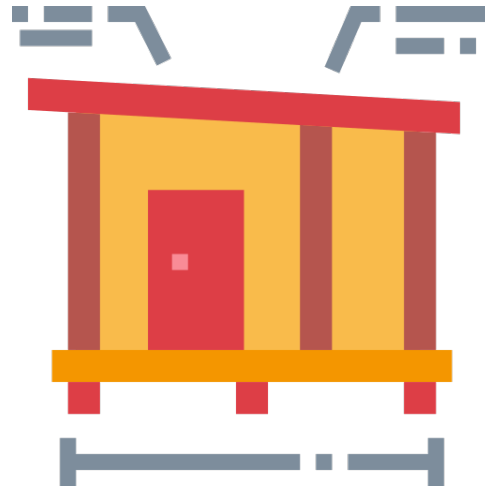
Recommended action:

Detailed investigation required and cracks to be sealed if needed.

Research Gap



Combined effects of drivers



Structure level
damage quantification



3D Visualization & Report

Objectives

A Digital Tool to Analyze and Visualize the Risk of Structures under Compound Flood Hazards

Hydrodynamic simulations

Quantify damage methods

Interactive visualization map

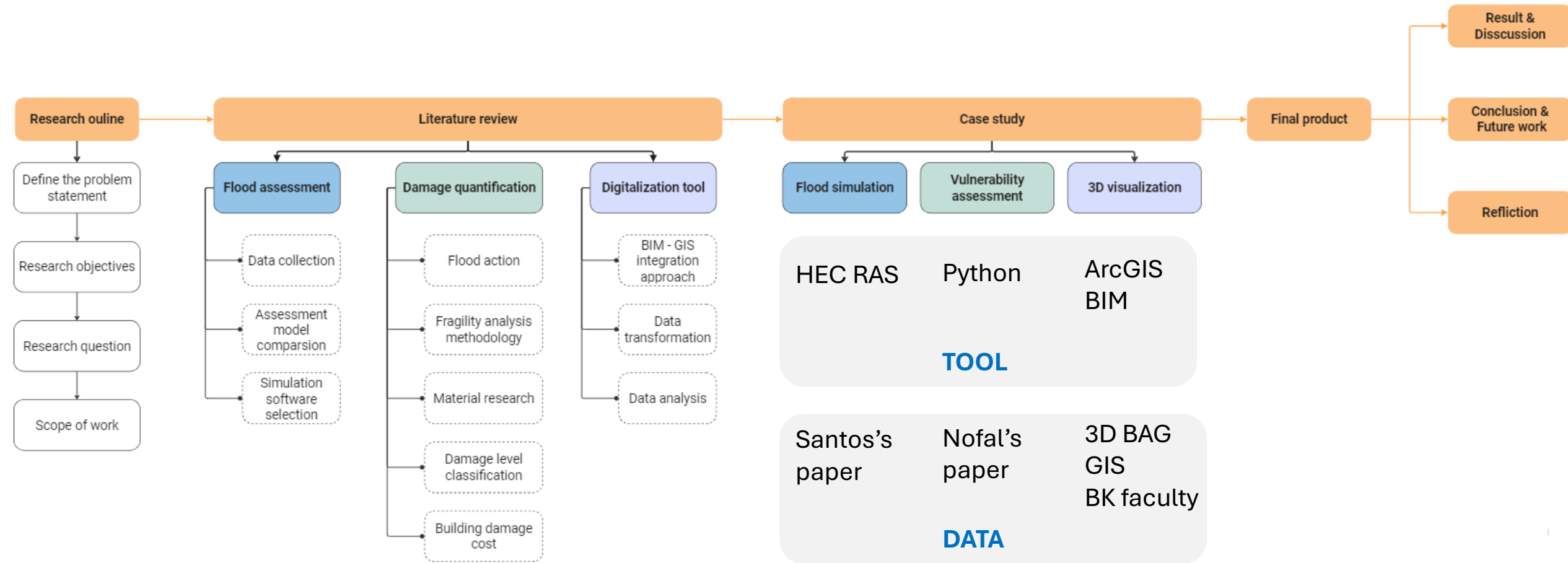


Main research question

How We Built a digital tool to quantify damage to building structures in compound floods considering future climate scenarios that guides the designers and engineers to identify vulnerable components and report the cost.

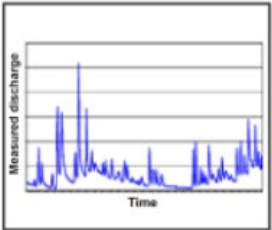


Methodology Framework

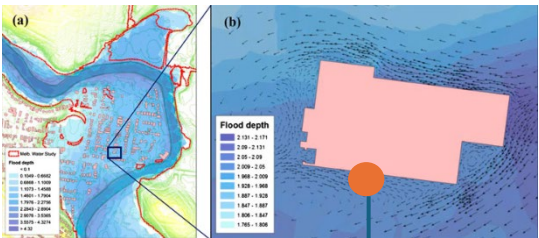


Case Study

Hydrological data



Flood simulation



Depth spatial distribution map

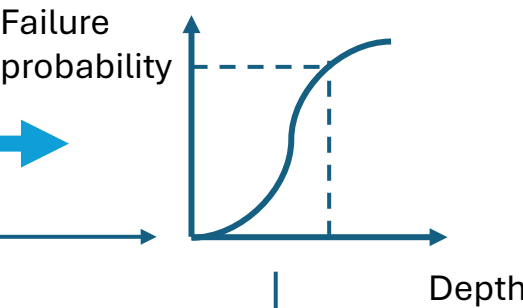


System
Residential building

- Window
- External wall
- Floor
- Heating
- Door
- Roof
- Internal wall
- ⋮

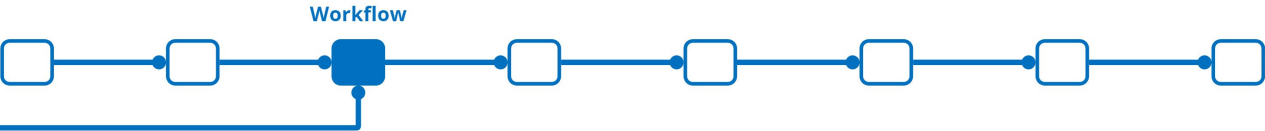
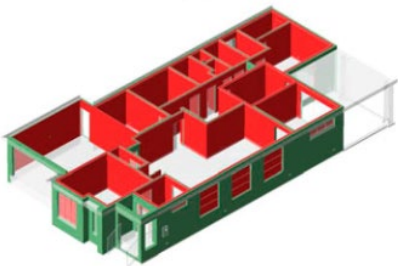
Subsystems
Building components

Vulnerability analysis

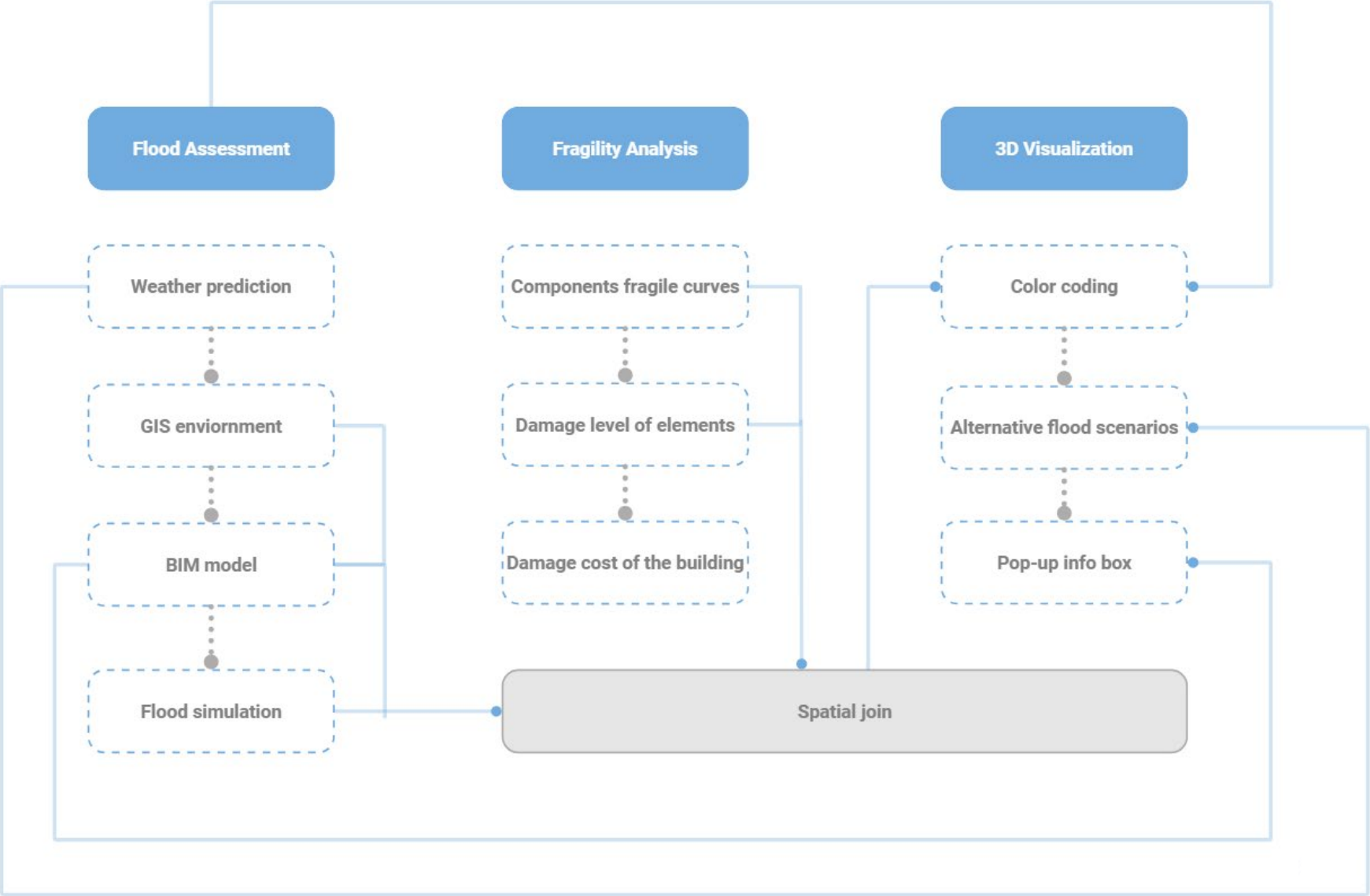


DS	Fragility	Recommend ed action
DS1	a-b	Nothing
DS2	b-c	Check
DS3	c-d	Reinforce
DS4	d-f	Replace

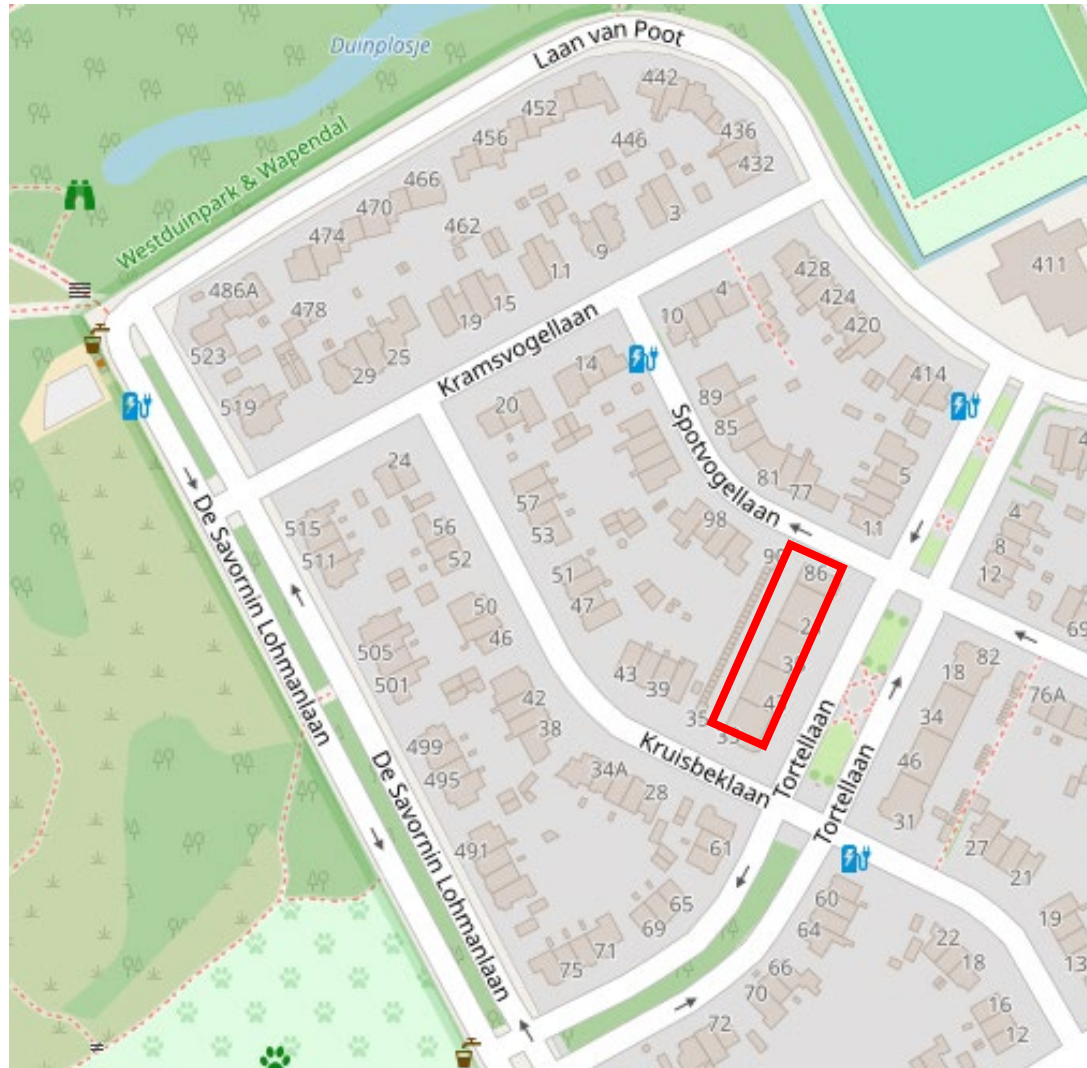
3D visualization



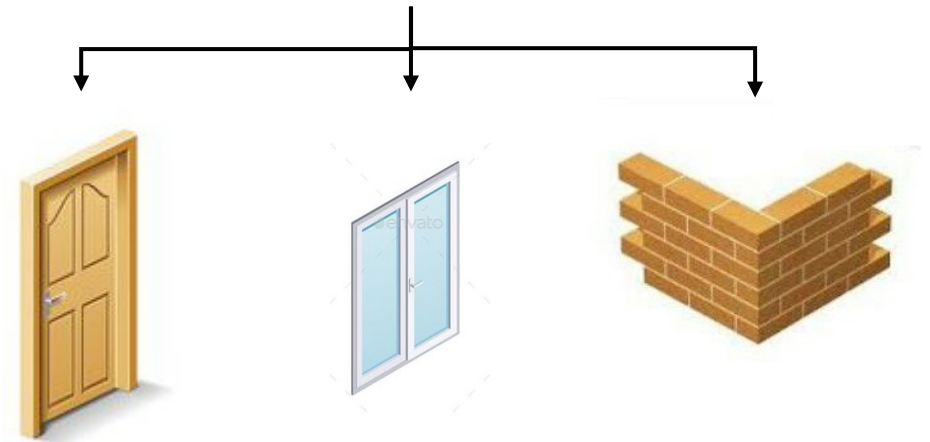
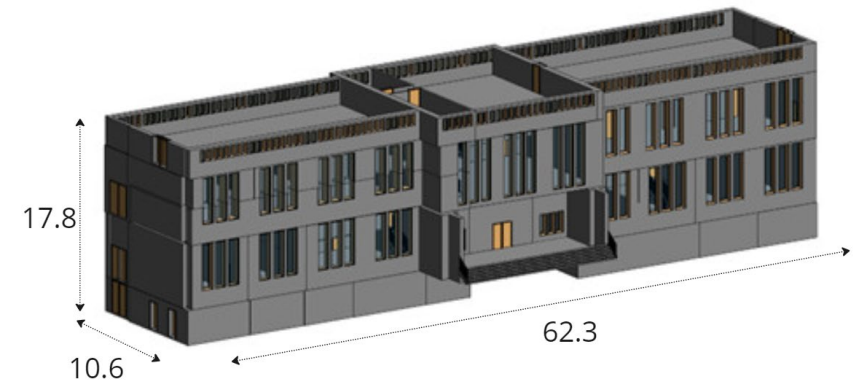
Workflow







Two-story residential building with a basement



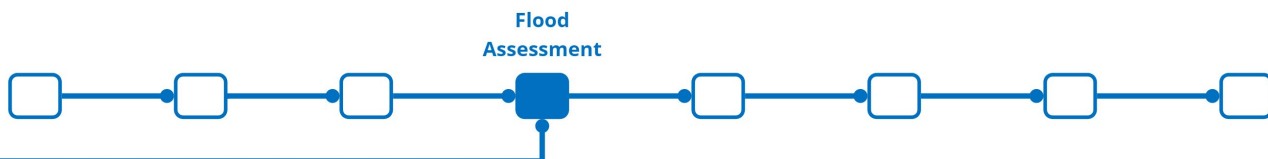
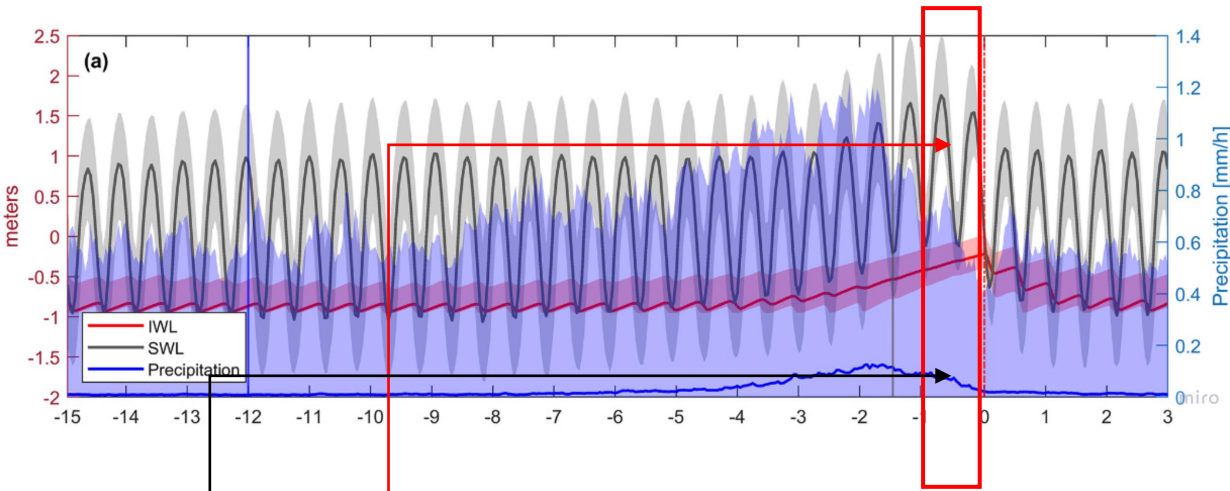
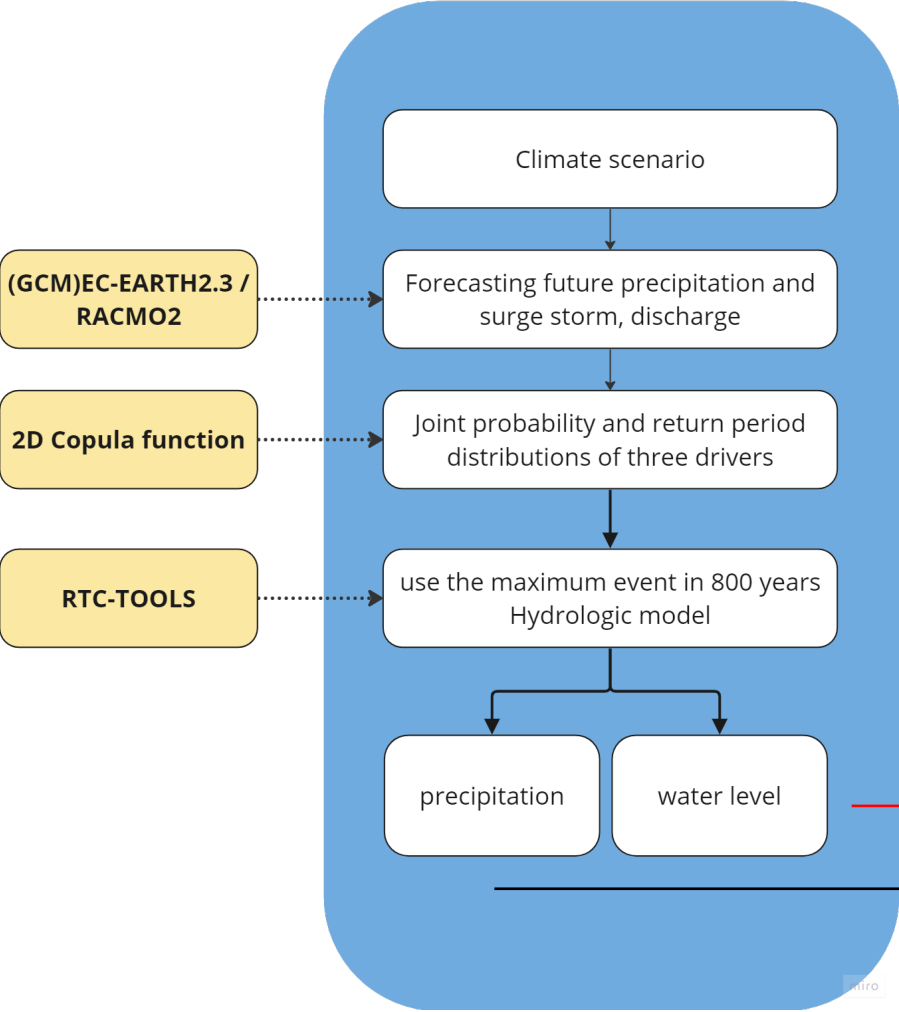
Timber

Glass

Masonry

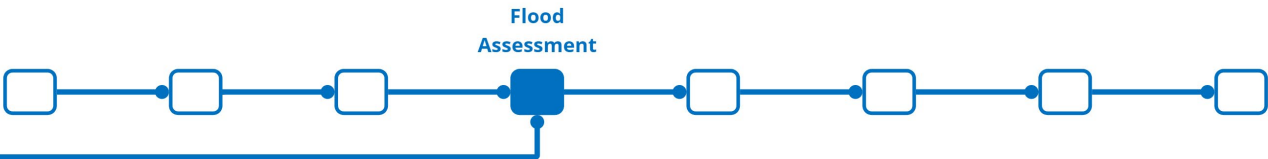
Flood Assessment

Data collection

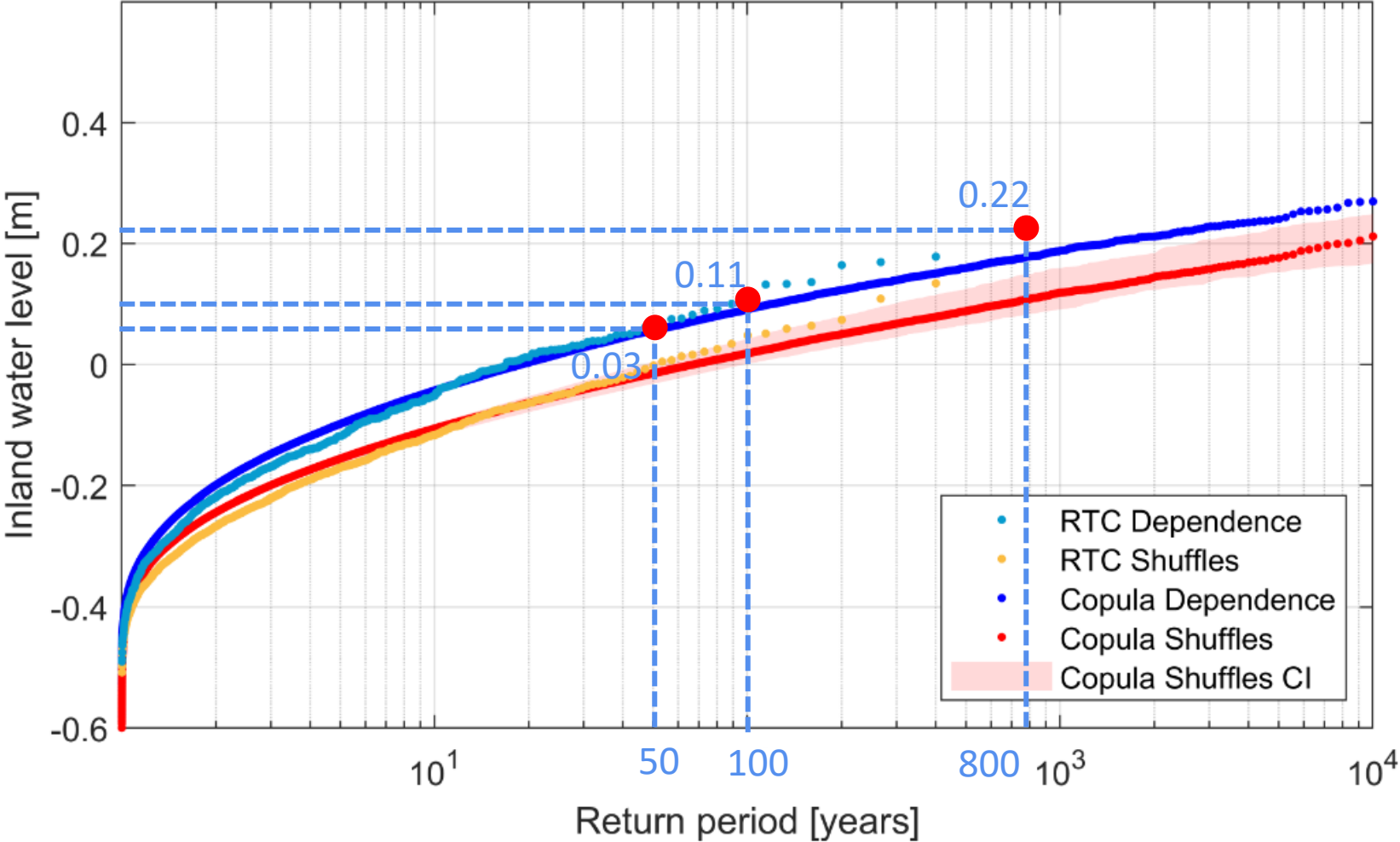


Return period (T)	Probability of exceeding in a given year (P _e)
50	1/50
100	1/100
800	1/800

$T = 1 / P_e$



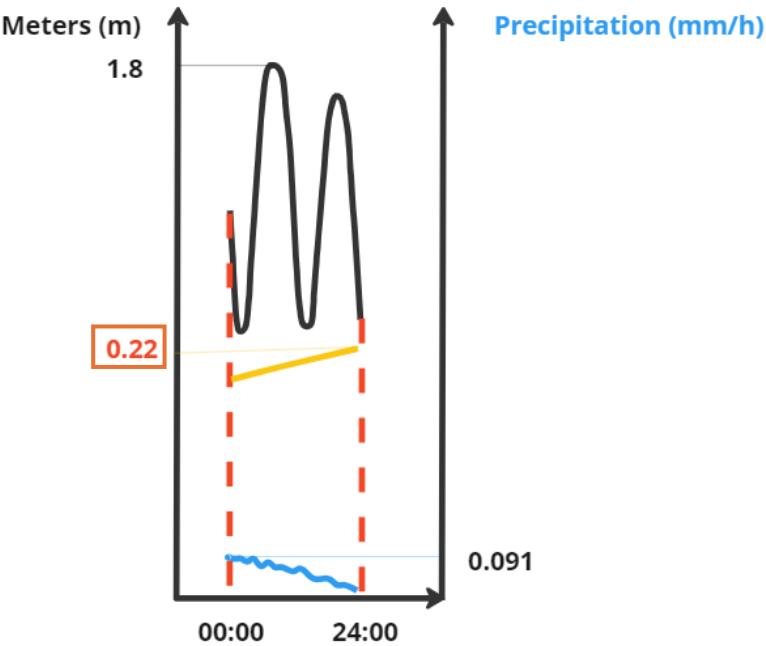
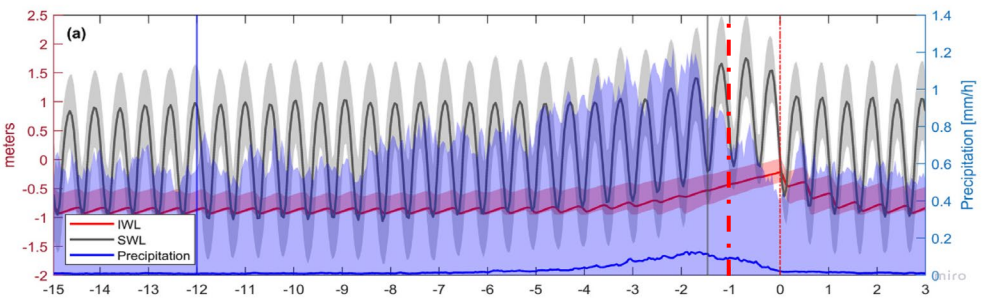
Flood scenario



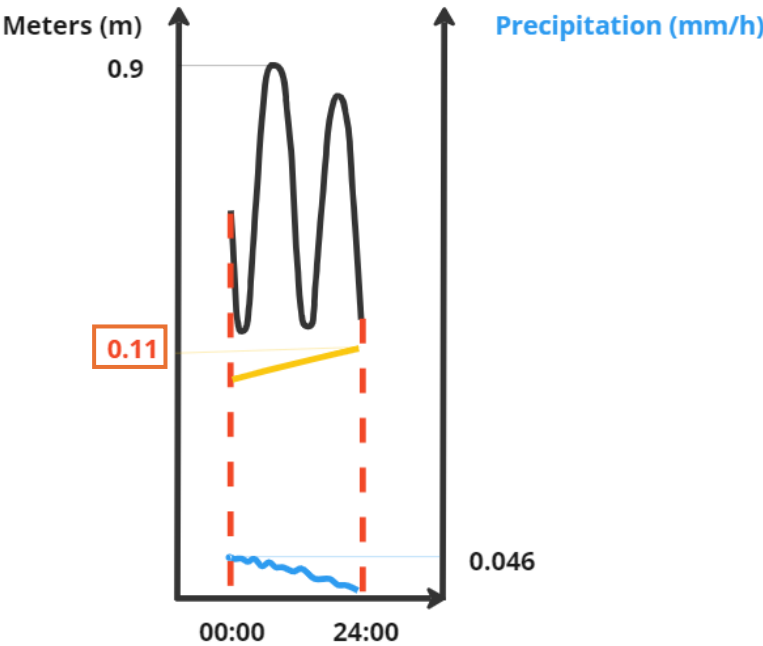
Flood
Assessment



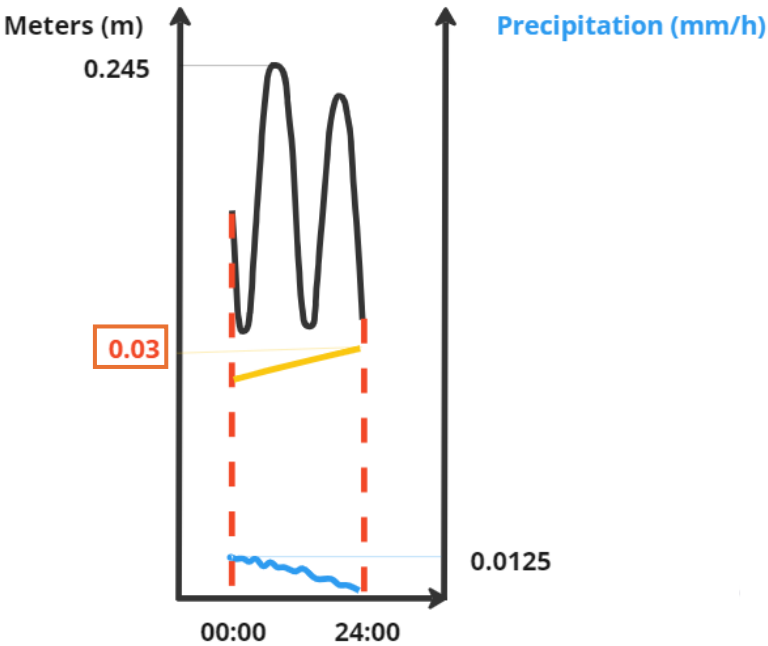
Flood scenario



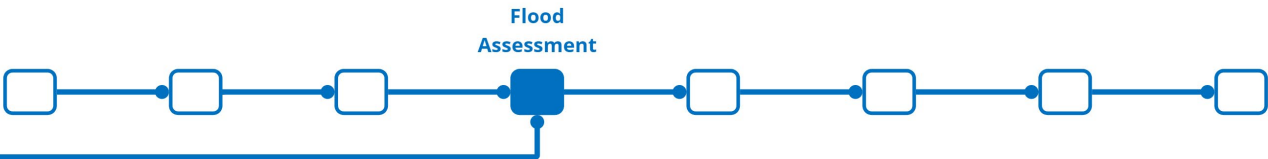
T = 800



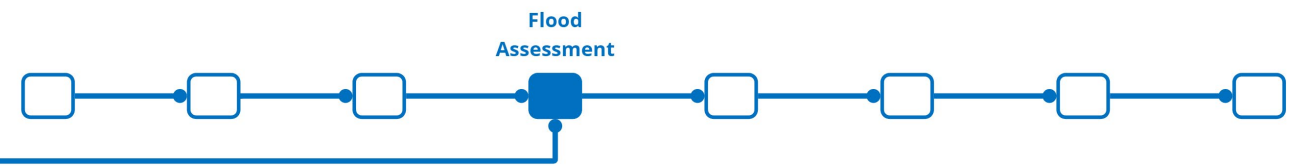
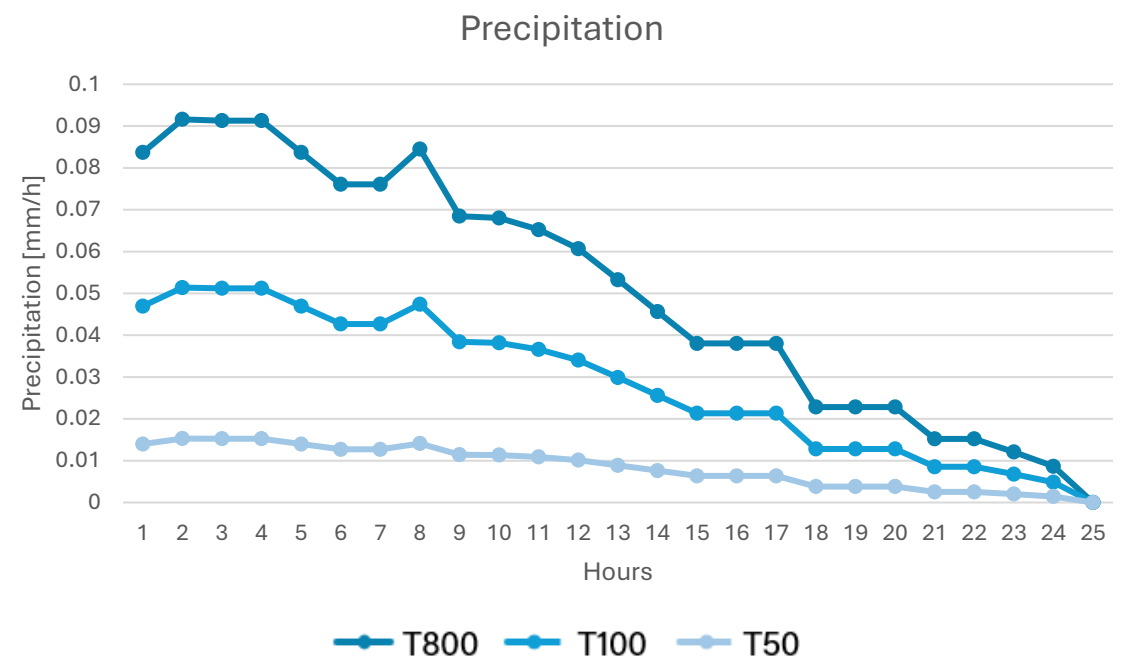
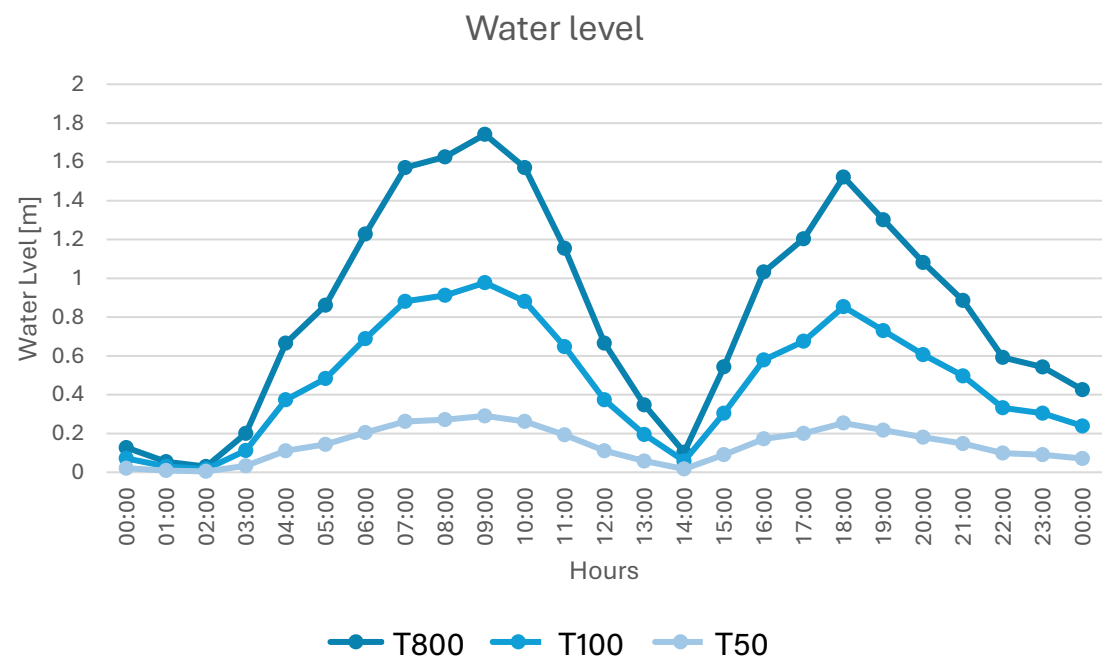
T = 100



T = 50



Flood scenario



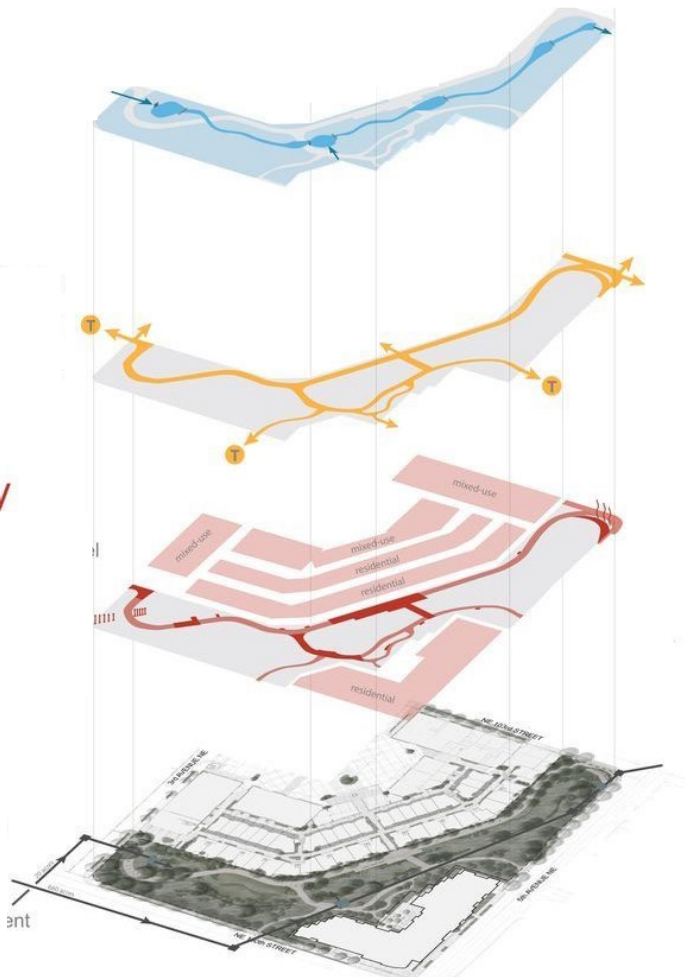
Data collection

water

mobility

community

utility

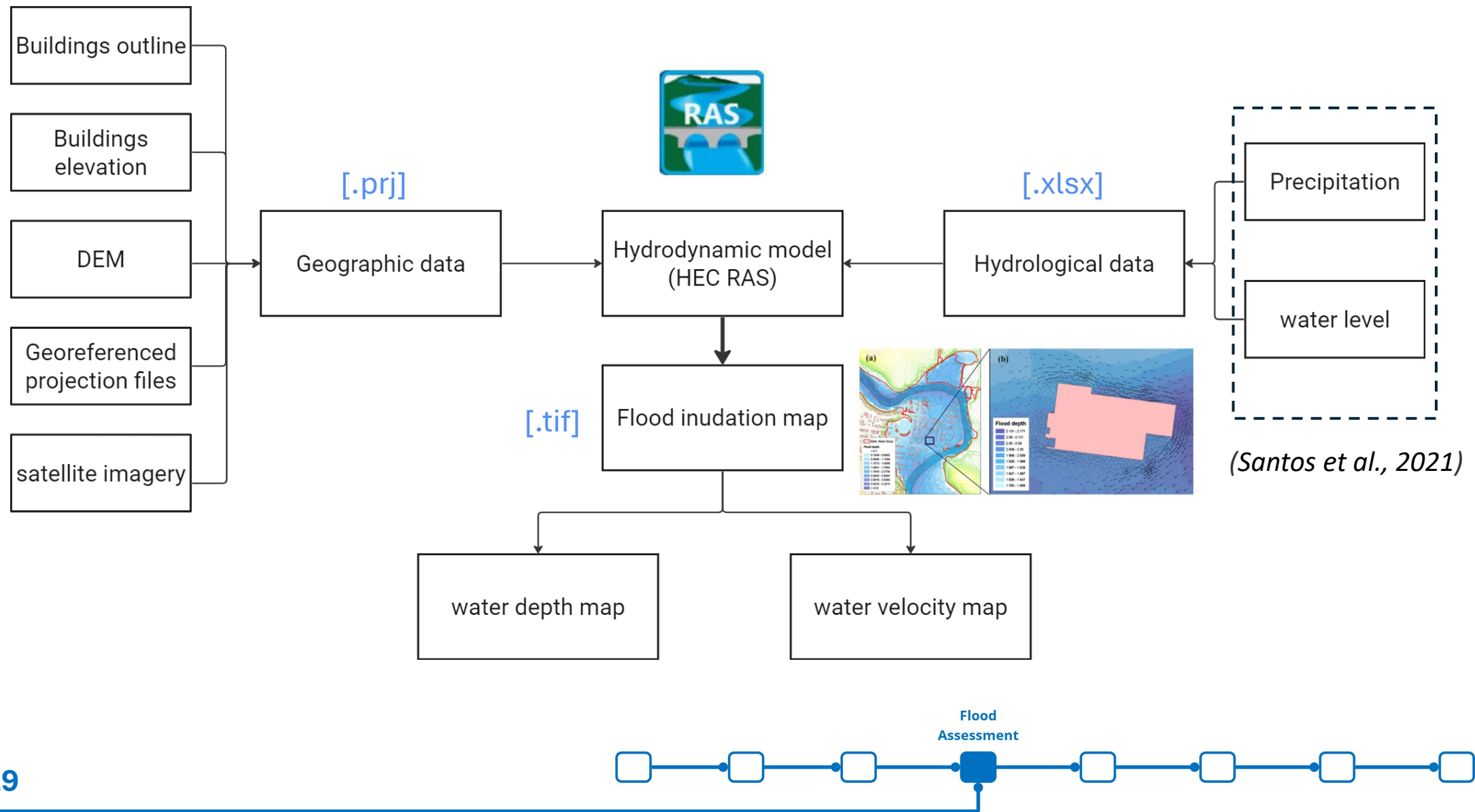


Data	Type	Format	Description
Hydrologic data	3 scenario drivers data in excel	.xlsx	Precipitation Water level
GIS	Georeferenced projection files	.prj	
	DEM(Digital elevation model)	.tif	16-level resolution Hi-Res Terrain Corrected
	Satellite imagery	.tif	16 level
BIM	3D Building in revit	rvt.	with components layers
	3D BAG	OBJ	LoD 1.3

Flood Assessment

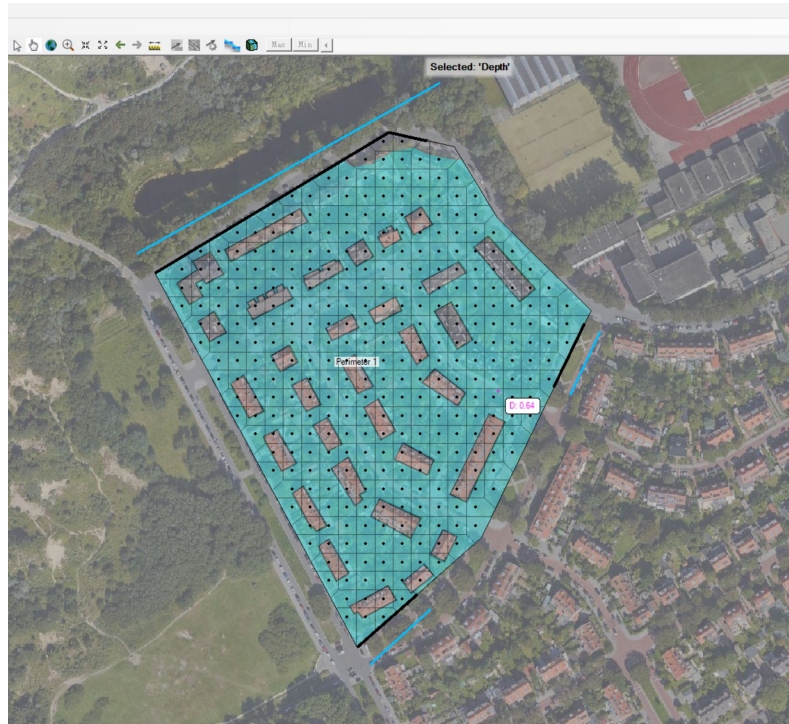


Flood simulation

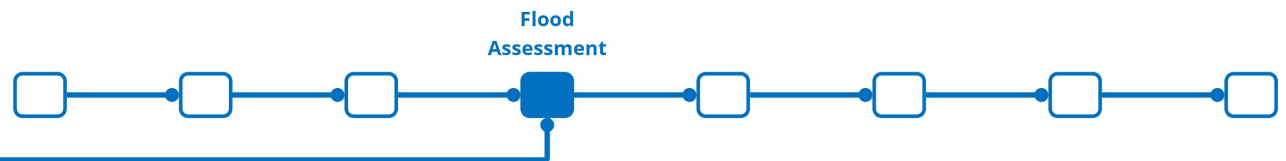
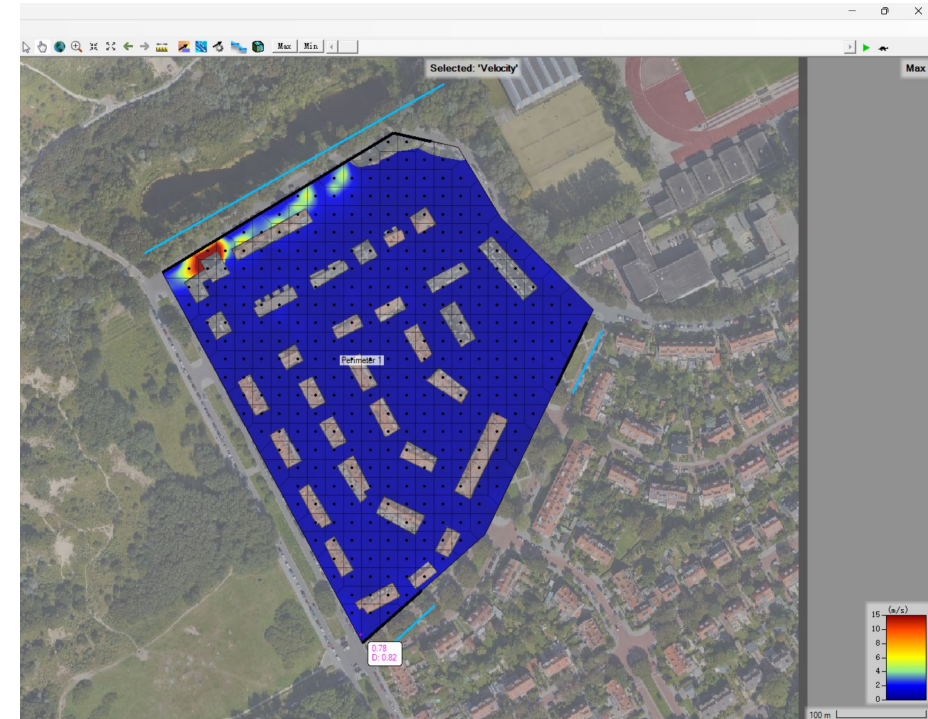


Flood simulation

Water depth distribution map



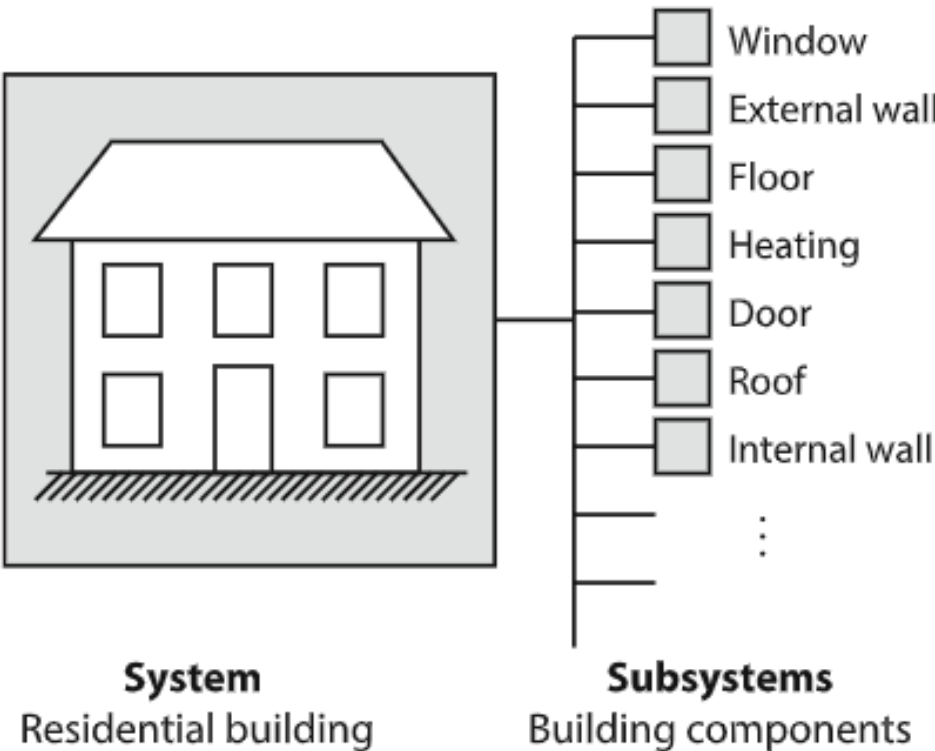
Water velocity distribution map



Vulnerability Analysis

Vulnerability analysis

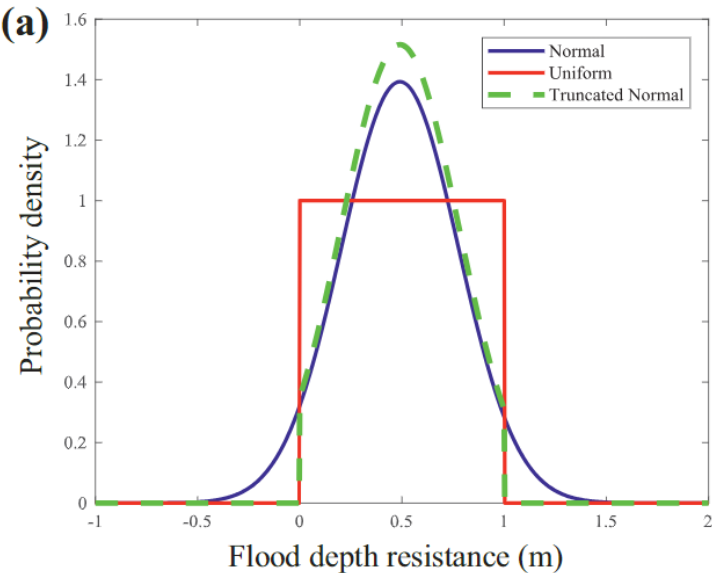
- Material Resistance
- Fragility curve
- Damage level
- Overall cost



Envelop materials

glass
masonry
concrete
timber
tile
masonry

Resistance



Fragility

Vulnerability
Analysis



Vulnerability analysis

- Material Resistance
- *Fragility curve*
- Damage level
- Overall cost

Assumptions: Each component is affected by flooding independently of each other.

$$F_r(x) = \Phi \left[\frac{\ln(x) - \lambda_R}{\xi_R} \right]$$

$\Phi[\bullet]$ = standard normal cumulative distribution function, λ_R = logarithmic median of resistance R , ξ_R = logarithmic standard deviation of resistance R . (Nofal et al., 2020)

Vulnerability
Analysis



Vulnerability analysis

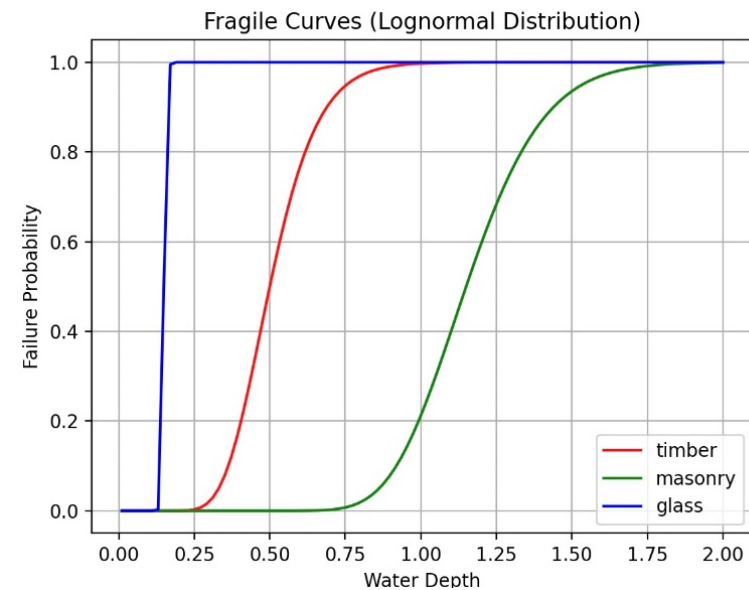
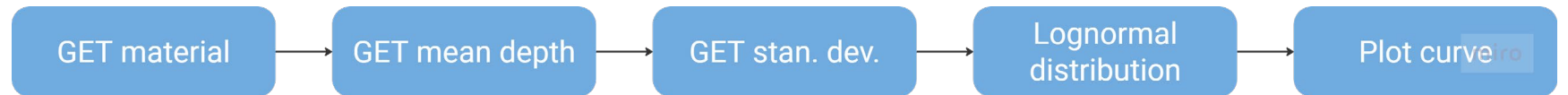
-- Material Resistance

-- Fragility curve

-- Damage level

-- Overall cost

Component	glass	timber	masonry
Min depth	0.05	0	0.8
Mean depth	0.15	0.5	1.15
Max depth	0.25	1	1.5
Stan dev. Of depth	0.05	0.25	0.175

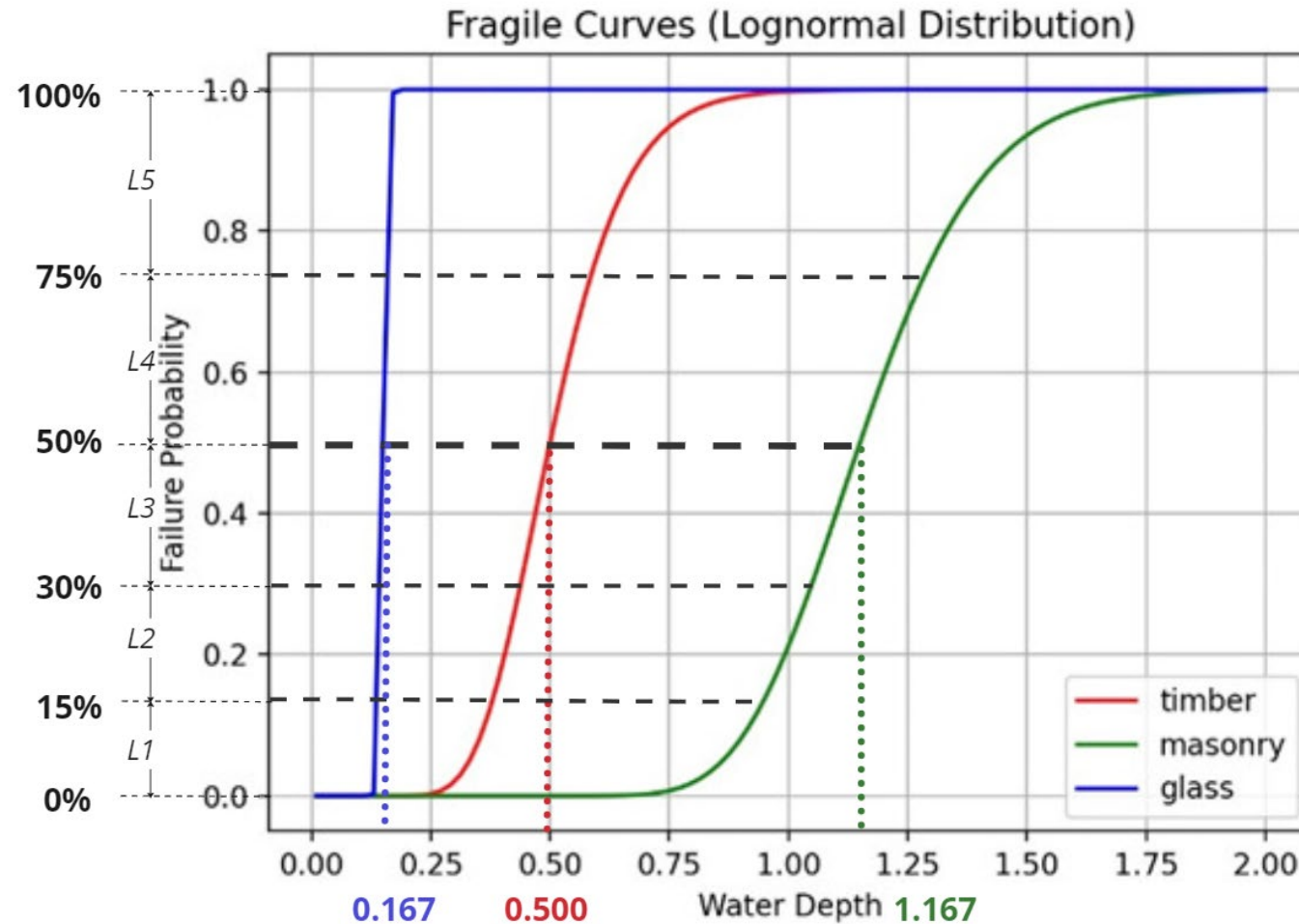


Vulnerability
Analysis



Vulnerability analysis

- Material Resistance
- Fragility curve
- **Damage level**
- Overall cost

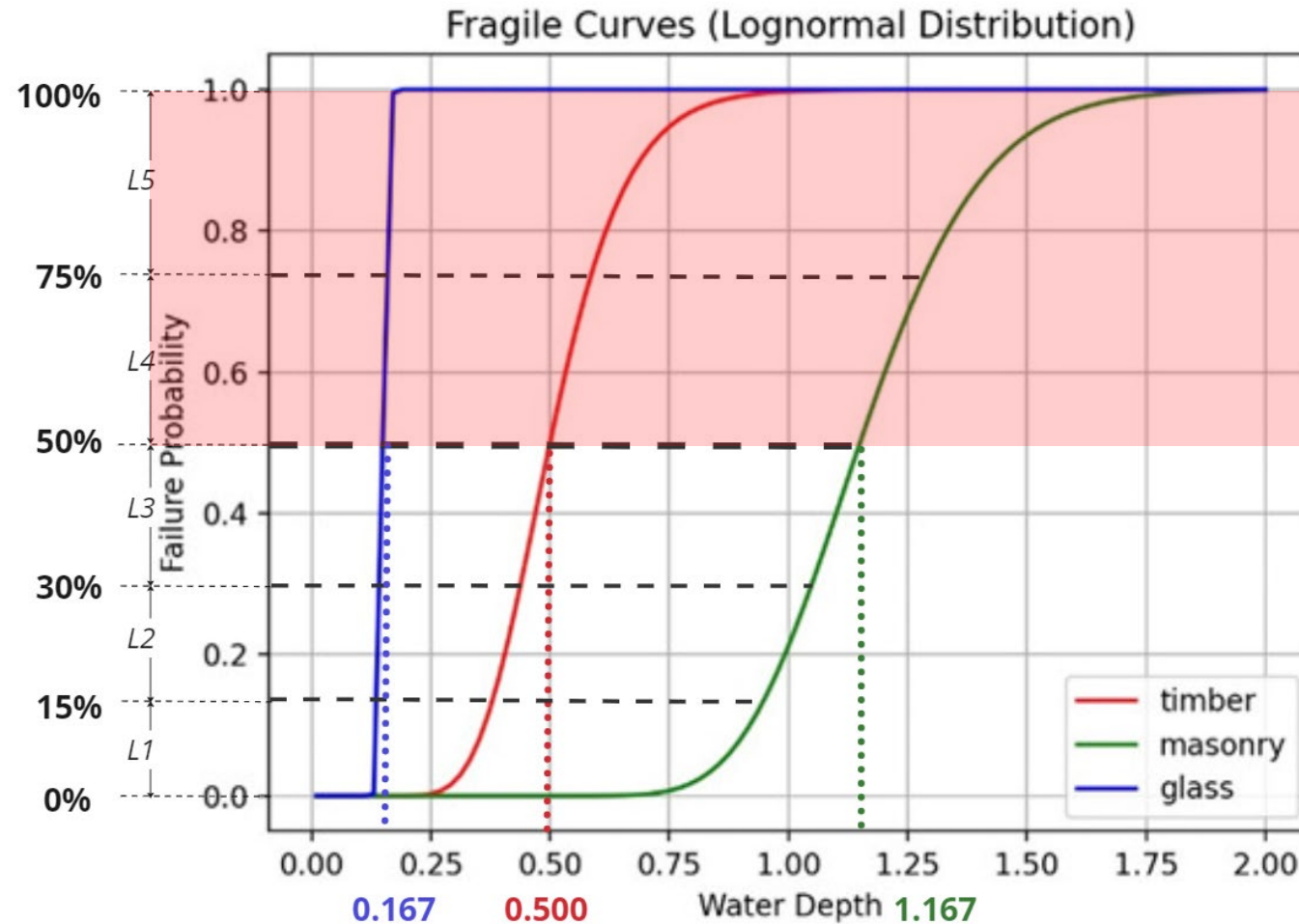


Vulnerability
Analysis



Vulnerability analysis

- Material Resistance
- Fragility curve
- **Damage level**
- Overall cost



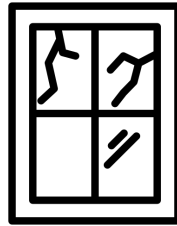
Collapsed

Vulnerability
Analysis

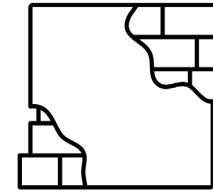


Vulnerability analysis

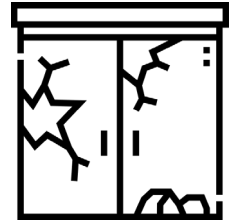
- Material Resistance
- Fragility curve
- Damage level
- Overall cost



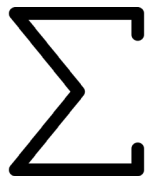
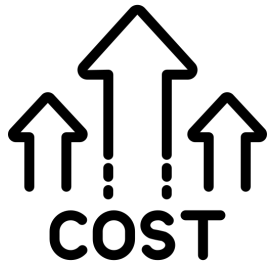
Window



Wall



Door



Number of loss function $\times$ Mean replacement cost per component

$$L_t(IM = x) = \begin{pmatrix} L_1^1 \\ L_1^2 \\ \vdots \\ L_1^n \end{pmatrix} + \begin{pmatrix} L_2^1 \\ L_2^2 \\ \vdots \\ L_2^n \end{pmatrix} + \begin{pmatrix} L_3^1 \\ L_3^2 \\ \vdots \\ L_3^n \end{pmatrix} + \dots + \begin{pmatrix} L_N^1 \\ L_N^2 \\ \vdots \\ L_N^n \end{pmatrix} = \begin{pmatrix} L_t^1 \\ L_t^2 \\ \vdots \\ L_t^n \end{pmatrix}$$

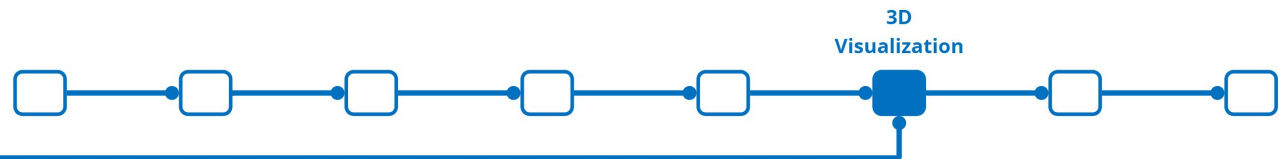
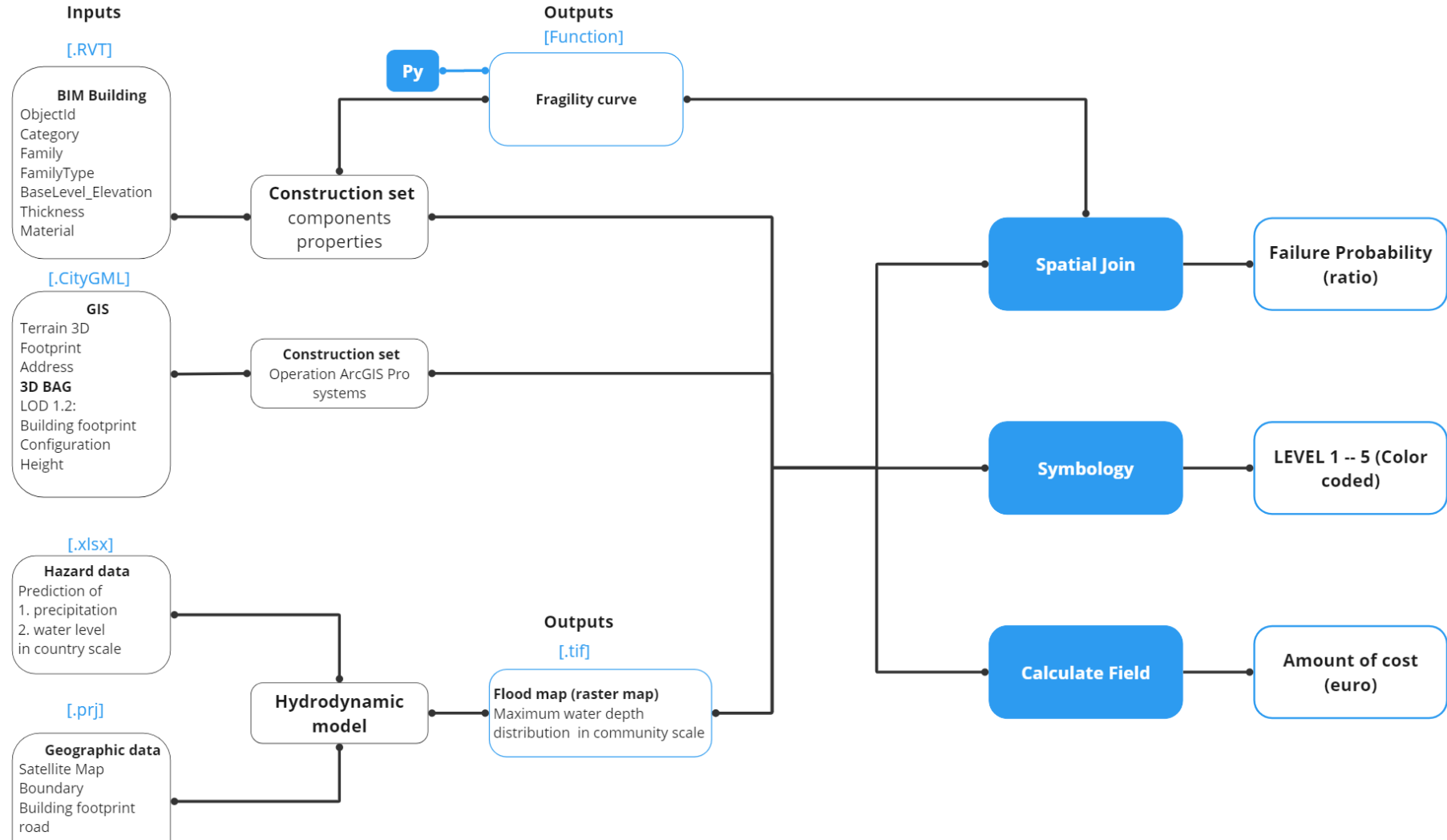
Vulnerability
Analysis



3D Visualization

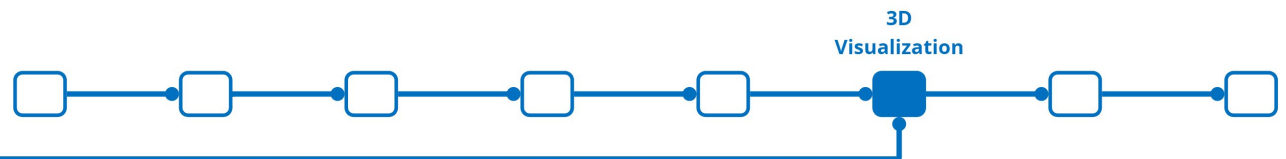
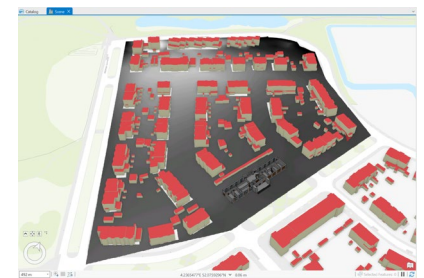
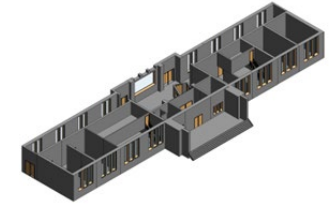
3D Visualization

- Workflow
- Integrated model
- Color coded
- Display mode



- Workflow
- **Integrated model**
- Color coded
- Display mode

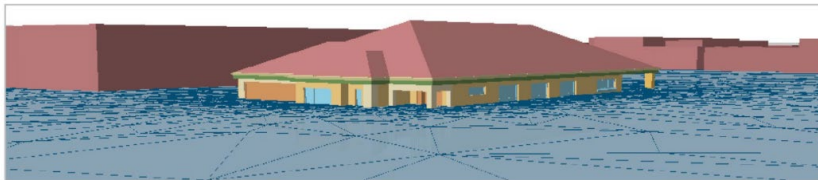
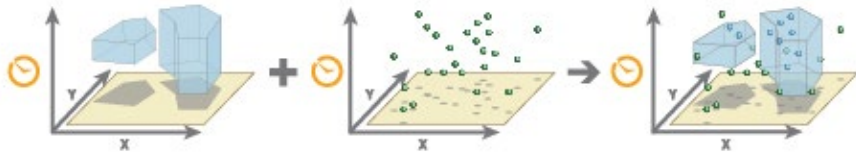
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3D Visualization

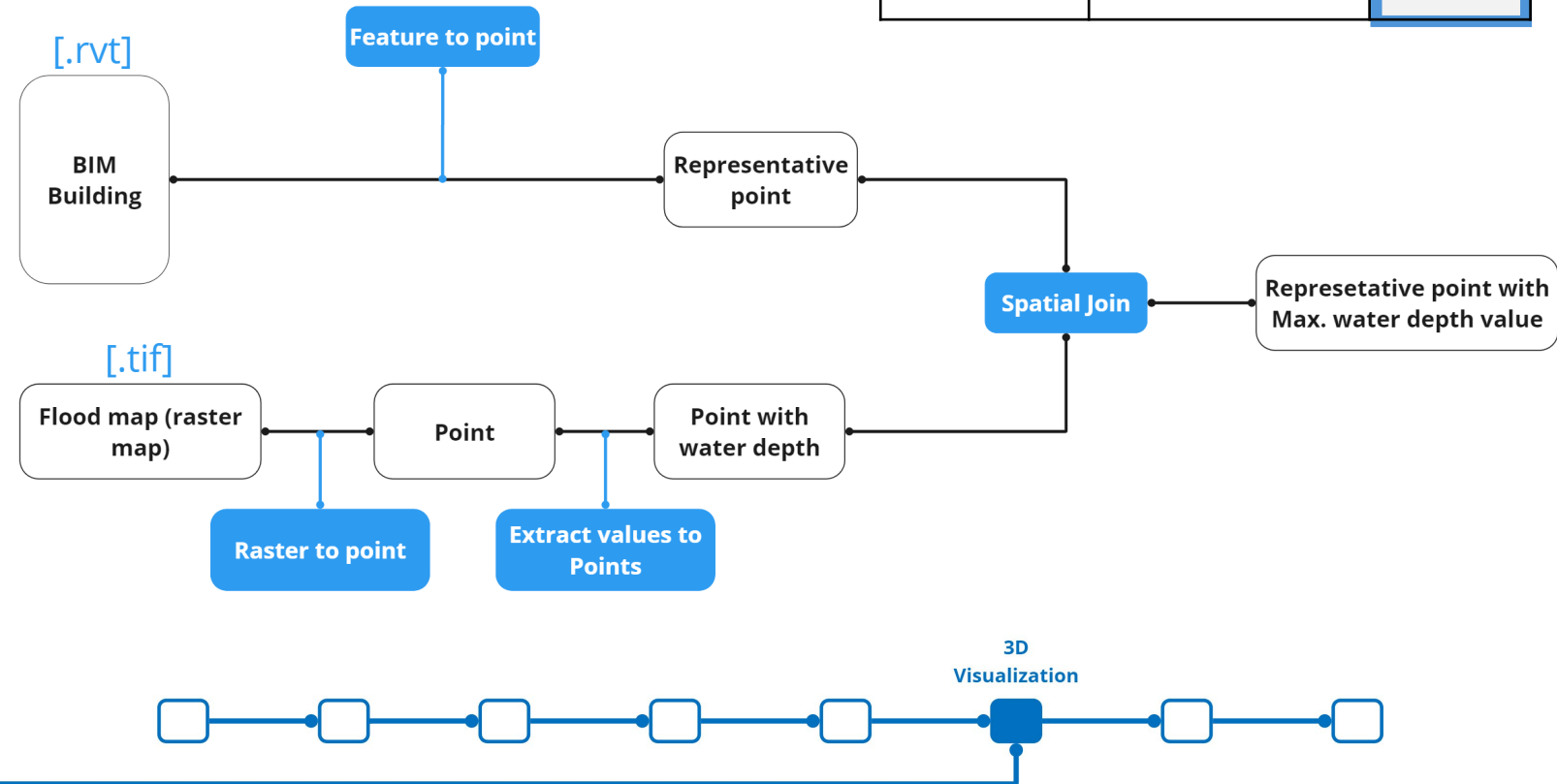
- Workflow
- Integrated model
- Color coded
- Display mode

Spatial Join



Attributes table

Class	Material	depth
Wall	Masonry	0.8
...	Masonry	0.6
Wall	Masonry	0.6
Window	Glass	0.7
...	Glass	0.9
Window	Glass	0.6



3D Visualization

- Workflow
- Integrated model
- Color coded
- Display mode

Attributes table

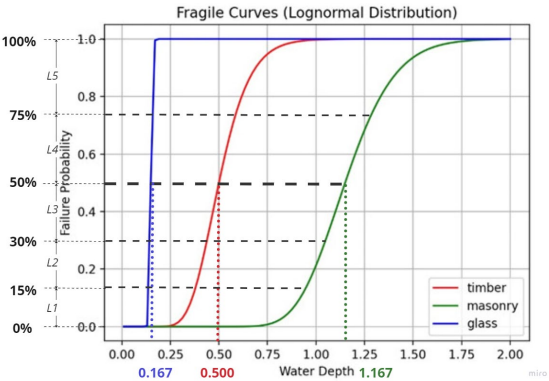
Class	Material	depth
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...	Glass	0.9
Window	Glass	0.6



Level
L1
...



COLOR
...



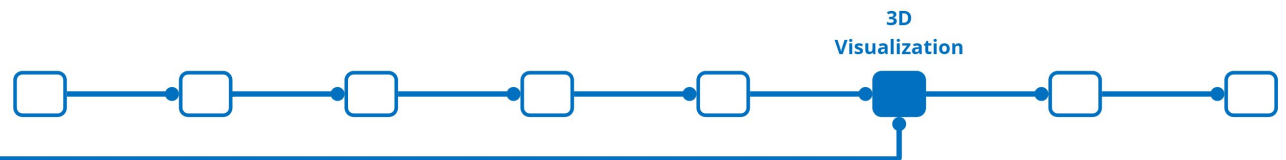
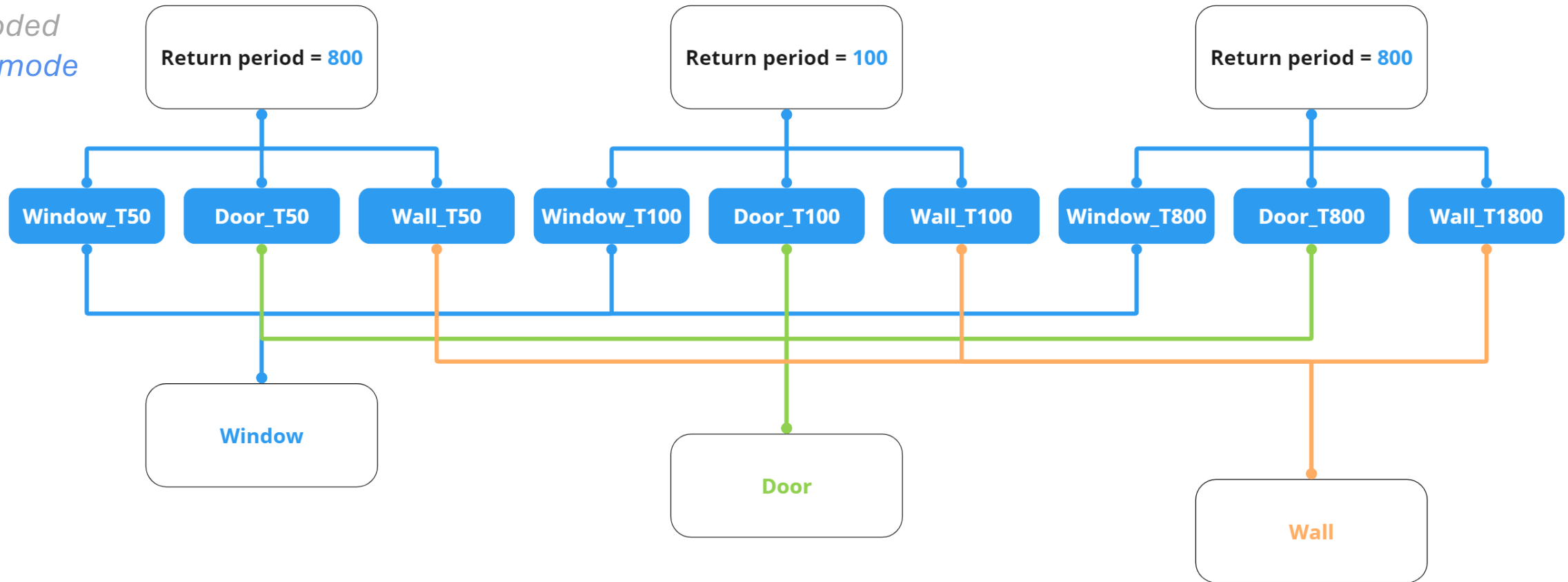
Materials	L1(m)	L2(m)	L3(m)	L4(m)	L5(m)
Timber	0.370	0.440	0.500	0.600	1.000
Glass	0.125	0.140	0.167	0.180	0.200
Masonry	0.900	1.150	1.167	1.300	2.000

3D
Visualization



3D Visualization

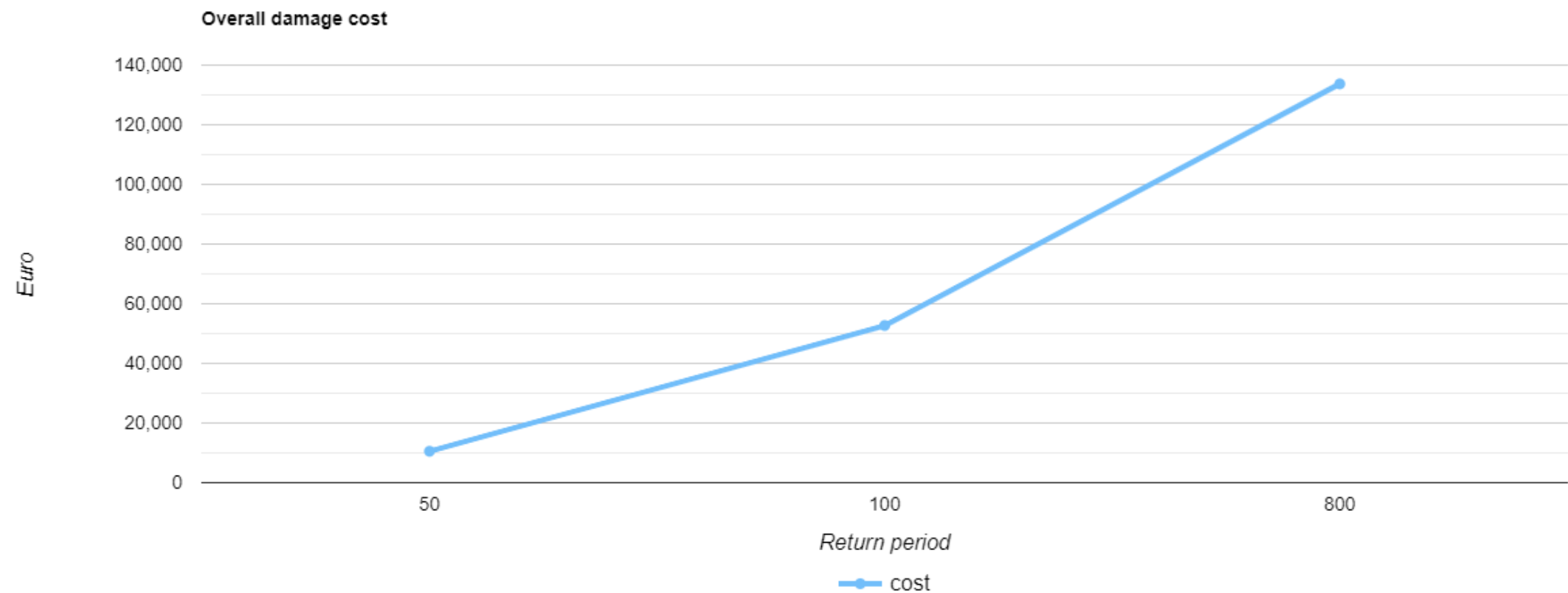
- Workflow
- Integrated model
- Color coded
- *Display mode*



Result & Discussion



Overall cost



Result & Discussion

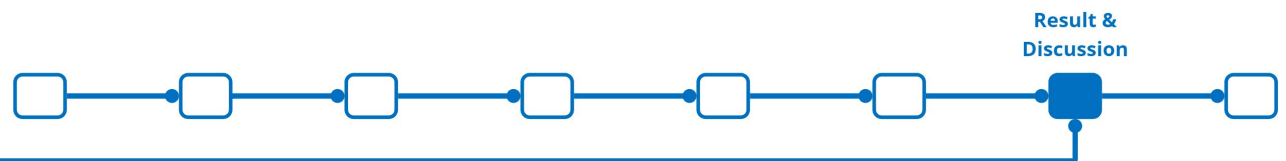
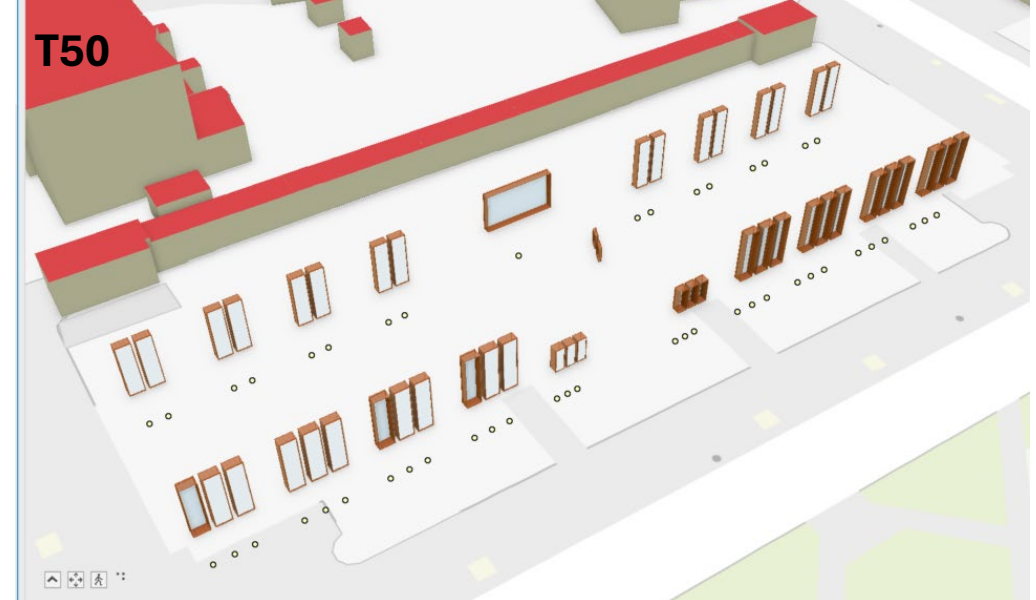
Result & Discussion

- In flood scenarios mode
- In components mode
- Future work



Result & Discussion

- In flood scenarios mode
- In components mode
- Future work





Result & Discussion

-- In flood scenarios mode

-- In components mode

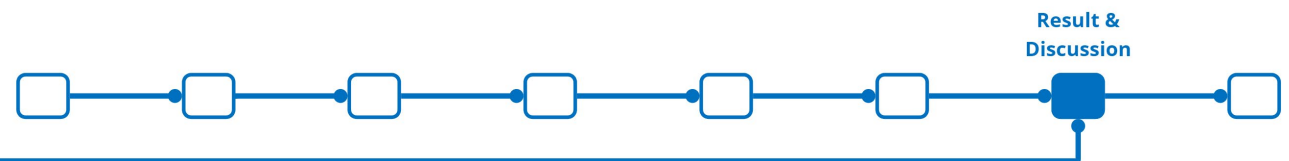
-- Future work



In components mode



In flood scenarios mode



Result & Discussion

-- In flood scenarios mode

-- In components mode

-- Future work

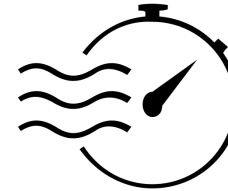
Open-Source Data Integration

- Color coded on elements
- Web-Based Visualization (ArcGIS online)
- Dynamic and interactive



Structure analysis

- Interior and Exterior Evaluation
- Multifactor analysis



Stakeholder and Public Benefits:

- Enhanced Real-Time Forecasting



Conclusion & Reflection

Conclusion

How We Built a digital tool to **quantify** damage to building structures in **compound floods scenarios** considering **future climate change** that guides the designers to **identify vulnerable components** throughout their lifecycle.

Future scenario

- Based on predicting data
- Scale it into 3 scenarios

Quantification damage

- Quantify flood result – hydrodynamic simulation
- Quantify vulnerability – fragility curve
- Quantify the cost of building

Visualization

- BIM – GIS integration system
- Display mode

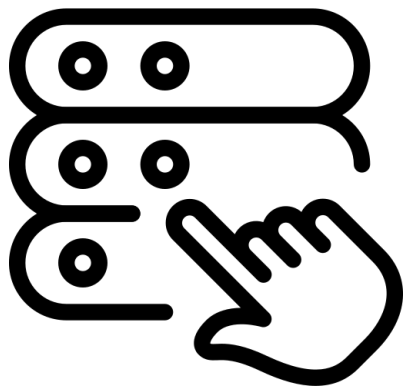
Conclusion
& Reflection



“Do fast, Fail fast, and Learn fast”

Tools:

- MIKE FLOOD
- HEC RAS



Structure analysis method:

- Finite element analysis
- Monte Carlo model

Visualization

- Open-source manner
- Existing software

Conclusion
& Reflection



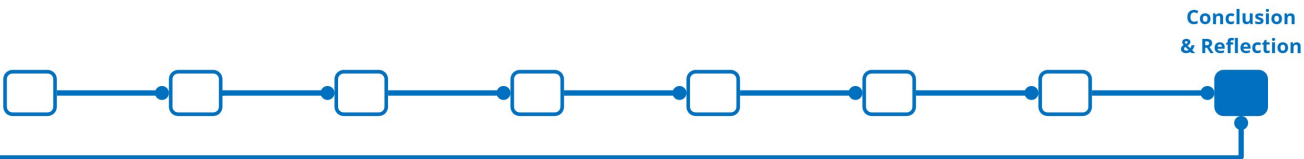
A Digital Tool to Analyze and Visualize the Risk of Structures under Compound Flood Hazards

Academic Value:

- Interdisciplinary Approach
- Innovative Techniques

Societal Value:

- Risk Mitigation
- Economic Savings



Thank you

