

# Safety Concept for the Assessment of Different Failure Scenarios on Load-Bearing Glass Facades

**Nathalie Nießer**  
Prof. Dr.-Ing. Geralt Siebert  
Institute and Laboratory for Structural Engineering



## Challenges in Facade Construction

Recently, increased efforts have been made to explore the possibility of using glass panes as structural components, such as shear stiffeners. However, there are obstacles to the widespread use of these panes, even though they have proven their load-bearing capacity in structural systems. The sudden failure of individual glass panes is a major concern because it can affect the overall structural safety. **To better understand the causes of this unpredictable, behaviour of glass facades, a numerical and physical sensor concept in the form of a hybrid digital twin will be developed. This involves both measurements of real load-bearing systems and simulations using virtual models and sensors.** The virtual model will be approximated in a continuous process using measurements of the real structure.



## Real Life Test Facilities

### Buildings with Monitoring Potential

#### Roof truss of the cathedral "Zur Schönen Unserer Lieben Frau" in Ingolstadt

- For continuous monitoring and early detection of structural issues by using 3D laser scans



#### Canopied railroad near Ingolstadt

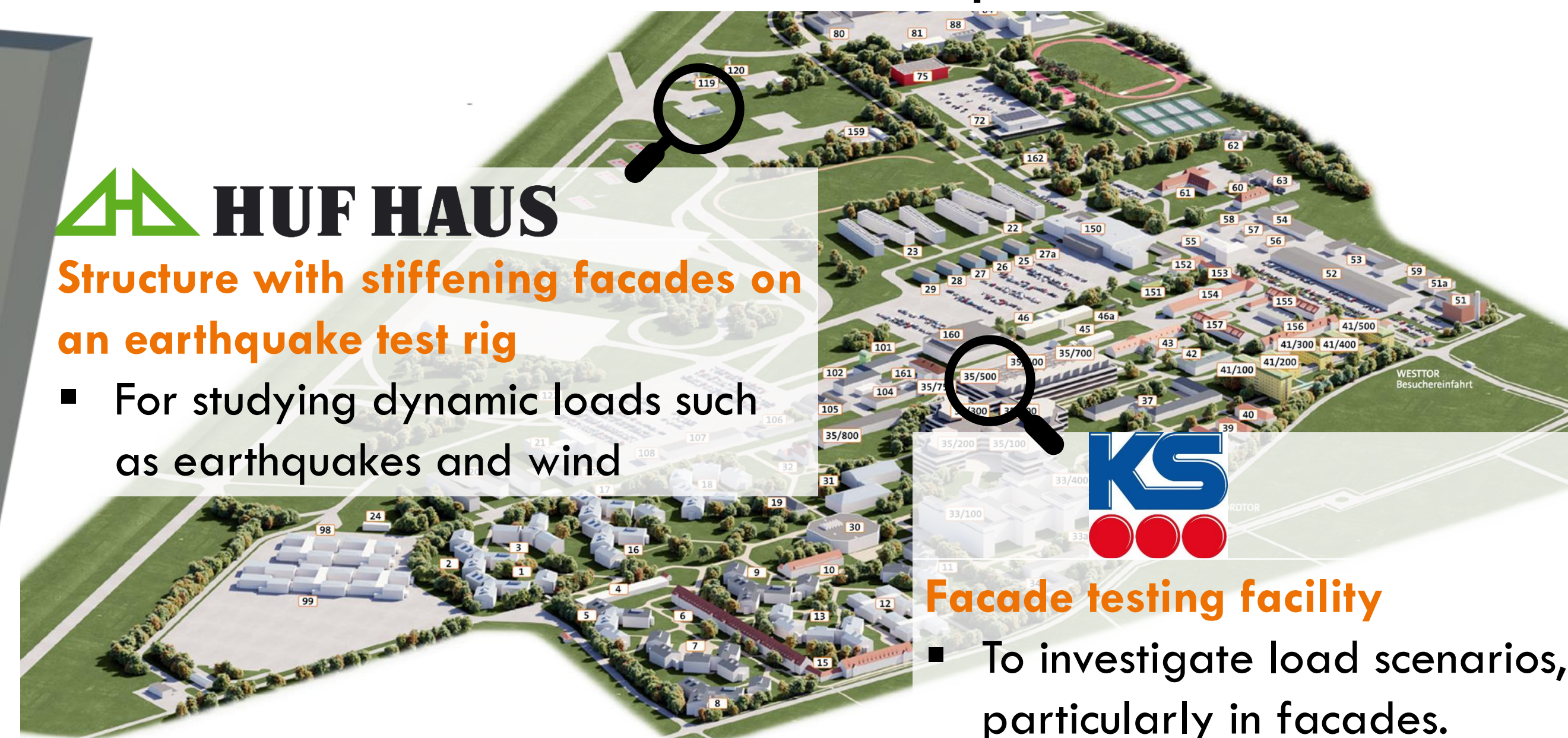
- Assessment of structural integrity using advanced sensor techniques



### Test Stands on the UniBW Campus

#### HUF HAUS Structure with stiffening facades on an earthquake test rig

- For studying dynamic loads such as earthquakes and wind



#### Facade testing facility

- To investigate load scenarios, particularly in facades.

## Hybrid Digital Twin for Glass Facades

### Virtual building model based on sensor measurements

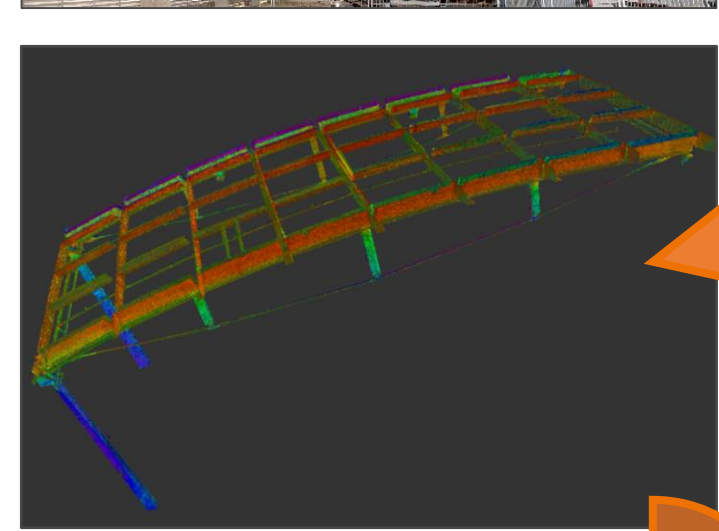
- Investigation of load scenarios: wind, earthquake loads
- Continuous monitoring and early detection of structural issues
- Assessment of structural damage through advanced monitoring techniques

### Virtual building model based on 3D laser scans

- Creation of a virtual building model as realistic as possible

### Simulation models

- Simulation of the glass pane failure
- Analysis of the effects on the overall structure
- Investigation of redundancies and load redistribution



**Virtual building model + Real-life test facilities = Prediction of allowable dynamic deformation for glass facades**

## Prediction of Allowable Dynamic Deformation for Glass Facades

### How to predict the allowable dynamic deformation of glass façades, representing the maximum load-bearing of the structure?

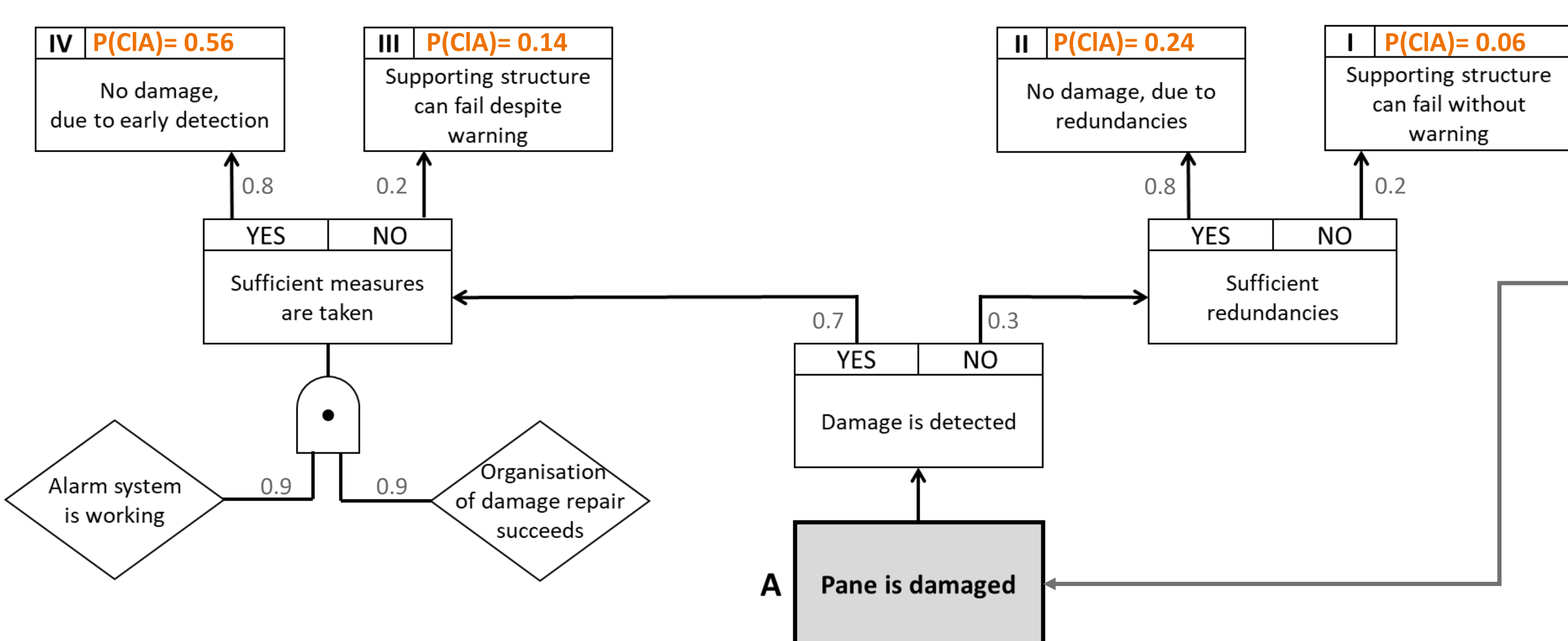
- To develop an experiment method to determine structural deformation by using sensor measurements

### How to combine the effect of external dynamic load and mass of the structure to determine the structural deformation?

- To develop a numerical procedure to determine structural deformation
- To validate the numerical procedure for determining the structural deformation

- Contribution to more sustainable constructions
- Improved assessment of structural damage and early problem detection
- Optimized maintenance and risk assessment

## Safety Assessment of Failure Scenarios – Concept



The consequences can be reduced by

- Improved alarm system
- Investigation of redundancies

Consequences	$\sum P(CIA) \%$
Very High	6
High	14
Low	80
	100

### Causes and Consequences Diagram:

- Illustrates causes leading to events impacting structures
- Incorporates various reasons for impacts:
  - Execution and assembly errors
  - Weather influences
  - Incorrect static calculations and construction supervision
- Assessing damage detection and response:
  - Can damage to a pane be detected? Answer: YES or NO
  - Were sufficient measures taken? Answer: YES or NO
  - Integrating a functioning alarm system or sufficient redundancies**
  - Determining the probability of undamaged occurrence or system failure despite warnings.
- Digital Twin Utilization:
  - The complexity of cause and consequence relationships can be vast and intricate
  - A digital twin aids in collecting data and evaluating these relationships, enhancing understanding and response strategies

## References

- Farrar, C.; Worden, K.: An introduction to structural health monitoring. In: Philosophical transactions. Series A, Mathematical, physical, and engineering sciences 365 (1851), pp. 303–315 (2007).
- Neumer, D.: Beitrag zur Aussteifung von Gebäuden durch Glas – Konzentrierte Lastenleitung im Eckbereich. Dissertation. Universität der Bundeswehr München, Neubiberg. Institut für konstruktiven Ingenieurbau (2018).
- Schneider J.: Sicherheit und Zuverlässigkeit im Bauwesen: Grundwissen für Ingenieure. Unter Mitarbeit von Hanspeter Schlatter. 2. Auflage. ETH Zürich: vdf Hochschulverlag AG (1994)

## Keywords

- Sensor networks
- Glass Failure Analysis
- Virtual Building Model
- Monitoring