



Innovation and Networking for Fatigue and  
Reliability Analysis of Structures – Training for  
Assessment of Risk



# Reliability of structures exposed to traffic loads and environmental loading

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ESR6

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# Project Objectives

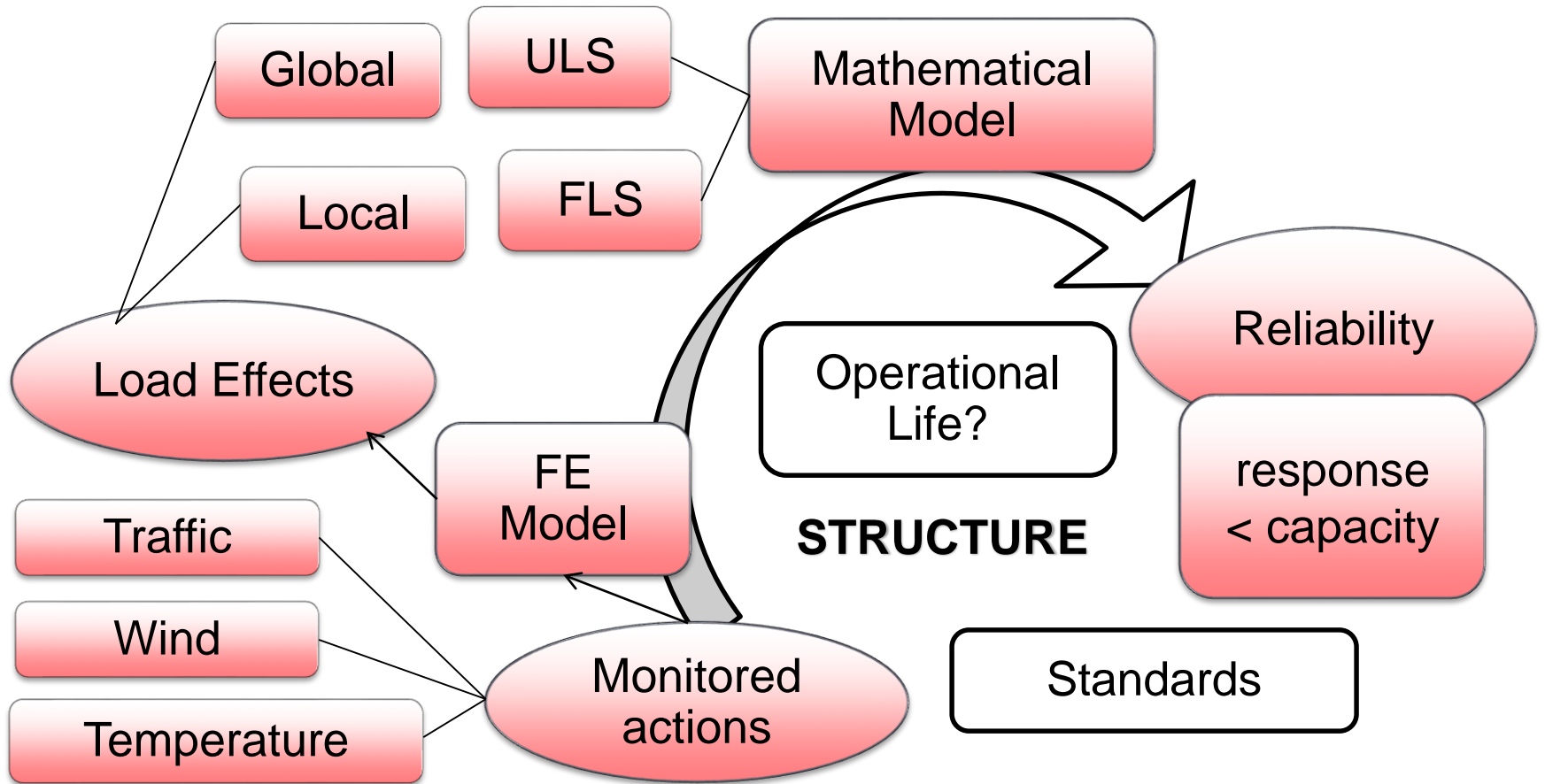
- Updated Mathematical Algorithm
  - Influence of Monitoring Data Type
  - Traffic + Wind
- 
- Extreme Events + Fatigue

# Millau Viaduct



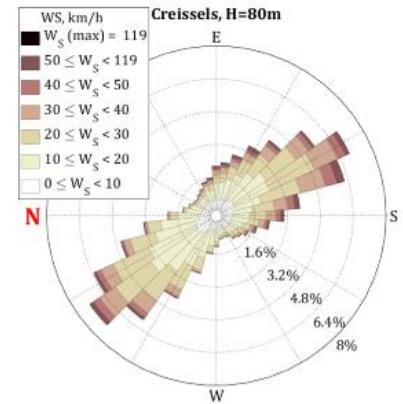
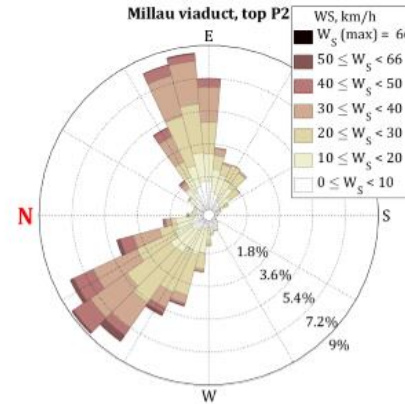
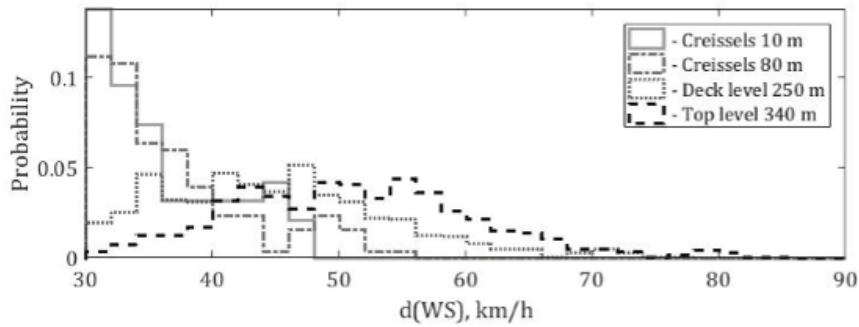
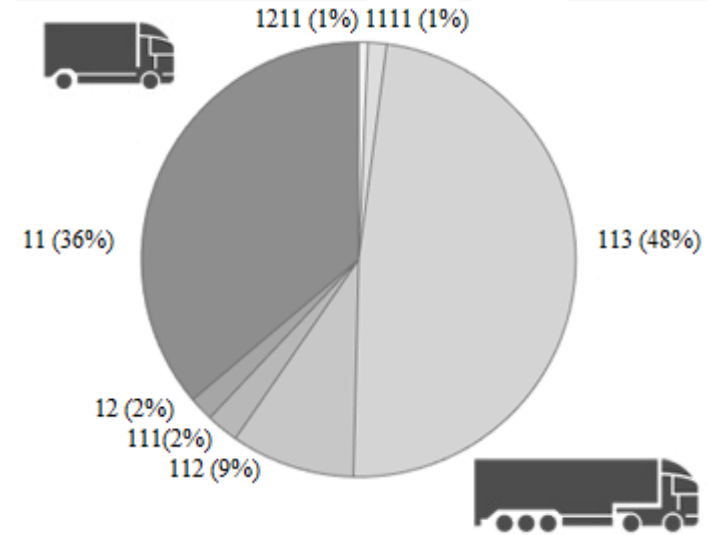
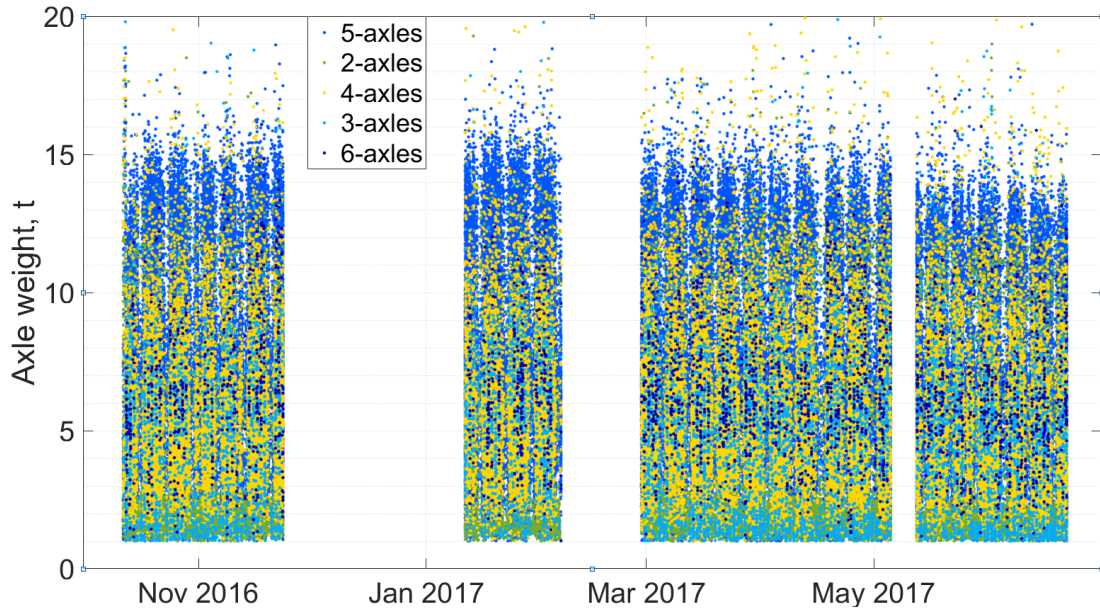
Millau Viaduct  
Valley of Tarn, France

# Main Idea





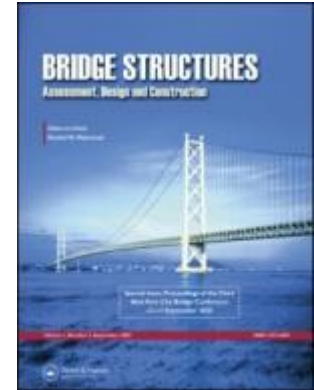
# Monitoring Data



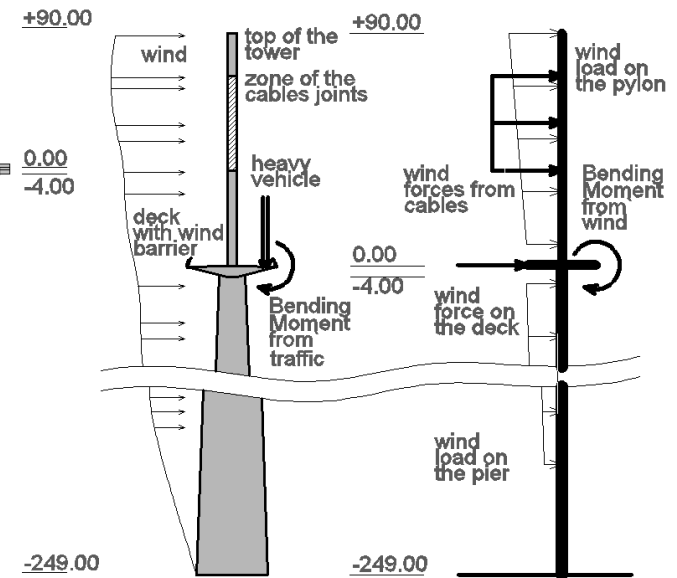
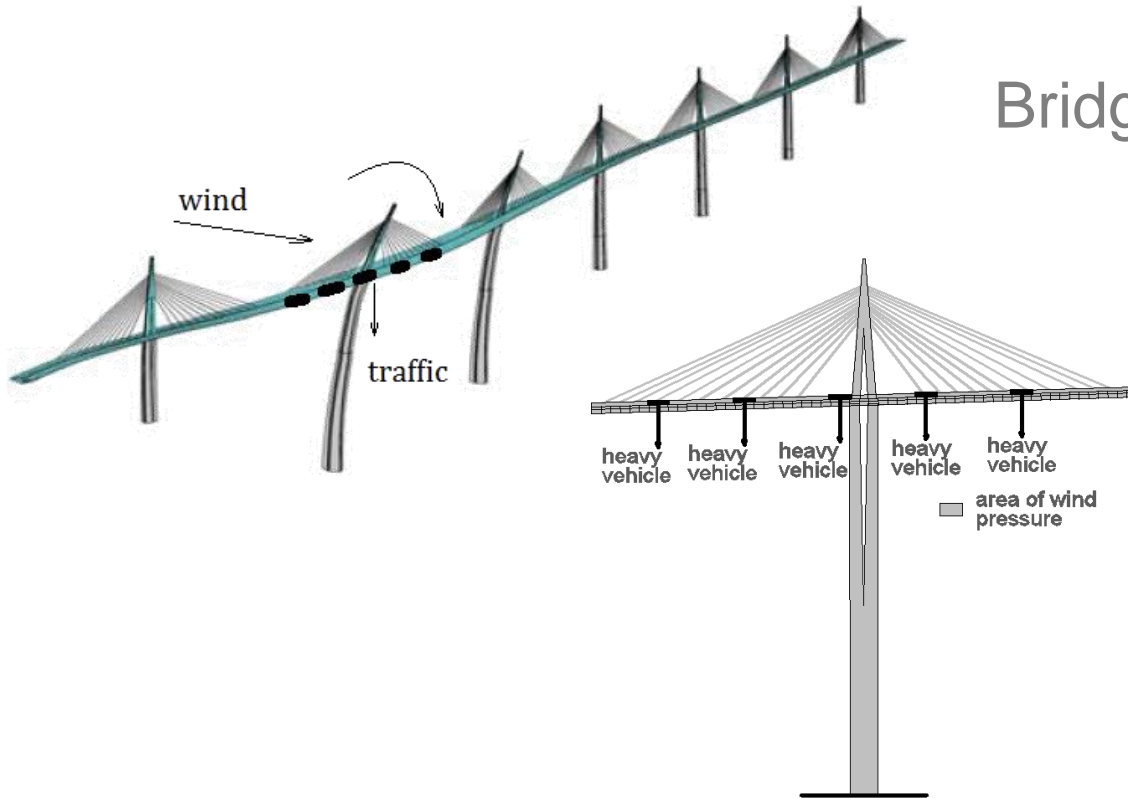
# Achieved results

# Traffic + Wind

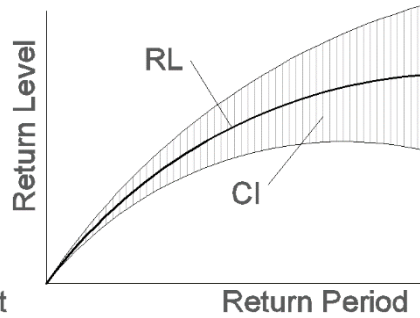
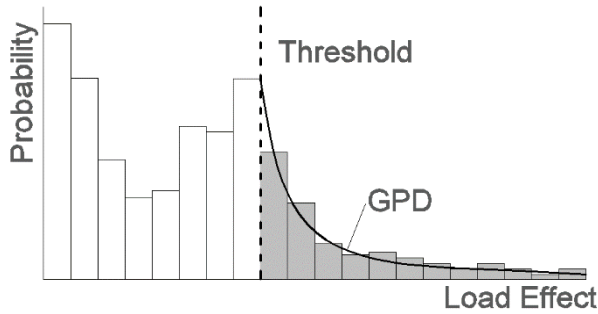
“Analysis of the effect of the combination of traffic and wind actions on a cable-stayed bridge”



2018  
Bridge Structures



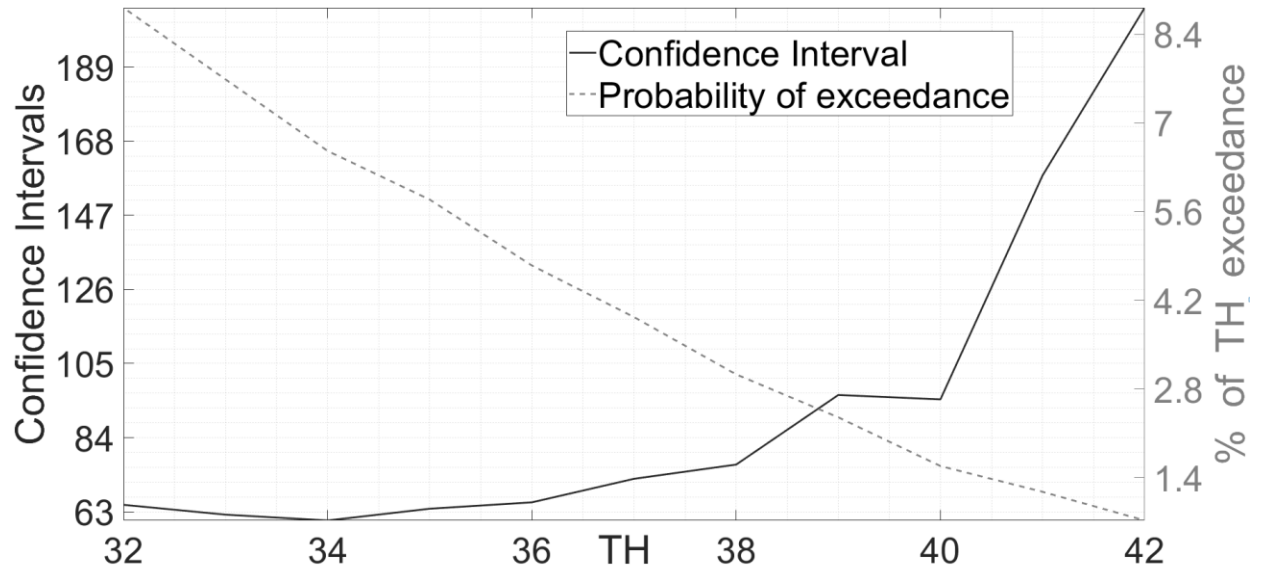
# Predictions



Extreme Values Theory  
Peaks Over Threshold

## Updated Threshold Choice

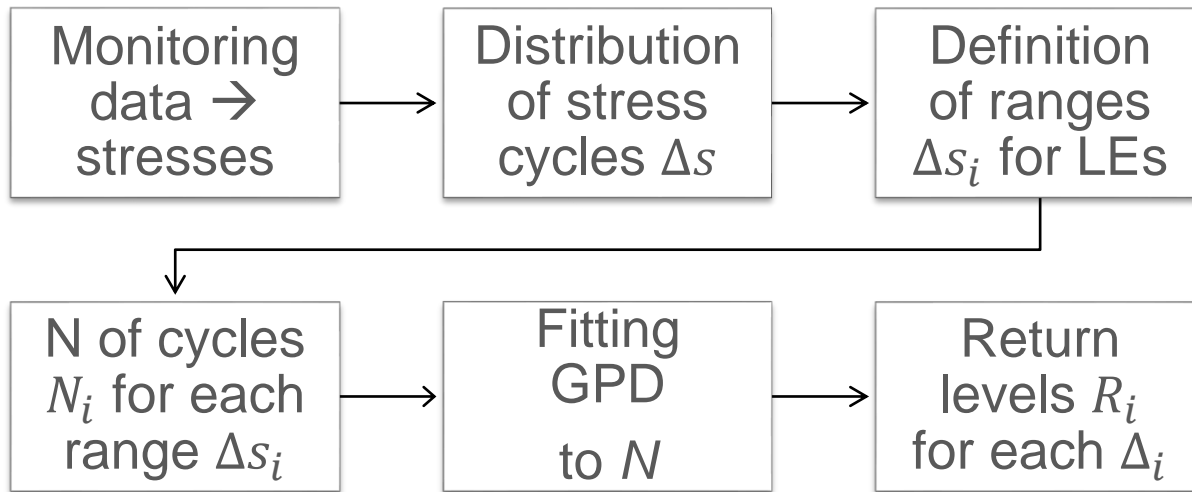
based on  
Confidence  
Intervals  
for Return Levels





# GPD for Fatigue

“Generalized Pareto Distribution for reliability of bridges exposed to fatigue ”



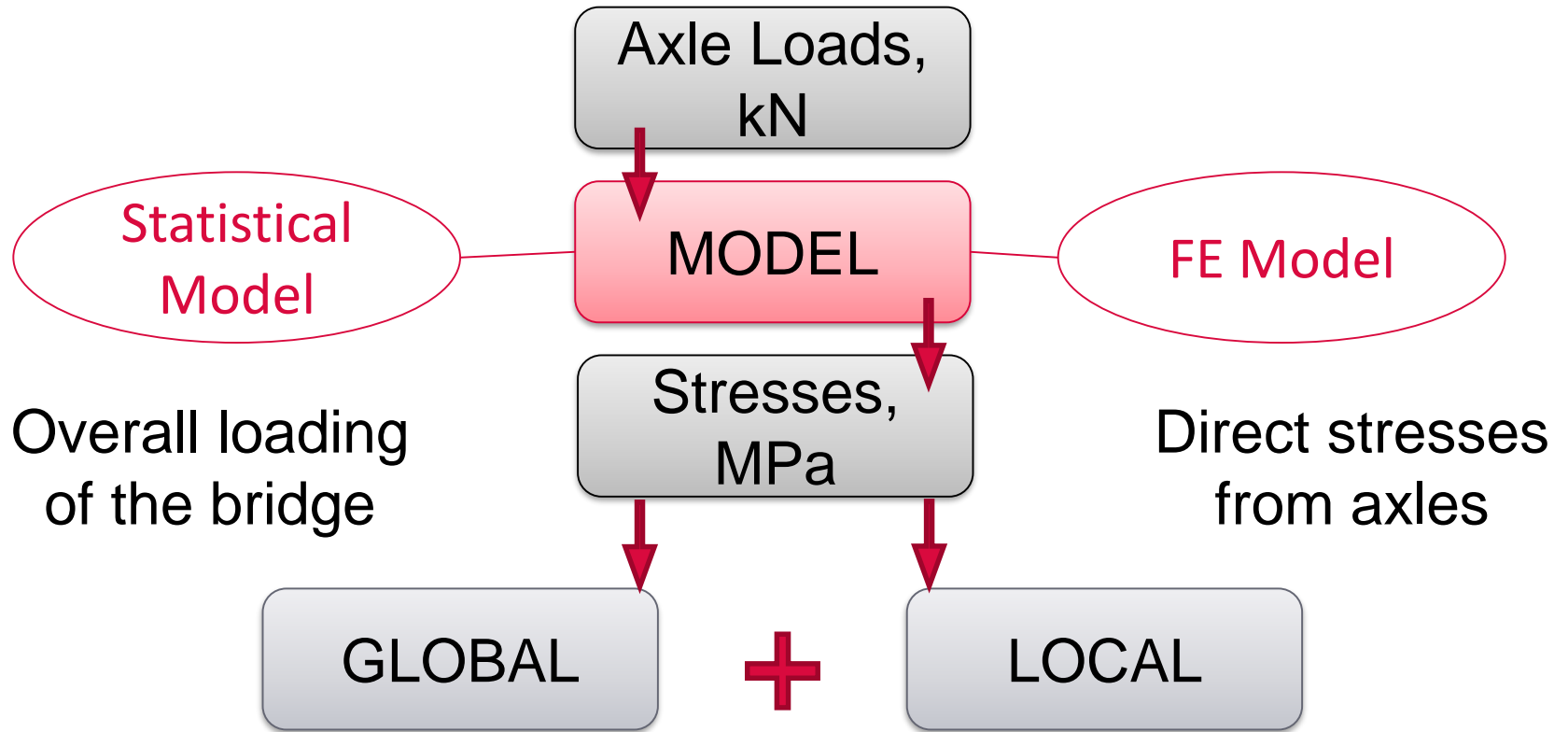
FEEDBACK:

→ Extreme Events + Fatigue → separate vehicle types

→ study both local and global stresses → FE model

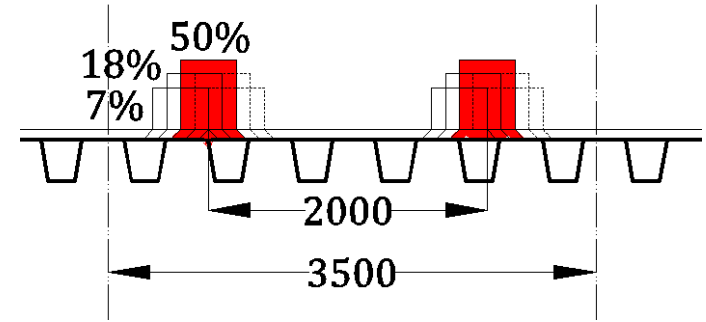
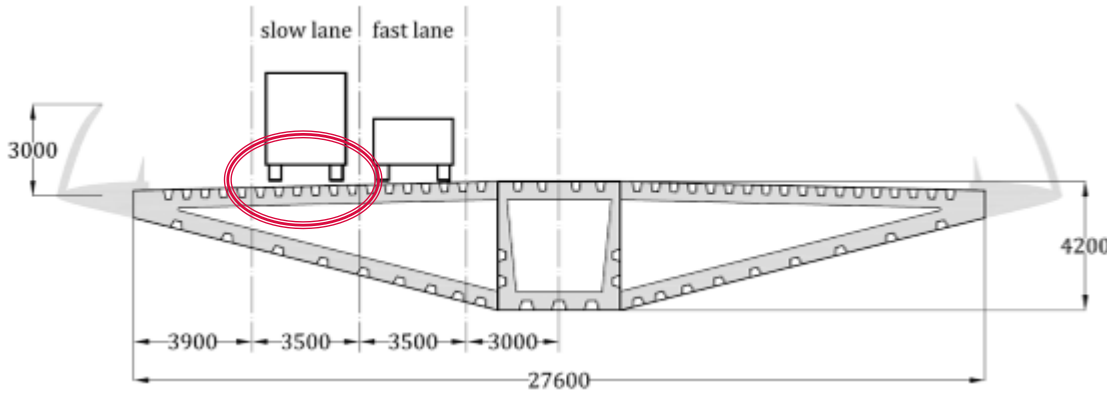
# On-going work

# Extreme Events + Fatigue



$$\rightarrow D = \sum d(\sigma_L + \sigma_G)$$

# FEM – Local Effects

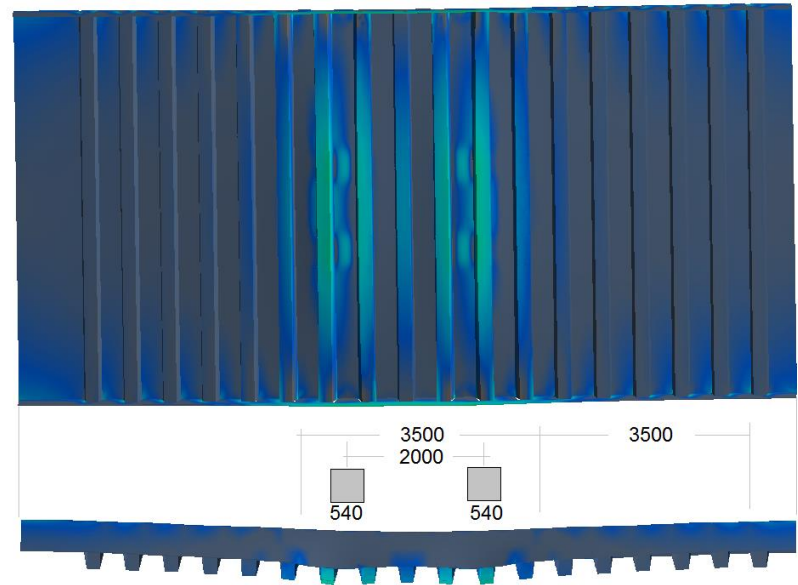
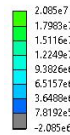


6-meters deck element

- Single axle
- Group of two
- Group of three

5 transversal positions

Max  
Principal  
Stress  
Units: Pa



$$P_{\sigma}(\sigma_i) = \int_L \int_V \int_A \int_G P_{\sigma}(\sigma_i|L, V, A, G) \times p(L, V, A, G) dL dV dA dG$$

L – Location of the element along the bridge

V – Type of the vehicle axle group

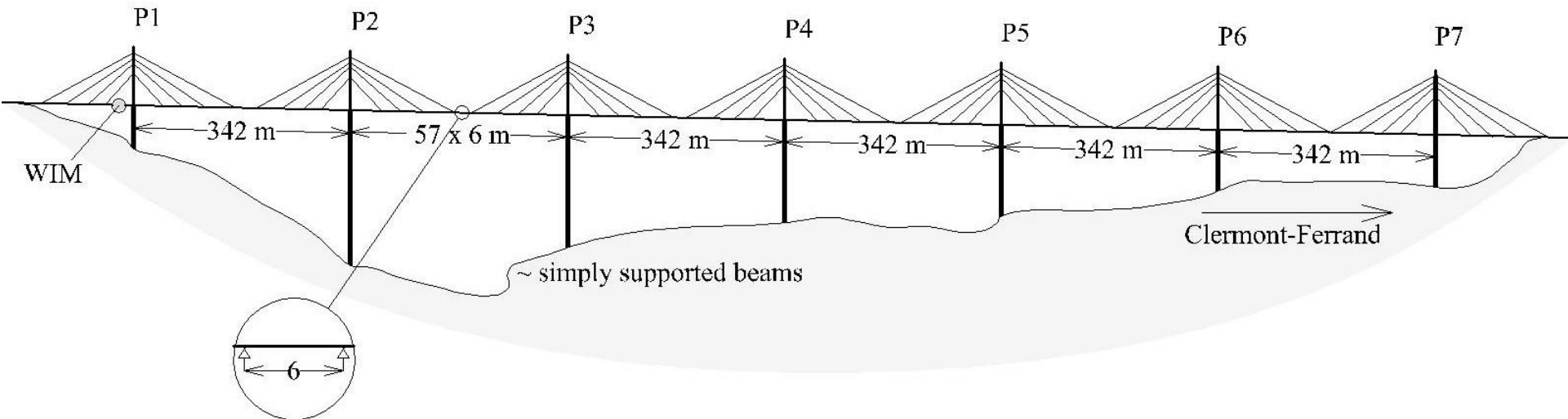
A – Amplitude of the load

G – General loading of the structure

# Statistical Model

$$P_{\sigma}(\sigma_i) = \int_L \int_V \int_A \int_G P_{\sigma}(\sigma_i | L, V, A, G) \times p(L, V, A, G) dL dV dA dG$$

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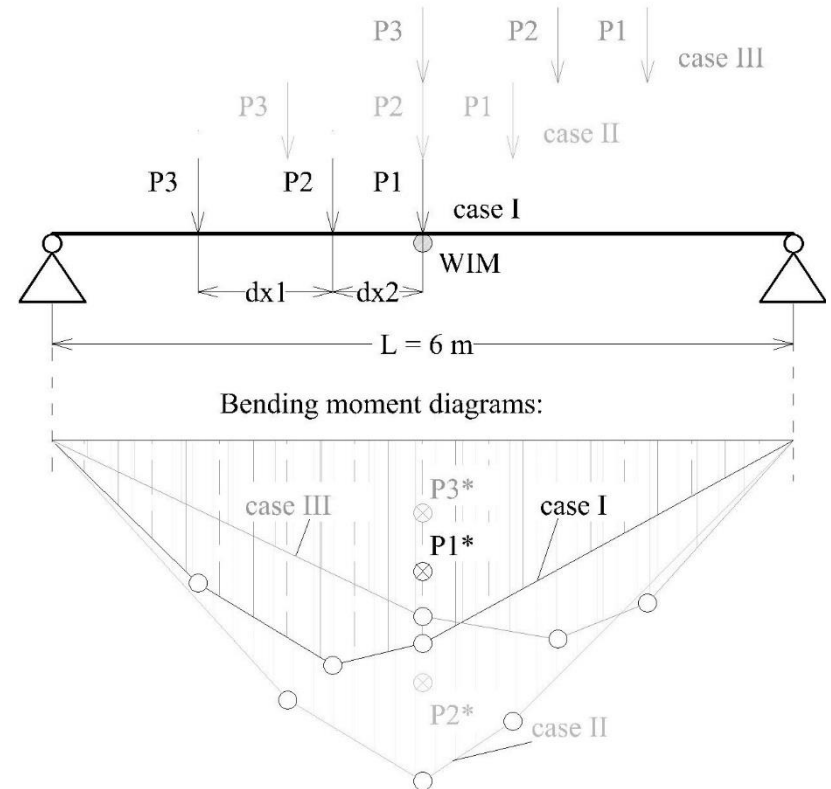
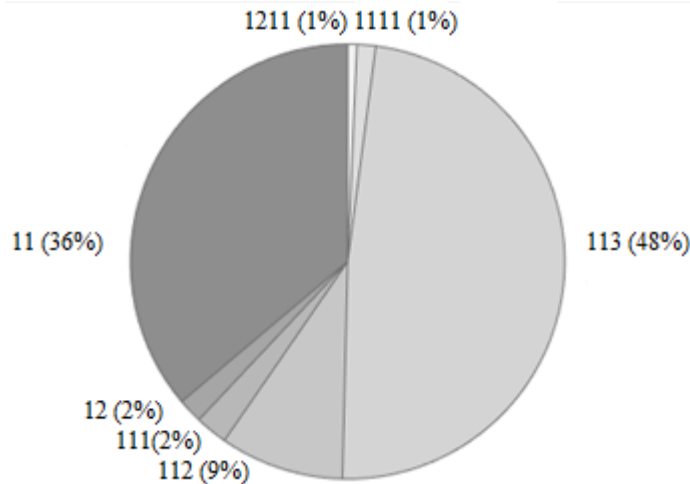




# Statistical Model

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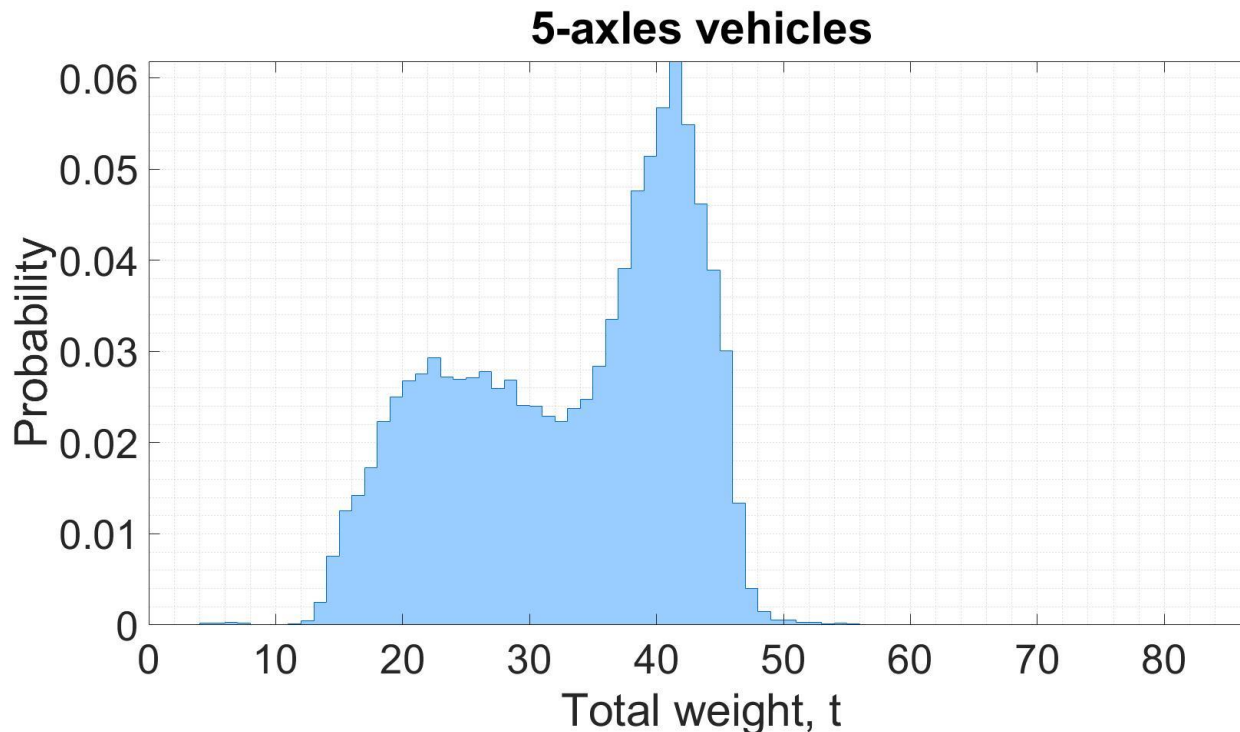
V – Type of the vehicle axle group



# Statistical Model

$$P_{\sigma}(\sigma_i) = \int_L \int_V \int_A \int_G P_{\sigma}(\sigma_i | L, V, A, G) \times p(L, V, A, G) dL dV dA dG$$

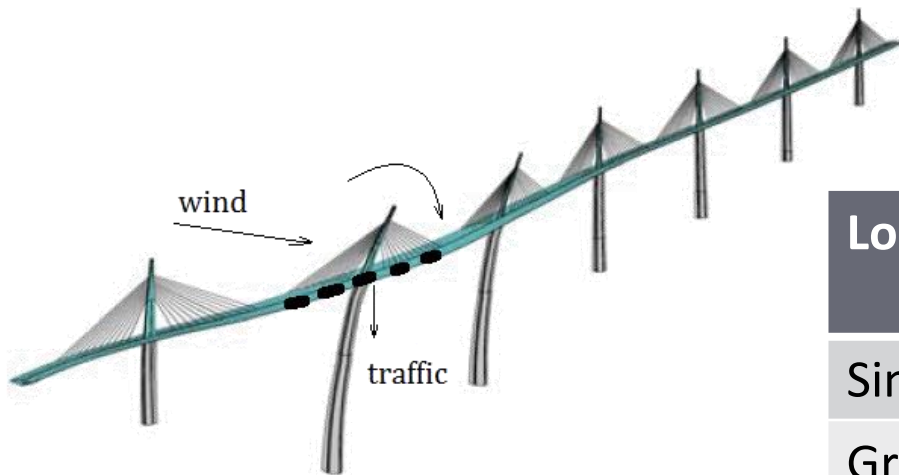
A – Amplitude of the load



# Statistical Model

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G – General loading of the structure



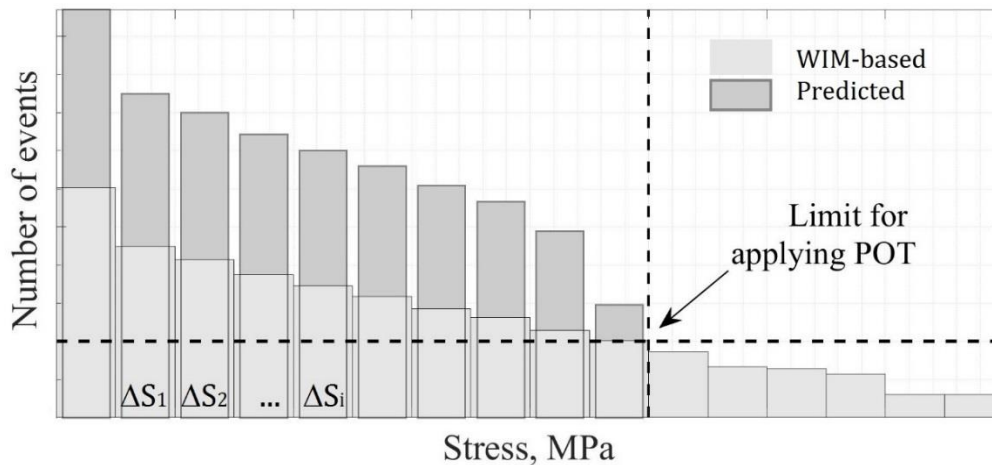
5-axles vehicles over one span

| Lorry queues | N of cases | %     | Mean group weight, t |
|--------------|------------|-------|----------------------|
| Single       | 70412      | 90,46 | 32,6                 |
| Group of 2   | 7024       | 9,024 | 66,0                 |
| Group of 3   | 389        | 0,500 | 98,1                 |
| Group of 4   | 11         | 0,014 | 116,8                |
| Group of 5   | 2          | 0,002 | 149,5                |



# GPD for Fatigue Damage

$$\begin{aligned}
 S = \sigma_L + \sigma_G &\rightarrow \Delta S_i \rightarrow N_i \\
 &\rightarrow GPD(N_i) \rightarrow s_i, k_i \\
 &\rightarrow RL_{N_i} = f(s_i, k_i)
 \end{aligned}$$



$$D = \sum d(S)$$

# Reliability Analysis

Limit State Function  $\rightarrow f(D) = f(\sigma_L, \sigma_G)$

$\rightarrow f$  ( Location,  
Vehicle Type,  
Amplitude of load,  
Transversal position,  
General loading )

$\rightarrow$  **Reliability** of studied elements

# Thank you for your attention

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<https://esr6infrastar.blogspot.com>

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Stay tuned

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