Civil Structural Heath Monitoring 2, CSHM2
September 28 - October 1, 2008, Taormina - Sicily (Italy)

Extreme Traffic Load Effects on Medium Span Bridges

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1 Extreme Traffic Loads

- Method

- Results

2 Extreme Traffic Effects

-Traffic Effect Measurement

- Traffic Data

- Traffic Effect Modeling

- Results

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Scope

Re-assessment of the Eurocode traffic load model for road bridges based on :

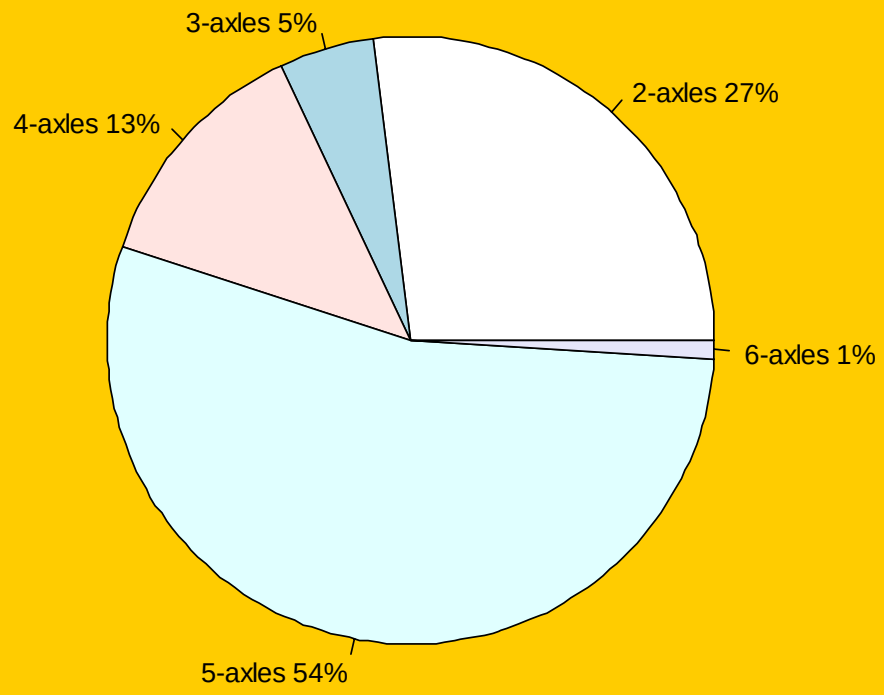
- *Recent weigh-in-motion data,*
- *Measured effects on a medium span bridge,*
- *Extrapolated 1000 years return period estimates using the extreme value theory,*
- *Consistency of the prediction with realistic extreme loading events.*

Methodology

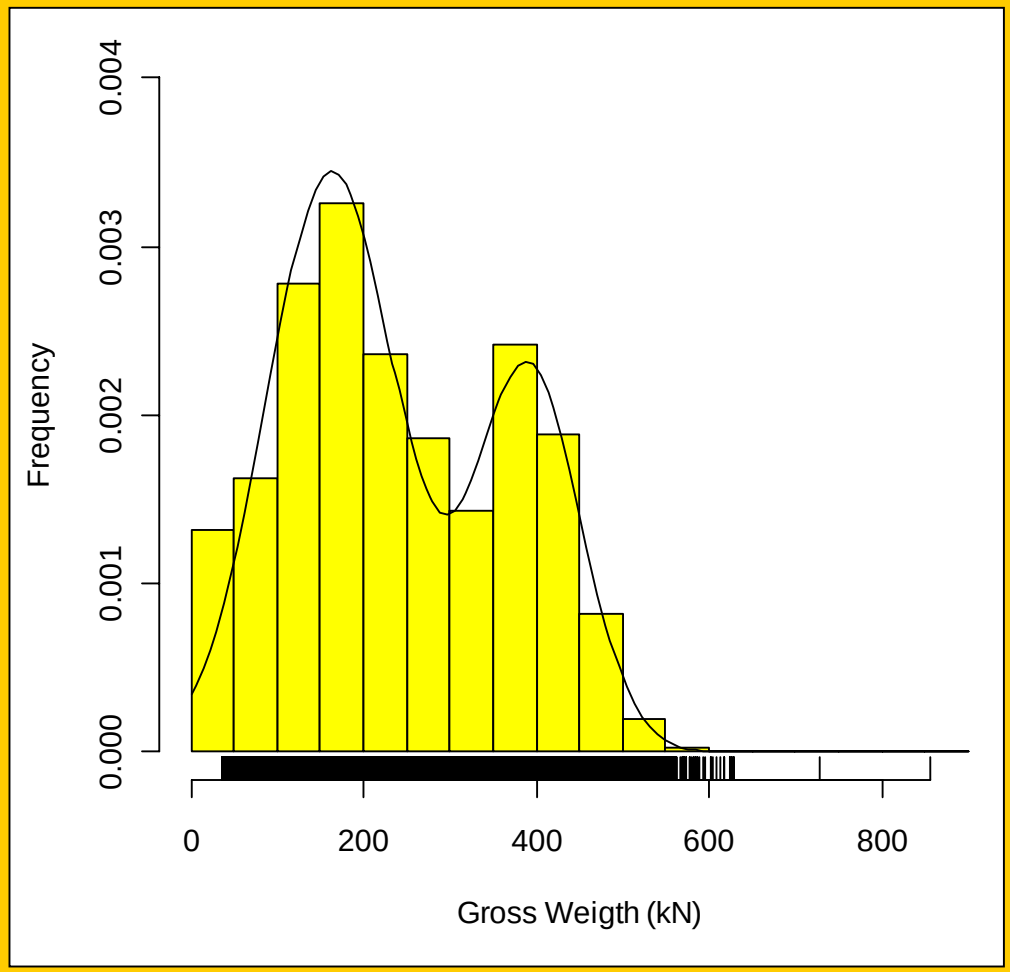
-*Long term data records for extreme value estimates,*
- Parameter estimation of the weight distributions using the measured data,
- Asymptotic distribution of extremes,
- Identification of critical traffic load events,
- Model selection for predicting extrapolated values.

Weigh-in-Motion Data

- *Data of trucks (> 35 kN) collected in June and September 2007 on the highway A64 (Muret),*
- *Traffic flow during the working days : 1500-1600 trucks/day.*



Truck Gross Vehicle Weight Distribution



Maximum Likelihood Parameter Estimates

Bimodal normal density distribution of the gross vehicle weight

$$f(x)=\frac{1-p}{\sqrt{2\pi}\sigma_1}\exp\left(-\frac{(x-\mu_1)^2}{2\sigma_1^2}\right)+\frac{p}{\sqrt{2\pi}\sigma_2}\exp\left(-\frac{(x-\mu_2)^2}{2\sigma_2^2}\right)$$

Parameter estimates:

p	μ_1 (kN)	σ_1 (kN)	μ_2 (kN)	σ_2 (kN)
0.33	**165**	**70**	**378**	**46**

Gumbel Asymptotic Distribution

Asymptotic cumulative distribution of the daily gross vehicle weight maxima drawn from a fixed number n = pN of loads normally distributed:

$$G_n(x) = \exp(-\exp(-a_n(x - b_n)))$$

with the parameters:

$$a_n = \frac{\sqrt{2\ln(n)}}{\sigma_2} \quad \text{and} \quad b_n = \mu_2 + \sigma_2\left(\sqrt{2\ln(n)} - \frac{\ln(\ln(n)) + \ln(4\pi)}{\sqrt{2\ln(n)}}\right)$$

Thinned Poisson Process

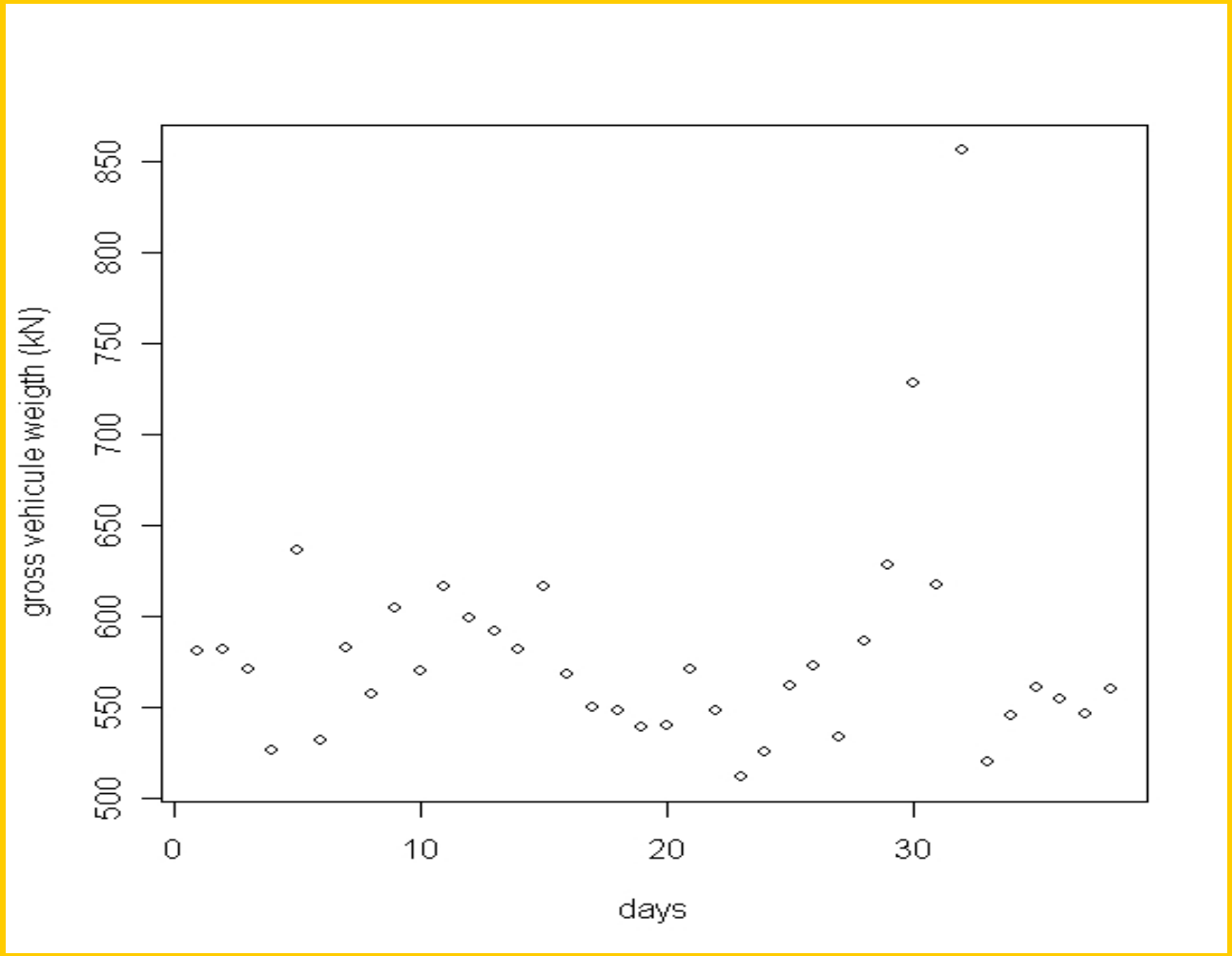
Daily max weight distribution of a heavy truck, Ditlevsen et al. (1995):

$$G(x)=\sum_{n=0}^{\infty}\frac{(pNT)^n\exp(-pNT)}{n!}\left(\Phi\left(\frac{x-\mu_2}{\sigma_2}\right)\right)^n=\exp\left(-pNT\left(1-\Phi\left(\frac{x-\mu_2}{\sigma_2}\right)\right)\right)$$

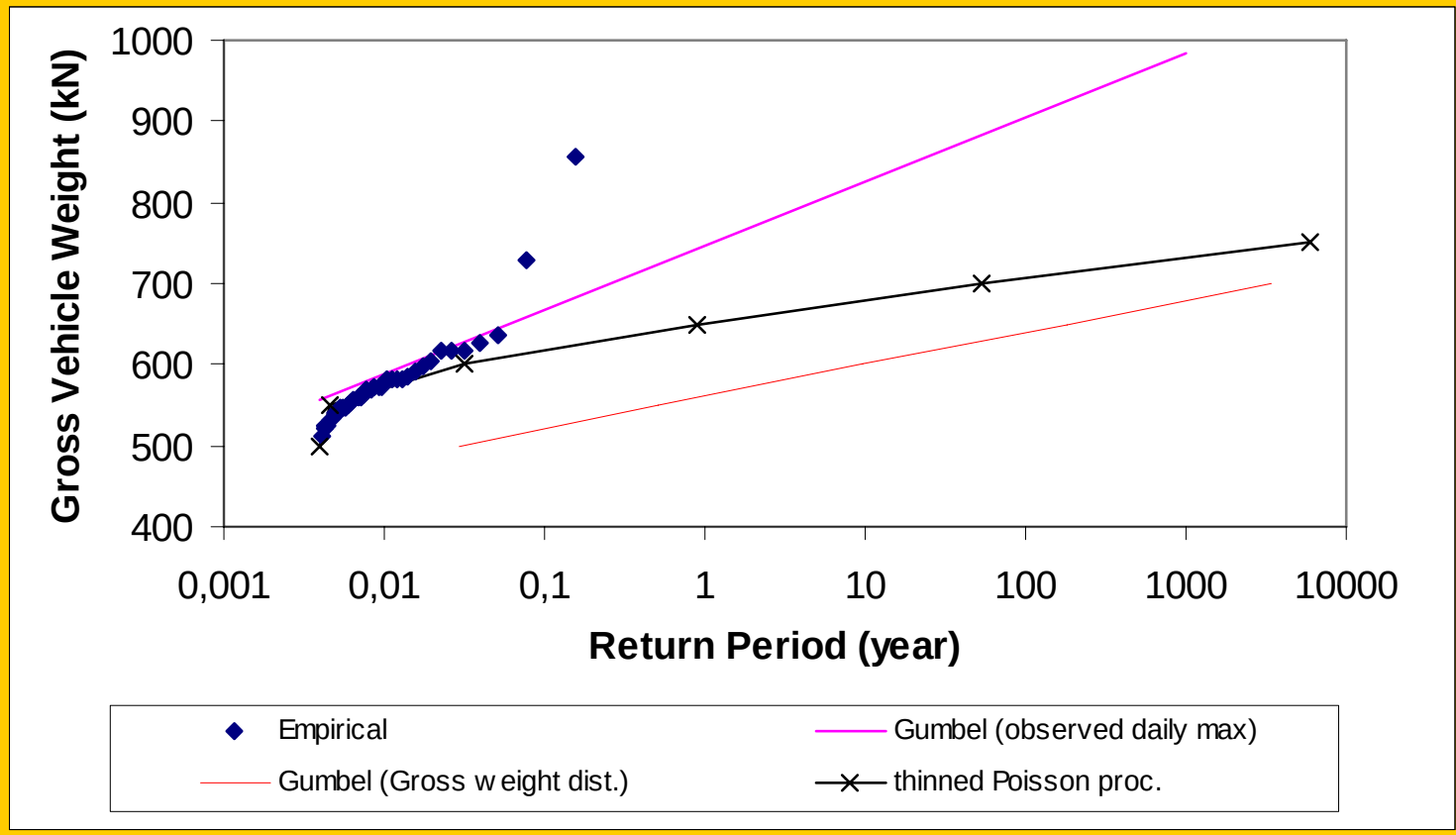
where T=1 day, Φ is the cumulative normal distribution and $1-\Phi\left(\frac{x-\mu_2}{\sigma_2}\right)$ *is the thinning probability*

Recorded Daily Maximum Gross Weight

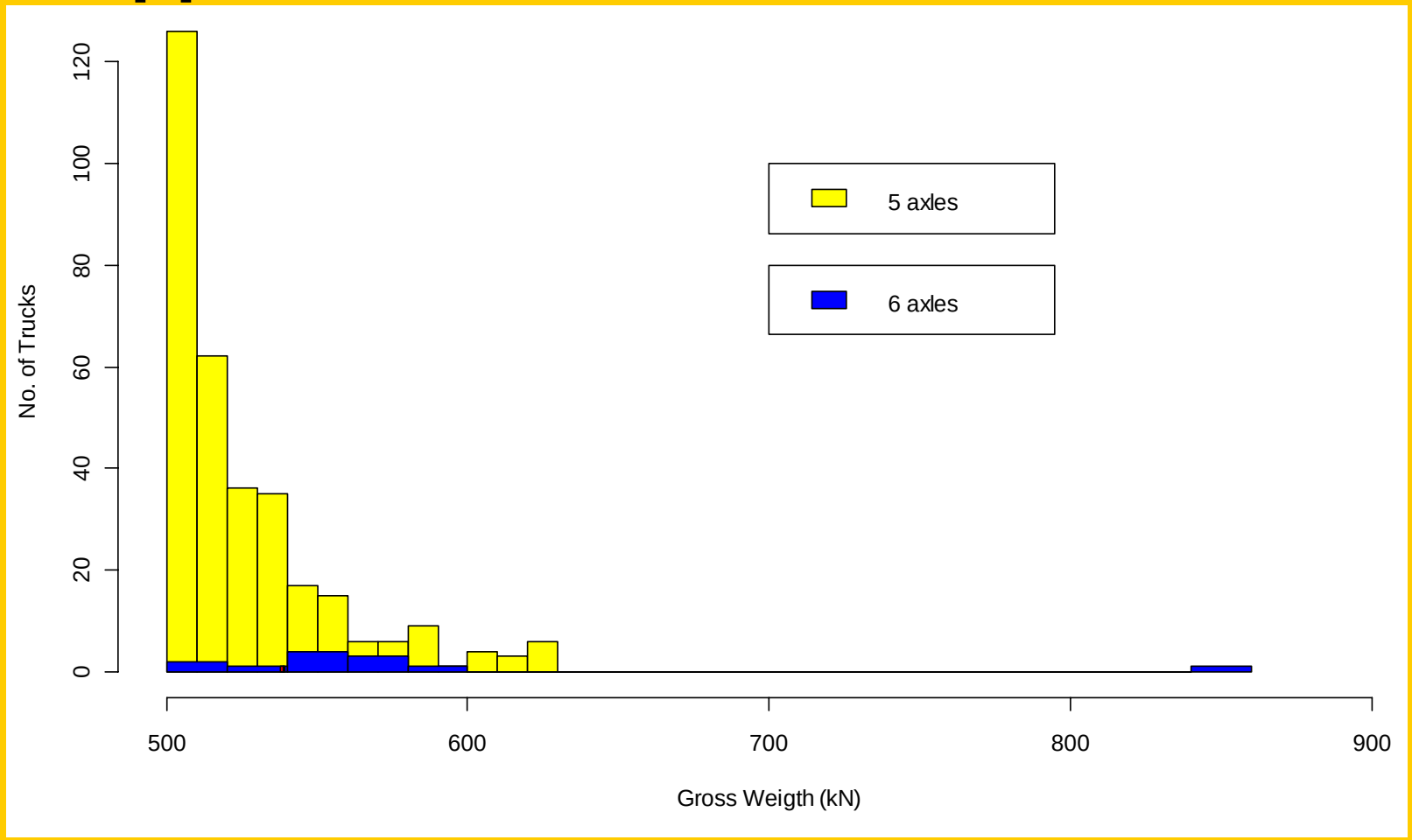
Derived from 38 working days, WIM data record on highway A64 (June-Sept. 2007)



Extreme Gross Vehicle Weight with respect to given Return Periods



Upper Tail of the GVW Distribution



Summary on the GVW

-1000 yrs return period of the GVW:
predicted with the Gumbel asymptotic distr. (680 kN),
and with the Thinned Poisson Process (730 kN)
are below the extrapolated Gumbel estimate from the measured daily maxima (985 kN),

- The observed extreme load events are not described by the fitted bimodal distribution + the Gumbel extreme value distribution,

- Tractors with a semi-trailer on a tridem axle (class 5) were involved in all the observed extreme events.

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Case Study: Roberval Bridge (Senlis A1)

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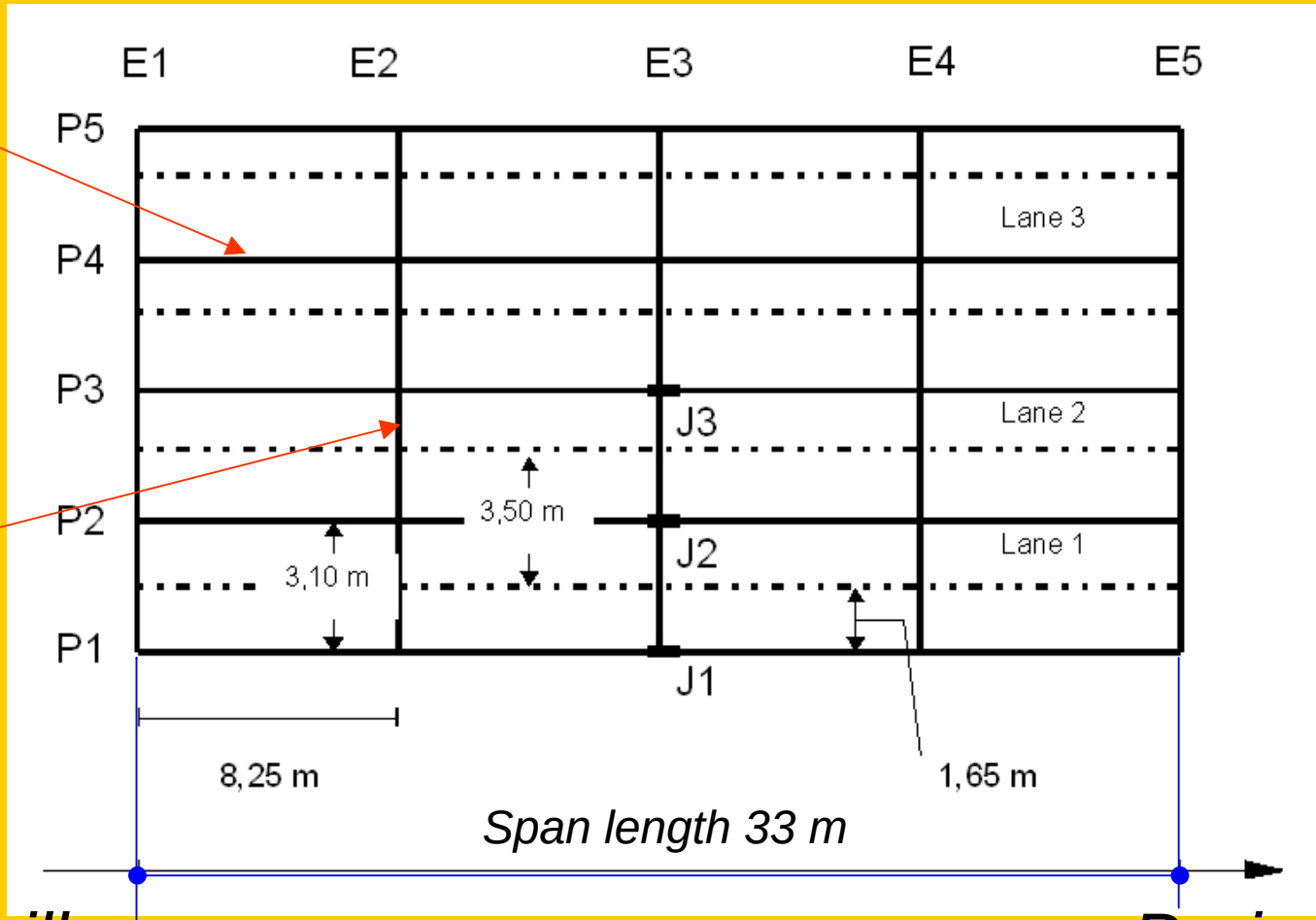
Simple supported prestressed concrete bridge

Each 33 m span consists of
5 girder beams,
5 cross braces,
carries 3 lanes.

Strain Gauges Location

$P_1 – P_5$ Girder Beams

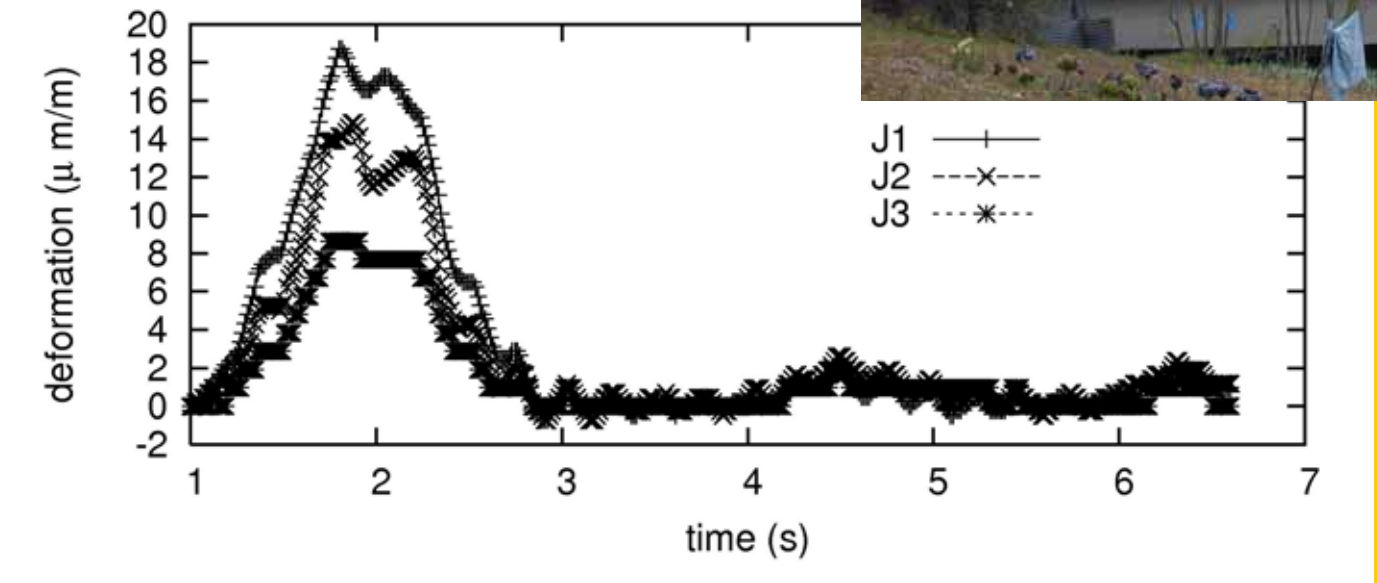
$E_1 – E_5$ Cross Braces



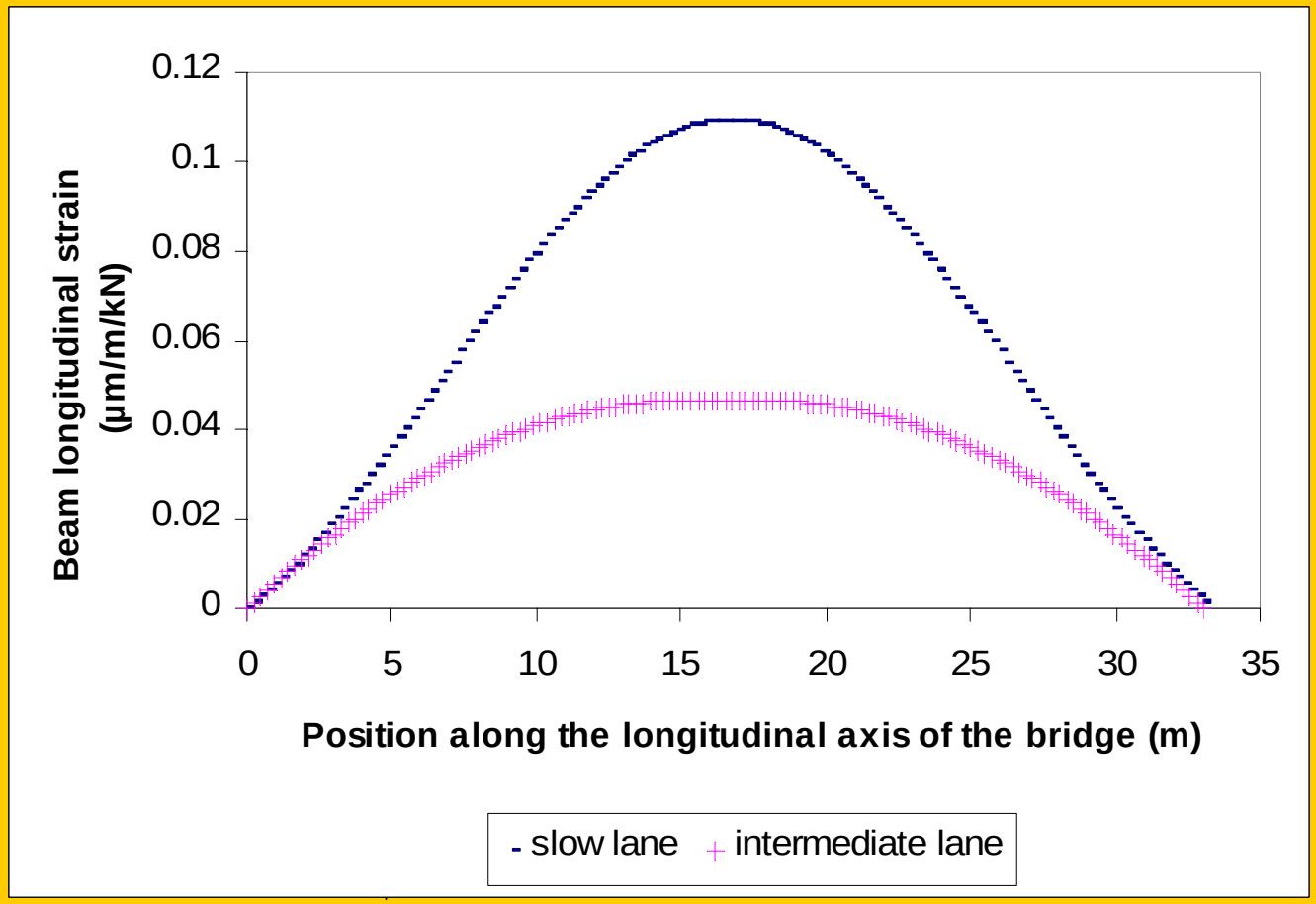
Instrumented beam P1 at mid-span

Strain gauge with a protective coating

Measured signal at mid-span for a 5-axle truck



Measured Influence Lines

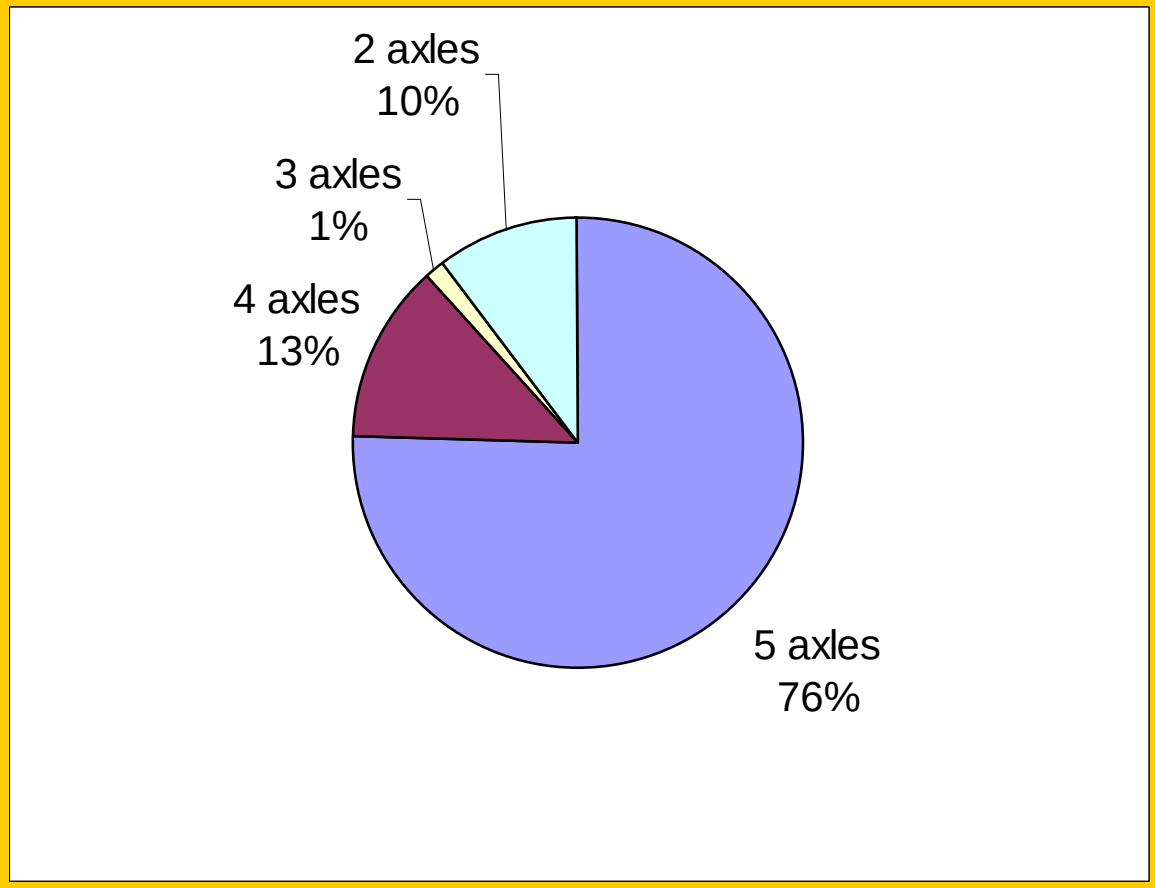


Recorded Traffic Data

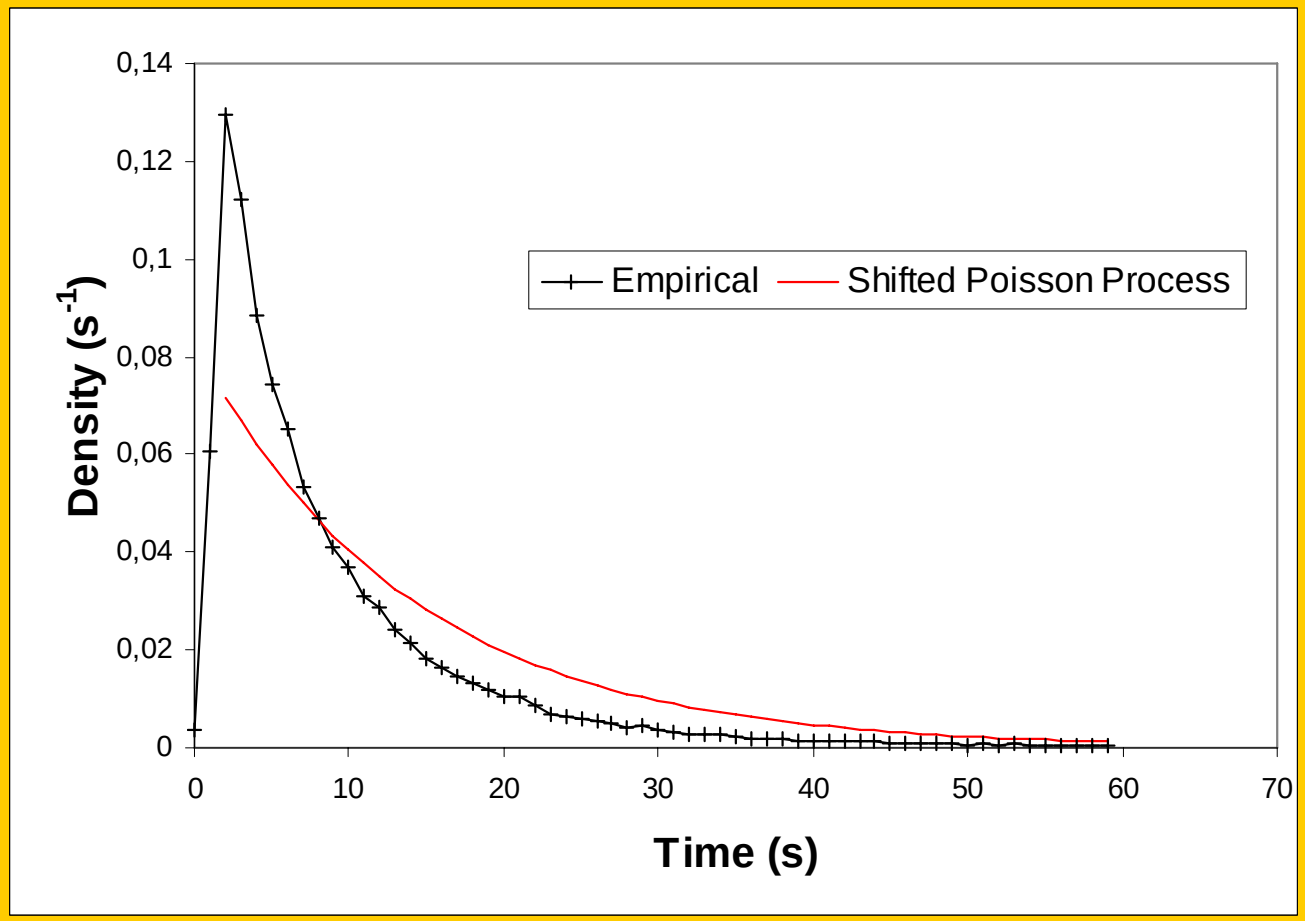
- *Data of trucks (> 35 kN) collected in February 2005, A1 motorway, slow and medium lanes, direction Lille to Paris,*

- *Traffic flow (working days): 8500 trucks/day (77 % on the slow lane).*

Truck population



Vehicle gap (GVW > 35 kN) on the slow lane



Distribution of the maximum strain amplitude over a time period T:

k independent Thinned Poisson processes:

$$G(x) = \prod_{i=1}^{k} \exp\left(-\nu_i T\left(1 - F_i(x)\right)\right)$$

ν_i are the rates of the load effects with a cumulative distribution F_i, derived from:

- *the load configurations (truck weights, locations),*
- *the static influence lines.*

Truck Meeting Events on the Bridge

Observed maxima of the load effect: meeting in both lanes of two 5- and 6-axles trucks with a tridem:

$$G(x) = \exp\left(-N_{12}T\left(1-\Phi_{12}(x)\right)\right)$$

with: $\nu_{12} = 2p^2 N_1 N_2 \frac{L}{V}$,

N_1, N_2: *traffic intensities in lane 1 and 2,*
V: speed, L: spacing between tridems (3m),
ϕ_{12} *: cumulative normal distribution of the load effects*

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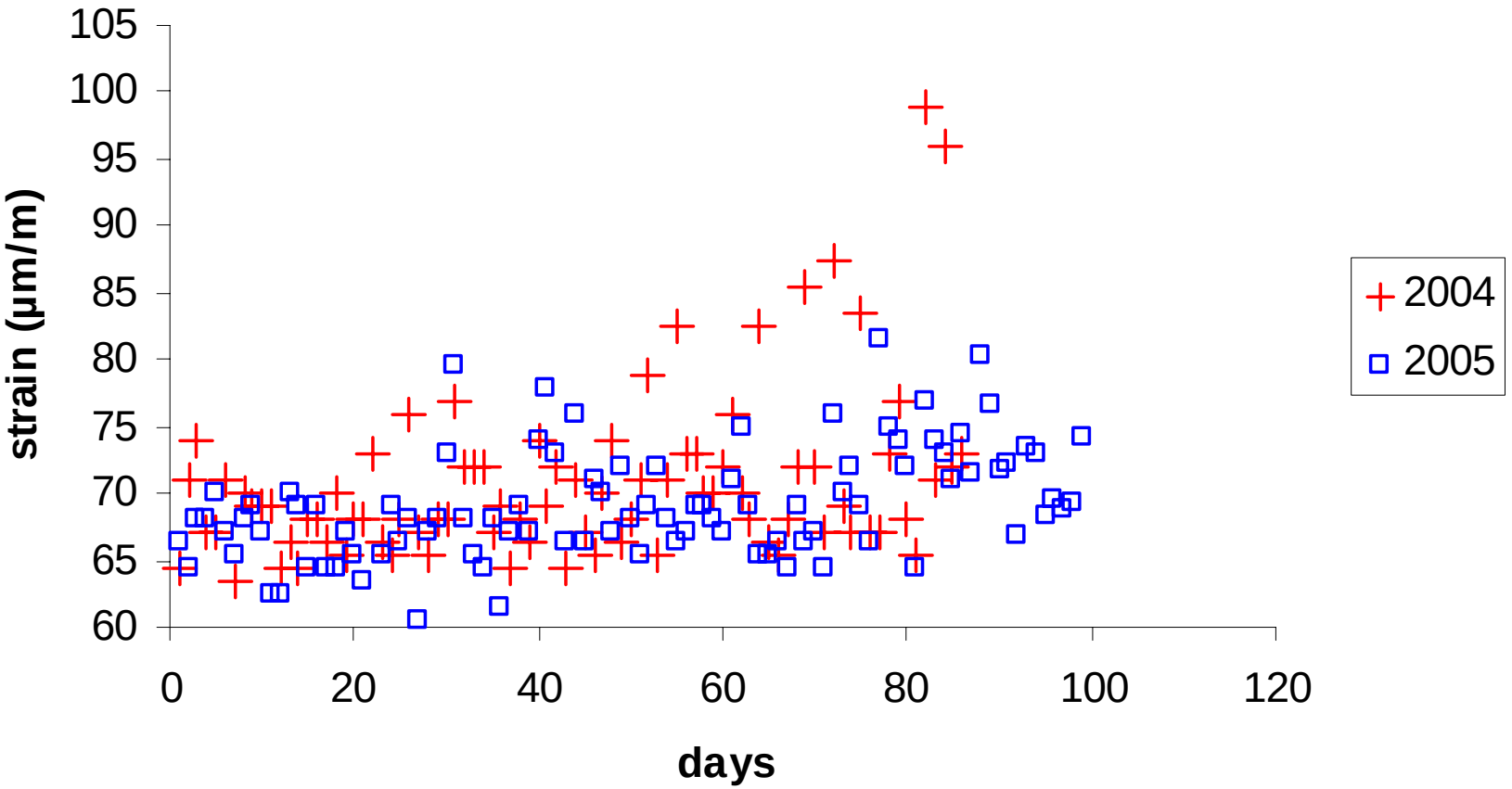
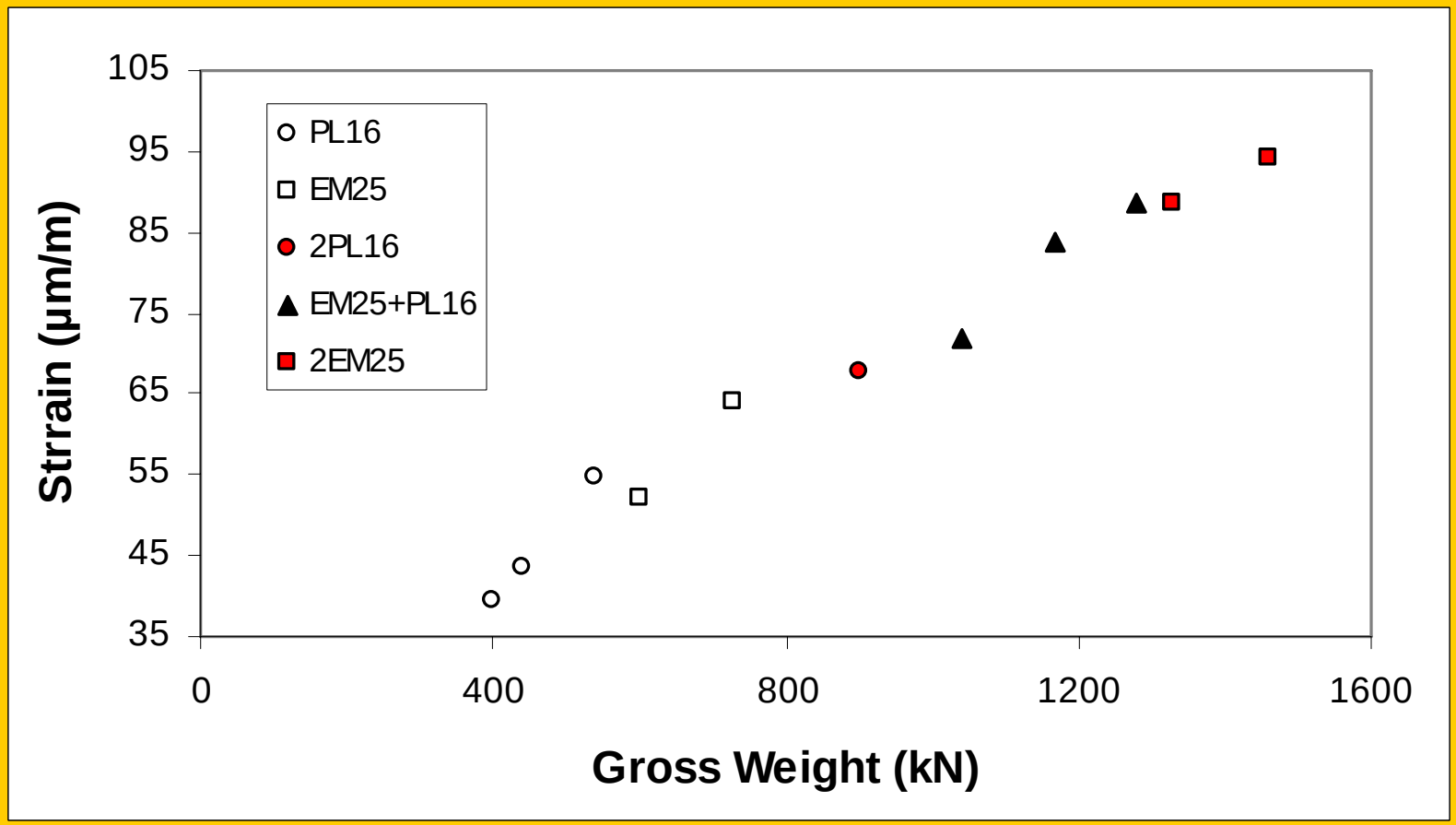
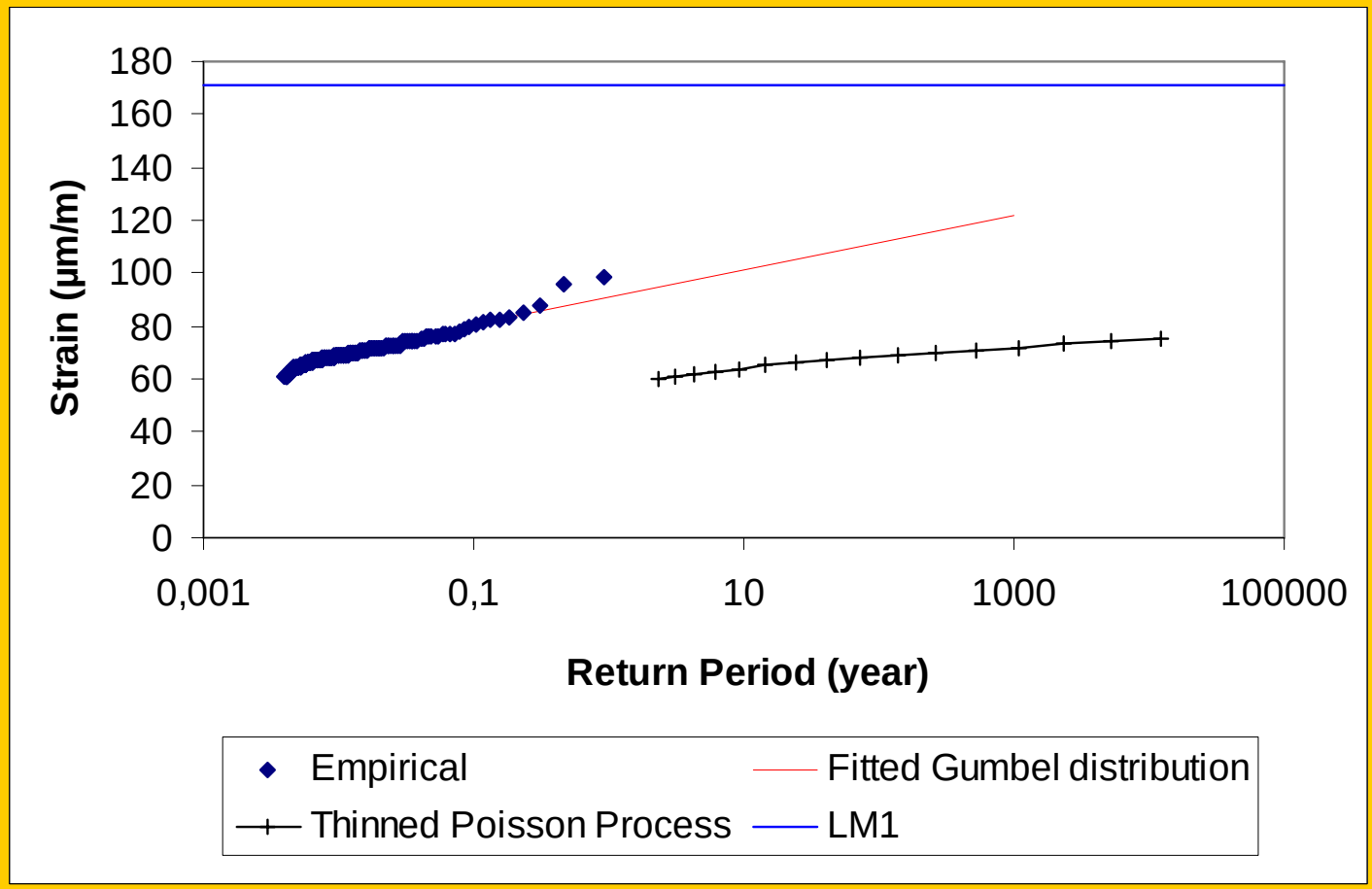
Daily maximum recorded strain



Strains under Overloaded Trucks



Extreme strain estimates with respect to the return period



Conclusions (1)

- *Extensive WIM data needed for a good description of the upper tail of the GVW distribution*
- *the extreme traffic loads and load effects with a given return period are underestimated by the bimodal model*
- *the extreme value distribution must be derived from an homogeneous population of trucks*

Conclusions (2)

- Improved predictions needed for the extreme GVW,

- the 1000 years return period load effects extrapolated with the Gumbel distribution (fitted on the daily max observed) is 50% below the load effect calculated with the Eurocode load model LM1.