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Finding the Distribution of Bridge Lifetime Load Effect by Predictive Likelihood

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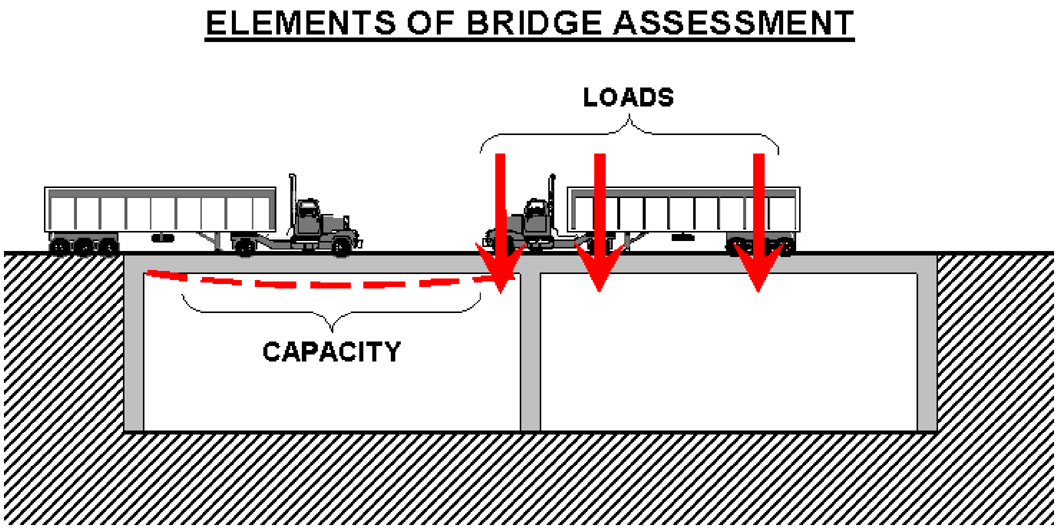
Introduction

- About €6 bn is spent in the EU annually on bridge repair and replacement
- Thus it is costly and also very disruptive
- Short- to medium-length (20-50 m) bridges are the most common
- The assessment of bridge capacity is relatively accurate
- Load assessment is difficult & less accurate due to large variations in traffic



Conclusion: There are large potential savings through accurate load assessment

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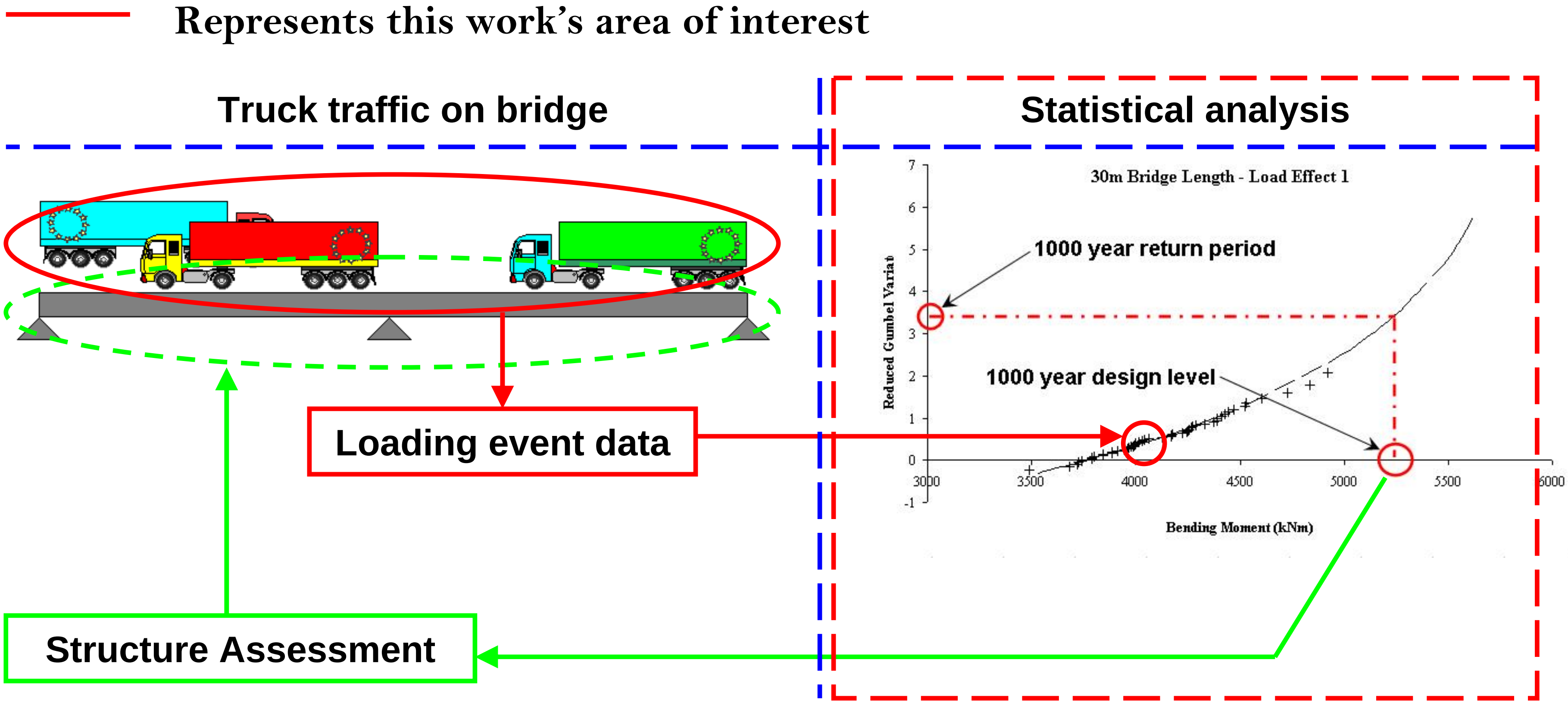
Assessment Process



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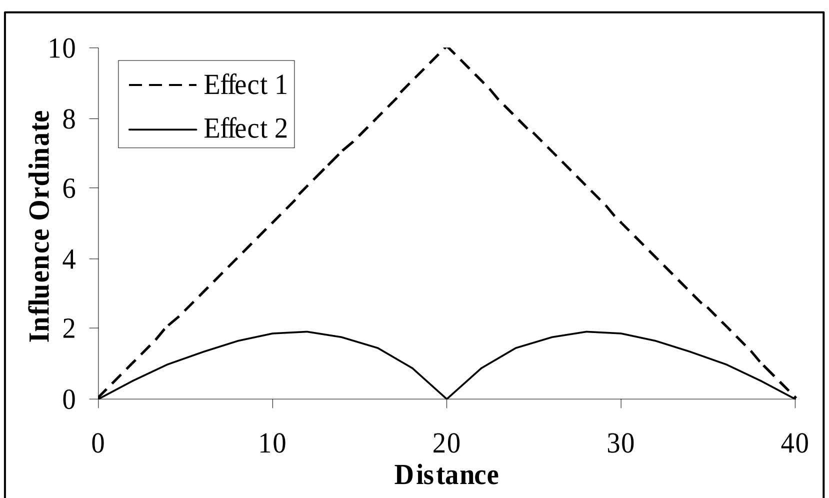
Traffic Load Simulation

- Real traffic is measured using **Weigh-In-Motion** technology

- The traffic's **characteristics** are statistically modelled

- **Monte Carlo simulation** from these models allows much more traffic to be studied



- Generated traffic is passed over the **influence lines** of interest to obtain the bridge traffic load effect

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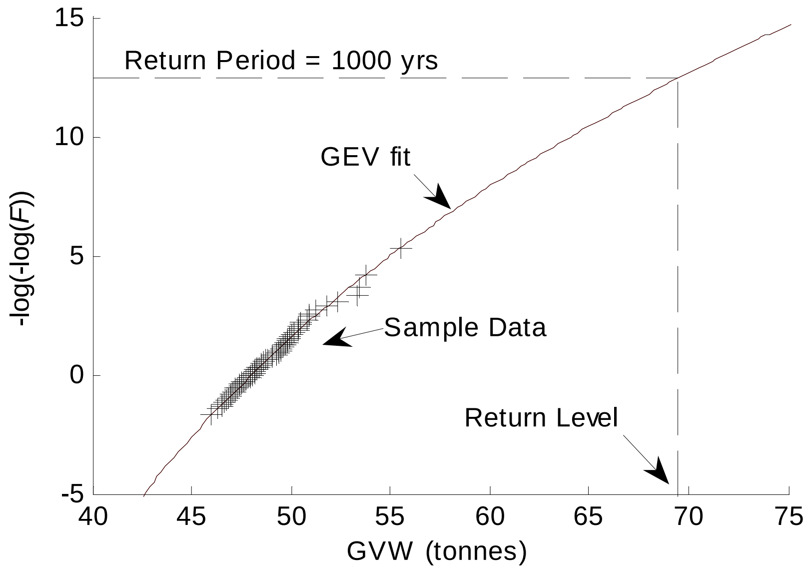
Standard Statistical Analysis

- Extreme value analysis is usually used (block maxima or POT)

- Using block maxima, for the load effect/characteristic of interest:



1. Daily maximum values (typically) are noted (stationarity)

2. A GEV distribution models the data

3. The required return level is obtained (1000-years for EC1.3)

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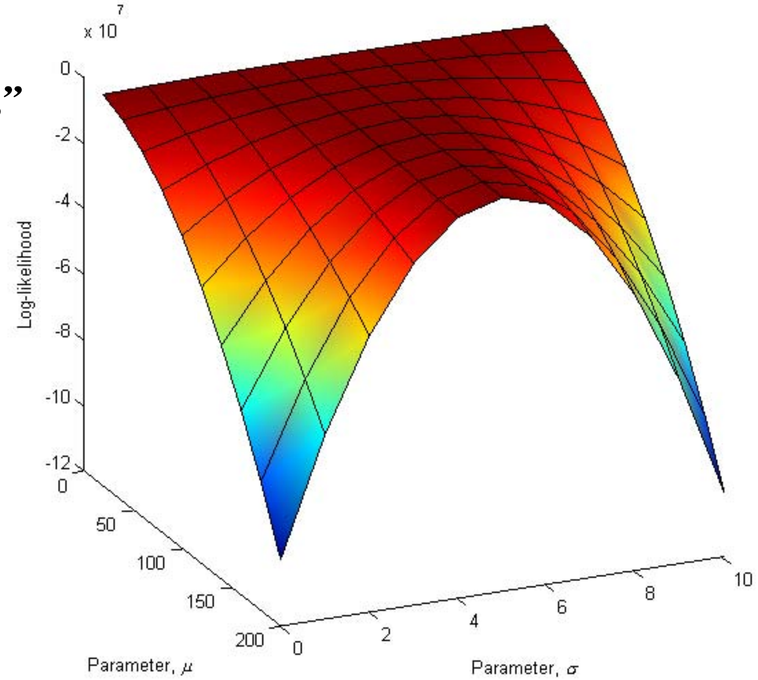
Problems

The Eurocode 1.3 design level is that with:
"a 10% probability of exceedance in 100 years"

Usually taken as a 1000-year return period

- No variability allowed for in the 1000-year RP prediction

- Model/fit uncertainty not taken into account:
  - width of likelihood surface
  - predictions from adjacent fits (near parameter vectors)



Conclusion: The model parameter vector confidence intervals should be taken account of in the prediction

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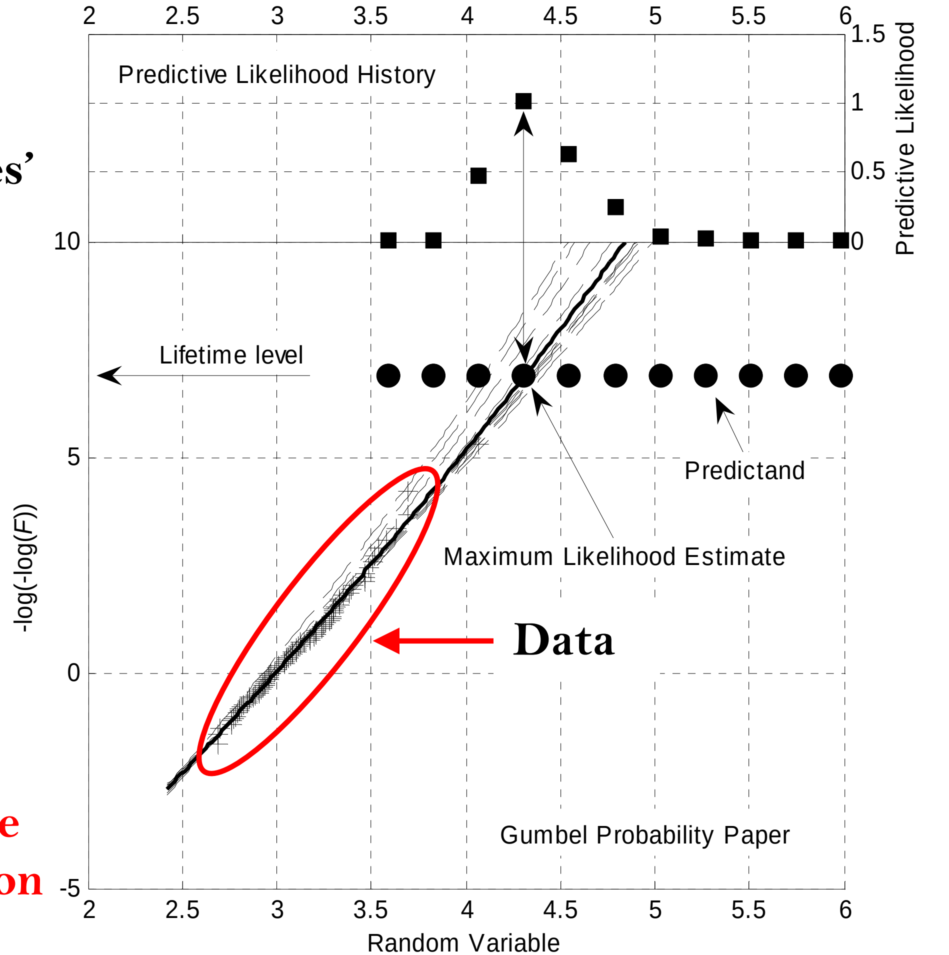
Predictive Likelihood

- Given the data as the only true known
- for a range of possible 'prediction-values'
- the predictive likelihood function is evaluated for each
- A distribution of PL values results

The predictive likelihood function:

$$L_P\left(z\,|\,y\right)=\sup_{\theta} L_y\left(\theta;y\right)L_z\left(\theta;z\right)$$

Best fit of — known data — & — possible prediction



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Modifications

The predictive likelihood noted is Fisherian predictive likelihood

Two modifications are made to improve this:

1. Variability of the fitted model parameters are included
 (the *n*-dimensional width of the likelihood surface: $\sqrt{\left|\mathcal{I}\left(\theta_z\right)\right|}$)

2. A vector transformation into the correct parameter domain $\left|\partial\theta_z / \partial\theta\right|$
 (does not affect the shape of the curve due to normalization)

Thus: Modified Predictive Likelihood: $$L_{MP}\left(z \mid y\right) = \frac{L_P\left(z \mid y;\theta_z\right)}{\left|\frac{\partial\theta_z}{\partial\theta}\right|\sqrt{\left|\mathcal{I}\left(\theta_z\right)\right|}}$$

These changes are generally insignificant

Application

- Data from the A6 Paris-Lyon motorway is used
- A 1000-day MC traffic sample is generated
- 1000 daily maximum static load effects are noted for:
    1. Load Effect 1: mid-span moment of a simply-supported bridge
    2. Load Effect 2: Left hand shear in a simply-supported bridge
    3. Load Effect 3: Central support moment of a two-span bridge
- Two forms of analysis for the design level:
    1. Standard extreme value analysis (1000-year RP)
    2. Predictive likelihood analysis
       (the 100-year lifetime load effect distribution)

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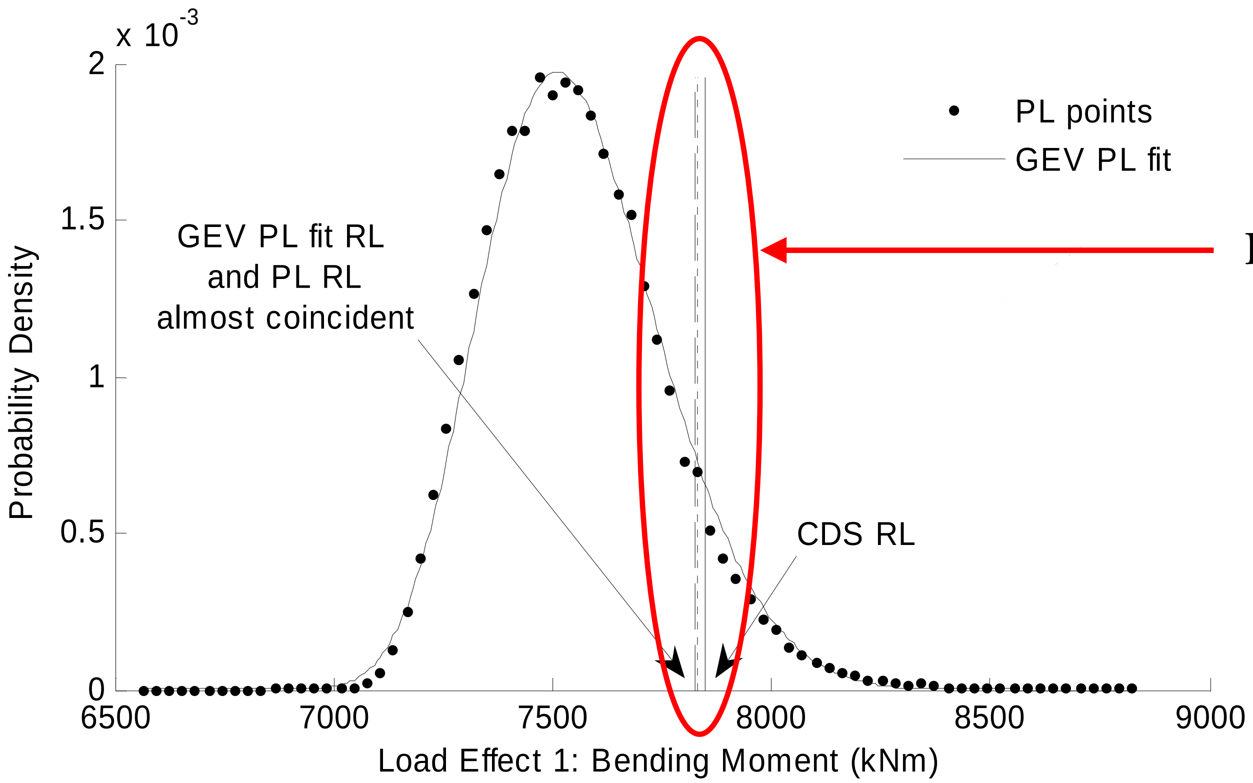
Sample Results - Load Effect 1, 30 m bridge length



Results of both analyses almost agree

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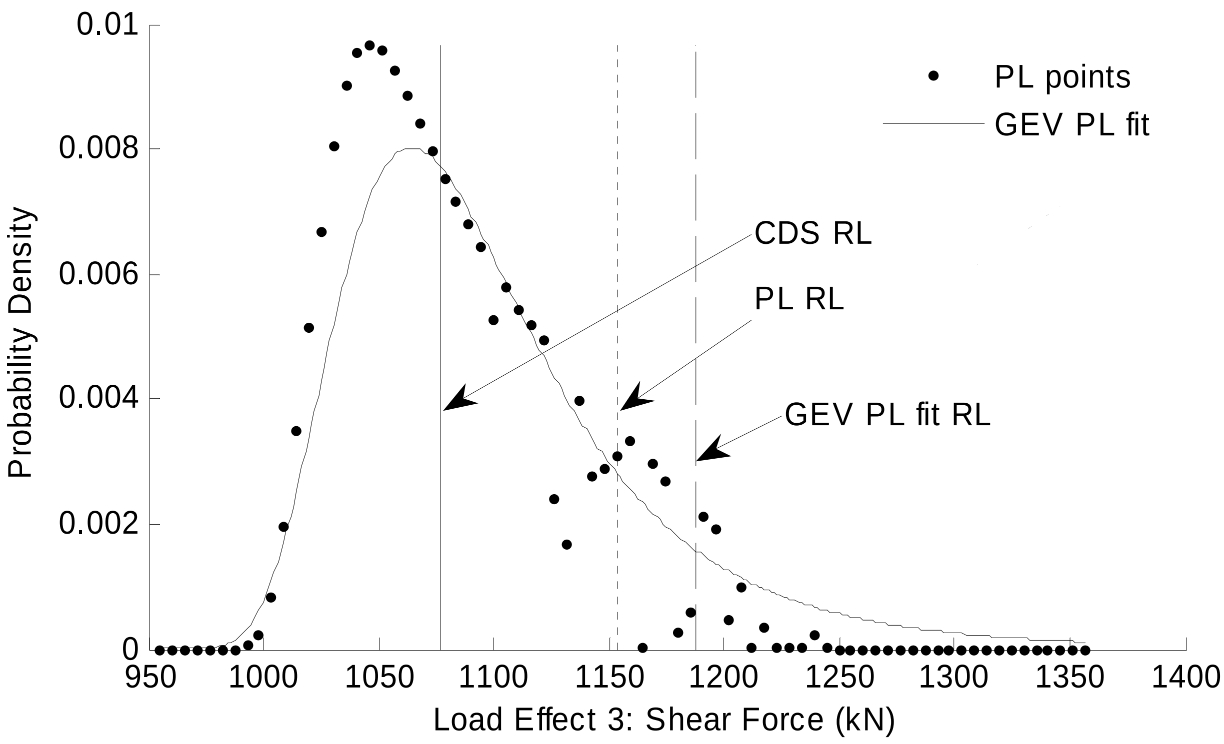
Sample Results - Load Effect 3, 40 m bridge length



- PL points **less stable** numerically
- 'Best fit' GEV distribution **smoothes** this
- Significantly **different** answer to standard analysis

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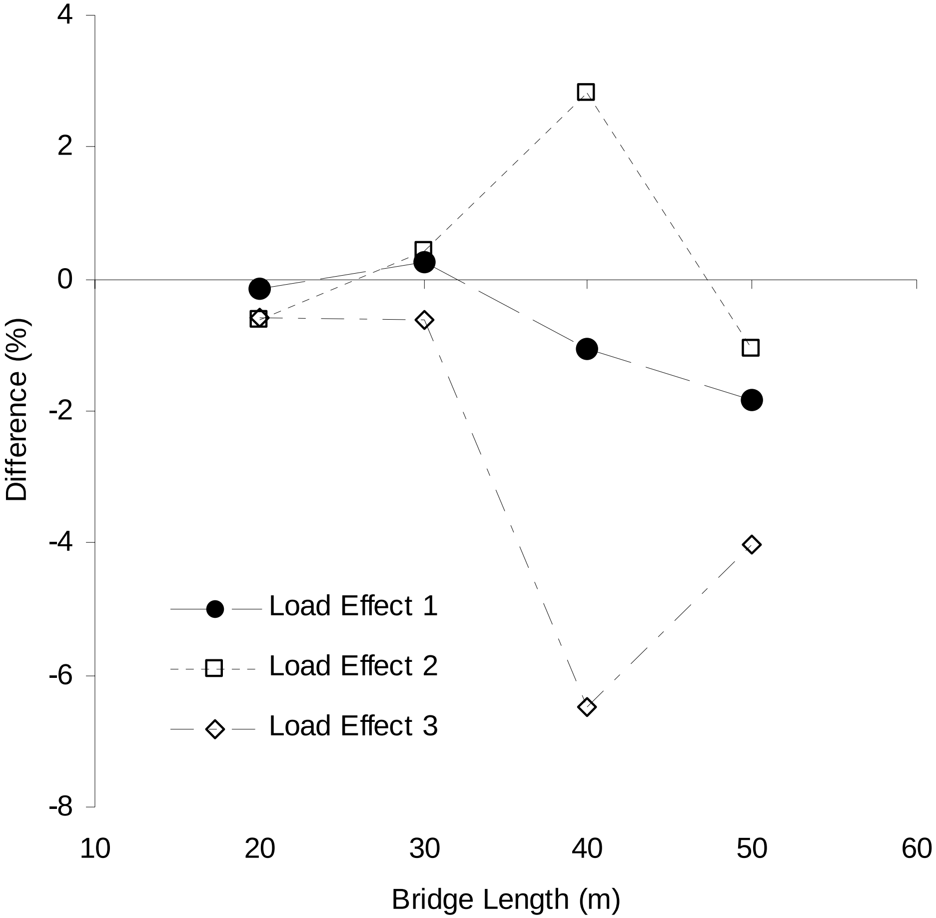
General Results



- Percentage difference of standard EV analysis to the PL results
- PL to be preferred as more information is returned from sample
- Standard analysis is generally non-conservative

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Conclusions

The different results of the

predictive likelihood (100-year with 10% probability of exceedance)

and the

standard EV analysis (1000-year return period)

show these definitions of probability are not equivalent

Conclusions

Predictive likelihood:

- accounts for more variability

- obtains more information from the sample

- gives the lifetime distribution of load effect

- generally gives slightly more conservative results for the data studied

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