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Civil Structural Health Monitoring 2

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Recent Advances in the Governing Form of Traffic for Bridge Loading

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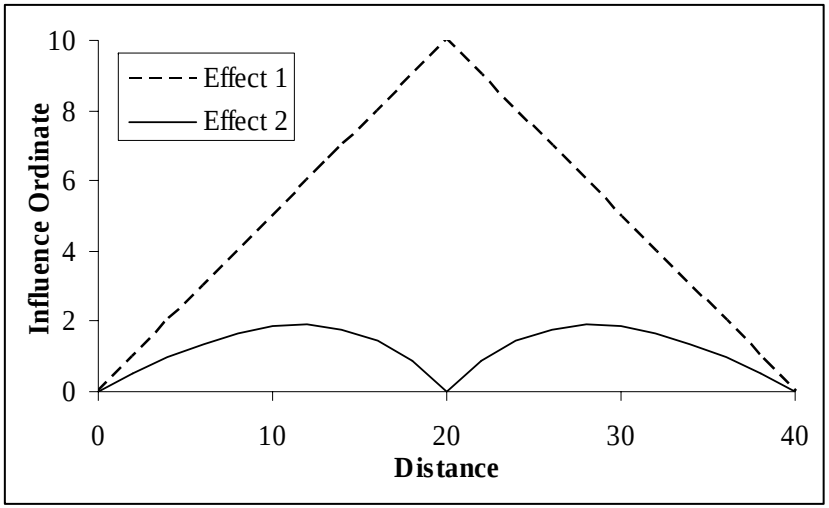
Basis of Research

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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Basis for Statistical Analysis

Weaknesses in the statistical analysis of bridge traffic loading arise from:

1. **Choice of Population:**

   Must be appropriate to model, e.g. stationarity.

2. **Distribution of Extreme Load Effects:**

   Use Generalized Extreme Value distribution to avoid a priori decisions.

3. **Estimation:**

   Use minimum variance estimators, e.g. maximum likelihood.

4. **Choice of Thresholds:**

   Use the correct model for the data, avoiding the 'tail' data problem.

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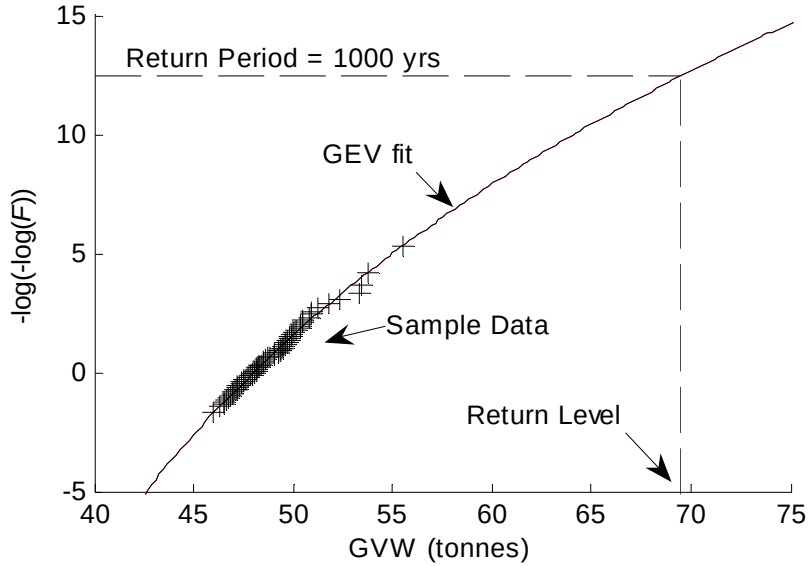
Standard Statistical Analysis

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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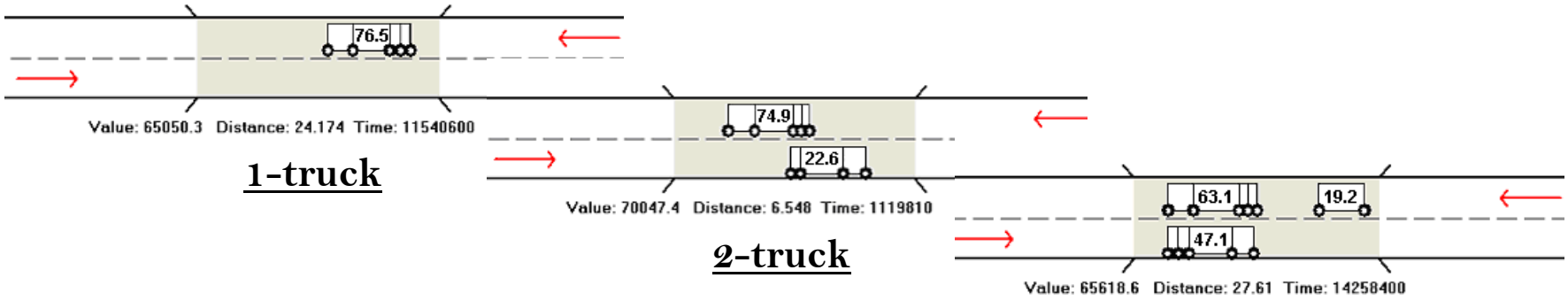
Latest Statistical Analysis - I

In bridge traffic loading, different events occur:



These loading events have different statistical distributions…

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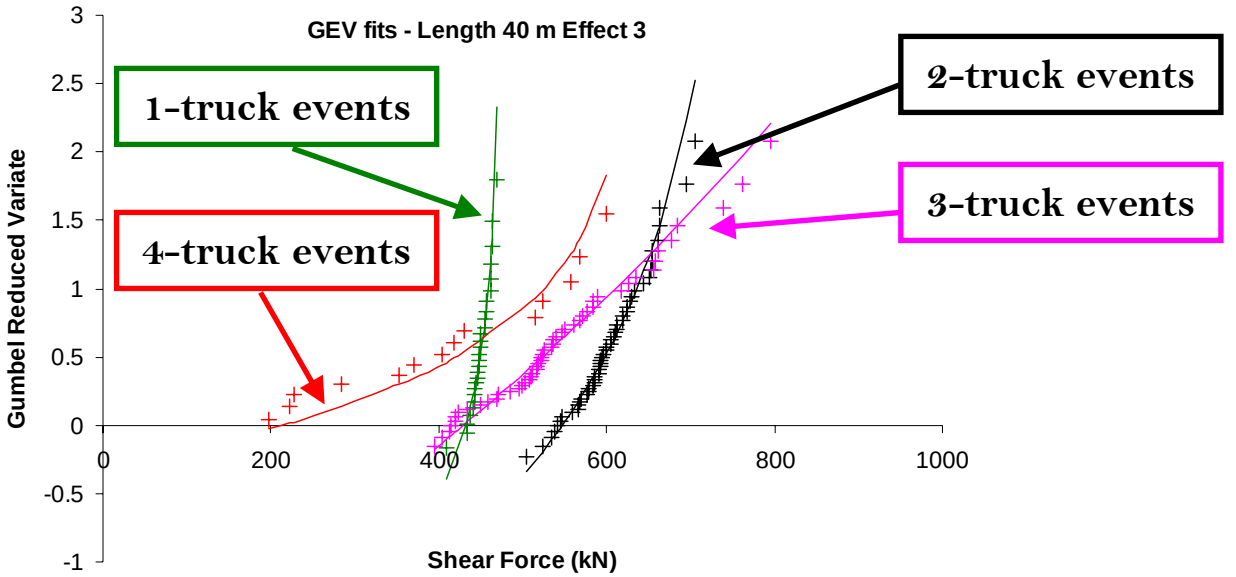
Latest Statistical Analysis - II



We suggest a new composite distribution of load effect (Caprani et al 2008):

Composite Distribution ⟹ $G_C(z) = \prod_{i=1}^{N} G_i(z)$ ⟸ Individual Event-type Distribution

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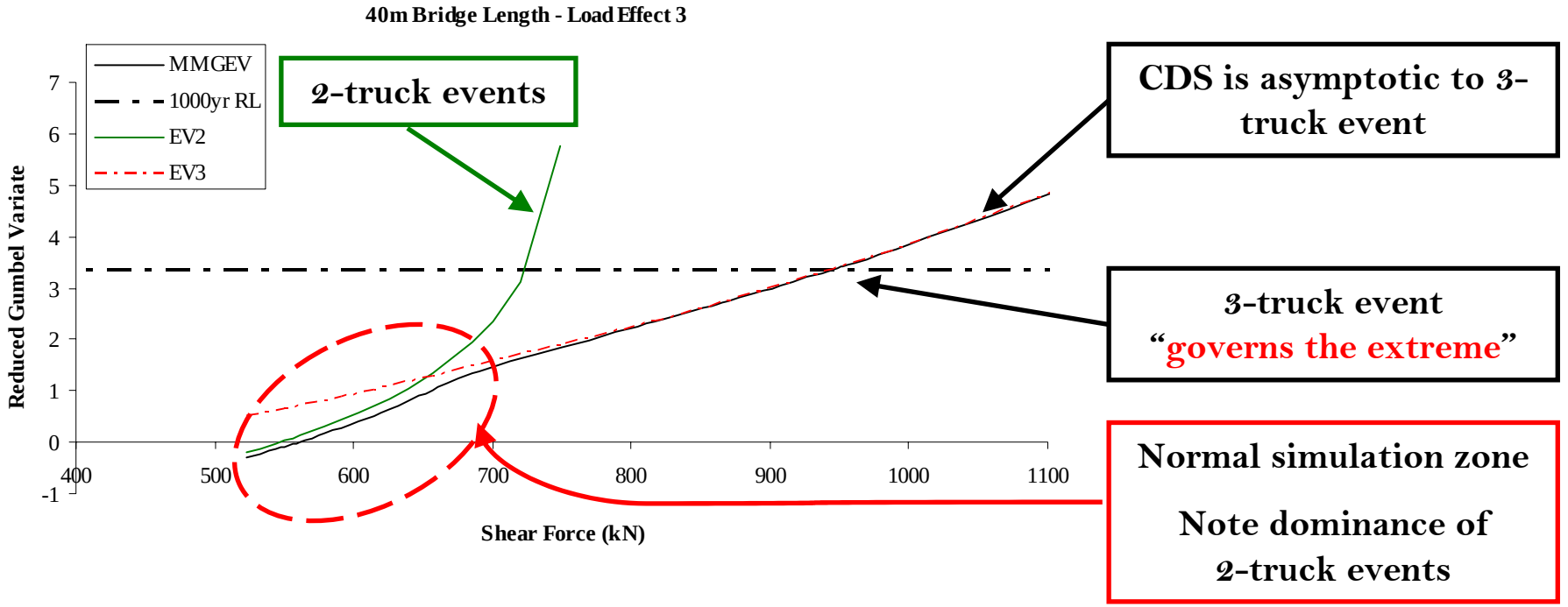
Latest Statistical Analysis - III

Extrapolating:



New model shows that 3-truck events are very important in short to medium span bridges - this had been the subject of doubt

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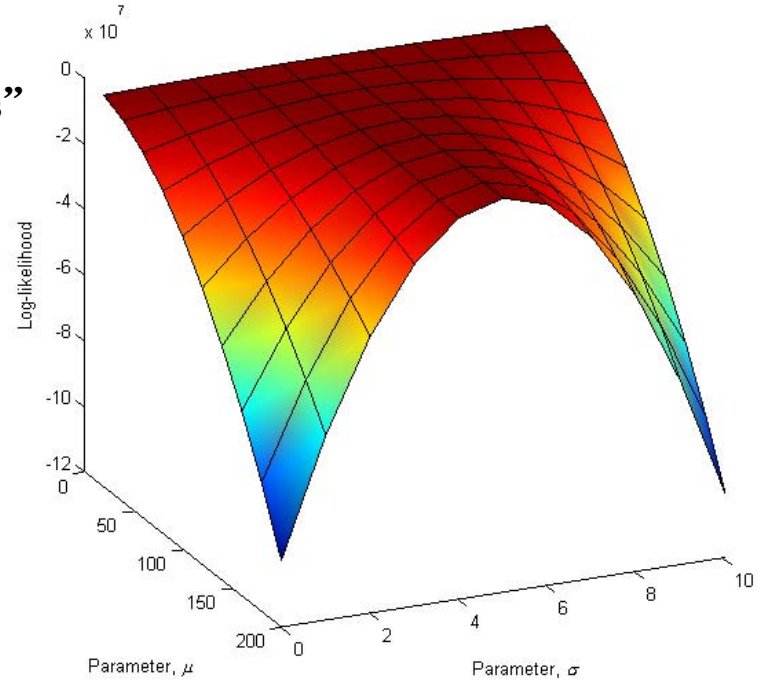
Problems

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'

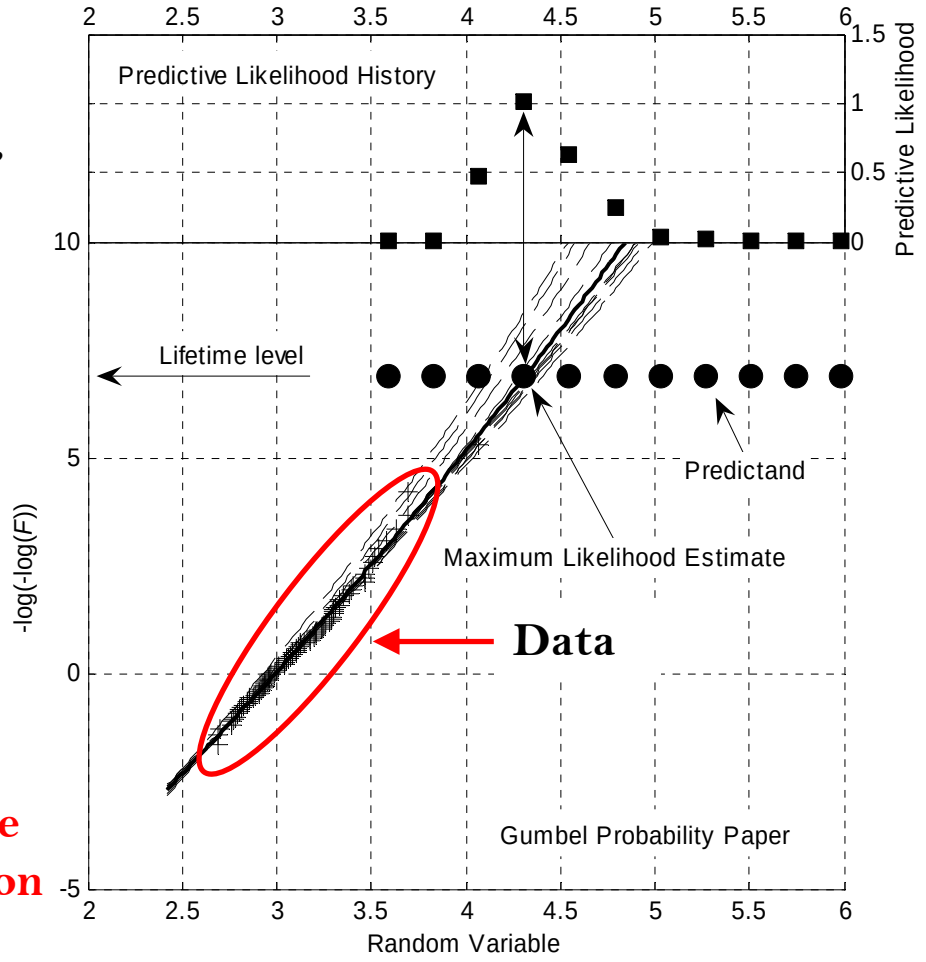
the predictive likelihood function is evaluated for each

A distribution of PL values results

The predictive likelihood function:

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

Best fit of known data & possible prediction



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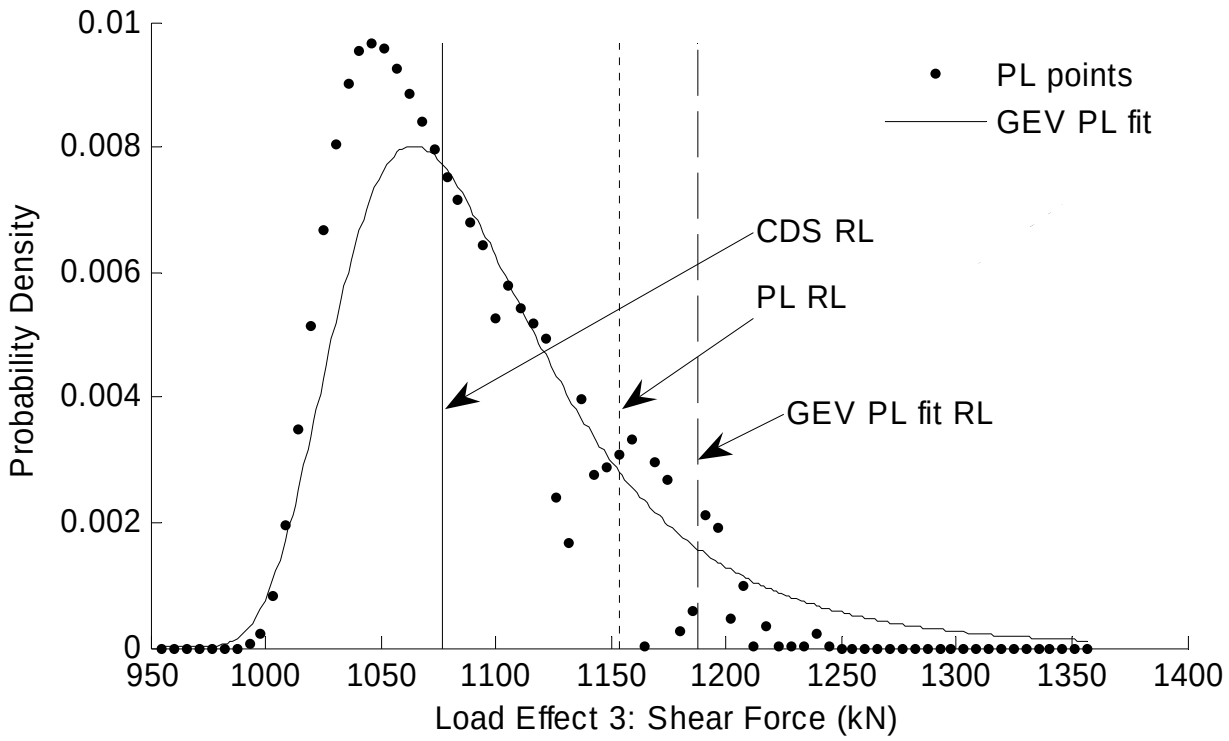
Sample Results - Load Effect 3, 40 m bridge length



PL points **not** very numerically **stable**

'Best fit' GEV distribution **smoothes** this

Significantly **different** answer to standard analysis

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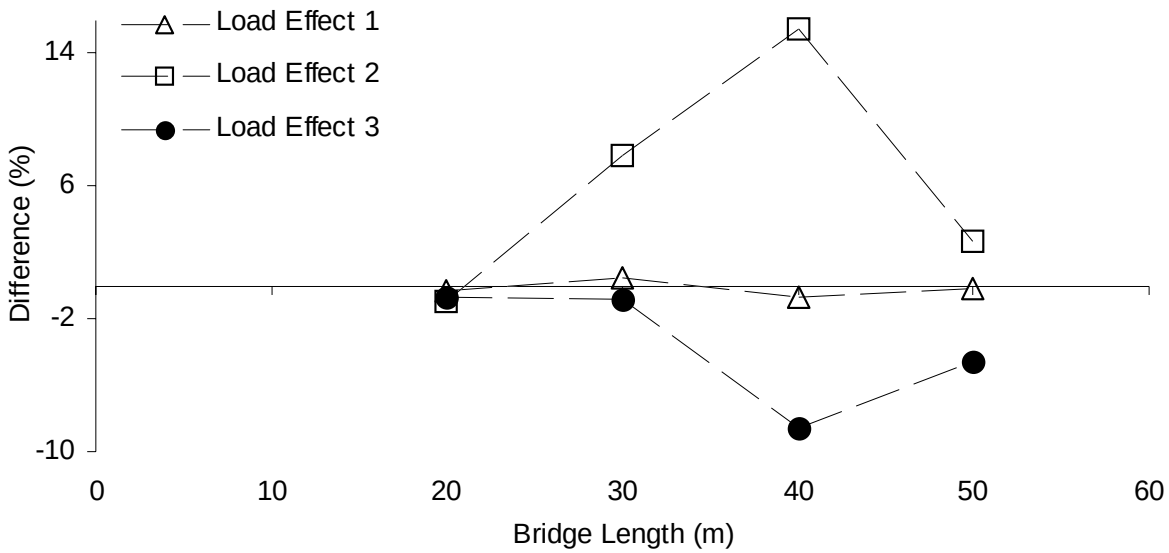
Sample Static Results

Effect of these latest improvements:



Changes in static loading of up to 14%

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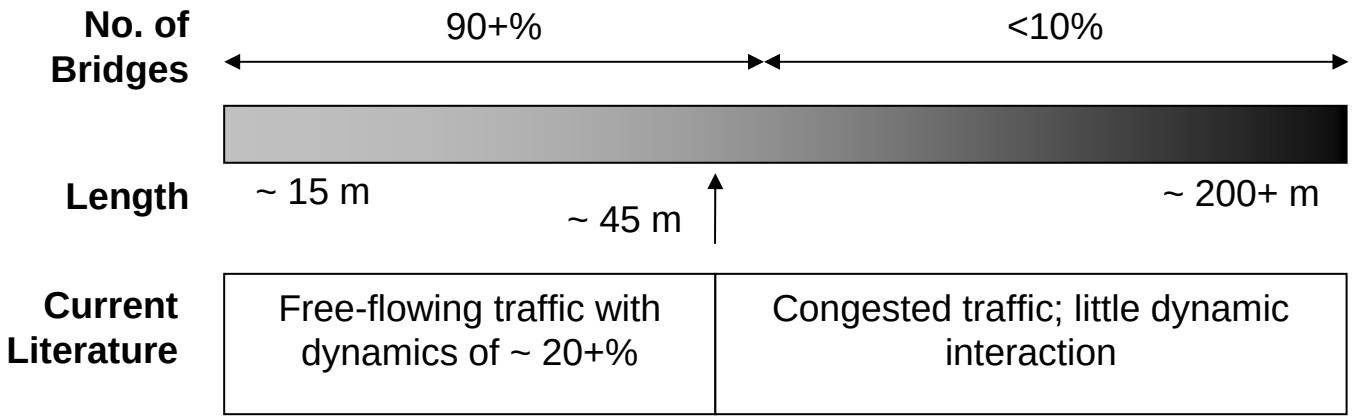
Governing Loading Scenarios

Two loading scenarios govern a certain range of bridge lengths



Thus: it is important to quantify extreme dynamic effects…

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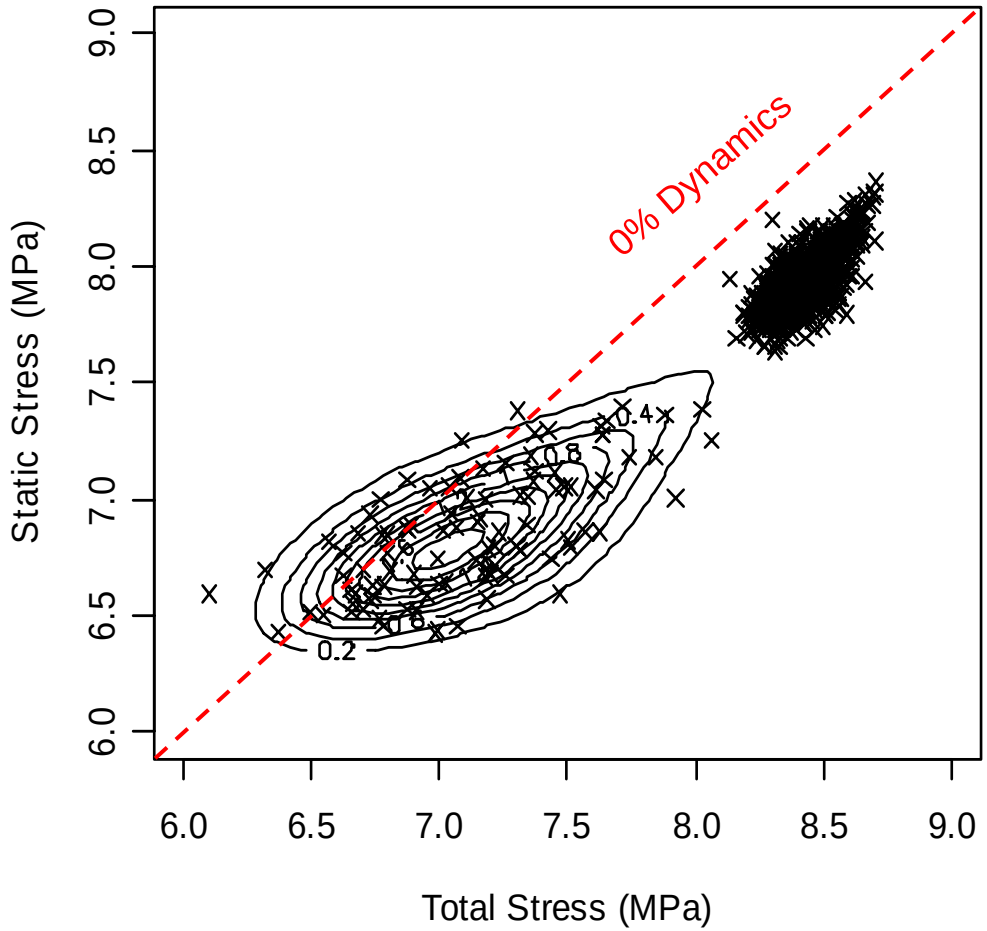
Allowing for Dynamics - I



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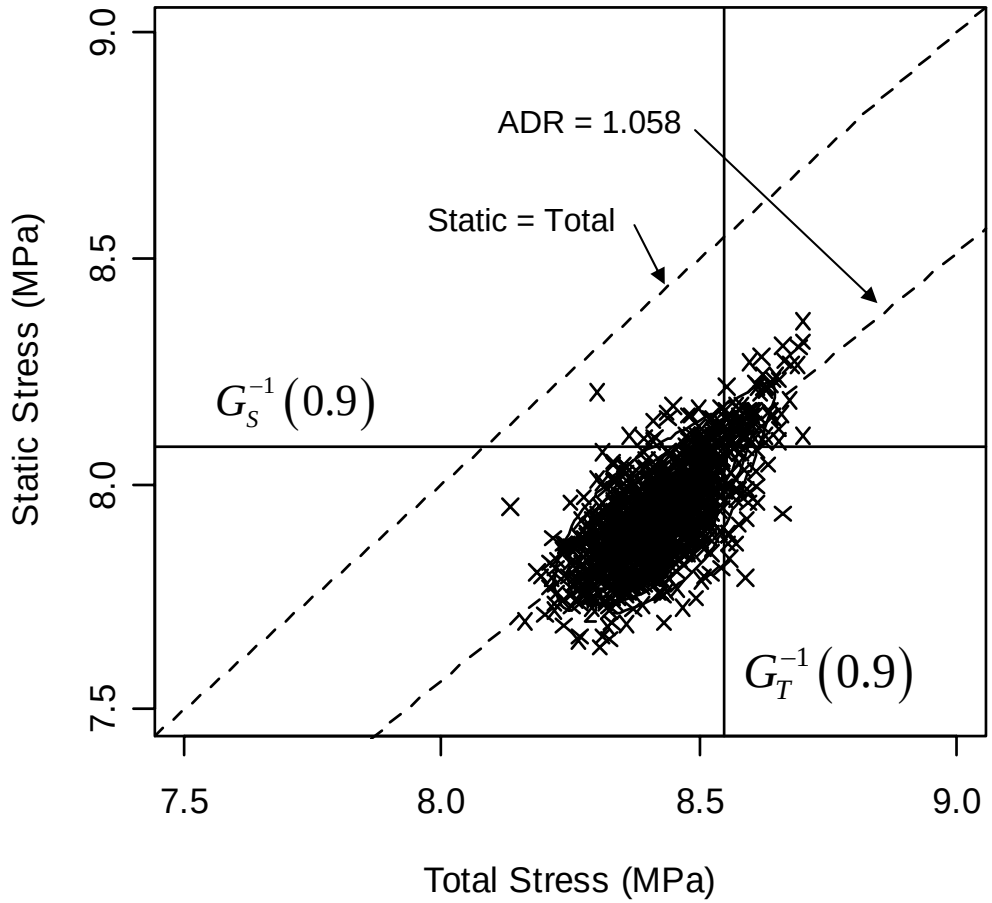
Allowing for Dynamics - II



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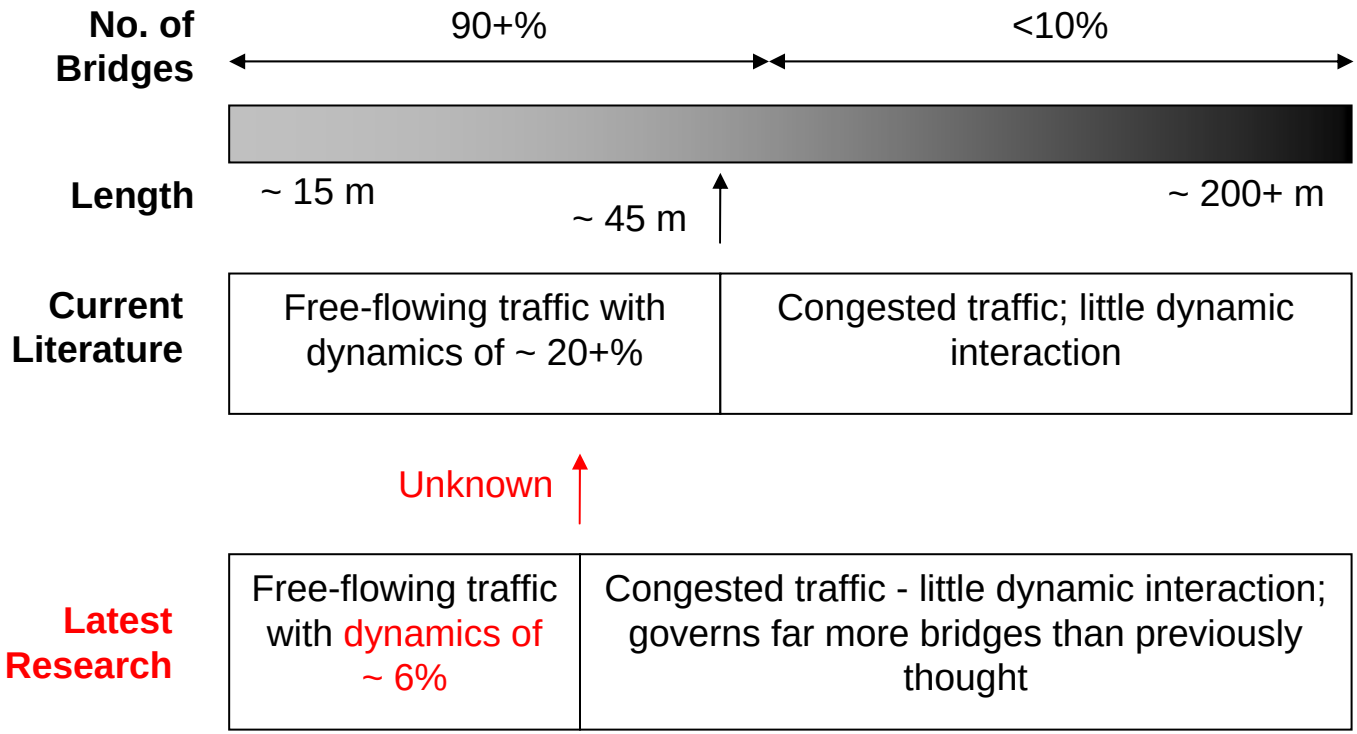
Effect of Result

This latest finding greatly affects the current assumptions:



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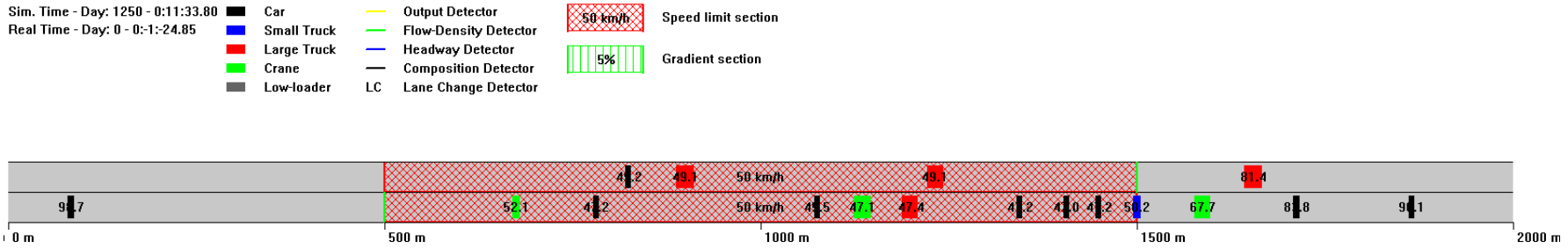
Congestion Modelling I

Use the Monte Carlo generated traffic

with the Treiber IDM traffic microsimulation model…



We can compare congested and free-flowing microsimulation results

to Standard Free-flow and Congestion Models…

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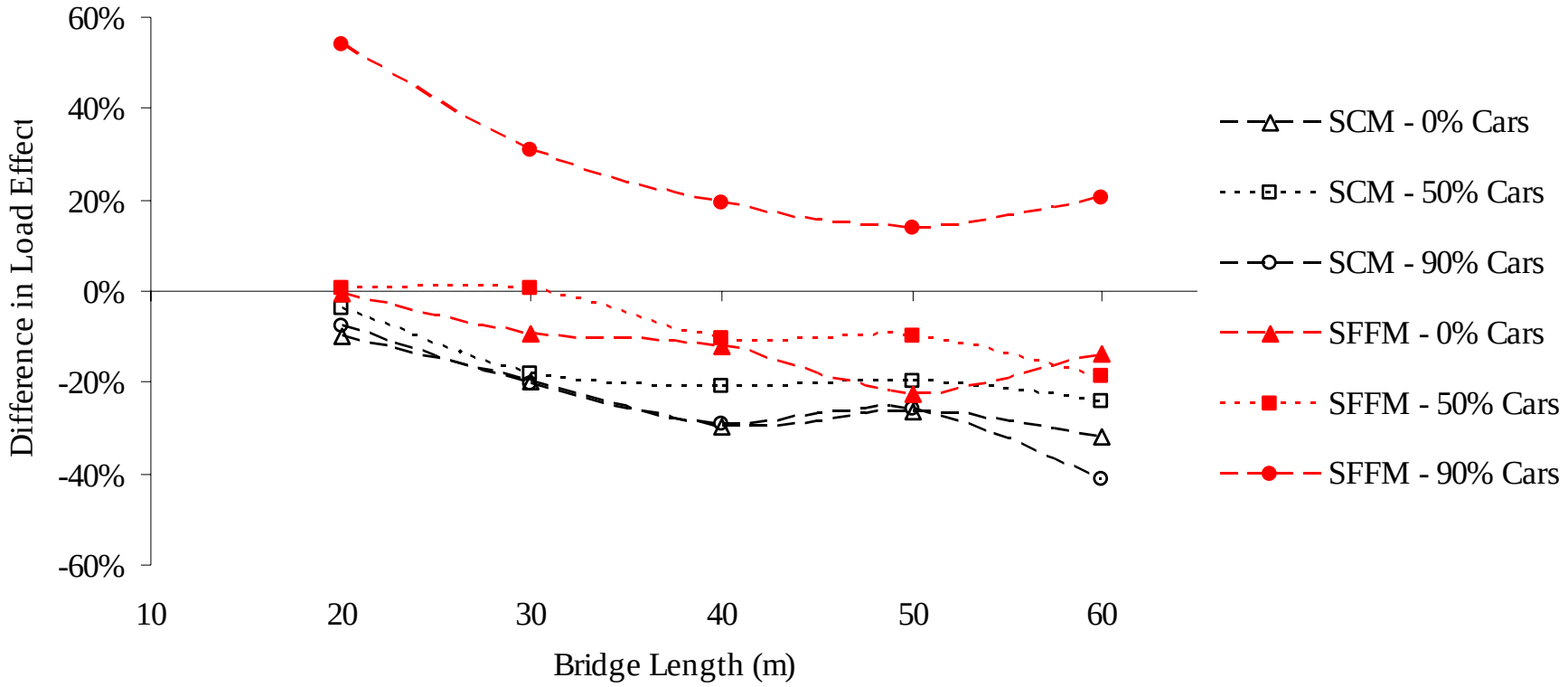
Congestion Modelling II



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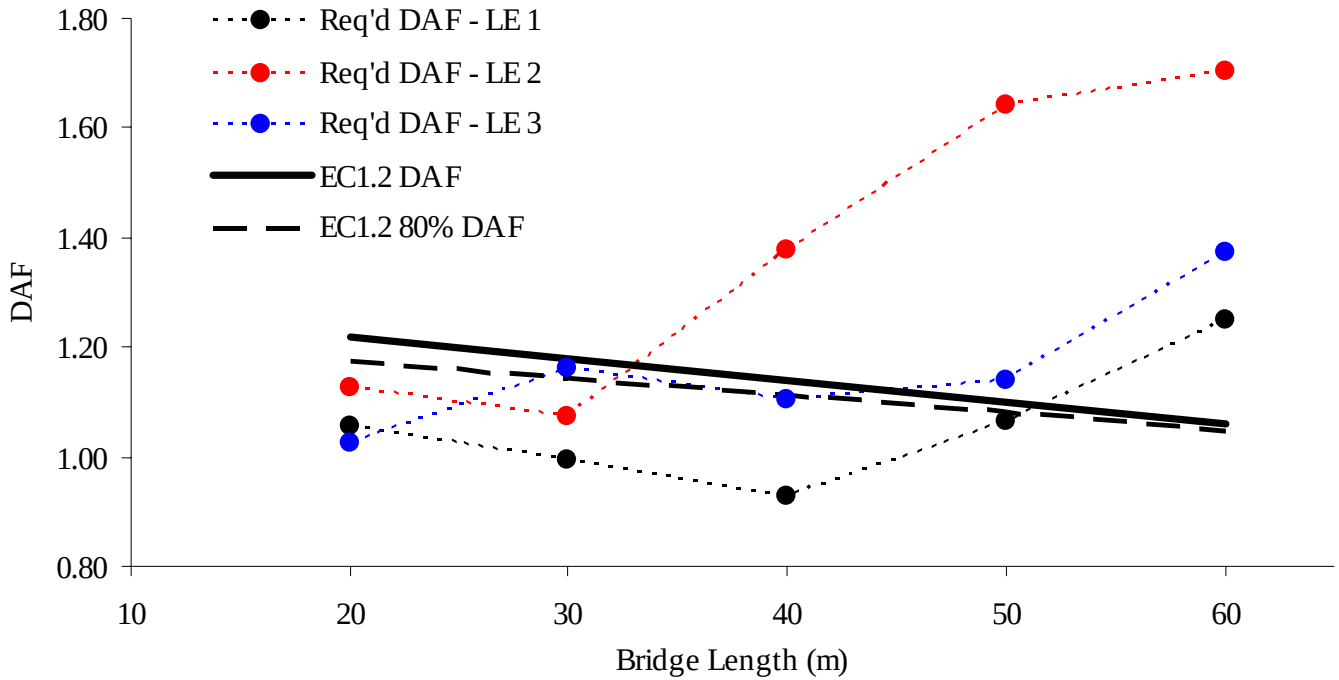
Governing Form of Traffic

Using: Required DAF = Congested Model LE / Free-flow Model LE



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Conclusions

The governing form of traffic is sensitive to DAF

⇨A bridge lifetime DAF is more suitable than the current approach

Statistical methods can greatly improve loading estimates

⇨ More improved forms of analysis must be employed

The assumed governing loading scenarios are not certain

⇨A calibrated microsimulation model helps to solve this

Acknowledgments

The authors gratefully acknowledge the co-operation of the *Laboratoire Central des Ponts et Chausées*, Paris for WIM data and supporting development of the microsimulation model.