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Dublin Institute of Technology & University College Dublin

Civil Structural Health Monitoring 2

28 September – 1 October 2008,

Taormina, Sicily

Recent Advances in the Governing Form of Traffic for Bridge Loading

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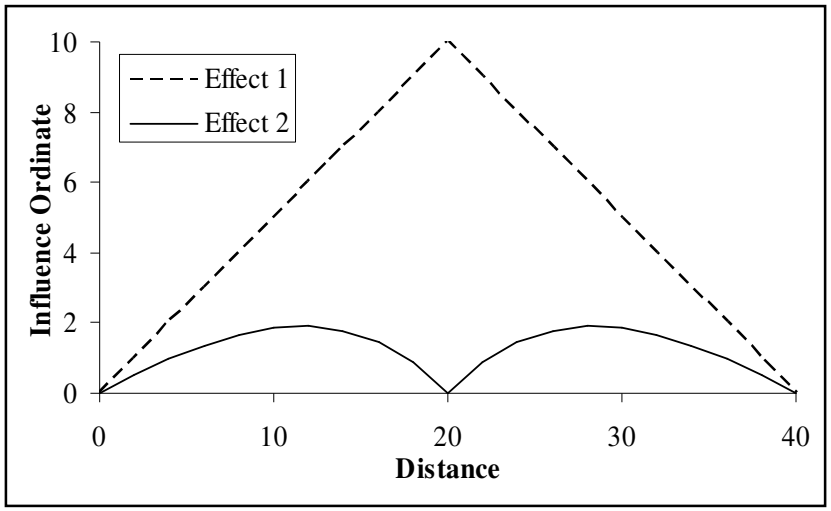
Basis of Research

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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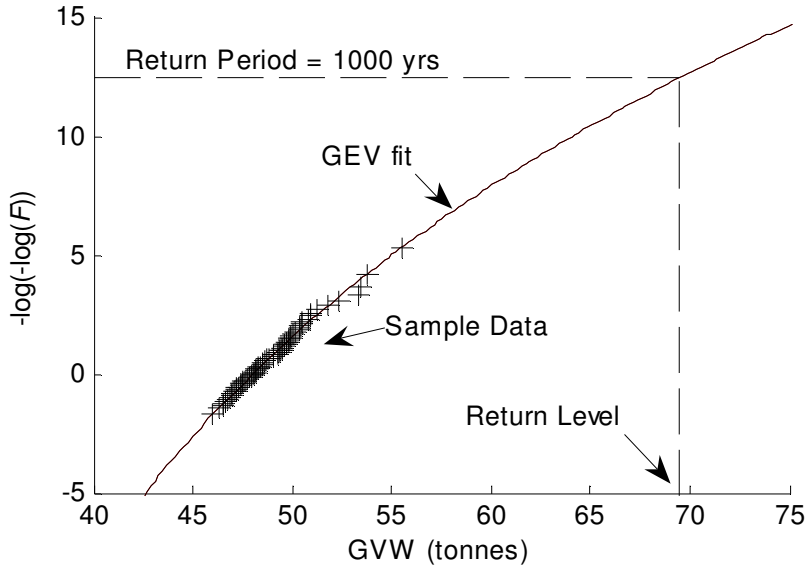
Standard Statistical Analysis

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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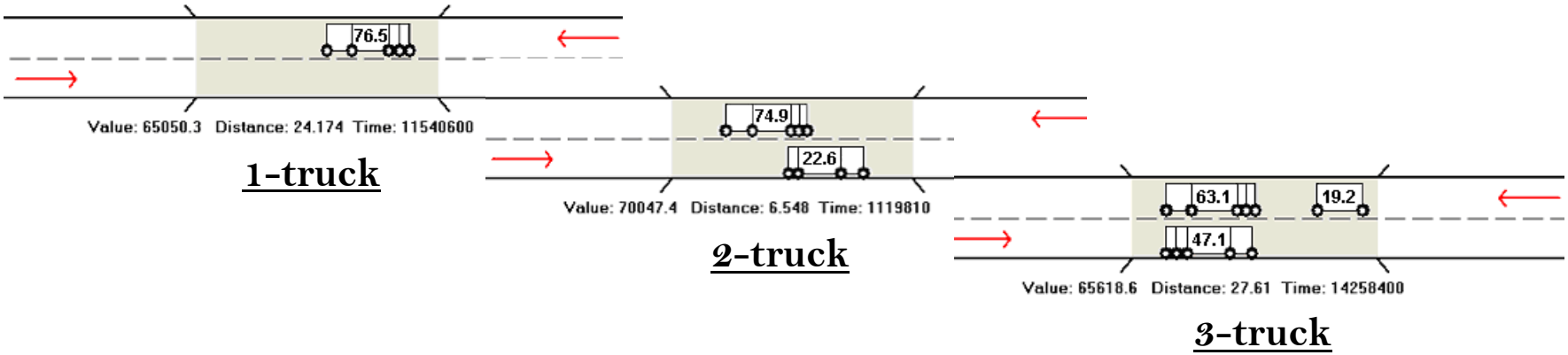
Latest Statistical Analysis - I

In bridge traffic loading, different events occur:



These loading events have different statistical distributions…

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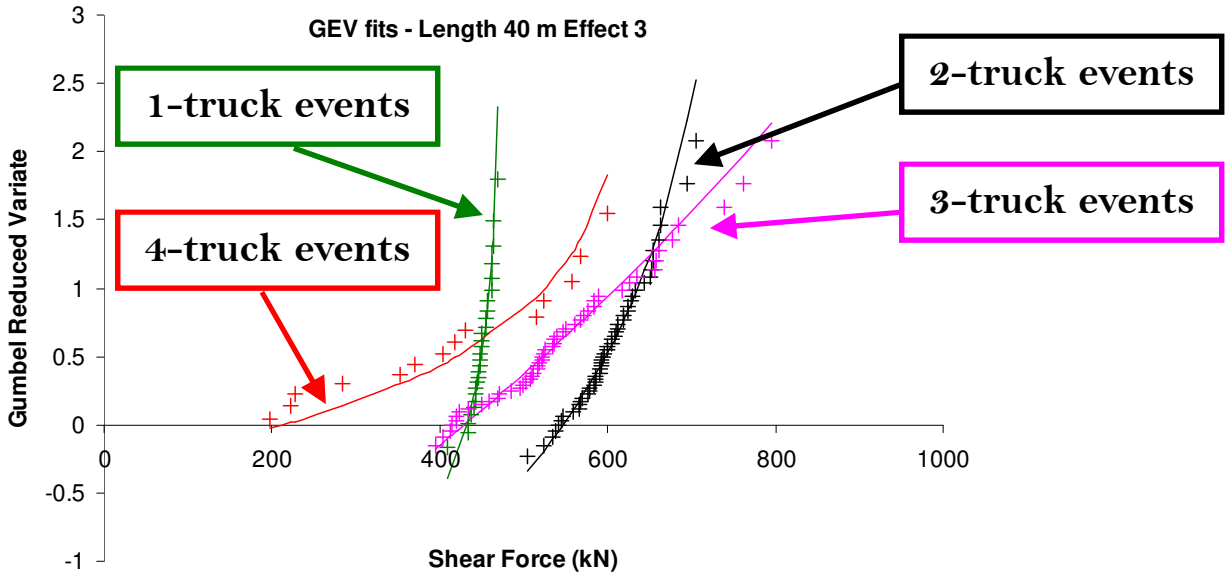
Latest Statistical Analysis - II



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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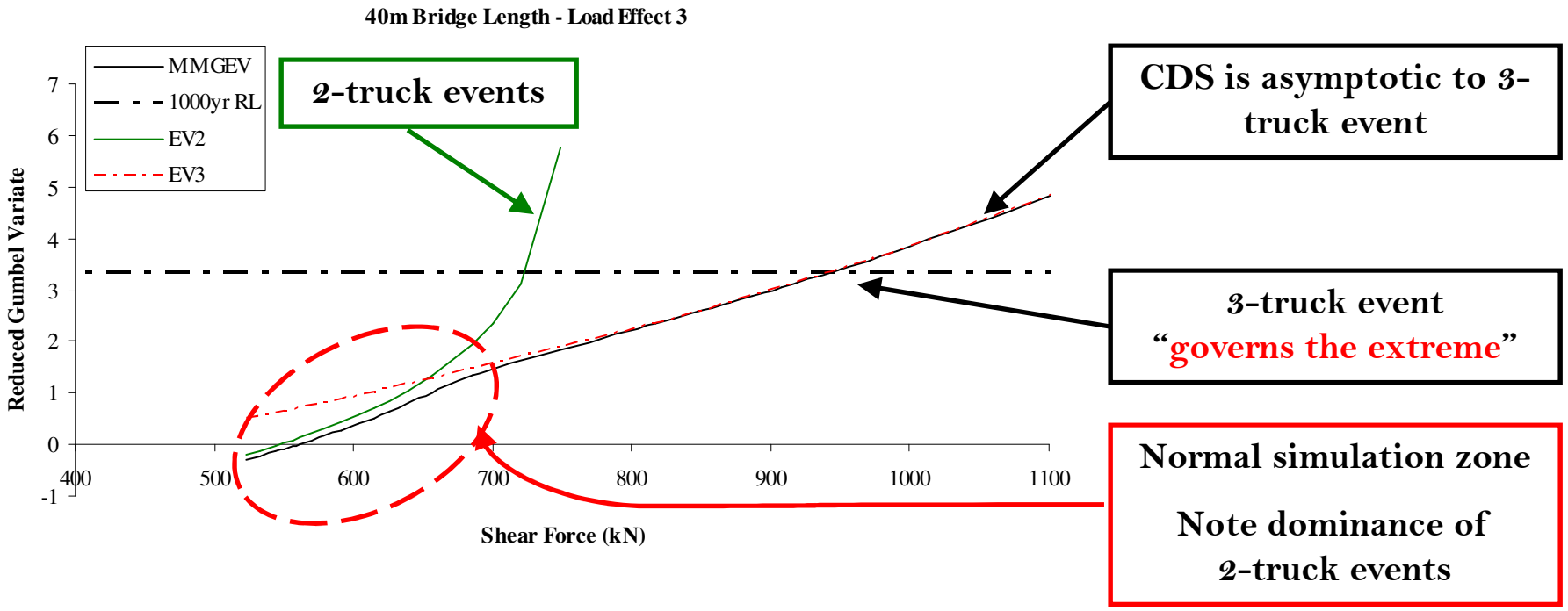
Latest Statistical Analysis - III

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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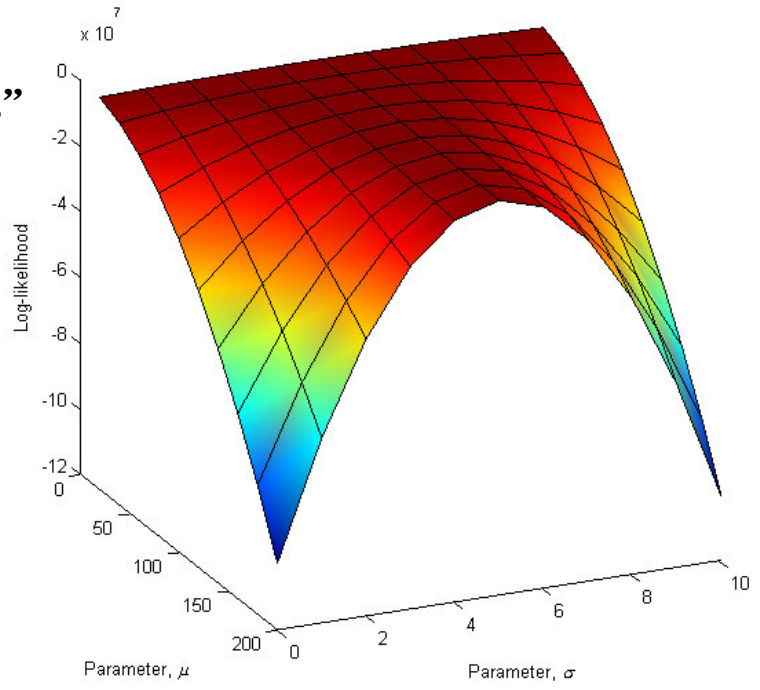
Problems

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'

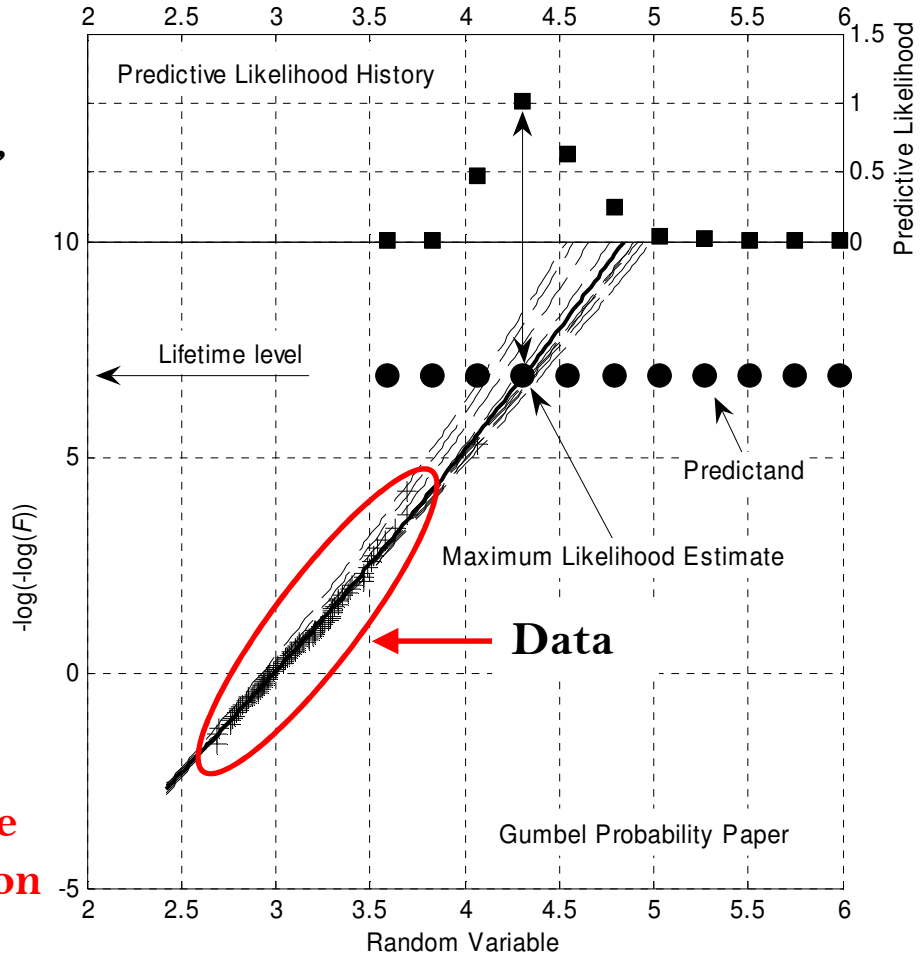
the predictive likelihood function is evaluated for each

A distribution of PL values results

The predictive likelihood function:

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

Best fit of known data & possible prediction



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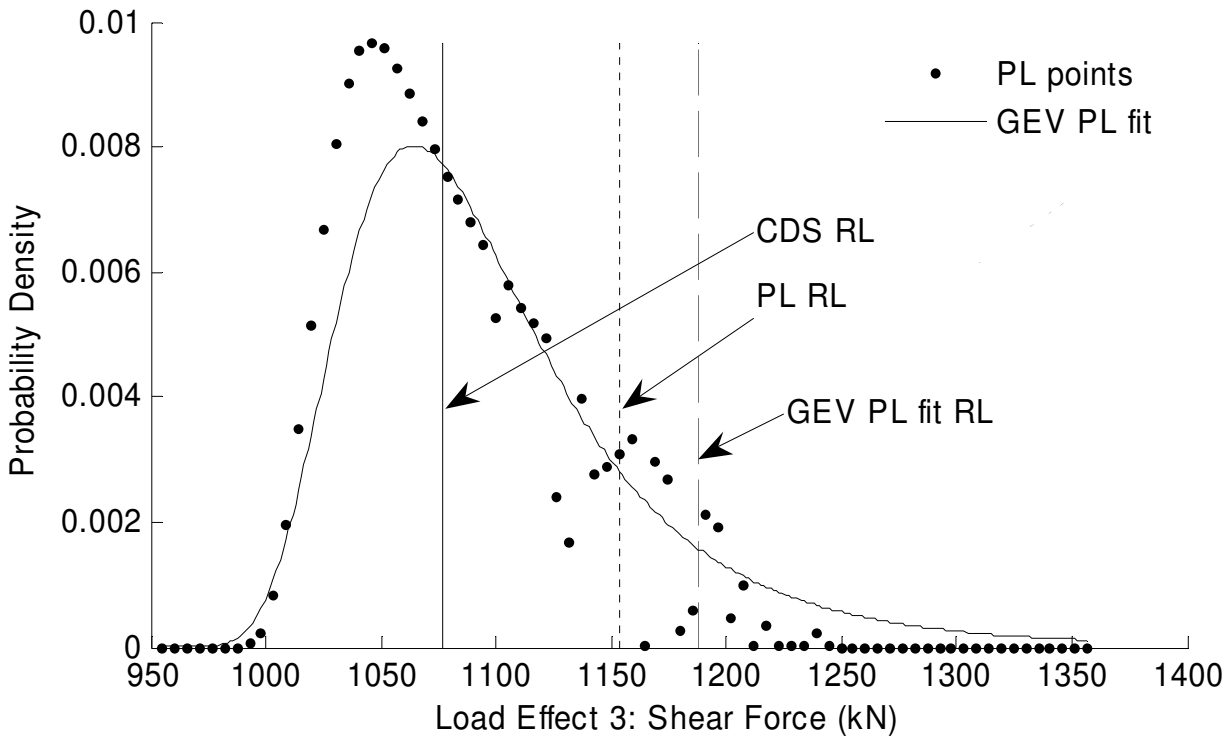
Sample Results - Load Effect 3, 40 m bridge length



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

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

Significantly **different** answer to standard analysis

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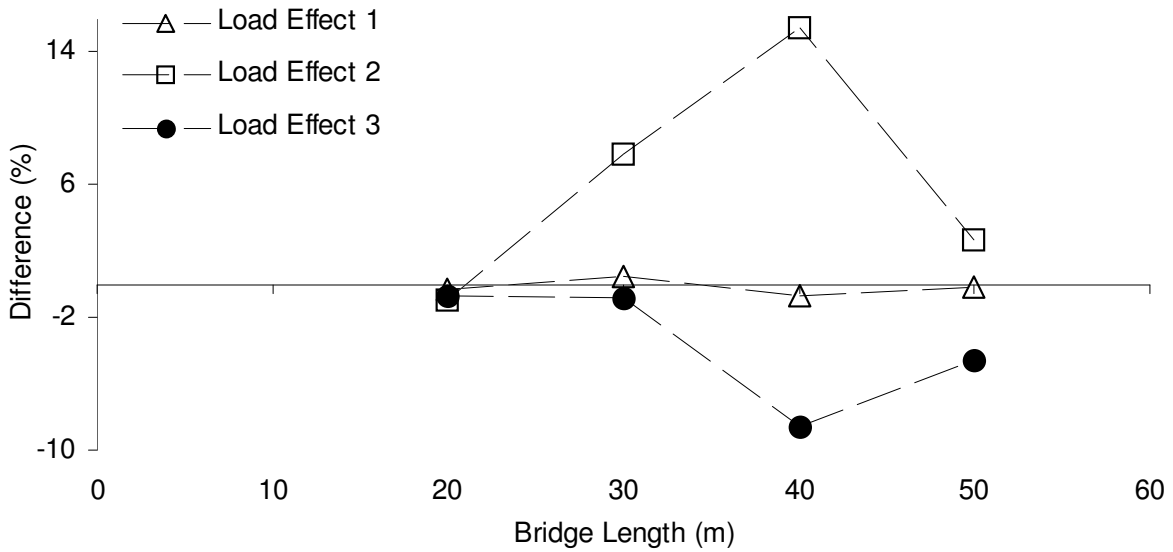
Sample Static Results

Effect of these latest improvements:



Changes in static loading of up to 14%

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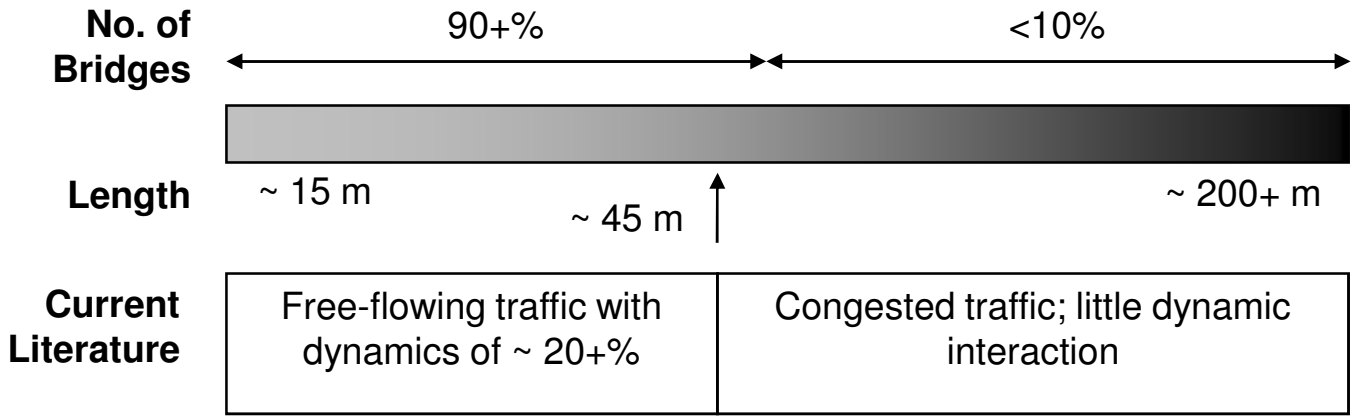
Governing Loading Scenarios

Two loading scenarios govern a certain range of bridge lengths



Thus: it is important to quantify extreme dynamic effects…

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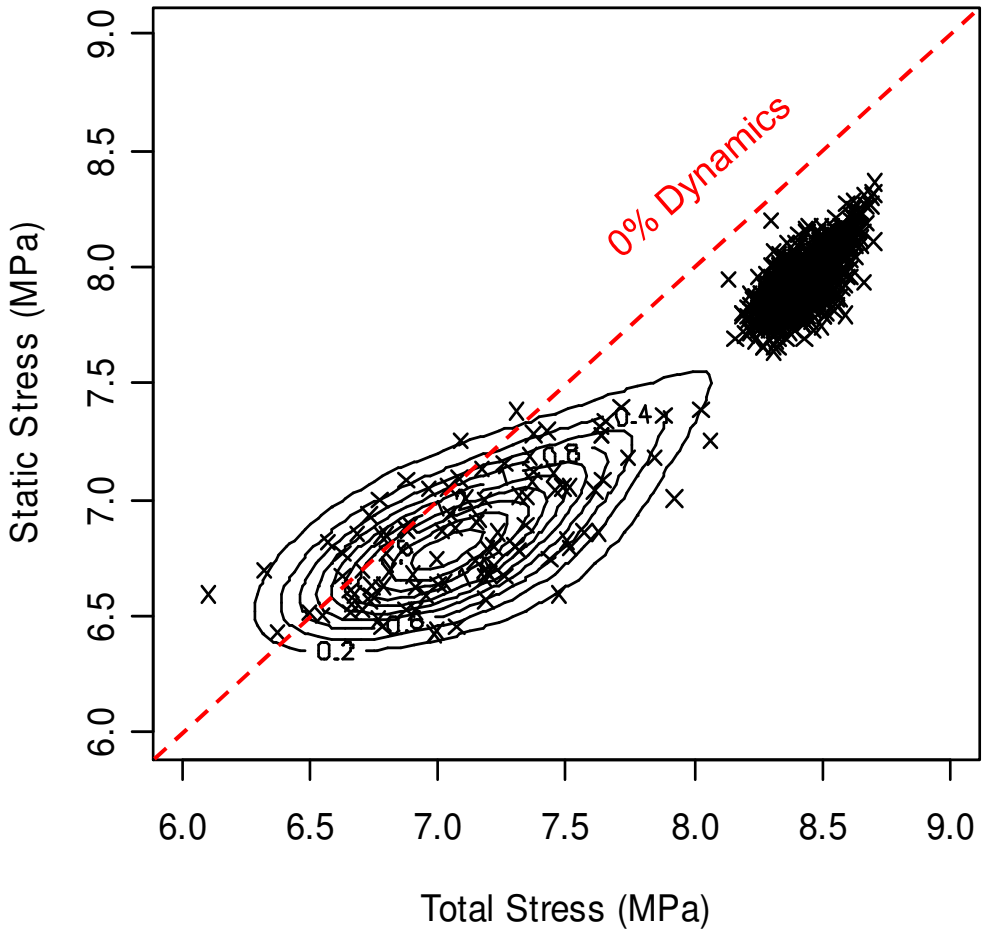
Allowing for Dynamics - I



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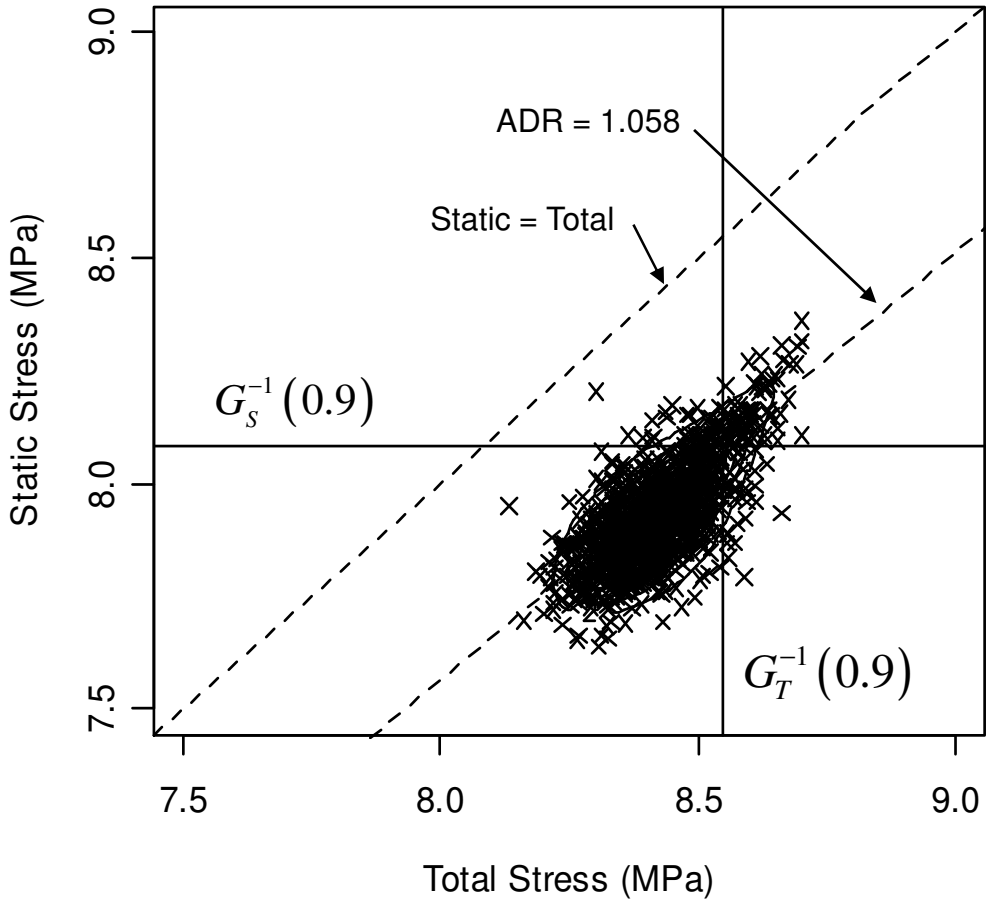
Allowing for Dynamics - II



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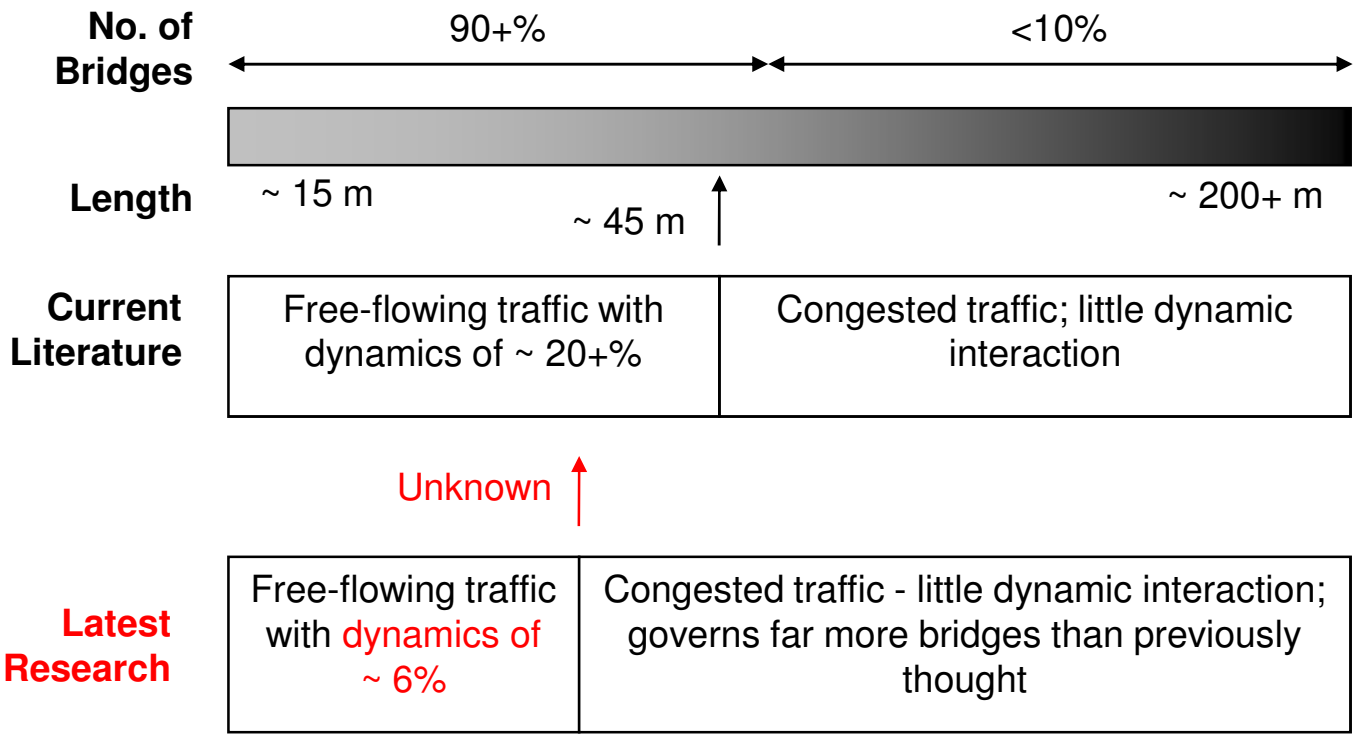
Effect of Result

This latest finding greatly affects the current assumptions:



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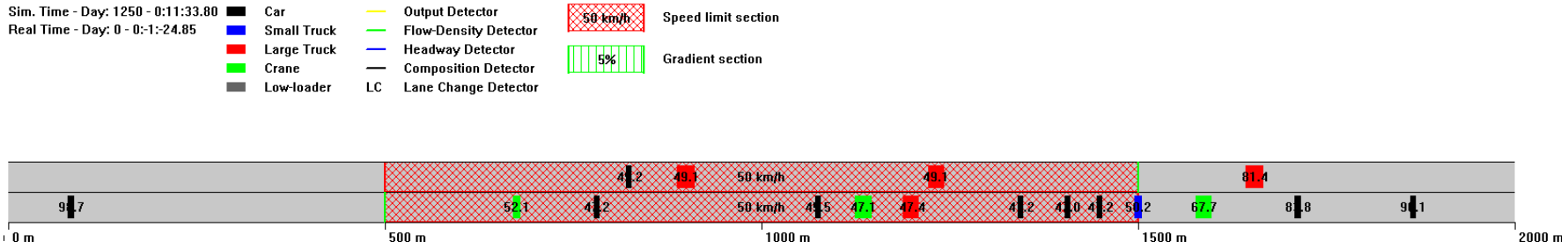
Congestion Modelling I

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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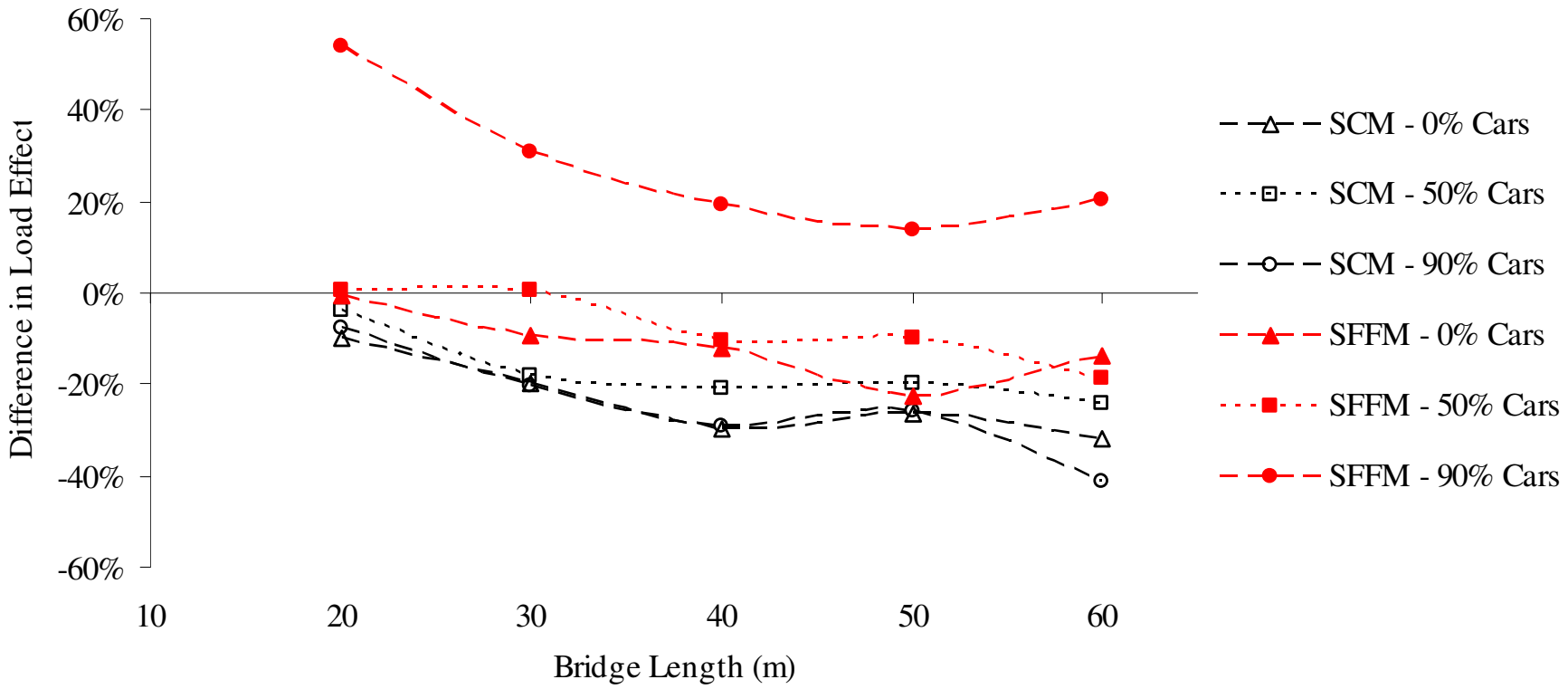
Congestion Modelling II



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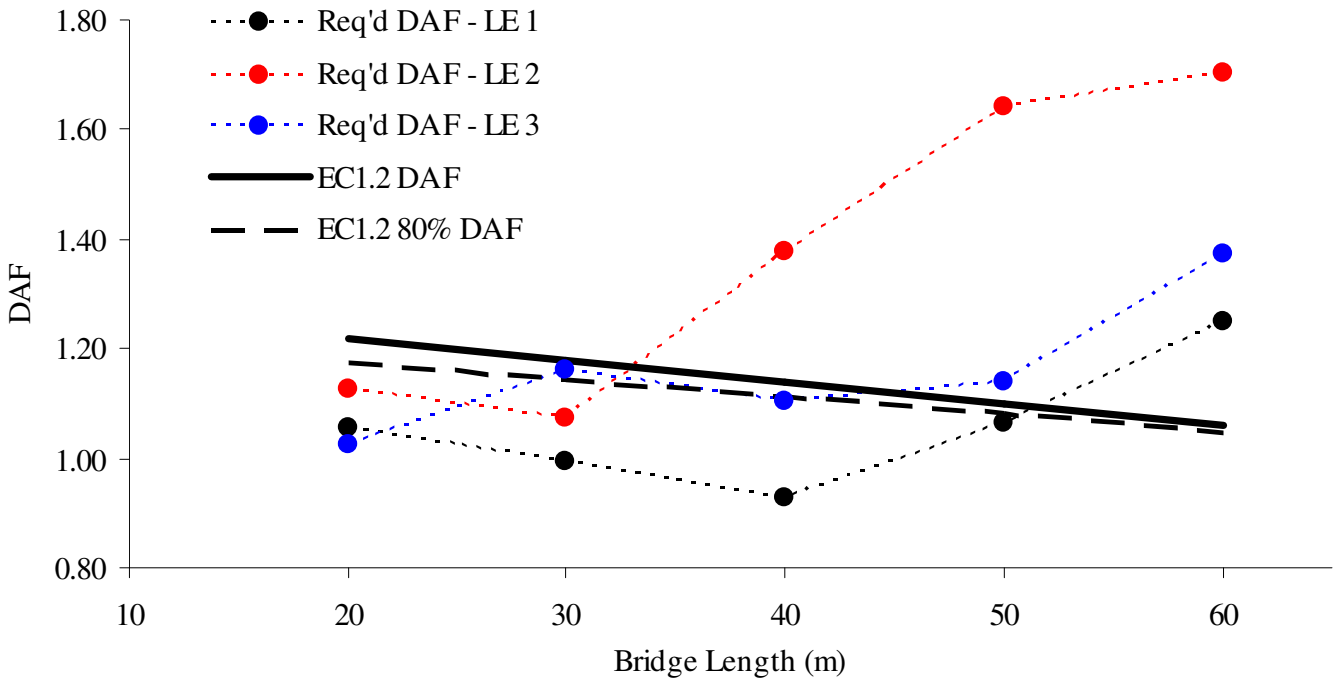
Governing Form of Traffic

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.

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