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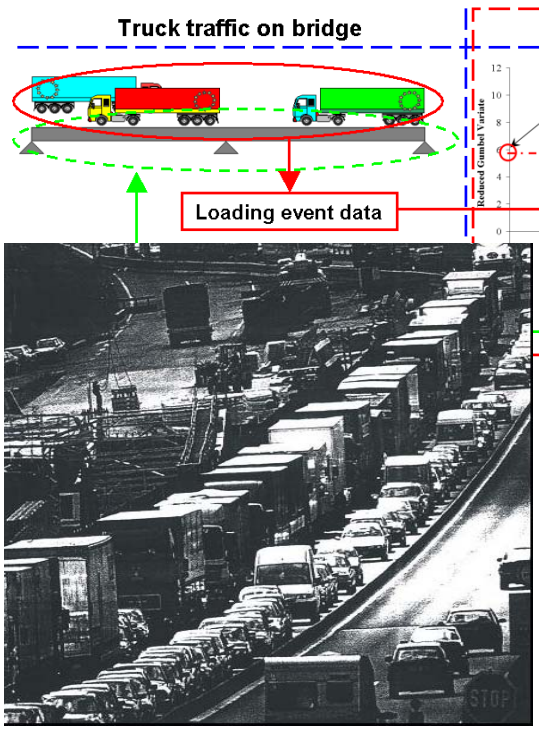

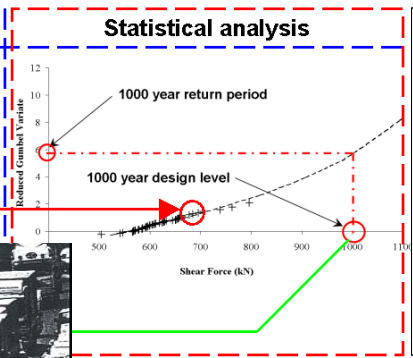

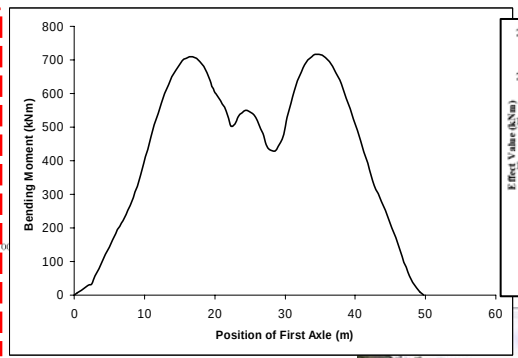

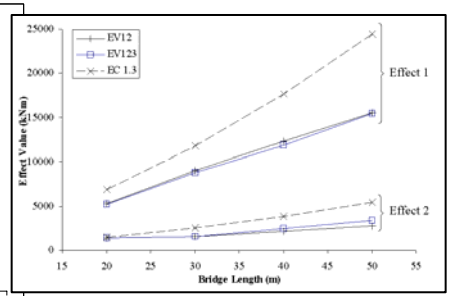

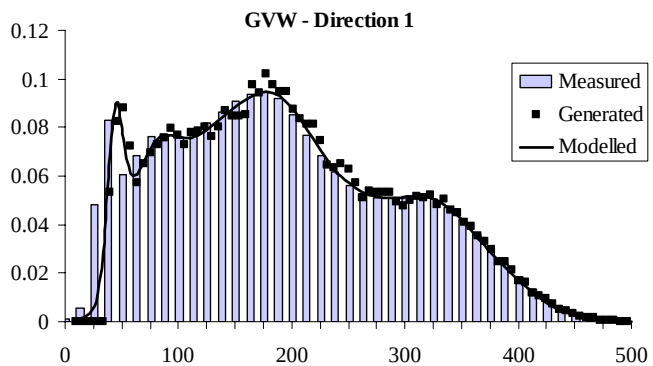

Probabalistic Analysis of Highway Bridge Loading Events

Probabalistic Analysis of Highway Bridge Loading Events

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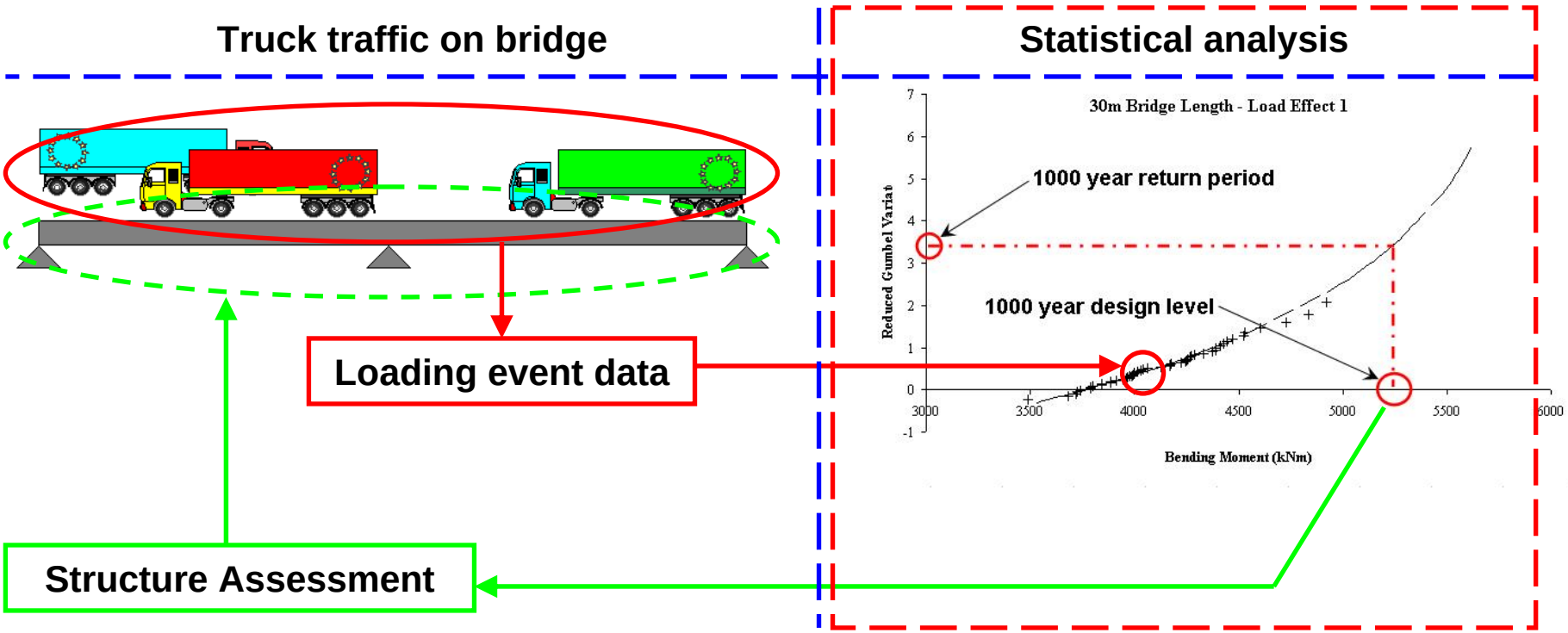
Flow chart description of project & primary application

Represents this project's area of interest



Traffic is generated using Monte Carlo simulation from Weigh-In-Motion data

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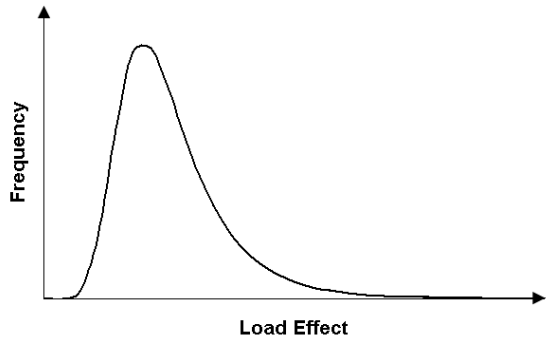
Statistical Analysis:

- The load effects noted each day form a statistical distribution
- The maximum load effect of each day form another distribution
    - these effects meet stationarity requirements (only daily cyclical variations are taken into account)
    - thus they are of an extreme value distribution form
- When plotted, the maximum daily load effect values should conform to the Generalized Extreme Value distribution

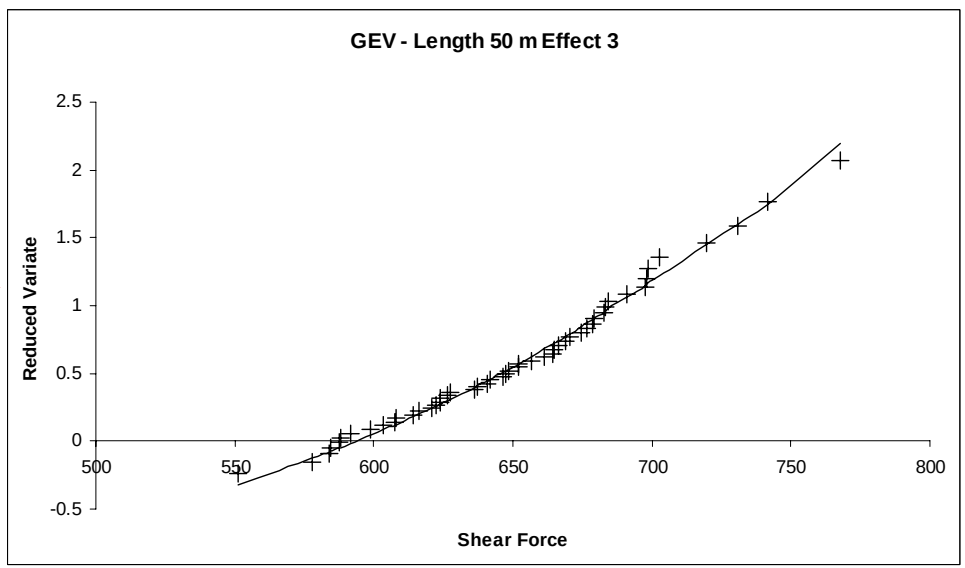


$$G(z) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

- Each event must also be independent and identically distributed (iid)
- This means that the same statistical mechanism generated all the events

Data & GEV plotted on Gumbel probability paper

Note: Reasonable fit



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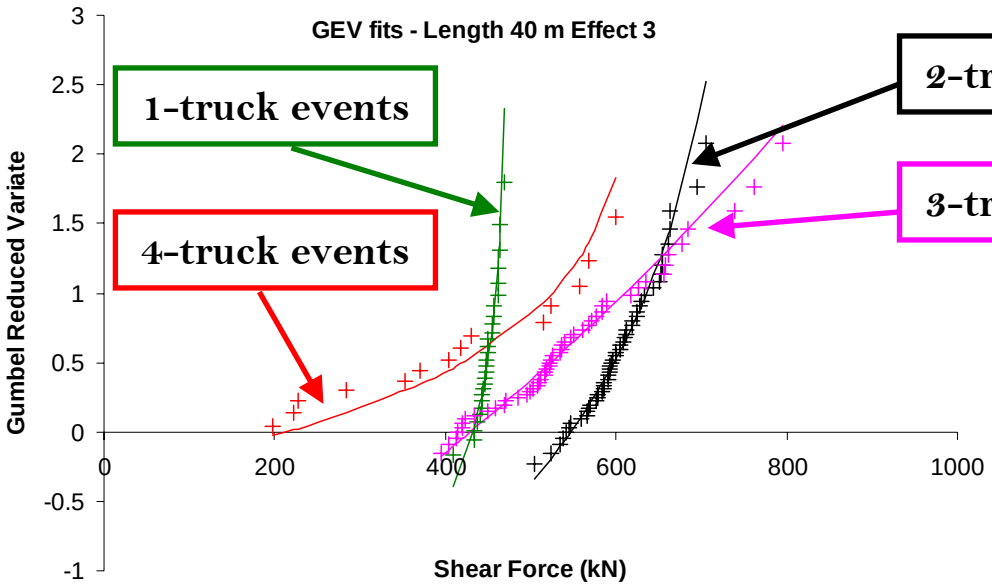
Further Statistical Analysis:

- Subsequent examination revealed the iid assumtion to be incorrect

- Truck event statistics depends on the number of trucks comprising the event:



Note that if the iid assumtion were correct, these plots would be all the same – clearly not so

Thus a new type of analysis was required…

Literature reviews of the statistical analysis of extreme wind speeds revealed similarites:

- 2-truck events ∝ thunderstorms
- 3-truck events ∝ hurricanes

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Mixed Mechanism Statistics:

The theory of Gomes & Vickery for extreme wind speeds in mixed climates was adopted:

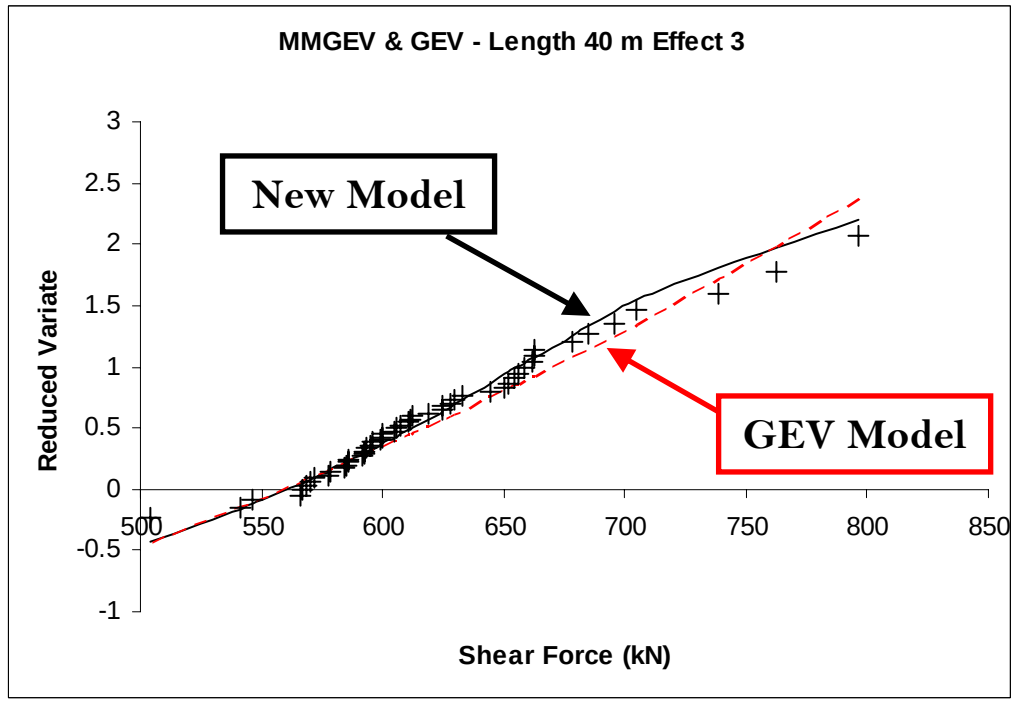
$$MMG(z) = \prod_{i=1}^{n} G_i(z) = \exp[-f(z)]$$

$$f(z) = \sum_{i=1}^{n} \left[1 + \xi_i \left(\frac{z - \mu_i}{\sigma_i} \right) \right]^{-1/\xi_i}$$

Thus each event-type is analysed seperately & then combined for the compostite distribution

The iid assumption is now met

Note also the double curvature of the new model which tends to fit the data better



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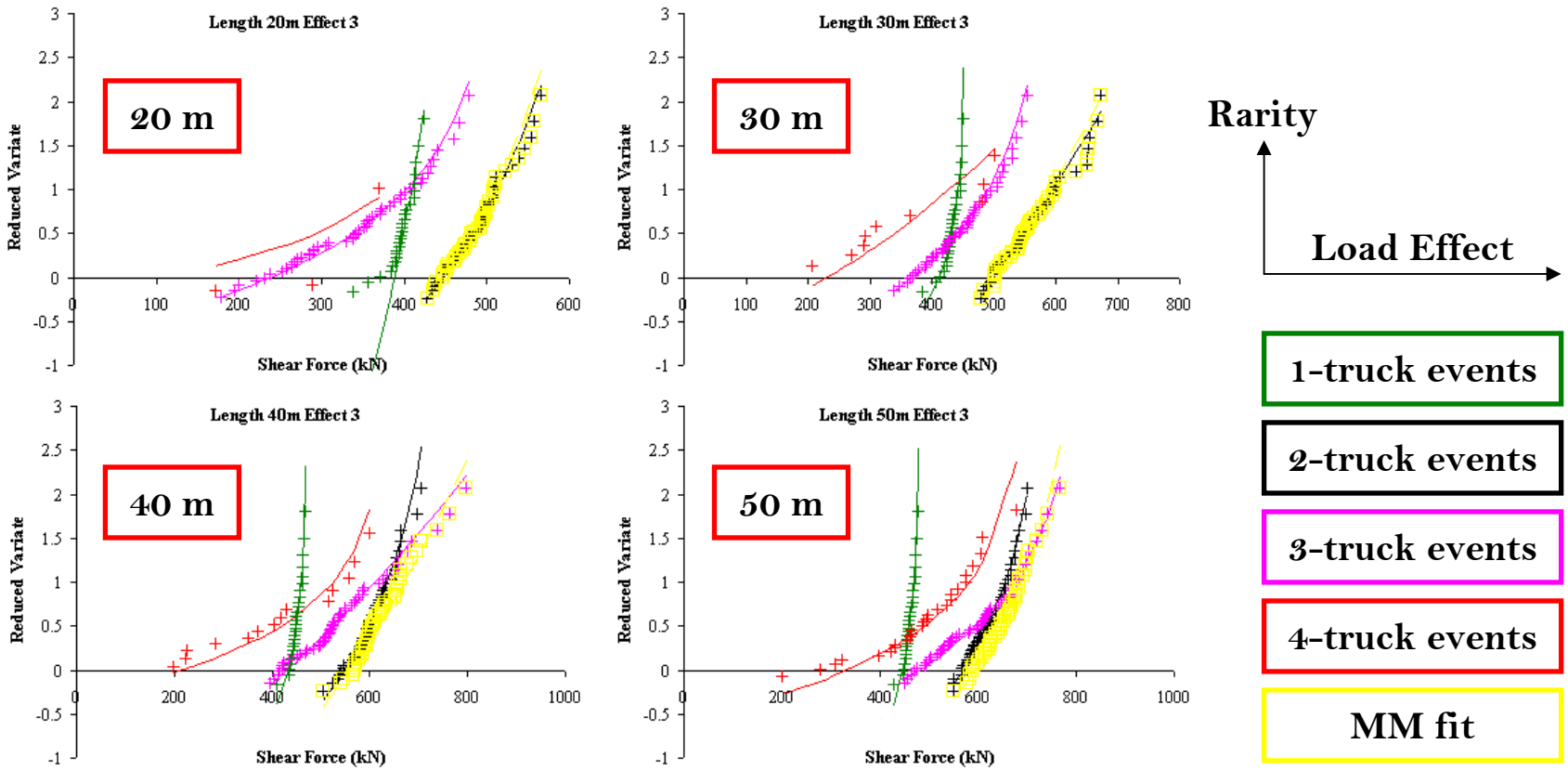
Mixed Mechanism Statistics:

Sample graphs are given below

- Note 3-truck events become important as the bridge length increases

- Single and 4-truck events are not evidently critical



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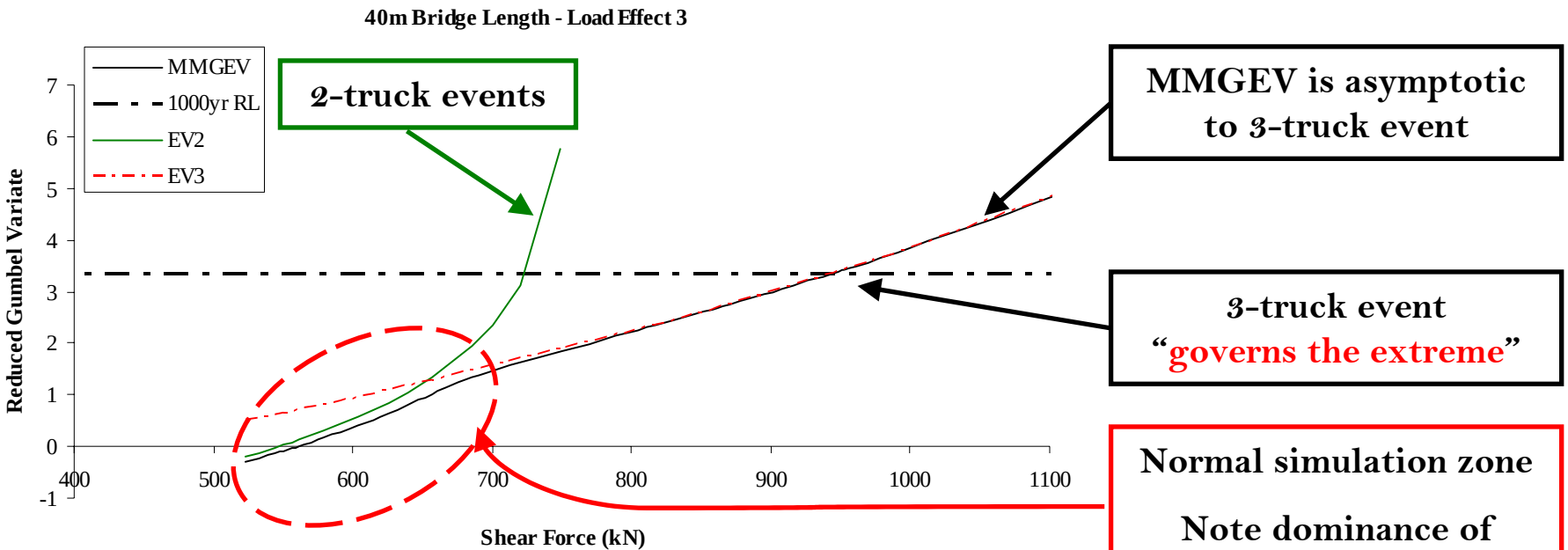
Mixed Mechanism Statistics:

Removing the data and non-essential curves for clarity & extending the axes:



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

Note that the graphs curve upwards – there is a physical limit to the load effect

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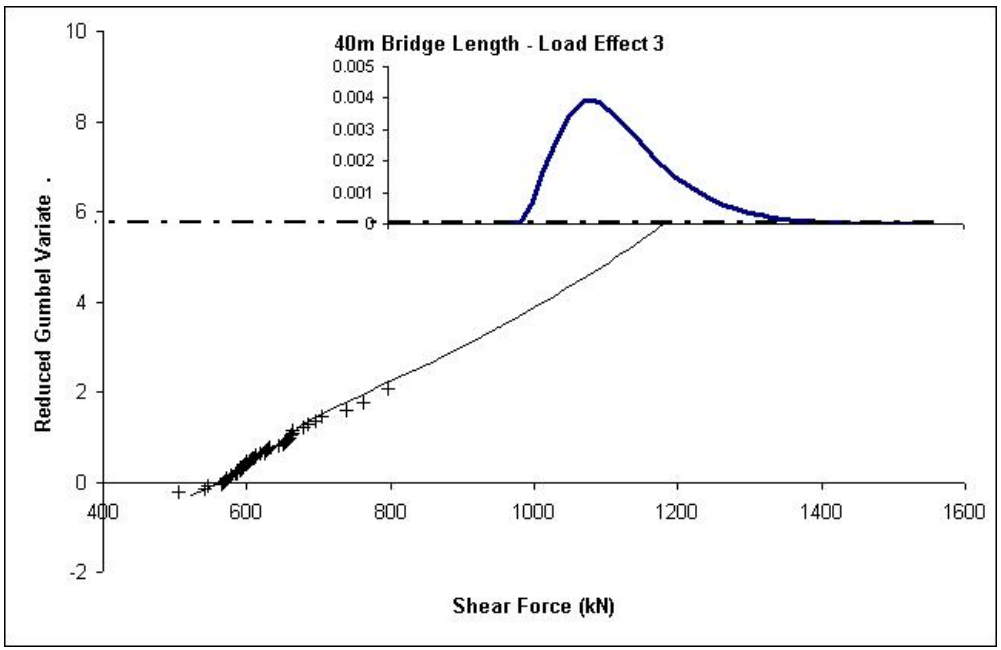
Variability of extrapolated extreme:

If the procedure was repeated we would get similar but different results

If we did this many times we could form a distribution of the characteristic value

It is usual to assume a Normal shape for this distribution



This "full" process is not required - can use an alternate method based on statistical likelihood

Predictive Likelihood can be used to obtain the distribution directly

This method assesses the "relative credibility" of one predictant against another

Variation of the parameter values as well as the inherent variation is accounted for

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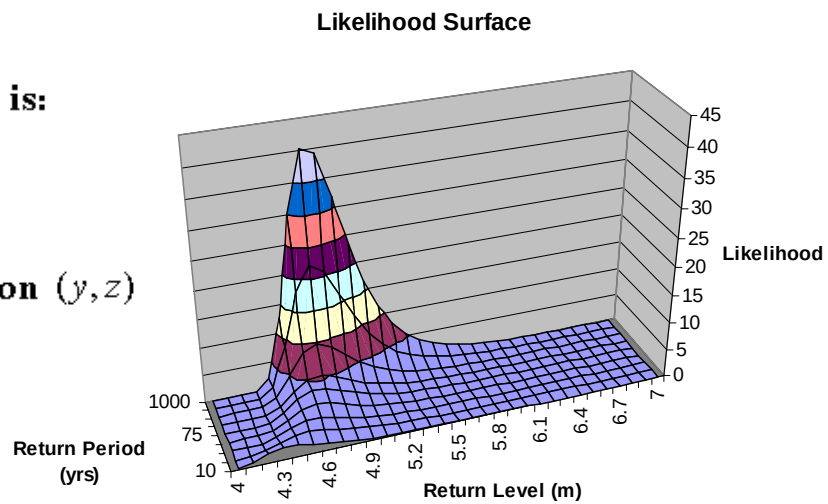
Predictive Likelihood:

The relative support of the predictand, given the data is:

$$L_p^*(z \mid y) = \frac{L_p(z \mid y)}{\sqrt{|I^z(\hat{\theta}_z)|}} \left\| \frac{\partial \hat{\theta}}{\partial \hat{\theta}_z} \right\|$$

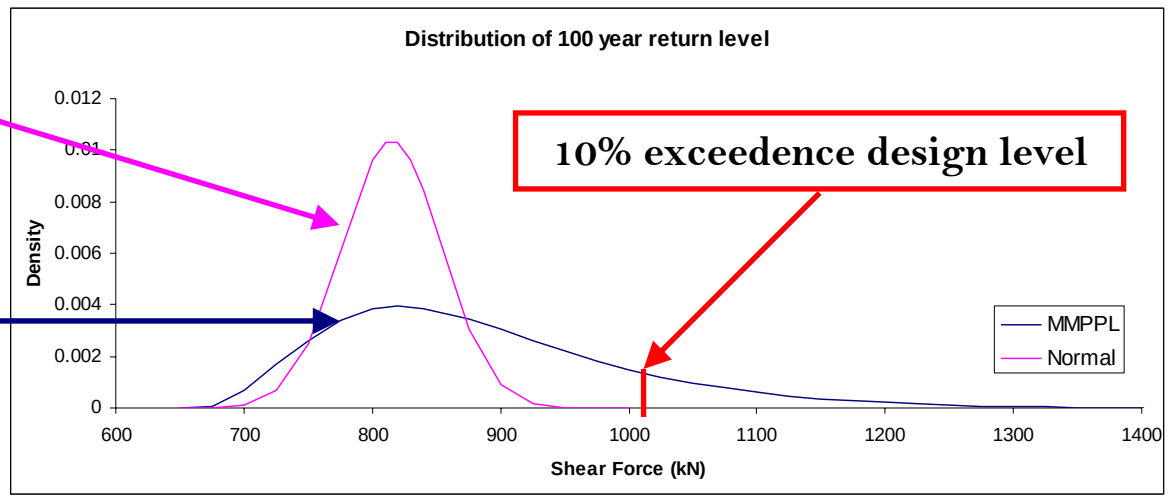
$I^z(\hat{\theta}_z)$ **is the observed information matrix of** L_p **based on** (y, z)

$$L_p(z \mid y) = k(y) \sup_\theta f(y;\theta) g(z;\theta)$$



Normal Approximation via "delta method"

Mixed Mechanism Profile Predictive Likelihood – highly skewed



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Importance of Assumed Headway:

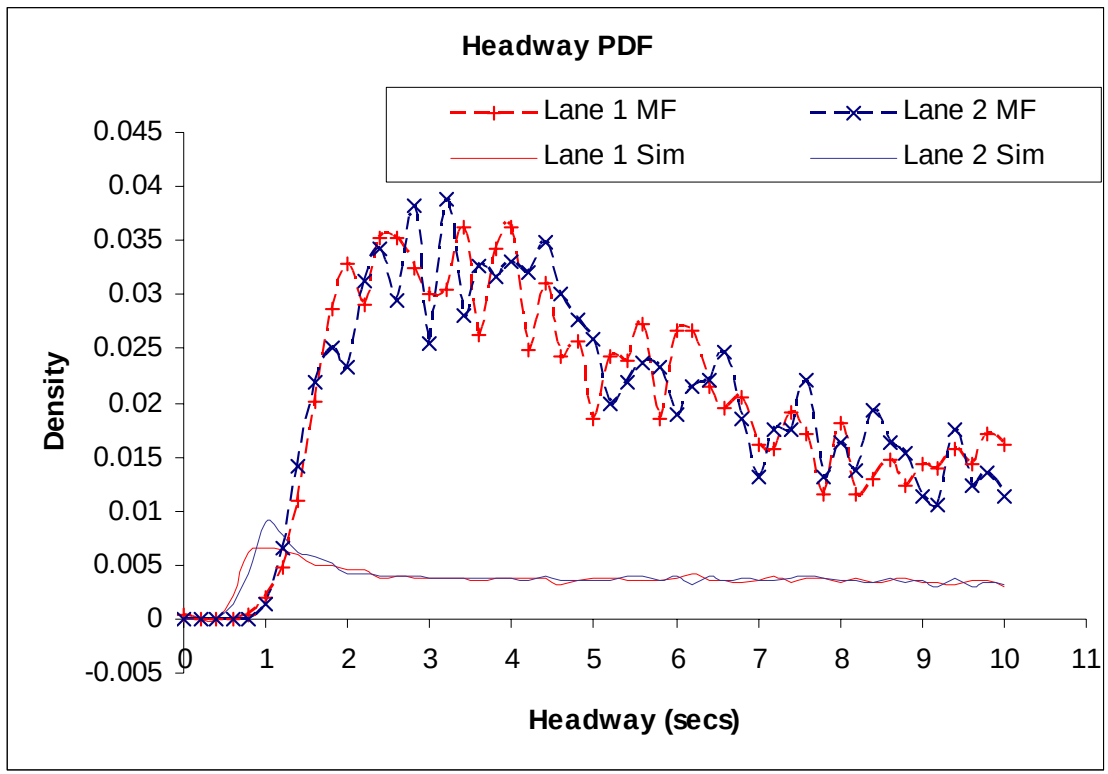
The results presented are based on a 5 m assumed minimum headway

2% (approx) of trucks need to be modified to meet this 5 m criterion

These time-modified trucks in turn comprise 43% (approx) of the trucks involved in the Significant Crossing Events (SCE)

The simulated & measured headways also display significant differences:

More accurate modelling of the headway is thus critical



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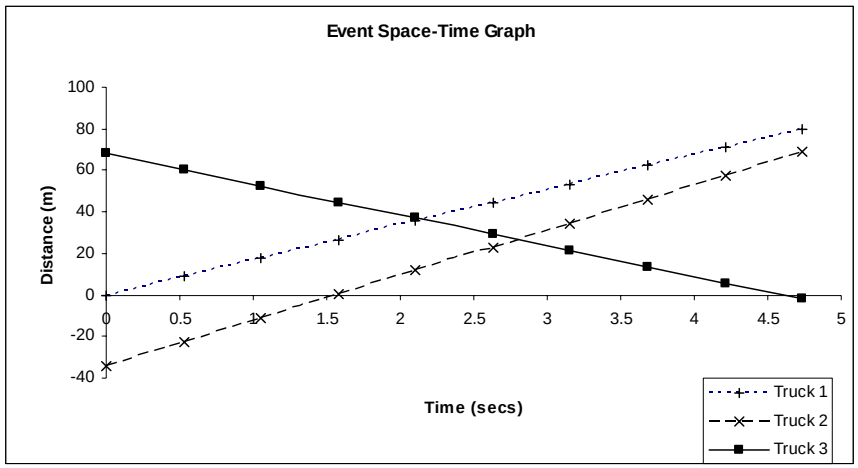
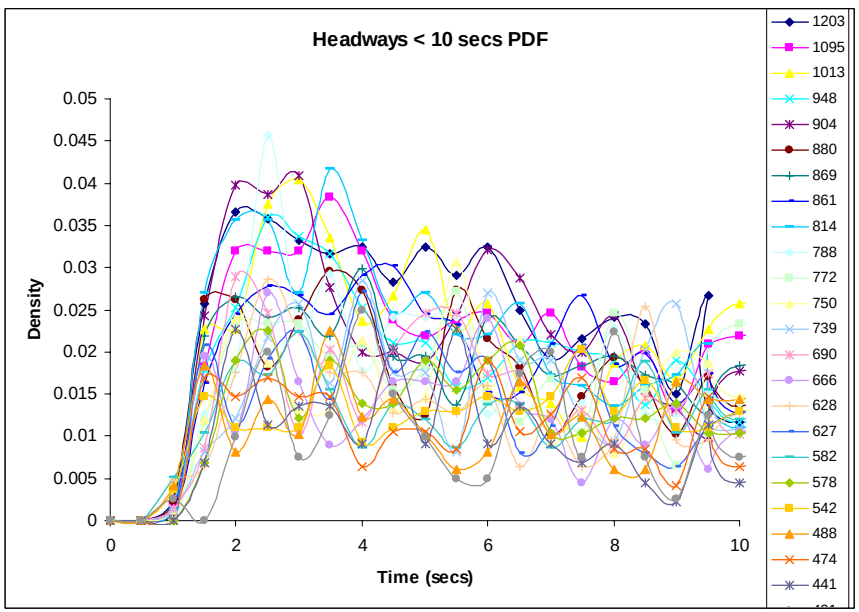
Modelling of Measured Headways:

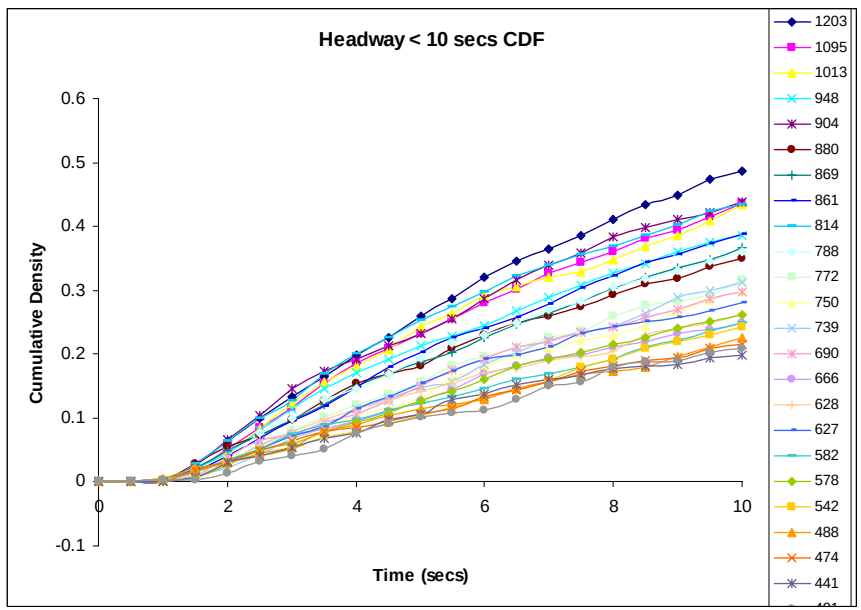


Space-Time graphs of SCE's show events normally take about 4.5secs

Thus improve accuracy of headway modelling up to 10 secs

The distribution of headways < 10 secs depends on flowrate





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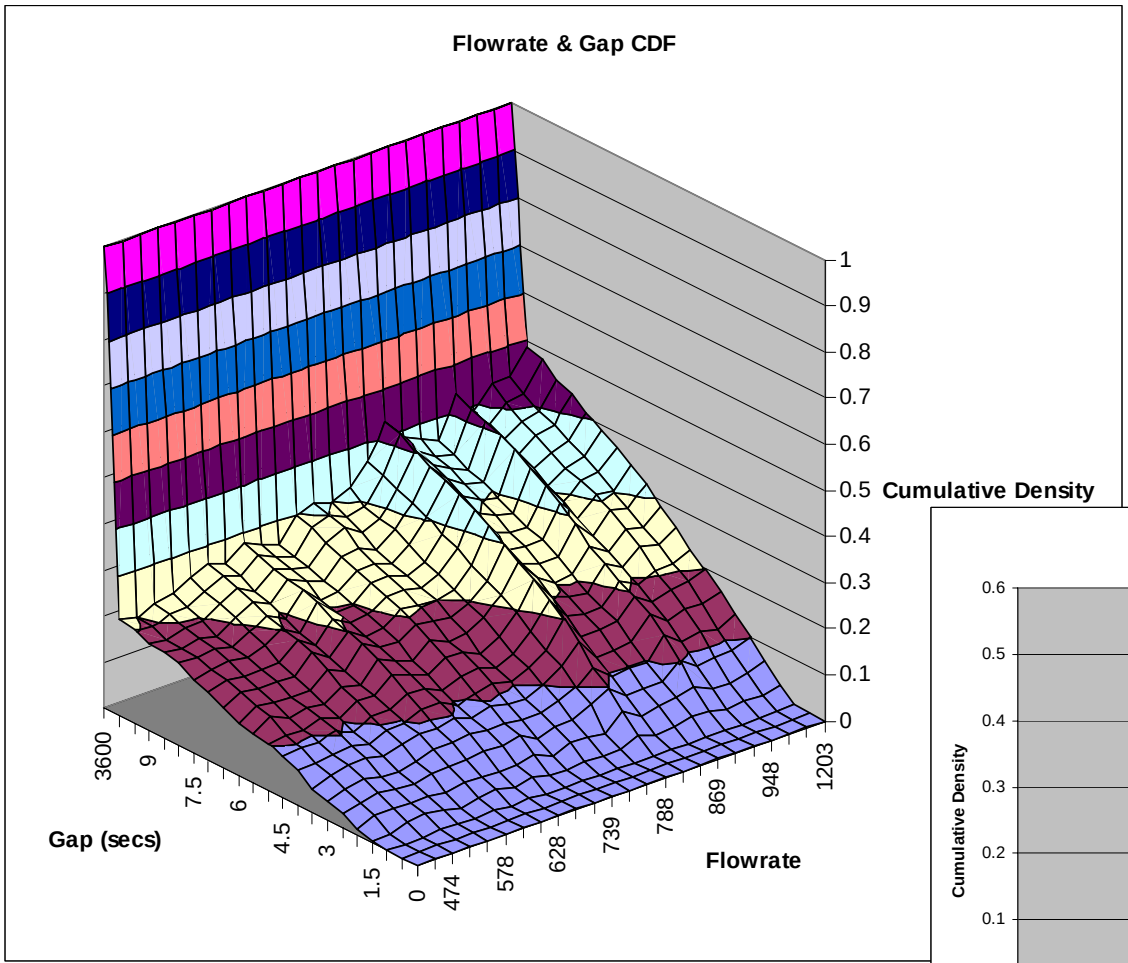
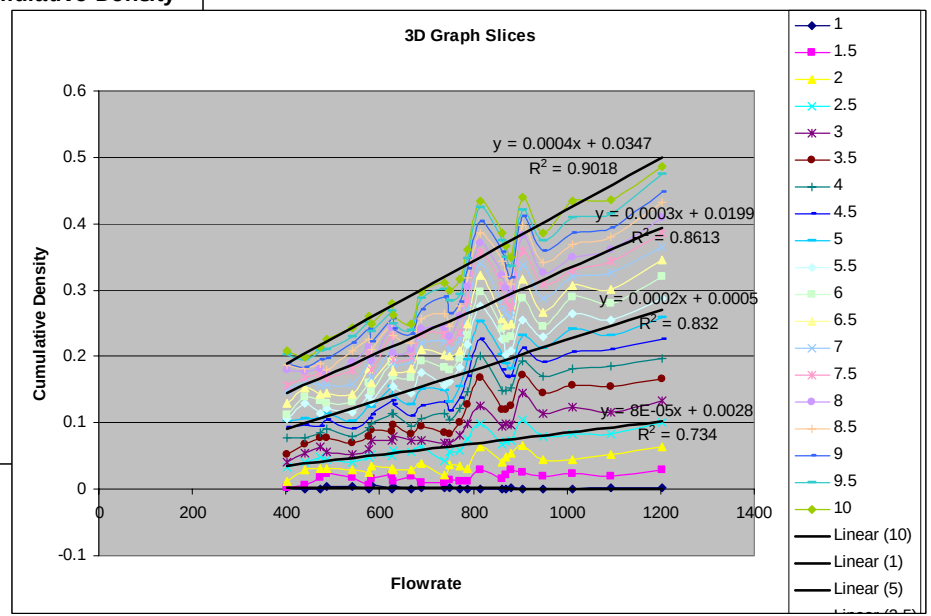
Modelling of Measured Headways:



This measured 3D graph is to be modelled & then used to generate headways in the simulations



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Modelling of Measured Headways:

General European trends were also found:

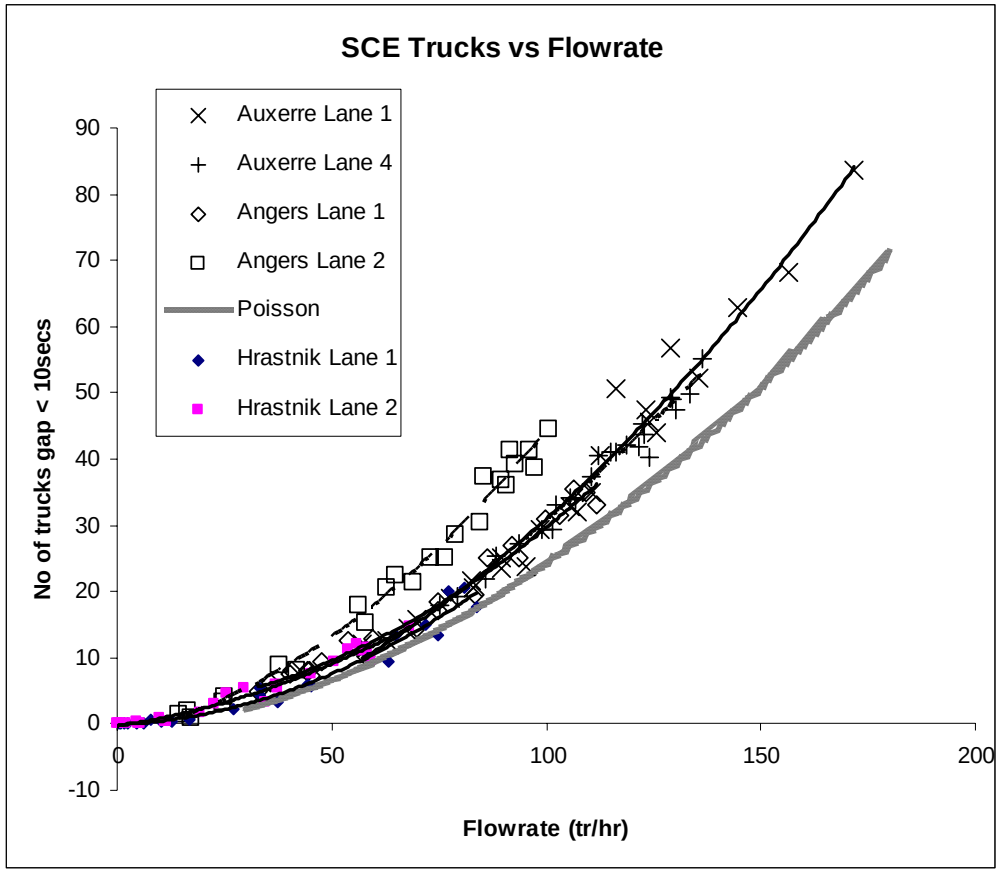
Trucks drivers appear to cluster "quadratically" (not erratically!)

The data comes close to a Poisson distribution but is not exactly Poisson

The Angers Lane 2 data behaves differently

- this may be due to differing site geometries (eg right hand turn) as it is a Route Nationale

- Auxerre is a motorway site



Conclusion: Accurate assessment of the importance of 3-truck events is thus very close