Monitoring of Traffic Loads and Bridge Performance using a WIM System

Bridge and Transport

Infrastructure Research (BaTIR)

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This investigation has been carried out within the 6th European FP project **ARCHES** (Assessment and Rehabilitation of Central European Highway Structures), investigating the definition of a more accurate bridge dynamic amplification factor

Topics

- **Introduction**
- **Definitions (DAF, ADR)**
- **Simulations**
- **Discussion of Results**
- **Calculation of ADR using a Bridge Weigh-In-Motion System**
- **Increment in Dynamics for the critical section**
- **Variation of DAF for different levels of bridge damage**
- **Conclusions**

Introduction

- Correct Assessment of bridge lifetime total traffic load requires accurate consideration of the following important components:
  - ❖ Maximum Lifetime Static load effect
  - ❖ Level of Dynamic interaction likely to occur for critical load scenario.
- These two components are not independent of each other.
- Previous findings indicate that higher interaction occurs for lighter vehicles, or lesser combinations of vehicles.
- The reduced probability of high static load effect and high dynamic interaction must be considered.

Definitions

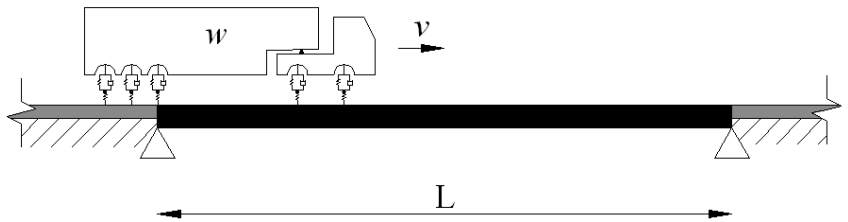
- Static Load effect – No interaction between vehicles and bridge is considered.
- Total Load effect – Interaction between vehicles and bridge is considered.
- DAF – Dynamic Amplification Factor (for a particular load scenario)

$$DAF = \frac{\text{Max. total load effect}}{\text{Max. static load effect}}$$

- ADR – Assessment Dynamic Ratio (for a particular period)

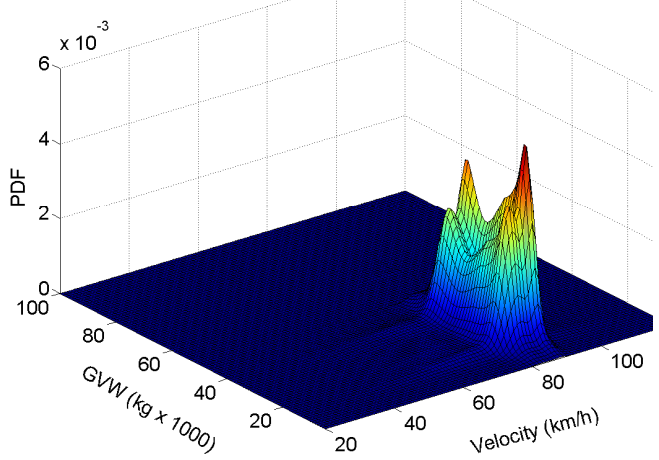
$$ADR = \frac{\text{Max. total load effect experienced over a prescribed period of time}}{\text{Max. static load effect for the same period}}$$

Example – Single-vehicle event

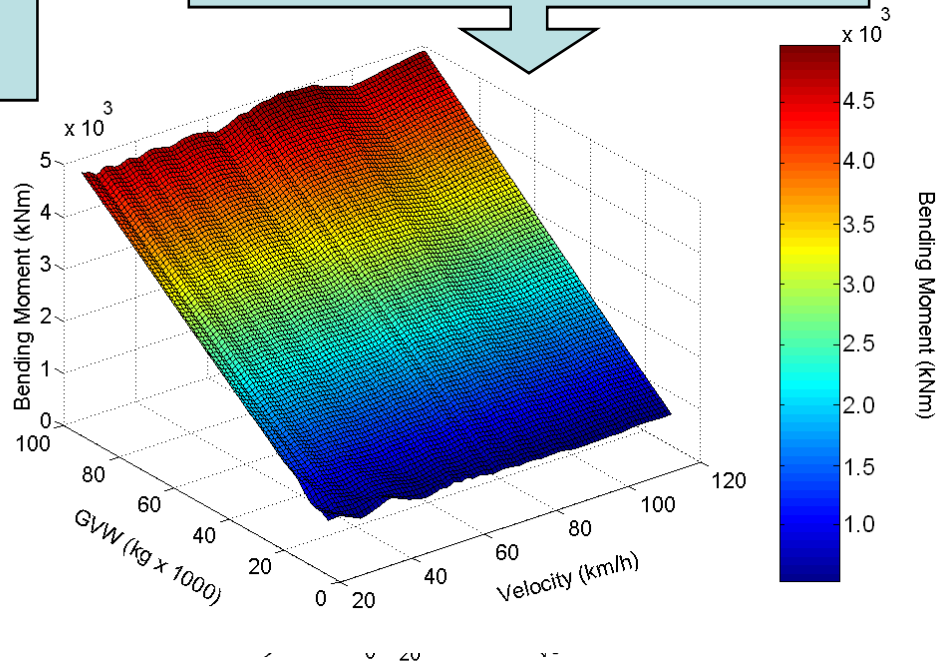


- Single 5-axle articulated vehicle of variable GVW and velocity crossing 25 m beam.
- Constant values of axle-spacing, weight distribution, vehicle damping , etc.
- Road profile with IRI of 2.69 m/km used.

From WIM data a bi-variate distribution is obtained

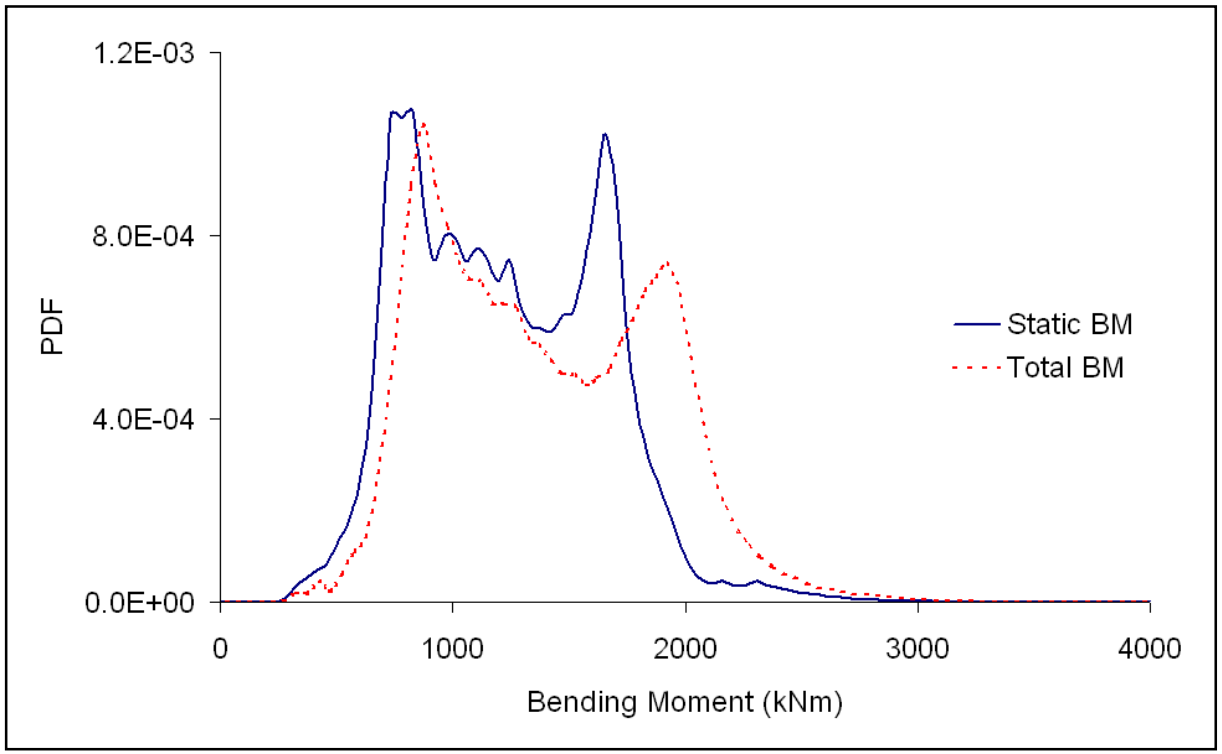


Using Numerical models, Load effect for all events are obtained (Static & Total)



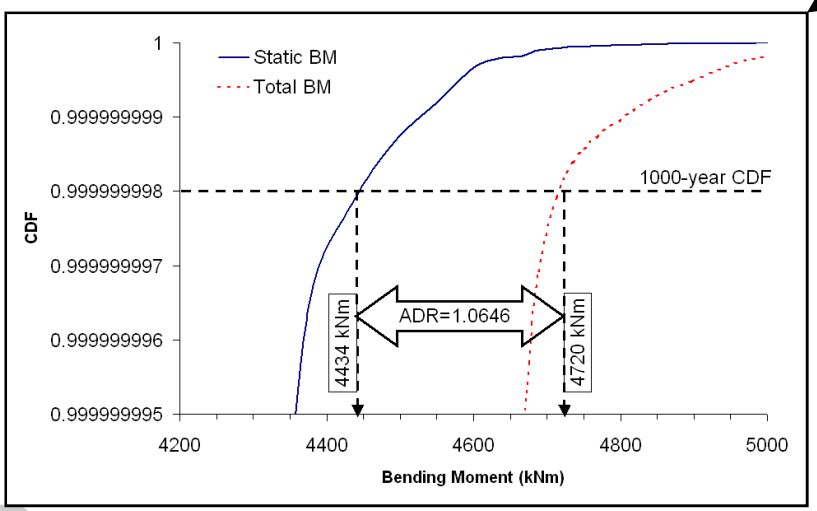
Distribution of load effect

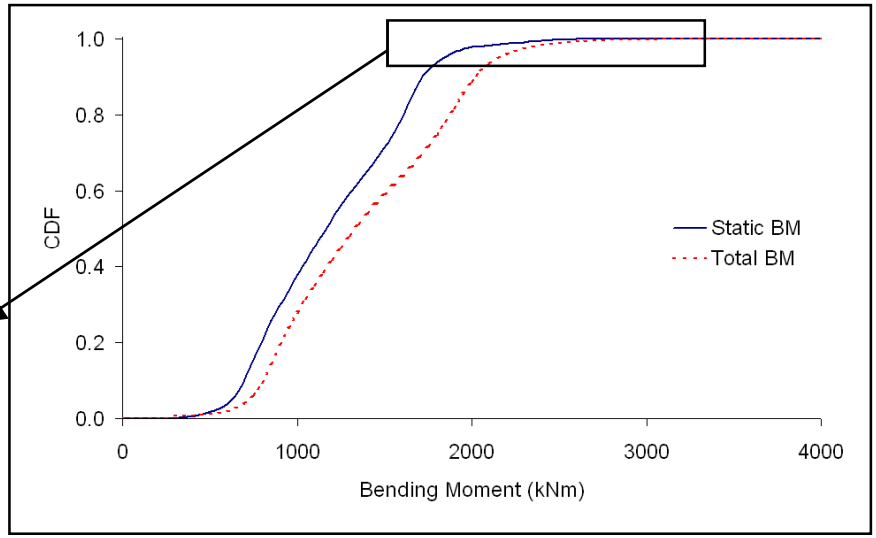
Combining probability of event with bridge response for the event allows for the full, exact distribution of load effect (static or total) to be obtained



Distribution of load effect

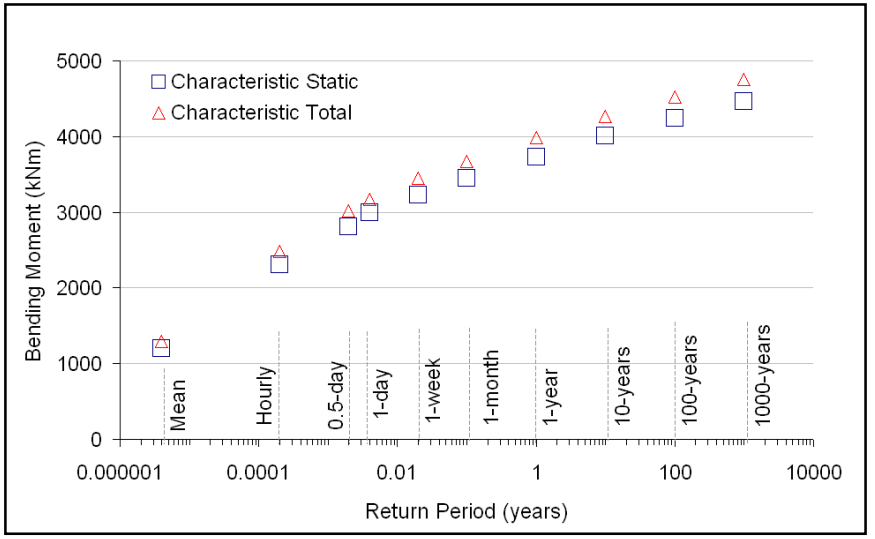
Examination of the upper tail of the distributions allow for characteristic values & ADR at any return period to be assessed

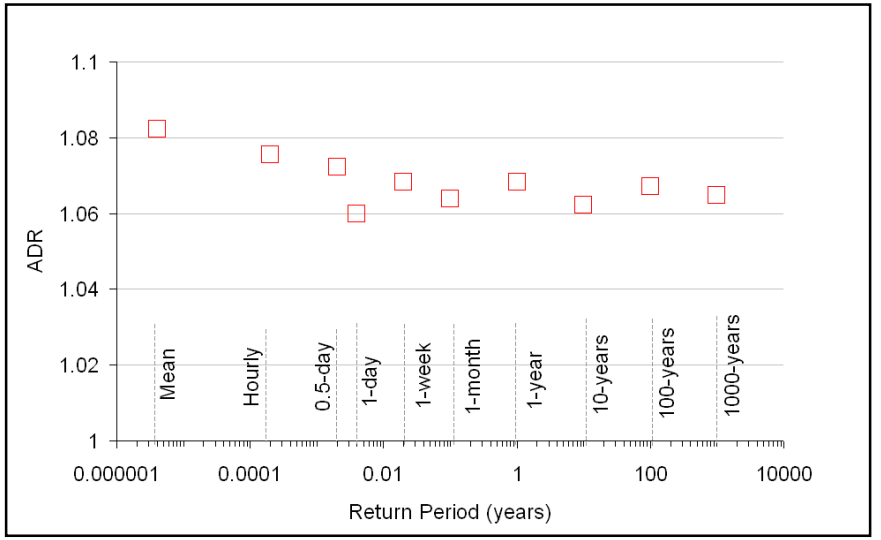




Influence of return period on ADR

- Characteristic Value of static and Total Load effect obtained for various return periods.
- The trend of ADR with return period to be assessed
- Variability of ADR reduces as return period increases

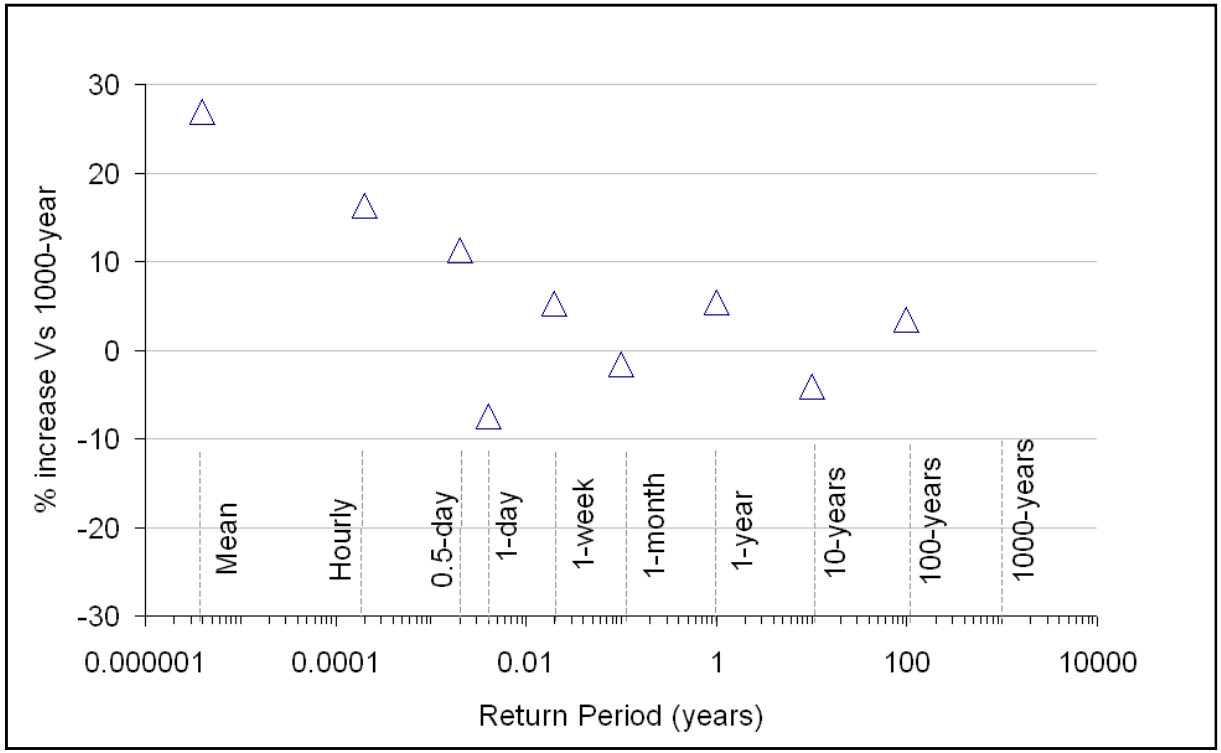




Normalisation of errors

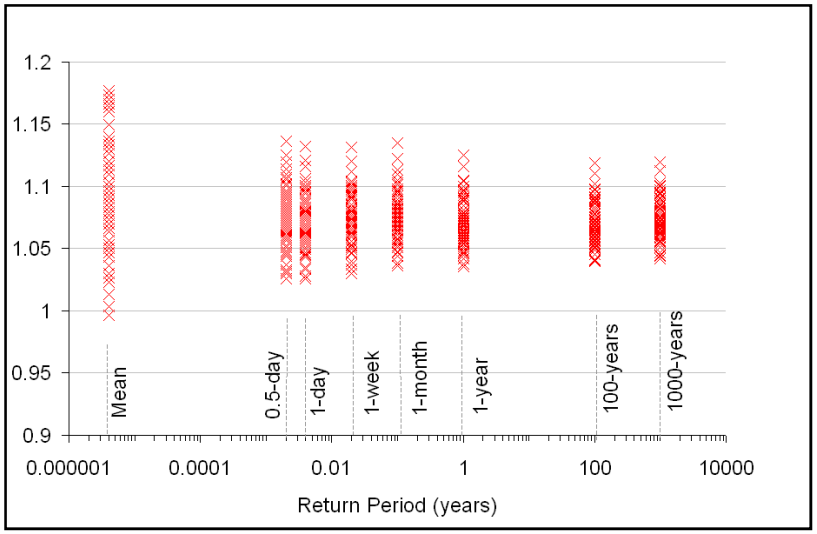
Compare the observed ADR for shorter return periods with the 1000-year ADR using:

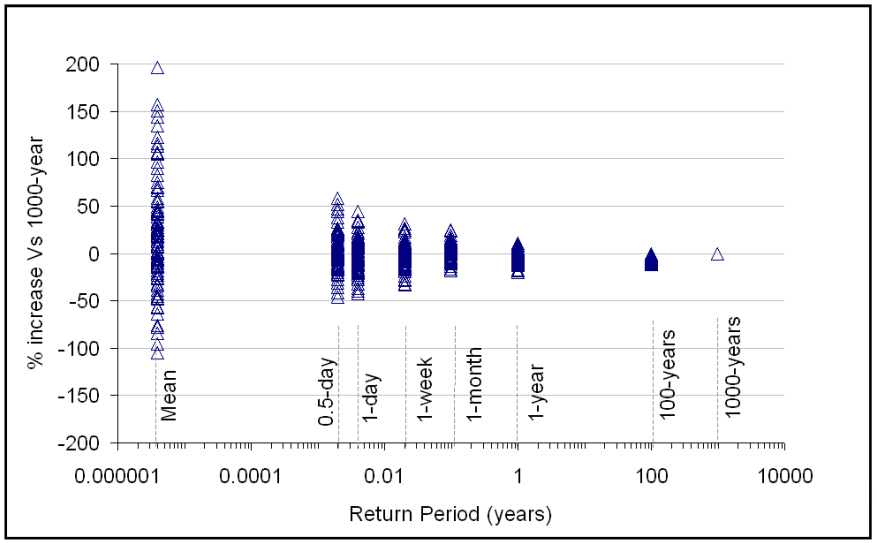
$$\%\ increase = \frac{100 \times (ADR_R - ADR_{1000-year})}{(ADR_{1000-year} - 1)}$$



Multiple road profiles

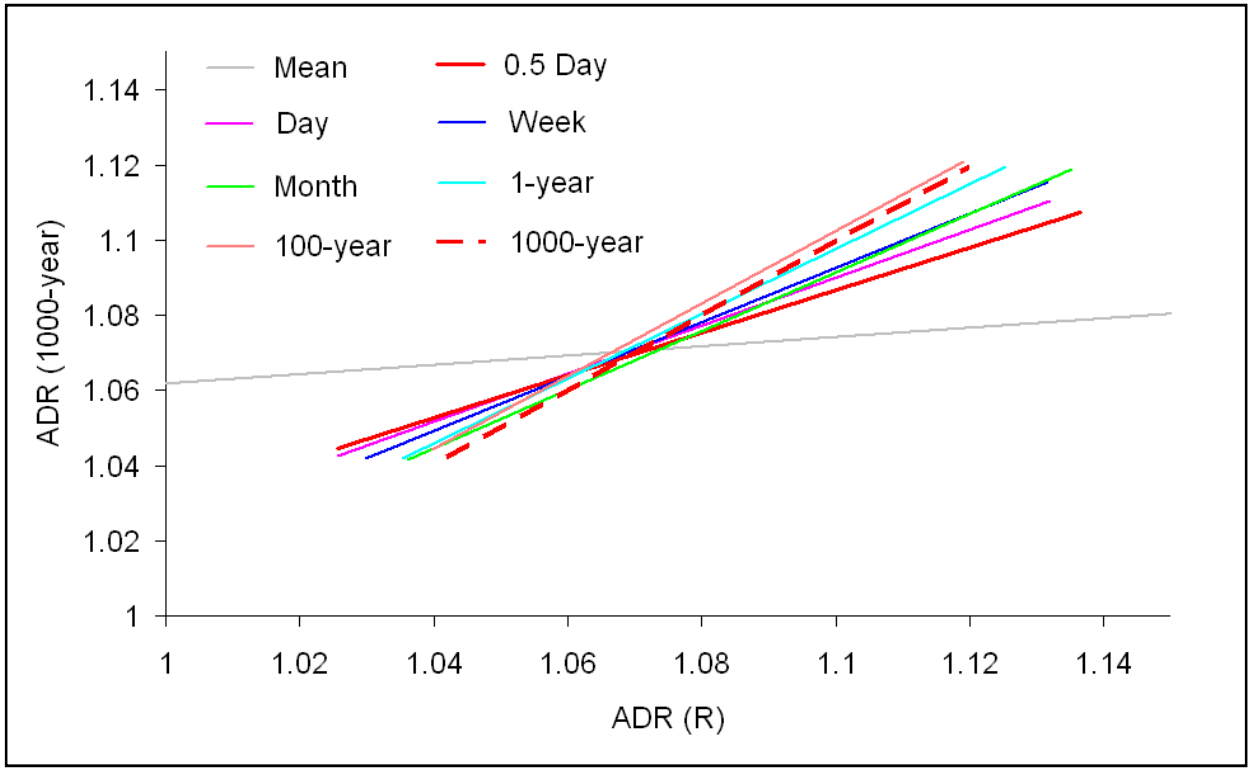
- Repeated for 100 different road profiles (all of very good/good quality), i.e. IRI <6m/km.
- Range of possible ADR reduces as return period increases.
- Good representation of a site-specific 1000-year ADR is achieved by using only 1-month of data.





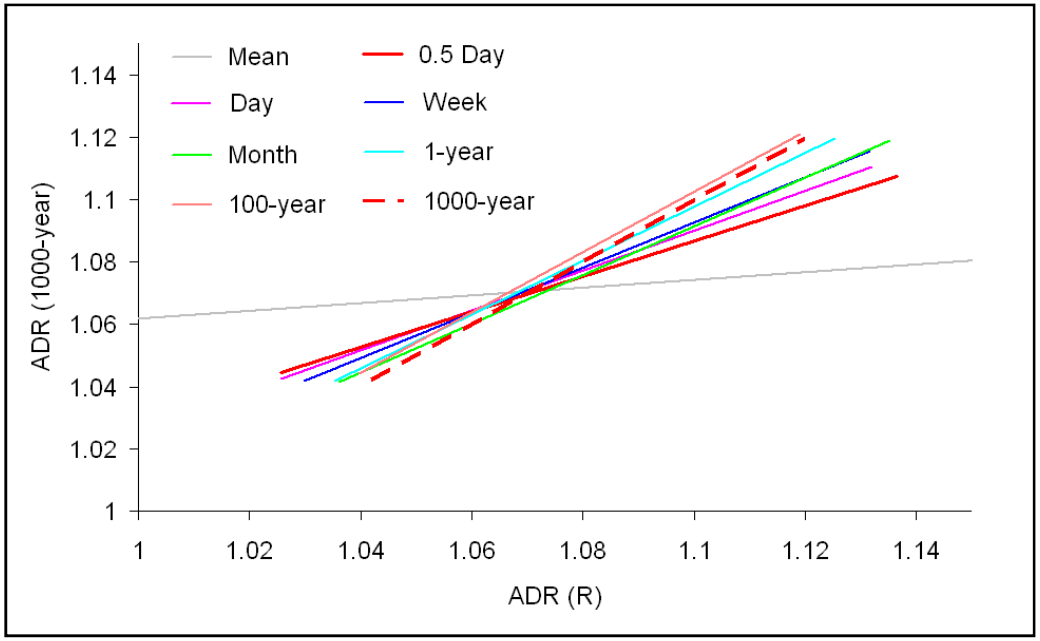
ADR for different time periods

- Comparison between observed 1-month ADR and observed 1000-year ADR shows a correlation exists.
- Assessment of high 1000-year ADR tends to be conservative using 1-month ADR



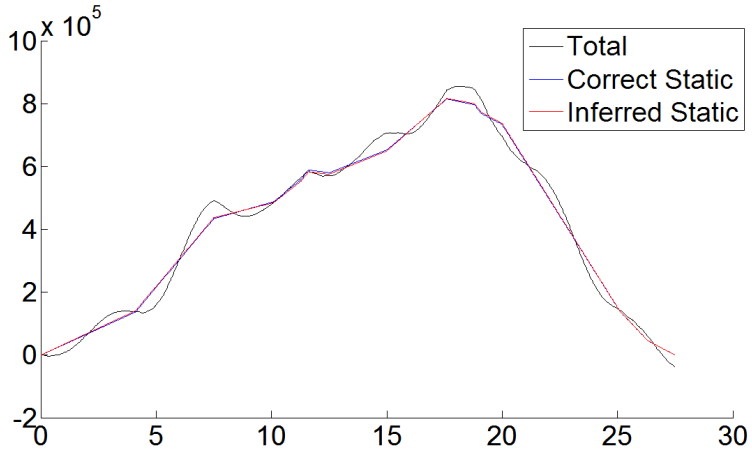
Correlation of ADR

- Correlation improves as considered period increases



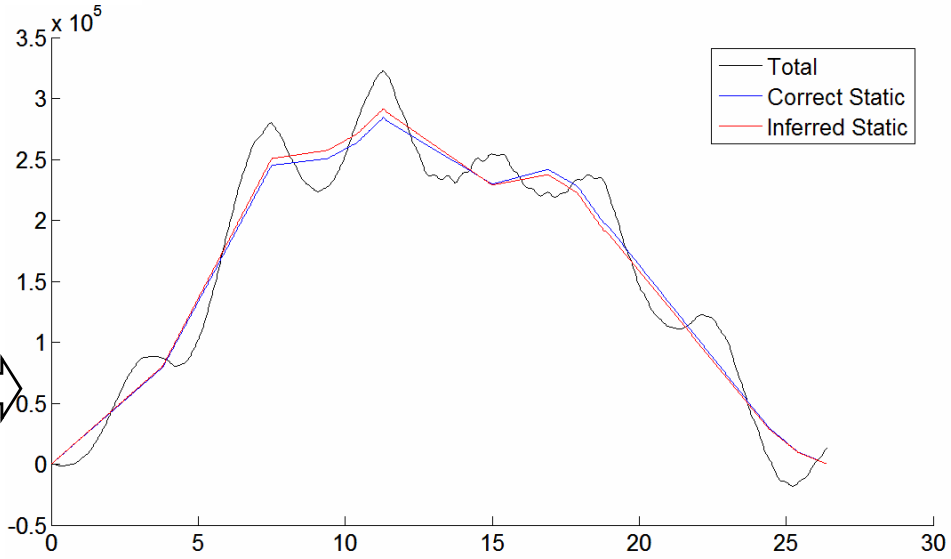
	Return Period (R)						
	Mean	**0.5 Day**	**Day**	**Week**	**Month**	**1-year**	**100-year**
1000-year	0.353	0.808	0.853	0.910	0.949	0.975	0.997

Influence of the Accuracy of a Bridge Weigh-In-Motion System in the Determination of ADR

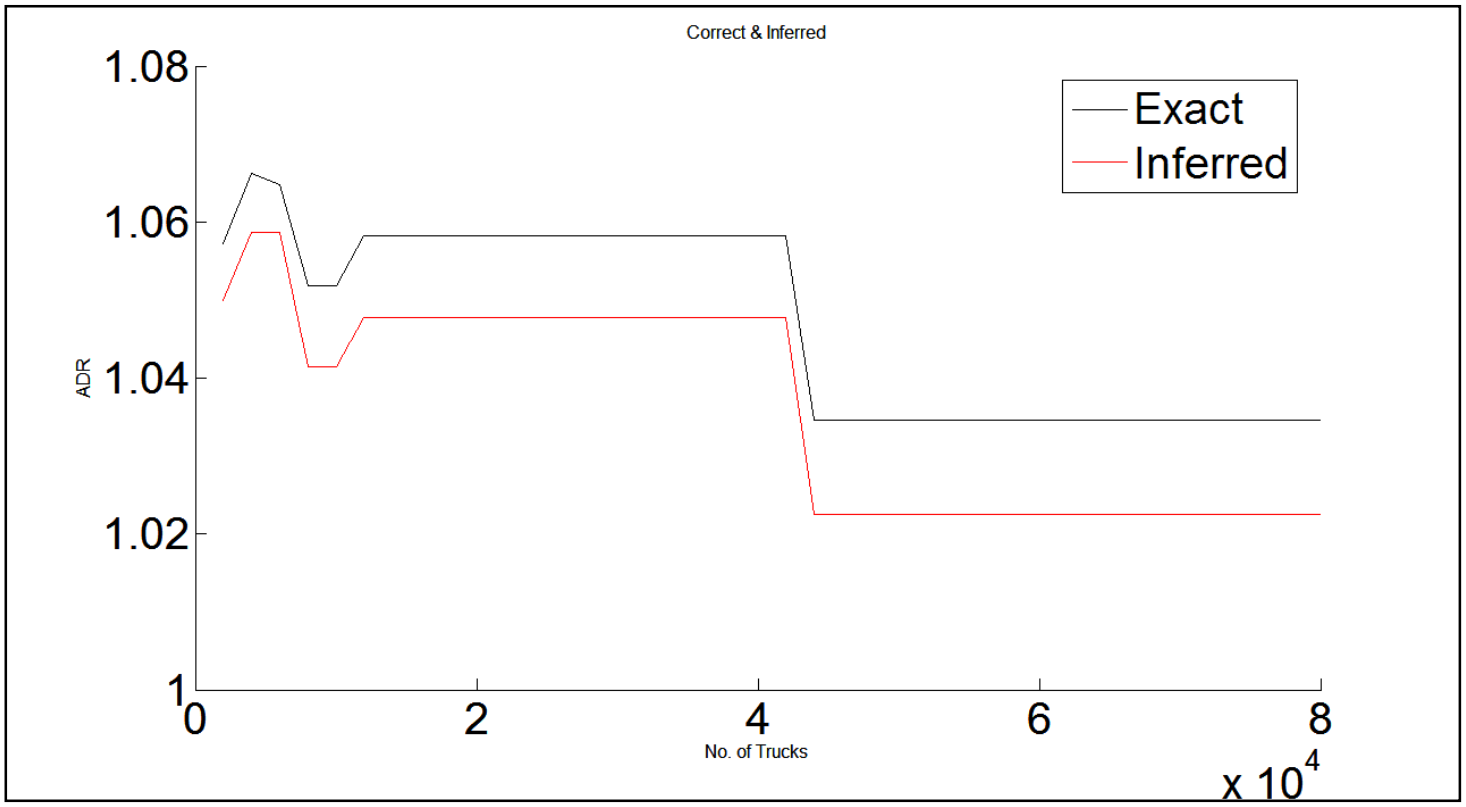


Very accurate determination of static weights, and hence, DAF

Front axles are overweighed and rear axles and underweighed. As result, predicted DAF smaller than real DAF



Comparison of Real ADR and Predicted ADR by B-WIM system (B+7)

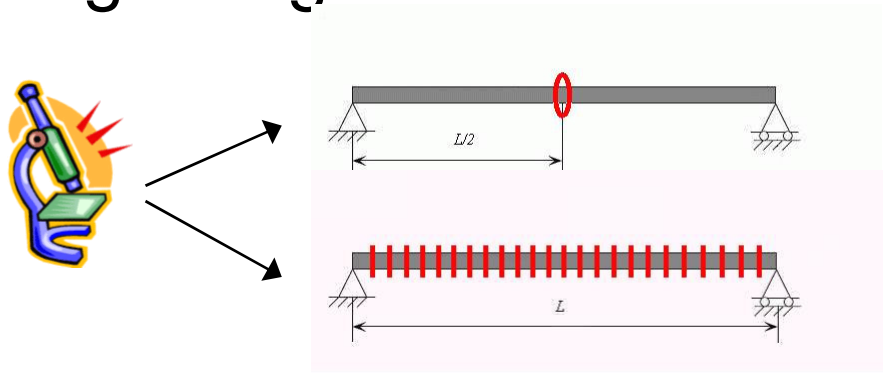


2 months on 15 m bridge (2000 heavy 5-axle trucks/month)

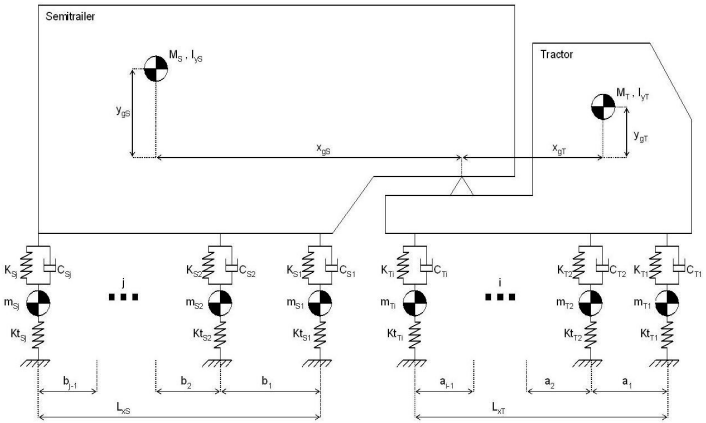
Analysis of other critical locations worse than midspan

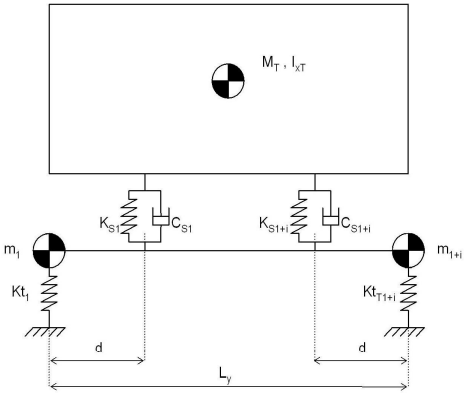
Maximum Bending Moment is not always at mid-span

Whole bridge length

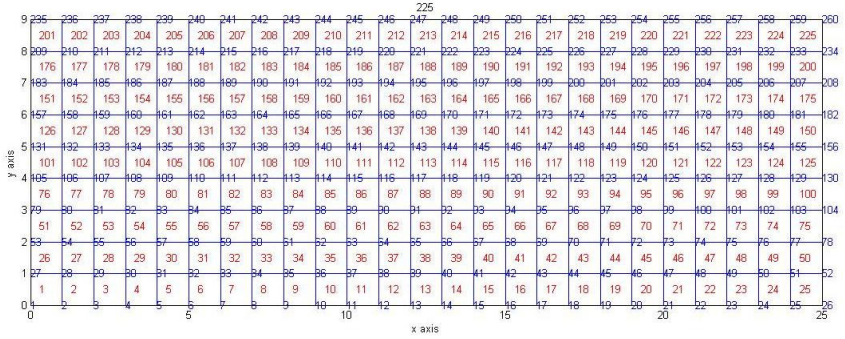


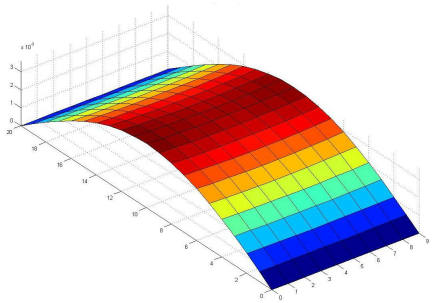
3-D Vehicle-Bridge Interaction Model

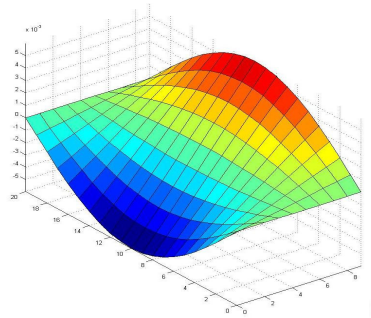




Truck Model

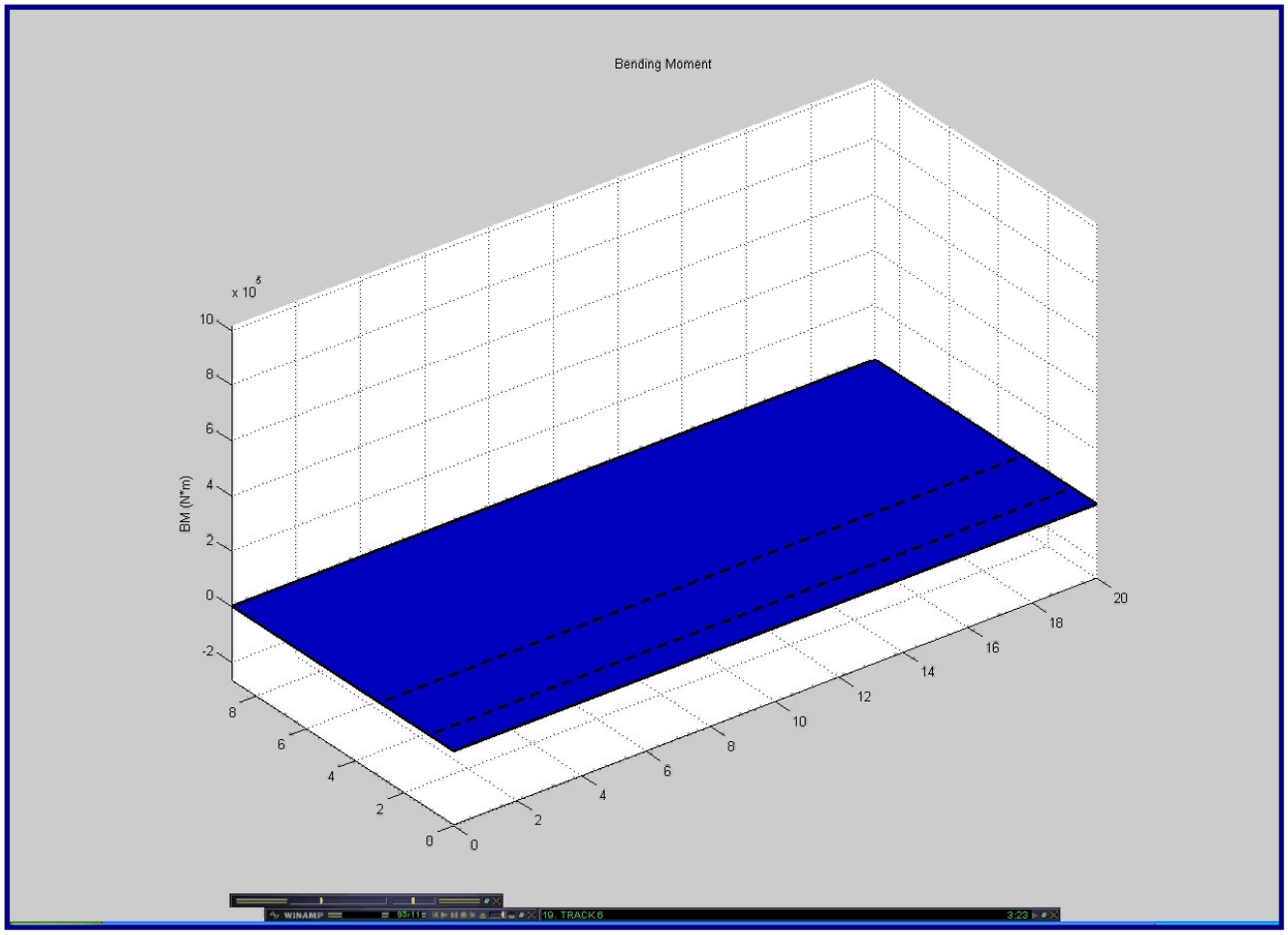






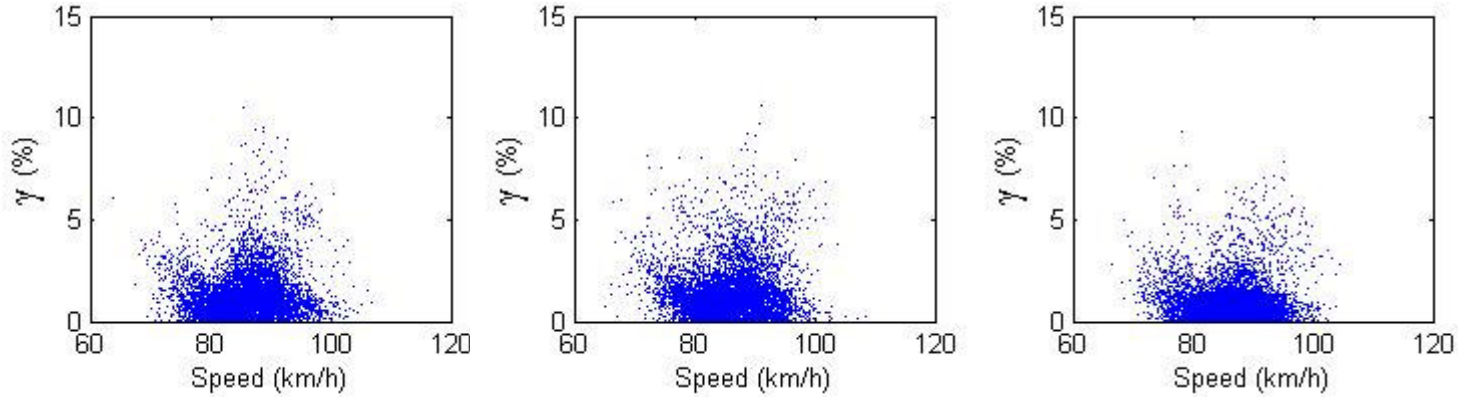
Bridge Model

Example of Simulation

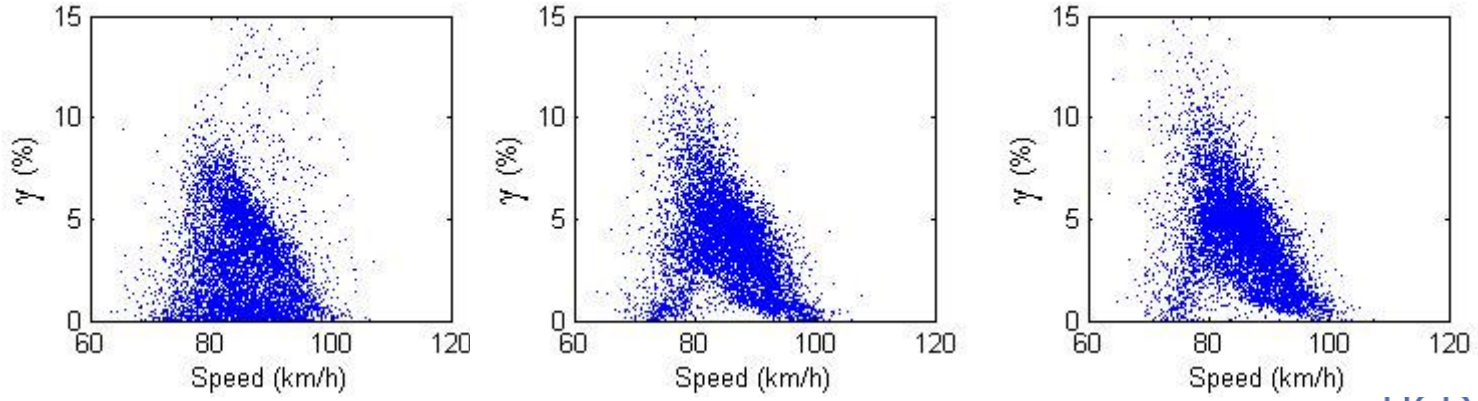


Increment in Dynamic with respect to midspan location

15m Span (3 different profiles)



25m Span (3 profiles)

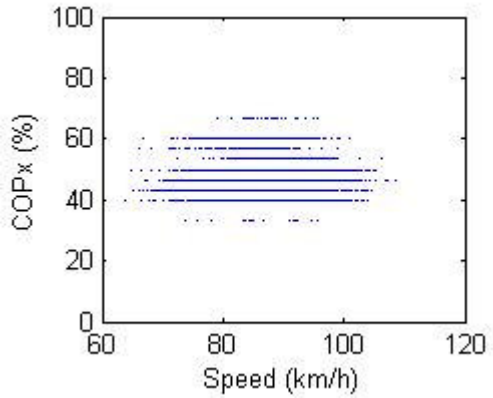


Location of the Critical Section

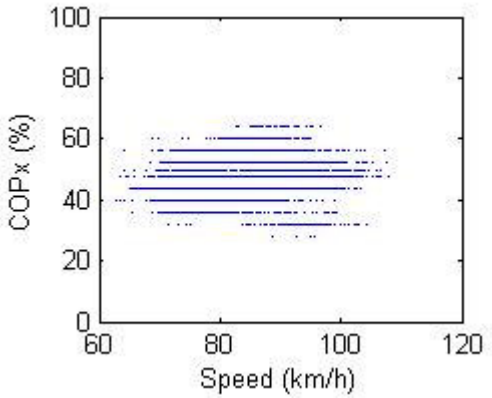
COP = **C**ritical **O**bservation **P**oint

Section along the bridge where the overall maximum occurs. Expressed in percentage of bridge length.

15m Span



25m Span



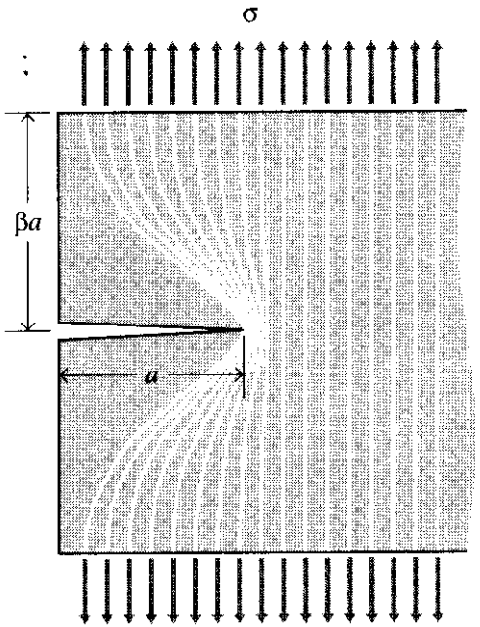
Maximum stresses developed on a bridge may occur within a range of: 30% to 70%

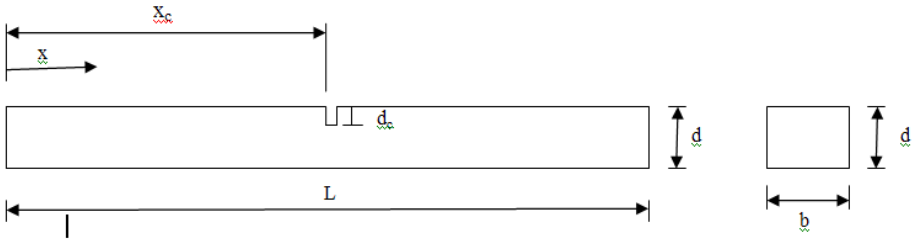
Influence of bridge damage on DAF

MODELLING OF A CRACK

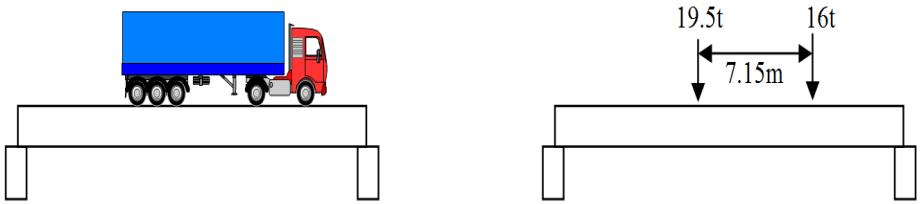
Idealisation of Unloaded Region Near Crack Flanks

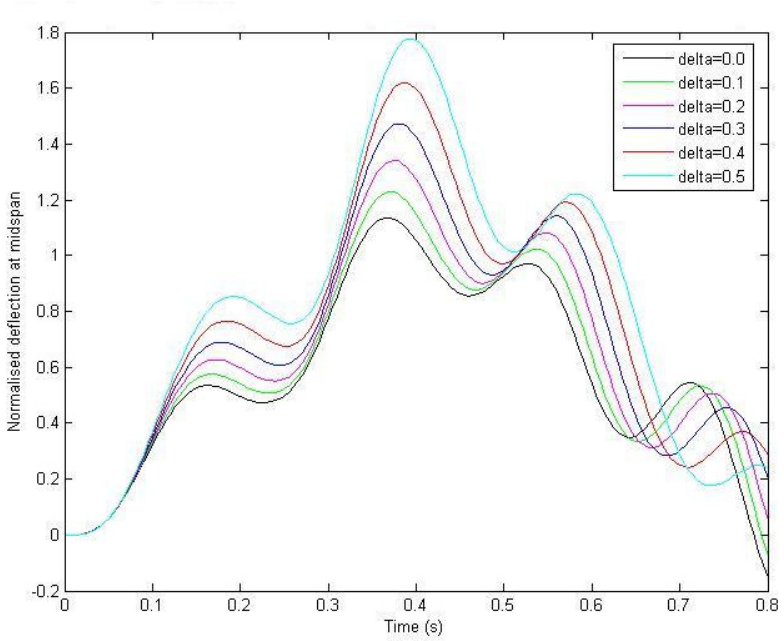
$$EI(x) = \frac{EI_0}{1 + C\,exp(-\frac{2\alpha|x - x_c|}{d})}$$

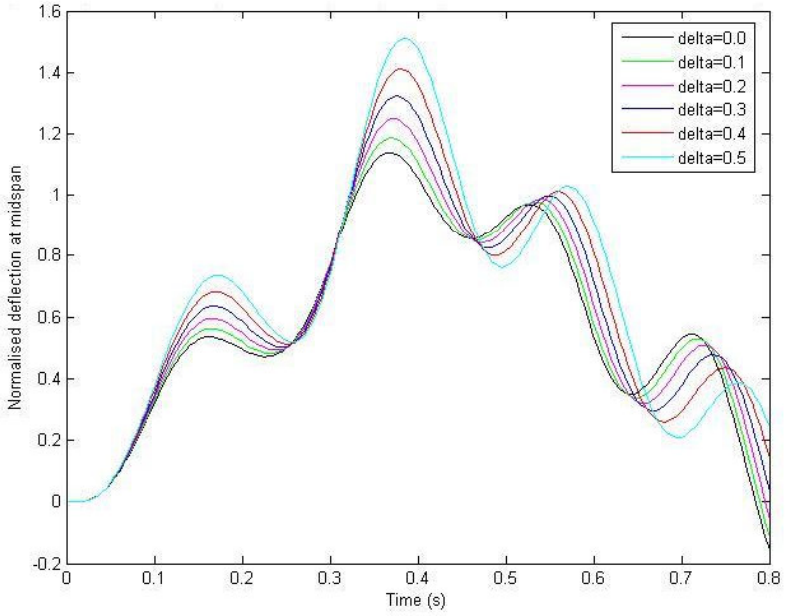




Simulations of a Moving Load on a Deteriorated Bridge



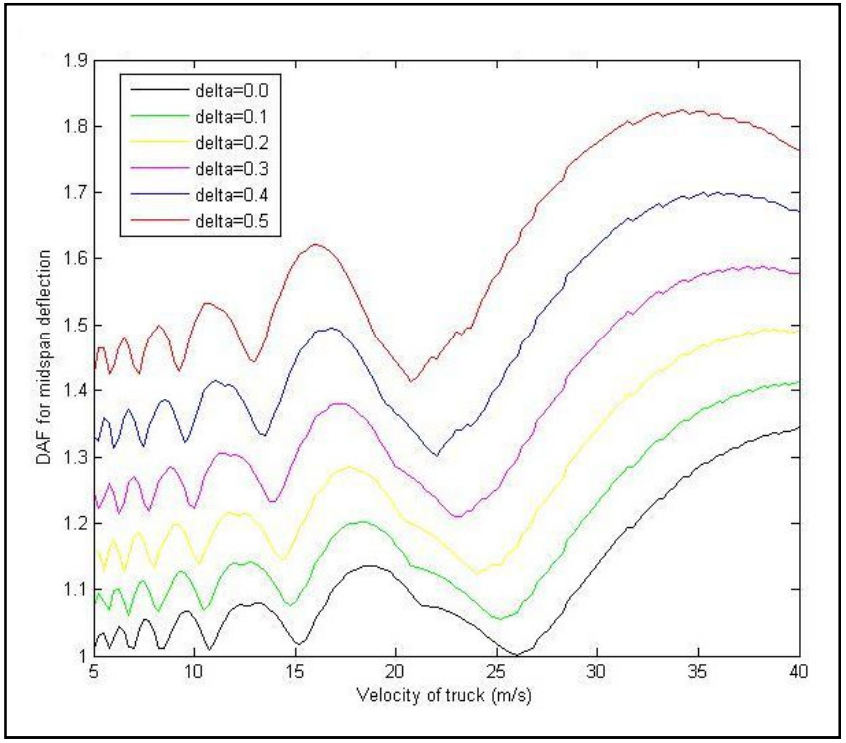




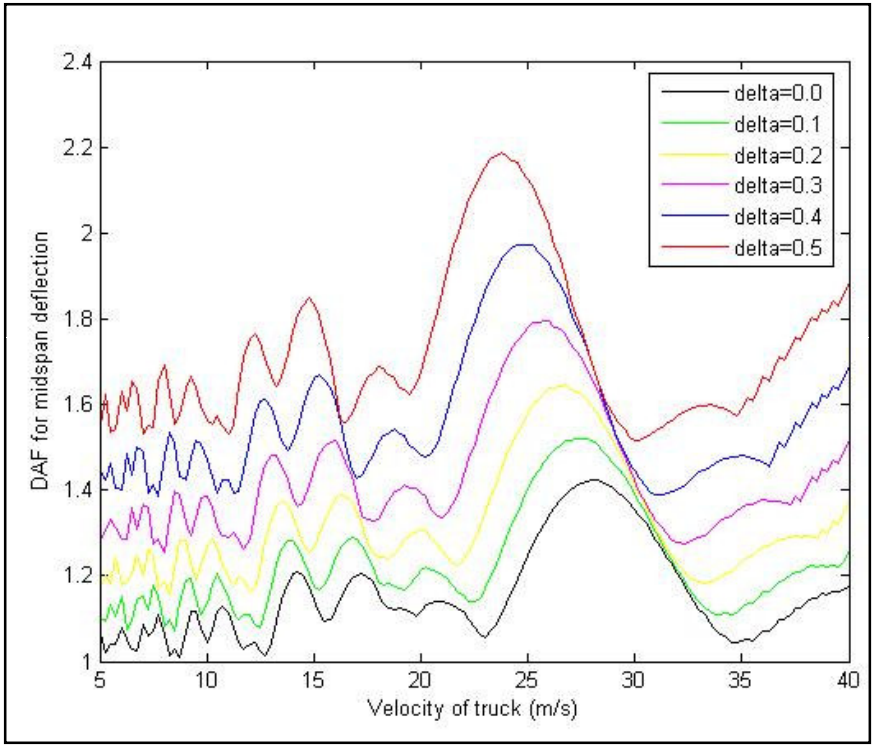
Damage at ½ span

Damage at 1/4 span

Dynamic Amplification Factors for Different Levels of Damage



11 m span



17 m span

Conclusions

- Bridge Weigh-In-Motion can be employed to determine a site-specific characteristic dynamic total effect (DAF/ADR) but a safety factor depending on its accuracy class may be necessary

- In a simply supported structure, the section holding the worst total moment can differ from the.midspan section

- Further insight into the determination of ADR and its practical implementation and the use of DAF to monitor structural changes is necessary

Acknowledgments

The authors wish to thank the 6th European Framework Project **ARCHES** (for the support towards this investigation.