Weigh-in-motion and traffic load monitoring

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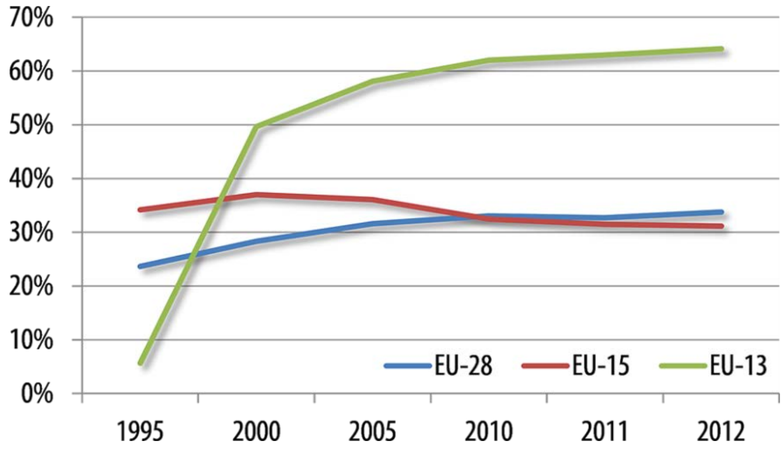
Scope of the Fact Sheet

The factsheet outlines the available weigh-in-motion (WIM) technologies, summarises the bridge traffic load modelling procedures and presents potentials of bridge-WIM technique to be used for monitoring of bridges.

Outline

- Traffic loading in Europe
- Measurements of traffic loading
- Weigh-in-motion:
  - Pavement WIM systems
  - Bridge WIM systems
- WIM and bridges:
  - Traffic loading
  - Monitoring of structural characteristics
- Conclusions

Traffic Loading



- freight traffic will continue to grow
- international haulage:
  - EU-15 from 37.0% to 31.2%
  - EU-13 from 49.6% to 64.2%!
- unthinkable increases after joining the EU

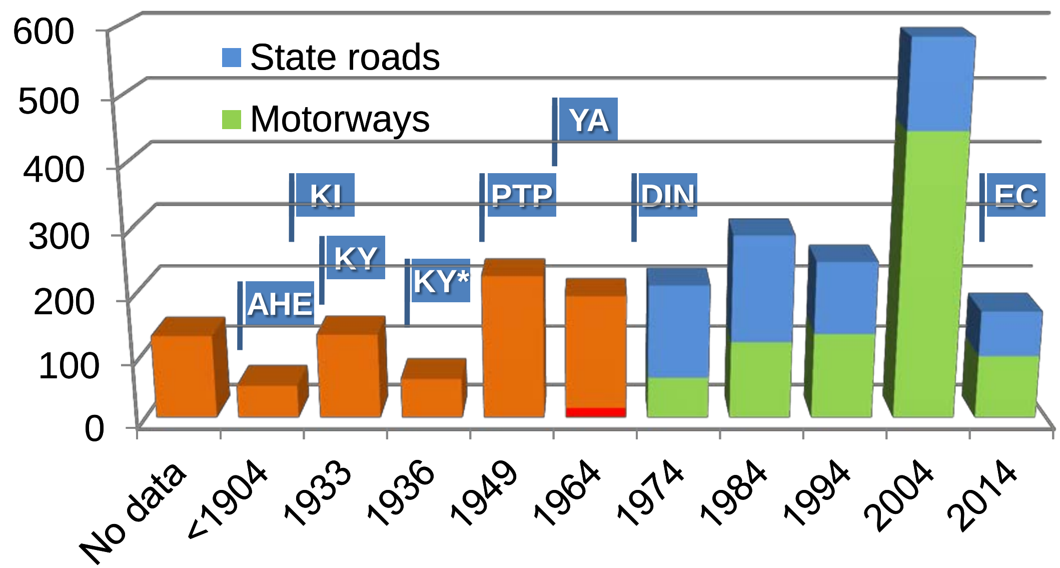
Country	2010	2011	2012
Lithuania	88.1	89.3	89.7
Slovenia	85.5	86.7	88.6
Luxembourg	93.1	92.1	87.3
Slovakia	81.2	83.2	82.8
Latvia	75.5	78.5	78.7

Country	2010	2011	2012
UK	6.1	5.5	5.4
Sweden	9.7	9.5	9.3
France	9.8	9.4	9.3
Italy	15.1	10.6	9.8
Finland	14.9	11.6	13.8

Traffic Loading and Bridges

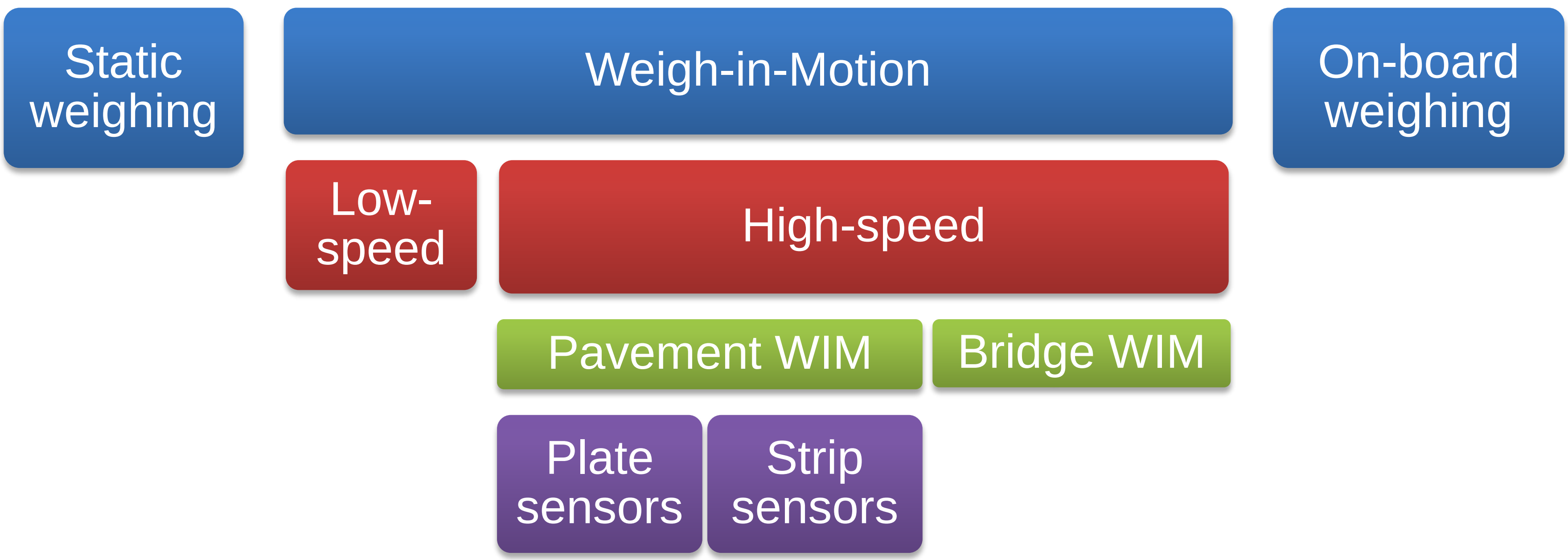
Bridge loading

- bridge failures are not acceptable as they can take lives
- average age of European brides >60 years:
  - deteriorated
  - designed according to different codes
  - under-designed for modern traffic
  - affected by much higher loading
- problem: if traffic loading increases safety factors decrease and this is acceptable only to a certain level



Measurements of Traffic Loading

- traffic counters the most common devices for collecting traffic data
- to know the actual ALs and GVWs of the heavy vehicles these need to be weighed



Static Weighing

- most accurate and most common weighing technology
- in most countries the only means for direct enforcement
- certified devices calibrated as often as possible

Static weighing

Low-speed WIM

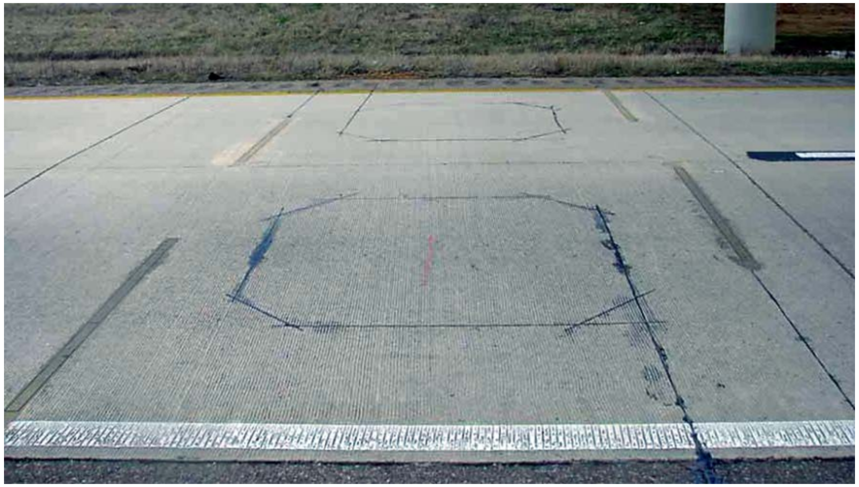
- in controlled conditions (<10 km/h)
- for accurate pre-selection and sometimes direct enforcement
- requirements and test procedures in international recommendations (OIML R 134, 2009)

High-speed WIM or WIM Systems

Measure *dynamic* axle loads at *highway speed* and *uncontrolled conditions* and calculate estimate of their static axle weights

- typically deliver:
  - exact time
  - single and group axle loads
  - gross vehicle weight
  - number of axles
  - length and axle distances
  - speed
  - vehicle classification…

- short history:
  - first WIM in late 1950's
  - boom of installations in 1980s
  - intense developments in 1990s (COST 323, WAVE, REMOVE)
  - today high focus on applications

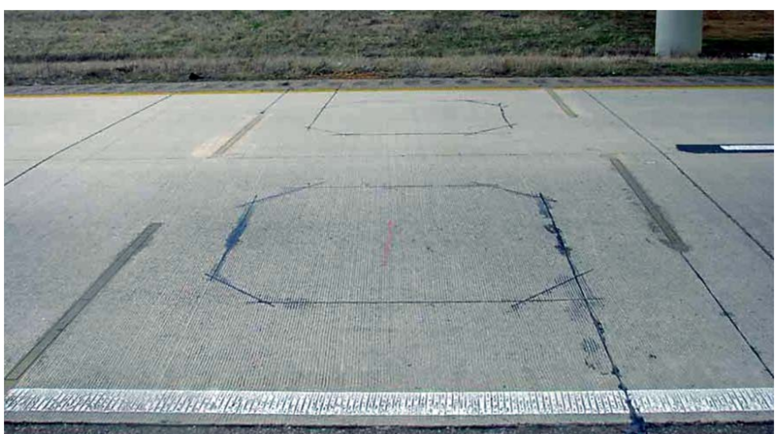


High-speed WIM or WIM

- WIM-system can be divided into:
  1. external structure (pavement, bridge)
  2. sensors or transducers
- combination of both results in two types of WIM installations:
  - *pavement* WIM systems and
  - *bridge* WIM systems.
- most common sensing technologies:
  - piezo-electric
  - piezo-quartz
  - strain gauges
  - fibre optics

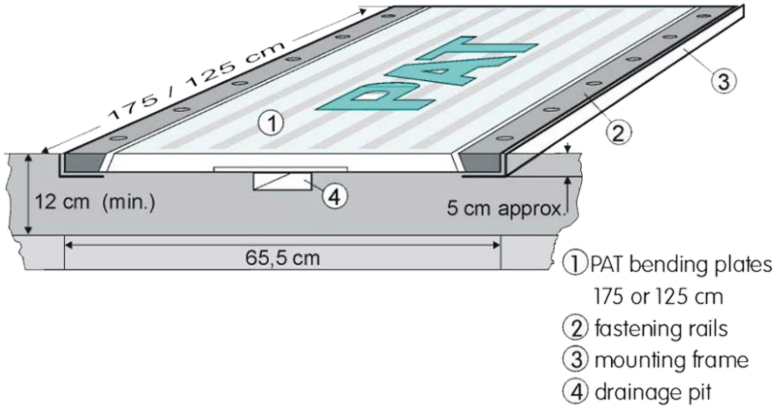
Pavement WIM systems

- typical installation consists of:
  - inductive loops
  - WIM sensors, in different setups.
- based on the width of the sensors:
  - plate sensors and
  - strip sensors



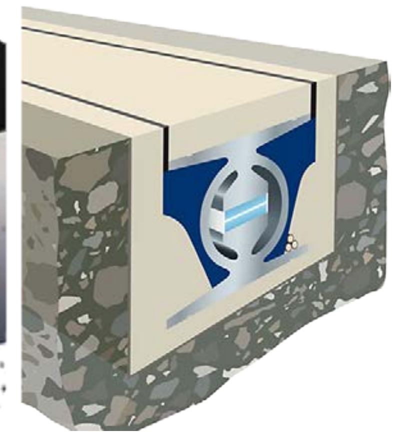
Pavement WIM – Plate sensors

- width is larger than the tyre, the total axle load is acting on the sensor
- similar devices for static and LS axle load measurements
- two prevailing technologies:
  - bending plates
  - load cell devices
- more accurate than strip sensors
- installation is:
  - aggressive to pavement
  - for a load cell device can last 2 days



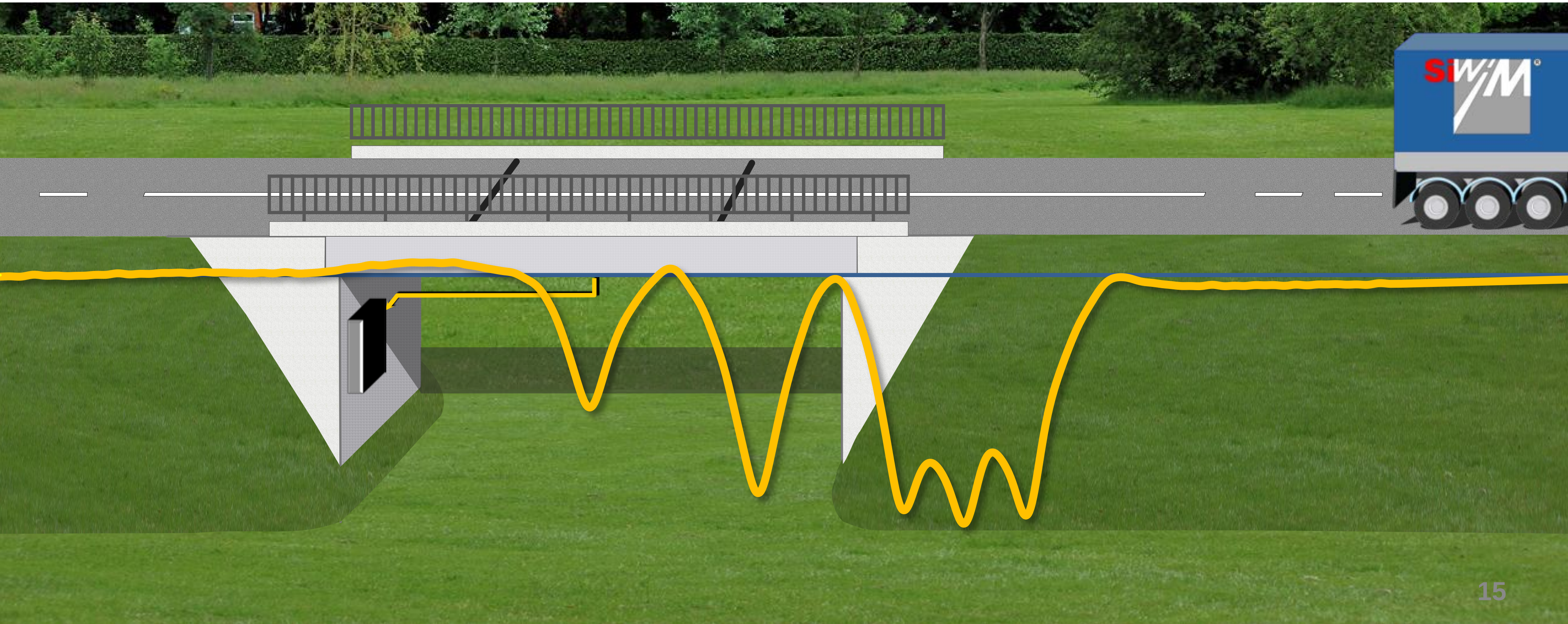
Pavement WIM – Strip sensors

- length of tyre footprint larger than width of the sensor
- signals must be integrated
- 3 dominant technologies
  - *piezo-electric*
  - *piezo-polymer*
  - piezo-quartz
- typically installed in < 1 day
- proven technology
- relatively high accuracy on smooth pavements
- difficulties in flexible pavements



Bridge WIM

Bridge WIM uses an existing instrumented road structure – a bridge or a culverts – to weigh vehicles in motion



Bridge WIM

- since 1980s, successful since 2000
- provide the same data as P-WIMs
- advantages:
  - complete portability, without affecting the accuracy
  - high accuracy
  - ease of installation, *without interrupting the traffic*
  - additional structural information
- disadvantages:
  - proper bridge is needed
  - less common structures require bridge experts

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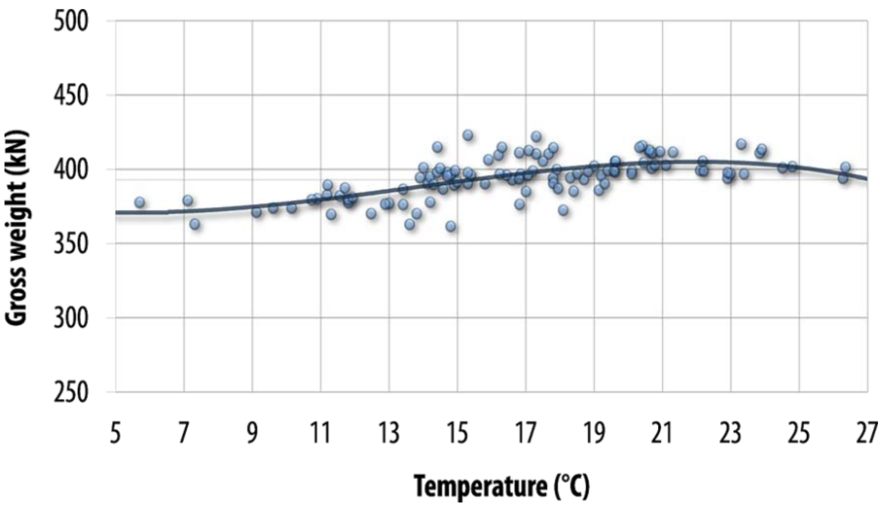
Accuracy of WIM systems

- determined by the combination of the accuracy and reliability of its measurements
- most common way to describe WIM performance:

  error of the results is within ±xx% for yy% of measurements
- criteria vary for single axle loads, axle group loads and GVW
- COST 323 WIM specifications widely accepted standard

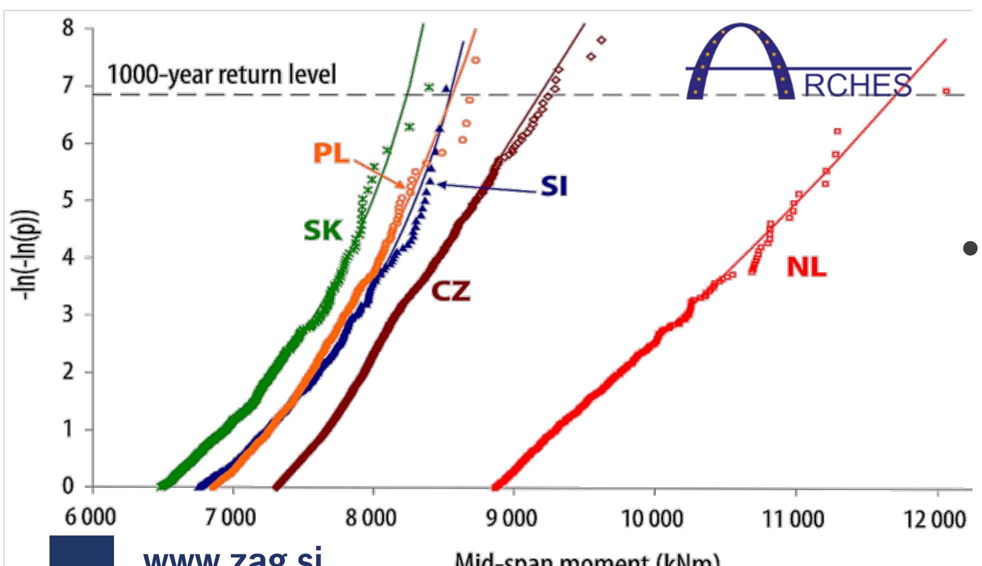
- accuracy factors:
  - road condition
  - quality of installation
  - type of sensors
  - maintenance and calibration
  - environment…



Applications of WIM data for Bridges

Traffic Loading and Bridges

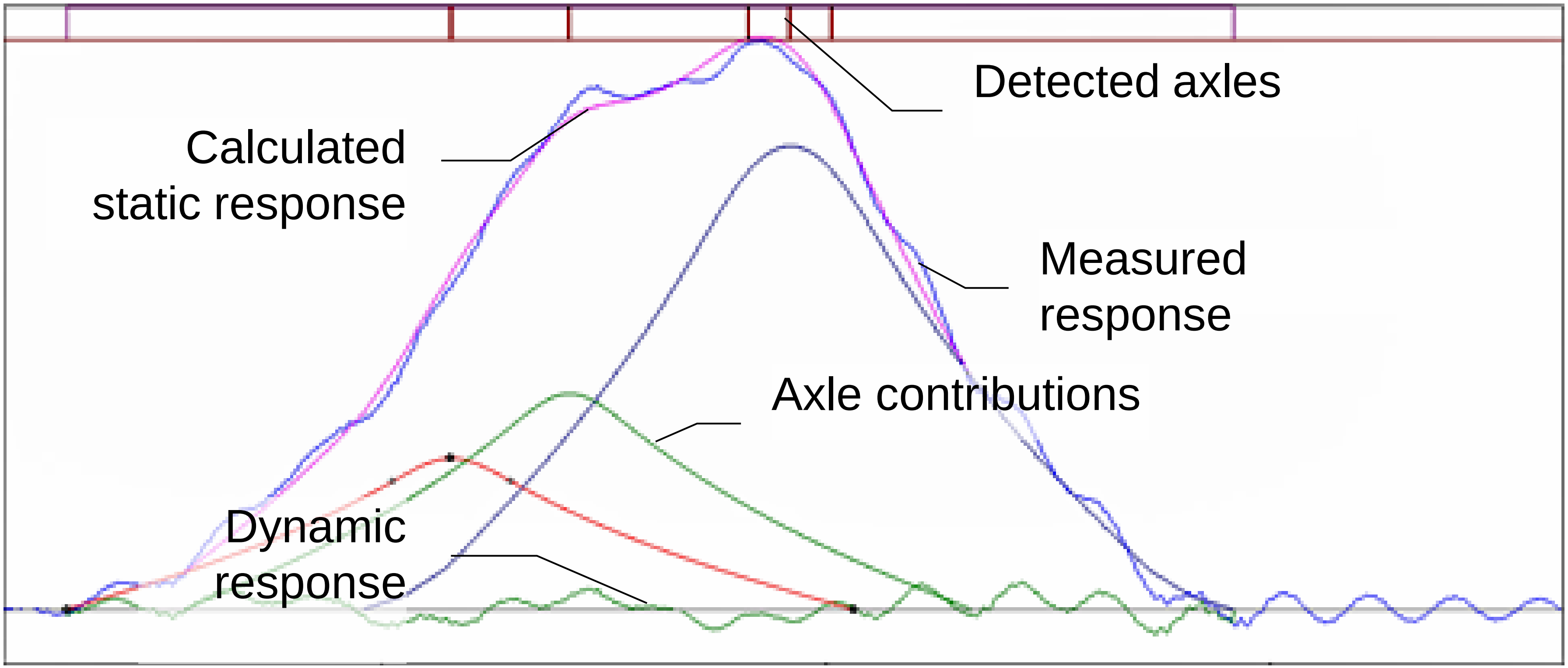
- accurate design and assessment requires reliable estimates of characteristic lifetime maximum traffic load effects
- these are very different from one country to another



- free flowing traffic for short spans, congested traffic for spans >50m
- Extreme Value Distributions
  - Gumbel (type I),
  - Fréchet (type II) and
  - Weibull (type III))

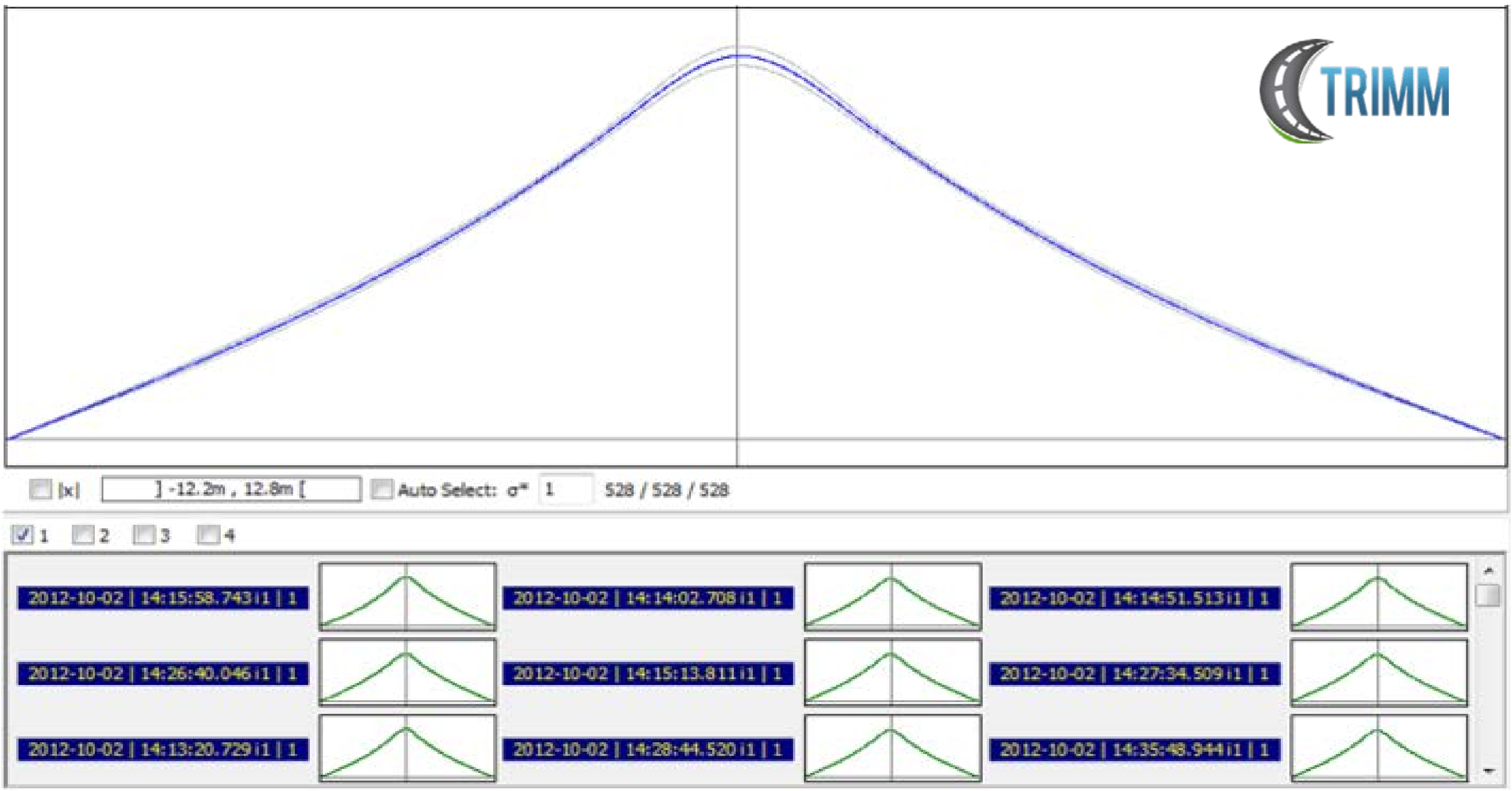
  fitted to block maxima, e.g., maximum daily or weekly values
- alternatives:
  - POT (Peak Over Threshold)
  - Rice formula
  - long run simulations

B-WIM (SiWIM®) and Bridge Behaviour

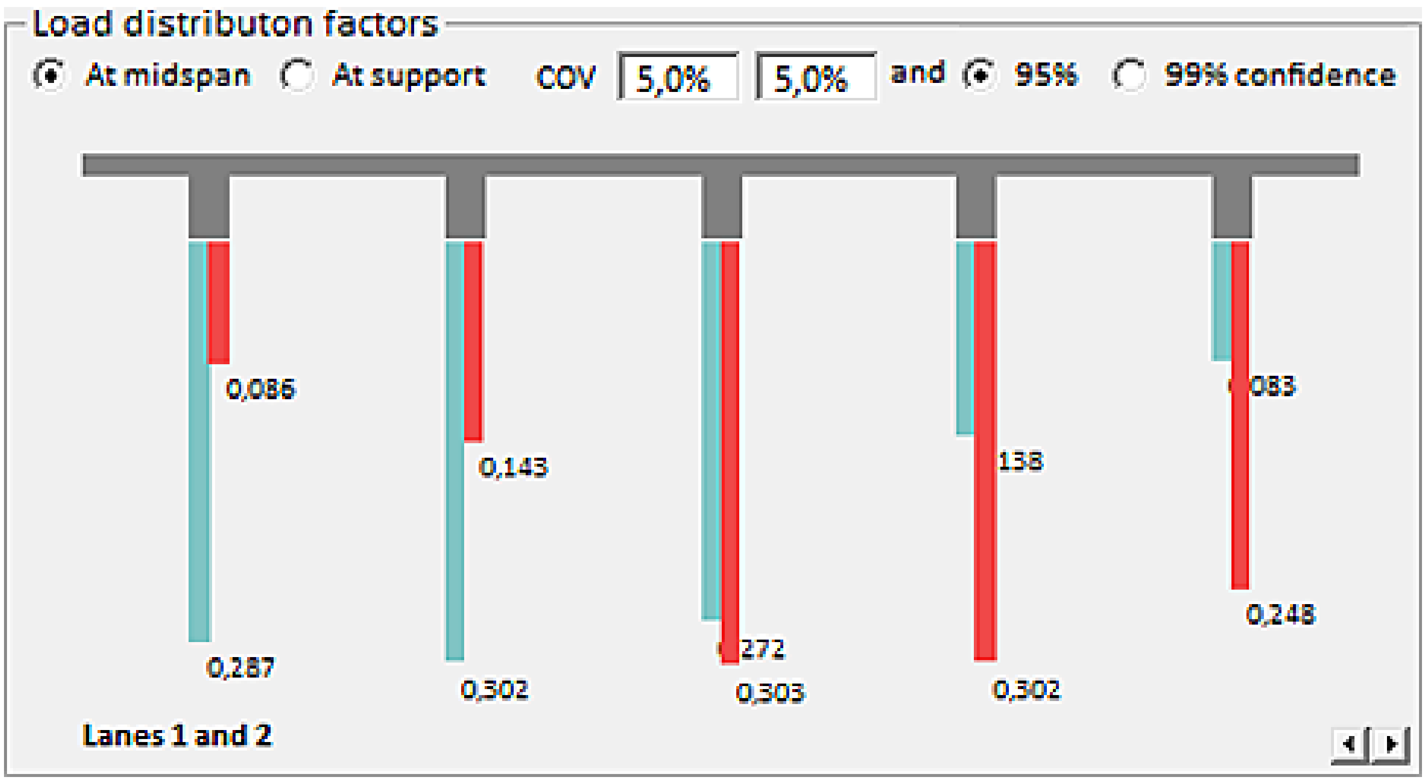


$$\varepsilon(t) = A_1 I_1(t) + A_2 I_2(t) + \cdots + A_N I_N(t)$$

SiWIM® and influence lines



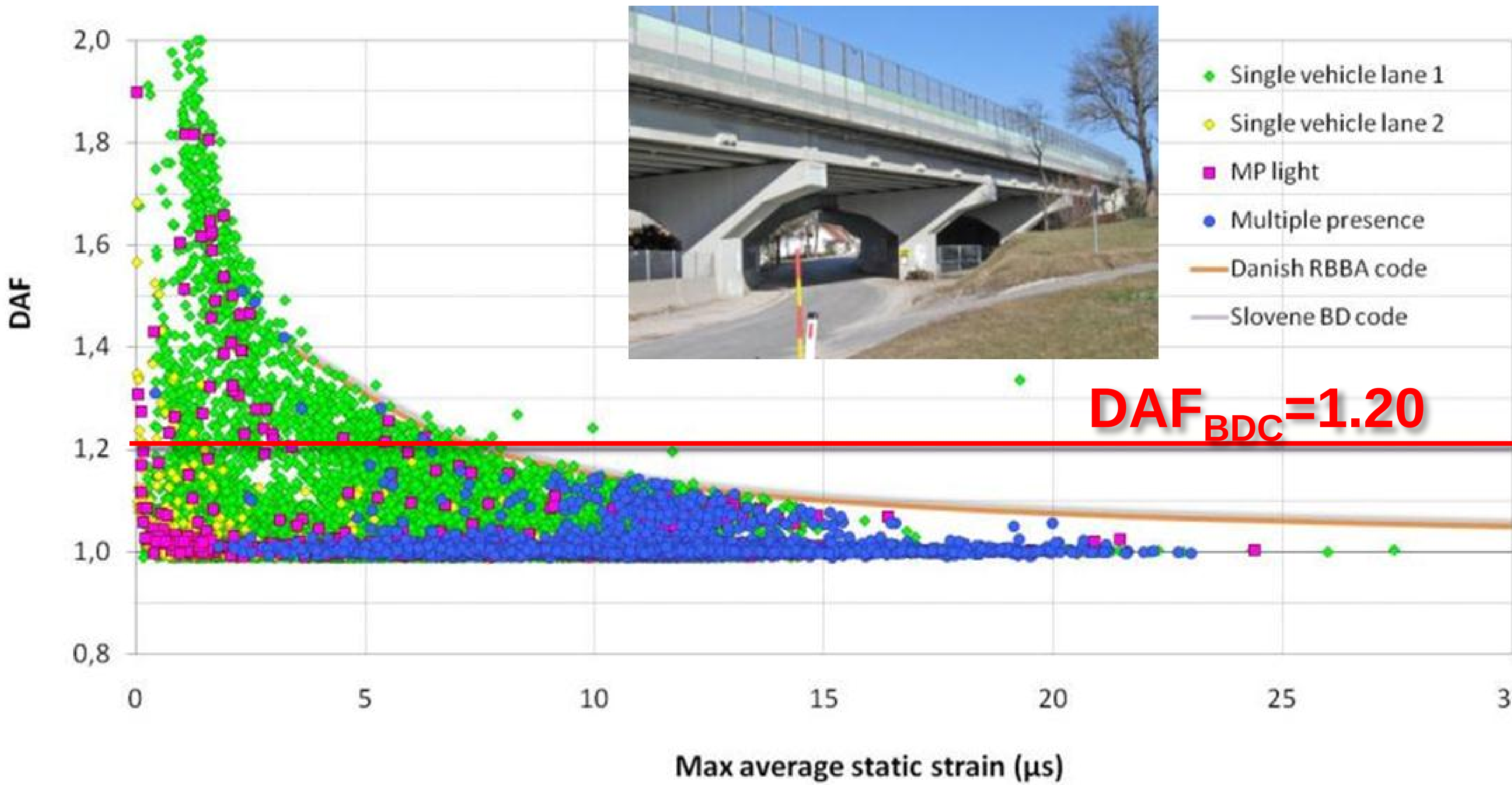
Load Distribution Factors

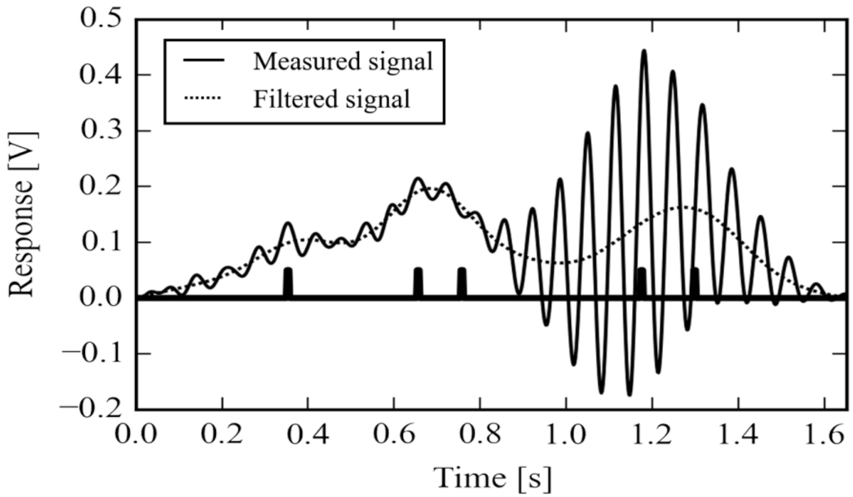


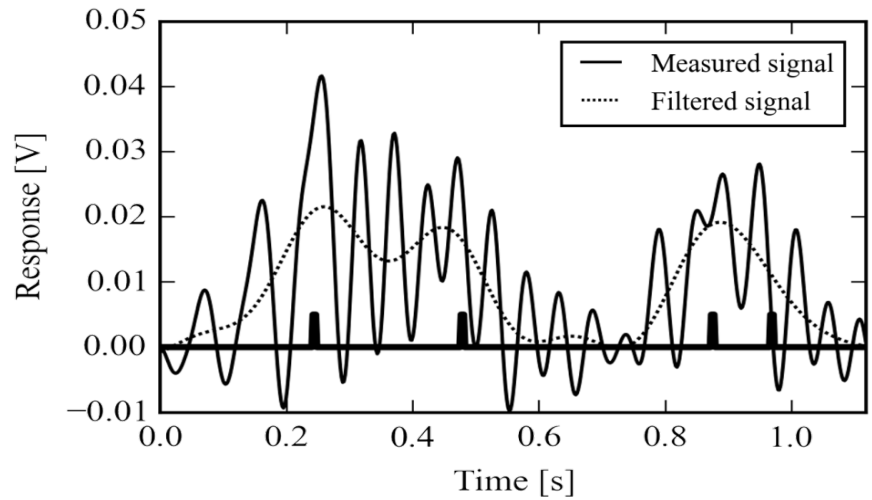
Dynamic loading on bridges

- DAF – Dynamic Amplification Factor: ratio between maximum (dynamic) and static loading
- problem: combining the extremes of static and dynamic effects gives high DAF
- options for assessment:
  - DAF from (design) codes – conservative
  - realistic values:
    - theoretical studies on extreme expected DAF
    - monitoring of every vehicle‘s DAFs with SiWIM® system

DAF – 7×25m beam-and-slab bridge




Measured signal
Filtered signal
Response [V]
Time [s]
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6


Measured signal
Filtered signal
Response [V]
Time [s]
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0.04
0.03
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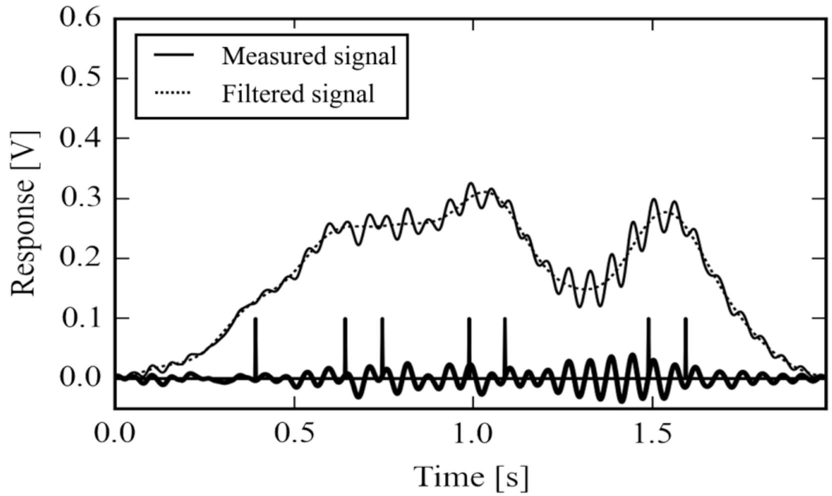
0.0 0.2 0.4 0.6 0.8 1.0


Measured signal
Filtered signal
Response [V]
Time [s]
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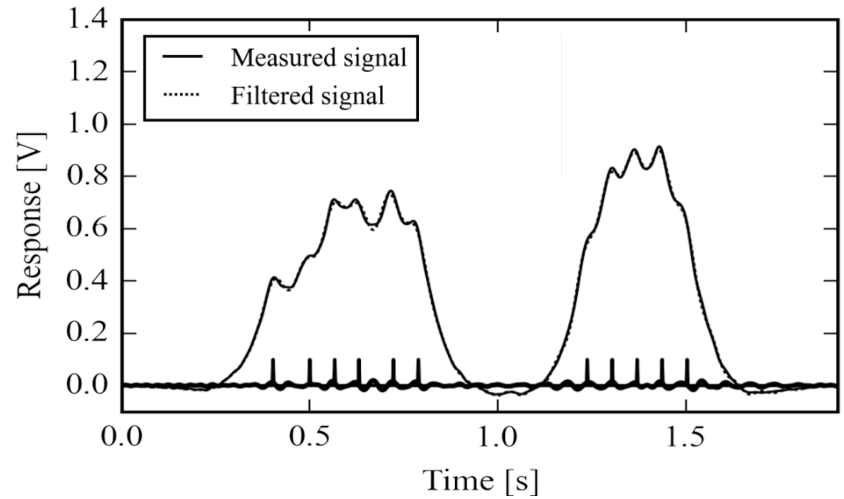
0.4
0.3
0.2
0.1
0.0
0.0 0.5 1.0 1.5


Measured signal
Filtered signal
Response [V]
Time [s]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0 0.5 1.0 1.5

Conclusions

- road traffic will continue to increase and knowing traffic data is key to reducing uncertainties about bridge loading
- loading different from one country to the other (one road to the other)
- WIM a proven technology that provides unbiased information
- accuracy of good systems around ±5 to ±7% for 95% of results
- adequate setup, calibration and maintenance a must
- most popular pavement WIM systems, bridge WIMs emerging
- B-WIM provides useful parameters to improve structural modelling:
  - influence lines
  - load distribution factors
  - dynamic amplification factors…
- more info on www.iswim.org (International Society on WIM)

Thanks for listening!