The Next Generation of Bridge Weigh-in-motion Systems

Bridge WIM measurements of short slab bridges without axle detectors

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Contents

- History of bridge WIM
- Instrumentation
- Major improvements
- Typical accuracy

- Free-of-axle detector B-WIM systems

Bridge WIM Systems

Bridge WIM systems

All B-WIM systems involve an existing instrumented structure from the road network.

B-WIM systems can be used as any other WIM system to collect traffic data.

Any WIM system can provide data for bridge assessment, but B-WIM can give some extra information for this purpose.

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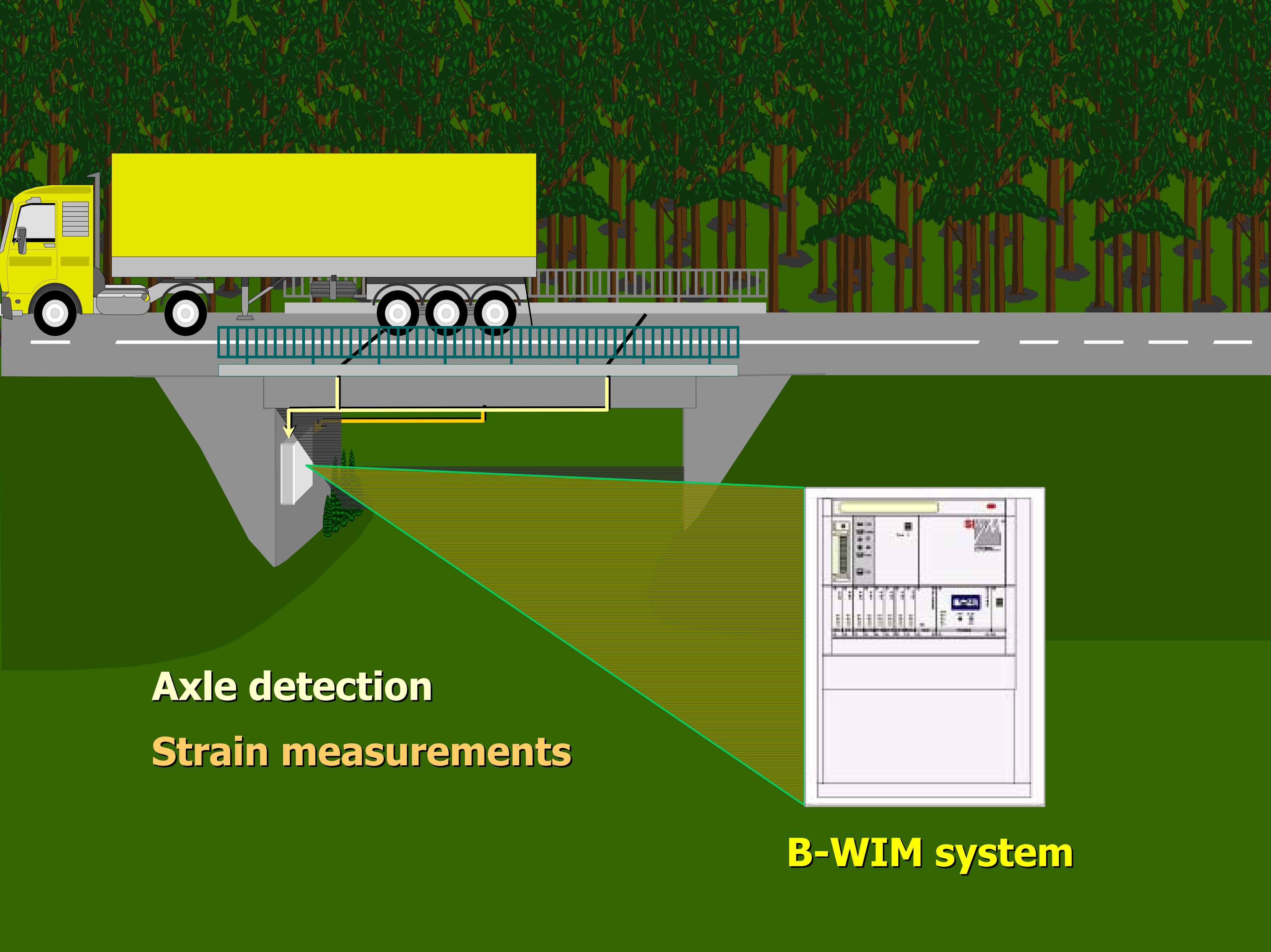
Axle detection
Strain measurements
B-WIM system


izletnik

Bridge WIM

Especially appropriate for:

- short term measurements:
  - it can be easily installed and detached
  - probably the only WIM system, where accuracy of portable installation is as of permanent one
- bridge assessments due to supplementary ‘structural’ data
- installations on heavily trafficked roads due to less or even no interference with traffic

History of B-WIM

- 1979: developed by F. Moses and his team
- 1984-86: AXWAY and CULWAY in Australia
- 1991-95: individual systems in SI, IE ...
- 1996-1999: extensive developments in COST 323 and WAVE
- 1999-2002:
  - development of SiWIM system
  - research in Sweden
  - work in Japan and Tailand

B-WIM before WAVE & COST 323

- 2 approaches:
  - original system, last updated in early 90's
  - CULWAY in Australia (170+ systems)
- limitations of B-WIM:
  - recommended only for some types of bridges
  - good GVW but poor axle weight accuracy
  - limited computer power
  - problems with multiple presence of vehicles
  - not well adapted for Europe

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Advantages of bridge WIM systems

- long scale provides accurate results
- no 'off-scale' weighing
- many times bridges cannot be avoided
- easy and fast instrumentation and maintenance
- portability
- can be used for enhanced bridge assessment due to extra data they provide

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Research on B-WIM in WAVE

- to increase their accuracy
- to extend their applicability to:
  - short slab bridges
  - orthotropic deck bridges
  - longer span box girders
- to develop and investigate new algorithms
- involvement of IE, FR, DE and SI

Instrumentation

- Measurement of bridge deflections under the moving load:
  - Strain transducers
  - Strain gauges
- Recording of axles on the bridge:
  - Axle detectors:
    - Permanent
    - Detachable
  - FAD


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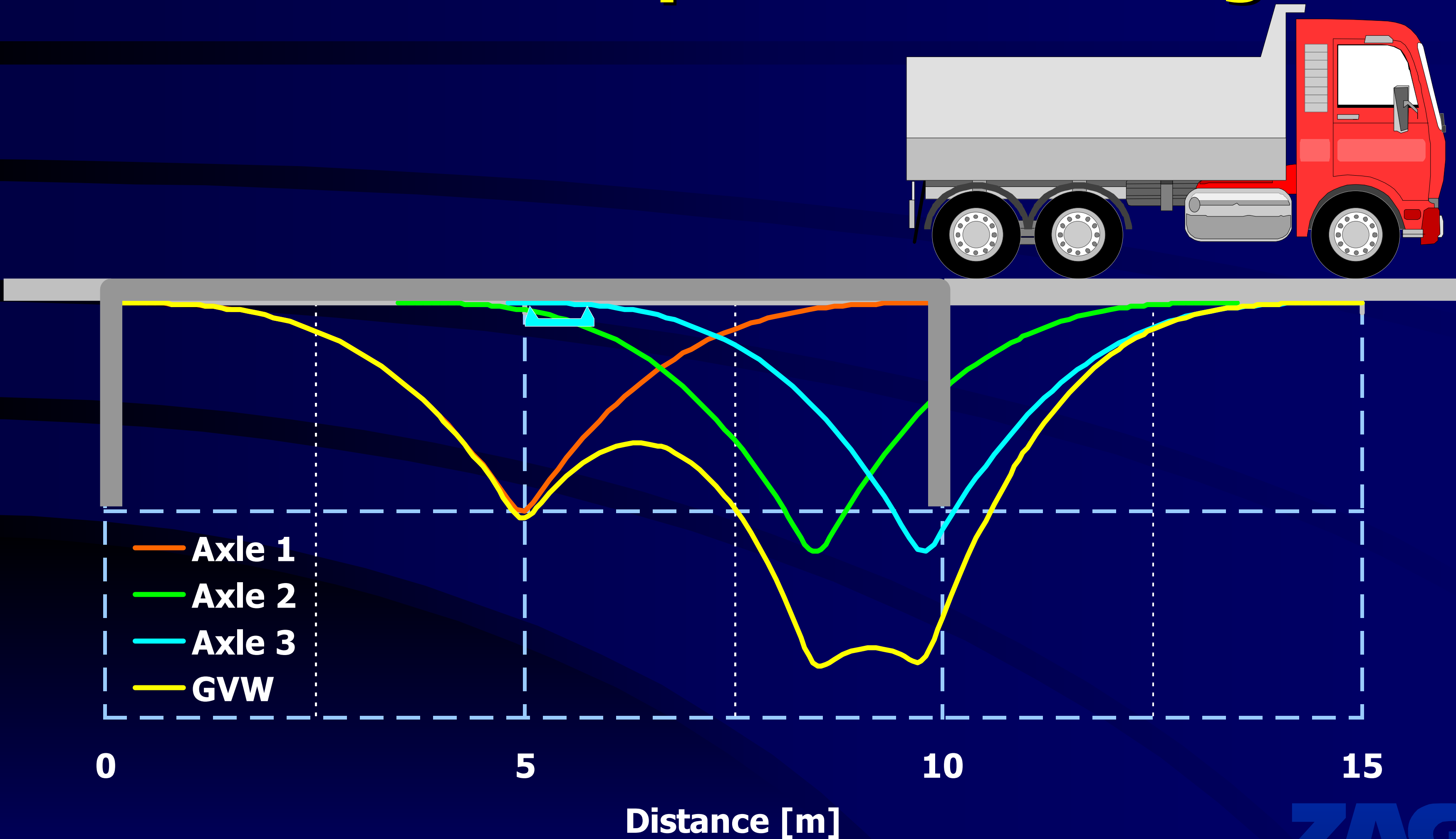
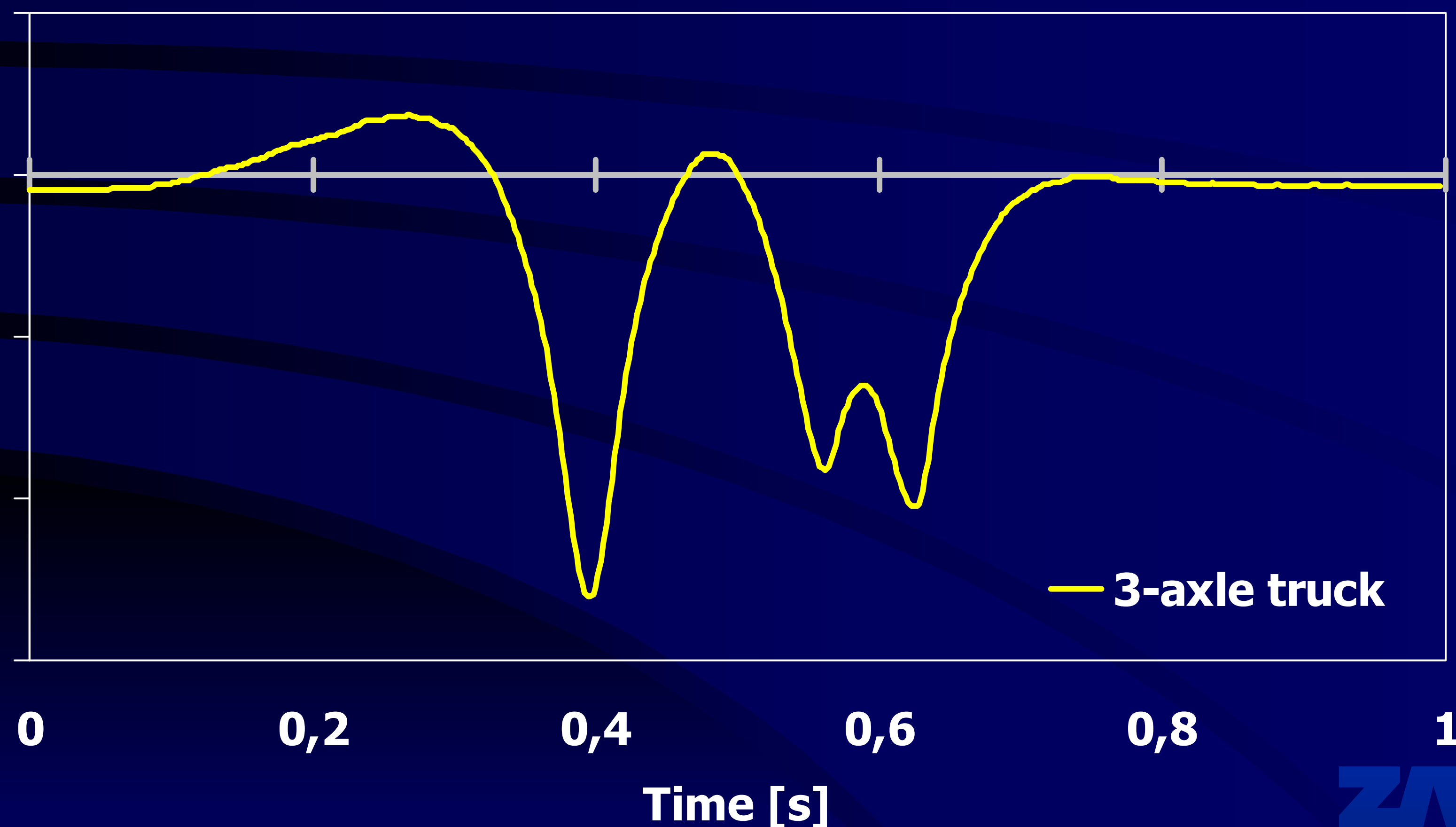
Modelled response of a bridge



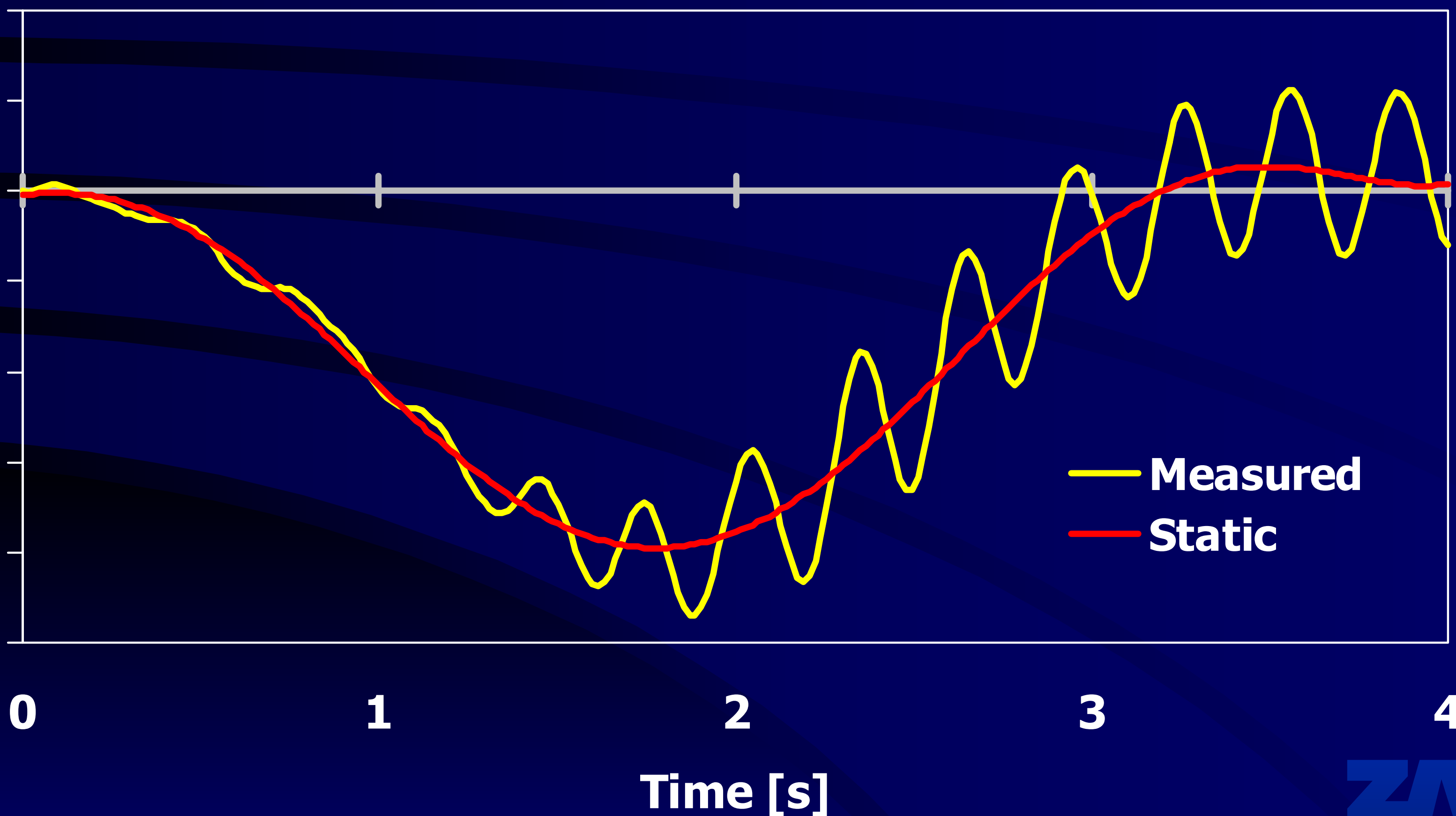
Measured response

8-m concrete integral slab bridge

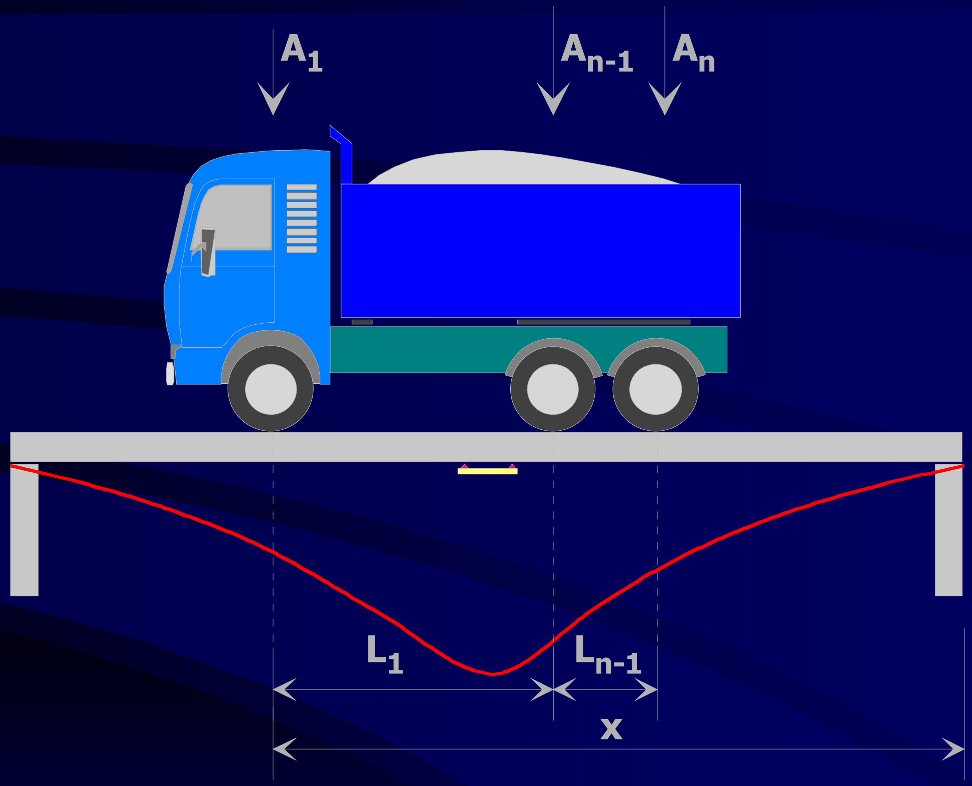


Measured response

32-m simply supported concrete beam bridge

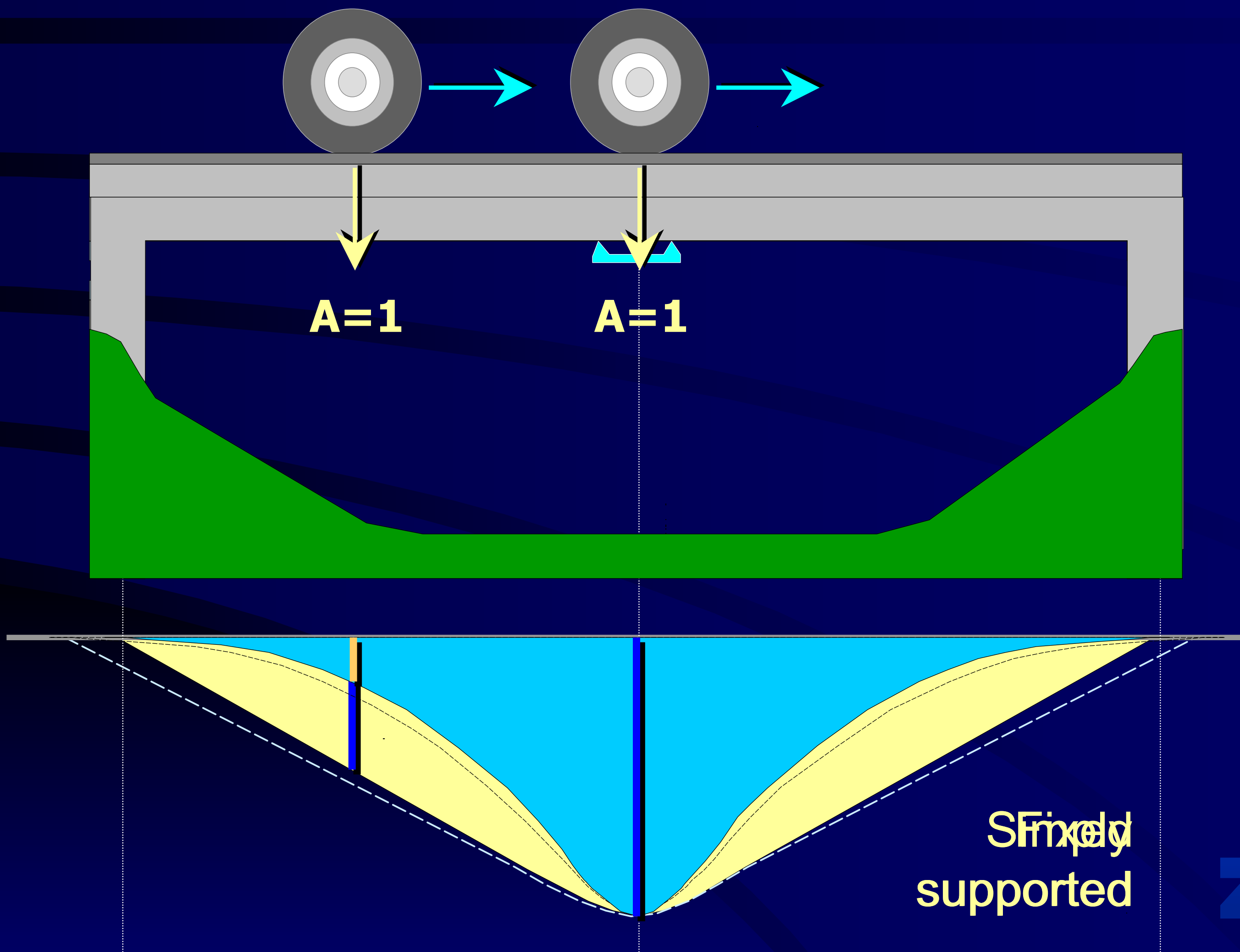


B-WIM principles

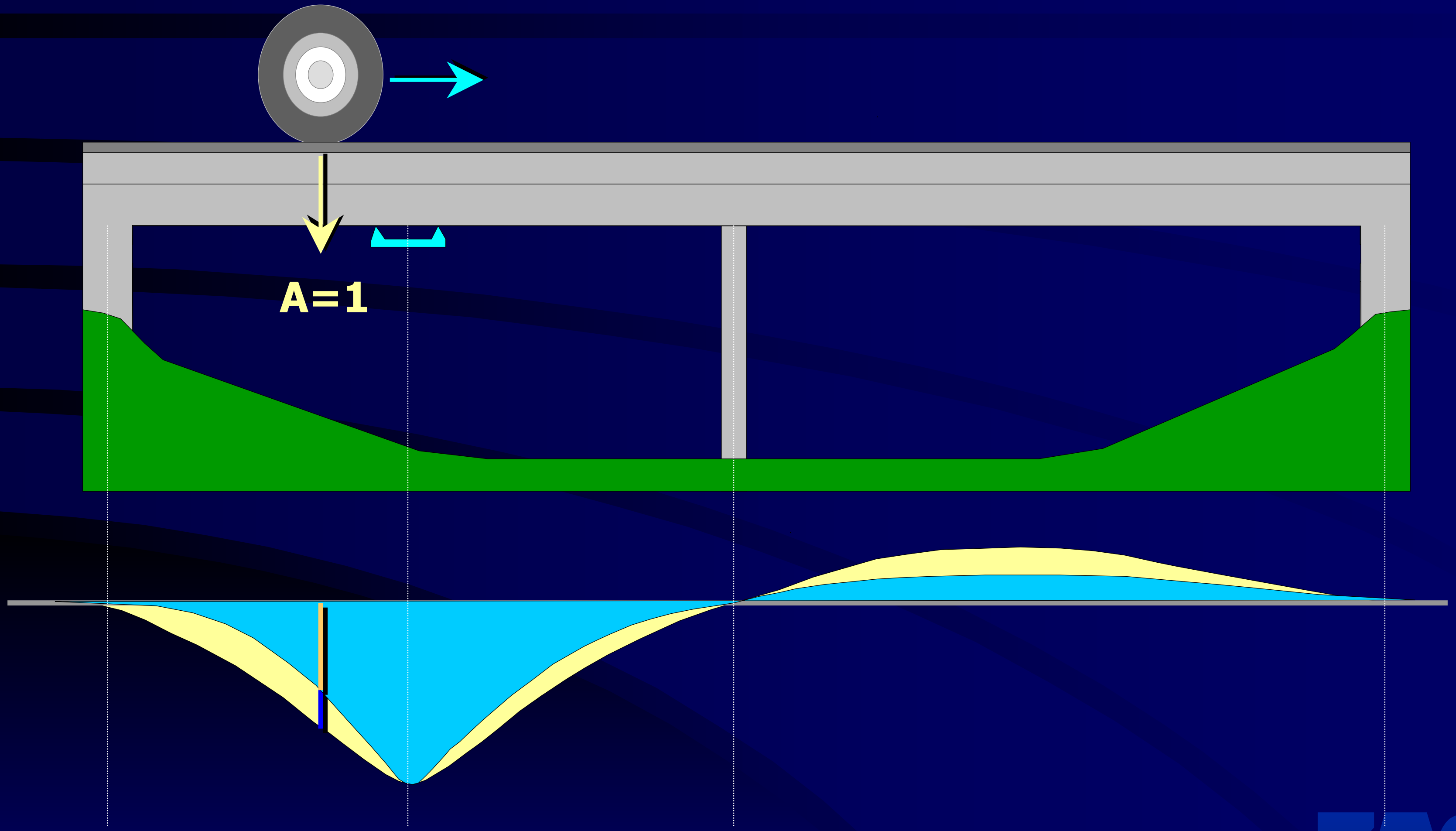


$$M_E(t) = A_1 I(x) + A_2 I(x - L_1) + A_3 I(x - L_1 - L_2)$$

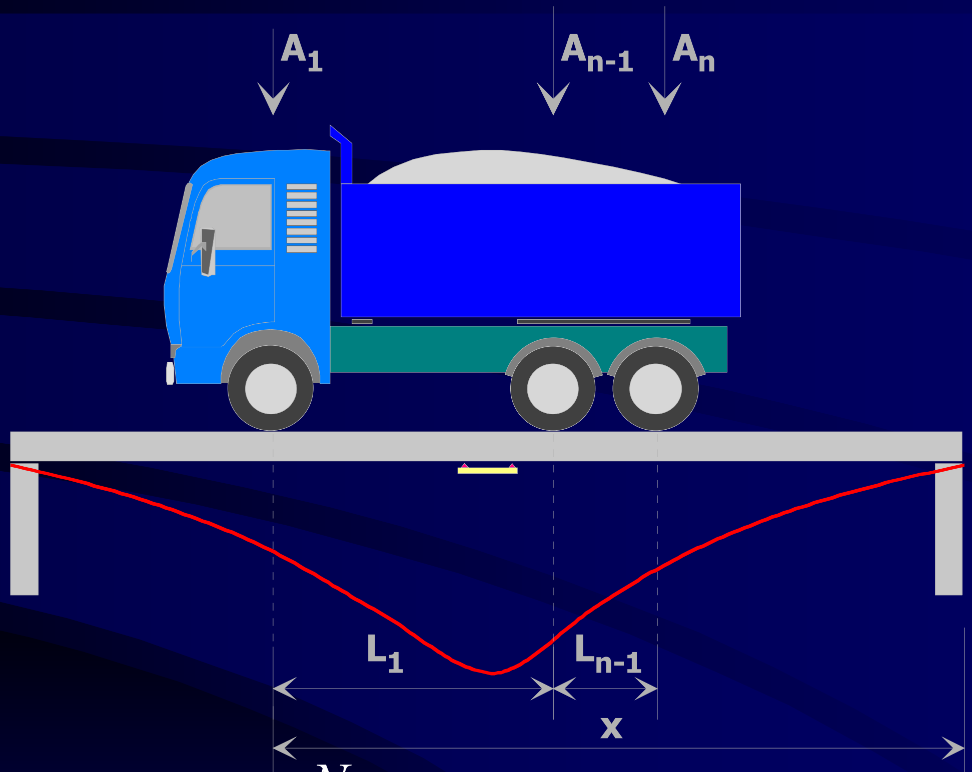
Selection of influence line



Selection of influence line

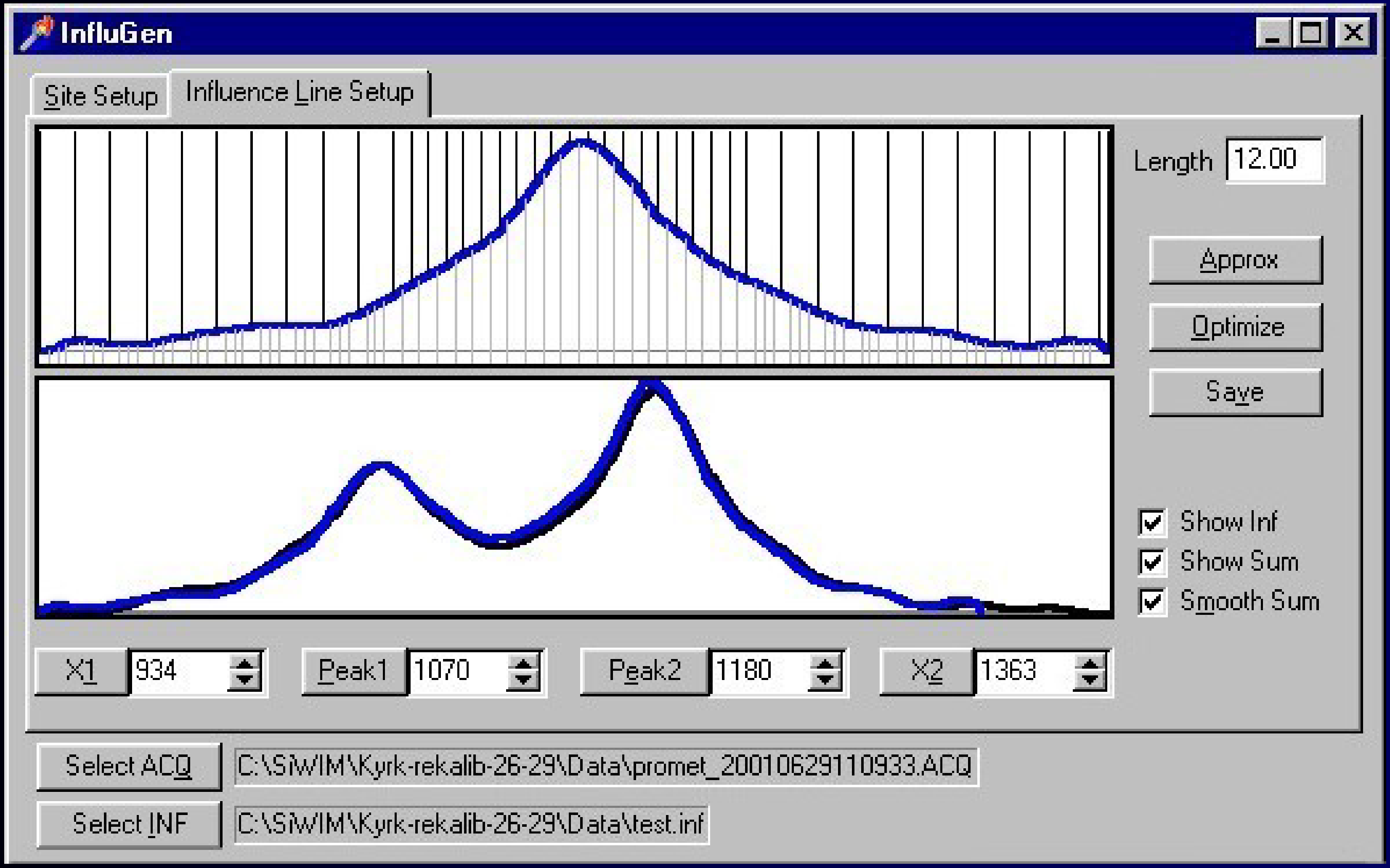


B-WIM principles



$$M_E(t) = A_1 I(x) + A_2 I(x - L_1) + A_3 I(x - L_2)$$

$$M_E(t) = \sum_{i=1}^{N} A_i I(t) = M$$



InfluGen
Site Setup
Influence Line Setup
Length
12.00
Approx
Optimize
Save
Show Inf
Show Sum
Smooth Sum
X1
934
Peak1
1070
Peak2
1180
X2
1363
Select ACQ
C:\SiWIM\Kyrk-rekalib-26-29\Data\promet_20010629110933.ACQ
Select INF
C:\SiWIM\Kyrk-rekalib-26-29\Data\test.inf

Selection of bridges

- in the past:
  - on bridges with spans up to 30 m and
  - on culverts (the Australian CULWAY system)
- today:
  - it does not really matter
- types:
  - short slab bridges
  - beam/deck bridges
  - long-span bridges

Slab bridges

- advantages:
  - being short and slender, they enable more accurate calculation of single axles and axles of a group which in most cases increases accuracy of measurements
  - easy to instrument and maintain
  - in many countries the predominant type of the bridge (60% of all bridge stock in Sweden)

Slab bridges

Span length:

- 1 to 15 m, optimal 5 to 10 m

Thickness of the superstructure

- 30 to 60 cm
- soil layer up to 1 m (conditionally to 2 meters)

Boundary conditions

- fixed supported the preferred type of structure

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Single vs. multiple spans

- no theoretical limitation to instrument both
- two factors:
  - multiple-span bridges generally longer => higher probability of multiple presence events
  - bridges with 2 or more shorter spans (up to 12 meters) allow for efficient 2-line FAD installation, with one plane of ST in each span

Girder/deck bridges

- Advantages:
  - being generally longer they give better GVW
  - stresses due to traffic loading are concentrated in beams/girders in longitudinal direction => strains are easier to measure than on 2D slab bridges
  - being longer than slab bridges, it is often easier to deal with dynamic effects

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Girder/deck bridges

- Disadvantages:
  - they are fewer than slab bridge
  - span is generally longer, which results in higher probability of multiple presence events
  - superstructures are deeper, which results in lower axle load accuracy
  - spans with length around 30 m can exhibit considerable dynamic excitations

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Girder/deck bridges

Span length:

- newer: over 15 meters
- older: from few meters

Thickness of the superstructure:

- could be well over a meter

Boundary conditions:

- usually simply supported at first and last abutment, with an extension joint in the pavement
- newer multi-span structures usually continuous over the intermediate supports

Long-span bridges

- Features:
  - Conventional B-WIM instrumentation not possible
  - measurements can be taken on their ‘substructures’ in lateral direction (stiffeners)
  - short secondary spans and very thin steel deck provide sharp strain peaks => FAD
  - Due to sensitivity in lateral direction, more strain detectors are needed in the transverse direction which gives transverse position of trucks in lanes
  - measurements can be used for fatigue calculation

Long-span bridges

- Disadvantages:
  - No real time, long-term measurements yet
  - More complex installation

B-WIM on steel box girders

- Belleville bridge

Skewness of the bridge

- minor effect on accuracy of results for properly instrumented and evaluated bridges (1 accuracy class per 15-20°)
- after checking of the test measurement and calibration data, angles up to 60° are acceptable (90° being straight)
- skewed bridges however require additional attention during installation and calibration

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Static vs. dynamic loading

- The reasons for dynamic or WIM results not being identical to statically weighed results:
  - Axle and vehicle movements (bouncing)
  - Bogie axle height differences
  - Other load transfers
- As a result, weights measured by WIM are unlikely to be the same as those measured statically

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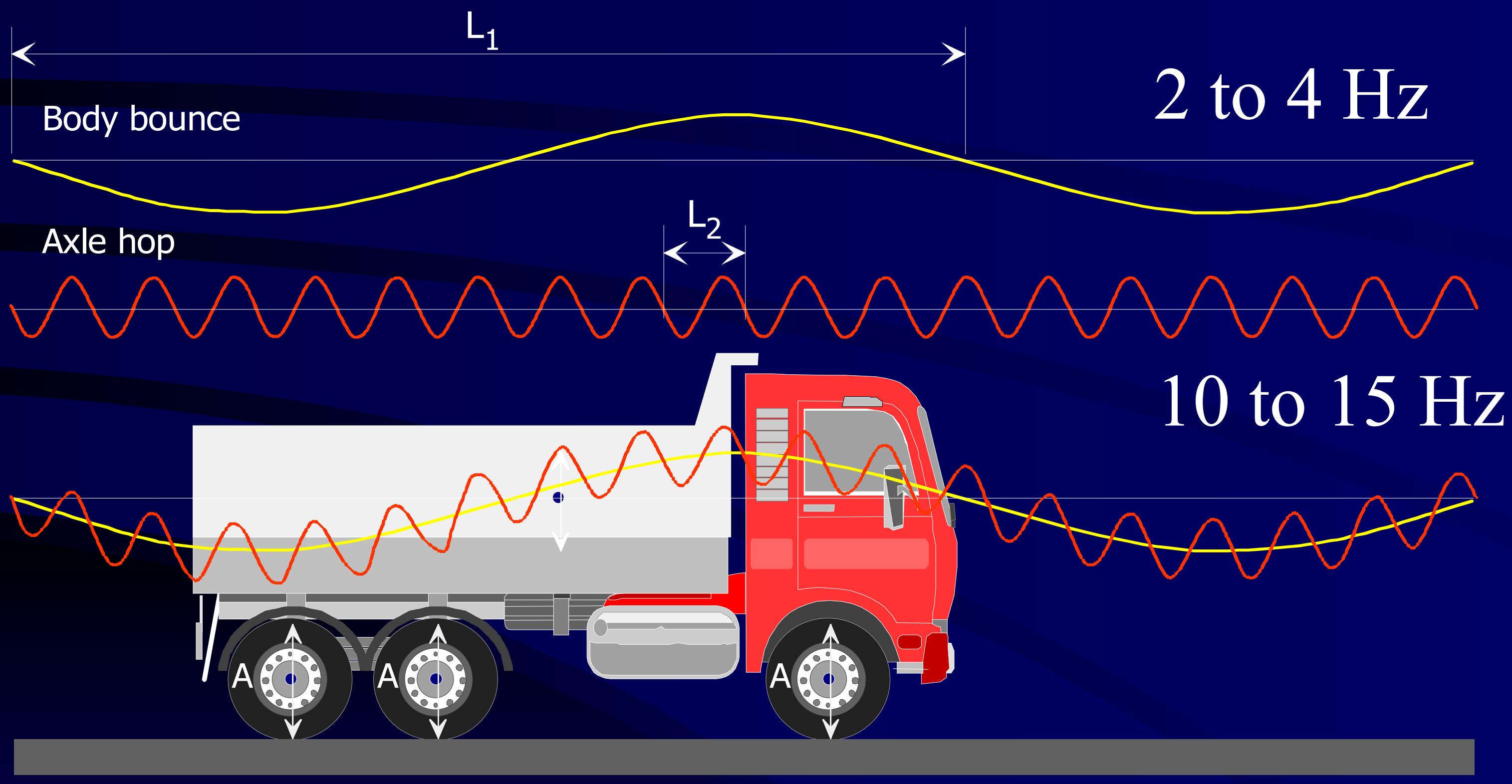
Static vs. dynamic loading



Dynamic effects and B-WIM

- bridges are long => dynamic effects have less effect on accuracy of B-WIM than on P-WIM systems
- beam/deck bridges:
  - problem eigen frequencies (A. Gonzales)
- shorter slab bridges:
  - with no major unevenness (bump, ruts, bad expansion joints) on the approach to the bridge, the level of dynamic effects is low
  - in other cases, (rigid) vehicles ‘fly’ over the bridge
  - importance of velocity calibration

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Accuracy of bridge WIM systems

- the fact that the whole length of a span is used for weighing should provide 'accurate' results
- important parameters:
  - selection of the influence line
  - type of the bridge
  - vehicle-bridge interaction:
    - quality of the approach
    - velocity

Recent results

CET test – Luleå, Sweden – June '97

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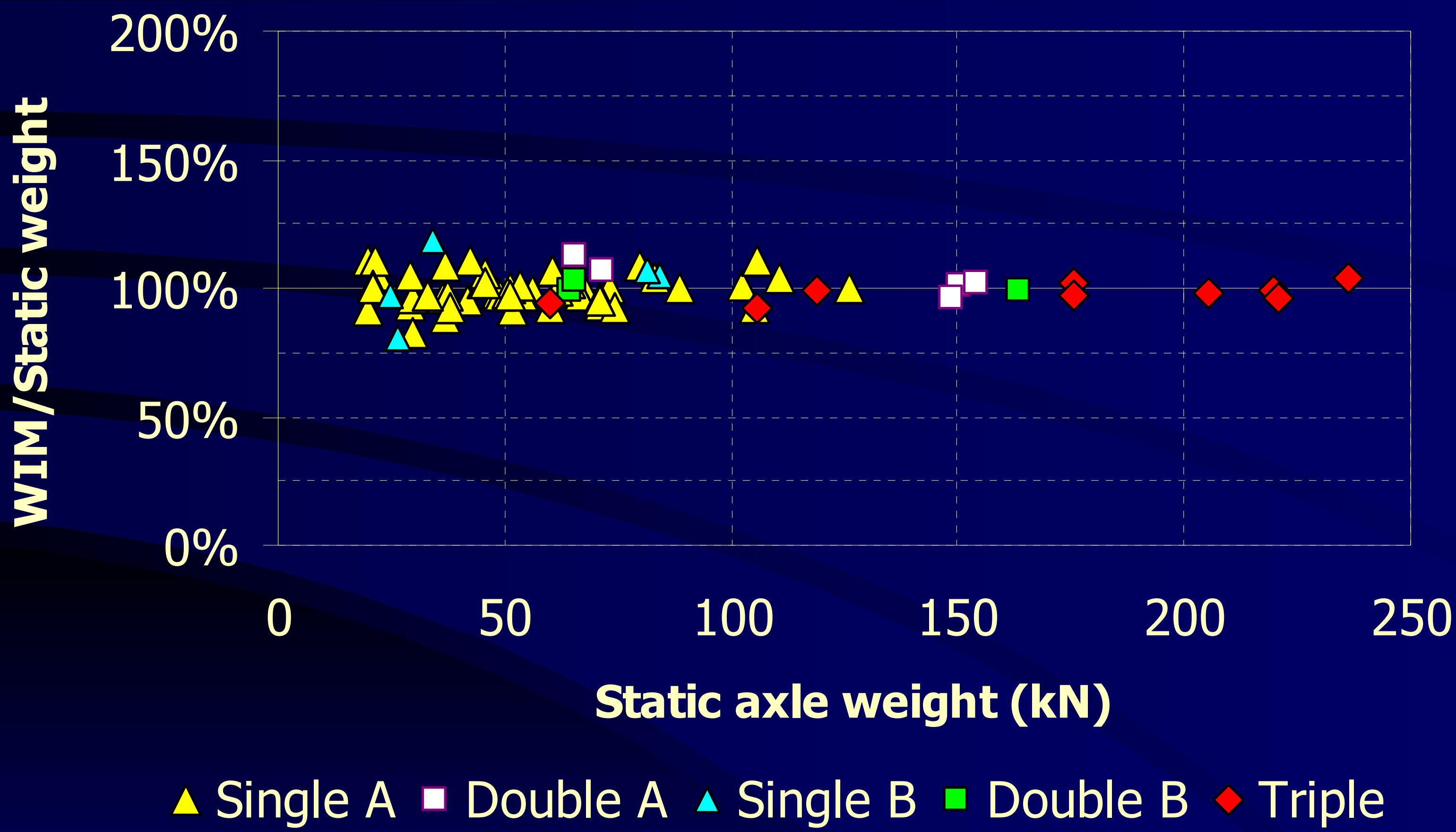
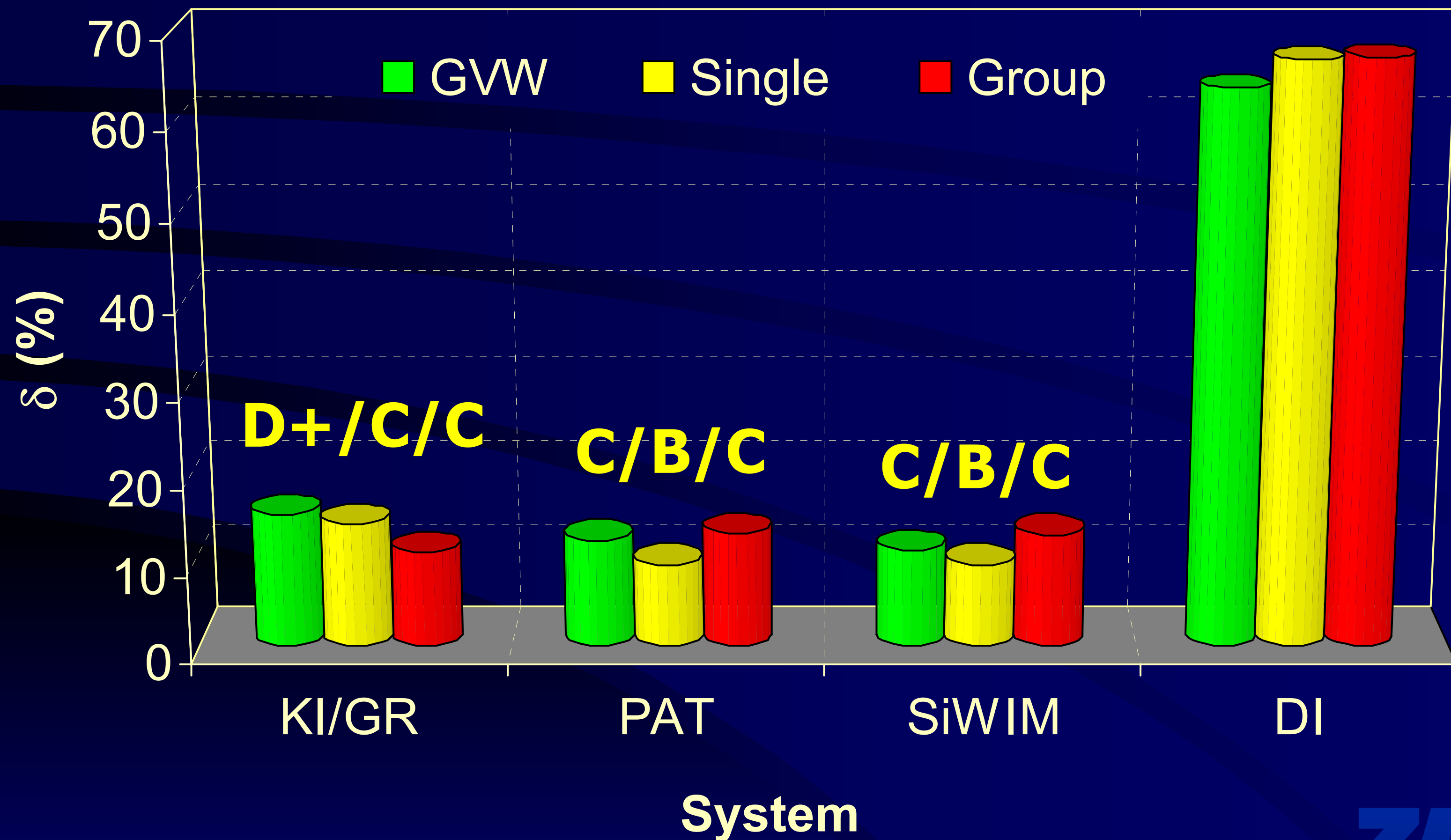
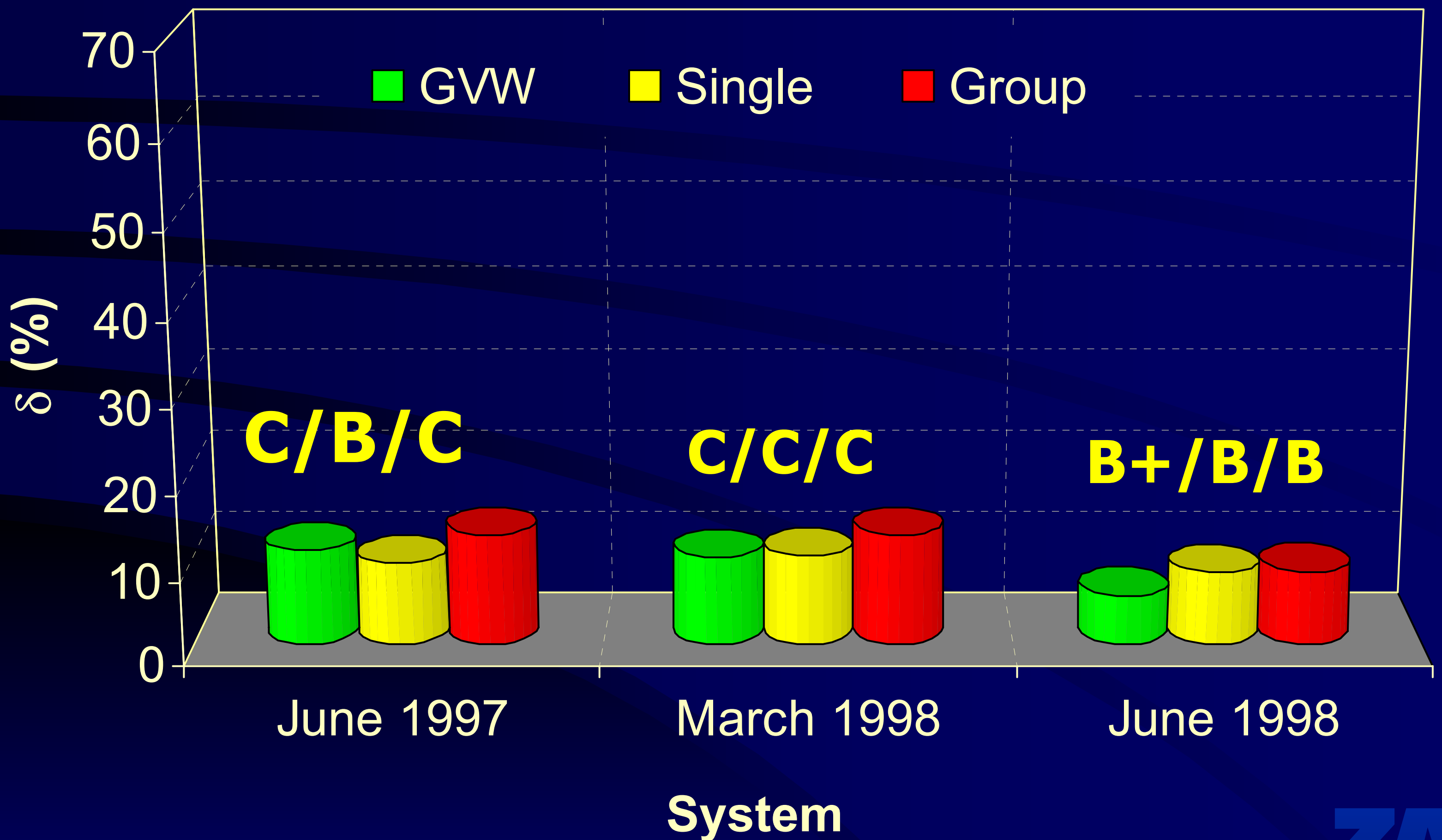


CET test – Luleå, Sweden – June '97



CET test – Luleå, Sweden




C(15)*


C(15)

B(10)*

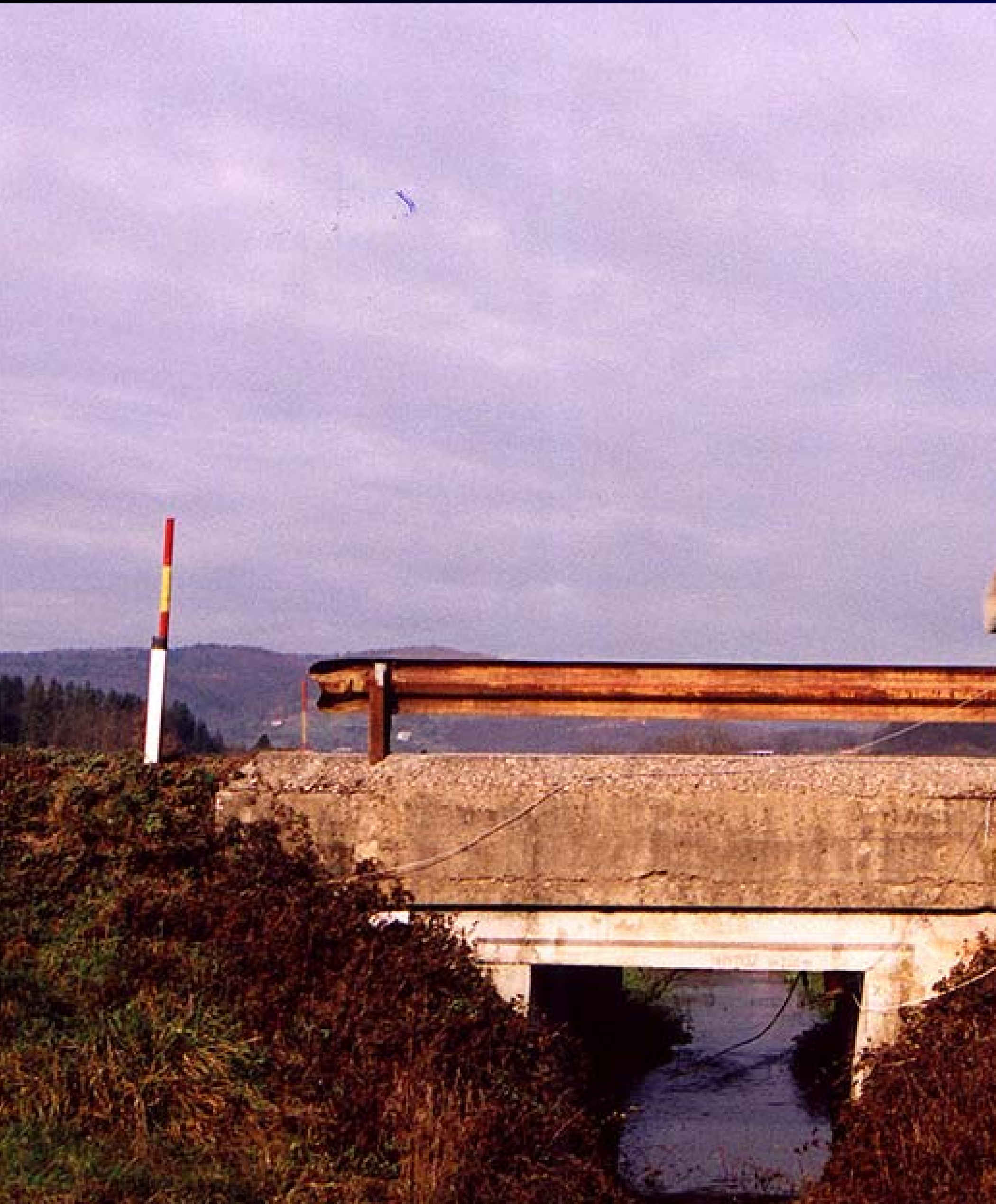
D(20)*


D(20)*/B(10)


C(15)*


B+(7)


D(25)*




C(15)*


A(5)/D+(20)

Bridge Weigh-in-Motion Measurements on Short Slab Bridges Without Axle Detectors

FAD bridge WIM system

- FAD (Free-of-Axle Detection B-SIM system):
  - on some bridges it is possible to detect axles without axle detectors
  - it greatly improves durability and easiness of installation of WIM systems

FAD bridge WIM system

Parameters which influence strain response under the moving vehicle:

1. Shape of the influence line
2. Ratio between the span length and the (shortest) axle spacings
3. Thickness of the superstructure
4. Dynamic interaction of the vehicle-bridge system

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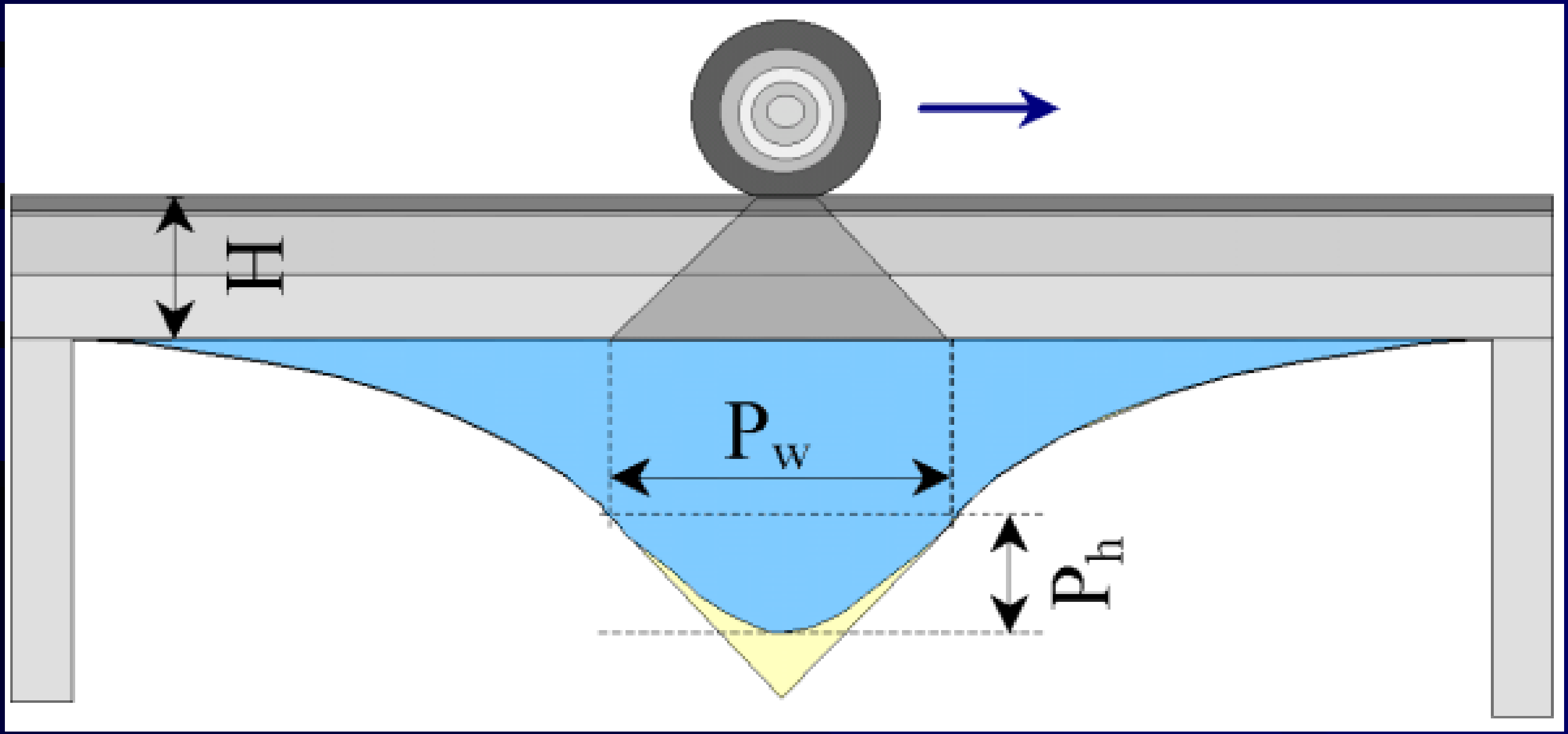
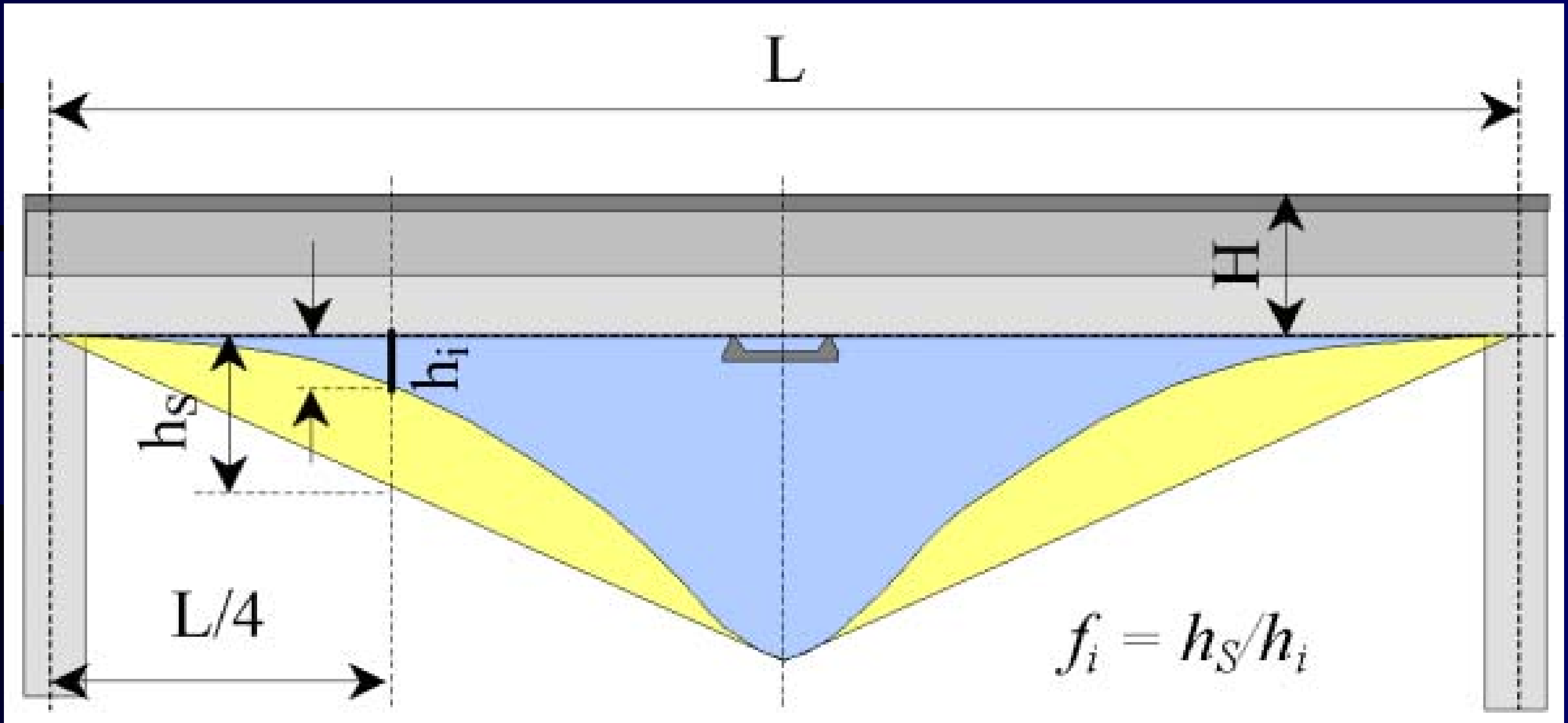
FAD bridge WIM system
Influence of structure's thickness



FAD bridge WIM system

Effect of influence line



$$FAD = \frac{L \times h}{d_{\min} \times f_i} < 2$$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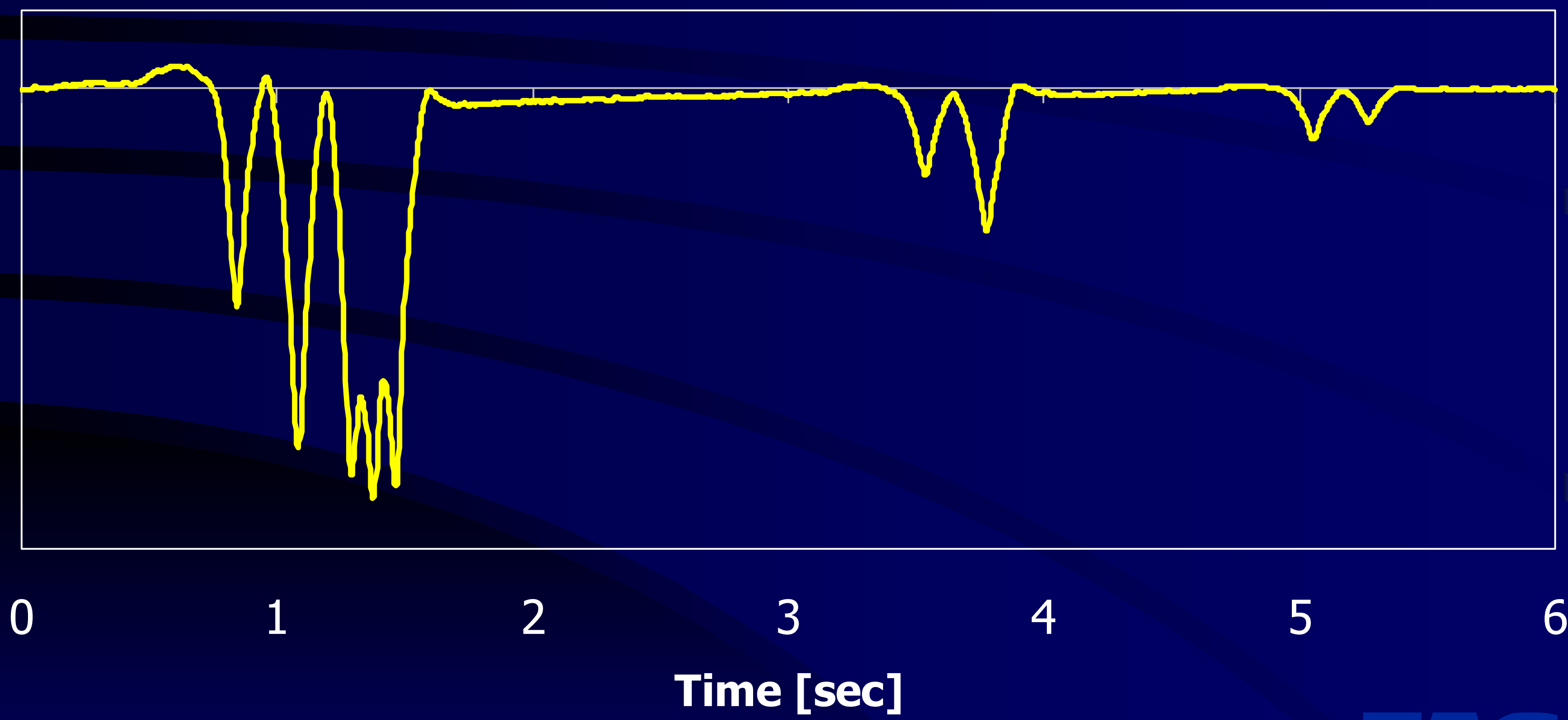
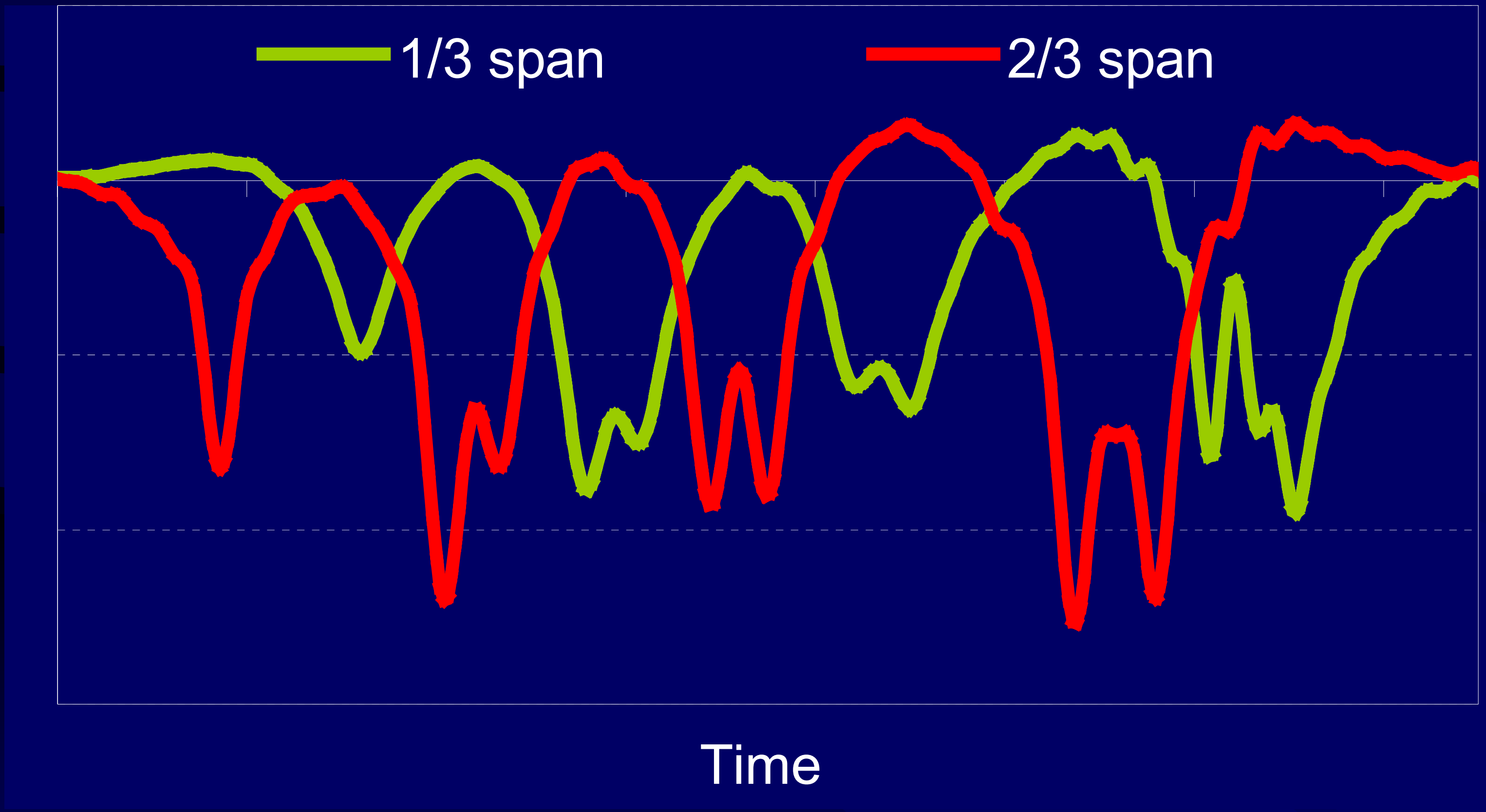
2×3-m ‘integral’ slab bridge

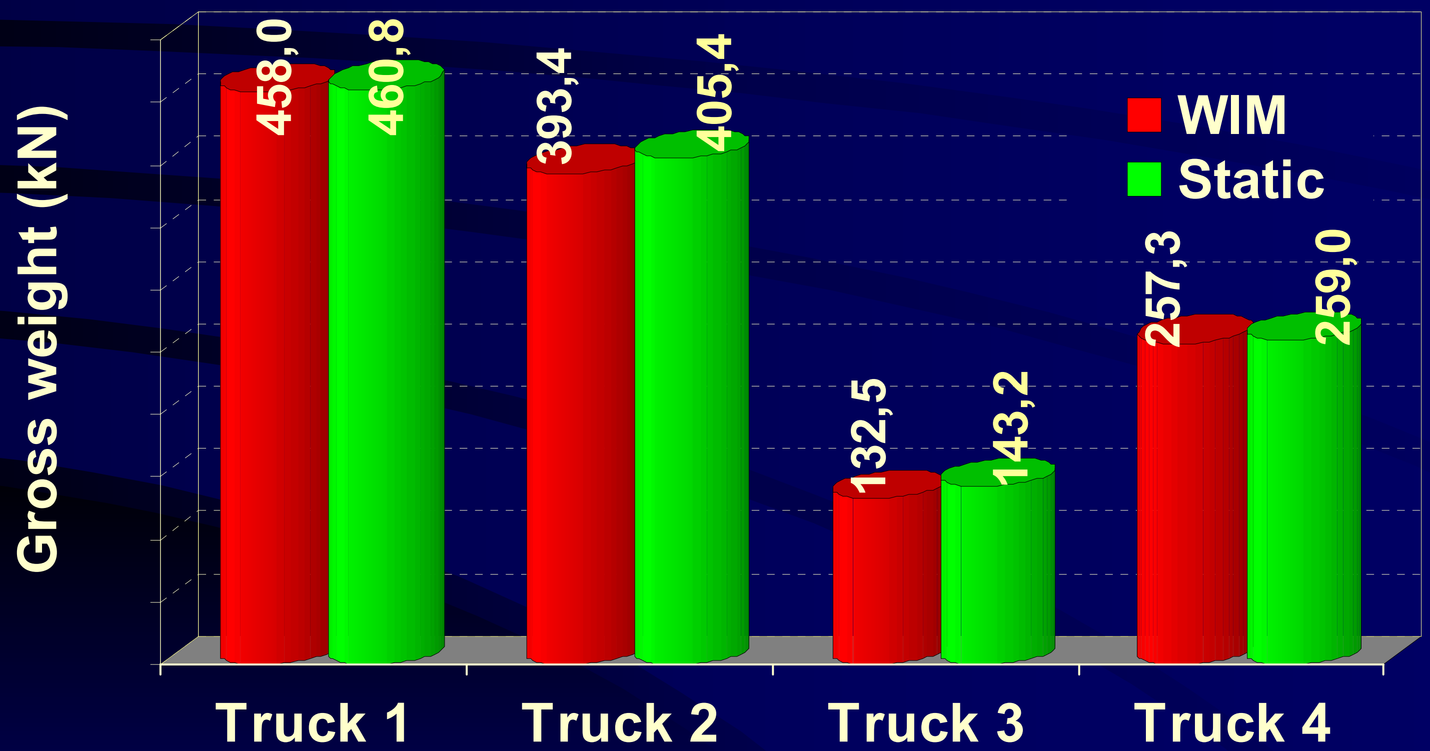



2,7m

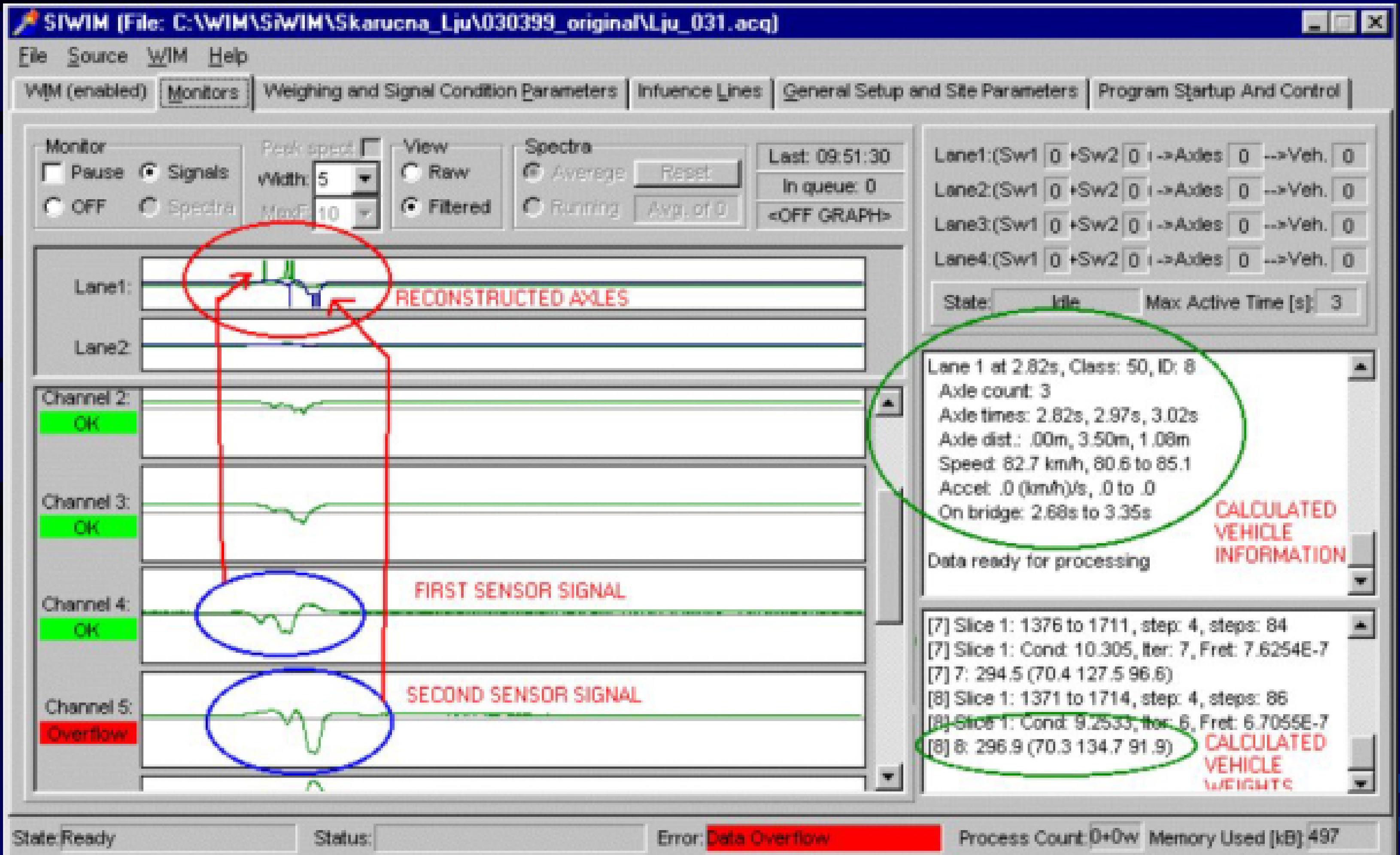
9-m integral bridge



9-m integral bridge



FAD software



Conclusions

Considerable progress since COST 323/WAVE:

- better selection of appropriate bridges
- higher accuracy - up to B+(7) :
  - measured influence lines
  - velocity calibration
  - calibration per axle rank
- improved user-friendliness – SiWIM system:
  - automized calibration
  - influence lines generation

Conclusions

Considerable progress since COST 323/WAVE:

- Free-of-Axle Detector (FAD) B-WIM concept
- calibration:
  - by vehicle type
  - by axle rank
- perspectives for:
  - enforcement
  - bridge assessments
  - special traffic requirements
  - due to its portability