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ISWIM Workshop
Benefitting from Weigh-in-Motion Data

ISWIM
International Society for Weigh in Motion

Use of WIM Data in Europe

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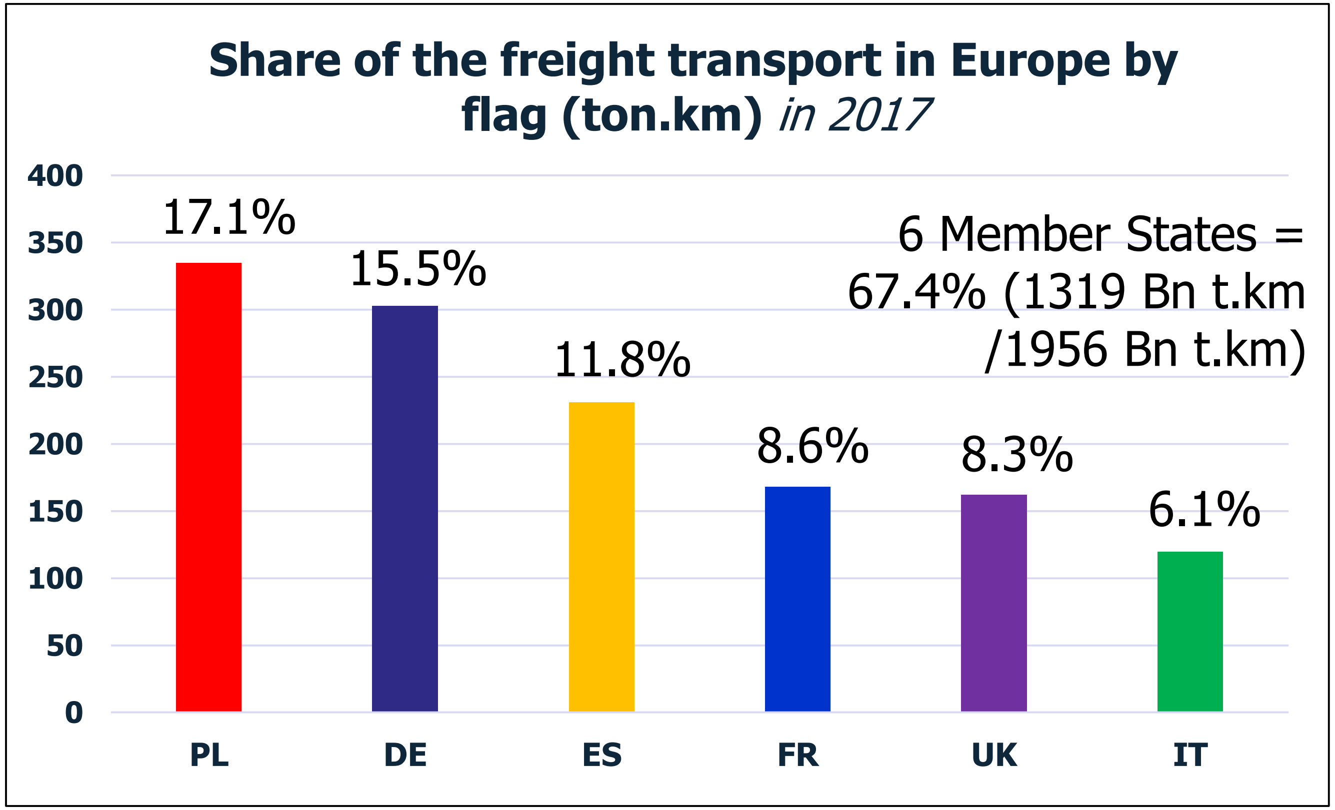
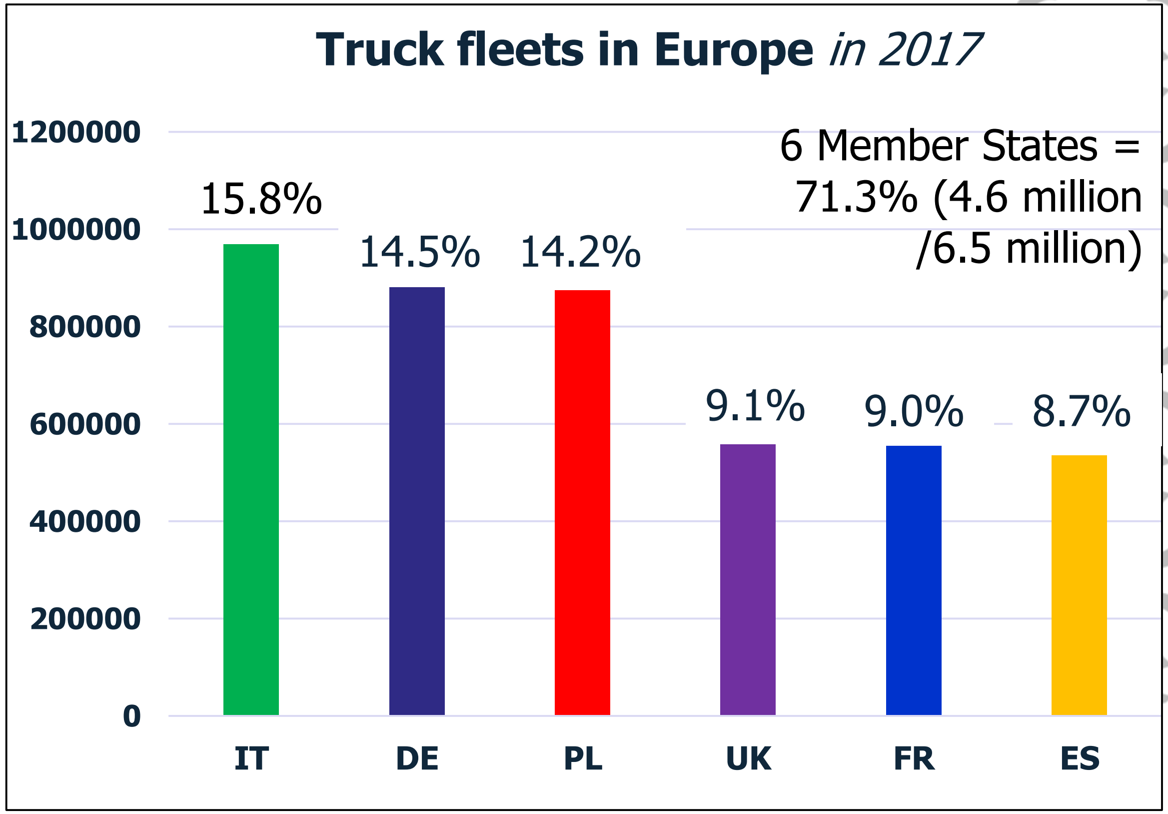
Road Freight Transport in Europe (Facts and Figures)





- ❖ 77% of the in-land freight is carried by road
- ❖ 35% is made of International transport (t.km)
- ❖ 75% of t.km over medium/long distance (> 150 km)
- ❖ 85% of tonnage carried over < 150 km, 1% over > 1000 km

WIM Data Collection and Applications

- Data collection 24/24, 7/7 without staff required
- All vehicles in the equipped lanes are weighed
- Discrete and safe, quick installation, low intrusive
- Allows to assess infrastructure wear (e.g. fatigue) and to plan future maintenance works
- Allows to develop and (re)calibrate loading codes (bridge and pavement)
- Allows monitoring the road freight transport activity and heavy traffic on a road network
- Helps to ensure a better compliance of weights and sizes of HGVs, thus to increase road safety, infrastructure durability and to guarantee a fair competition in freight transport

Required Accuracy of WIM Systems (COST323) by Application

- Heavy traffic monitoring, statistics on road freight movements, HGVs, etc.: low accuracy = C(15) to D(25), but no bias
- Infrastructure assessment (pavement, bridge, extreme loads and fatigue assessment): medium accuracy = B(10) to C(15), high scattering may lead to biased assessments (e.g. non-linearity in fatigue)
- Overloads screening: high accuracy = B+(7) or B(10), possible adjustment of the threshold of overload detection
- Direct enforcement: very high accuracy = A(5) + Legal metrology certification: OIML class 5 or 10, m.p.e. instead of statistical approach (100% of the data in the tolerances)

Road Safety: Truck Spacing Monitoring on a Motorway (A63, Atlandes, France)

Direction	Dist	Day	Night
North > South	25-50m	7.1%	3.1%
	5 à 25m	1.9%	0.8%
	Doubtful (<5m)	0.1%	0.2%
	>= 50m	90.8%	95.9%
South > North	25-50m	7.5%	4.8%
	5 à 25m	2.1%	1.4%
	Doubtful (<5m)	0.2%	0.2%
	>= 50m	90.1%	93.6%

- Flow > 4,400 trucks/day/direction
- Route: France ↔ Spain

- Truck spacing (free traffic)
- *Wild platooning*, without permit, automation nor connectivity
- ⇒ Safety risk

Traffic Monitoring: Lifted Axles Counting

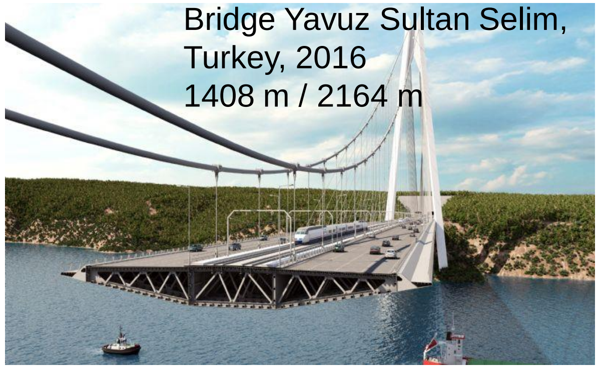
1.1 – 3.7 – 5.7 – 1.3+1.3 – 3.4 m

7.0 – 1.3 m

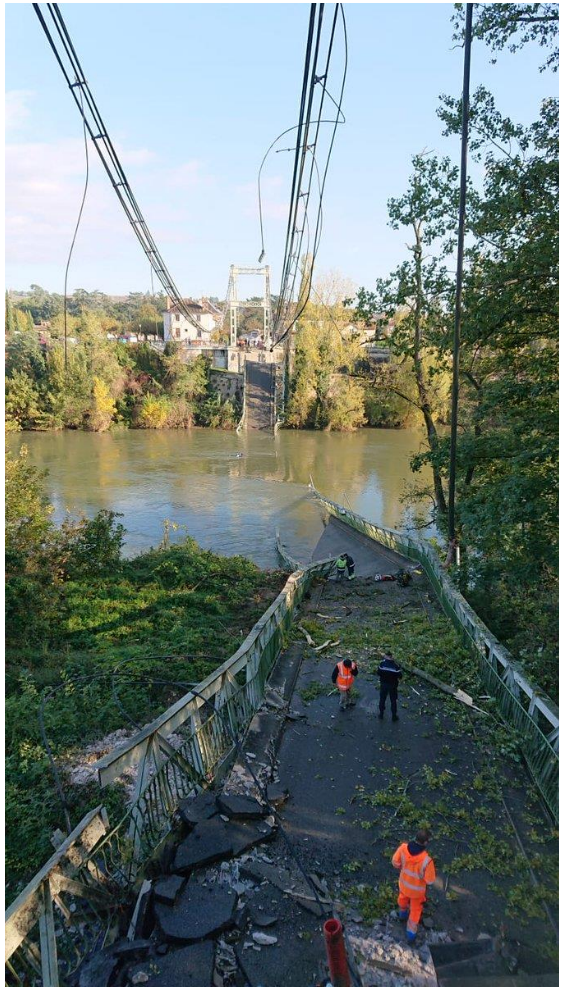
- ❖ Deviation from the mean spacing may reveal a lifted axle (low std dev. of the axle spacing)
- ❖ Robustness depends on the silhouette (high for T2S3)

Bridge Issues - Evolution

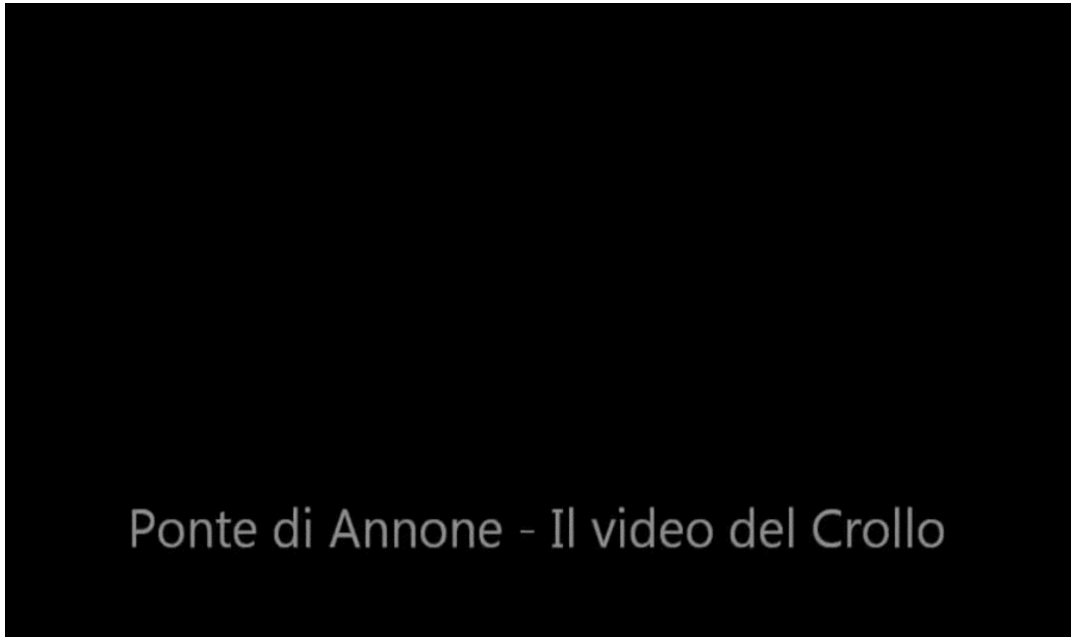
- Bridges are lighter with high performant materials, more accurate design, economy of material and energy, while traffic loads continuously increase
  $\Rightarrow$ increase of the ratio: LIVE LOAD/DEAD LOAD
- Long span bridges are sensitive to the accumulation of heavy vehicles, shorter ones to single trucks' loads
- Fatigue can affect steel and composite bridges
- Not all the bridge collapses result from overload, but overloads increase risks
- Traffic loads are not fully known (time history, load pattern)
- The bridge safety factors are progressively and implicitly decreasing (material aging + load increase)



Bridge Collapses under Overloads



Mirepoix, 2019



- ❖ Some bridges are aging, with limited load capacity
- ❖ Overload may cause bridge collapses:
  - Sully s/Loire (France, 1986)
  - Mirepoix (France 2019)
  - Annone (Italy, 2018)
  - Aulla (Italy, 2020)

Sully s/Loire, 1986

Aulla, 2020

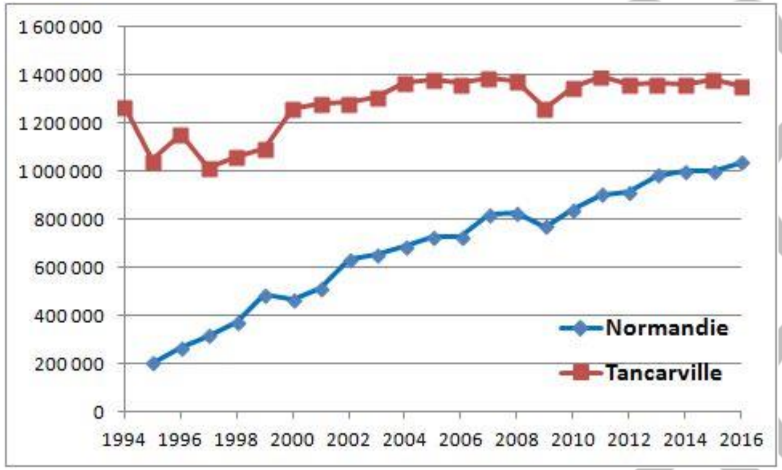
Abnormal Loads on a long span cable-stayed Bridge (Normandy) - Challenge

- ❖ Bridge of Normandy (1995) over the Seine river, cable-stayed, main span 856 m, total length 2.1 km, orthotropic steel deck sensitive to fatigue, toll bridge

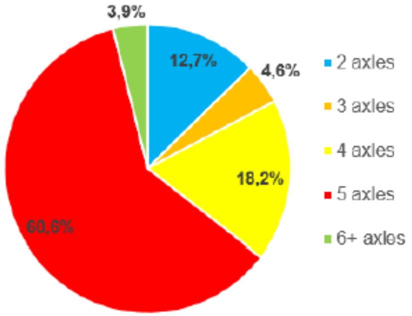
- ❖ Maximum allowed GVW: 44 t
- ❖ 2018: feasibility study to allow abnormal loads up to 120 t

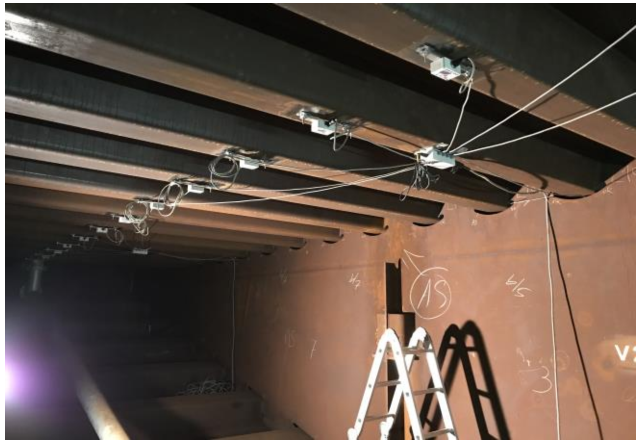
Instrumentation and WIM Data Collection

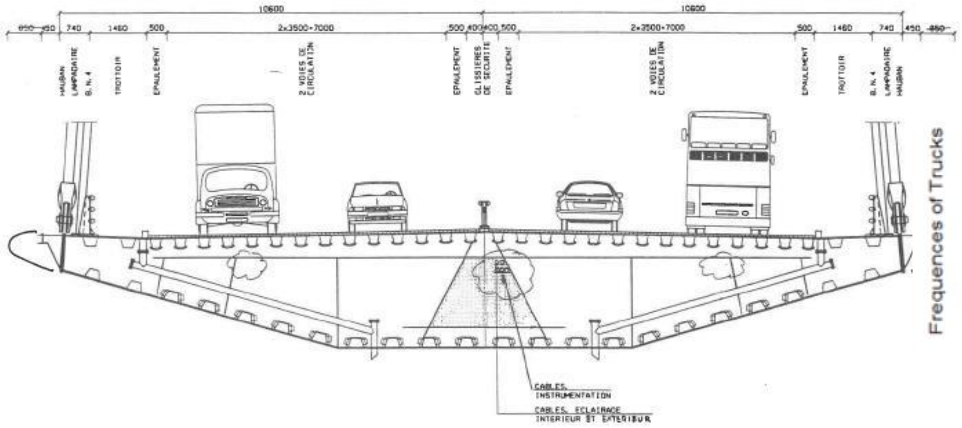
- Loading assessment: traffic flow increased
- Use of B-WIM (SiWIM) to assess the current traffic loads

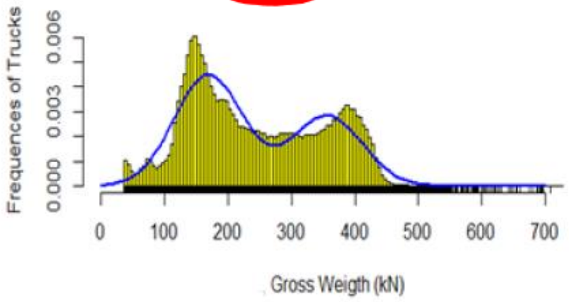


- Calibration, accuracy assessment and WIM data collection over 6 months:
  - Rather low accuracy COST323 D(25)
  - Sufficient for fatigue assessment





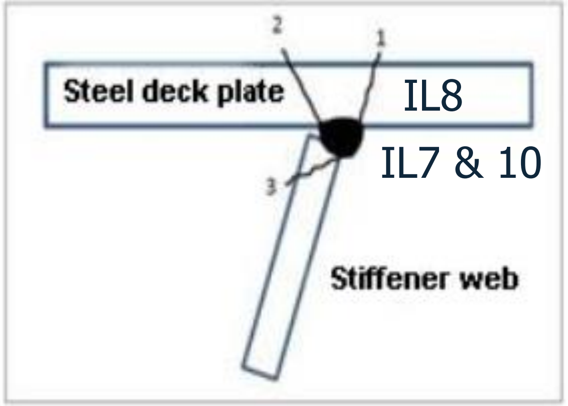


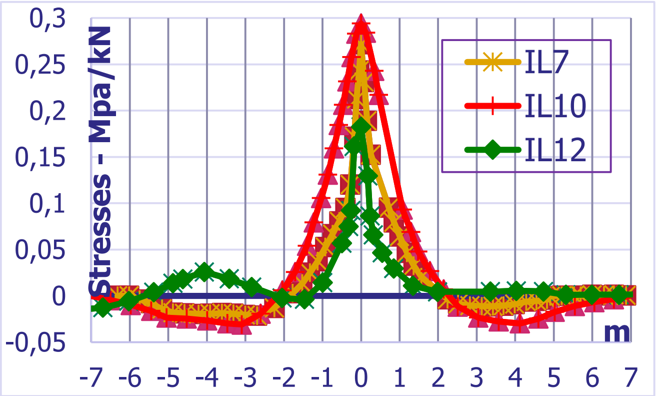


B-WIM (SiWIM) installed in July 2017

Fatigue Assessment

- 4 traffics considered (recorded WIM data), with various aggressiveness
- Most critical details analyzed with influence lines
- Lifetime calculations (Miner law, class 71) for each traffic flow…
  - … for the abnormal loads
  - Assessment of the lifetime reduction (in %)





Infl. line	Crane 1 (96 t)	Crane 2 (108 t)	C1 (94 t)	C2 (120 t)
IL7	9.778 (1.53%)	9.530 (1.57%)	13.754 (1.10%)	4.124 (3.56%)
IL10	4.349 (0.78%)	4.348 (0.78%)	5.354 (0.63%)	2.140 (1.57%)
IL8	13.238 (2.59%)	13.140 (2.61%)	19.976 (1.73%)	6.280 (5.30%)

Traffic	A29	A20	RN4	A9
IL7	254	296	274	75
IL10	57	40	33	10
IL8	586	588	573	113

	A29	4 AL	Final	red.
IL7	254	3190	235	7.37%
IL10	57	1496	55	3.67%
IL8	586	4618	520	11.3%

The Netherlands/Rotterdam
Van Brienenoord Bridge

Determination of ULS & fatigue spectrum as an input for recalculation and determination of the rest life of the bridge and the design of reinforcement operations

Both bridges instrumented with OSMOS Optical Strands
Eastern bridge : 51 strands
Western bridge : 12 strands

Mitigation of Overloads on Bridges by WIM

- Most of overloaded vehicles cross bridges illegally **periodically** above all on secondary roads
  - thus, monitoring continuously bridge crossings will allow to detect the first overloads, identify the vehicles (camera…) and take preventive measures (e.g. company warnings)…
  - … or to take measures afterwards, but before the bridge collapse

- Identification of illegal crossings can allow targeted checks nearby the bridge

- On main highways/motorways, most bridges are well designed even against overloads (partial safety factors). However, direct enforcement can dissuade overloading.

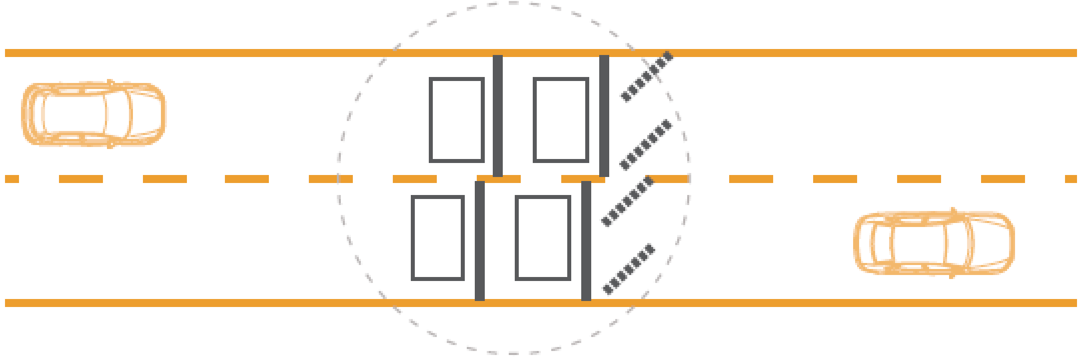
WIM for Direct Enforcement

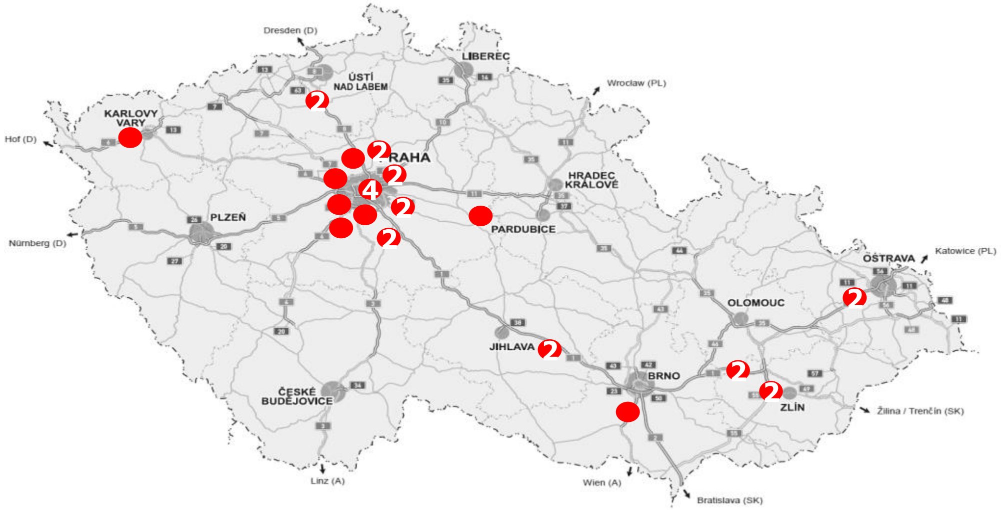
- Two EU Member States already implemented HS-WIM for direct enforcement: Czech Republic (since 2011-13) and Hungary (2017). However, the test procedure in CZ remains with a statistical approach (95% of measurements within the tolerances)[1]
- Four more EU Member States are engaged in the process:
  - Belgium: R&D + tests since 2016 (SPW)
  - France: National research project (2014-…), DoT (DGITM) + IFSTTAR/Univ Gustave Eiffel + Cerema, phase 1 (feasibility, tests of sensors and systems – Kapsch + Sterela - done, phase 2 in progress (type approval procedure)
  - Germany: two R&D projects supervised by BAST (methodology and type approval process)
  - Poland: AGH carrying out tests on site

[1] Czech Metrology Institute, 21/5/2010, art. 5.4.6.3 Weigh-in-motion accuracy tests
"The number of relative errors exceeding the maximum permissible error P_{de} *must not be greater than 5%, with their distribution among individual vehicle types being recorded."*

Direct Enforcement in Czech Republic

- ❖ Fully-Featured WIM System
  - ➢ 2 inductive loops per lane
  - ➢ 4 quartz sensors per lane
  - ➢ 2 piezo sensors per lane



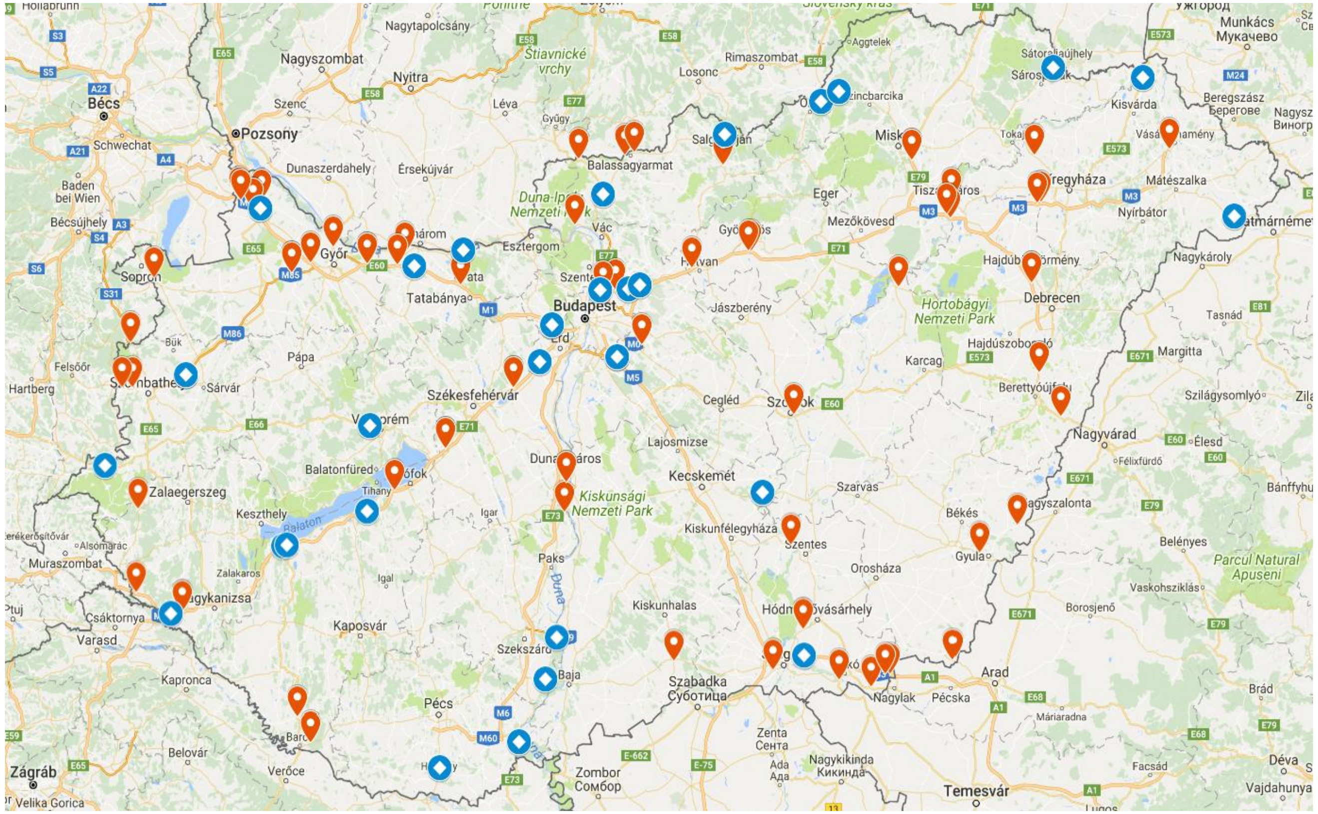


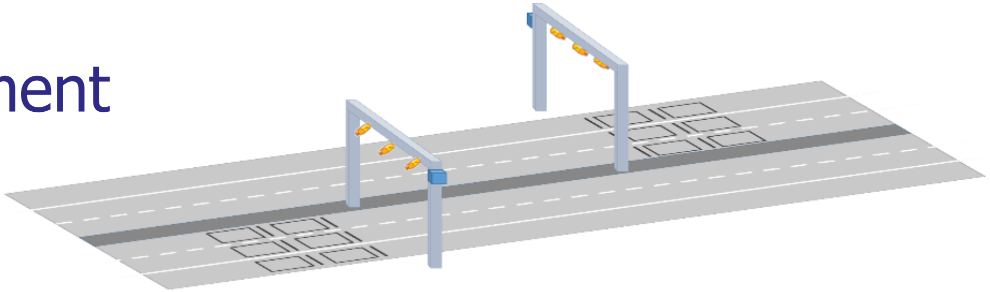
„Velke Mezirici"

- ❖ Performances
  - ➢ Gross weight tolerance ±5%
  - ➢ Axle load tolerance ±11%
  - ➢ Multi-tire detection
  - ➢ Axle width accuracy ±10 cm
  - ➢ Speed accuracy ±1 %
  - ➢ Vehicle length accuracy ±0.3 m
  - ➢ Advanced vehicle classification
- ❖ Elimination of doubtful data

Direct Enforcement in Hungary

- ❖ 89 WIM systems, a half for direct enforcement

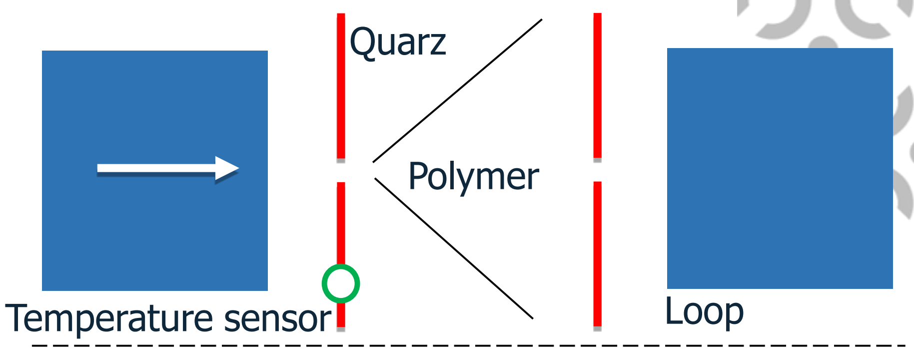


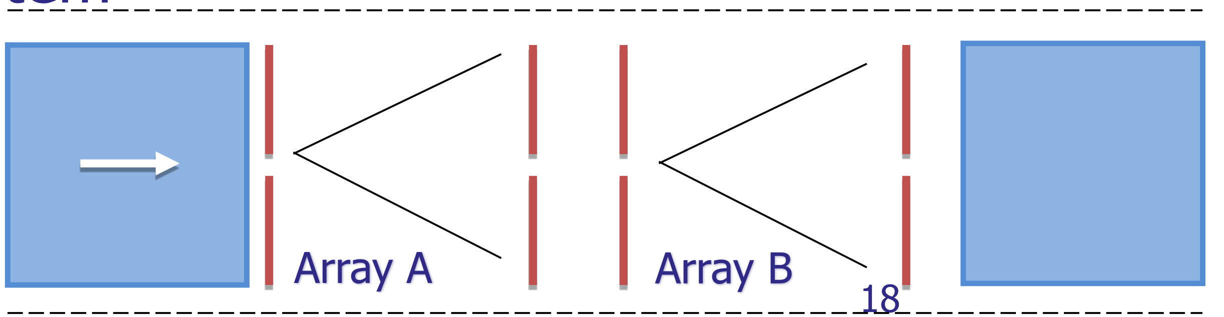


- ❖ OIML type approval by the Legal Metrology
  - ➢ Accuracy class for GVW: 5
  - ➢ Accuracy class for single-axle load (two-axle rigid vehicle): F
  - ➢ Accuracy class for single-axle load and axle-group load (but two-axle rigid vehicle): E
  - ➢ Scale interval: 100 kg

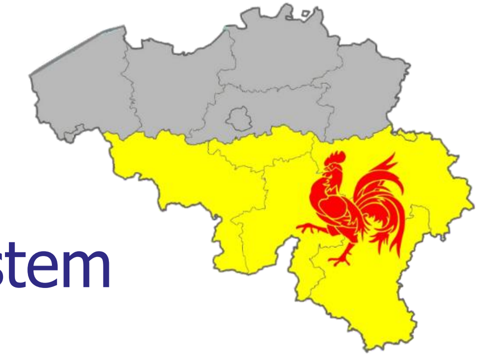
Belgium (1)

- 5 WIM systems installed since 2015 for pre-selection
  - ~ 9 millions trucks and light commercial vehicles (vans) weighed per year
  - Overload rates: vans (max 3.5t) : ~31%
    5-axles articulated (GVW 44 t, axle 12 t) : ~10%
  - > 95% of selected vehicles are penalized (but special permits and doubtful measurements)
- Royal decree: approval, verification and installation of measuring instruments used to monitor enforcement of the law relating to road traffic…
- …to deliver a type approval HS-WIM system for direct enforcement (OIML R-134)
- Validation method using a second WIM array (Array B)





Belgium (2)



- Results of 6-month test on a motorway with a Sterela system

Start Period	End period	Calibration	Conditions
September 2019	February 2020	Yes	II-R2**

Type of vehicles	Validated vehicles (out of)	Mean	Std. dev.	Accuracy	Confidence level	Out of tolerance
		%	%	%	%	
T2S3	182 (404)	0.33	1.49	5	99.999	0
U2 (vans)	186 (188)	-4.61	2.83	10	99.977	0

Accuracy according to the COST323. Test conditions: full environmental reproducibility conditions
Confidence level from a statistical Gaussian distribution.

- Type approval tests are in progress since May 2020, according to Specs by Sterela + METAS, approved by the Walloon Legal Metrology from Belgium
- OIML class 5 for 5-axle trucks, class 10 for vans
- Objective: direct enforcement implemented in 2021

MINISTÈRE
DE LA TRANSITION
ÉCOLOGIQUE
Liberté
Égalité
Fraternité

France – Direct Enforcement by WIM

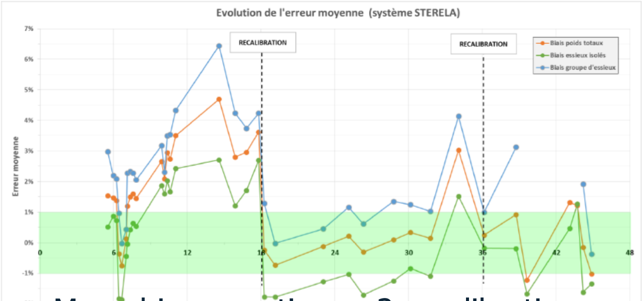
- 2014-16: lab and Accelerated Pavement Testing (APT) tests (Nantes) of several WIM sensors (piezoquarz, piezoceramic and piezopolymer)

	Quarz	Ceramic	Polymer
Lab: bending / Transv. location	0,04 % / 1.7%	1-5 % / no test	1-3 % / noise 3%
APT: speed / temp. / transv loc Total	1 / 3-4 / 5 % 10 %	2 / 1 / 11 % 17%	10 / 25 / 16 % 35%

⇒ only the piezoquarz are eligible for direct enforcement

- 2015-2019: on-road tests on motorway (A4, Saint-Avold) in eastern France:
  - 2 manufactured WIM systems by Kapsch and Sterela tested
  - 1585 vehicles weighed in motion and in static on approved scales, 68% T2S3, 18.5% vans
  - In 2018-19: both systems in class A(5) COST323 for 4+ axle trucks, B(10) for vans tolerances of the OIML class 5E met for 97-98% of the vehicles

System entity	Tolerance class OIML 5E	Kapsch		Sterela	
		Number	Out of tolerance	Number	Out of tolerance
Gross weight	±5%	522	18 (3.45 %)	236	5 (2.12 %)
Group of axles	±8%	531	5 (0.94 %)	240	3 (1.25 %)
Single axle	±8%	1031	16 (1.55 %)	462	9 (1.95 %)



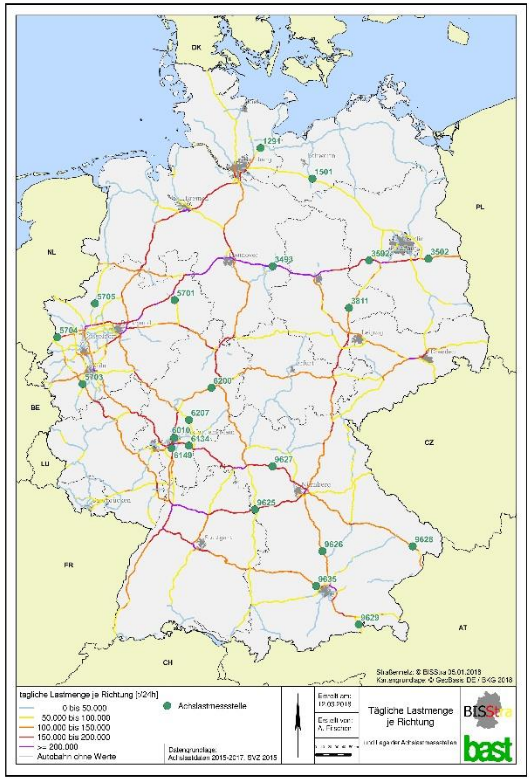
Mean bias over time – 2 recalibrations

- 2019-2020: development of a type approval procedure

Federal Highway Research Institute

Germany – Towards direct enforcement

- ❖ 21 WIM systems in operation on motorways for:
  - ➢ Statistical traffic monitoring
  - ➢ Pavement & Bridge management
  - ➢ Preselection for enforcement
- ❖ Direct enforcement and metrological requirements
  - ➢ OIML-certification of 1 system (class 10)
  - ➢ Class 10 (10%) not suitable for legal enforcement according to national regulations
  - ➢ OIML Class 2 (2%, used for static weighing) is wished to be legally on the safe side before court, however class 5 could be OK
  - ➢ Clarification on type approval procedure needed
  - ➢ Additional Regulation for HS-WIM
  - ➢ Direct enforcement would be very helpful and requires:
    → Further research in & development of technology is needed
    → Review of legal framework for direct enforcement

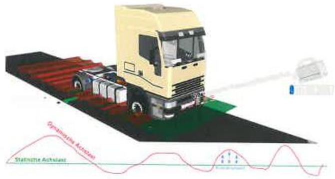


Germany – On-going projects

- Theoretical study and simulation of systems for direct enforcement

LIBRA–LASTEN IN BEWEGUNG RECHTSSICHER AUFZEICHNEN + partnership with an university and a WIM vendor

- Development and installation of a pilot system; specification of certification procedure and process (motorway near Düsseldorf)

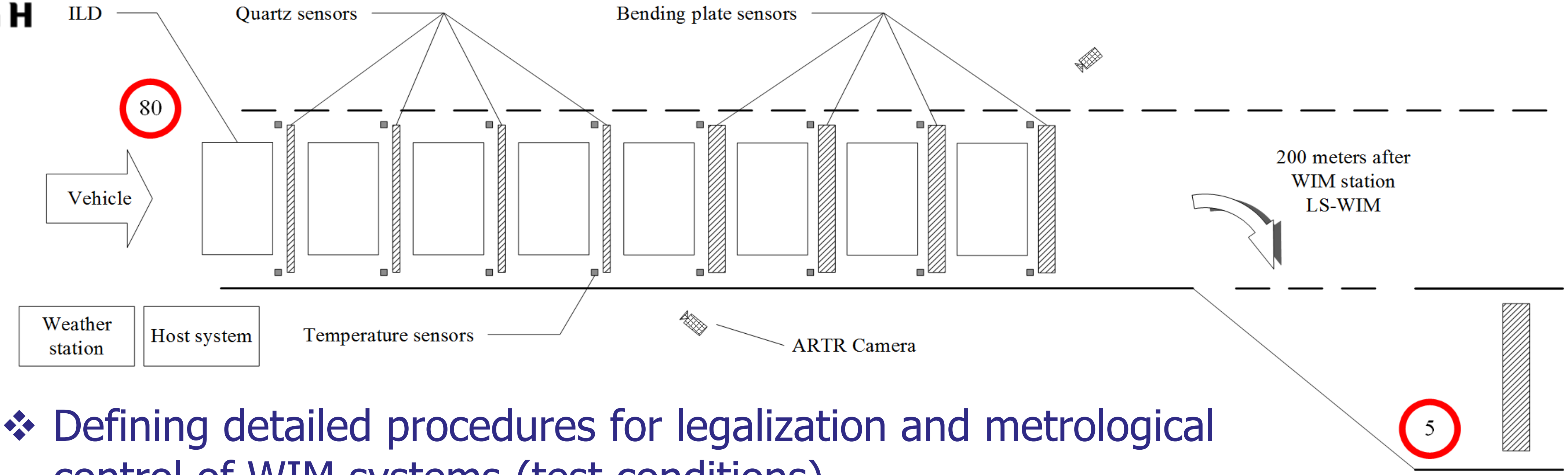


AKSLast

Automatisierte Gewichtskontrolle von Schwerverkehr basierend auf dynamischer Achslastverwiegung

- Development and installation of a pilot system
  - 5 rows of Kistler sensors and some additional sensors on highway
  - new algorithms for data processing
  - Objective: development of reference measurement systems
- Specification of certification procedure and process
  - first draft in discussion
  - national certification body is involved
  - procedure will be applied on the installed system

WIM test site for direct enforcement in Poland



- ❖ Defining detailed procedures for legalization and metrological control of WIM systems (test conditions),
- ❖ Defining technical requirements for such WIM systems

LS-WIM:

kapsch

KISTLER
measure. analyze. innovate.

TRAX elektronik

HS-WIM:

International Road Dynamics Inc.

CAT TRAFFIC

Conclusions and Perspectives

- Interest of WIM data for traffic monitoring and road safety by operators
- Bridge damage/collapse mitigation by WIM (overload ban)
  - Main concerns about bridge safety under overloaded trucks
  - Aging bridge stock in Europe, budget cuts for maintenance and repair
  - More flexibility for abnormal loads, permanent permits
  - Several bridge collapses or major damages and closure since 10-15 years

  ⇒ Use of WIM systems to identify overloads on weak bridges + company warning/profiling + adapted penalties (up to loss of reputation)
- Direct enforcement by WIM
  - On-going revision of the OIML R-134: ISWIM involved as an organization in liaison with the TC9/SC2/p11, and several EU countries are TC's members
  - Main challenge for the near future
  - Several issues still to be discussed: tolerances for type approval tests and initial verification, on-road tests vs dedicated test site, types of vehicles in the scope (e.g. vans?), range of approval (overloaded vehicles only?), etc.

Thank you for your attention

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