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PEC PSP

Sustainability is our mission.

iBridge Monitors

Helping engineers make *informed* decisions.

iBridge Monitors

How much is traffic damaging your bridge?

iBWIM –Real-time measurement of heavy goods vehicles.

How much is your bridge deviating from design?

iSHM –Long-term measurement of structural integrity.

2 Systems, built around a common core.

Hybrid systems can be tailored to individual needs.

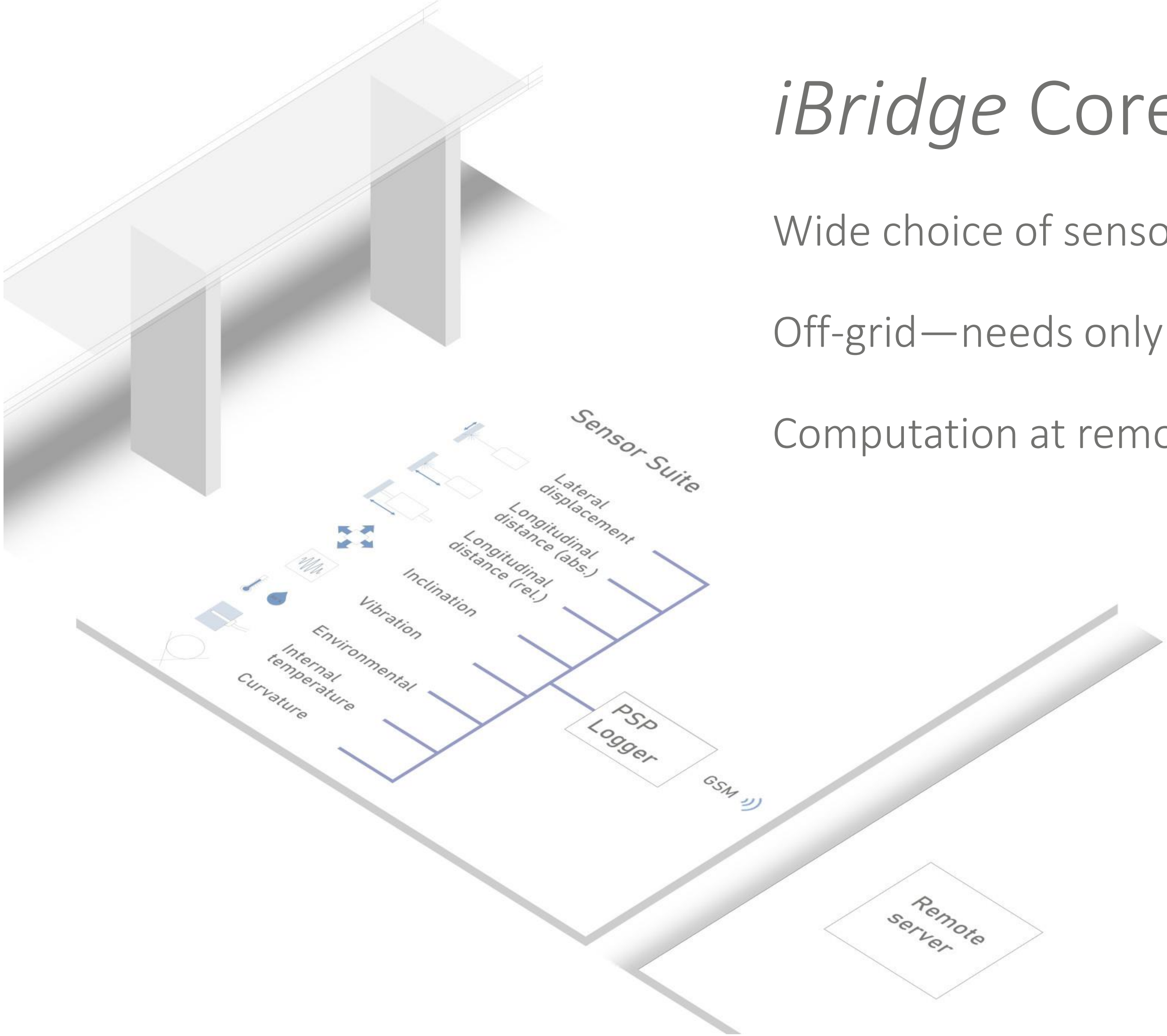
Outline

iBridge Monitor: Core Concept

iBWIM

iSHM

Predicting Bridge Condition



iBridge Core Concept:

Wide choice of sensors

Off-grid—needs only network coverage.

Computation at remote server.

Advantages of *iBridge* Approach

- On-site system is solar powered—no support infrastructure required, apart from mobile network coverage.
- Data logger supports multiple sensor types.
- Can be configured to measure individual events, at daily intervals, or at upto 3kHz.
- Communication with server can be event-driven (for speed) or at daily intervals (for power economy)

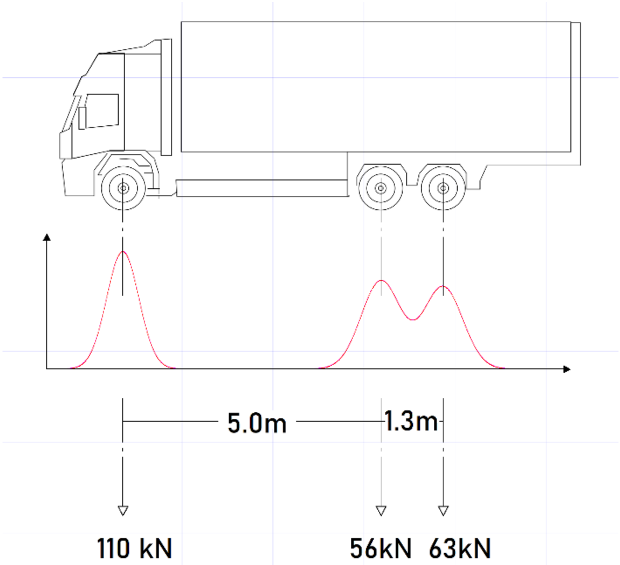
iBWIM

Measures the impact of vehicle axles on the bridge.

- Allows you to build up a Damage Model, i.e. an estimate of the degradation of the bridge caused by heavy goods vehicles.
- Detects and records *exceptional loads* that will inflict discrete damage on the bridge.

iBWIM

Heavy goods vehicle passes over bridge, the bridge deforms, we measure the strain induced by axles.

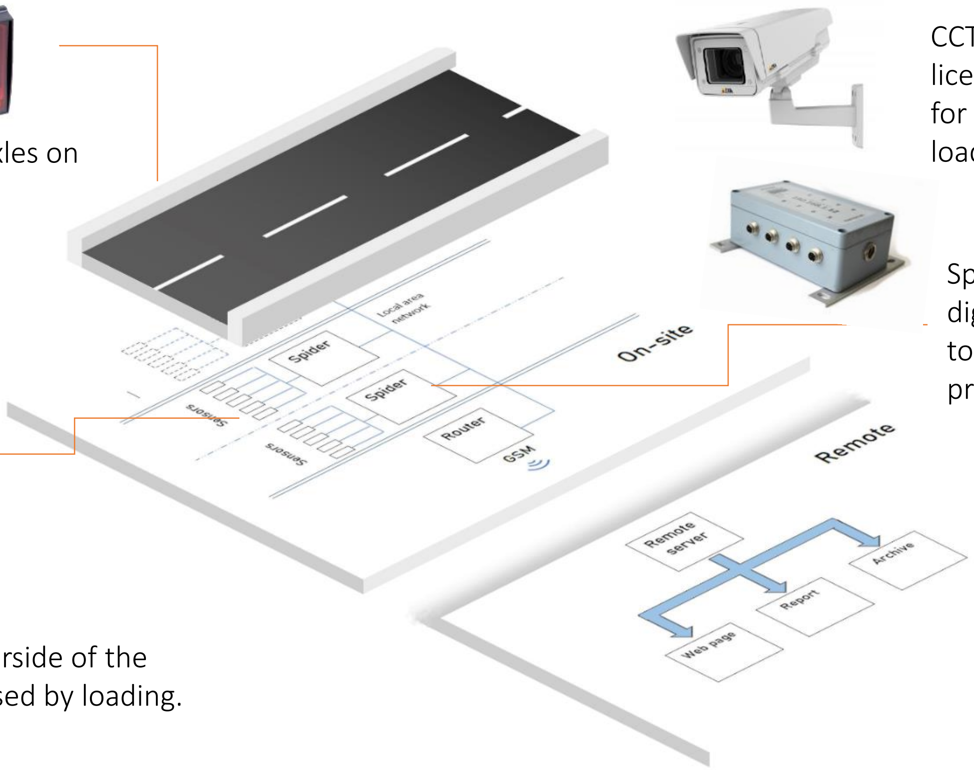


We deduce:

- Axle loads
- Axle separation
- Vehicle velocity

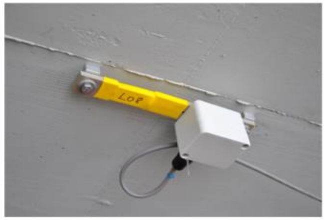
iBWIM

Lasers on super-structure detect axles. Improves ability to resolve axles on difficult bridges.



CCTV (optional) used with license plate recognition for recording exceptional loads.

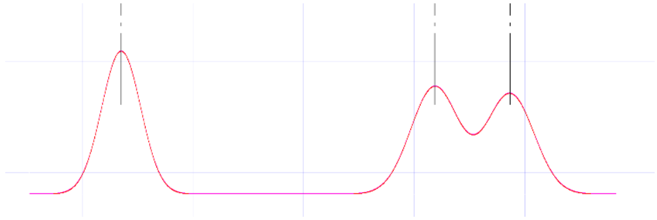
Spider units acquire and digitise data before passing to remote sensor for processing.

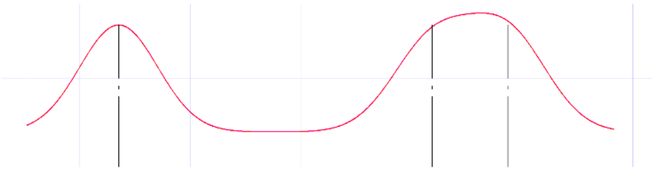


Strain gauges fitted on the underside of the Bridge detect deforfmation caused by loading.

iBWIM: Hard Bridges

In longer or stiffer bridges, the impacts of the axles merge—makes it harder to resolve the axles and accurately calculate the loads. Bridge harmonics corrupt strain measurements.





We resolve the axles using:

- Laser axle detection
- 32 bit digitisation.
- High sampling frequency (upto 3 kHz).
- Advanced signal processing and data analysis

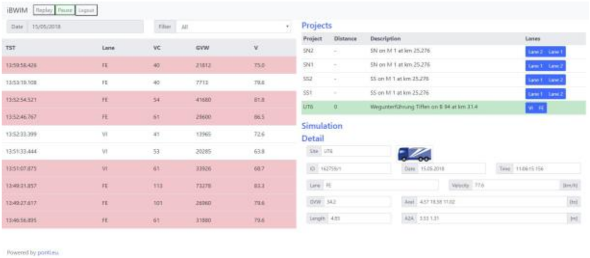
iBWIM: Accuracy

	5-10	11-23	24-35	>36
Slab	B(10)	B+(7)	B(10)	
Frame	B+(7)	A(5)	B+(7)	
Beam		B+(7)	B(10)	
Steel box girder				B(10)

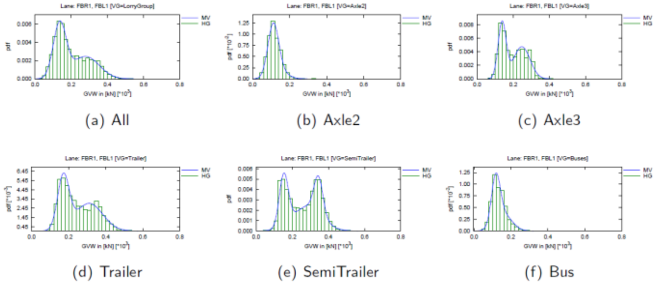
COST Rating	Tolerance [±%] within 5% Confidence interval	Application
A(5)	5	Legal
B+(7)	5-10	Legal force, with provisos
B(10)	10-15	Infrastructure maintenance and evaluation

iBWIM: Outputs

Record of bridge crossings online, updated in real-time.



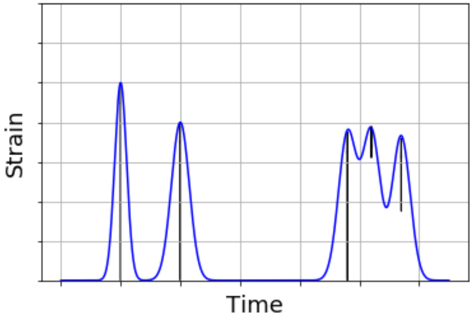
Statistical models of bridge loading.

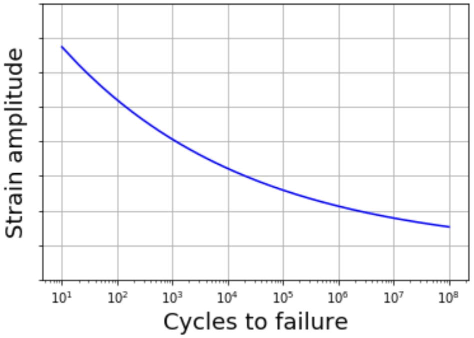


How does iBWIM estimate the damage to the bridge?

Fatigue

iBWIM tracks the amplitude and frequency of cyclic loading.

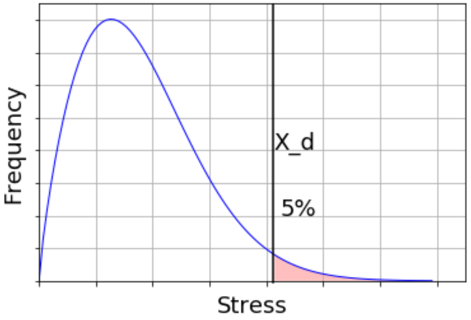




Estimated time to fatigue failure

Exceptional Loads

iBWIM can count how often exceptional loads violate the bridge‘s design limits.



Safety of design limits

Case Study: Sanga Bridge, Estonia

- Part of a survey of heavy goods traffic over Estonian roads, one of 16 bridges measured.
- 10 day measurement campaign, iBWIM unit using two Spider loggers. The iBWIM system was deployed twice at each of 16 locations, over a period of two years. No failures recorded
- Results formed part of a final report, showing distribution of heavy goods traffic over Estonian road network.



iSHM Structural Health Monitoring

Tracking long term changes in bridge geometry.

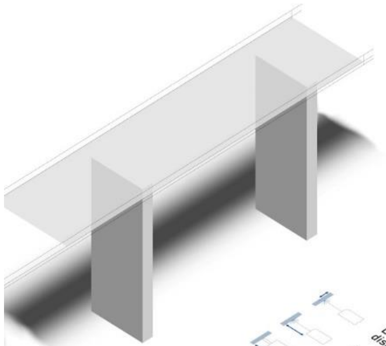
iSHM

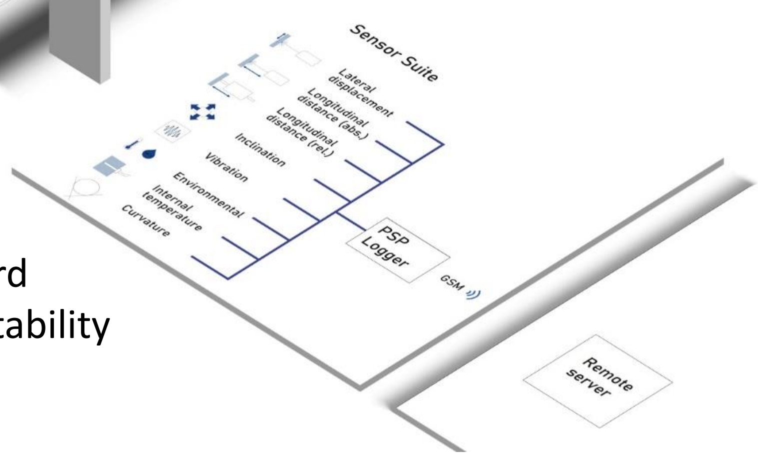
Long term measurement of subtle changes requires low noise, high precision electronics.

We use specially developed smart sensors with:

- On-board digitisation,
- Temperature compensation,
- Connected with industrial LAN.

iSHM



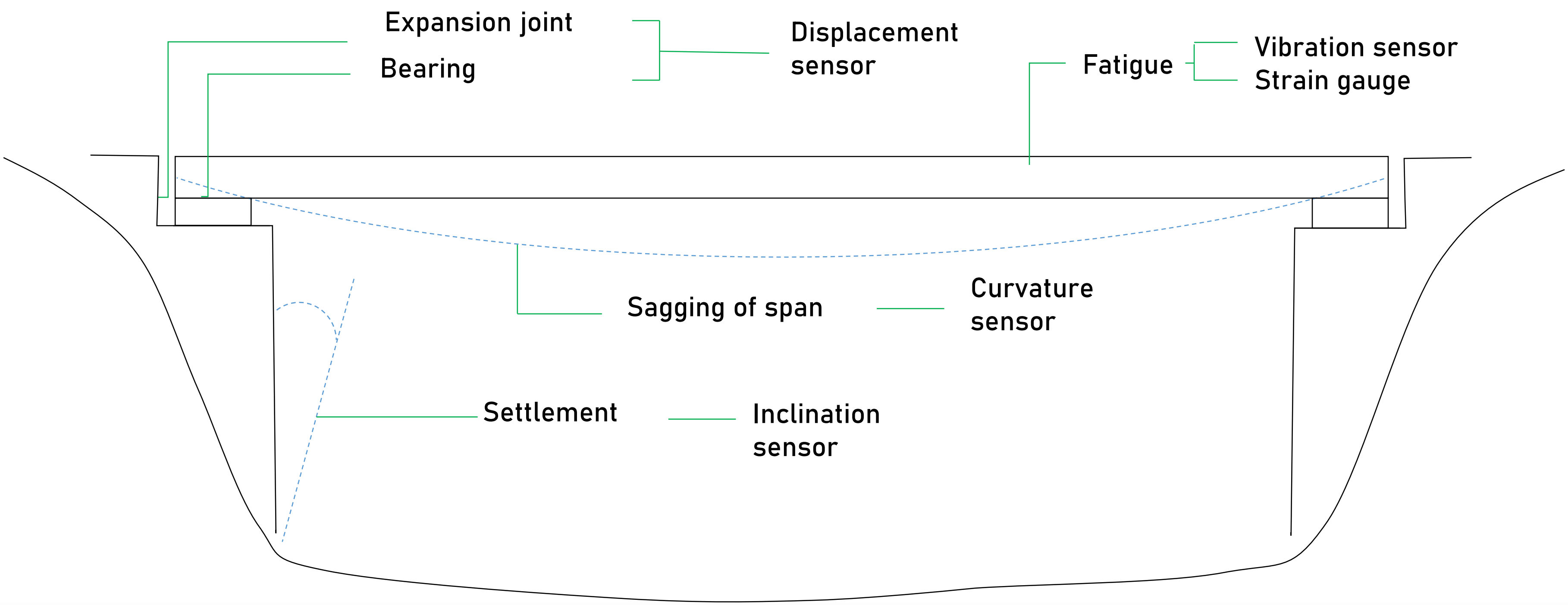


PSP Logger—self-powered, Independent, robust.

Periodic communication with server. Logger will cache data if link cannot be established.

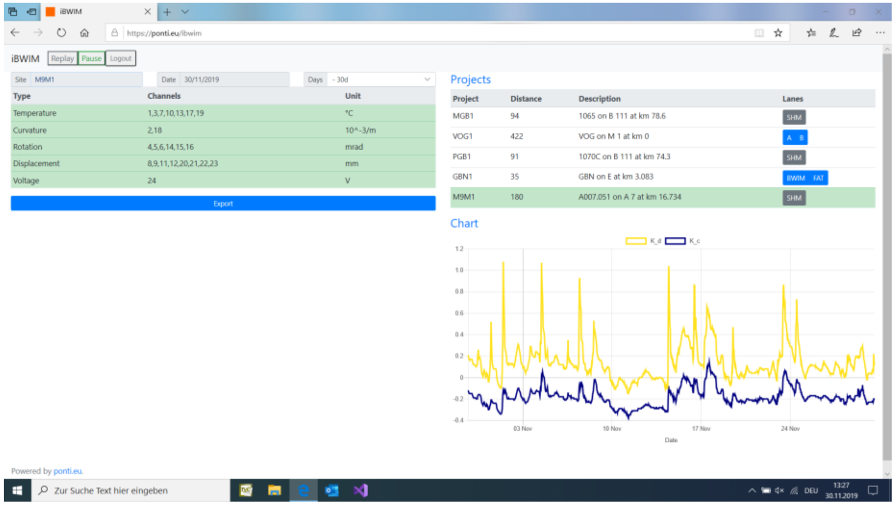
Smart sensors—on-board digitisation: improved stability and accuracy.

iSHM: What do we measure?



iSHM: Outputs

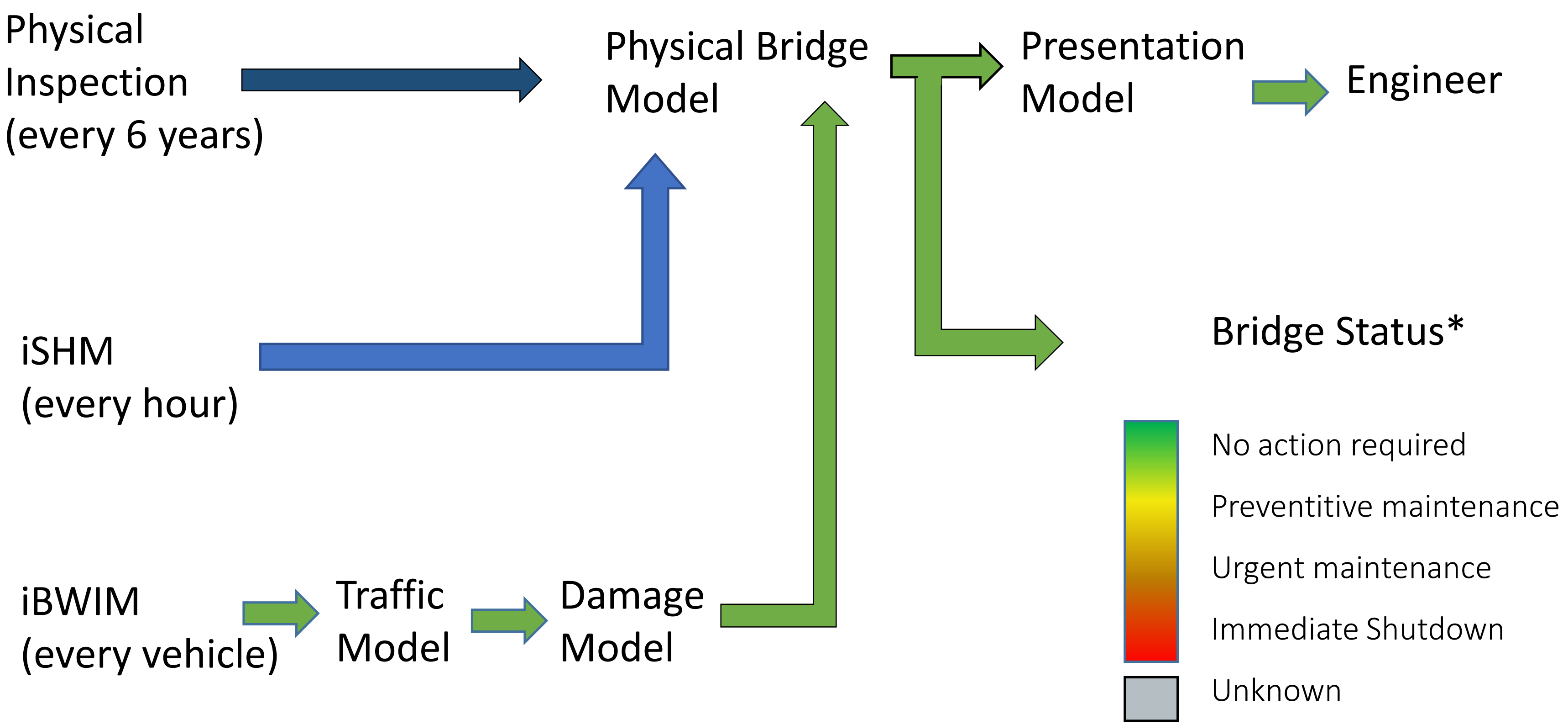
- Online record of measurements
- Online physical model of the bridge in near real-time
- Analysis of time series and trends
- Detection of transient events
- SMS alert when parameters exceed defined range



Case Study: M9 Linz, Austria

- 2x 4 lane road bridges, a total span >400m, >100,000 vehicles daily
- Fault was detected in one of the bridge bearings during routine inspection.
- Bridge remains open, because we are able to monitor the effect of the fault, and warn if it exceeds danger level.

How do iBridge Monitors support decisions?



*dicussed in Appendix A

Estimating the condition of the bridge

Given measurements how do we assess the status of the bridge?

How do we get from measure-ments to bridge status?

To assess the status of a bridge from measurements, we need:

1. A set of *features*—numerical values that are calculated from the measurements.
2. A *classifier*, i.e. a set of rules relating bridge status to the values of features.

How do we get from measure-ments to bridge status?

Measurement → Feature → Classifier → Status

Measurement

Value from sensor

e.g. displacement or strain

Feature

A numerical value on which we can make a decision

Takes:

- a measurement,
- engineering knowledge of the bridge and its history,

and gives e.g. for fatigue, weeks to live

The feature should be:

- Rigorous.
- physically meaningful.
- easily understood.

Classifier

Set of rules

e.g. **If** reliability index is less than 3.6
Then immediate shutdown

The rules may be expressed as simple thresholds, or as mathematical rules linking two or more features.

Status

Action to be taken—or not.

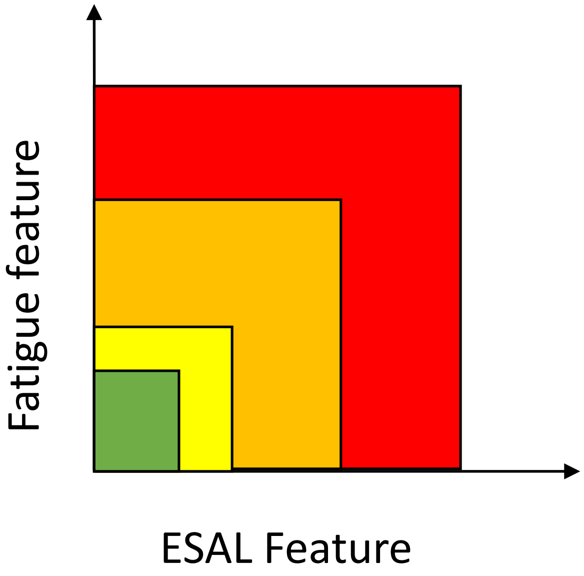
e.g. Immediate closure, preventitve maintenance.

Classifier: simple threshold

Thresholds set manually for each feature

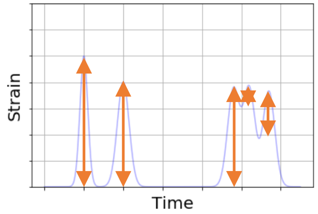
Correlation between features ignored.

- Easily understood
- Good for uncorrelated features
- Will be suboptimal if features are correlated.

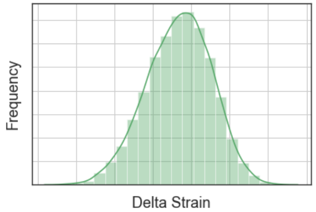


Features (iBWIM): e.g. fatigue

Measurement

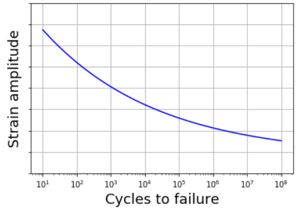


Impact history of bridge



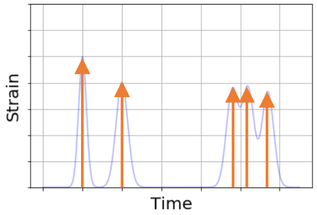
FEATURE:
Predicted residual lifetime

Engineering knowledge



Features (iBWIM): e.g. general loads

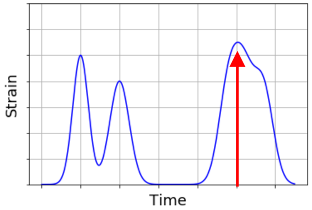
Measurement



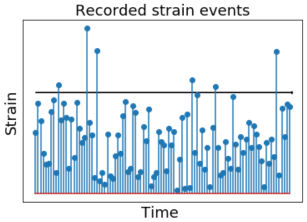
Calculate ESAL Scores → Bridge history → FEATURE: ESAL Score

Features (iBWIM): e.g. exceptional loads

Measurement



History



Number and severity of events

FEATURE:

Safety of design assumptions.

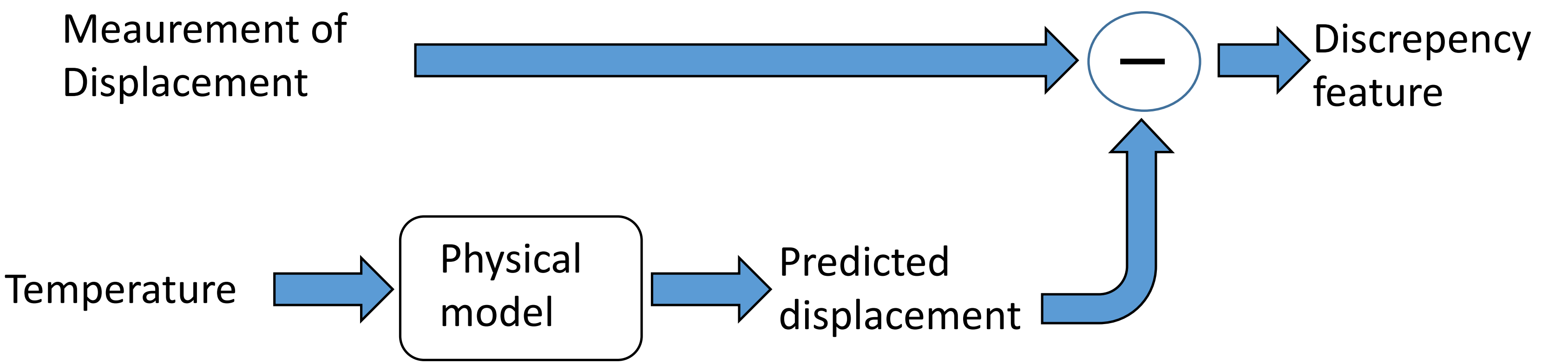
Features: iSHM Model based features

iSHM measurements are strongly affected by temperature.

- Variation due to temperature will often drown out the interesting data.
- Often the absence temperature induced variation is itself an important cue.

We use a simple physical model to predict the value of the measurement, then use the discrepency beween the prediction and the measurement as our feature.

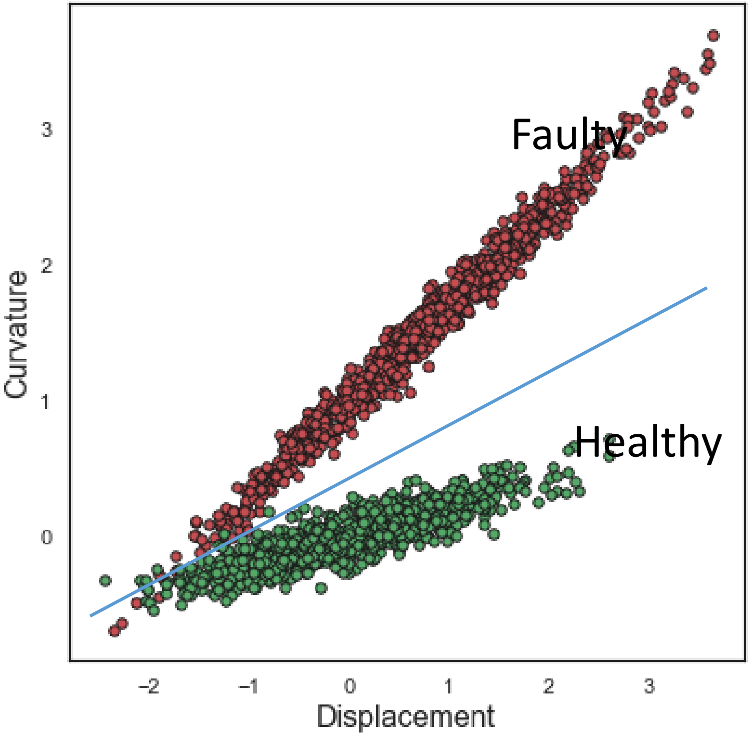
Features: iSHM Model based features



Classifier: using correlation between features

Consider a bridge pier with a suspected bearing fault. If the fault is serious (red measurement points), and the bearing is jammed, the pier‘s curvature will be closely related to the displacement discrepency, i.e. there will be a strong correlation between the displacement and curvature features. However, if the bearing is healthy (green points) there will be much less correlation. Depending on where the bearing jammed there will aslo be an offset between the clusters.

If we use simple feature thresholds to distinguish between the healthy and fault cases we will misclassify many measurements. Conversely, by using both features with a linear classifier (blue line), we can distinguish a faulty and healthy bearing much more accurately.



How are systems installed?

Training

Installation

- Demonstartion installation on pilot bridge.
- Commisioning of a trainee installed system.

Software

- Introduction to online monitoring system.
- Introduction to maintenance planning system.

On-Site

Typical workload, based on 2-man team:

- Installation (1-2days)
- Calibration (2 days)
- De-installation (0.5 days)
- Re-installation (0.5 days)

iBridge Monitors: Summary

- Easy to install—no disruption to traffic.
- Off-grid—only require mobile network coverage.
- iBWIM—weighs HGVs without stopping traffic
- iSHM—measures selected bridge parameters over the long term.
- Together, they update a model of the bridge that can be viewed from your office in near-real-time.

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Case Study: Mjölby bridge, Sweden

Type:	Highway bridge
Route:	E4
System:	Slab
Span width:	8m

Case Study: Metnitzbach bridge, Austria

Type:	Railway bridge
Route:	Tarvis – Amstetten
System:	Steel lattice framework
Span width	41m

Case Study: Nahon Nayok, Thailand

Description: 2x Road bridges, 2 lanes each.
Construction: Concrete span 13m and 20m
Requirements:Permanent measurement system to observe heavy goods traffic and filter out overloaded vehicles.

Solution: Each bridge was equipped with a two lane, 16 sensor, 2 spider
system, integrated with CCTV and linked to customer's own server.

- Robust topside sensors with specially tailored algorithms.
- Additional signal processing for harmonic suppression
- Axle detection algorithms optimised for Thai vehicles.

Case Study: Zauchen, Austria



Description: Railway, 2 tracks
Construction: Steel box girder (1908)
Requirements: Re-analysis for safety. Bridge approaching retirement, requires surveillance. Measure actual traffic loading.
Technical challenges: Weighing freight trains (typ. 180 axles) at full velocity (120 km/h).

Solution: 1 Spider system, semi-permanent (12 months)
Result: In addition to customer requirements, identified approach for linking stress cycles to single train events--relevant for residual lifetime prediction.

Appendix: COST323 Specifications

COST 323 is one of the actions supported by the COST Transport part of the European Commission's Transport Directorate, DG VII.

COST 323 does not constitute an official standard but provides technical specifications for WIM users and manufacturers and a reference upon which standardisation committees can draw.

COST 323 defines WIM systems by classes based on their level of accuracy. These classes are defined as follows, where the numbers in brackets indicate the confidence interval width:

- Class A(5): Legal purposes such as enforcement of legal weight limits.
- Class B+(7): Enforcement of legal weight limits in particular cases, if the Class A requirements may not be satisfied, and with a special agreement of the legal authorities; efficient pre-selection of overloaded axles or vehicles.
- Class B(10): Accurate knowledge of weights by axle groups, and gross weights, for:
    - infrastructure (pavement and bridge) design, maintenance or evaluation, such as aggressiveness evaluation, fatigue damage and lifetime calculations
    - pre-selection of overloaded axles or vehicles
    - vehicle identification based on the loads.
- Class C(15) or D+(20): Detailed statistical studies, determination of load histograms with class width of one or two tonnes, and accurate classification of vehicles based on the loads; infrastructure studies and fatigue assessments.

Spares

Sensors:	Strain gauges, laser axle detectors CCTV (optional)	Displacement, strain, curvature, inclination, vibration, environmental
Sampling:	Event-driven, upto 1kHz depending on bridge type.	Interval based, from 1Hz to daily.
Comms:	Event-driven, or burst-firing.	Daily, with option for data cacheing for power economy.