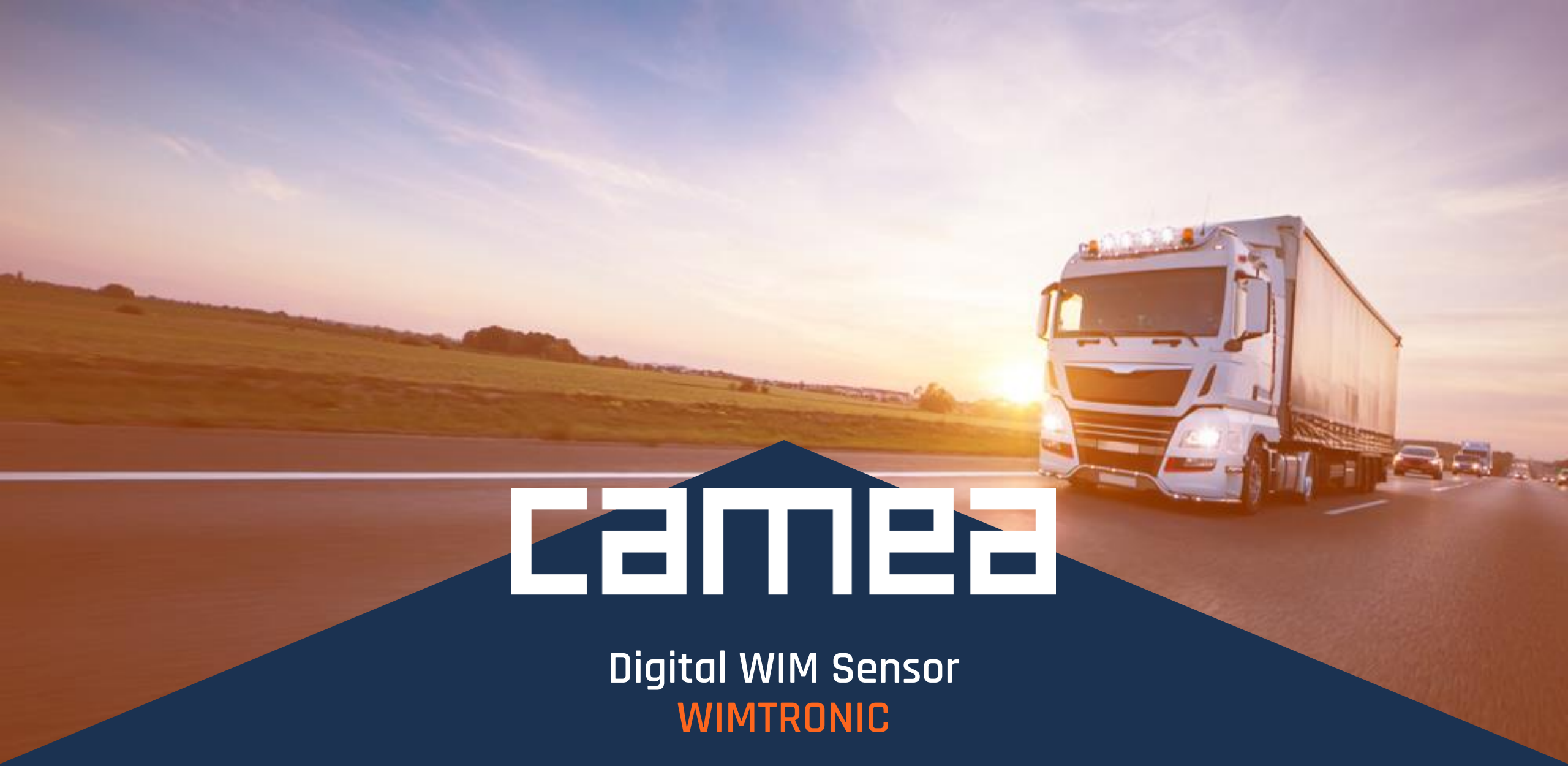


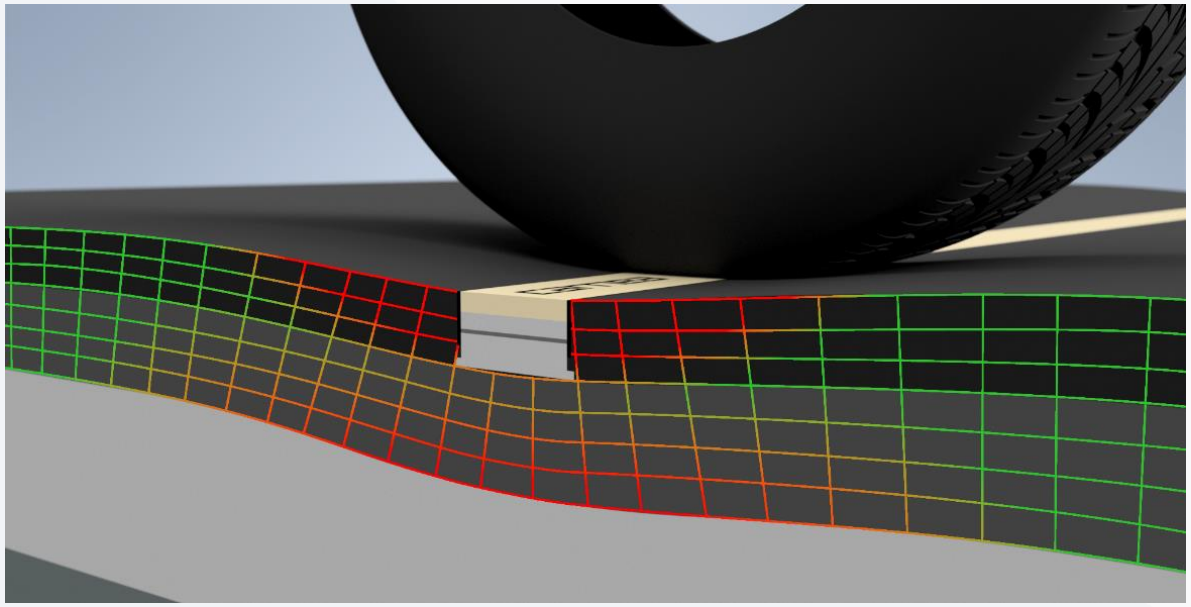
Digital WIM Sensor
WIMTRONIC

Small Road Intrusion • High Accuracy • Advanced Validation • Easy Installation • Novel Features

Low Sensor Height - Less Road Damage

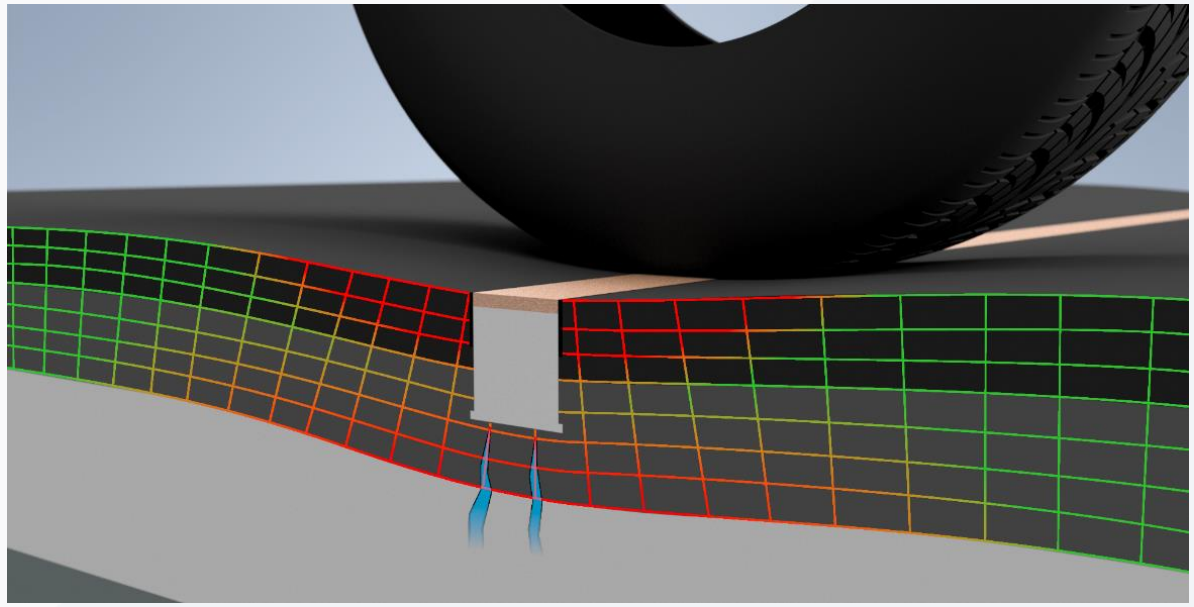
WIMTRONIC

- Lower profile design
  - Less intrusive



OTHER DIGITAL WIM SENSORS

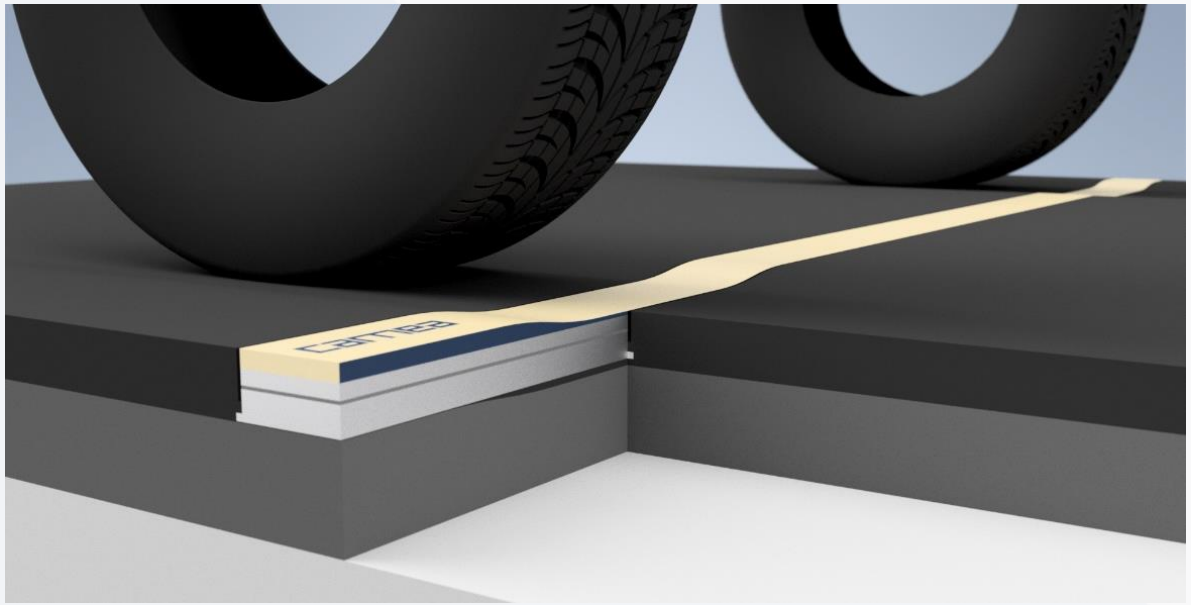
- Higher profile design
  - More intrusive



High Abrasive Layer - Long Lifetime

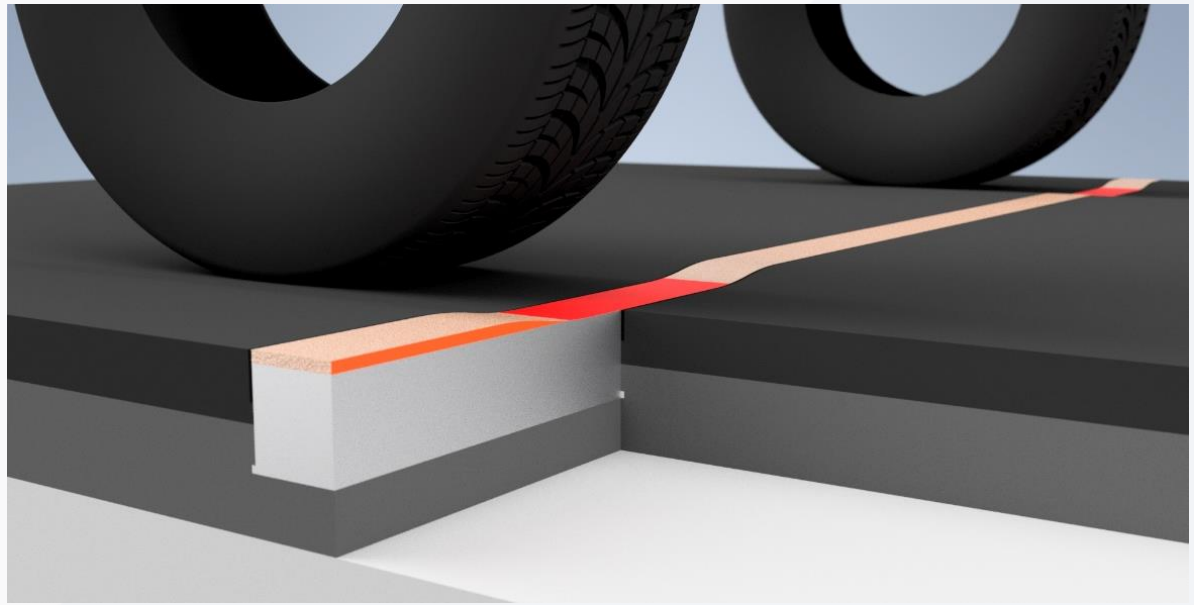
WIMTRONIC

- Higher sensor abrasive layer
  - Longer service life



OTHER WIM SENSORS

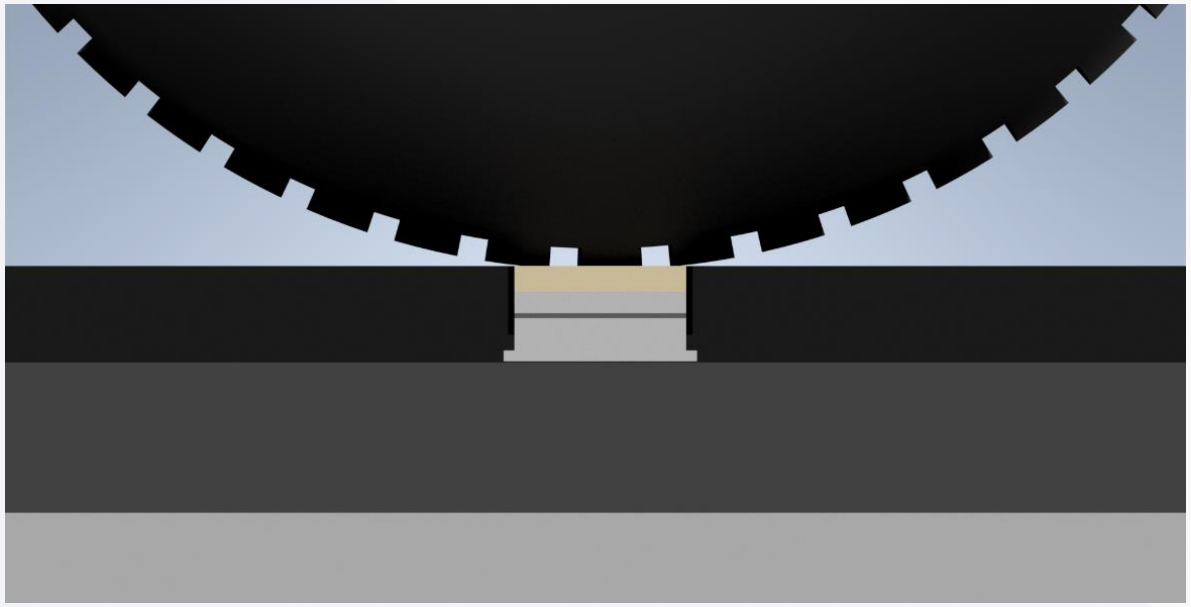
- Lower sensor abrasive layer
  - Shorter service life



Wide Sensor - High Accuracy

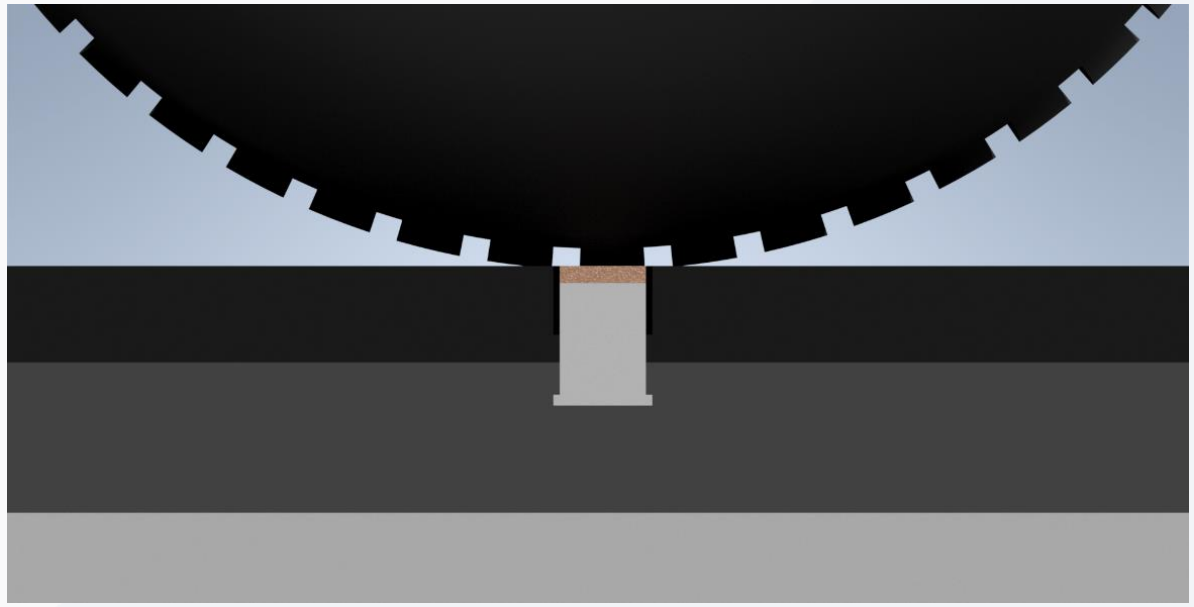
WIMTRONIC

- Longer tire contact - 80 mm
  - Accuracy less affected by tire pattern



OTHER WIM SENSORS

- Shorter tire contact - 40-70 mm
  - Tire pattern can affect accuracy



Independent Load Cell Measurement

WIMTRONIC

- Responses of all load cells are measured independently
- More measurements
  - Higher accuracy, reliable results
- Independent measurements
  - Tire position, footprint, pressure etc.
- Two rows of load cells
  - Braking, torque, rutting, bending speed, travel direction, diagnostics etc.

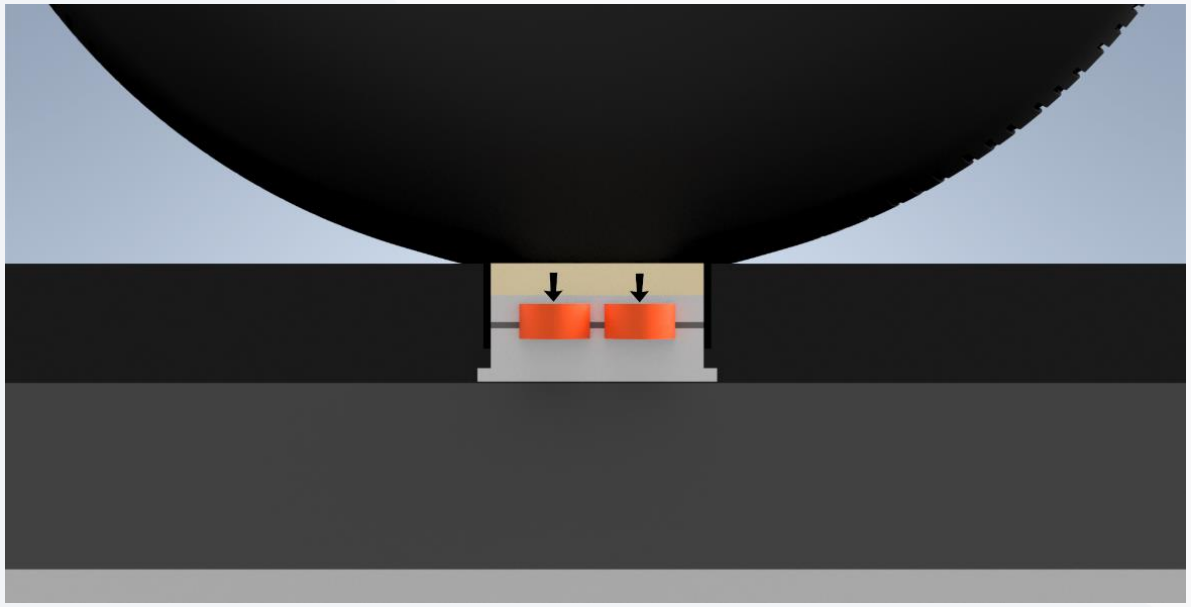
ANALOG WIM SENSORS

- All load cells are connected in parallel and measured together
- One measurement per sensor
  - Potentially lower accuracy
  - Only load forces can be measured
  - Must be equipped with additional tilted sensors to get the tire position
- One row of load cells
  - No additional measurements available

Double Measurement - Higher Accuracy

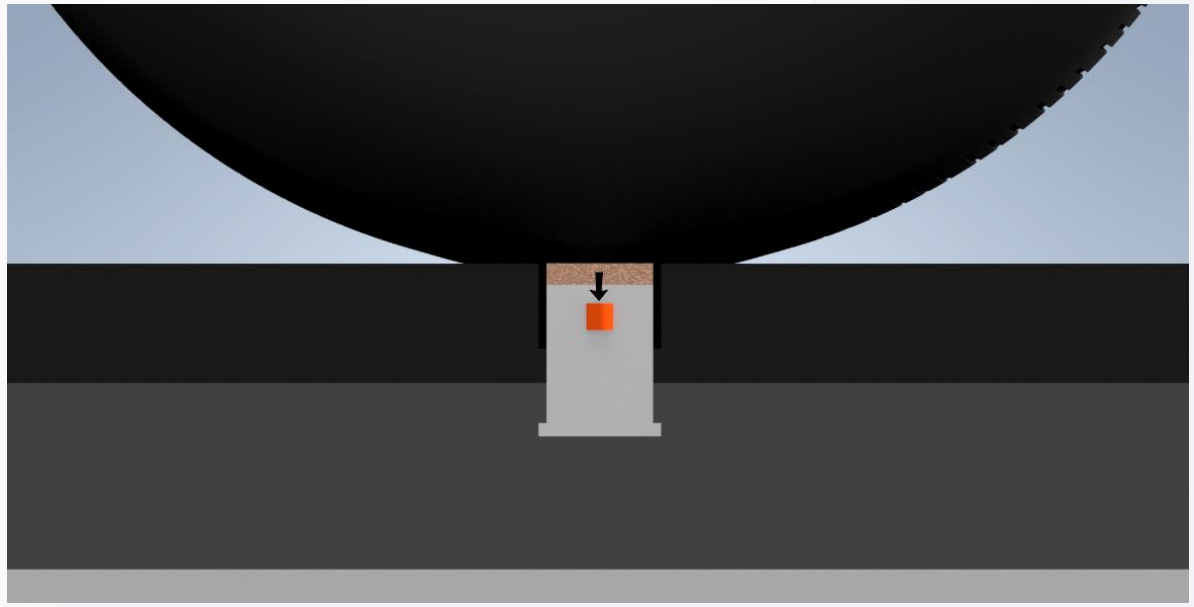
WIMTRONIC

- Double measurement
  - Higher accuracy, additional data



OTHER WIM SENSORS

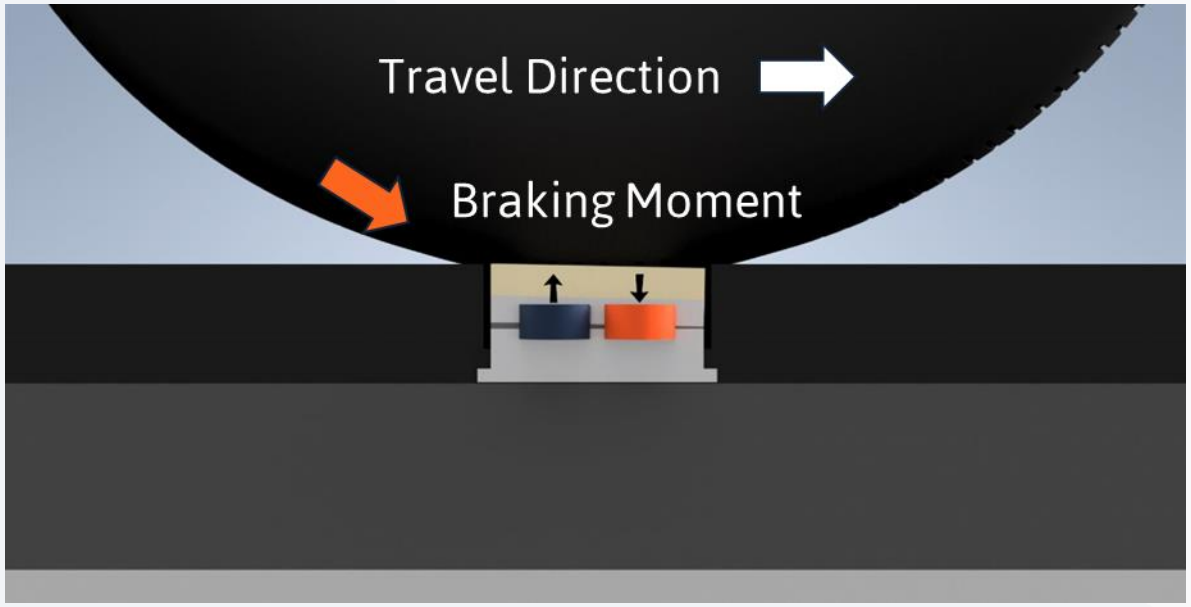
- Single measurement
  - Lower accuracy, no additional data



Braking Detection - Measurement Validation

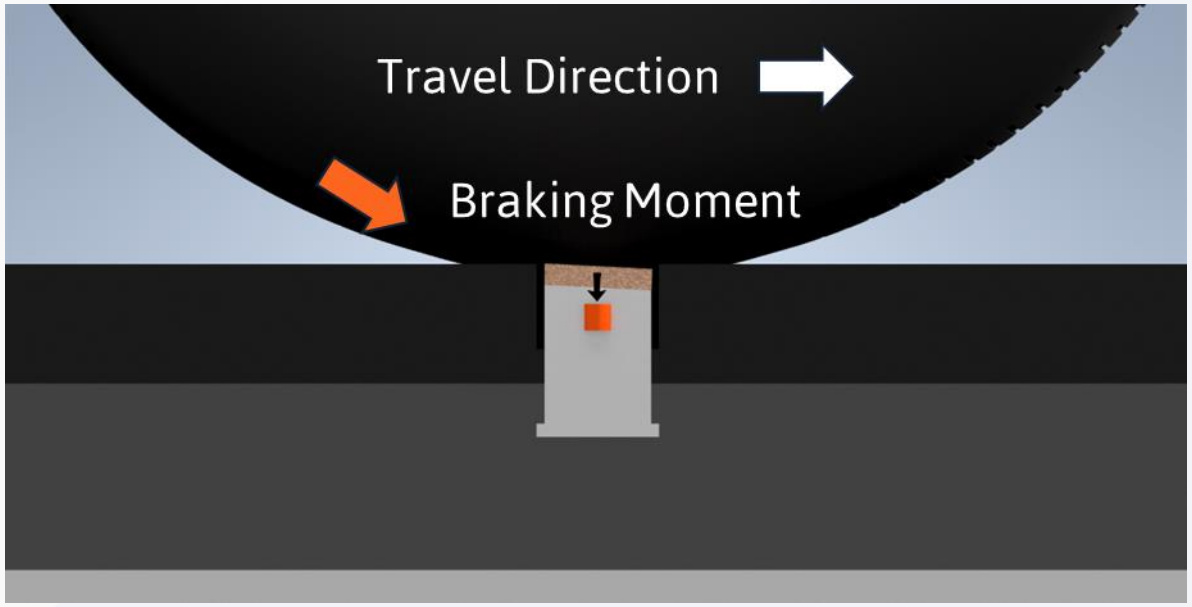
WIMTRONIC

- Braking can be detected
  - Inaccurate data can be invalidated



OTHER WIM SENSORS

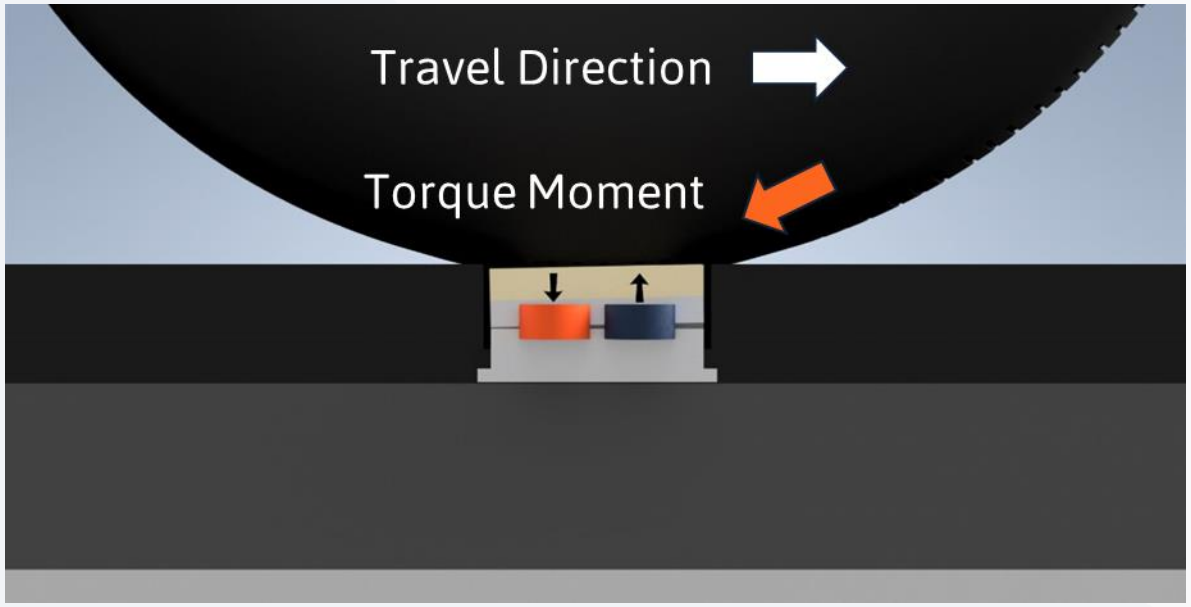
- Braking cannot be detected
  - Incorrect data affects accuracy



Torque Detection - Measurement Validation

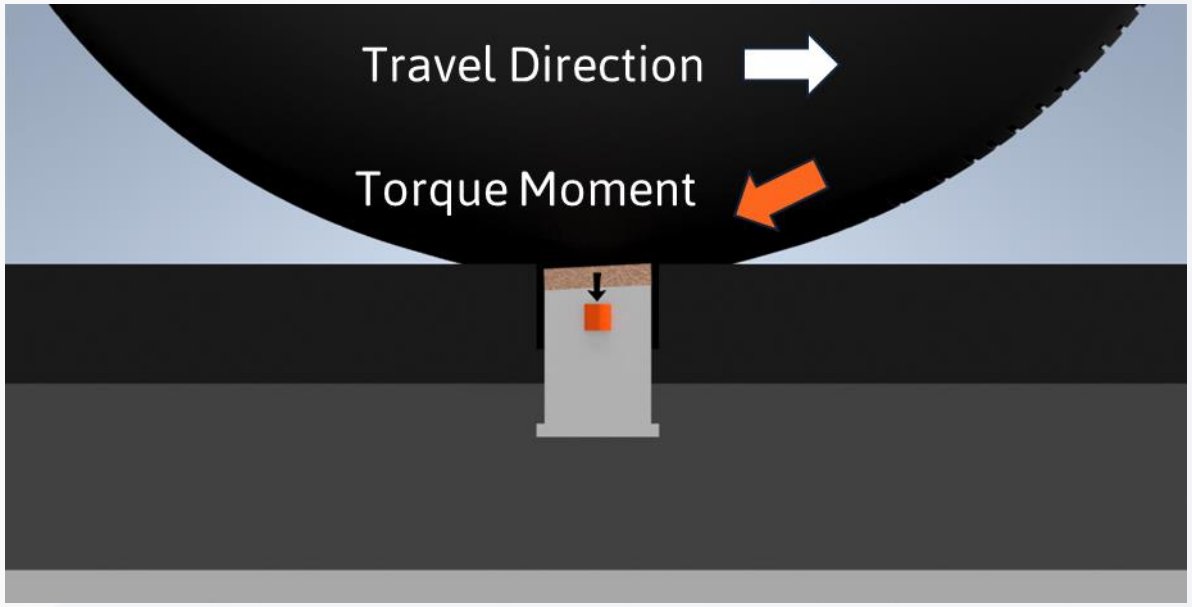
WIMTRONIC

- Torque can be detected
  - Inaccurate data can be invalidated



OTHER WIM SENSORS

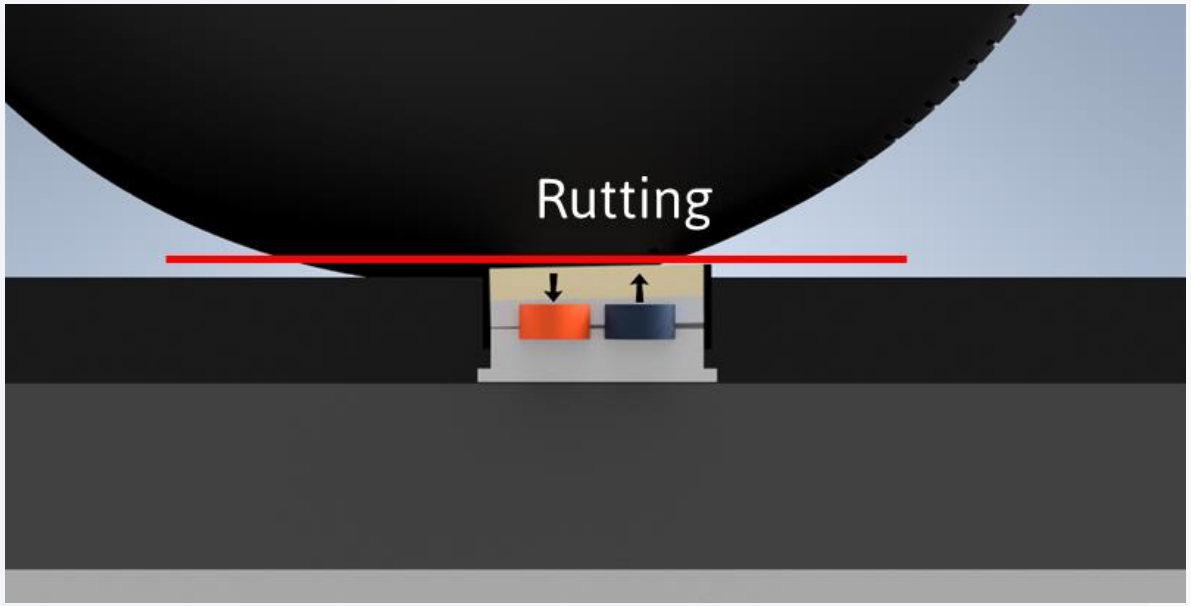
- Torque cannot be detected
  - Incorrect data affects accuracy



Rutting Detection - Measurement Validation

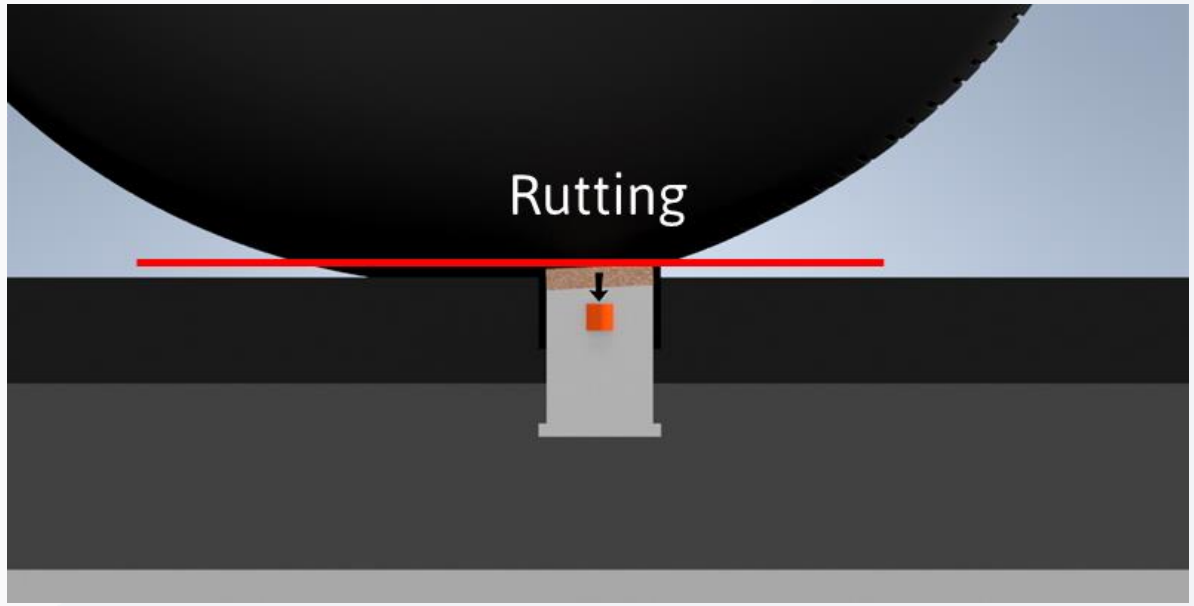
WIMTRONIC

- Rutting can be detected
  - Inaccurate data can be invalidated



OTHER WIM SENSORS

- Rutting cannot be detected
  - Incorrect data affects accuracy



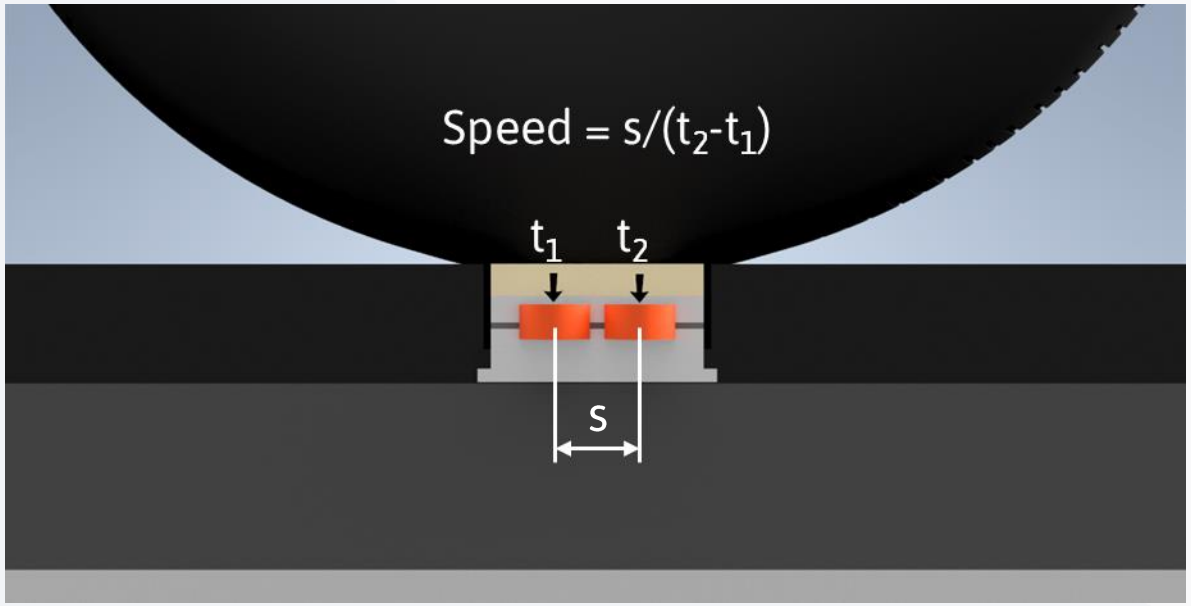
Wheel Speed - Measurement Validation

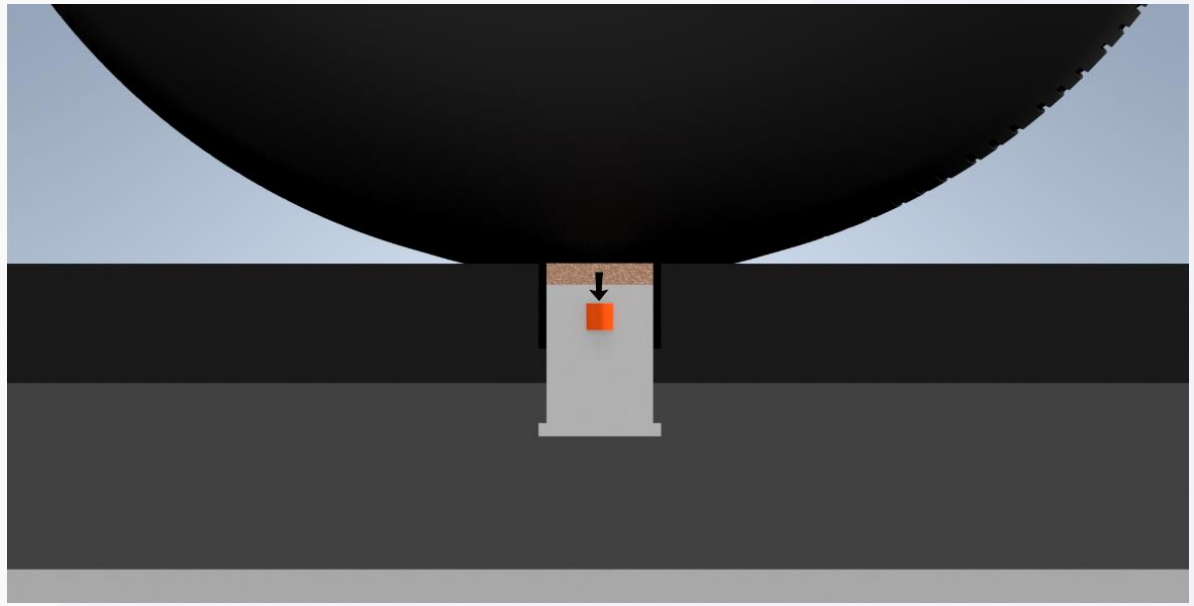
WIMTRONIC

- Two successive measurements
  - Speed can be determined

OTHER WIM SENSORS

- Single measurement
  - Speed cannot be determined





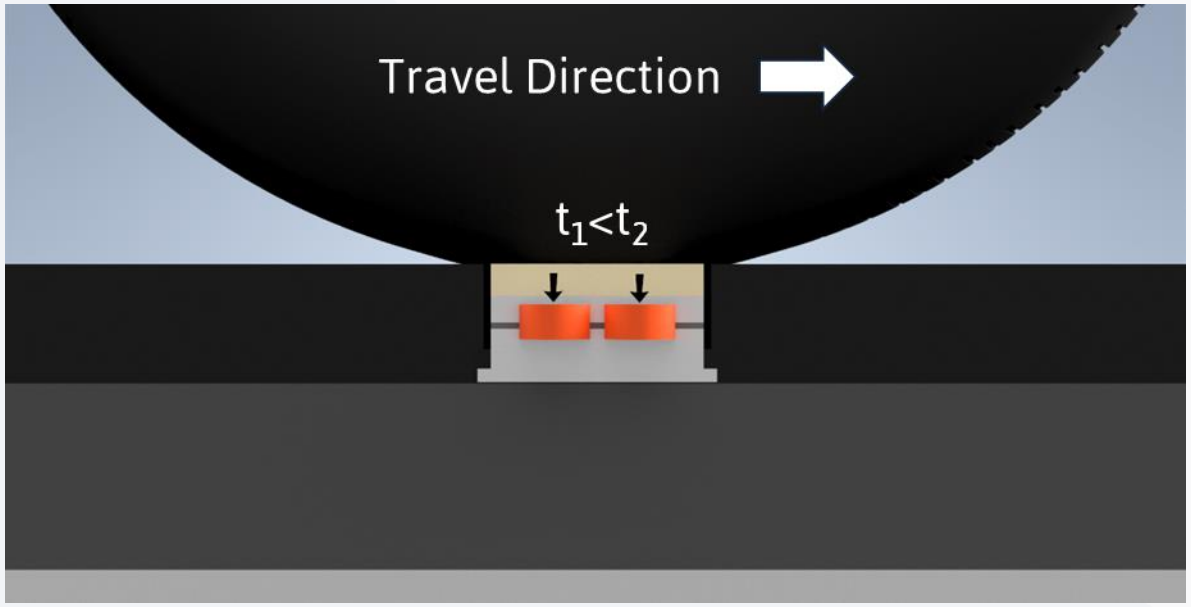
Travel Direction Detection

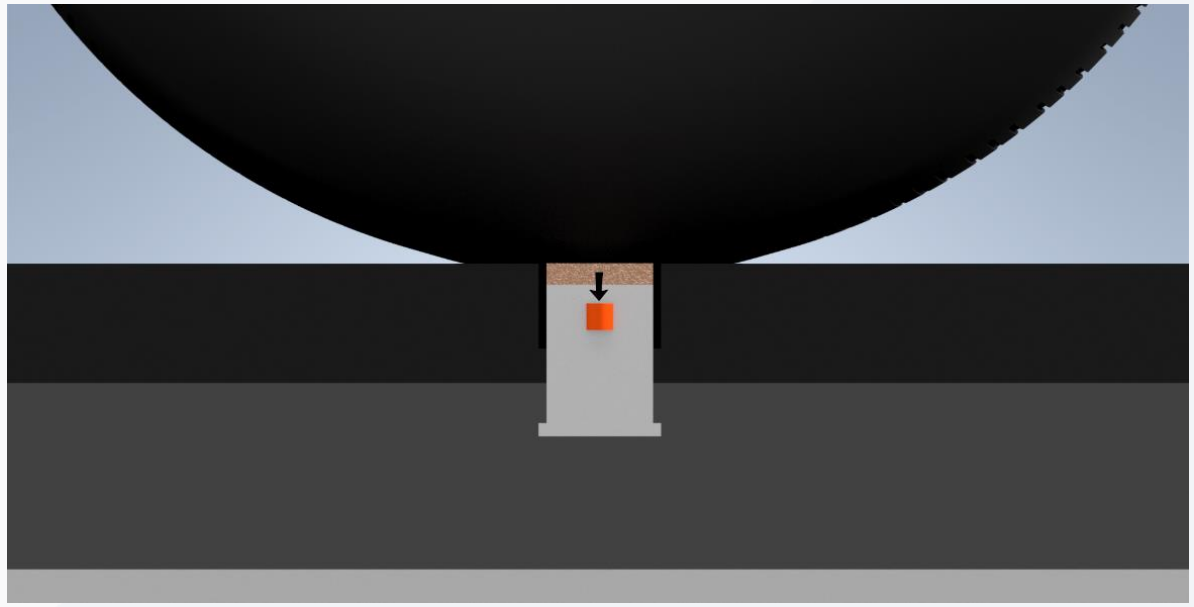
WIMTRONIC

- Two successive measurements
  - Travel direction can be determined

OTHER WIM SENSORS

- Single measurement
  - Travel direction is undetectable

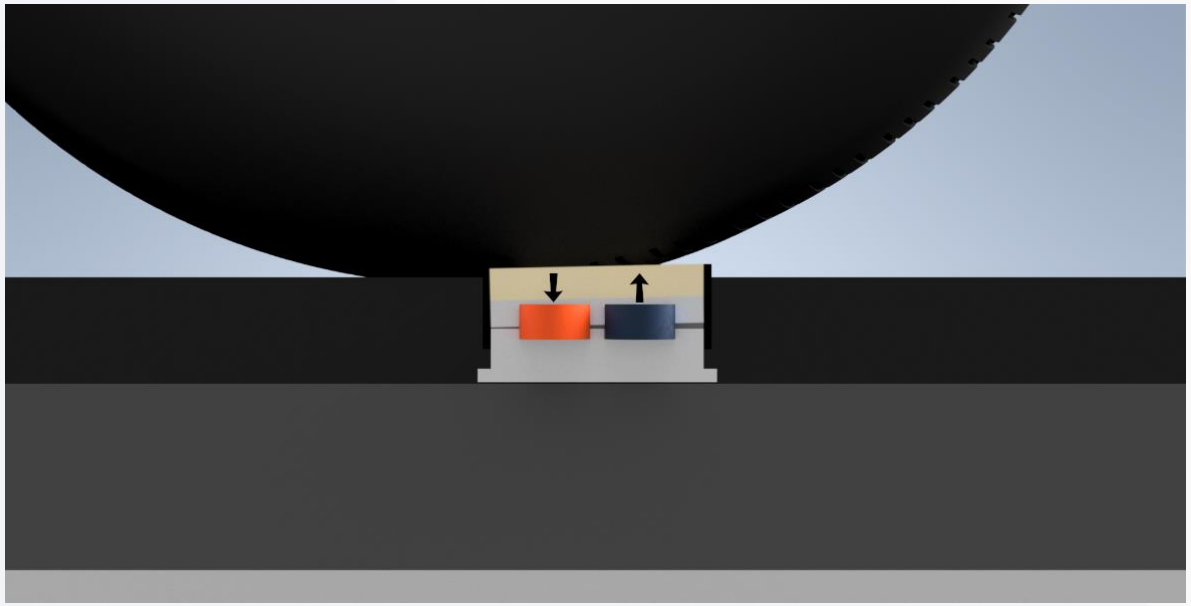




Low Side Bending Effect

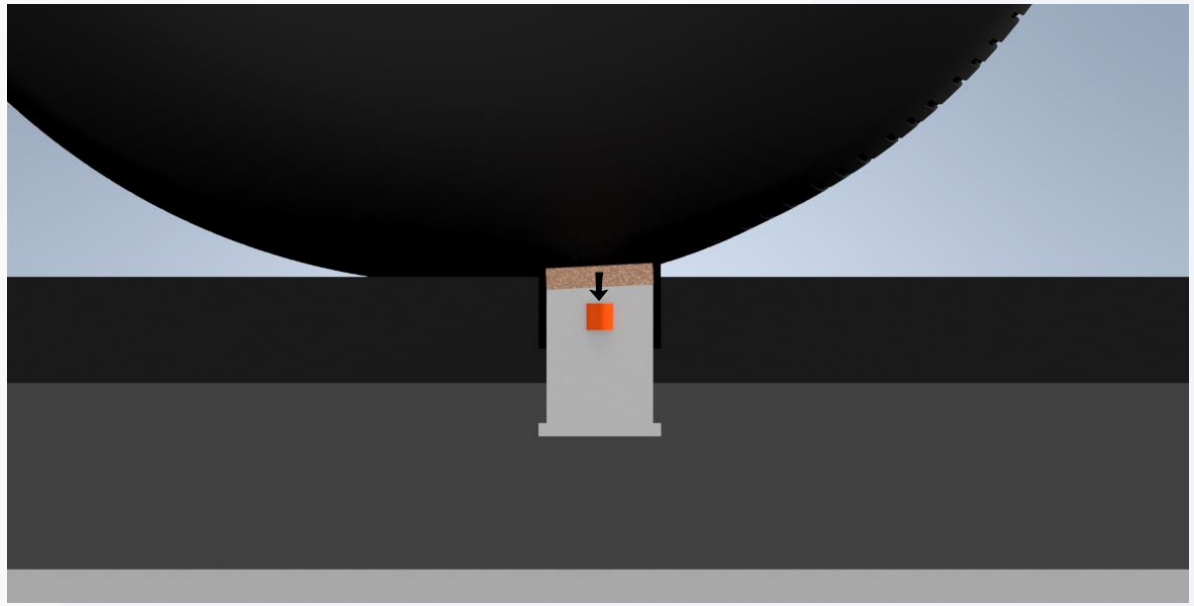
WIMTRONIC

- Sensor side bending is low
  - Greater overload resistance



OTHER WIM SENSORS

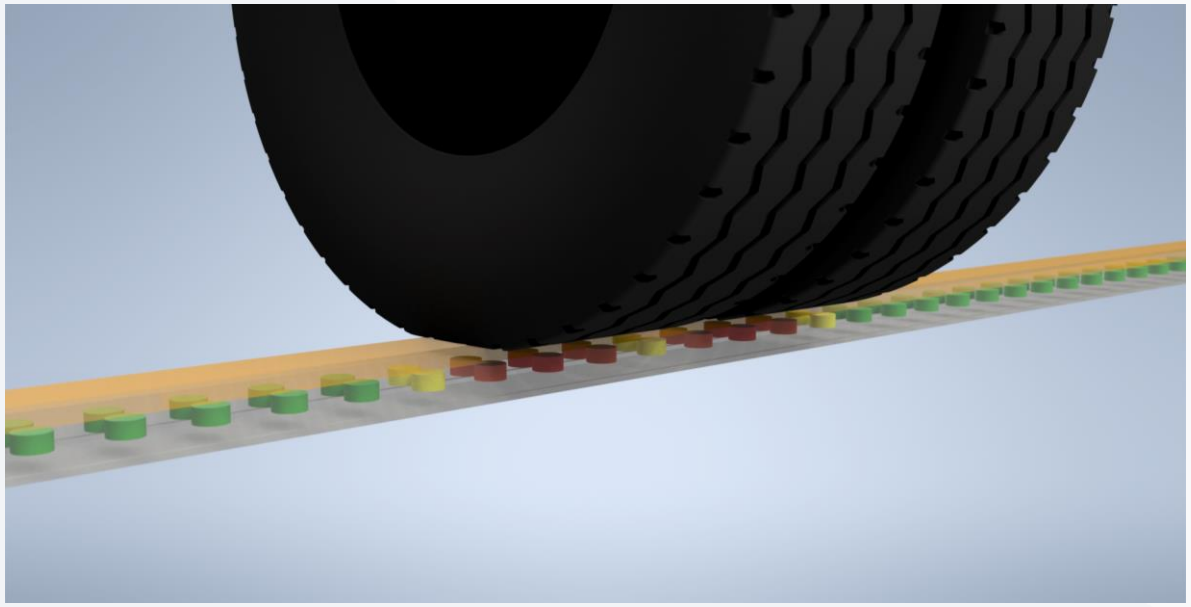
- Sensor side bending is high
  - Overloaded wheels can cause damage



Tire Position - Dual Tires and Wheelbase

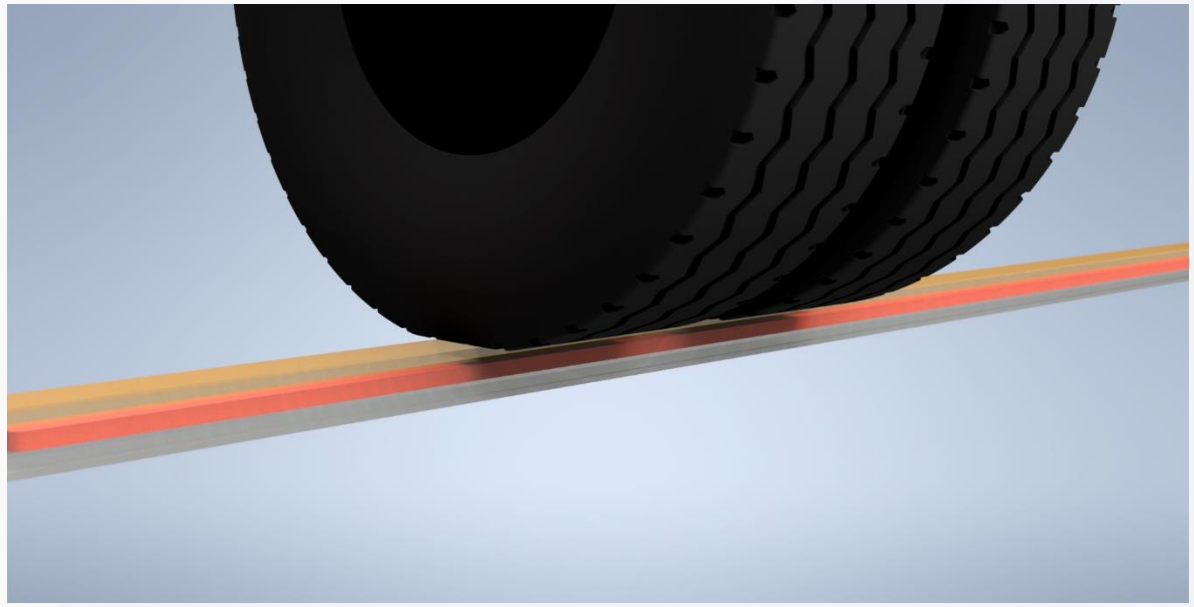
WIMTRONIC

- Tire position measurement
  - Dual tires and wheelbase



ANALOG WIM SENSORS

- One response of the entire sensor
  - Tire mount and position is unknown



Tire Footprint Measurement

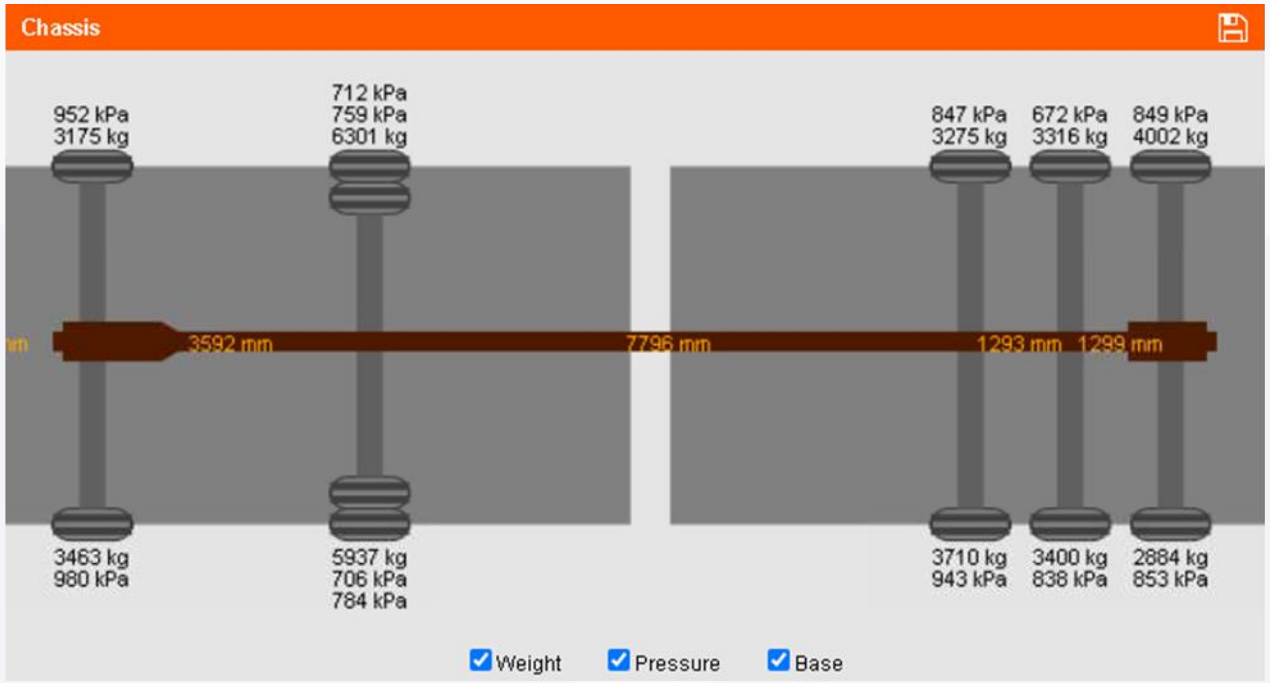
Underinflated

Correctly Inflated

Overinflated

Tire Pressure - Pressure-In-Motion (PIM)

Allows both weight and pressure measurement



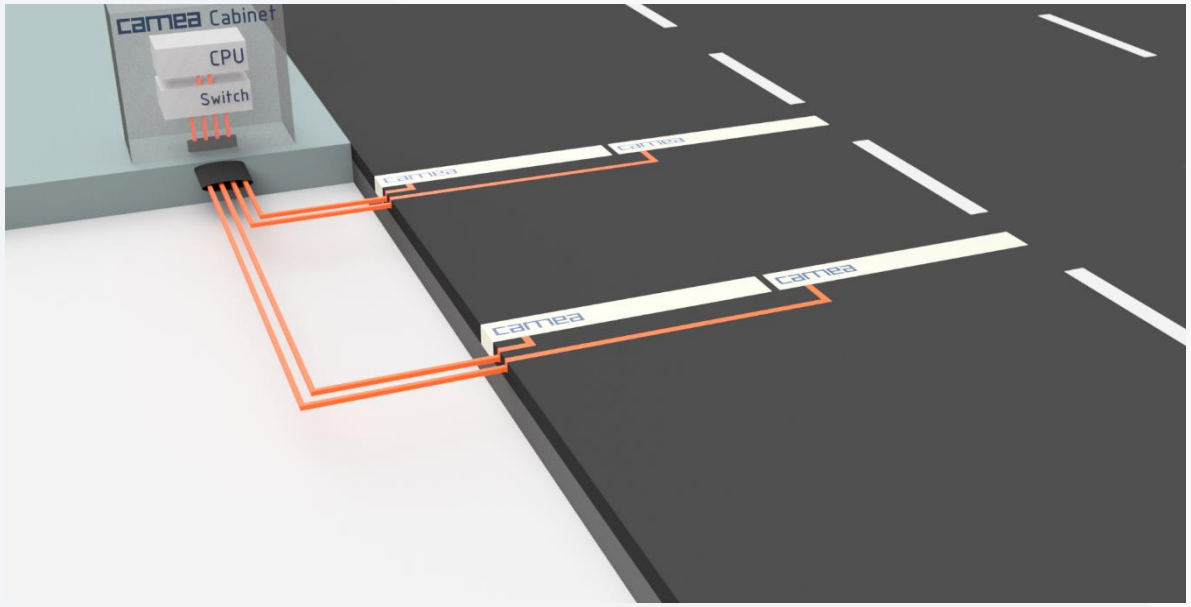
Road Deflection - Measurement Validation

Allows both wheel load and road deflection measurement

All-in-One WIM Solution

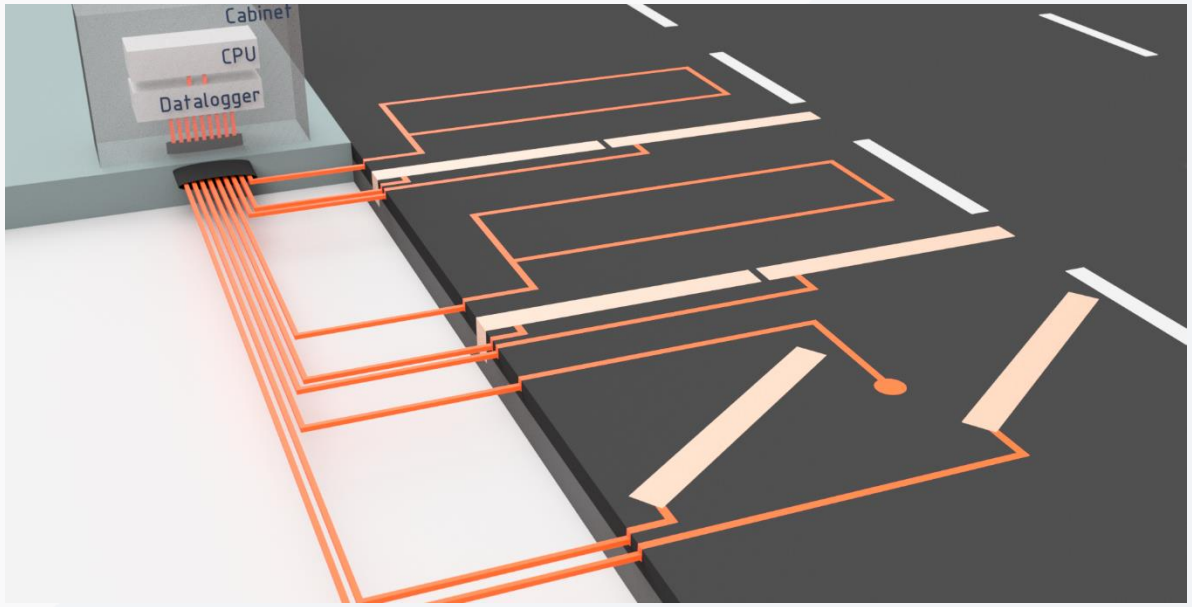
WIMTRONIC

- Replaces additional sensors needed for WIM
  - One PoE Ethernet cable per sensor



ANALOG WIM SOLUTIONS

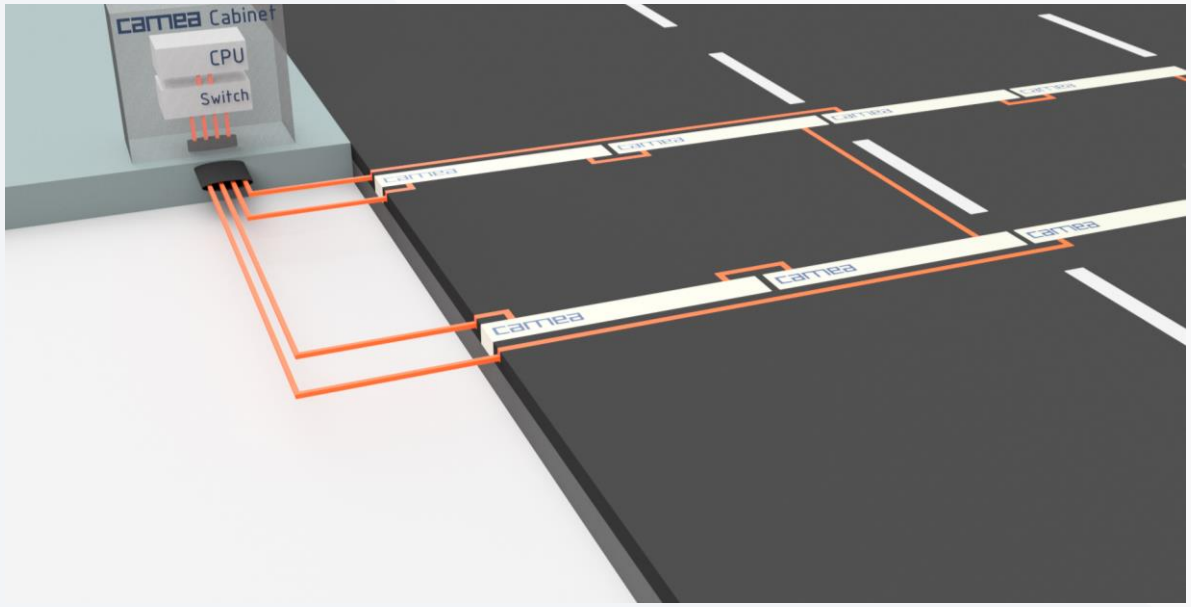
- Many different sensors and cables
  - Costly, tedious and damaging installation



Cheap and Easy Cabling

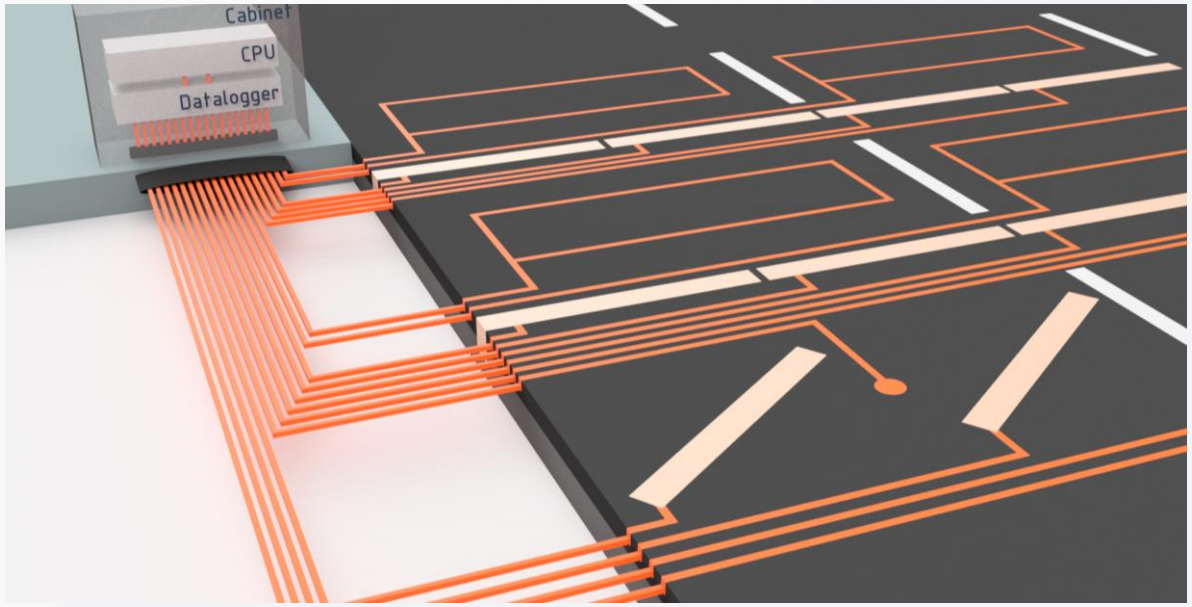
WIMTRONIC

- Interconnection version 2
  - 4 cables per 8 sensors (ring daisy-chain)



OTHER WIM SOLUTIONS

- Complex and expensive cabling
  - Up to 17 cables per one road lane



Pressure and Shear Force Measurement

WIMTRONIC

- Pressure force sensitive load cells
  - Perpendicular load force measurement
- Shear force sensitive load cells
  - Tangential shear force measurement
  - Can be used for validation of measurement
- Pressure and shear force sensitive load cells can be combined to exploit their best features

OTHER WIM SOLUTIONS

- Pressure force sensitive load cells only
  - Perpendicular load forces measurement only
- Shear forces caused by dynamics of moving vehicle can affect the accuracy
  - No information about shear forces available

Fusing Load Cell Technologies

WIMTRONIC

- Piezoelectric load cells
  - Best solution for measuring fast dynamic forces generated by moving vehicles
- Semiconductor strain gauge load cells
  - Useful for static measurements and calibration (approx. 50 times more sensitive than foil strain gauges)
- Both can be combined to exploit their best features or used individually

OTHER WIM SOLUTIONS

- Only one sensing technology
- Piezoelectric elements
  - 25+ years of experience, field proven
- Foil strain gauges load cells
  - Bulky, high sensor profile, potentially limited lifetime
- Fiber optic
  - Bulky, high sensor profile, costly

Piezoelectric Load Cells

WIMTRONIC

- Individually pre-loaded piezoelectric elements
  - Ensuring even and accurate longitudinal sensitivity over the entire sensor
- More than one row of load cells can be installed in the sensor body
  - Two rows of load cells as a standard
  - Multiple rows for highly accurate loading plates

OTHER WIM SOLUTIONS

- Piezoelectric quartz elements are pre-loaded by the sensor body
  - Due to manufacturing tolerances, the longitudinal sensitivity of the sensor may vary, especially at the edges of the sensor
- Only one row of load cells can be installed
  - Limited information about moving vehicles can be acquired by the sensor

Semiconductor Strain Gauge Load Cells

WIMTRONIC

- Semiconductor strain gauges can be used
  - Approx. 50 times higher sensitivity than foil strain gauges
  - Very small dimensions of the load cell
  - Unlimited number of measurement cycles for a long sensor lifetime
  - Higher overloading compared to foil strain gauges load cells

OTHER WIM SOLUTIONS

- Foil strain gauges commonly used
  - Lower sensitivity compared to semiconductor strain gauges
  - Large load cell design which leads to a bulky sensor with high profile
  - Potentially limited number of measurement cycles reduces sensor lifetime when used in roads with heavy traffic

Embedded Electronics

WIMTRONIC

- Rugged electronics
  - Dedicated amplifiers and A/D converters for each load cell
  - Low power high performance processor
  - On-board memories for measured data, parameters and calibration constants
  - Switch for daisy-chain interconnection
- Additional sensors available
  - Thermometers, magnetometers, accelerometers, radars, environmental (water, ice), etc.

OTHER WIM SOLUTIONS

- Datalogger and other electronics installed in a cabinet
  - Complicated and costly integration
  - Cabling placement and connections are labor costly and prone to failure
  - Cabling installation damages the road surface
  - Requires well trained and experienced labor

Digital Data Pre-Processing

- Ready for on-board pre-processing
  - Digital signal processing (DSP)
  - Weighing pre-processing
  - Compensations of temperature, etc.
  - Lateral sensor auto-calibration
  - Advanced validation of measured data
  - On-board diagnostics
  - Cumulative measurement statistics, etc.
- Allows cloud back-office processing
  - Simplifies on-site processing
  - Single server for several WIM stations
  - No local computer necessary

Conclusions – Sensor Build

The design minimizes road interference, increases accuracy, and enables implementation of innovative function

Feature	WIMTRONIC	Other Analog Sensors	Other Digital Sensors
Low sensor profile	✓	✓	✗
Long tire contact area	✓	✓	✗
High abrasive layer	✓	✗	✗
Two rows of load cells	✓	✗	✗
Low side bending moment	✓	✗	✗

Conclusions – Digital Processing

Digital processing of measured data reduces the number of sensors needed, simplifies installation, and offers new functions

Feature	WIMTRONIC	Other Analog Sensors	Other Digital Sensors
Independent load cell measurement	✓	✗	✓
Embedded datalogger	✓	✗	✓
Ethernet interface	✓	✗	✓
Daisy-chain interconnection	✓	✗	✗
Additional sensors on-board	✓	✗	✓

Conclusions – More Sensing Technologies

Different sensor technologies can be combined to make use of their best properties according to the needs of WIM applications

Feature	WIMTRONIC	Other Analog Sensors	Other Digital Sensors
Pressure sensitive load cells	✓	✓	✓
Shear sensitive load cells	✓	⊗	⊗
Individually preloaded piezoelectric load cells	✓	⊗	⊗
Semiconductor strain gauge load cells	✓	⊗	⊗

Conclusions – Innovative Features

The sensor allows advanced validation and refinement of data thanks to measurement of newly obtainable vehicle parameters

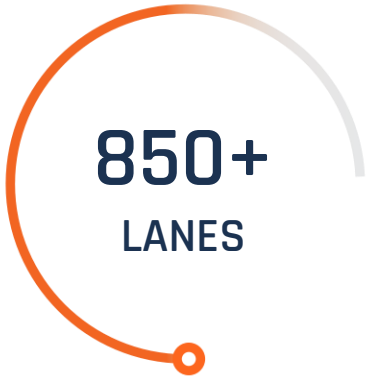
Feature	WIMTRONIC	Other Analog Sensors	Other Digital Sensors
Wheel Torque	✓	⊗	⊗
Wheel Braking	✓	⊗	⊗
Speed Measurement	✓	⊗	⊗
Road Rutting	✓	⊗	⊗
Travel Direction	✓	⊗	⊗
Road Deflection	✓	⊗	⊗

Conclusions – Tire Monitoring

Independent load cell measurements allow various tire-monitoring functions

Feature	WIMTRONIC	Other Analog Sensors	Other Digital Sensors
Tire Position	✓	⊗	✓
Dual Tires	✓	⊗	✓
Tire Footprint	✓	⊗	✓
Underinflated Tires	✓	⊗	✓
Overinflated Tires	✓	⊗	✓
Pressure-In-Motion	✓	⊗	?
Road Surface Pressure	✓	⊗	?

CAMEA – Direct Enforcement Expert



WEIGH-IN-MOTION

WIM DIRECT ENFORCEMENT

SPEED ENFORCEMENT

ITS WORLDWIDE