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Development of a Novel Weighing Digital Sensor for Further Evolution of WIM Technology

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Current HS-WIM Sensors

- The technologies are mature, but some features are missing or can be problematic
  - Interference with the road structure
  - Additional sensors necessary
  - Limited number of measured quantities
  - Longitudinal resolution
  - Measurement in the whole width of the traffic lane
- We developed a novel digital sensor CAMEA WIMTRONIC that addresses a number of these issues, and in addition offers some additional features

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An "Ideal" HS-WIM Sensor

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- Should be as low as possible to have minimum interference with the road structure
- Should be able to measure the position and width of each vehicle wheel individually
- Should be able to measure not only gravitational forces but also other quantities to reduce the number of additional sensors and their cabling

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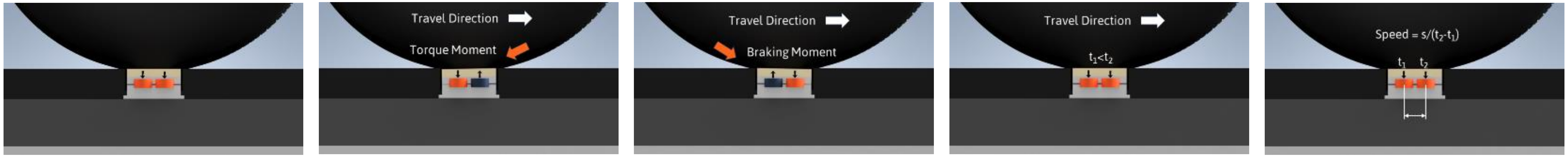
The Novel Digital Sensor Build

- 2 rows of piezo-quartz elements
  - Measurement of not only the vertical gravitational forces, but also the effects of horizontal forces (braking, torque)
  - Determination of direction and speed of the wheel
  - Advanced validation of measurements



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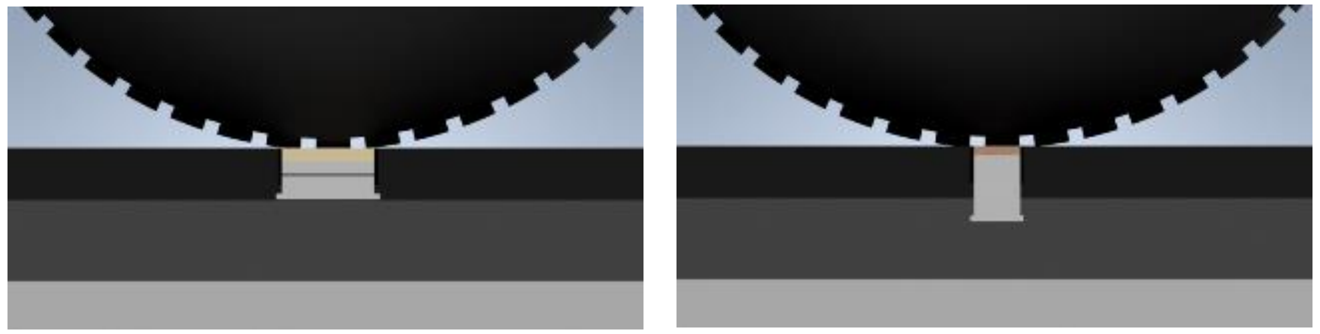
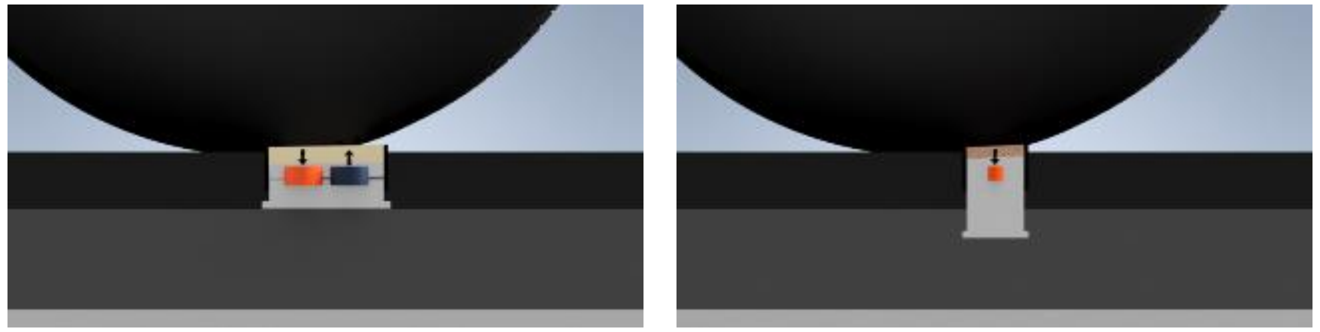
Sensor Build - Width

- Wider (80 mm) than common HS-WIM sensors used today (up to 50 mm)
  - Reduces road irregularity influence (larger part of the tire is on the sensor)



  - Low side bending effect



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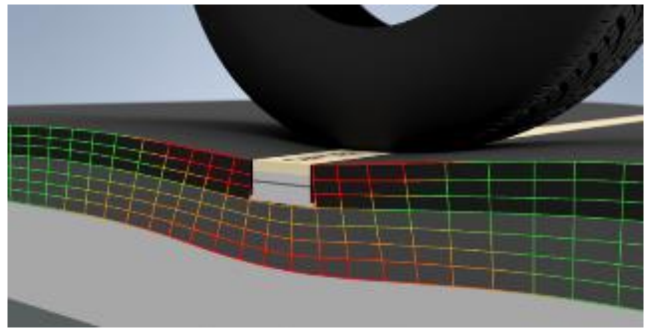
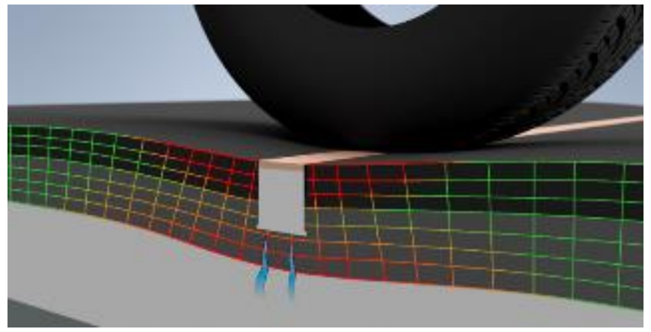
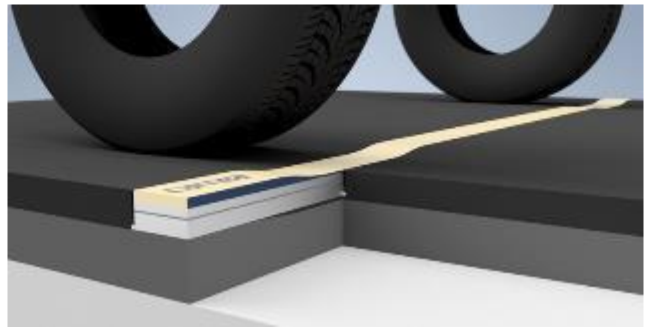
Sensor Build - Height

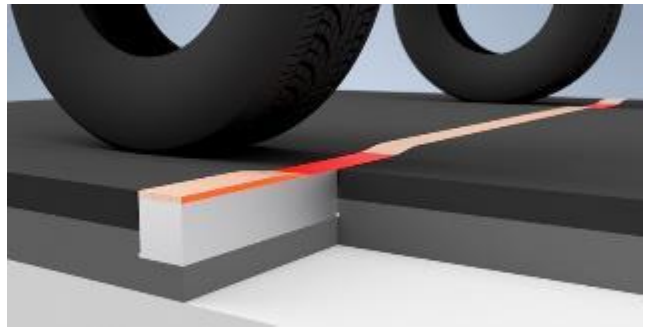
- Lower than most HS-WIM sensors used today
  - WIMTRONIC - 33mm body with a 12mm abrasive layer = total of 45 mm
- Lower body
  - Reduces interference with the pavement structure
  - Increase in pavement and sensor lifespan





- Higher abrasive layer
  - Longer lifetime in road ruts (can be grinded more)





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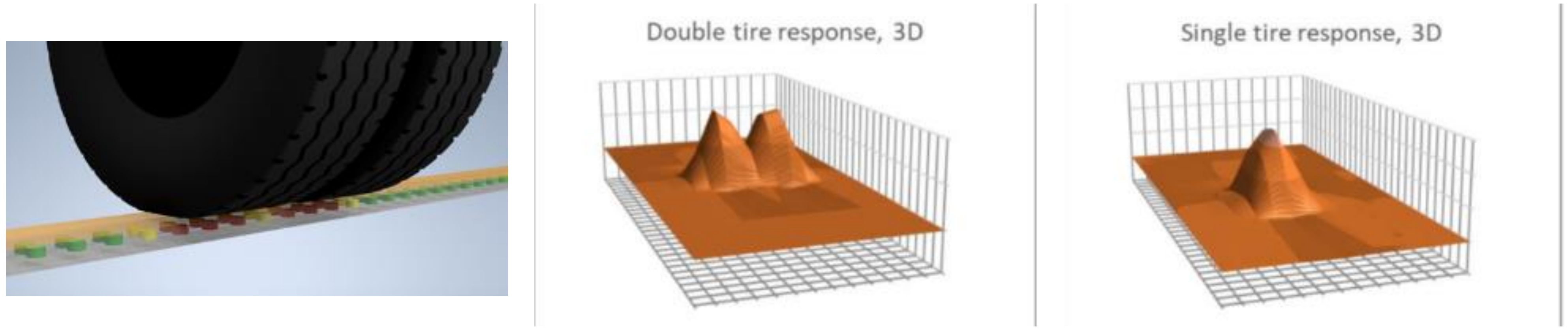
Embedded Signal Processing

- Individual processing of signals from sensing elements
  - Individual preload to ensure uniform sensitivity and accuracy
  - Detection of tire position and dual tires and wheelbase



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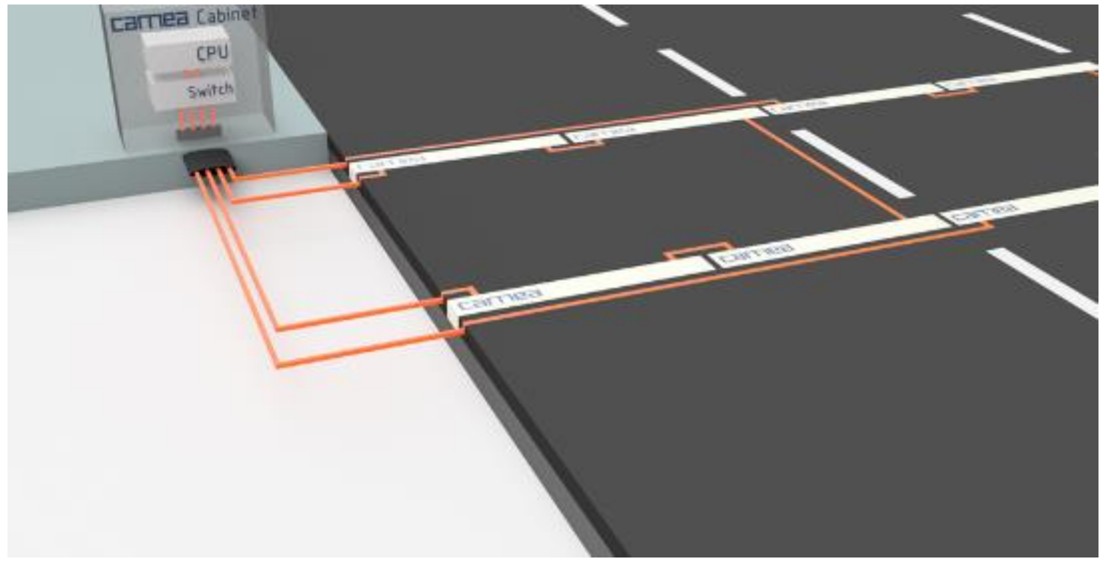
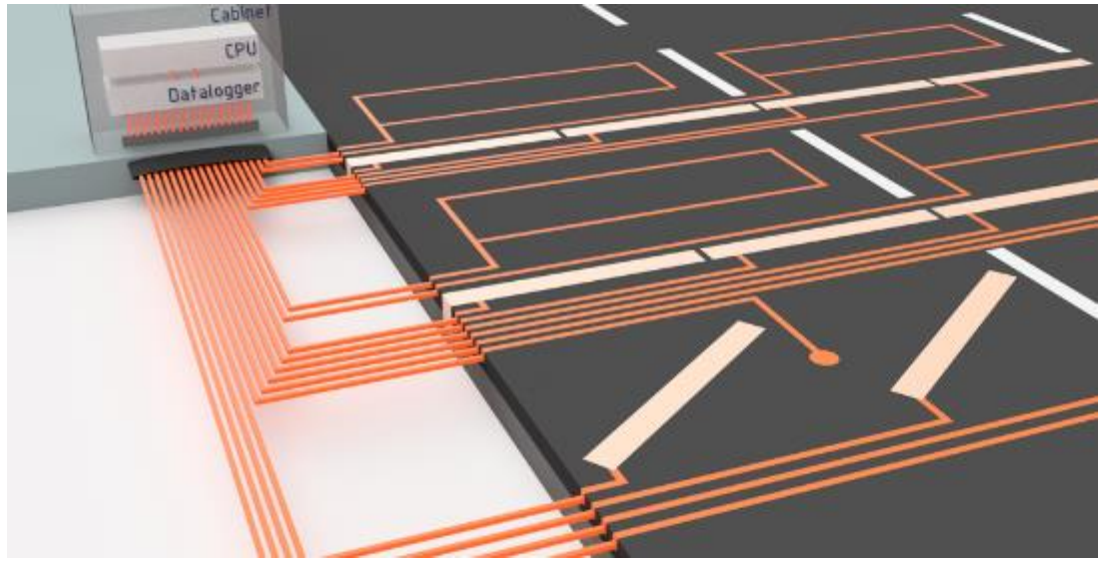
Embedded Signal Processing

- Additional sensing technologies inside and digital processing
  - Detection and classification of vehicles
  - Road and sensor temperature
  - Reduction of external sensors and cabling
  - Daisy chain support (a single cable leads to a pair of sensors)





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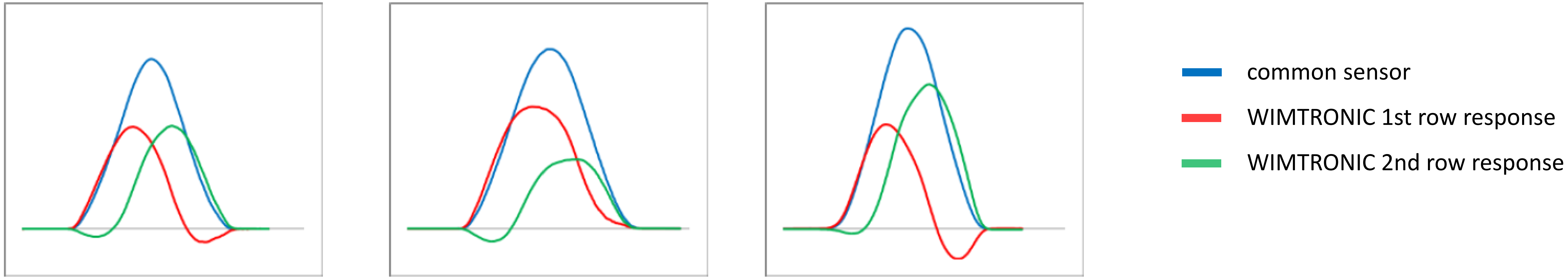
Measuring Gravitational and Horizontal Forces

- Measurement of the response ratio of each sensing element row
  - Information on both the vertical and horizontal components of the applied forces
  - Possible to determine if the wheel is moving uniformly, accelerating or decelerating
  - Validation and compensation of measurement results



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Weighing Accuracy

- Standard deviation of 2.4 %
  - Light twin-axle truck (because light twin-axle vehicles often show a higher error due to increased chassis vibration)
  - Fully loaded vehicles show an even lower weighing error
  - It makes sense to weigh fully loaded vehicles, light vehicles are probably not overloaded
- Laboratory conditions within 1 %
  - The in-field measured values are largely determined by the quality of the road, the installation of the sensor and the dynamics of the vehicle.

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Wheel Position and Detection of Multiple Tire Mountings

- Tests using a light two-axle truck with relatively narrow tires (195/70 R15)
  - Narrow tires have a small footprint and therefore have a larger measurement error than would be the case for trucks with wider tires
- Separate measurements even for wheels with multiple tire mountings
- Below is a table with tire width measurements, similar results were achieved for wheel position

Units	mm	mm	mm
Reference	195	195	195
	Wheel 1 Err.	Wheel 2 Err.	
	Single Tire	Outer Tire	Inner Tire
Average	3	2	3
	1.3 %	1.1 %	1.4 %
St. Dev. (68 % of results)	13	10	13
	6.6 %	5.2 %	6.8 %

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Tire Inflation Pressure Measurement

- Tests using a light two-axle truck with relatively narrow tires (195/70 R15)
- Measurement error of up to 21±13 kPa (4.8±3.0 %)
- Separate measurements even for wheels with multiple tire mountings

Units	kPa	kPa	kPa
Reference	430	350	395
	Wheel 1 Err.	Wheel 2 Err.	
	Single Tire	Outer Tire	Inner Tire
Average	21	0	8
	4.8 %	0.0 %	2.0 %
St. Dev. (68 % of results)	13	5	11
	3.0 %	1.5 %	2.9 %

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Sensor for Vehicle Classification

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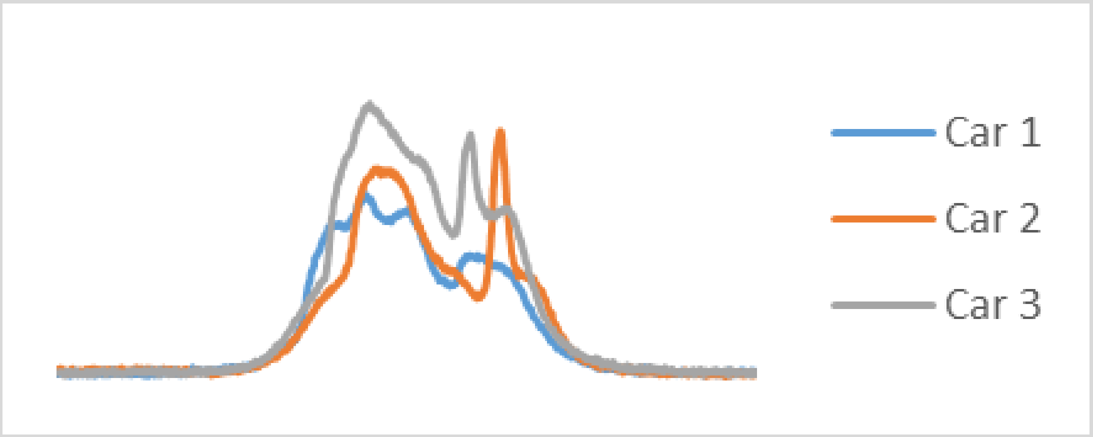
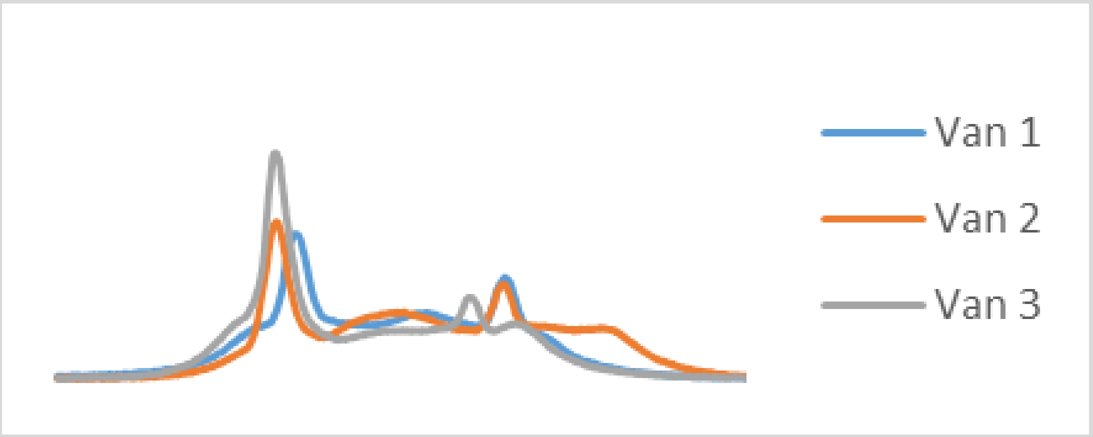
- Additional sensing elements to enable vehicle classification based on chassis design
- Necessary when the vehicle type cannot be determined from the axle arrangement alone (e.g., car vs van, bus vs truck)





Typical measured chassis responses of a passenger car and van

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Cumulative Road Load

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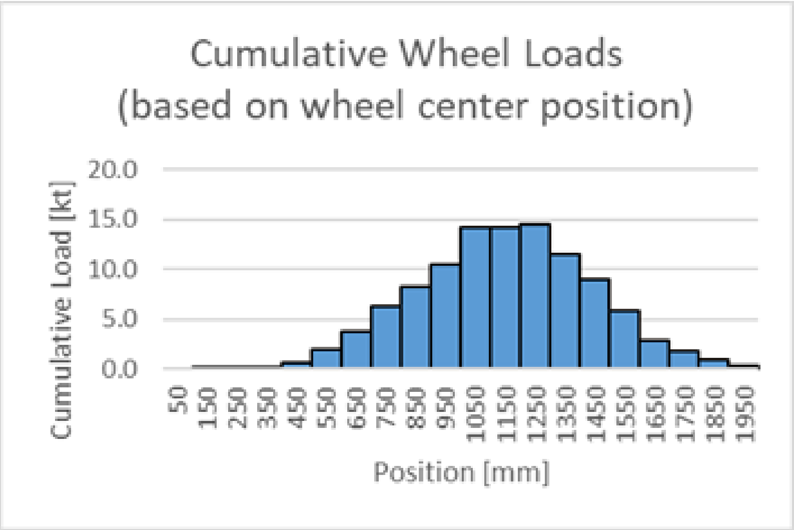
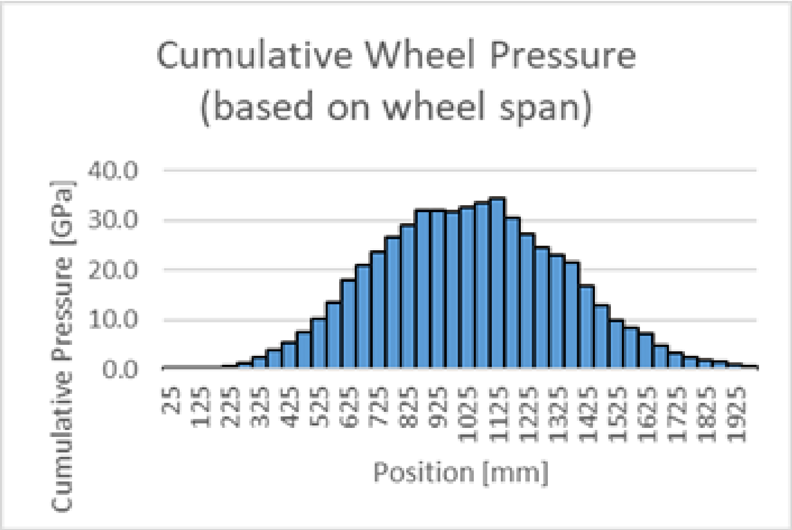
- Typically, ESALs (Equivalent Single-Axle Load) are used for road wear estimations
  - These use a resolution of a traffic lane or road
- The digital sensor allows a detailed analysis of the loads and pressures in the lateral profile of the roadway





Measured cumulative loads and pressures based on the lateral position of the wheel on the sensor

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CAMEA Experience

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- 1,550+ lanes equipped with Intelligent Transportation Systems (ITS) worldwide
- 850+ lanes equipped with WIM worldwide
- 200+ lanes equipped with WIM for direct enforcement
- WIM type approved and used for direct enforcement in many countries:
  - Czech Republic (also OIML certified)
  - Russian Federation
  - Ukraine
  - Austria
  - Kenya

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Conclusions

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- The digital sensor build minimizes road interference, increases accuracy, and enables implementation of innovative functions
- Digital processing of measured data reduces the number of sensors needed, simplifies installation, and offers new functions
- The sensor allows advanced validation and refinement of data thanks to measurement of newly obtainable vehicle parameters
- Independent load cell measurements allow various tire-monitoring functions

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