LiRA project: impact of connected vehicles and IoTs on pavement management system

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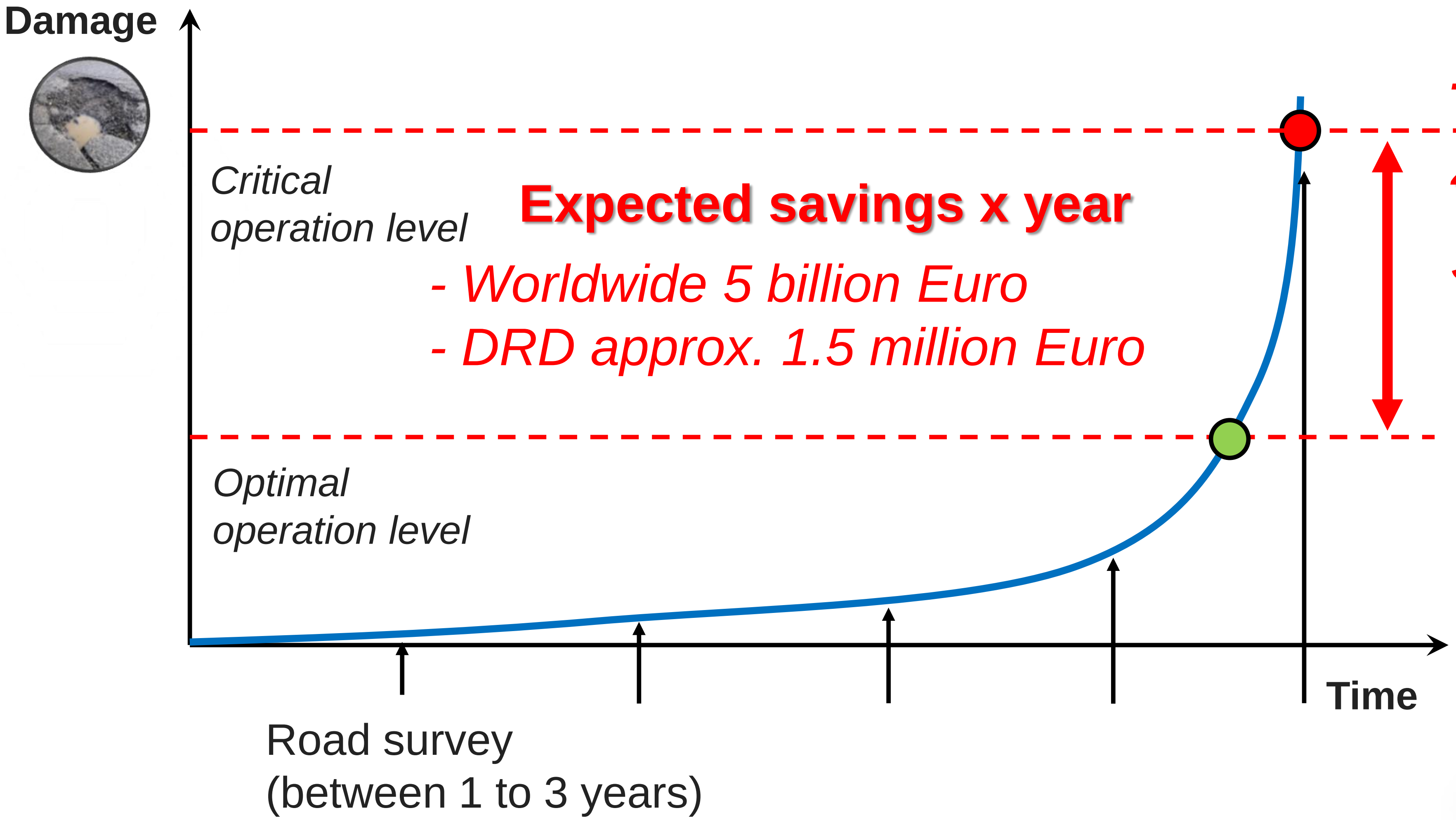
Background

Roads make a crucial contribution to economic development and growth and bring **important** social benefits.

The Road conditions change over the life time

Background

Worldwide more than **100 billion Euro are spent yearly on road pavement maintenance**.
DRD spends <u>every year</u> 30 million Euro in re-surfacing – approx 5 % due late maintance operation *(3800 km of roads)*



1. ***Direct extra costs***
2. *Safer roads*
3. *Maintenance based on road emissions (Noise and CO_2) – Healthier environment*

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Background

Worldwide more than **100 billion Euro are spent yearly on road pavement maintenance**.
DRD spends every year 30 million Euro in re-surfacing – approx 5 % due late maintance operation *(3800 km of roads)*

Standard road measures have been developed to guarantee proper road conditions and to optimize maintenance strategies focusing on (DRD operational costs 700.000 Euro per year) :

- Safety
- Comfort
- Durability
- Environmental Emissions (noise and Rolling Resistance)

Limitations

1) Costs
2) Weather
3) Road Geometry
4) Not always objective

Project idea

Can we find a more efficent way to monitor and mange the road network?

Modern cars are equipped with many sensors and can also provide further data including energy consumption.

Can in-vehicle car sensors be used to measure road conditions?

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What is LiRA?

LiRA project (Live Road Assessment) is a collaborative effort between

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GreenMobility
YOUR CITY CAR

SWECO

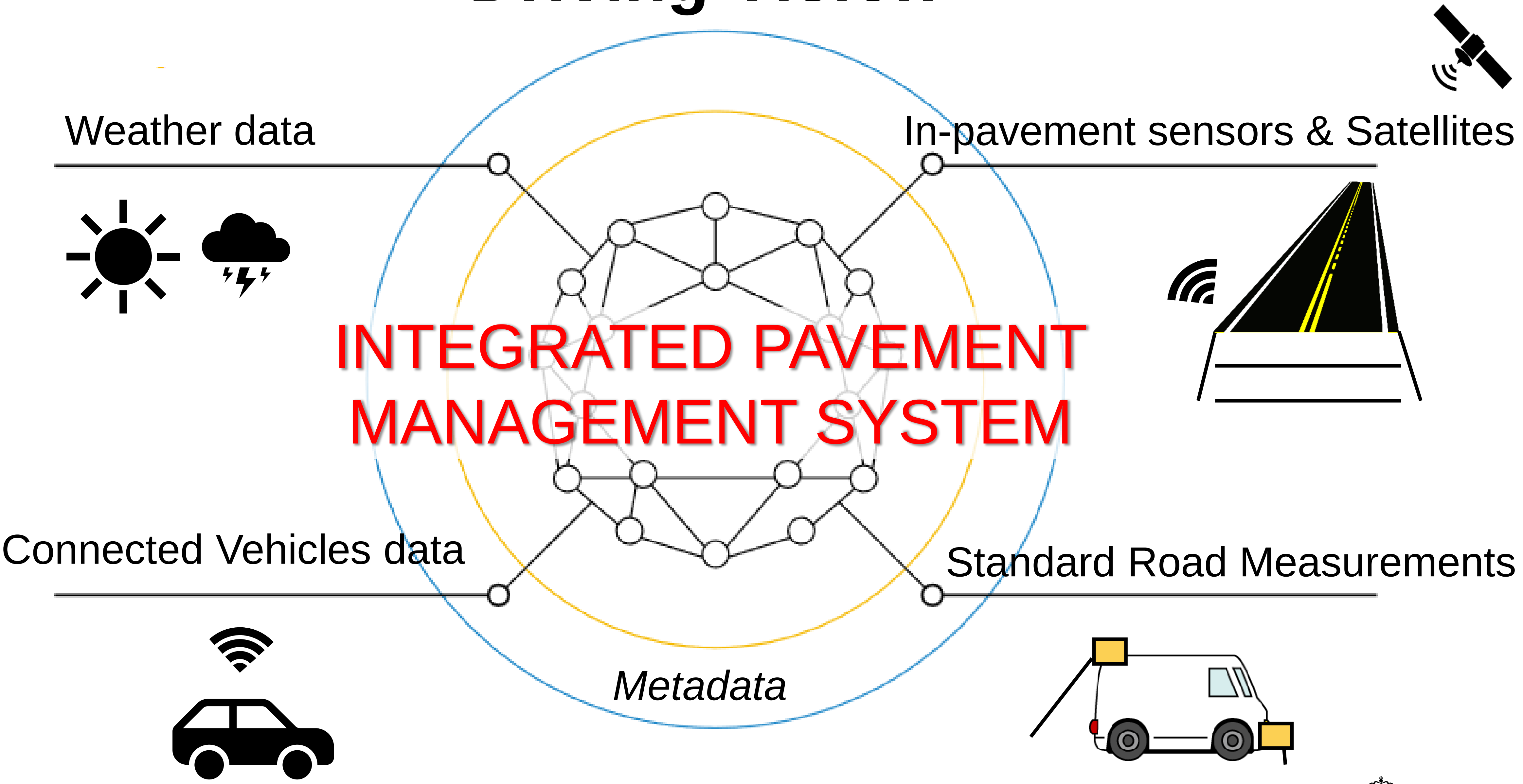
DTU
Danmarks
Tekniske
Universitet

Innovation Fund Denmark

LiRA Project → Goal → Vision

https://lira-project.dk/

Driving Vision

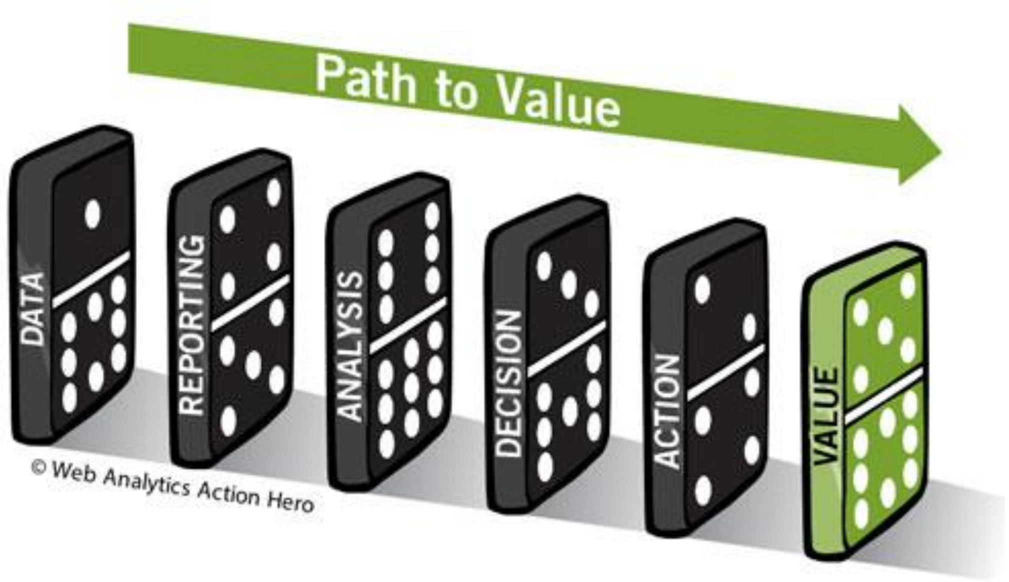


Project Goal

Develop and demonstrate a new method for performing live road condition surveys based on data collected by a connected fleet of vehicles.

- create additional *value for car sensors data*

- deliver a *prototype system demonstrated in Copenhagen*



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Project Goal

LiRA focused on delivering condition information at NETWORK LEVEL related to four different categories:

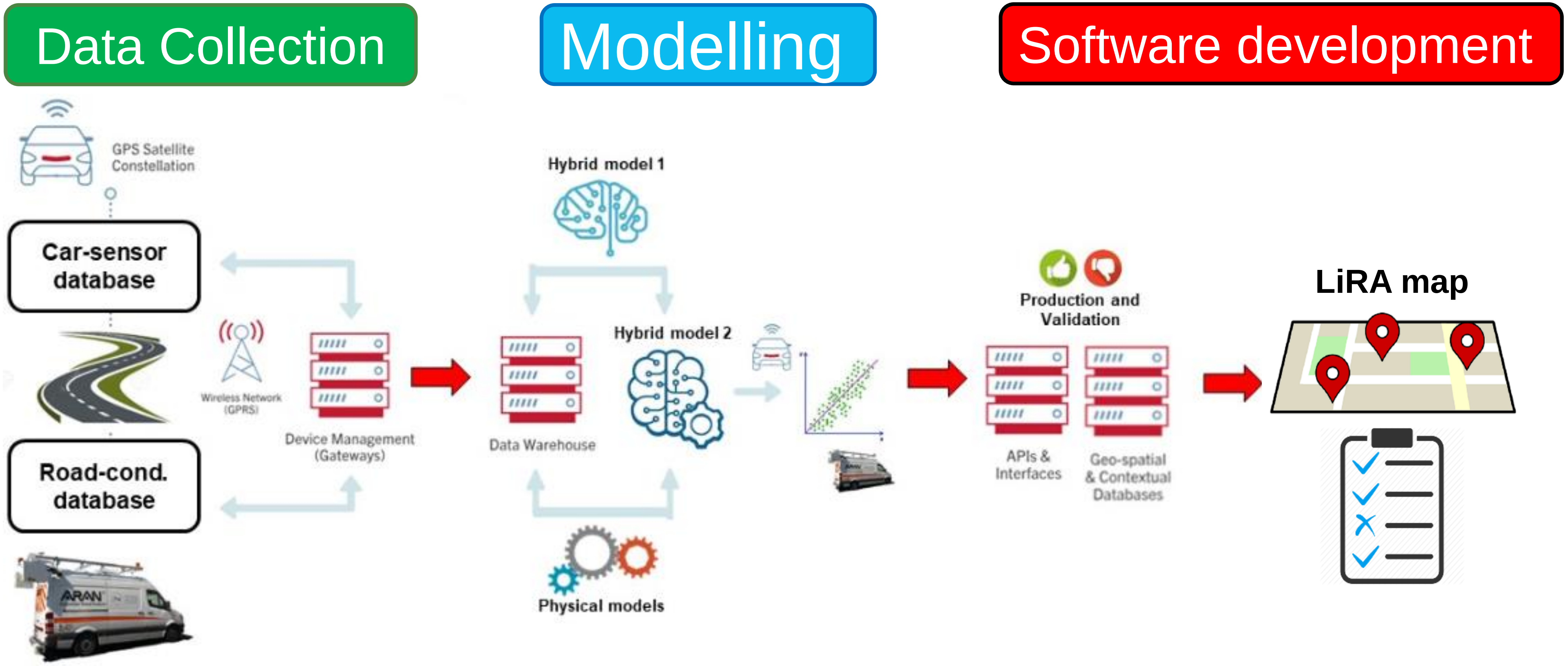
(i) Comfort – IRI and Profile Unevenness

(ii) Safety - Friction

(iii) Durability – Damage Index (DI) and Key Performance Index (KPI)

(iv) Emissions – Energy Consumption

Project Structure (2019 to 2022)



Data Collection

Main tasks

1. **Selection** of representative **road sections**

2. **Data collection** with Standard Vehicles and Cars

3. **Car data**: *hardware* and *software*

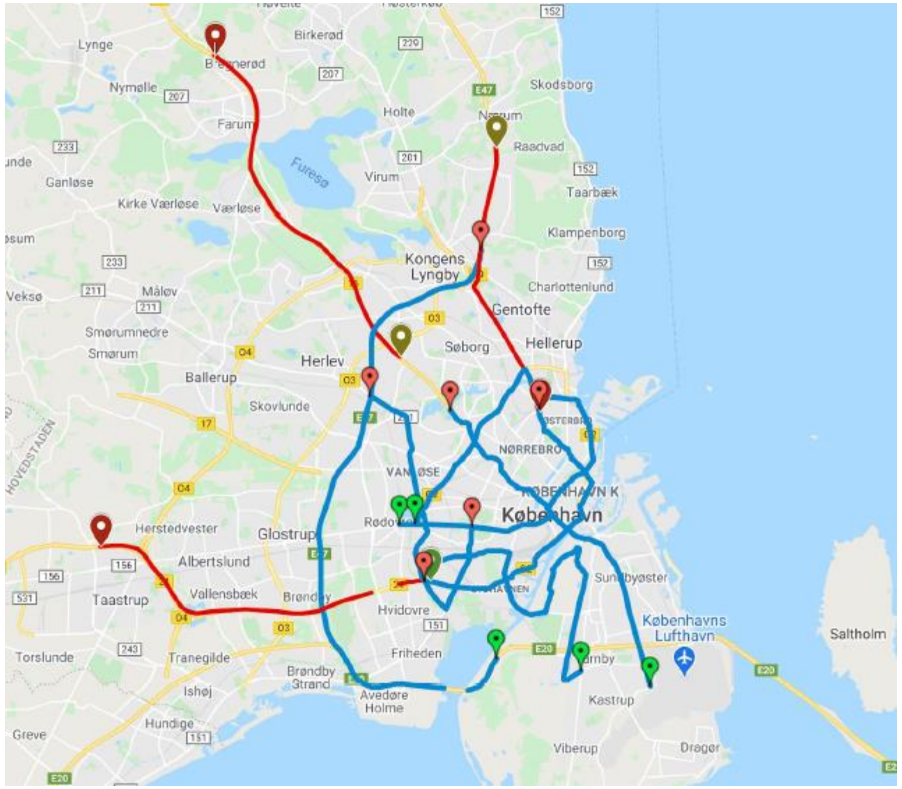
4. **Data Infrastructure**

Data collection

Representative sections

SECTIONS and ROUTES

- Selected sections



Section Type	Number or Direction	Length
*Trial 1 – DTU**	1 loop	4 km
Trial 2 – M13	2 – North and South	22 km
Motorways DRD	7 – North and South	179.6 km
Copenhagen Mun.	7 routes - both Direct.	190.0 km

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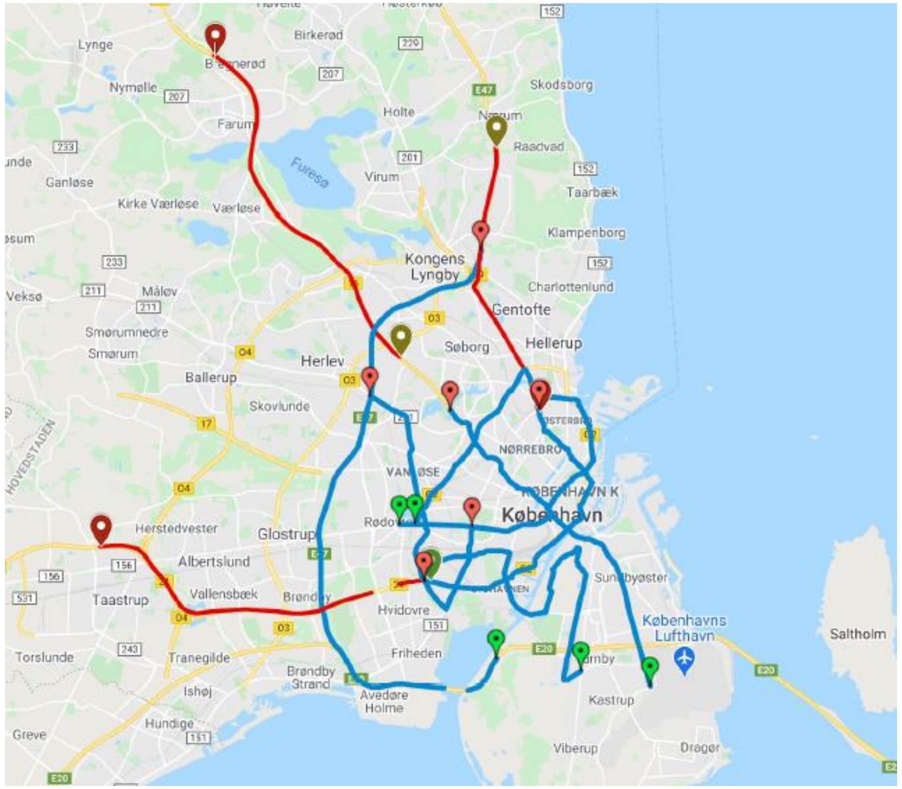
Representative sections

Data collection

SECTIONS and ROUTES

- Selected sections



TARGET VARIETY

- Road type
- Defects and Distresses
- Driver behavior

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Data collection

Data collection with Standard Vehicles

- P79 - Profilometer
- ViaFrik
- ARAN9000 – LCMS 2.0
- CPX
- VISUAL INSPECTIONS

ERPUG

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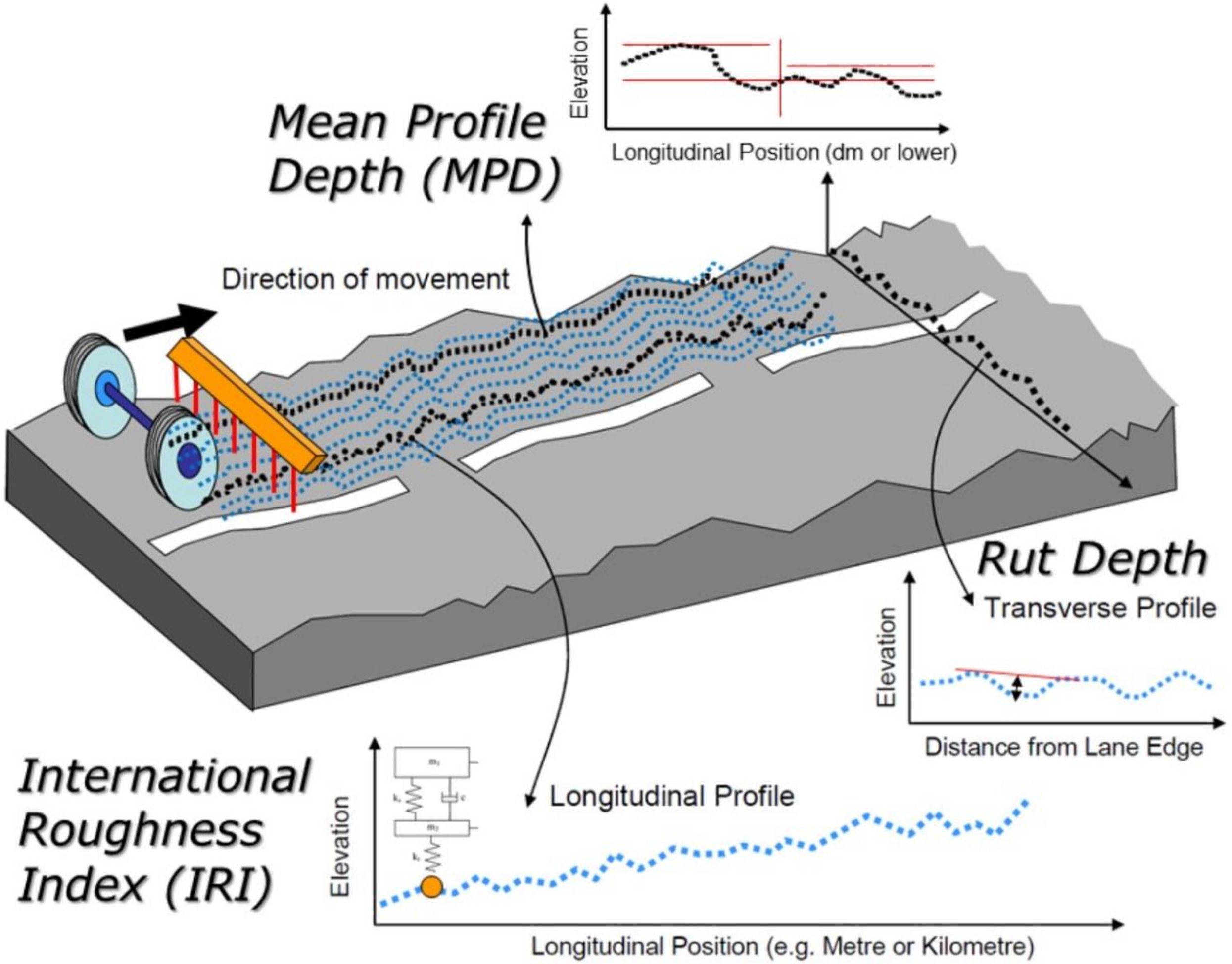
Data collection

Data collection with Standard Vehicles

P79 - Profilometer



Data collection with Standard Vehicles

ViaFrik

- electrically braked test wheel driven on a wet surface
- Both wheel paths
- 20% slip
- vertical and horizontal forces are monitored
- Data collected at constant speed when possible

Data collection with Standard Vehicles

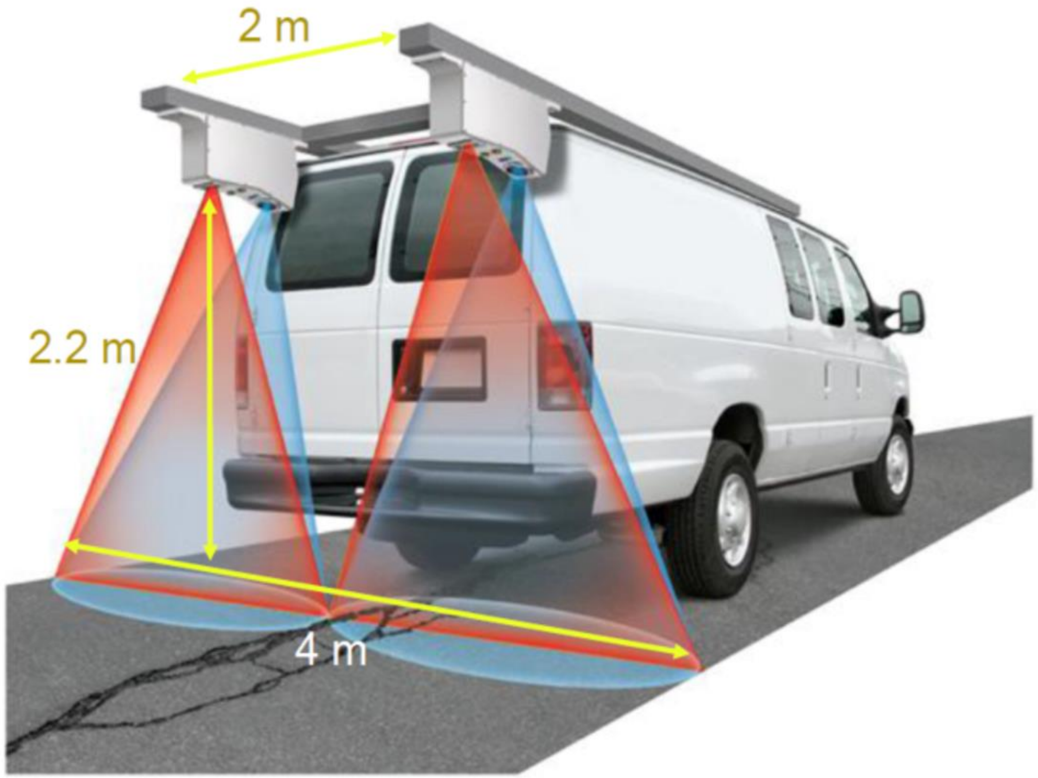
Data collection

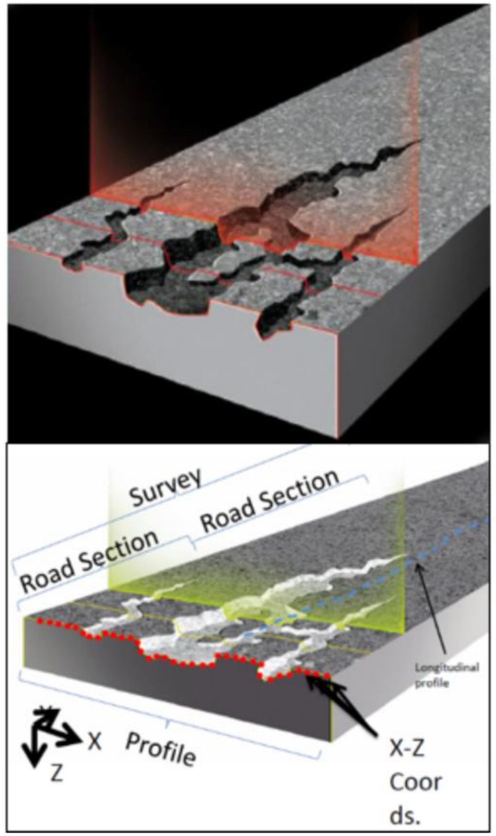
ARAN9000

Laser Cracking Measurement System (LCMS, 2Gen)

Defect Types detected by this technology

- Cracks
- Potholes and Delaminations
- Sealing and repairs
- Patches





Data collection

Data collection with Standard Vehicles

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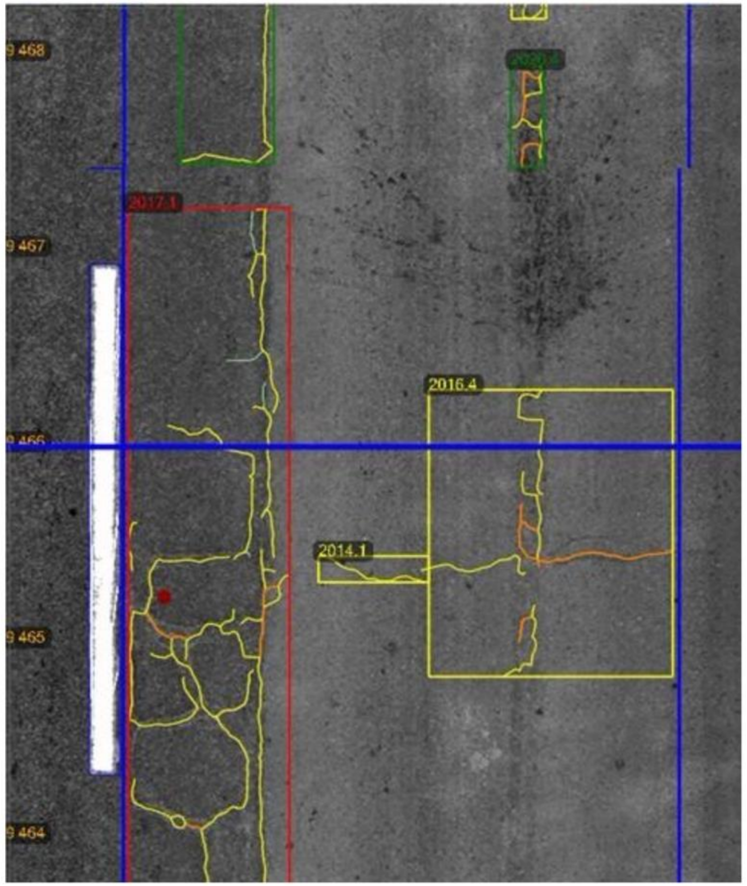

Example about Cracks

- Longitudinal (m)
- Transversal (m)
- Alligator (m^2)

Each type of Crack

- Small
- Medium
- Large

According to the crack width

Data collection

Data collection with Standard Vehicles

ARAN9000

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Key Performance Index (KPI) and Damage Index (DI)

We calibrated two Indexes to quantify the overall degree of damage and estimated remaining lifetime

$$DI = CracksSum + AlligatorCracksSum + PotholesSum$$

$$KPI = (CracksSum + AlligatorCracksSum + PotholesSum + RuttingMean) \cdot IRIMean$$

$$CrackingSum = (LCS^2 + LCM^3 + LCL^4 + LCSe^2 + 3TCS + 4TCM + 5TCL + 2TCSe)^{0.1}$$

$$AlligatorSum = (3ACS + 4ACM + 5ACL)^{0.3}$$

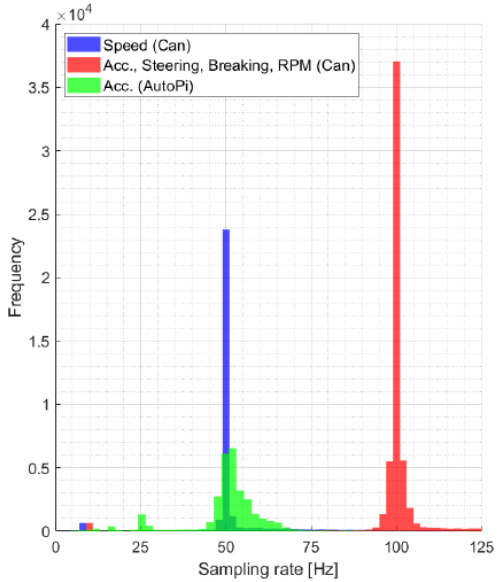
$$PotholesSum = (5PAS + 7PAM + 10PAL + 5PAD)^{0.1}$$

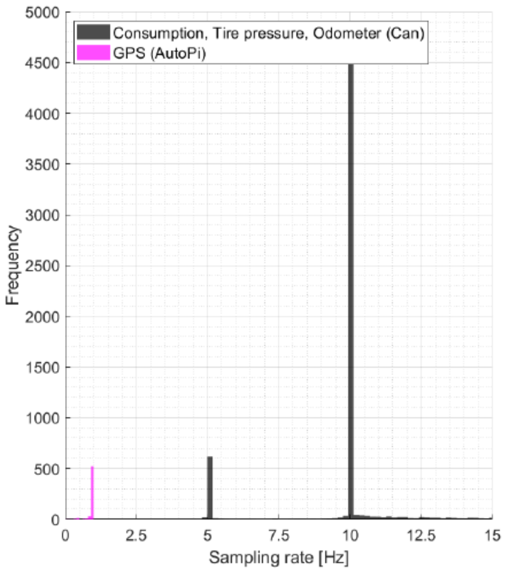
$$RuttingMean = ((RDL + RDR)/2)^{0.5}$$

$$IRIMean = ((IRL + IRR)/2)^{0.2}$$

Data collection

Car data: hardware and software





OBD data such as:

- *Tire pressure and rotation*
- *Steering Wheel position and accel*
- *Traction Instant consumption*
- *Accel x, y and z*
- *Breaking applied (both driver and electric)*
- *Total Potential Resistive Wheels Torque*
- *And more*

Can versus Can data

Cars
18 Renault Zoe ZE40

\+

Telematics Unit
18 AutoPi telematics unit

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https://lira-project.dk/wp-content/uploads/2020/12/LiRA-Webinar-Rasmus-Ostergaard-9th-Dec-2020_S1.pdf

Data Pipeline components

Data Pipeline

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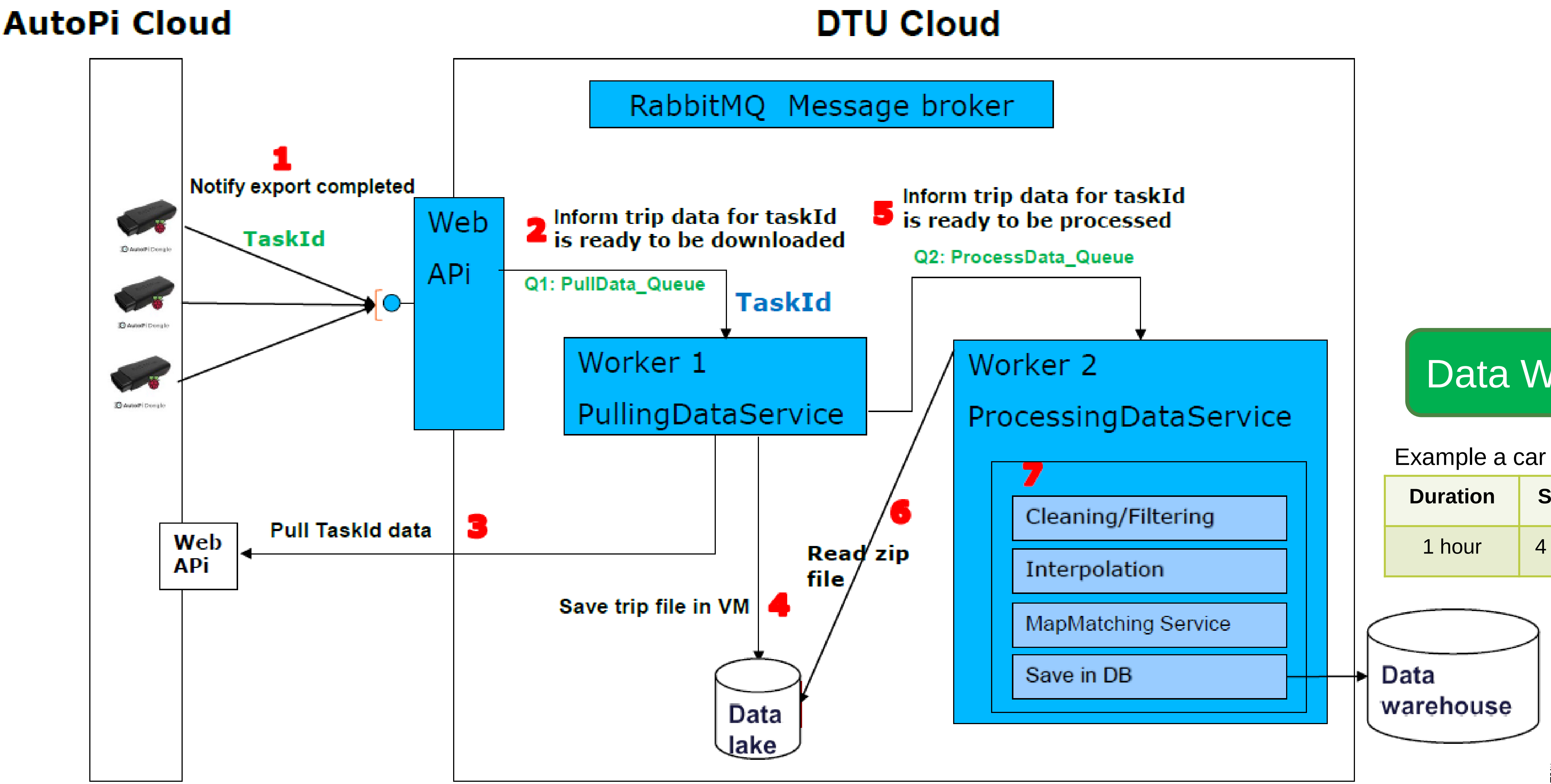

Data Warehouse

Example a car data trip

Duration	Size	Meas. Types
1 hour	4 GB	66

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https://lira-project.dk/wp-content/uploads/2020/12/LiRA-Webinar-Shahrzad-M.Pour-9th-Dec-2020.pdf

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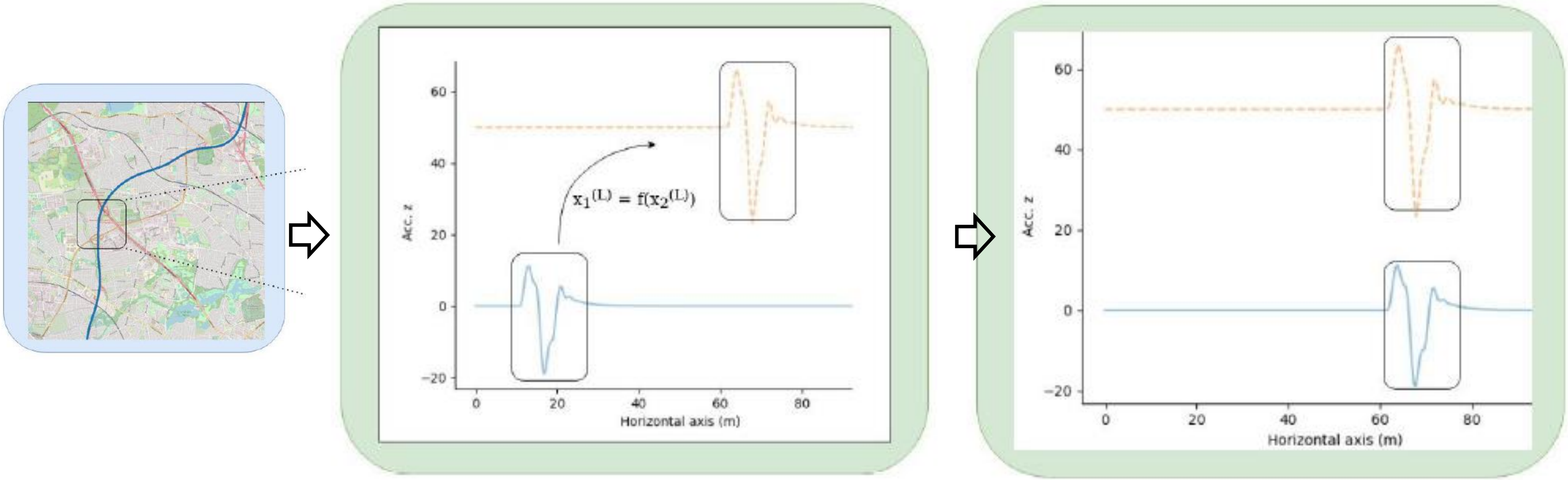
Data Analytics: preprocessing

1) Cleaning and data alignment



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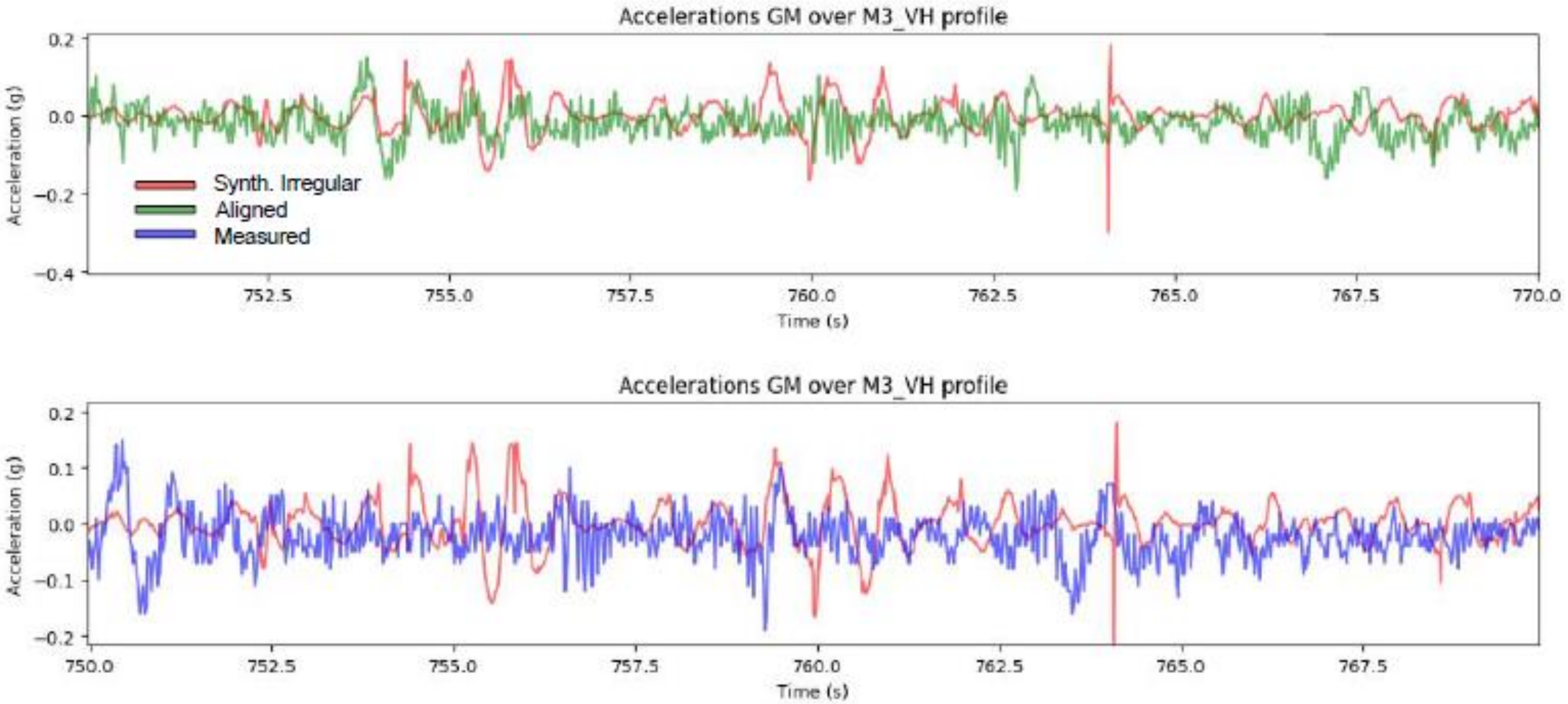

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Modelling

Model development

Predictions of significant road properties

1) IRI
2) Long. Profile unevenness
3) Friction
4) Damage Index
5) Key Performance Index
6) Energy Consumption

FUTURE

8) Noise

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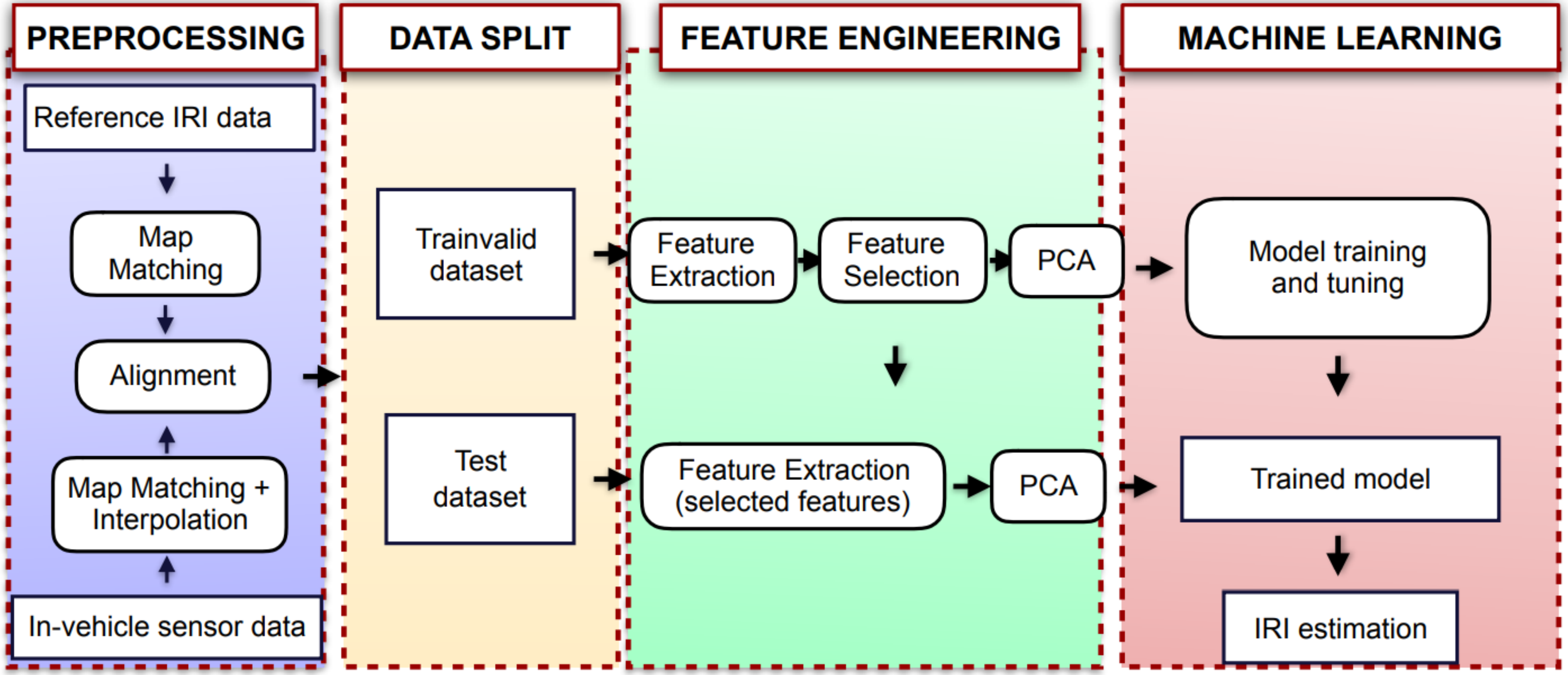
Modelling

Model development

International Roughness Index (IRI)

Standard Collection: *GreenMobility car driving on selected route*

DTU CPU (Milena B. and Tommy A.) ***developed a machine learning model to predict IRI***



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Modelling

Model development

International Roughness Index (IRI)

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1. Vertical acceleration and speed sensors
2. 3D acceleration and speed sensors
3. 3D acceleration, speed sensors and additional sensors

Feature	
0	GM.obd.whl_prs_fl.value-0_Signal distance
1	GM.obd.strg_acc.value-0_Mean
2	GM.obd.spd_veh.value-0_Negative turning points
3	GM.obd.whl_prs_rr.value-0_Max
4	GM.obd.trac_cons.value-0_Skewness
5	GM.acc.xyz.y-0_Total energy
6	GM.obd.whl_prs_fr.value-0_Variance
7	GM.acc.xyz.z-0_Standard deviation
8	GM.acc.xyz.x-0_Slope
9	GM.obd.acc_yaw.value-0_Positive turning points
10	GM.obd.strg_acc.value-0_Slope
11	GM.obd.strg_acc.value-0_Interquartile range
12	GM.obd.whl_prs_fl.value-0_Standard deviation
13	GM.obd.whl_prs_rl.value-0_Peak to peak distance
14	GM.obd.whl_prs_rl.value-0_Autocorrelation
15	GM.obd.whl_prs_rl.value-0_Skewness
16	GM.obd.whl_prs_fr.value-0_Entropy
17	GM.obd.acc_yaw.value-0_Skewness
18	GM.obd.strg_acc.value-0_Root mean square
19	GM.acc.xyz.z-0_Mean absolute deviation
20	GM.obd.strg_ang.value-0_Centroid

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Modelling

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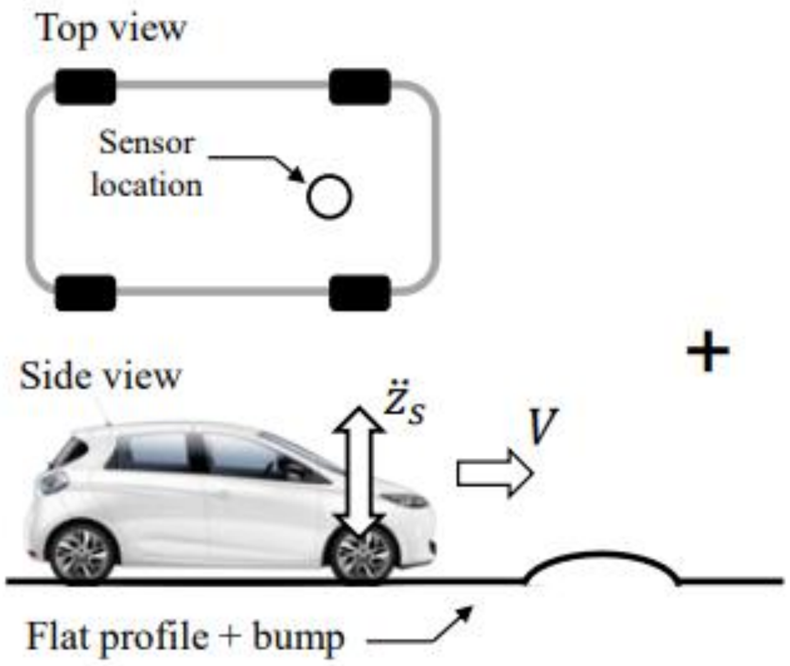
Model development

Longitudinal profile unevenness

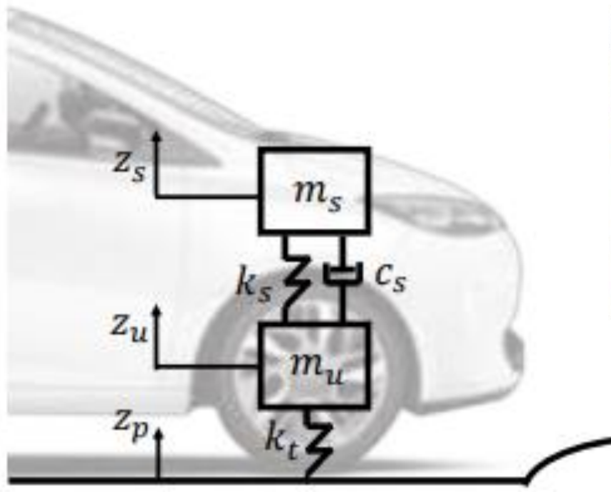
Platoon Collection: *GreenMobility car driving behind P79*

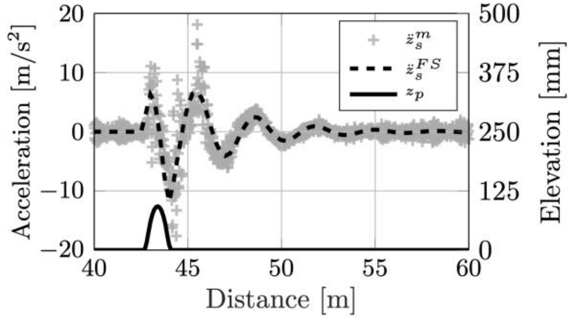
DTU Civil (Asmus S. and Eyal L.) ***developed a physical model to predict longitudinal profile***



+

Calibrated by optimization





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Model development

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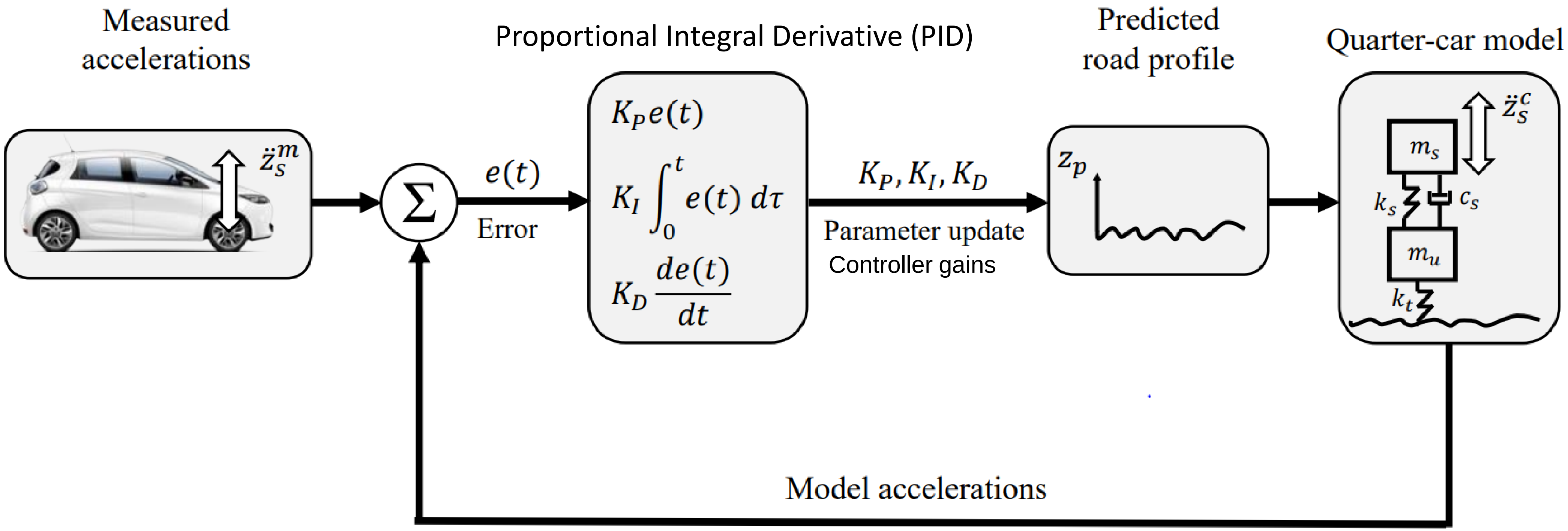


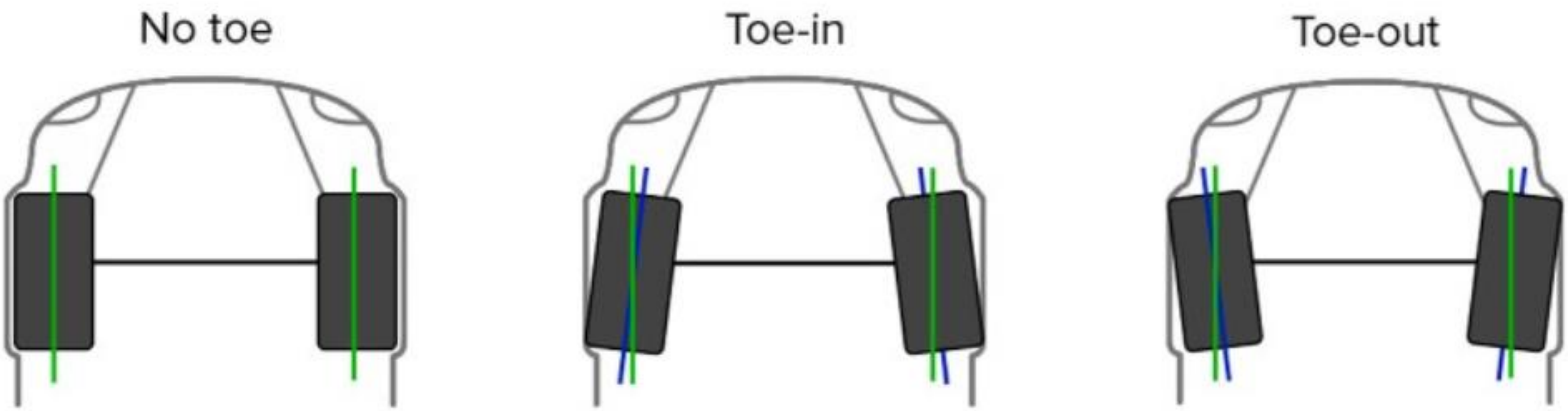
Modelling

Model development

Friction – Method based on Toe Angle

Platoon Collection: *GreenMobility car driving behind the Friction Vehicle*

DTU Civil (Eyal Lev.) ***developed a physical model to predict friction*** using car sensors.



Model development

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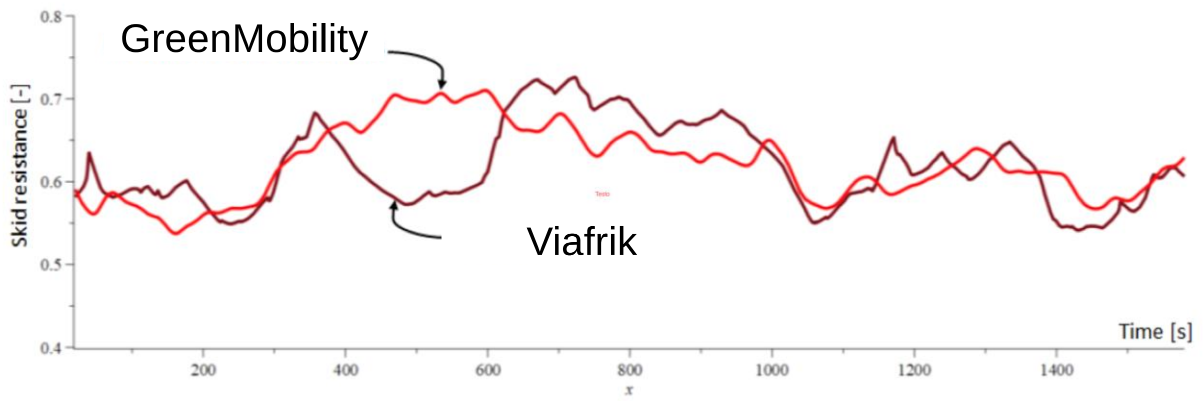

CHALLENGE: test was done at constant speed behind the VIAFRIK vehicle and sampling rate of accelerometer at 250 Hz

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Model development

Modelling

Friction – Skid resistance based on wheel rotations

RPM measurements of each wheel from the vehicle CAN bus. It is based on the fact that the *front wheels are the driven wheels*, while the *rear wheels are dragged behind and do not slip.*

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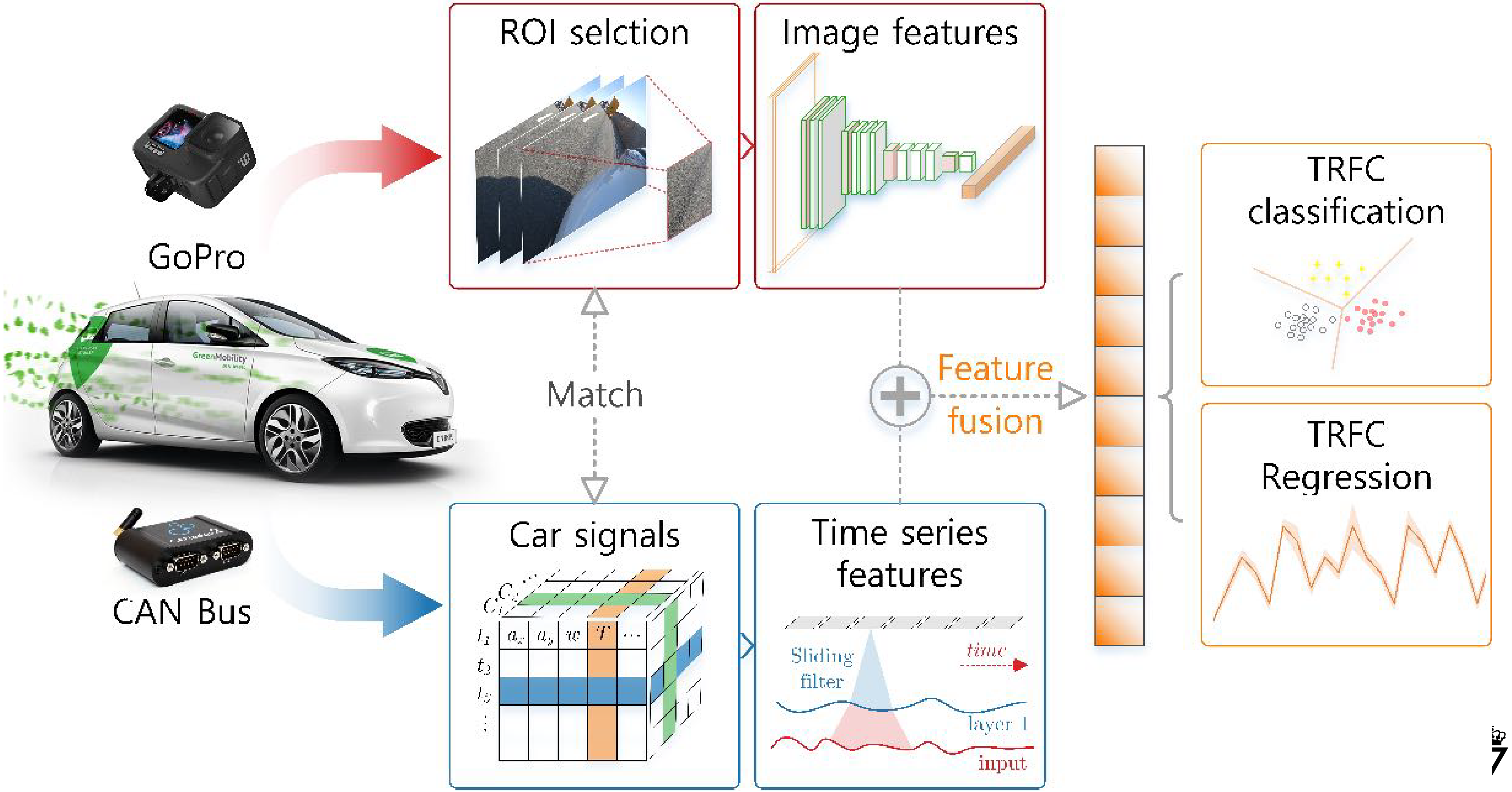
Modelling

Model development

Friction – Skid resistance based on wheel rotations



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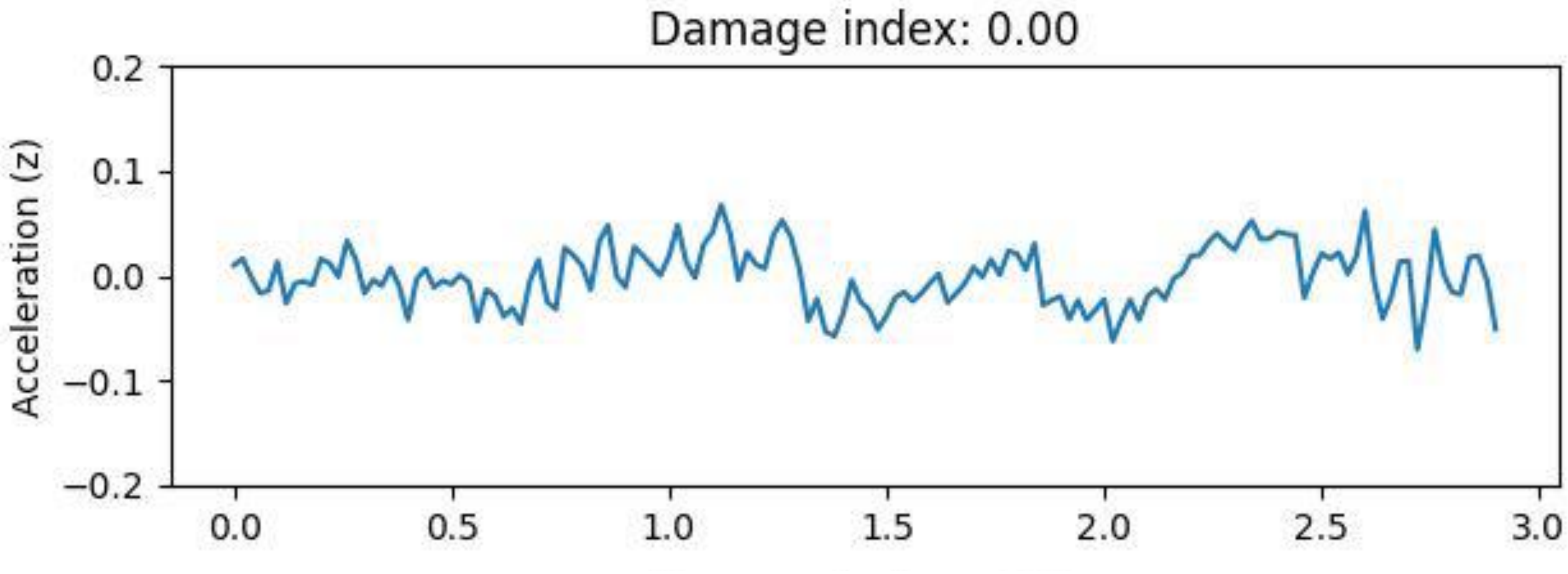
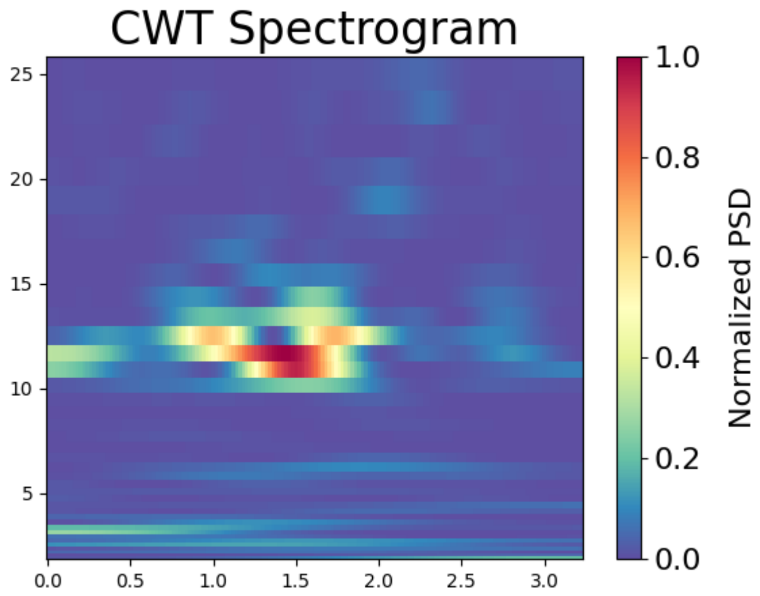
Model development

Modelling

Damage Index (DI) and Key Performance Index (KPI)

When I am driving on a road in GOOD conditions



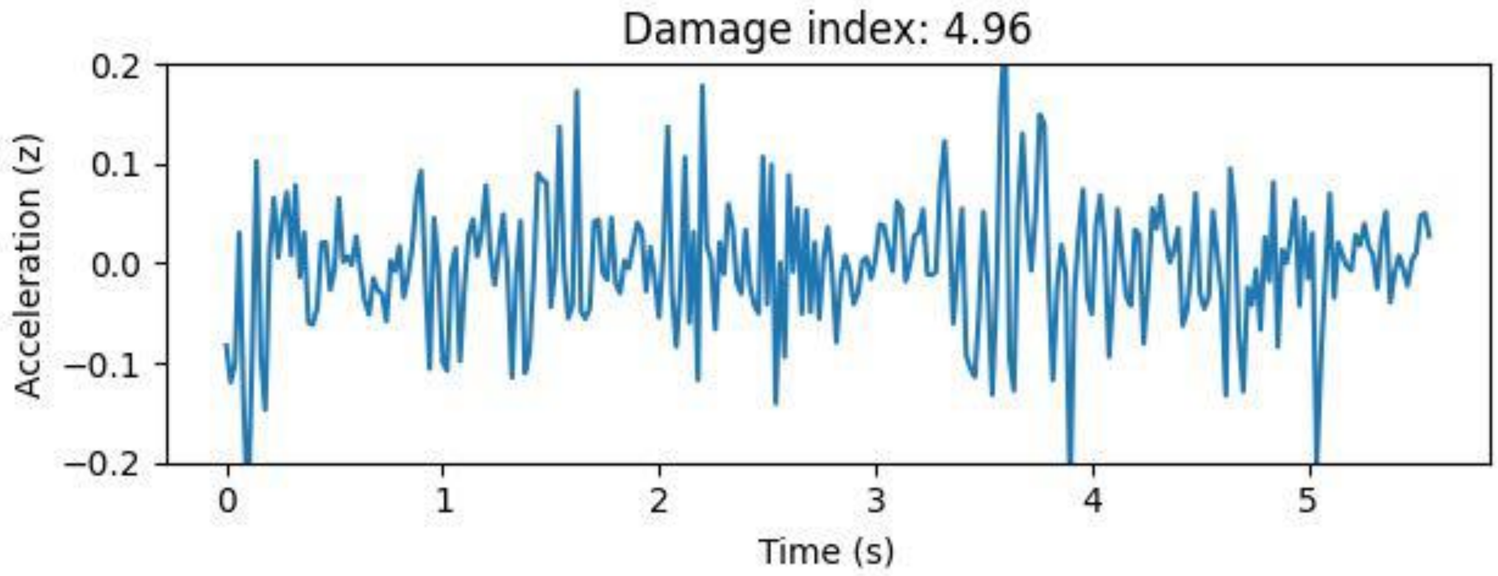


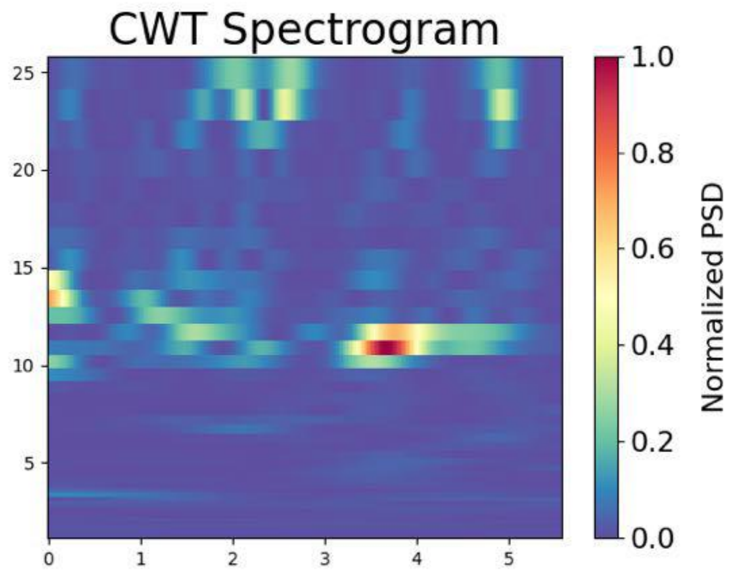
Model development

Modelling

Damage Index (DI) and Key Performance Index (KPI)

When I am driving on a road in BAD conditions



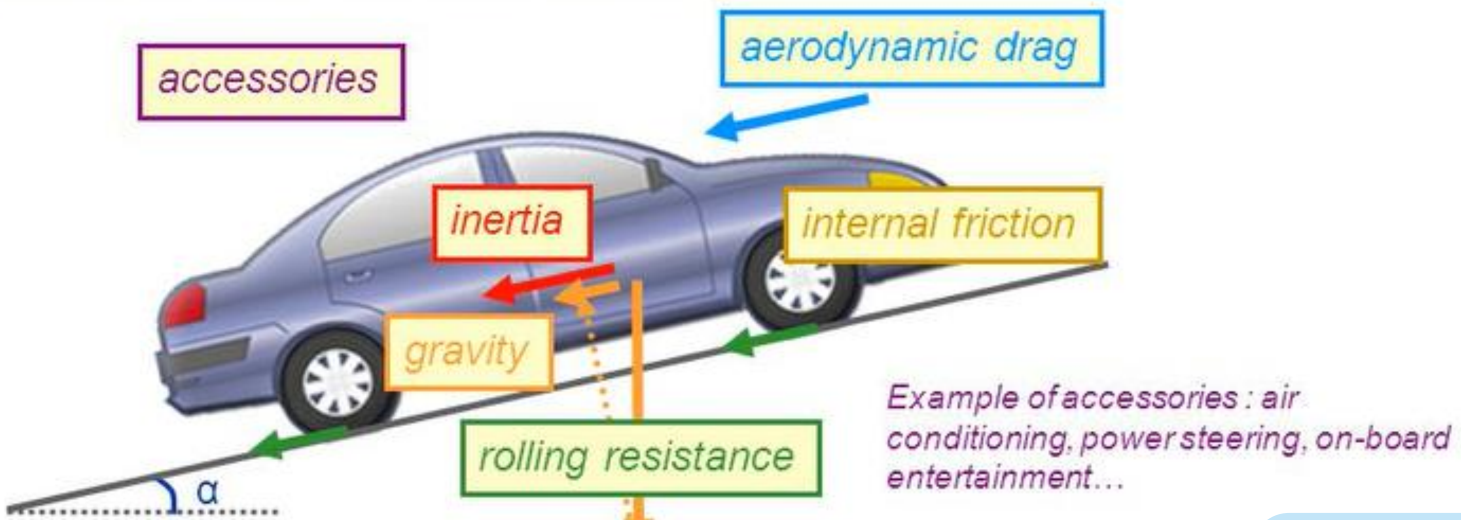


Modelling

Model development

Energy Expenditure

LiRA vision is to use Energy Consumption data and Inverted Road profile to *label the energy efficiency of the infrastructure*.



$$F_{RM} = C_{RR} \cdot M \cdot g + \frac{1}{2}\rho \cdot C_D \cdot A \cdot V^2 + M_{eq} \cdot \frac{dV}{dt} + M \cdot g \cdot \sin(\alpha) + \frac{P_{Int}}{V} + \frac{P_{Acc}}{V}$$

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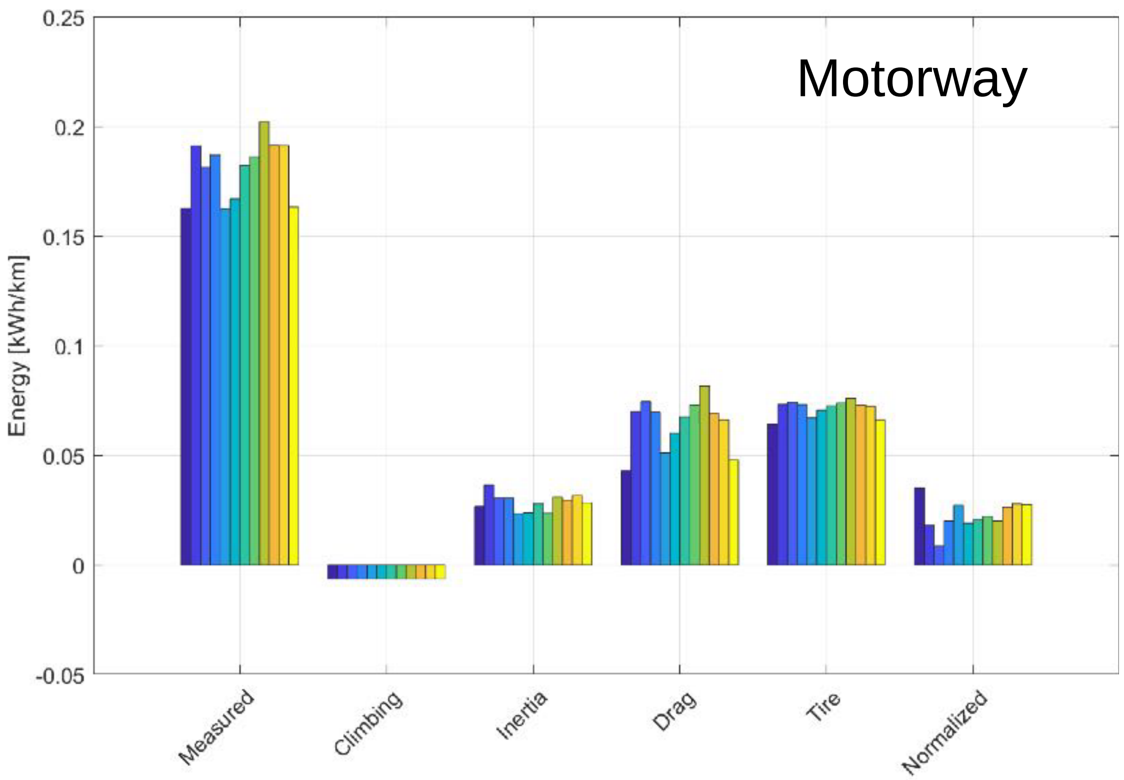
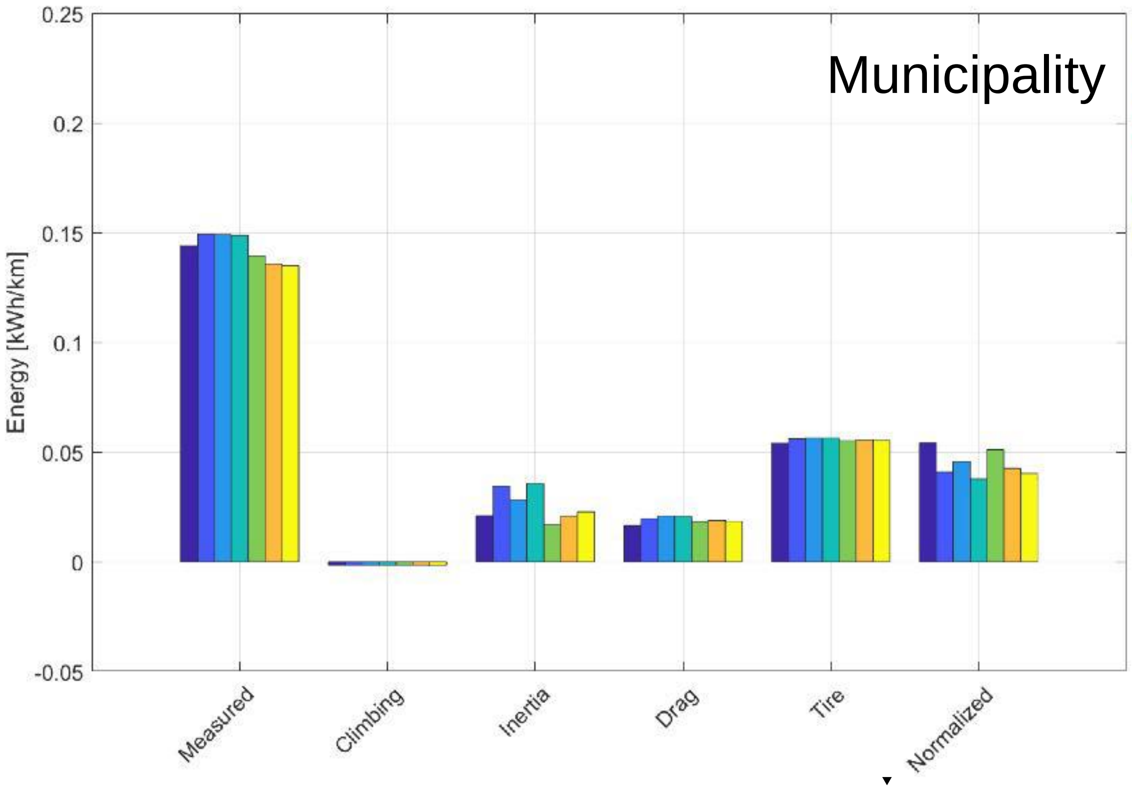
Modelling

Model development

Energy Expenditure

Measured Energy consumption vs Calculated, it is possible to find a Residual Energy (E normalized)





Conclusion – General

In the recent years, the *interest in using data from connected vehicles has increased* with the technological development of car sensors.

- ***New opportunities*** for road administrators
- ***New business*** for car industry and fleet operators
- ***New challenges***

LiRA project explores this new scenario trying to suggest benchmarks and directions for the industry

https://lira-project.dk/

LiRA

Innovationsfonden

COPENHAGEN JANUARY 16TH

LiRA END-SEMINAR

- Keynote: Jens Jørgen Holmboe, CEO of the Danish Road Directorate
- How big data will save resources for road management
- Collecting and using veheicle data for innovative road assessment
- Applying machine learning on vehicle data for predictive modelling
- Networking

Venue: Danish Road Directorate HQ, central CPH

A program with specific sessions and presentation will follow in December

REGISTER VIA DMH@VD.DK

DEADLINE FOR REGISTRATION JANUARY 5TH

GreenMobility YOUR CITY CAR

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