

TechDay Slovenia 2026

On-site tramway vehicle vibration measurements

University of Zagreb – Faculty of Civil Engineering

Chair for Railways

23.09.2026. Ljubljana, Slovenia

Speaker: **Krešimir Burnać, C.E.**

Content

- **Introduction – ENViLab and Chair for Railways**
- **URITMIS Project**
- **Tramway vehicle vibrations – evaluation of track condition**
- **Tramway track vibrations**

Accredited methods



Environmental noise

ISO 1996-2



Sound insulation in buildings

ISO 16283, ISO 717



Field measurements



Vibro-acoustic track assesment

EN 3095, EN 15461, EN 16510



Insertion loss of track

EN 13481-5, DIN SPEC 45673-3



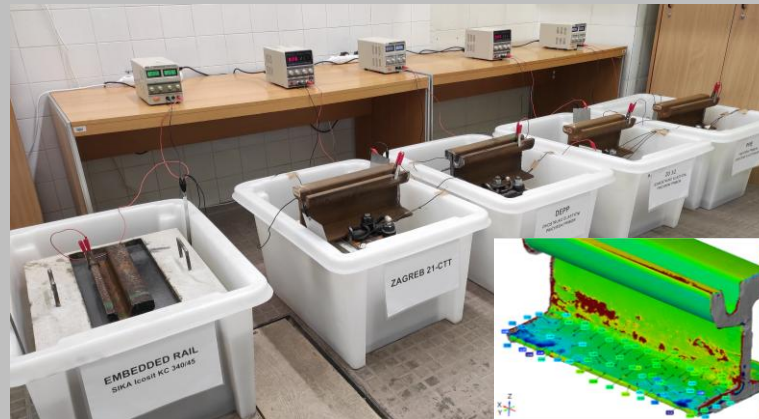
**In-situ acoustic characterisation
of noise barriers**

EN 1793, EN 16272

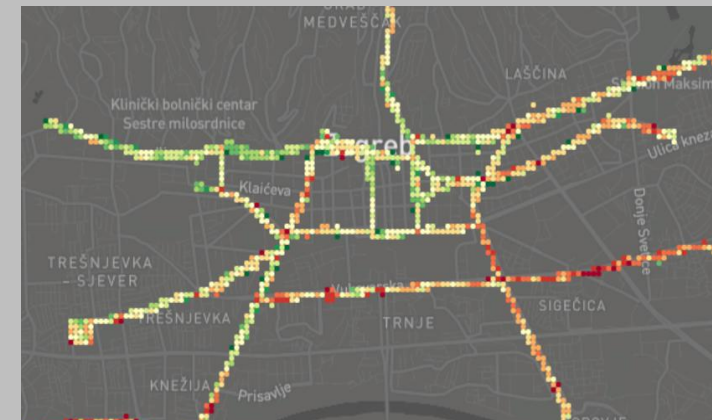
Lab measurements, analysis and monitoring



Electrical resistance of rail fastening systems
EN 13146-5



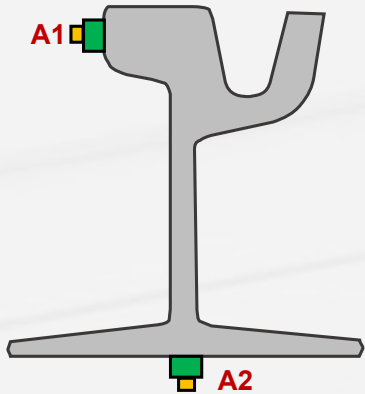
Analysis of stray current corrosion on rail tracks



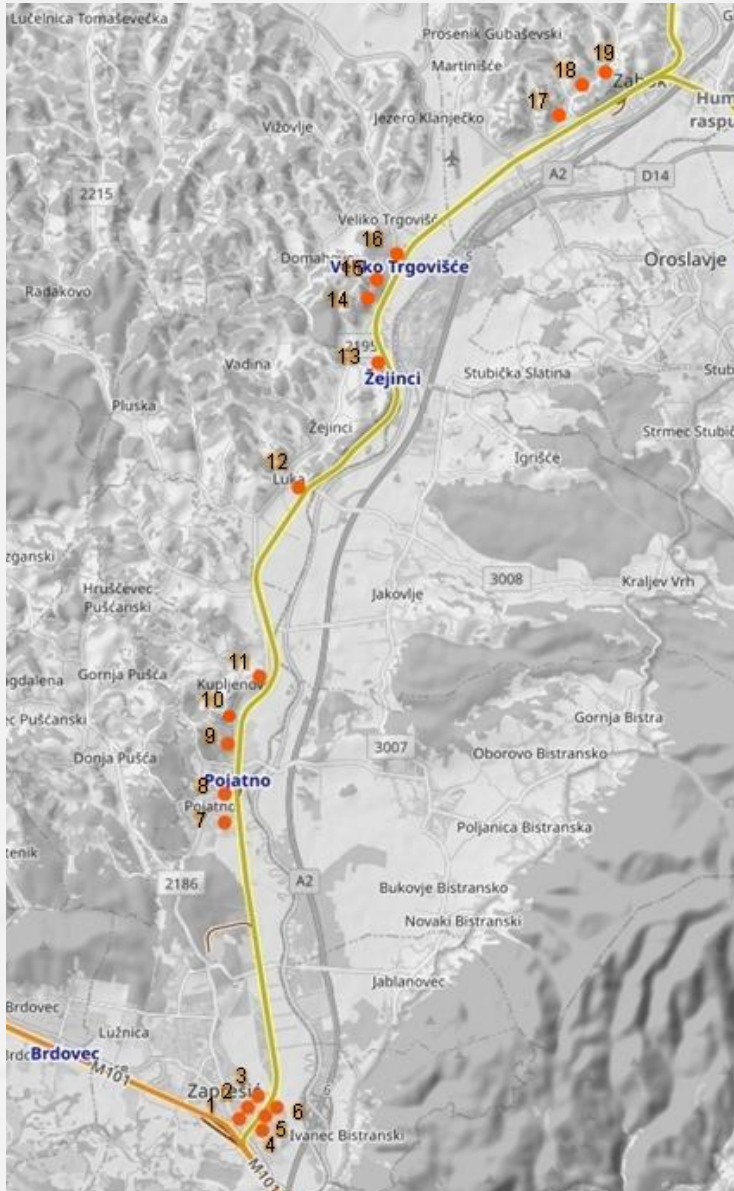
Network-wide monitoring of tram infrastructure

Vibroacoustic characteristics of the track

- Acoustic rail roughness (HRN EN 16510)
- Track decay rate (HRN EN 15461)

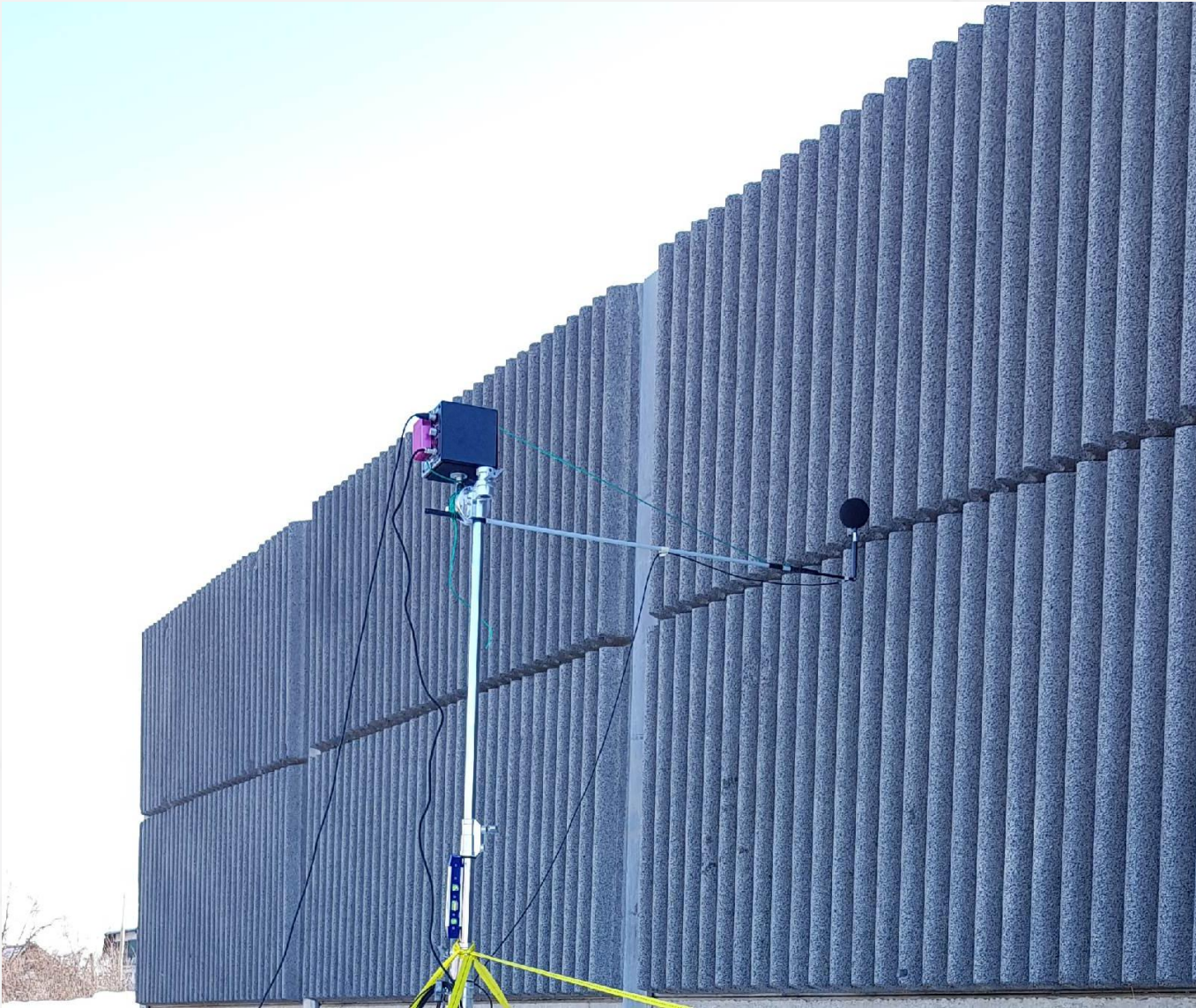


- Environmental noise measurements (HRN EN 1996) 





- Pass-by noise measurements
HRN EN ISO 3095

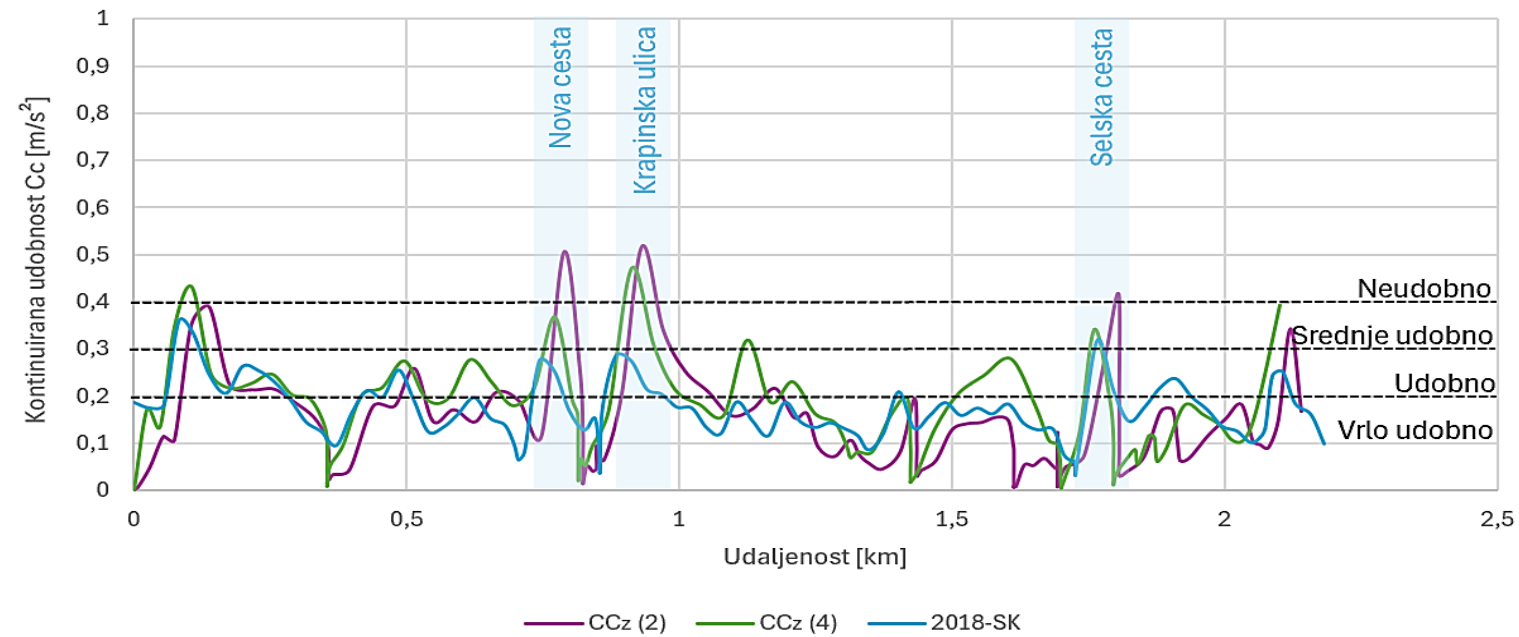


In-situ acoustic characterisation of noise barriers

- Sound reflection EN 1793-5 / TS 16272-5
- Sound isolation EN 1793-6 / EN 16272-6
- Diffraction over the barrier EN 1793-4 / EN 16272-4
- Insertion loss ISO 10847:2001 / TS 16272-7

Ride comfort in rail-bound vehicles

- HRN EN 12299
- Using low-cost devices (smartphones) and accelerometers



Collaboration and partners



KONČAR



DIV
GROUP

AIR-RMLD
Natural Gas Leak Detection System



PRUŽNE
GRAĐEVINE



Sveučilište u Zagrebu
Fakultet strojarstva i brodogradnje



SVEUČILIŠTE U ZAGREBU
Fakultet
elektrotehnike i
računarstva



Aalto-yliopisto
Aalto-universitetet
Aalto University



Budapest University of Technology and Economics



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University of Zagreb
Faculty of Civil Engineering

ENViLab supports research projects

URITMIS – Urban railway infrastructure predictive maintenance system based on monitoring of vibro-acoustic track properties

- Performing monitoring from in-service vehicles
- Advanced vibro-acoustic analysis
- Machine learning on vibration signals
- Digital twin based on in service vibrations



CIRCLEAR – Integrated Air and Noise pollution reduction solution for urban road infrastructure

- Optimisation of sound absorption properties
- Source identification
- Insertion loss



ENVIRAIL - Development of Advanced Techniques for Noise and Vibration Control on Urban Rail Tracks Using Alternative Materials and Machine Learning Methods

- Optimisation of sound absorbing surface
- In-situ and lab testing of absorption/insulation
- Optimising and testing track decay rates



CORRTRACK - Advanced Method for the Identification of High Corrosion Risk Zones in Urban Track Structures

- GPR mapping of slab track corrosion
- Infrared thermography
- Modelling of slab track corrosion



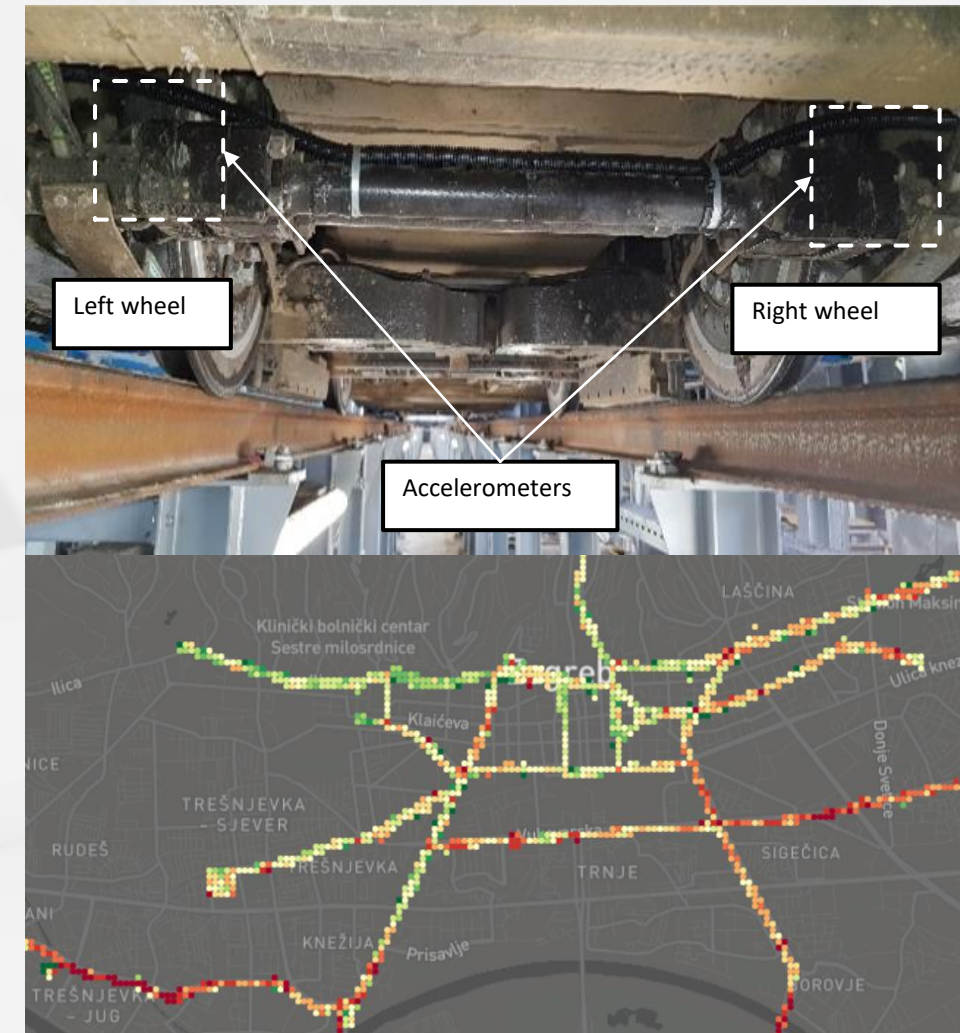


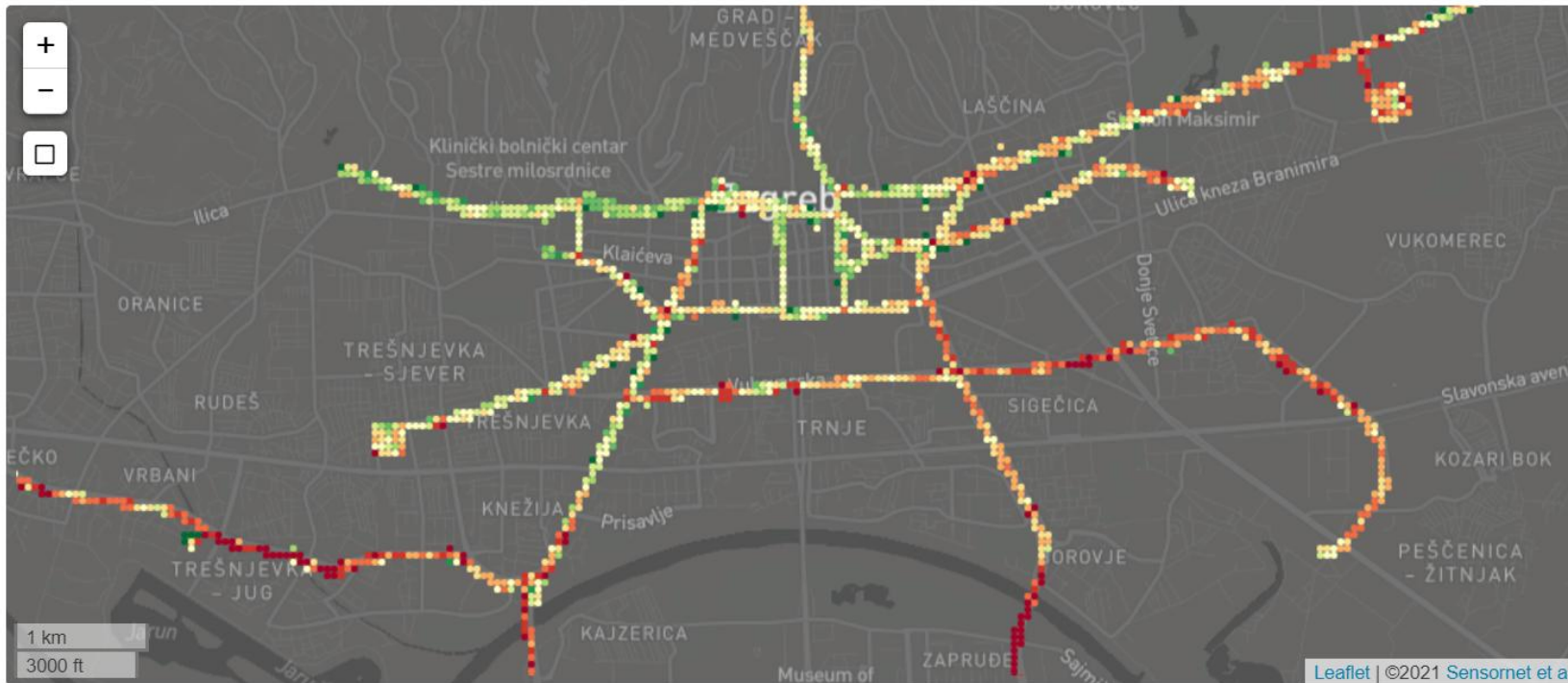
Financira
Europska unija
NextGenerationEU

URITMIS - Urban railway infrastructure predictive maintenance system based on monitoring of vibro-acoustic track properties

Main goals:

- Analyse the correlation between rail irregularities and rail defects and vehicle vibration
- Development of a tram track numerical model and digital twin with defined vibroacoustic characteristics
- Build a track predictive maintenance model based on machine learning methods



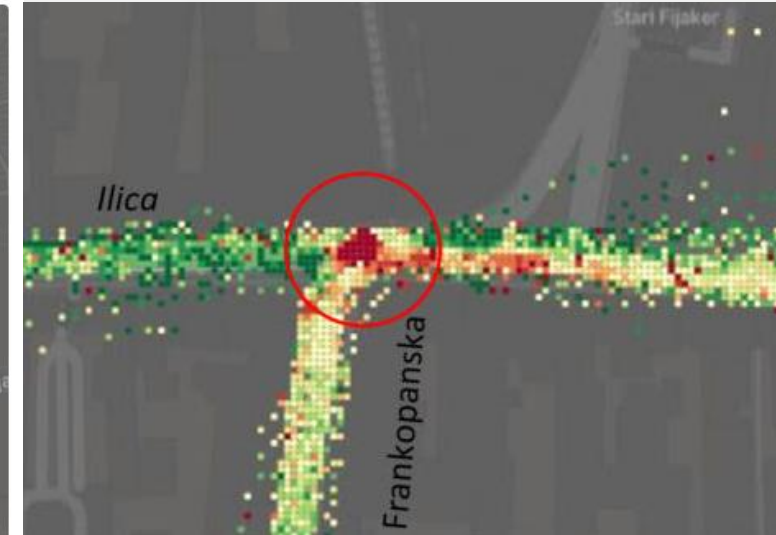


Layer: Vibrations Bogie Right Veq ref nm/s ▾

Differential mode: Off ▾

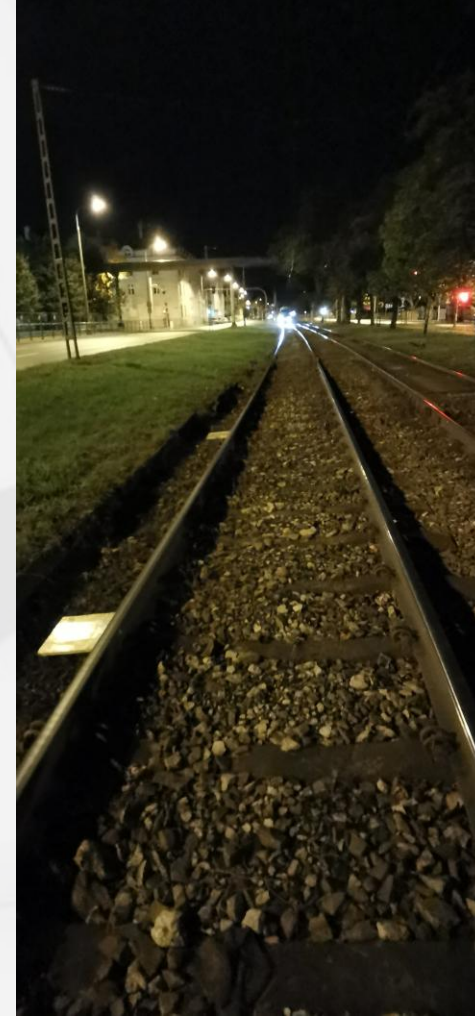
Zagreb tramway track network long term monitoring

- Identification of critical locations on the network
- Monitoring of the irregularities in real time
- Foundation for predictive maintenance model



Case study Zagreb - Vehicle vibration measurements

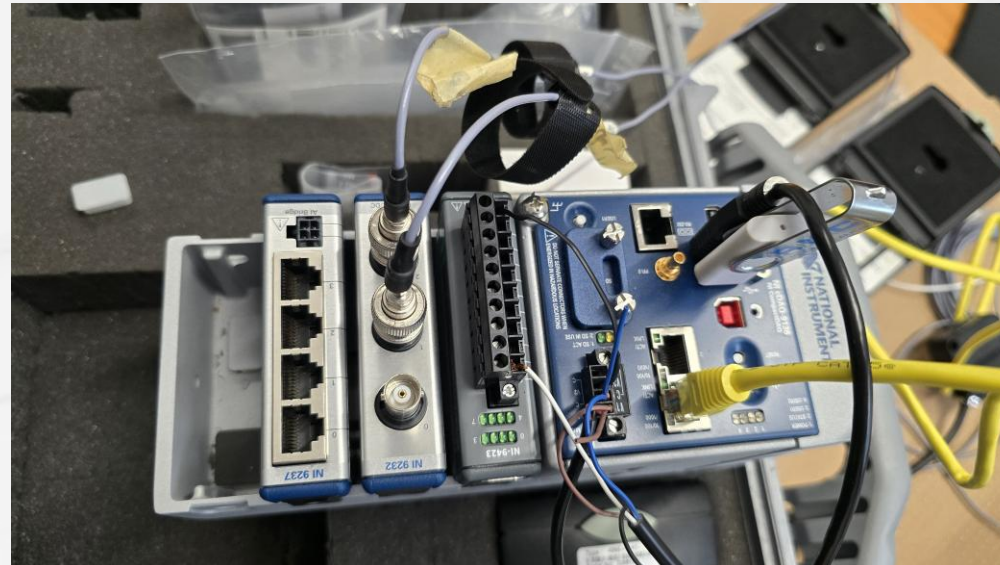
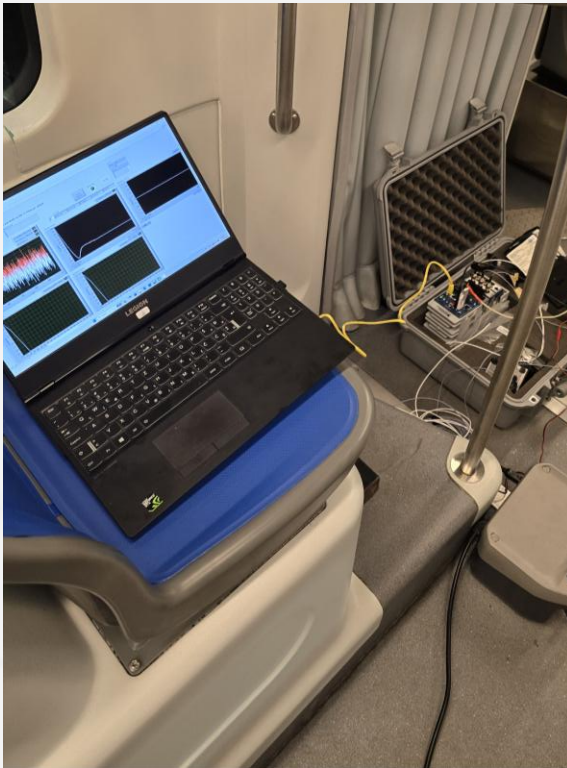
Test section



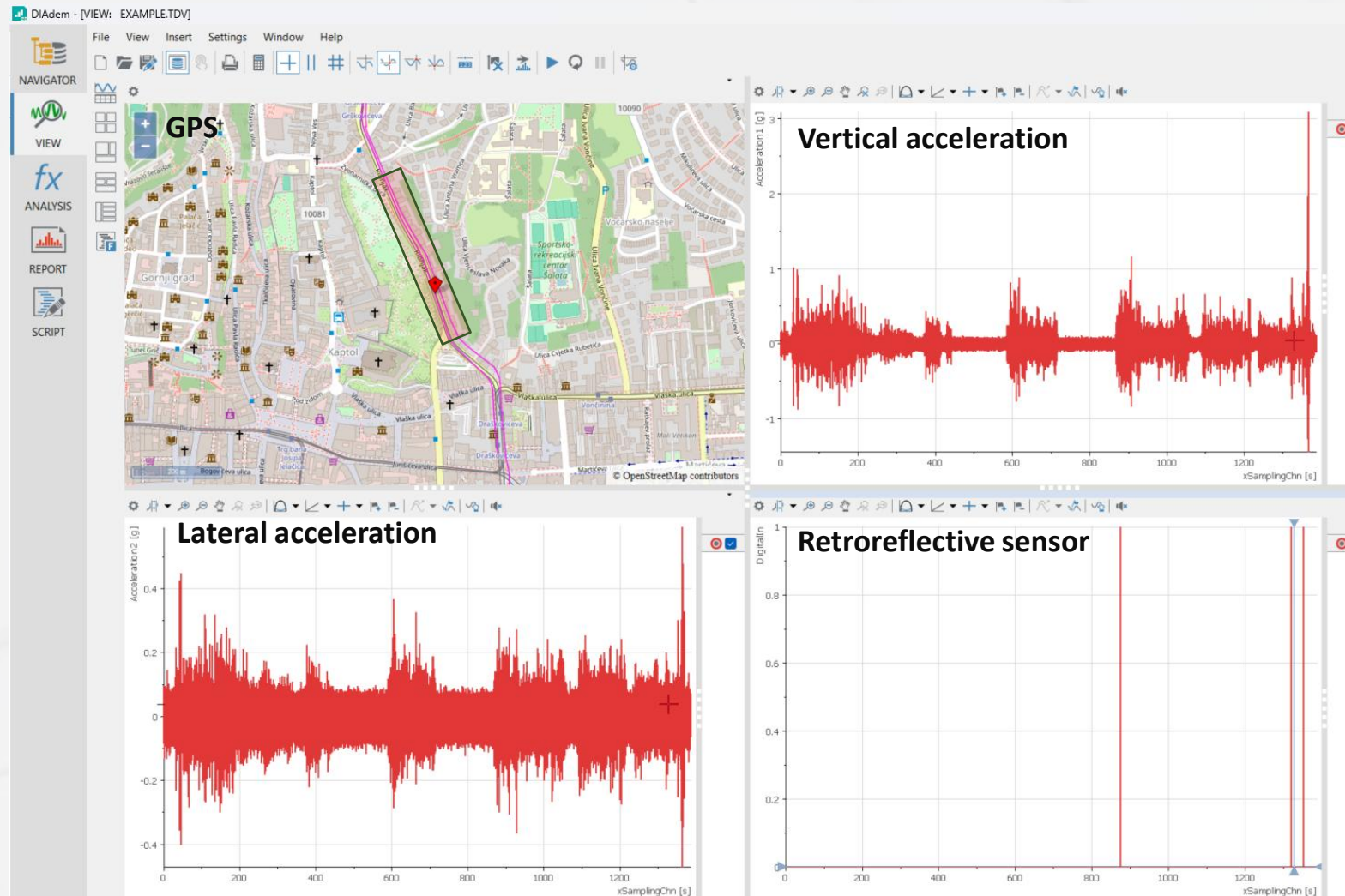
Vehicle vibration measurements

Data acquisition

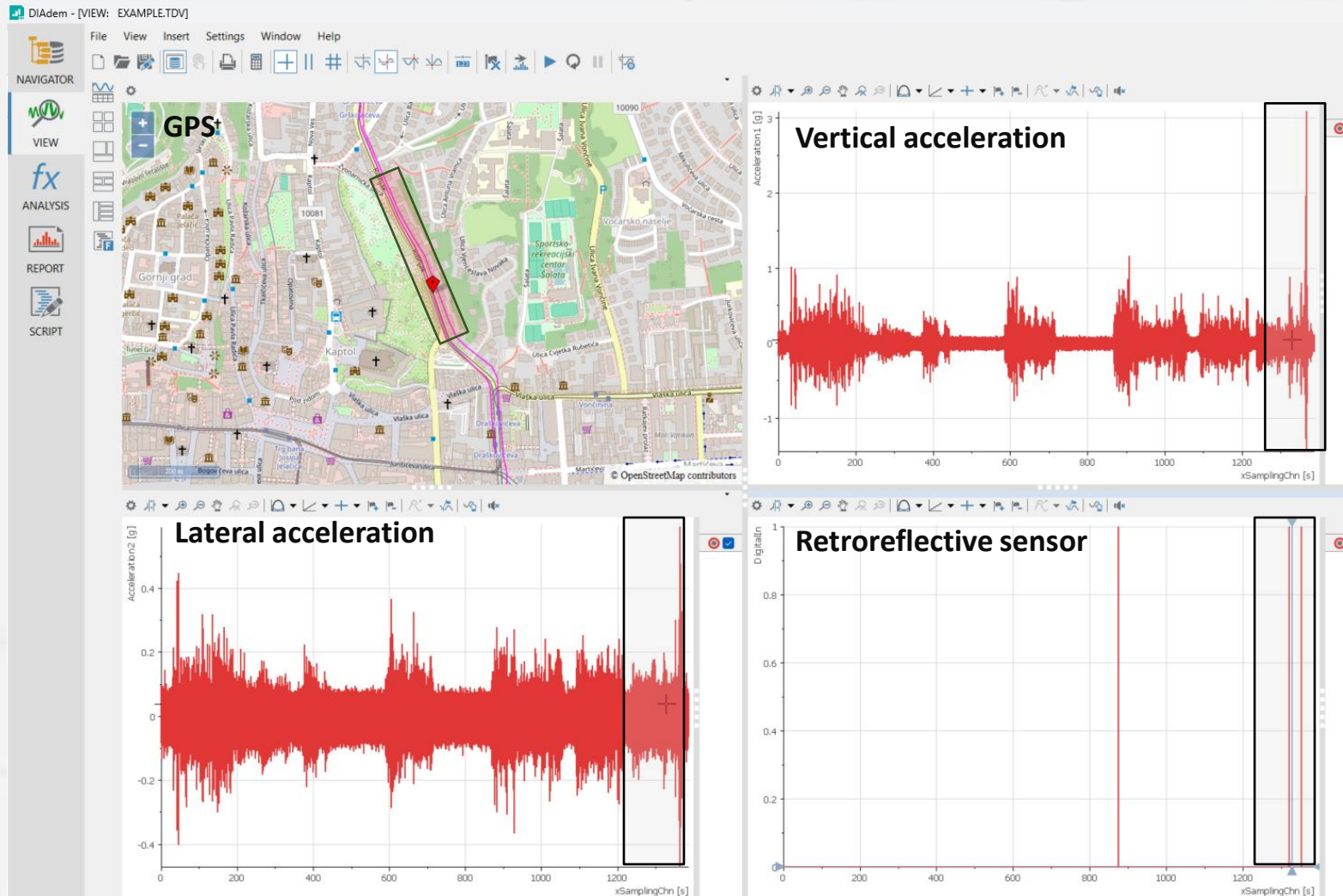
- Data acquisition NI cDAQ 9136
- Retroreflective laser Autonics BEN5-MDT
- USB GPS receiver
- NI LabView



- Localization using retroreflective sensors -> Test section

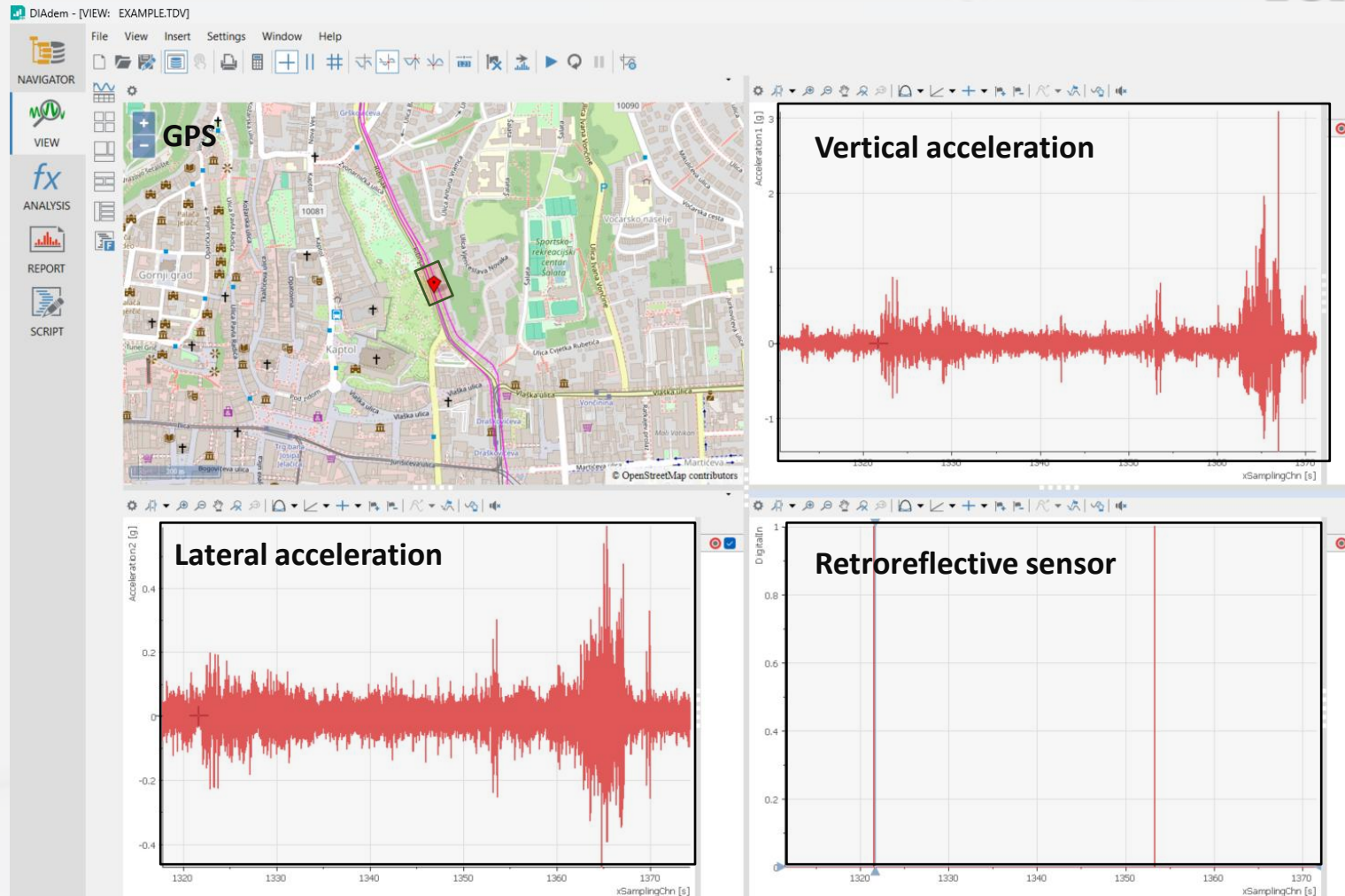


- Localization using retroreflective sensors -> Test section

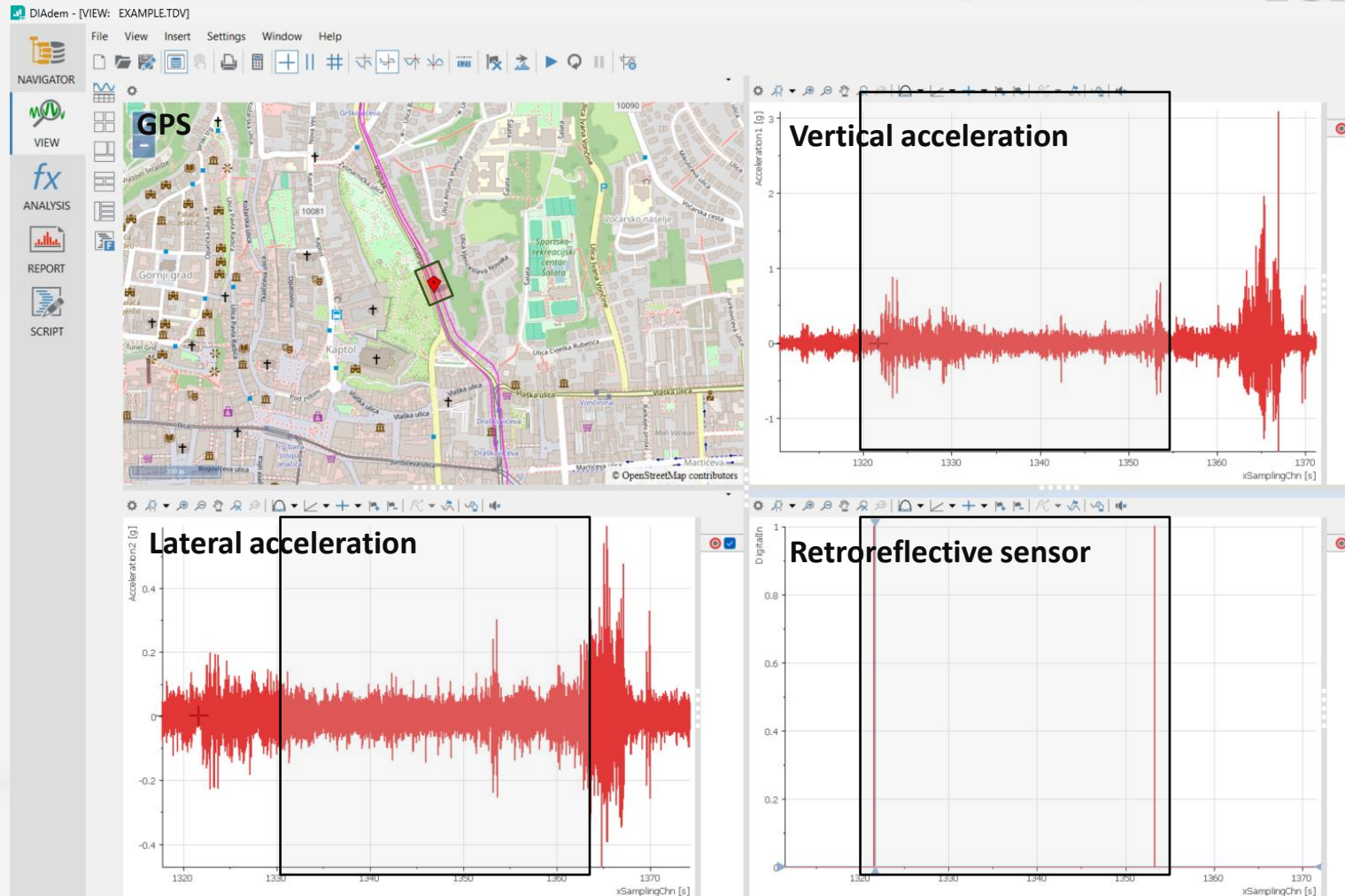


Vehicle vibration measurements

Data processing



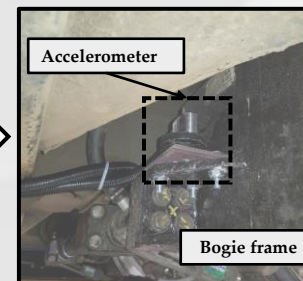
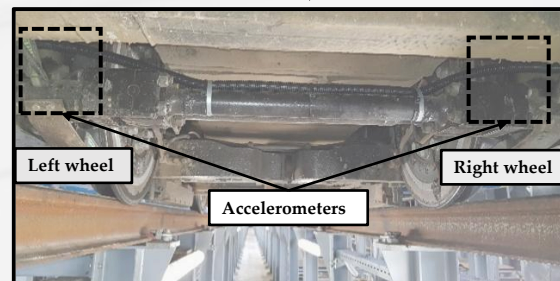
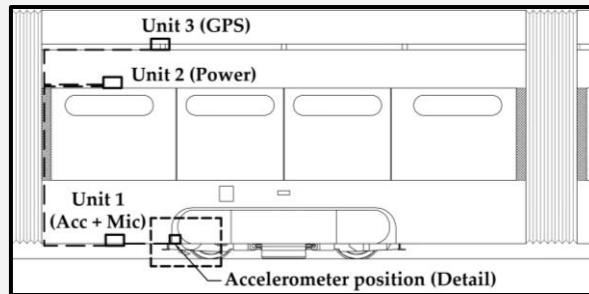
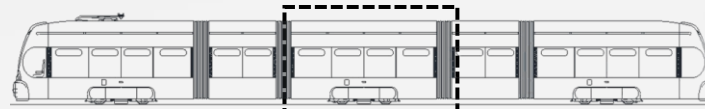
- Localization using retroreflective sensors -> Test section L ~ 12 m



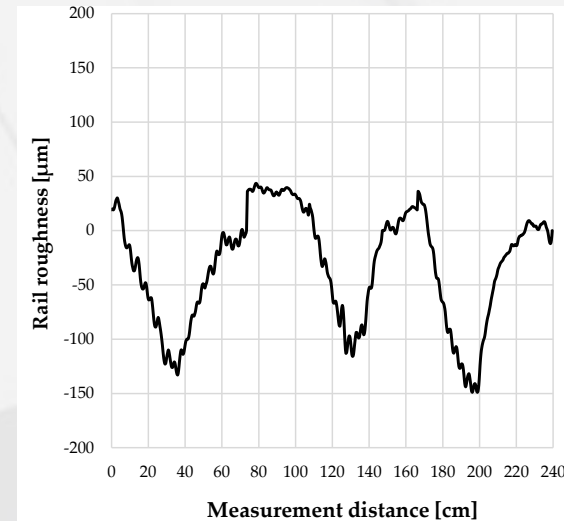
- Localization using retroreflective sensors -> Test section L ~ 12 m

Vehicle vibration measurements

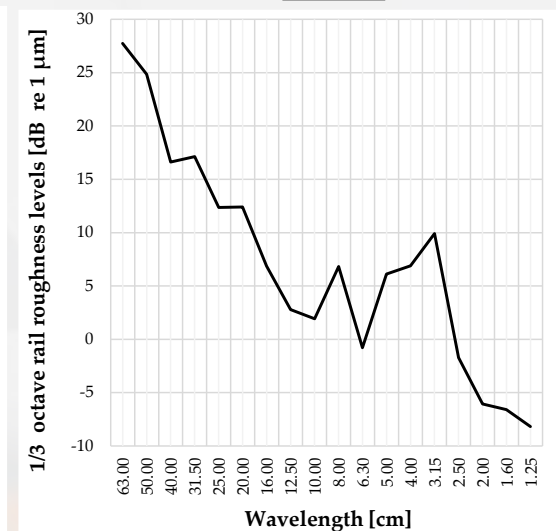
Indirect rail running surface evaluation



$r(LRS_{DIR})$



$r(\lambda_{DIR})$



Vehicle vibration measurements

Indirect rail running surface evaluation

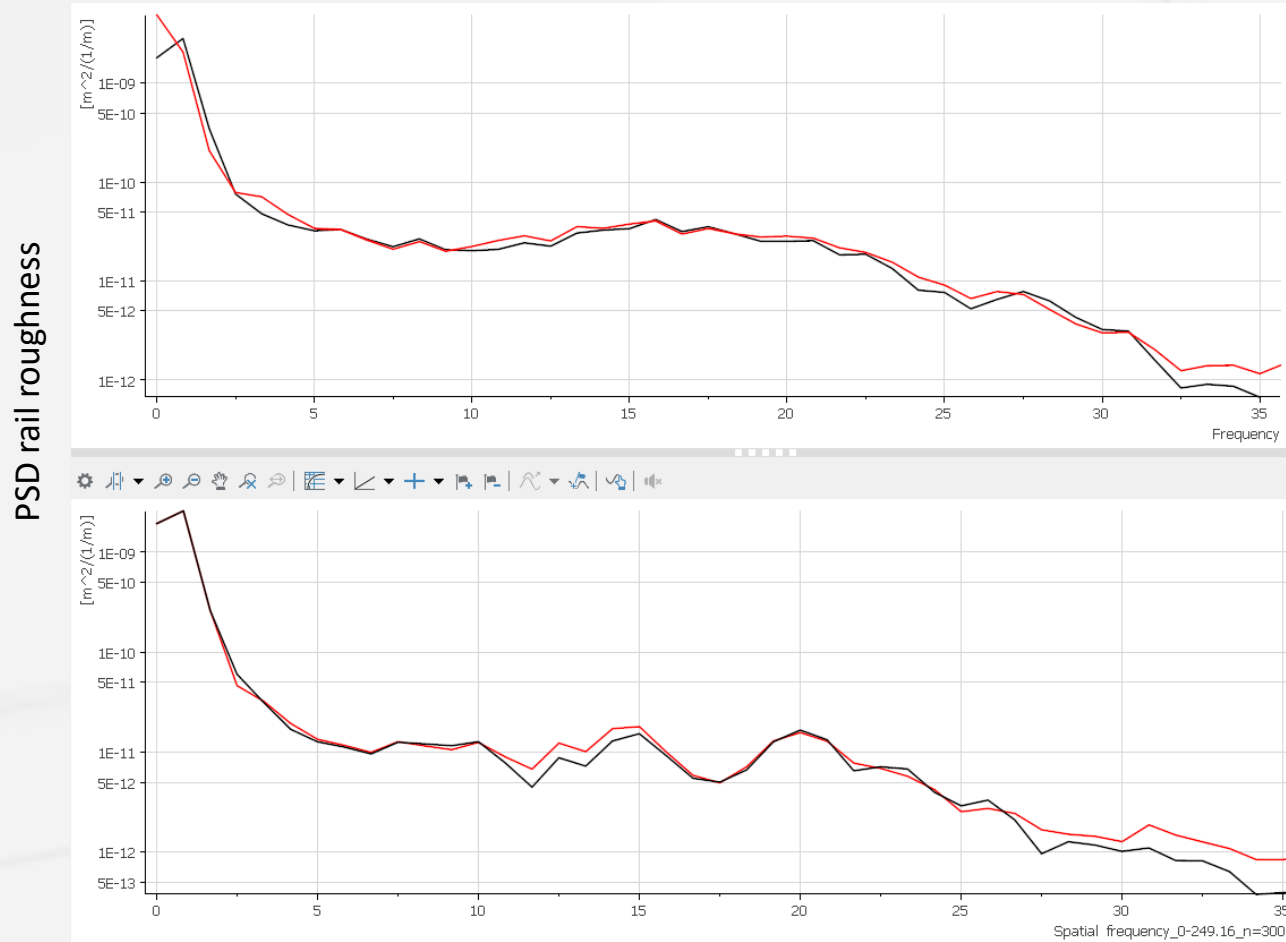
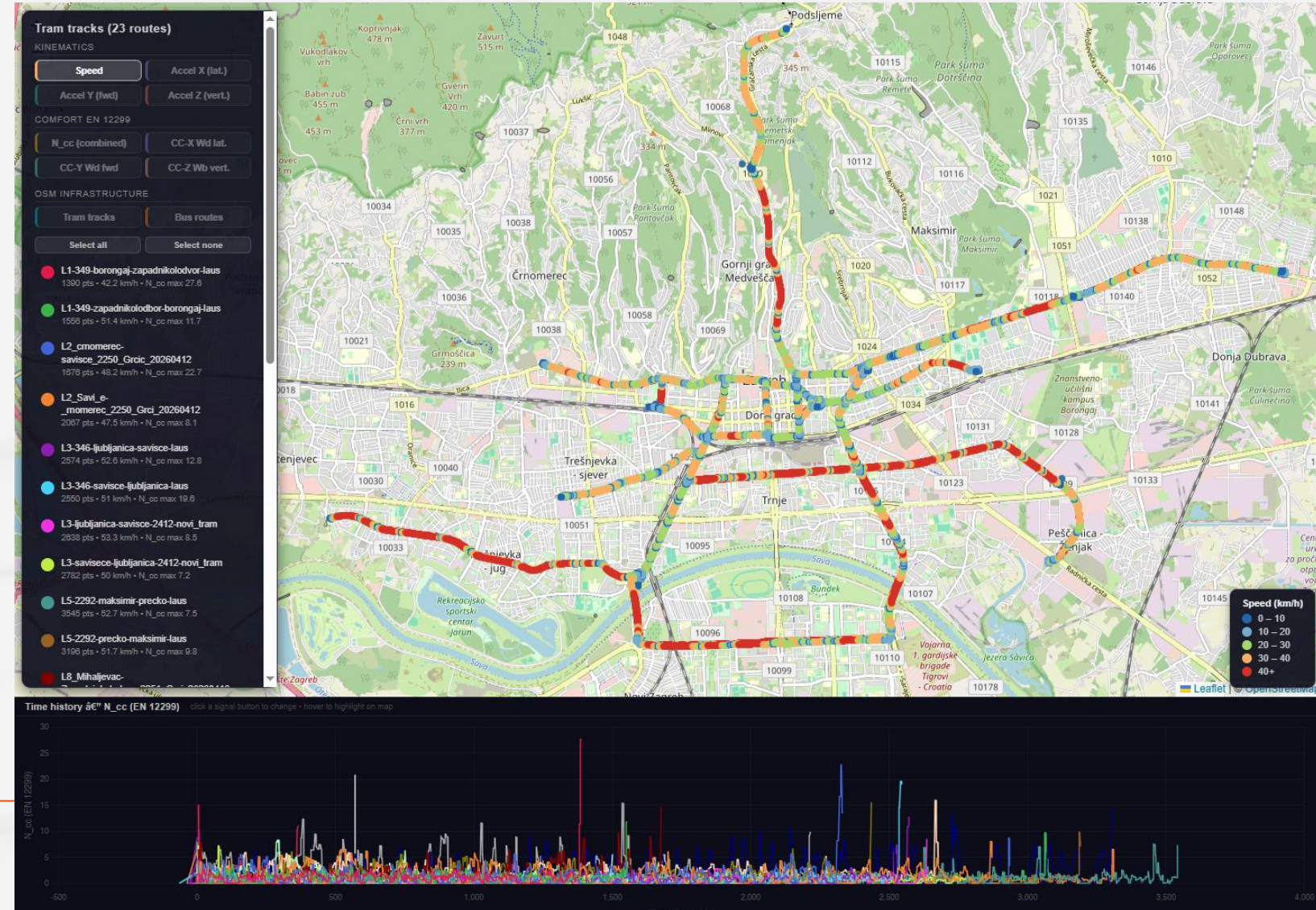
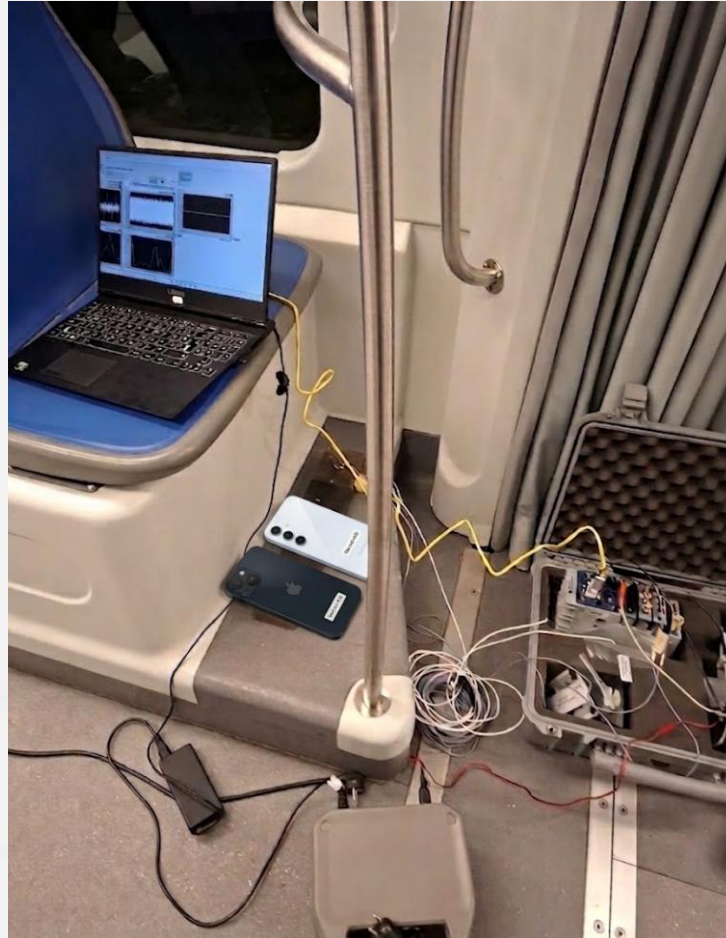


Figure: Direct r rail (black) vs indirect r rail
CALC (red); LR (Above), RR (below)

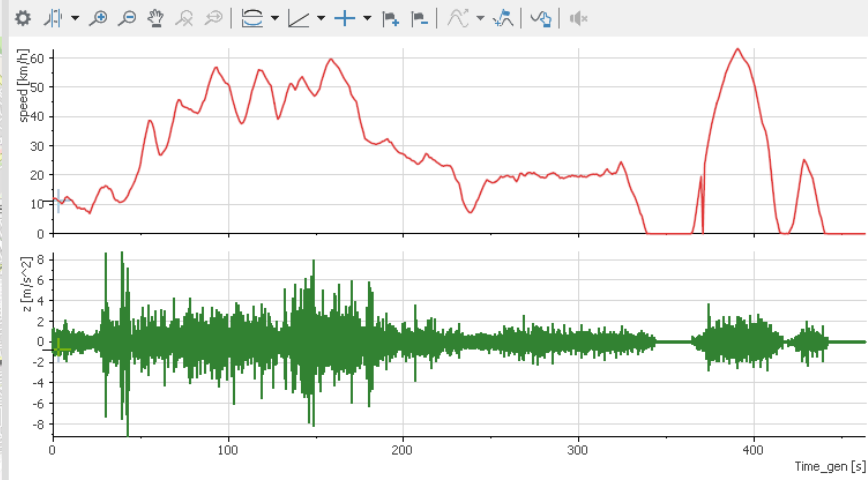
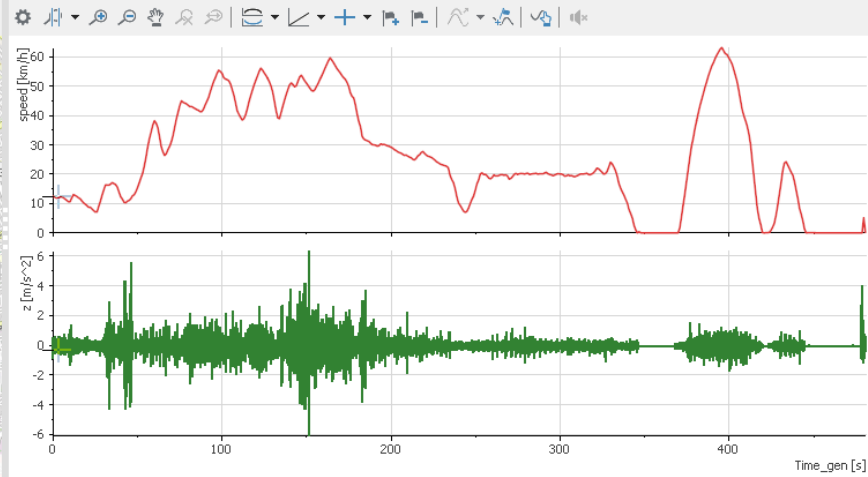
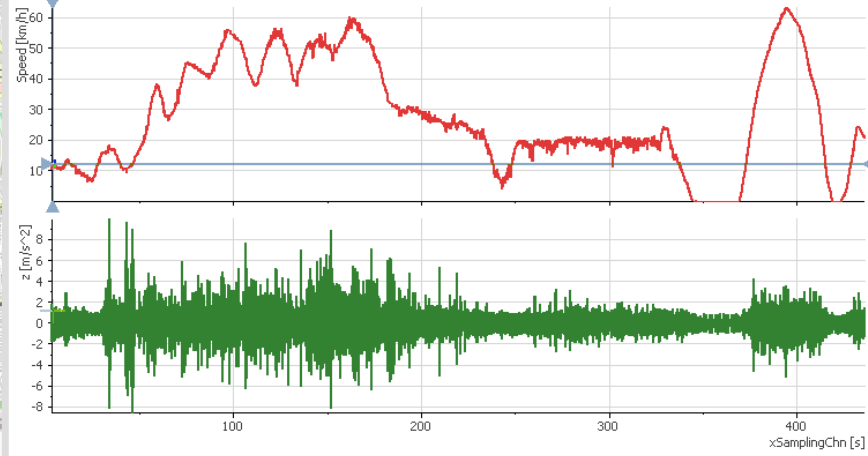
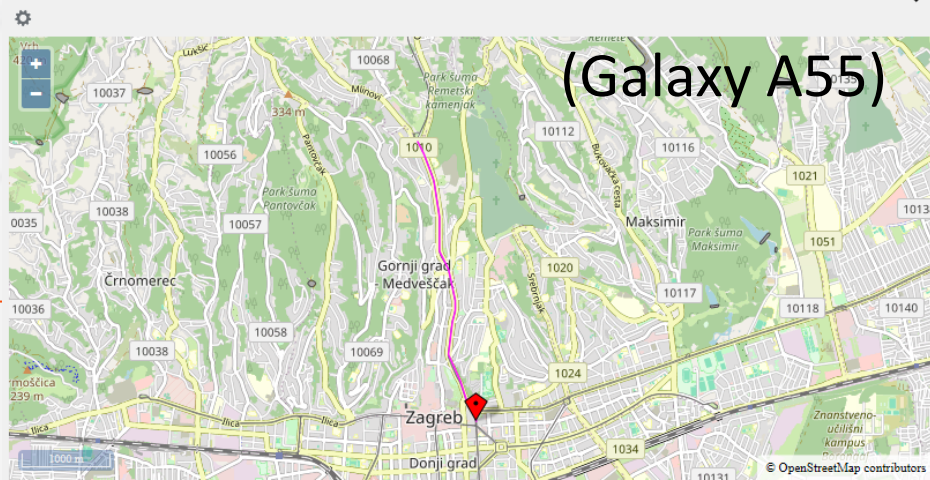
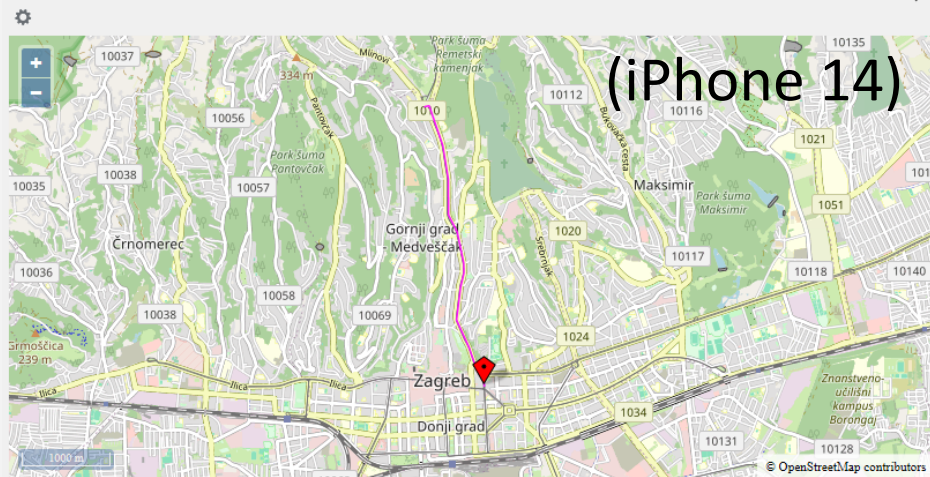
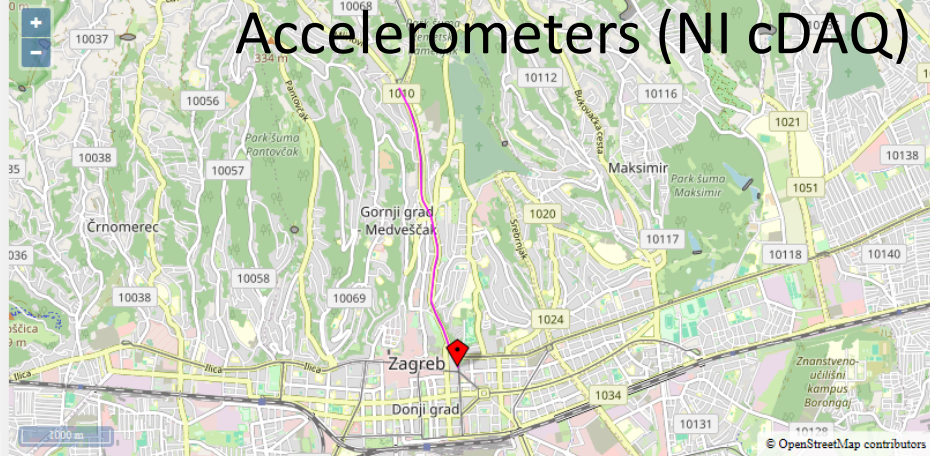
Vehicle vibration measurements

Ride comfort

- Smartphones (iPhone 14, Samsung Galaxy A55)
- Accelerometers (NI cDAQ)



Accelerometers (NI cDAQ)



ation measurements

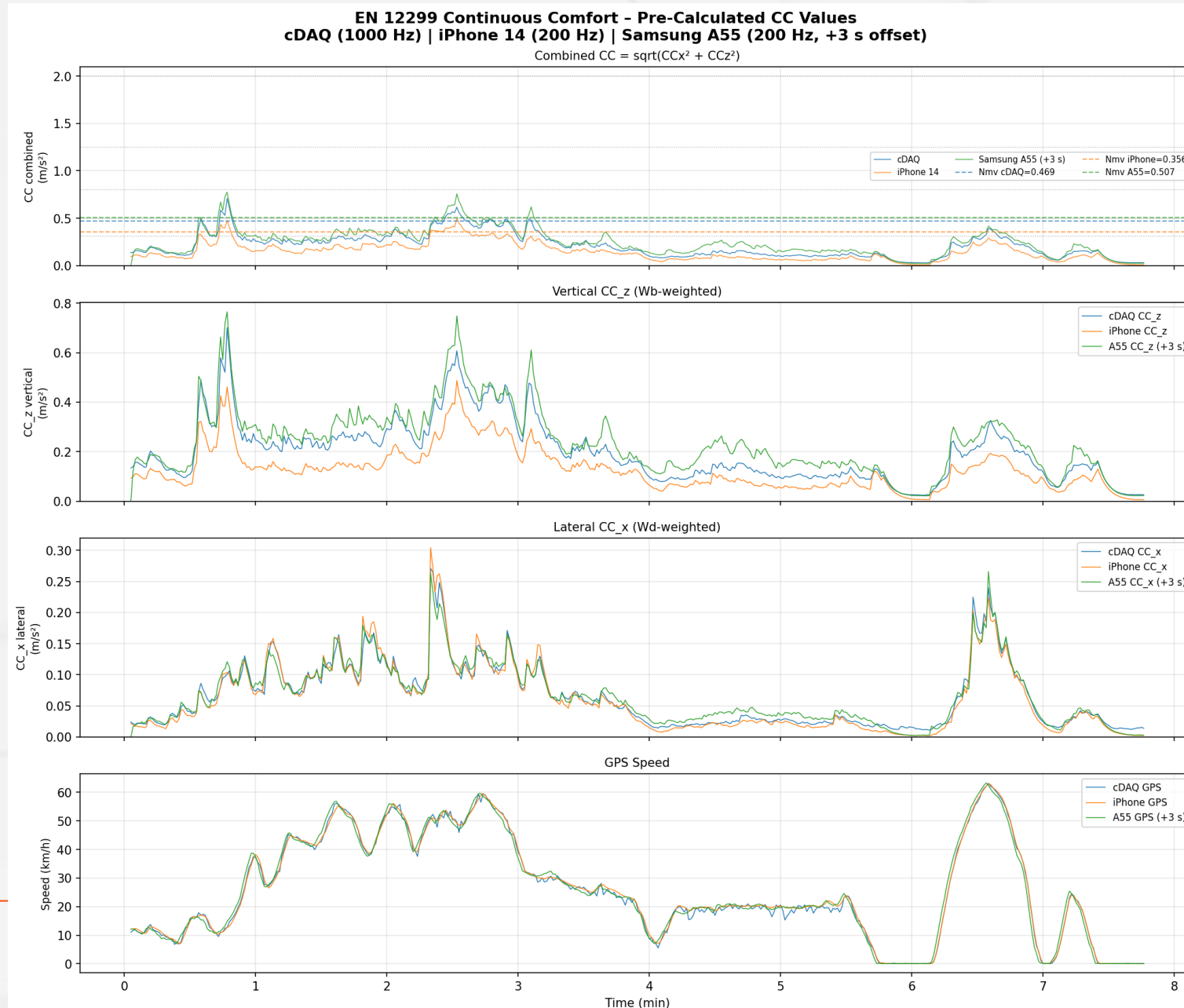
Ride comfort



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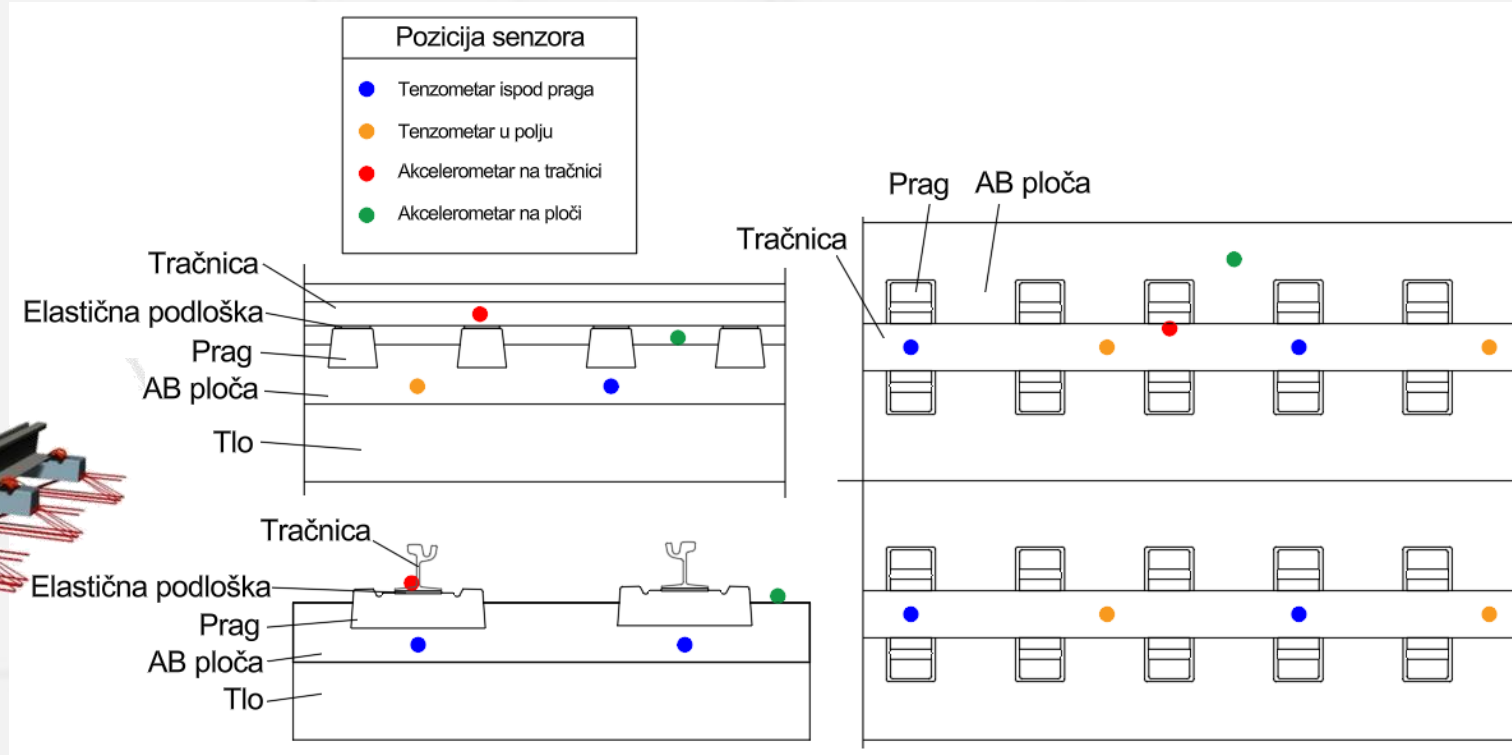
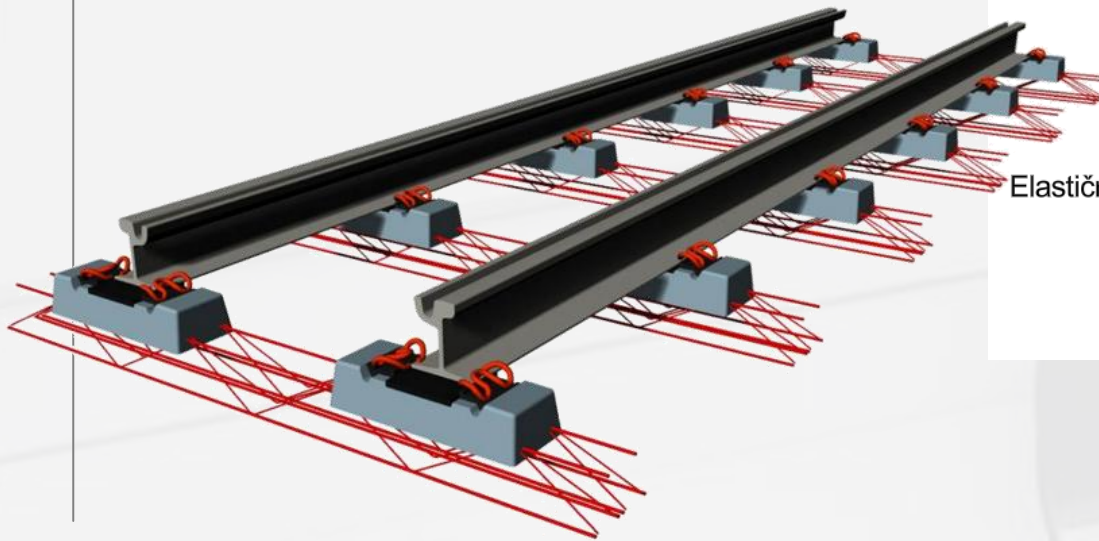
Vehicle vibration measurements

Ride comfort



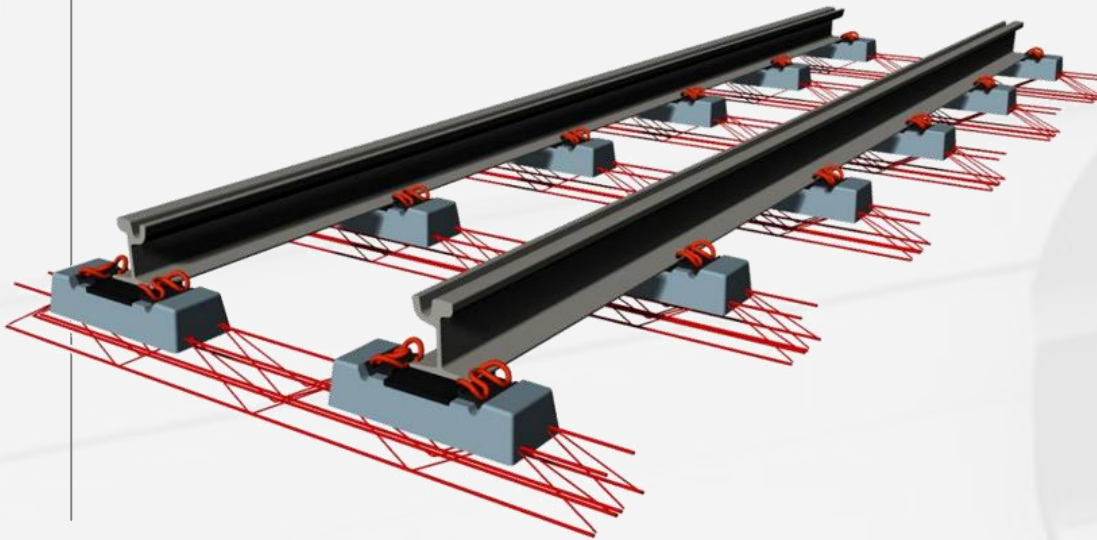
Track vibration and condition monitoring

- 12 strain gauges installed in the RC plate
- 2 strain gauges on the rail
- 2 accelerometers – on the rail and on the RC plate
- Microphone
- Weather station



Track vibration and condition monitoring

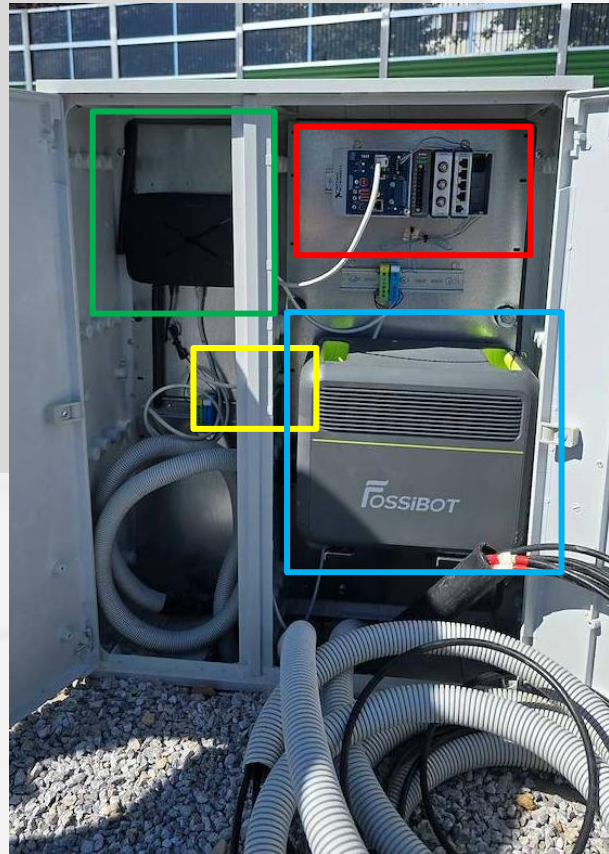
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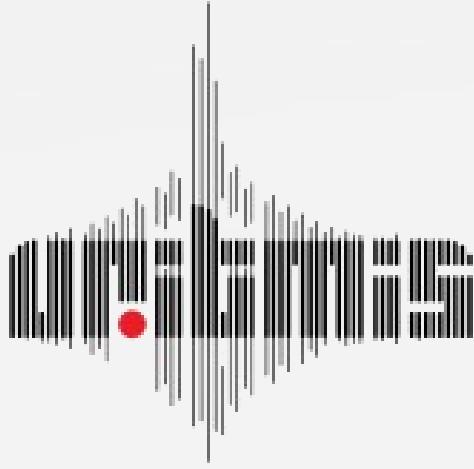
Track vibration and condition monitoring

Waterresistant closet to store the measurement equipment and safety:

- Router
- Rectifier 220 V-> 12 V
- Weather station
- cDAQ
- Spair battery



Funding



URITMIS – Urban railway infrastructure predictive maintenance system based on monitoring of vibro-acoustic track properties



ENVIRAIL - Development of Advanced Techniques for Noise and Vibration Control on Urban Rail Tracks Using Alternative Materials and Machine Learning Methods

Contact:

kresimir.burnac@grad.unizg.hr
envilab@grad.hr
ivo.haladin@grad.unizg.hr