



Modeling train induced ground vibrations with machine learning

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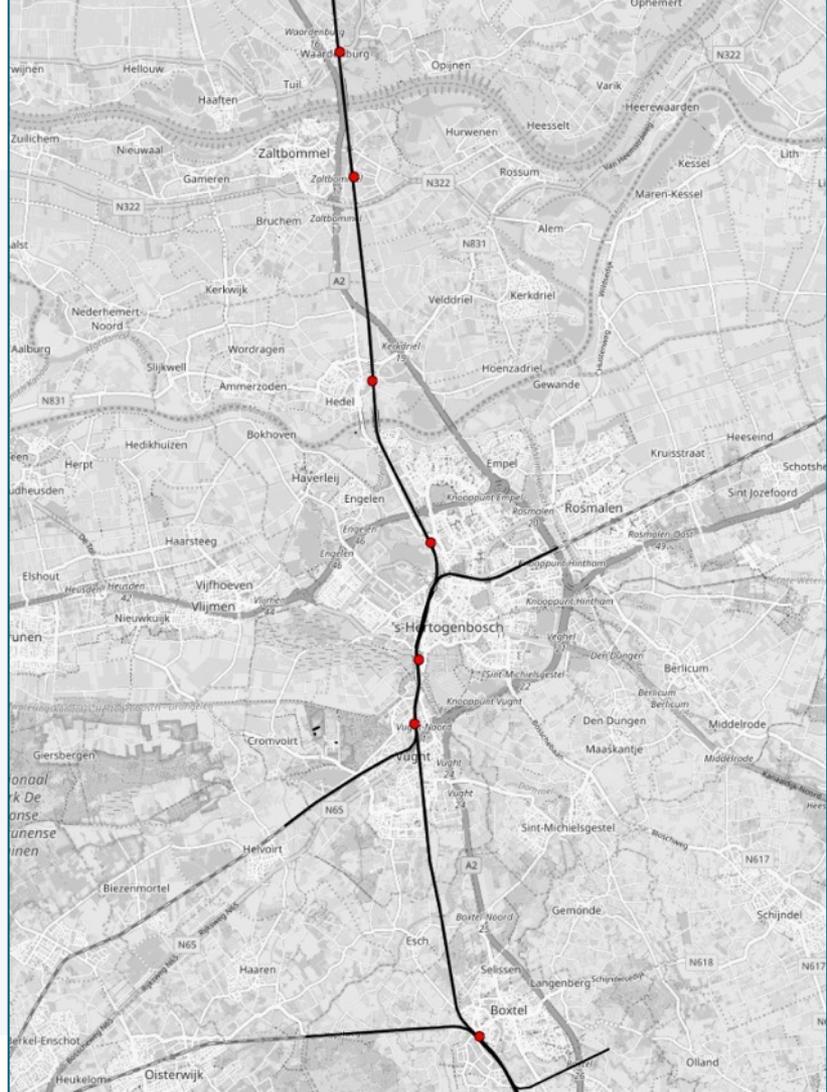
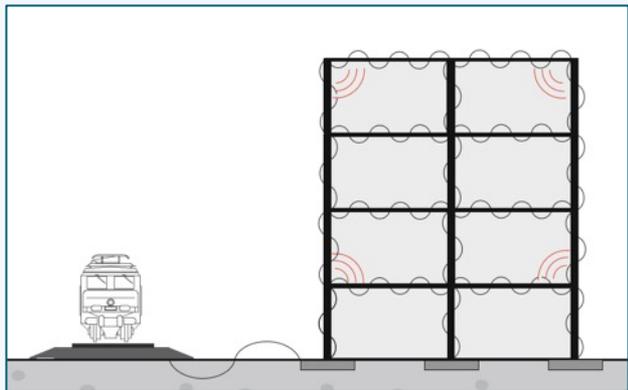
ProRail

Project

Track Meteren-Boxtel (PHS, MER, Tracébesluit)

Nuisance of vibrations caused by freight trains

Question lower speed = less vibrations?



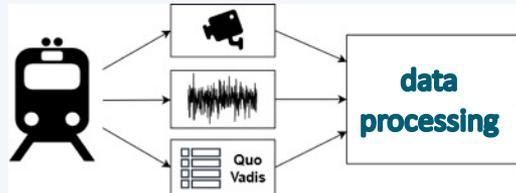
Measurement campaign

- vibration and train speed at 7 locations along track

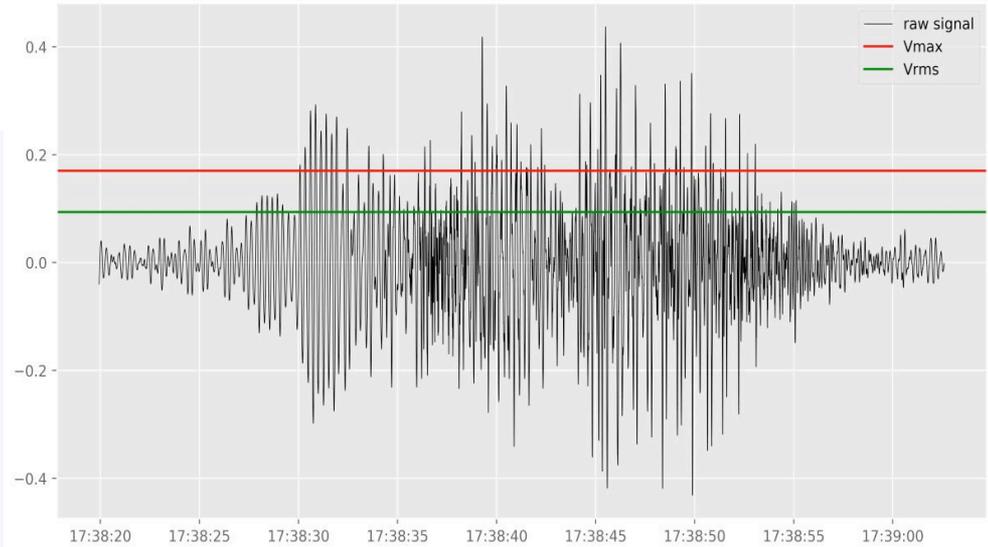


Measurement campaign

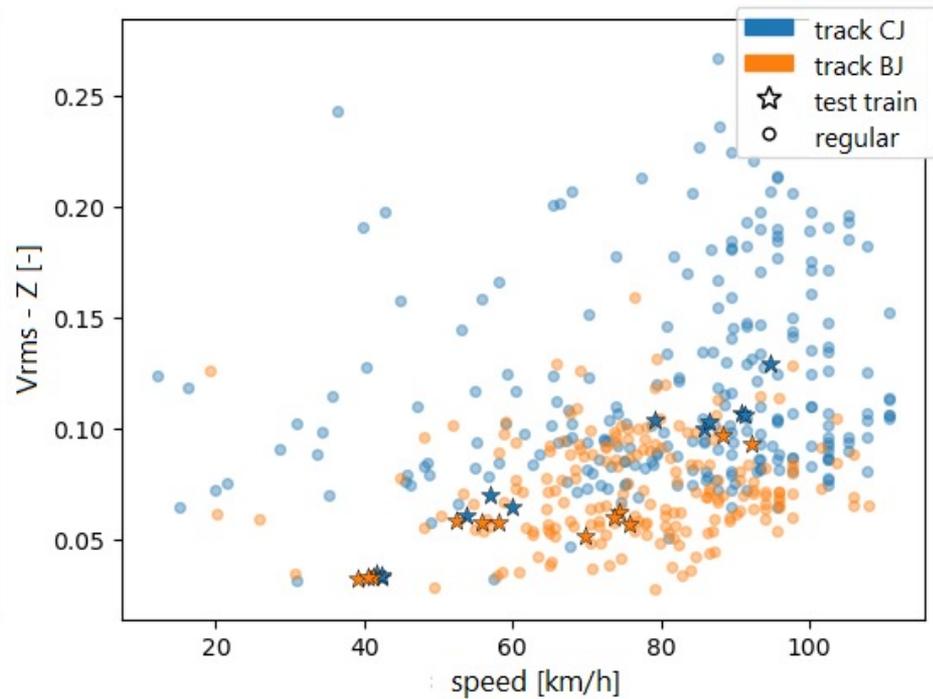
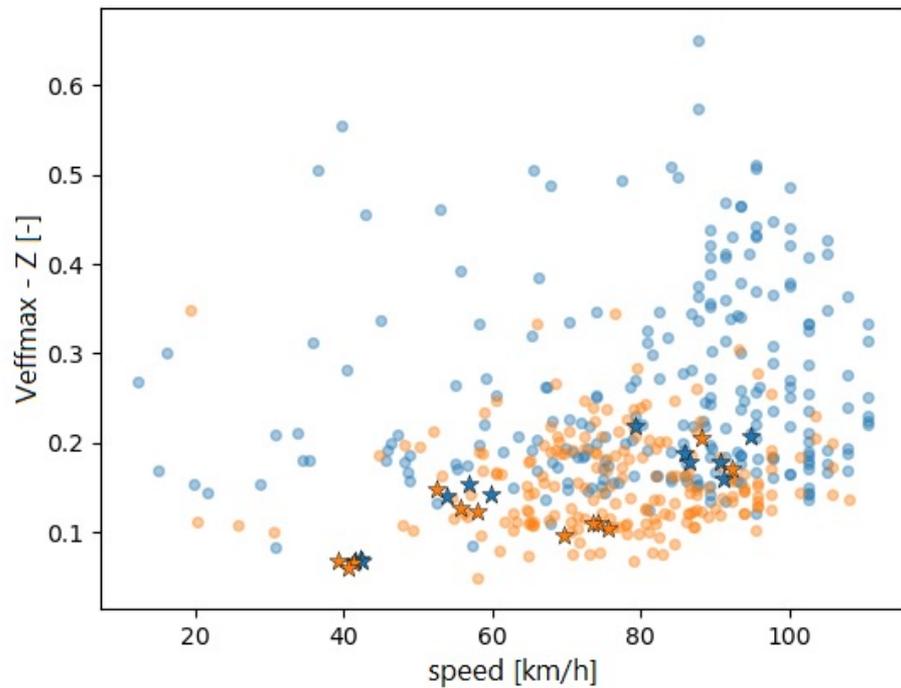
- varying speed: 95 – 60 – 40 km/h
- customized test train
- train metadata from QuoVadis
axle load, wheel load, wheel quality



Result: dataset of 350-560 passages

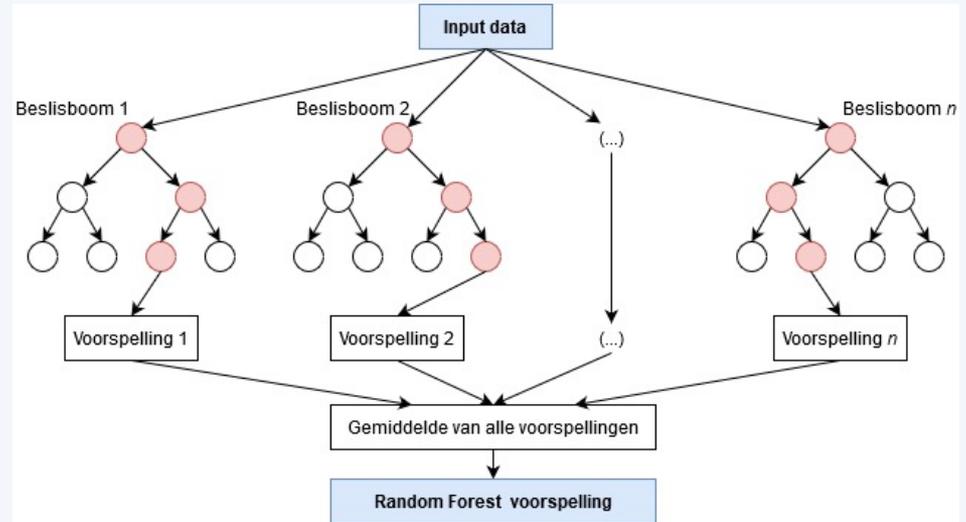


Example of result



Multivariate Regression vs Random Forest

$$V = \sum_{i=1}^n a_i v^i + \sum_{j=1}^m b_j Q_j + c$$



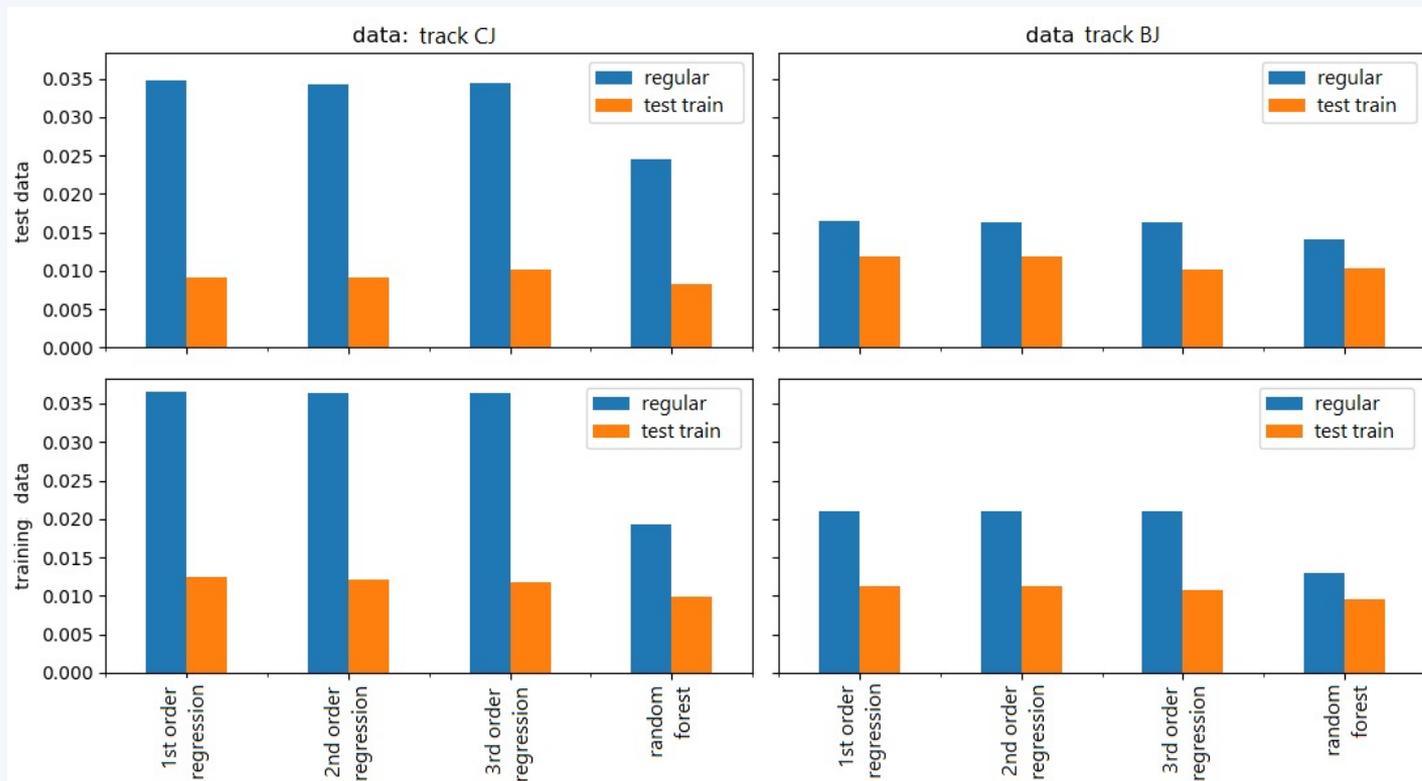
Selection of explaining variables

Selection of explaining variables:

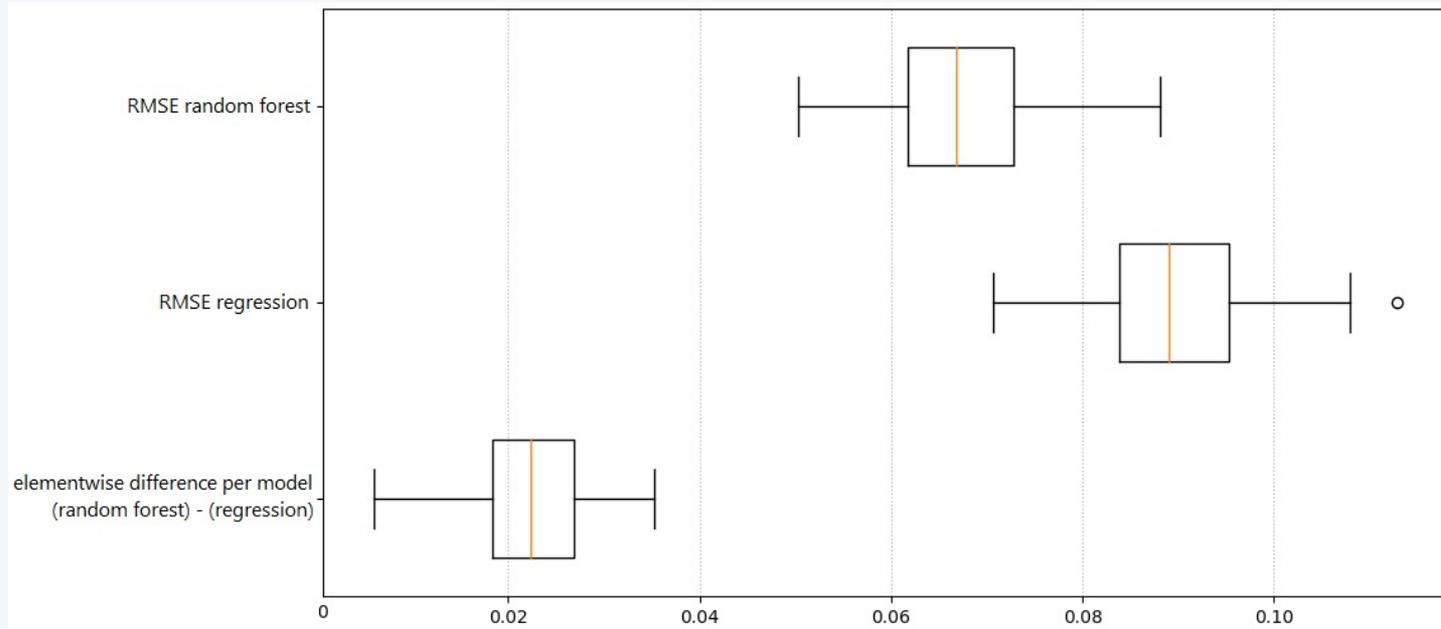
- the **passing speed** in km/h;
- the **static wheel load** in kN, aggregated to passage level as p80-value;
- the **peak wheel load** in kN, aggregated to passage level as p80-value (*);
- the **effective value** for frequencies **50-200Hz** , in kN and aggregated as p90-value (*);
- the **effective value** for frequencies **200-1000Hz**5, in kN and aggregated as p90-value;
- the **ratio of imbalance** between left and right wheels, aggregated to p80-value (*).

(*) not used in multivariate regression model

Model comparison: RMSE

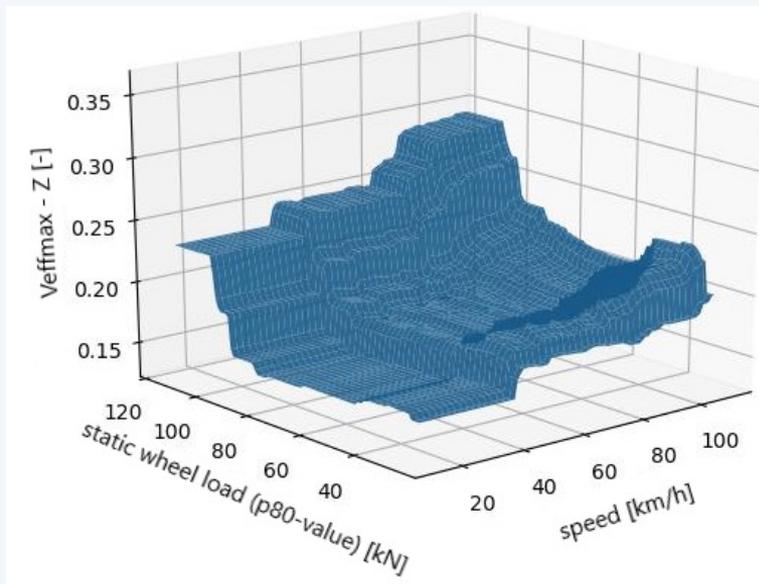


Model comparison: RMSE

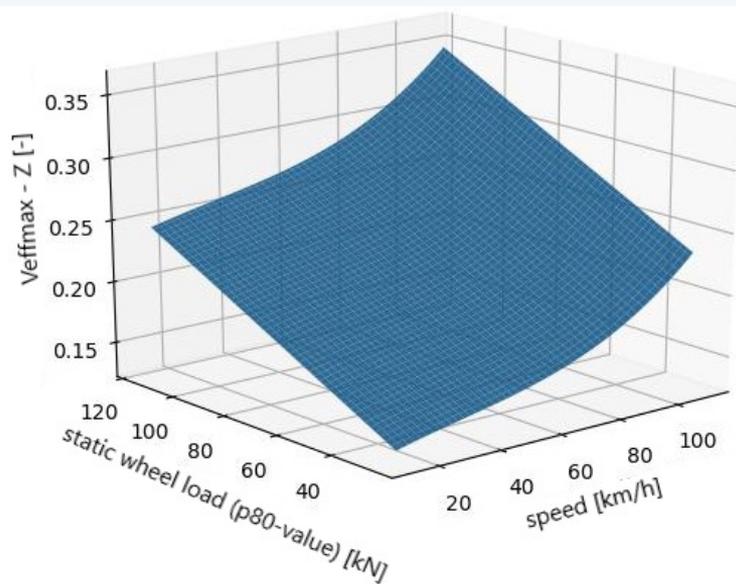


Model comparison: visualisation

Random Forest



Multivariate Regression

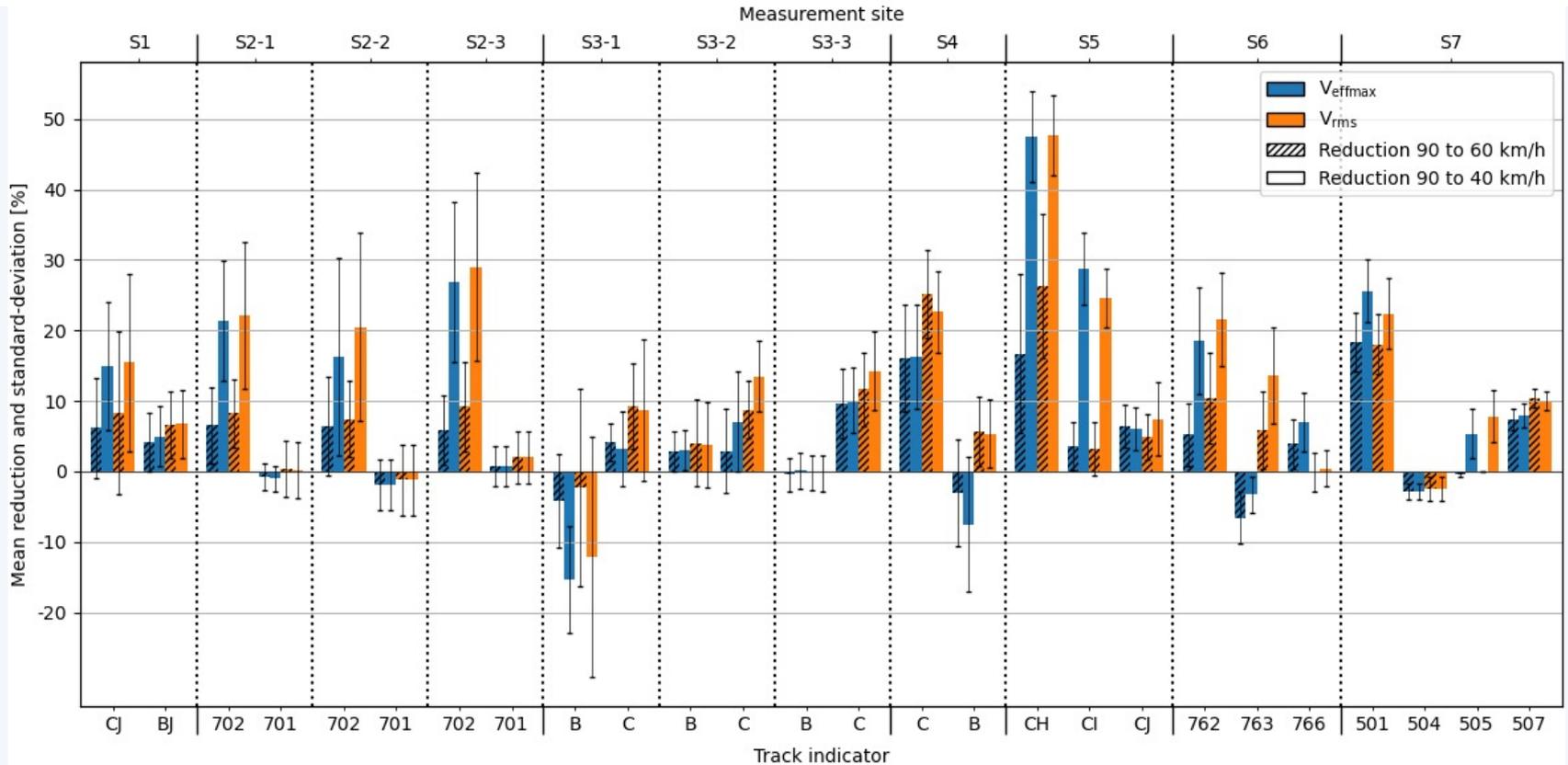


Model application: lower speed = less vibration?

Steps:

1. construct dataset using measurements
2. train a random forest model for prediction of vibrations
3. compose a representative set of passing freight trains (wheel load, axle load, etc)
4. run model for this set with train speeds 90 km/h – 60 km/h – 40 km/h
5. evaluate effect of lower speed on vibrations

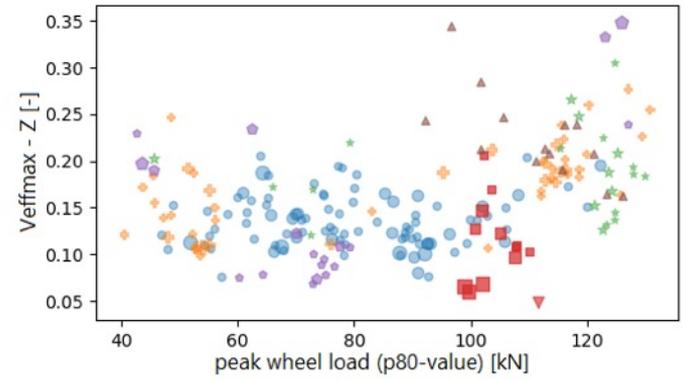
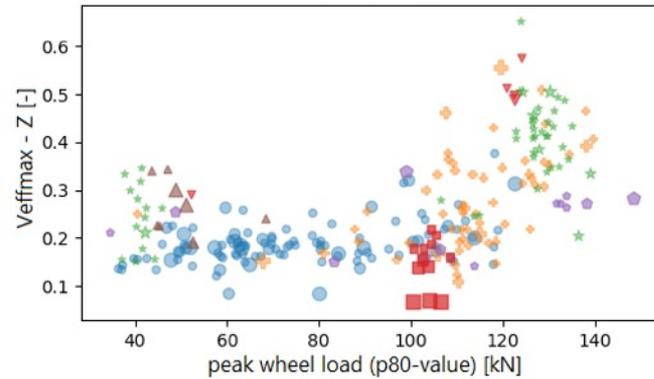
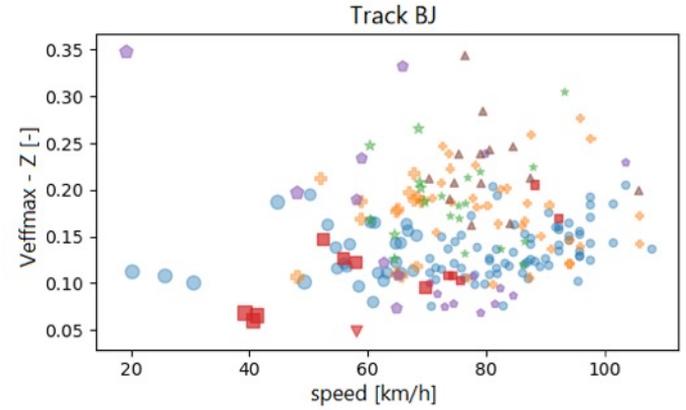
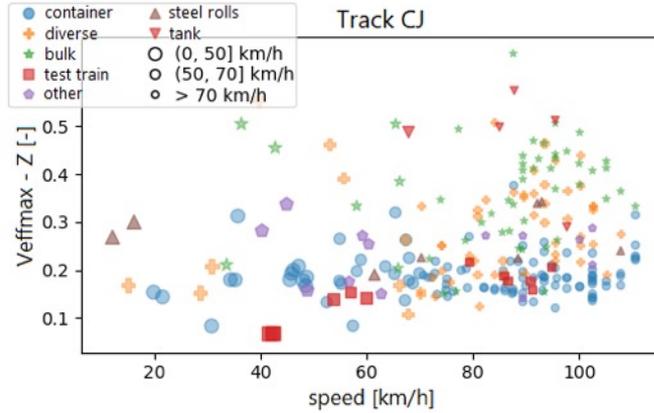
Model application: lower speed = less vibration?



Conclusions

1. Random Forest model
 - gives a **better prediction** than Multivariate Regression;
 - is able to **exploit** the underlying (non-linear) **structures** in the data;
 - allows to use **all available explaining variables**;
 - is able to **group and categorize data** on shared characteristics.
2. Simulations with the Random Forest model **provides insight** in
 - the **reduction of vibration** levels due to decrease in train speed;
 - the **role of other variables** causing vibrations.

Questions?



Witteveen + Bos

ProRail



Ministerie van Infrastructuur
en Waterstaat

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