Survey of curve squeal occurrence for an entire metro system

O. Eriksson, P.T. Torstensson, A. Pieringer,
R. Nilsson, M. Höjer, M. Asplund, A. Świerkoska

ICRI webinar on wheel-rail noise February 21 2023

2019 → **2021** → **2022**

2019


CHALMERS
UNIVERSITY OF TECHNOLOGY

Curve squeal on the Stockholm metro
Statistical analysis based on data collected by an onboard monitoring system
Master's thesis in Sound and Vibration
ANNA ŚWIERKOSKA
Department of Civil and Environmental Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

- MSc-thesis by Anna Świerkoska

2021

Curve squeal – influence of track design and maintenance status

- WP1: Curve squeal on TRV's infrastructure
- WP2: Analysis of measurement data from Stockholm metro
- WP3: Development of numerical simulation model
- WP4: Influence of track design and maintenance status

2022

IWRN 14
7-9 December 2022 Shanghai

- Sub. 83, A. Pieringer
- Ongoing work

- How does track design influence curve squeal occurrence?
- How does maintenance status influence curve squeal occurrence?

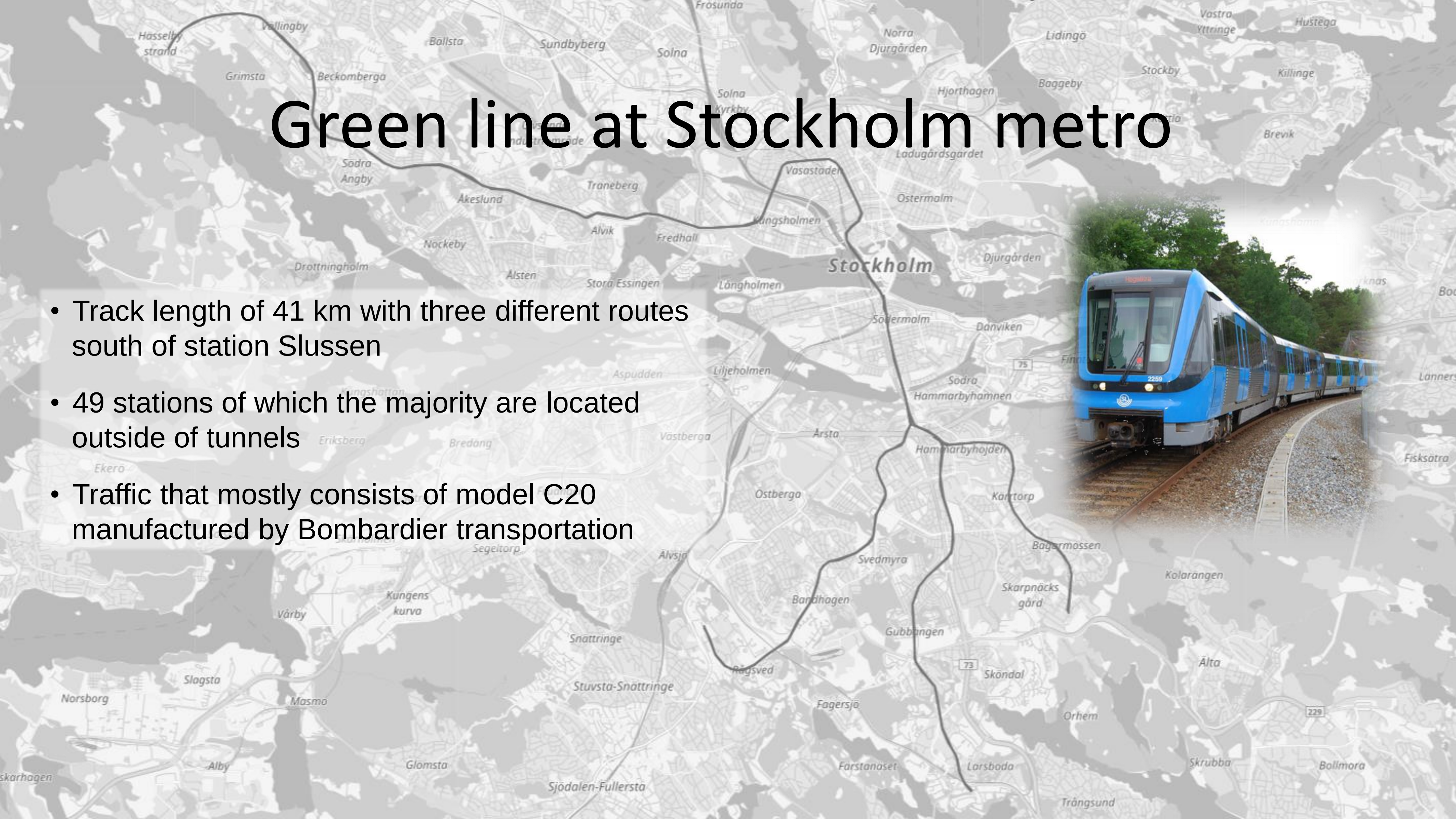
Literature

- Typically, conditions in few selected curves are investigated
- Previous observations:
  - The influence of **vehicle speed** is moderate [1]
  - Curve squeal occurrence increases with increasing **relative humidity** [2]
  - Curve squeal occurrence increases after **rail grinding** [1]

[1] Jiang, J., Hanson, D., Dowdell, B.: Wheel Squeal: Insights from Wayside Condition Monitoring. Notes on Numerical Fluid Mechanics and Multidisciplinary Design 139, (2016).
[2] Anderson, D., Wheatley, N.: Mitigation of wheel squeal and flanging noise on the Australian rail network. Notes on Numerical Fluid Mechanics and Multidisciplinary Design 99, (2008).

Green line at Stockholm metro

- Track length of 41 km with three different routes south of station Slussen
- 49 stations of which the majority are located outside of tunnels
- Traffic that mostly consists of model C20 manufactured by Bombardier transportation



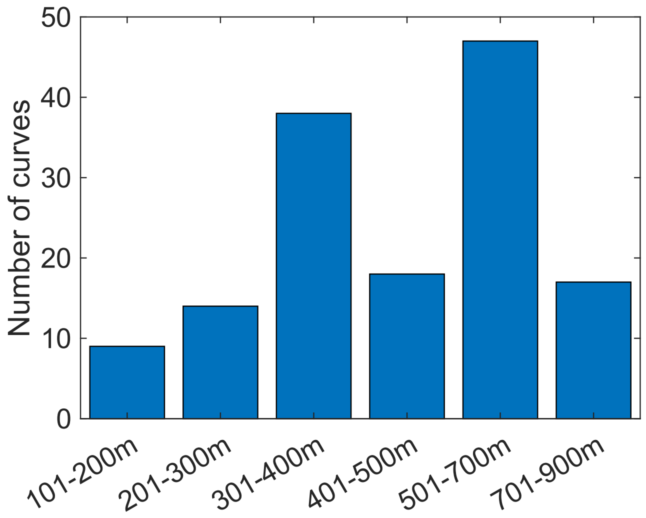
On-board monitoring system

- Noise is continuously measured at both wheels of the trailing wheelset of the leading bogie, or leading wheelset of the trailing bogie, depending on travelling direction
- Position and speed is collected with GPS
- Curve squeal is evaluated in time-intervals of 250 ms using the following criteria:
  - Vehicle located in a curve
  - SPL exceeds 95 dB
  - SPL in the frequency range above 1.6 kHz at the inner wheel exceeds that of outer wheel by at least 3 dB

Microphone

Data

- Data collected from two vehicles that have trafficked on the Green line between January 2019 – November 2021
- In total 143 curves and 379 776 vehicle passages
- All curves with radius below 900 m and circular sections of over 50 m length are included
- A squealing passage requires at least 0.5 s of continuous squeal (two consecutive positive samples)
- Air temperature and relative humidity are collected from the weather station located at Bromma airport in Stockholm



vti

IWRN 14
7-9 December 2022 Shanghai

Binary logistic regression analysis

- The regression model below is fitted to each curve individually

Intercept

$$logit(s) = ln\left(\frac{s}{1-s}\right) = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \theta_3 x_3 + \theta_4 x_4 + \theta_5 x_1 x_3 + \theta_6 x_3 x_4$$

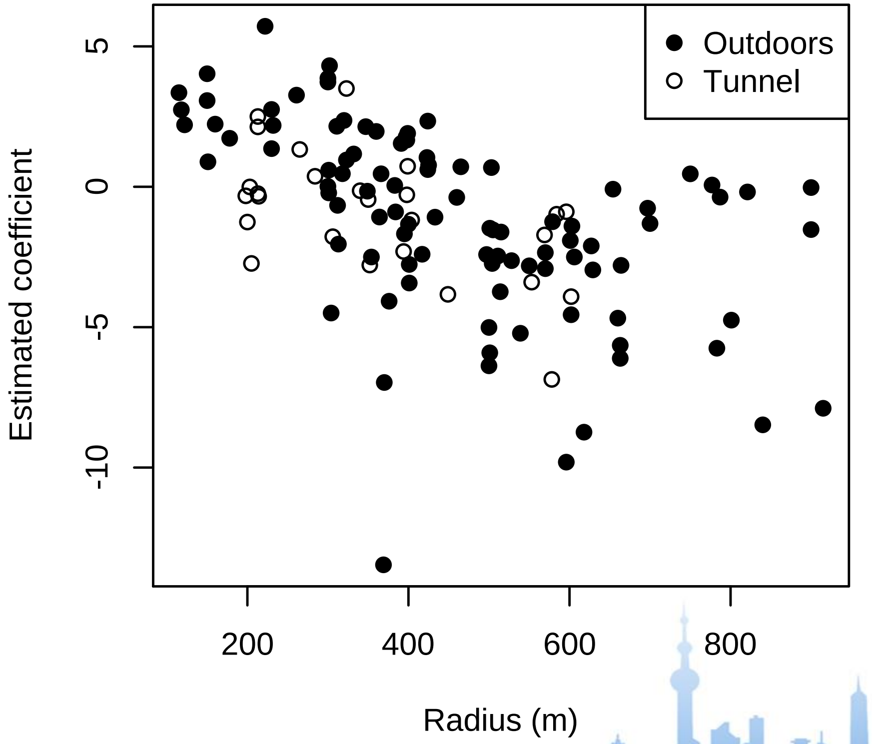
where θ_n are regression coefficients, s is the probability for curve squeal and explanatory variables are:
x_1 – vehicle individual
x_2 – rail grinding
x_3 – air temperature
x_4 – air relative humidity

- Vehicle speed was investigated by introducing several additional variables associated with constant speed (linear and quadratic terms), acceleration and retardation. No significant effect on squeal probability was found

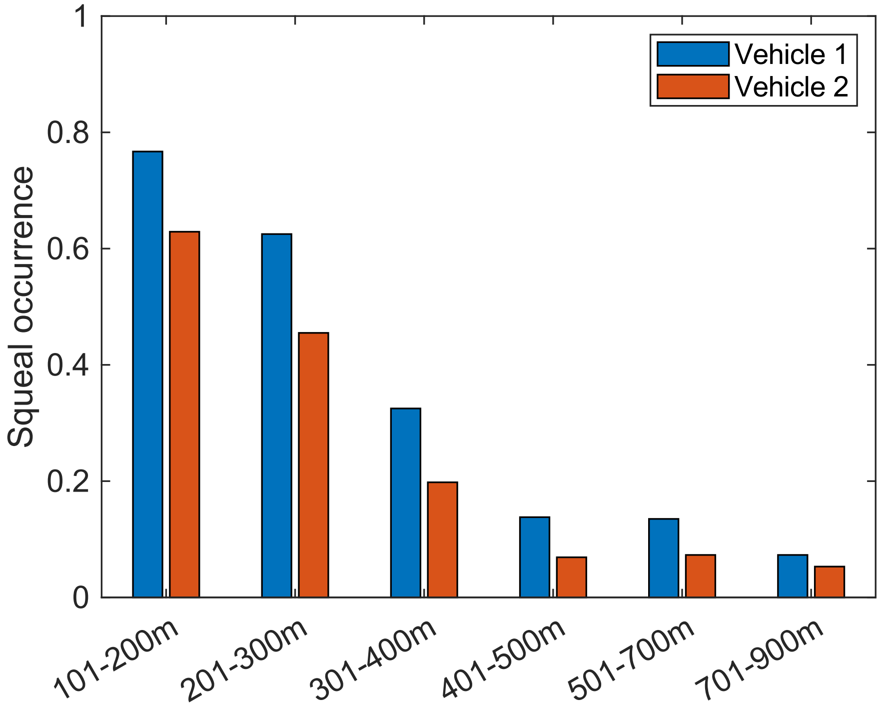
vti

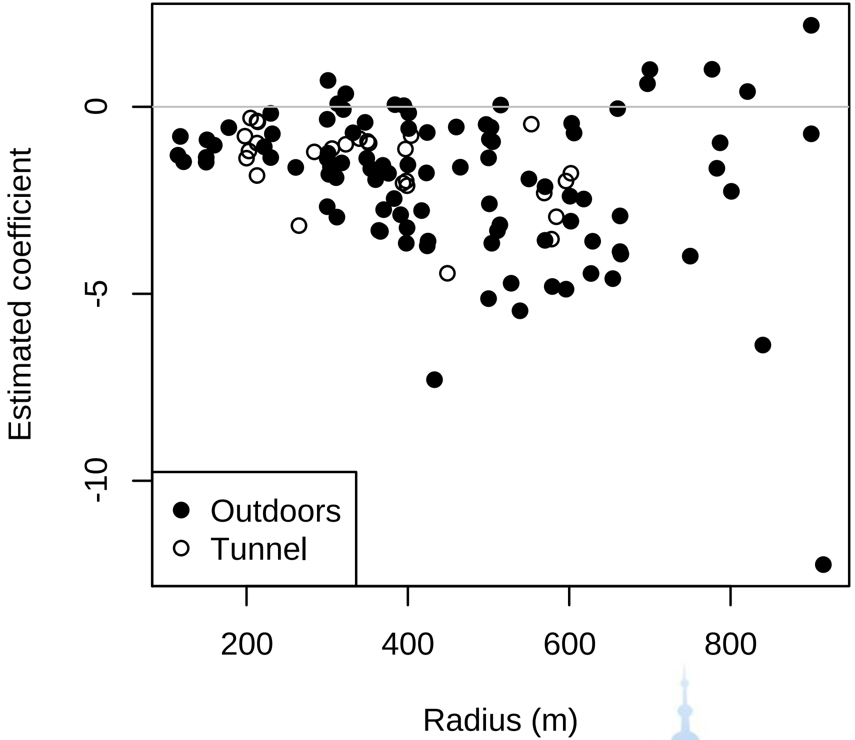
Influence of curve radius

- Squeal probability increases for decreasing curve radius (p<0.001)
- Impact of curve radius particularly accentuated for radii below approximately 600 m
- Similar results obtained for curves located in- and outside of tunnels
- Large differences between individual curves of similar radius



Influence of curve radius

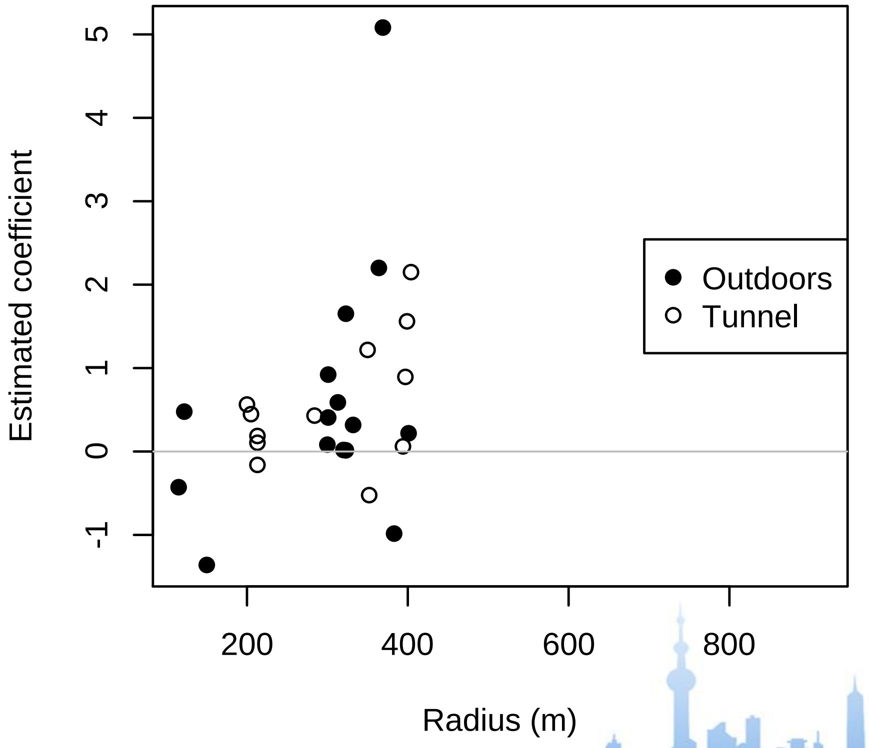




- Vehicle 2 is significantly less inclined to generate curve squeal than vehicle 1 ($p<0.001$)

Influence of rail grinding

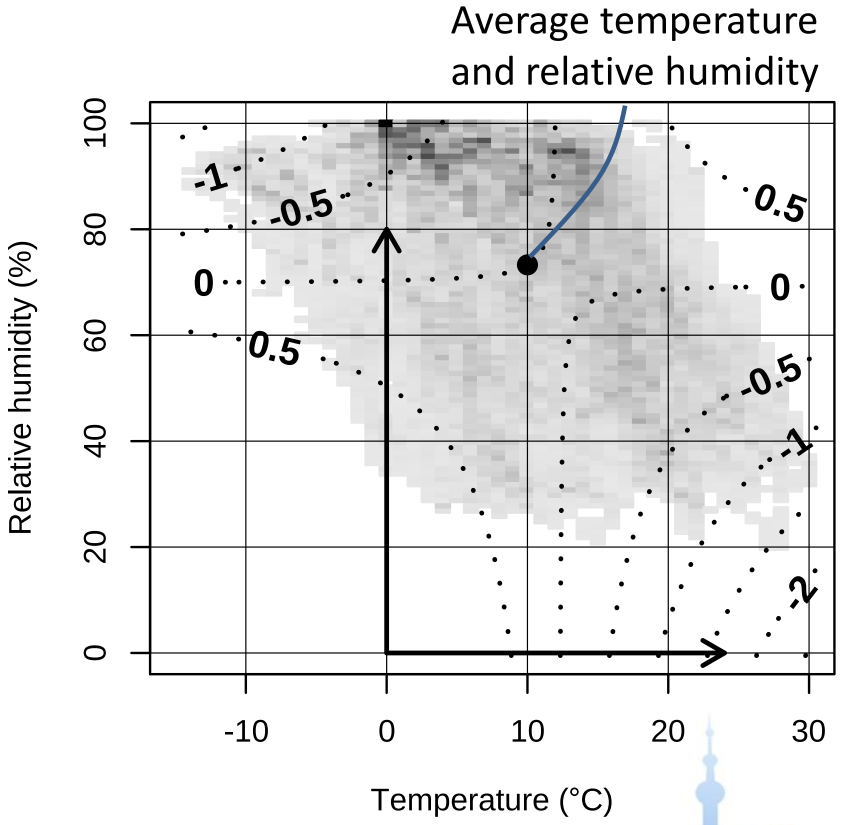
- Squeal probability increases after rail grinding. Significance at level $p=0.017$
- The effect of rail grinding gets more pronounced for increasing curve radius



IWRN 14
7-9 December 2022 Shanghai

Influence of environmental conditions

- Estimated regression coefficients for air temperature, relative humidity and their interaction are all significant at *p*<0.001
- The average response surface, *logit*(*s*), of curve squeal is shown to the right
- Complex relation between curve squeal probability and temperature/relative humidity

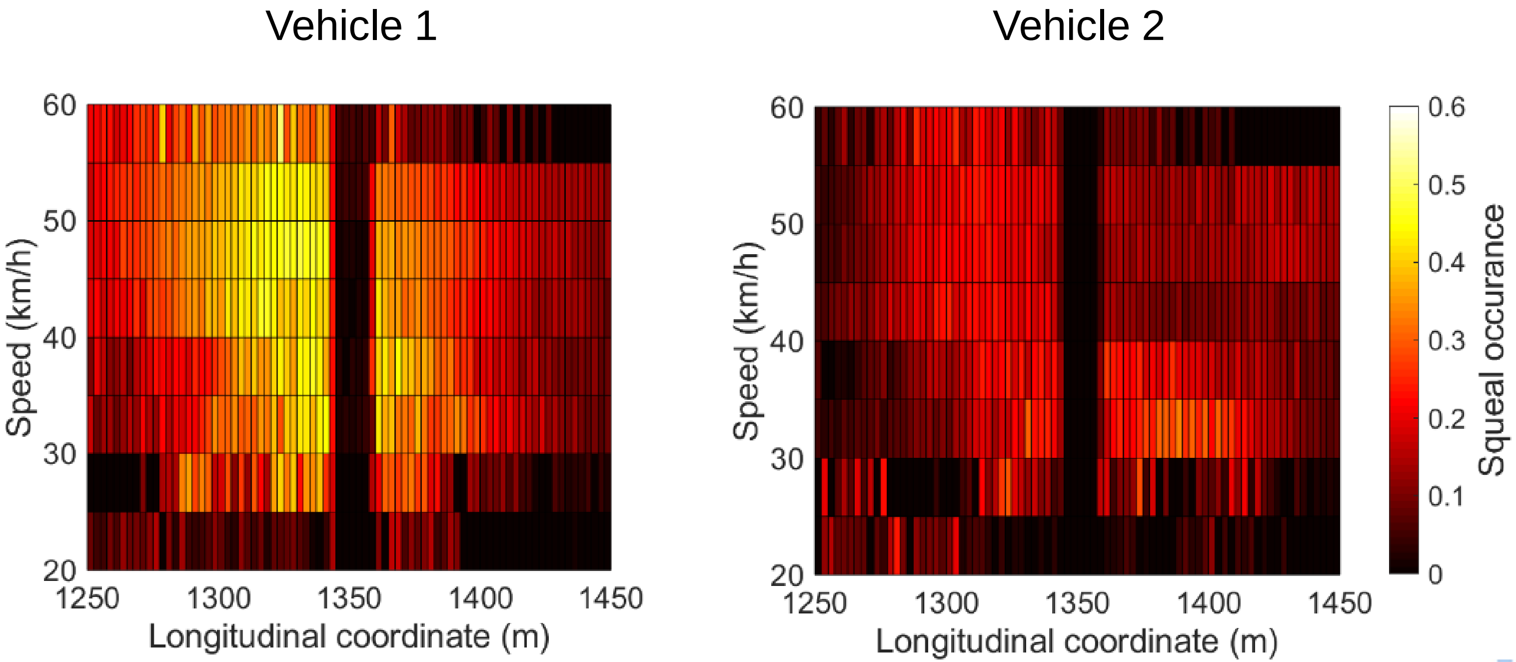


(grey color shows nr of vehicle passages)

vti

Are there squeal-free track sections?

- Observation from 213 m radius curve between Gamla stan and T-centralen



Conclusions

- Squeal probability has been investigated based on data collected by on-board noise monitoring during approximately 1.5 years of trains in regular traffic
- For curve radii below approximately 600 m, squeal probability shows an inverse proportionality with respect to curve radius
- Two studied vehicles show significantly different tendency to generate curve squeal
- Squeal probability increases after rail grinding
- At air temperatures above 10°C, squeal probability increases with increasing relative humidity. For air temperatures below 10°C, the opposite relation is found
- No significant relation between squeal probability and vehicle speed is found
- Indications on the existence of squeal-free track sections

Thanks for your attention!

Peter torstensson, peter.torstensson@vti.se

vti