Energy-friendly Road Design

State of Play

Outcomes & Applications

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The concept

Impact of geometric design decisions on **driving behavior**, which has a direct influence on **vehicle emissions**.







Different emission rates

New Technologies

Long time construction time **E39**

Emission model → *Energy model*

The lower the energy demand, the lower the emissions.

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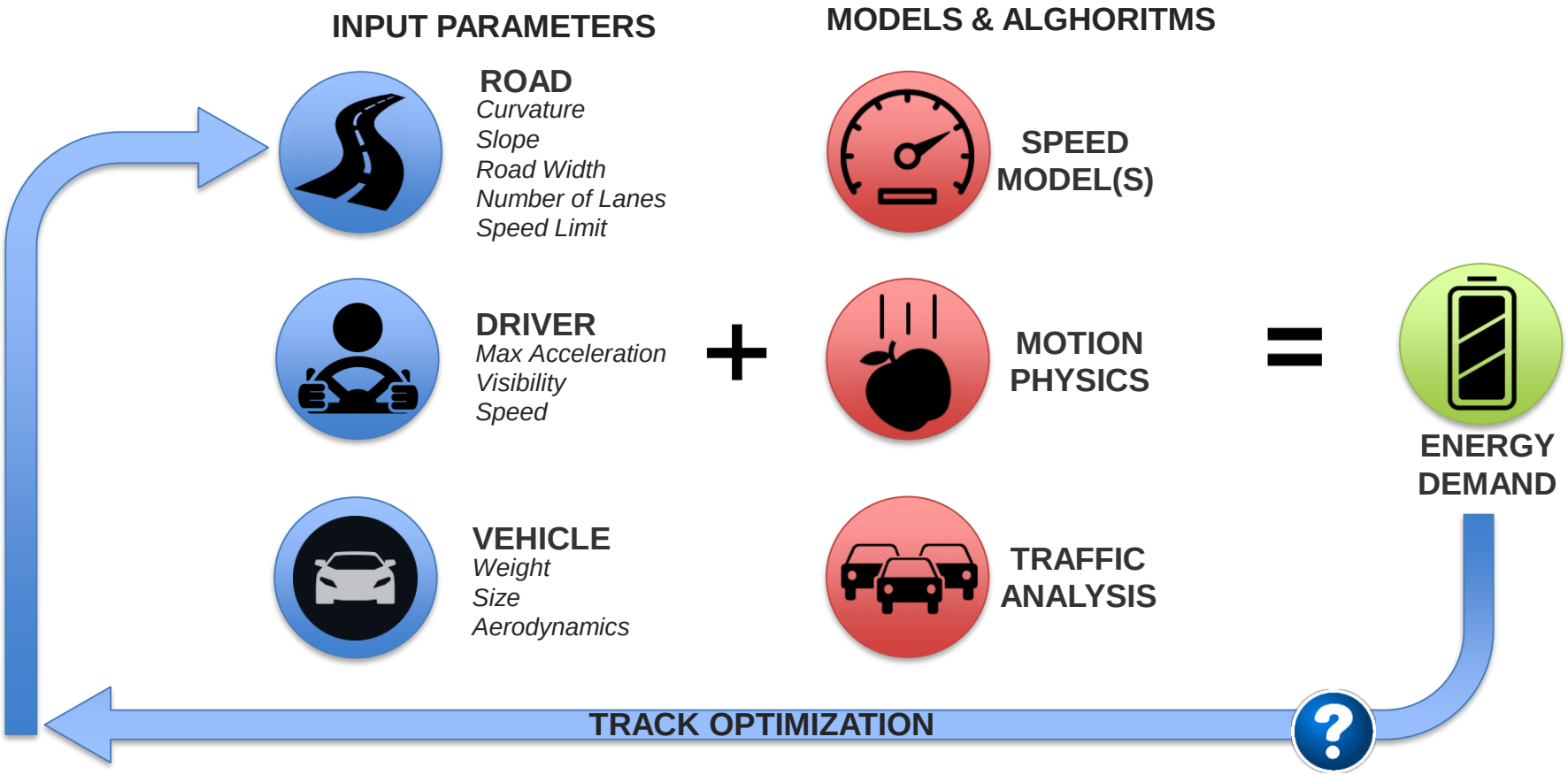
The process



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The Algorithm

SPEED MODEL(S)

EFFEKT

$$V = \beta_1 \cdot HKF + \beta_2 \cdot SF + \beta_3 \cdot B_d - 155{,}6$$

HKF: Horizontal Curve correction factor

SF: Slope correction factor

B_d: Pavement Width correction factor

SINTEF

$$V = V_0 \cdot e^{U(x_d, x_s, x_f, x_k)}$$

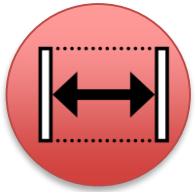
V_0: Estimated reference base-speed

$U(x_d, x_s, x_f, x_k)$: Linear regression function

INPUT PARAMETERS

Curvature

Slope



Road Width

Number of Lanes

Speed Limit

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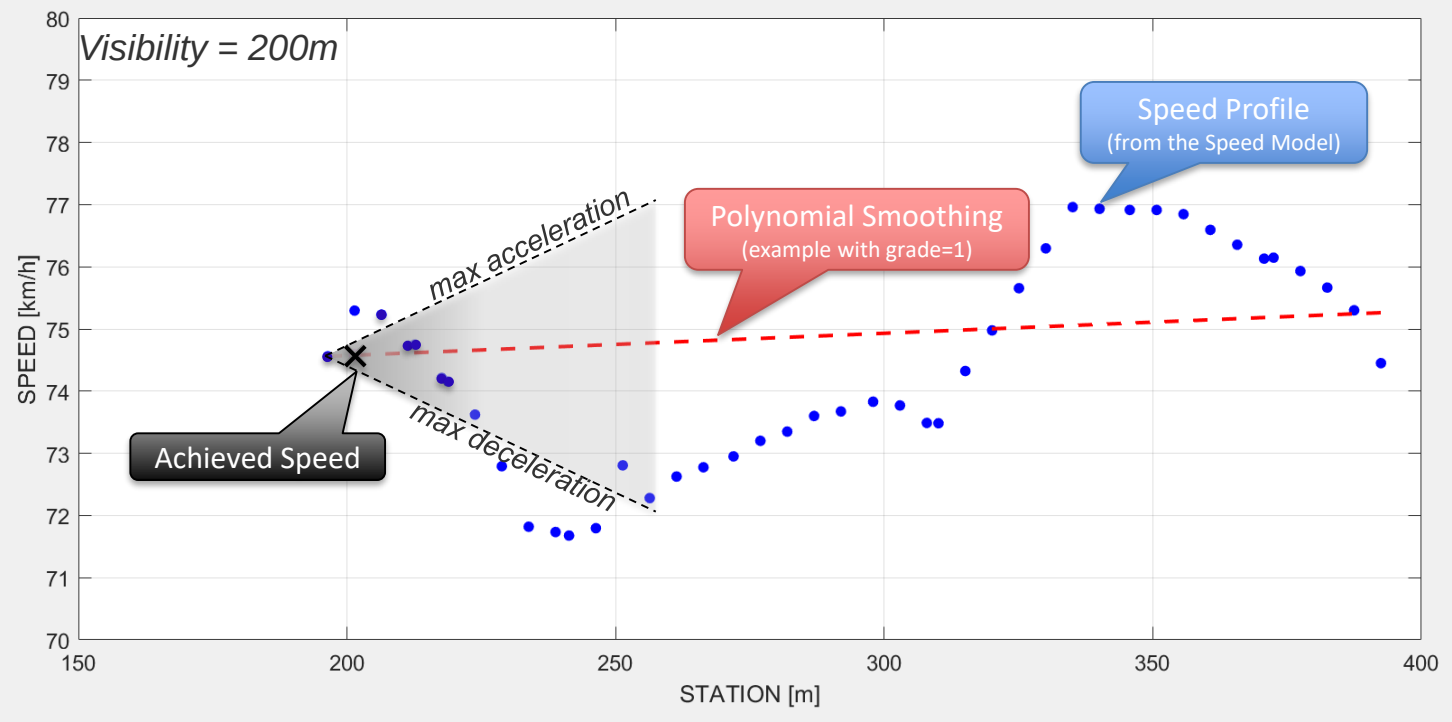
The Algorithm

DRIVER BEHAVIOR

VISIBILITY

GRADE

ACCELERATION



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The Algorithm

RESISTANCES

Rolling

$$R_r = 15 + 0.00003(V - 50)^3 \cdot P \quad [N]$$

Inertia

$$R_{in} \cong \beta \cdot \frac{dv}{dt} \cdot P \quad [N]$$

Grade

$$Ri = P \cdot sen\alpha \cong P \cdot tan\alpha = P \cdot i \; [N]$$

Horizontal Curvature

Air

$$R_{air} = \frac{1}{2} \cdot \rho \cdot c_d \cdot S \cdot v^2 \quad [N]$$

ENERGY

$$E = \sum R \cdot \mathrm{L} \; [\mathrm{KWh}]$$


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The Horizontal Curve Resistance

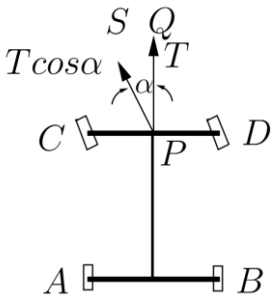
$$R_c = \frac{0{,}077 \cdot V^2 \cdot P}{2 \cdot R}\ [N] = \frac{1}{2} \cdot F_{centr}\ [N]$$

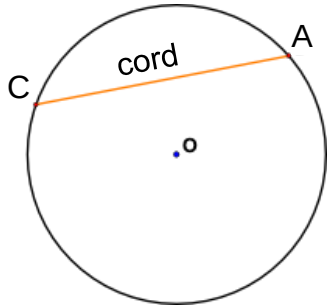
IT'S WRONG

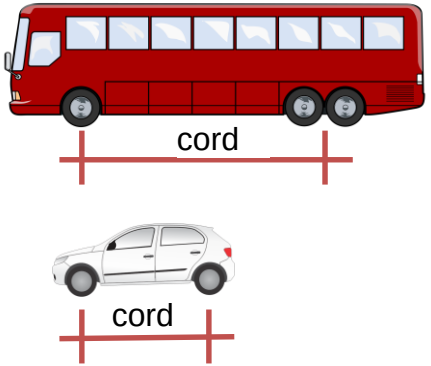
Garber, N. J., L. A. Hoel, and R. Sarkar.
Traffic and highway engineering.
Cengage Learning, Stamford, Conn, 2010.

$$R_c = T - T \cdot \cos\alpha\ [N]$$

Santagata et al.
Roads, vol.1 – Construction, Management and maintenance
Pearson, Ancona, 2016







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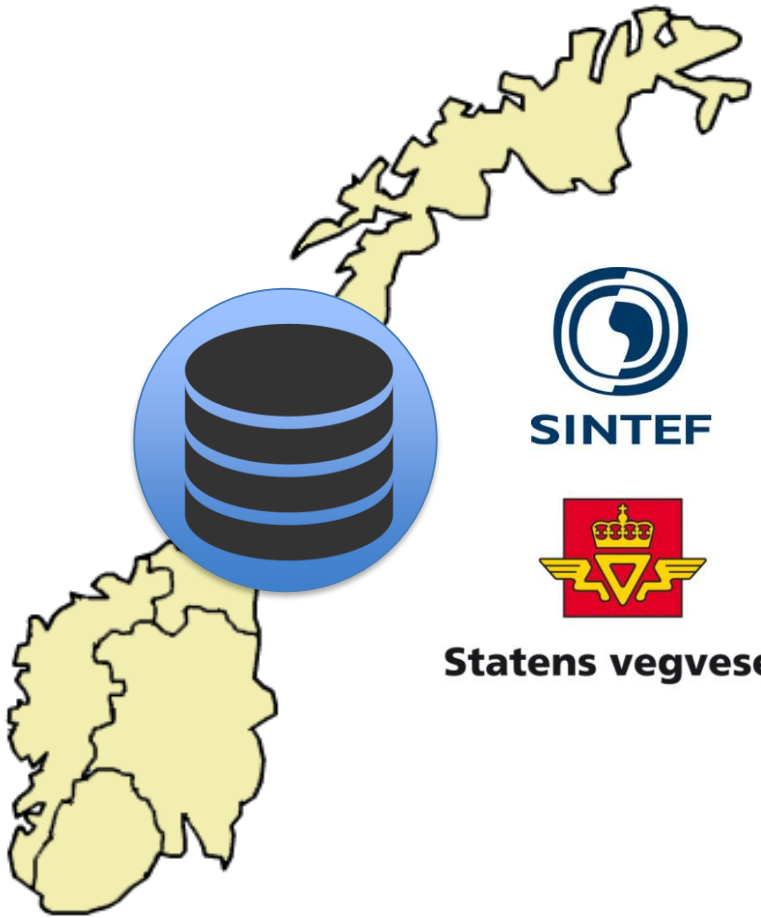
The Operating Speed Database



SINTEF

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2 2 years of data collection

Total Anonymous

1Hz High detailed

55k Thousands of trips in all Norway

Timestamp
Distance
Latitude
Longitude
Speed limit
Vehicle speed
Vehicle
- Id
- Length
- Width
- Weight
- Engine

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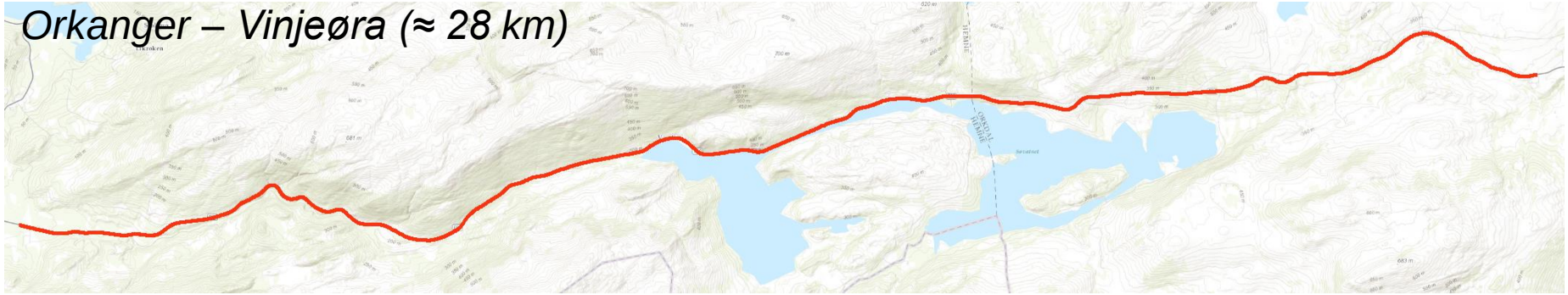
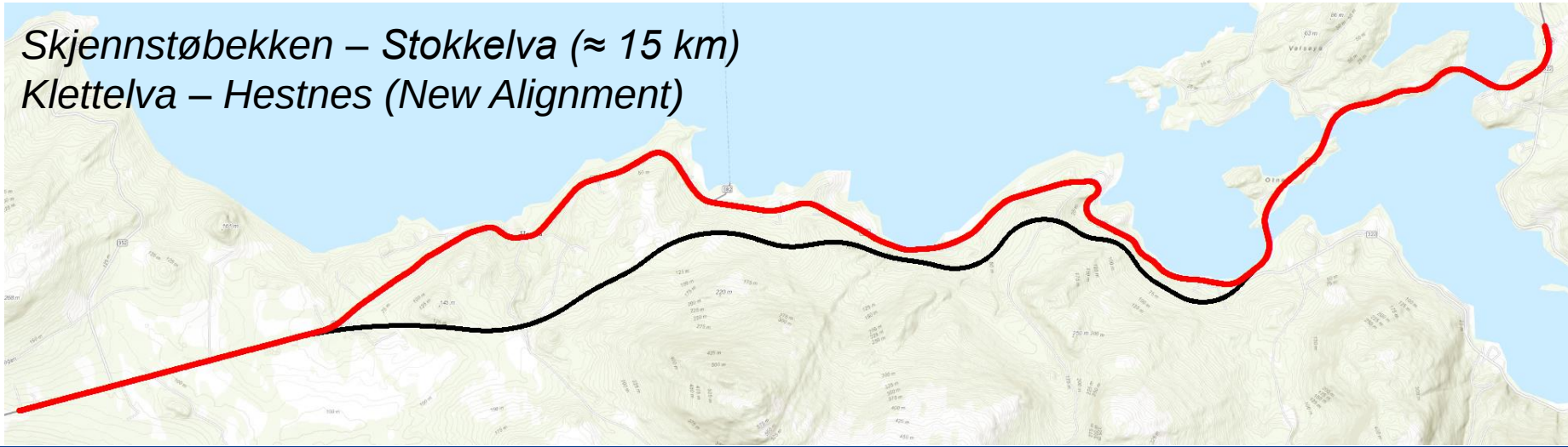
Case studies





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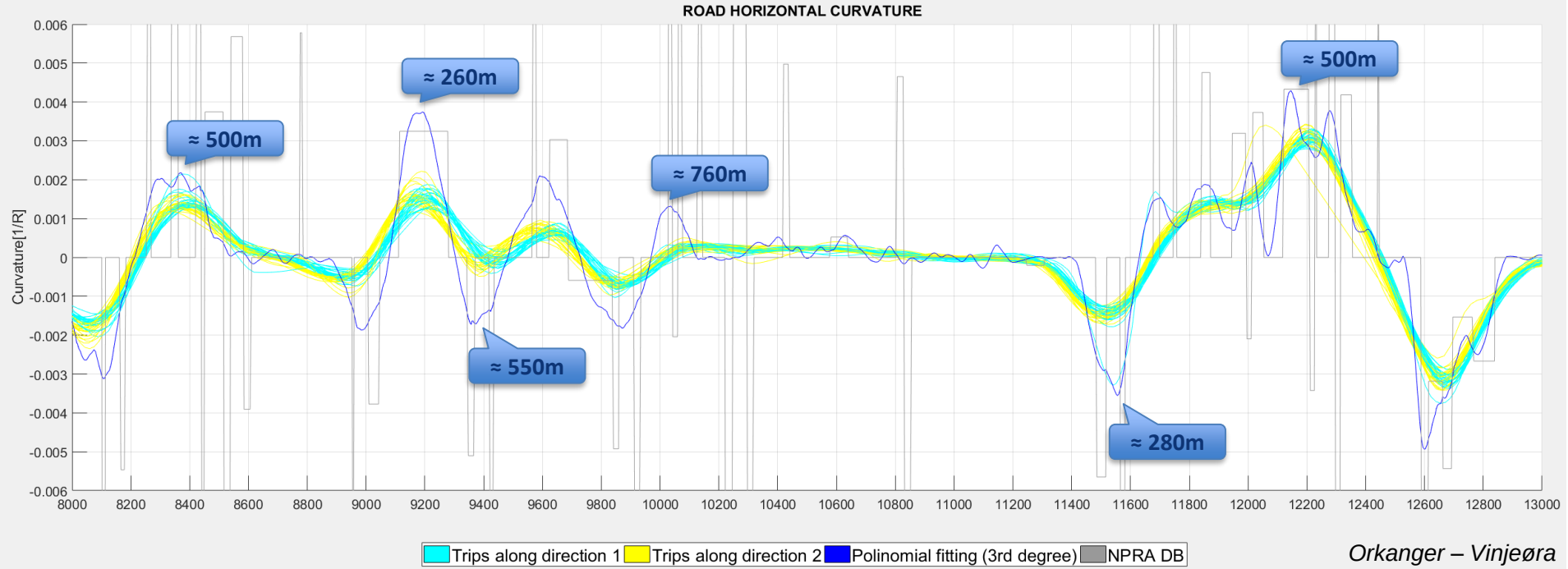
Results

- Differences between **road horizontal curvature** & **drivers behavior**
- Possible **inaccuracies** on NVDB database



Orkanger – Vinjeøra

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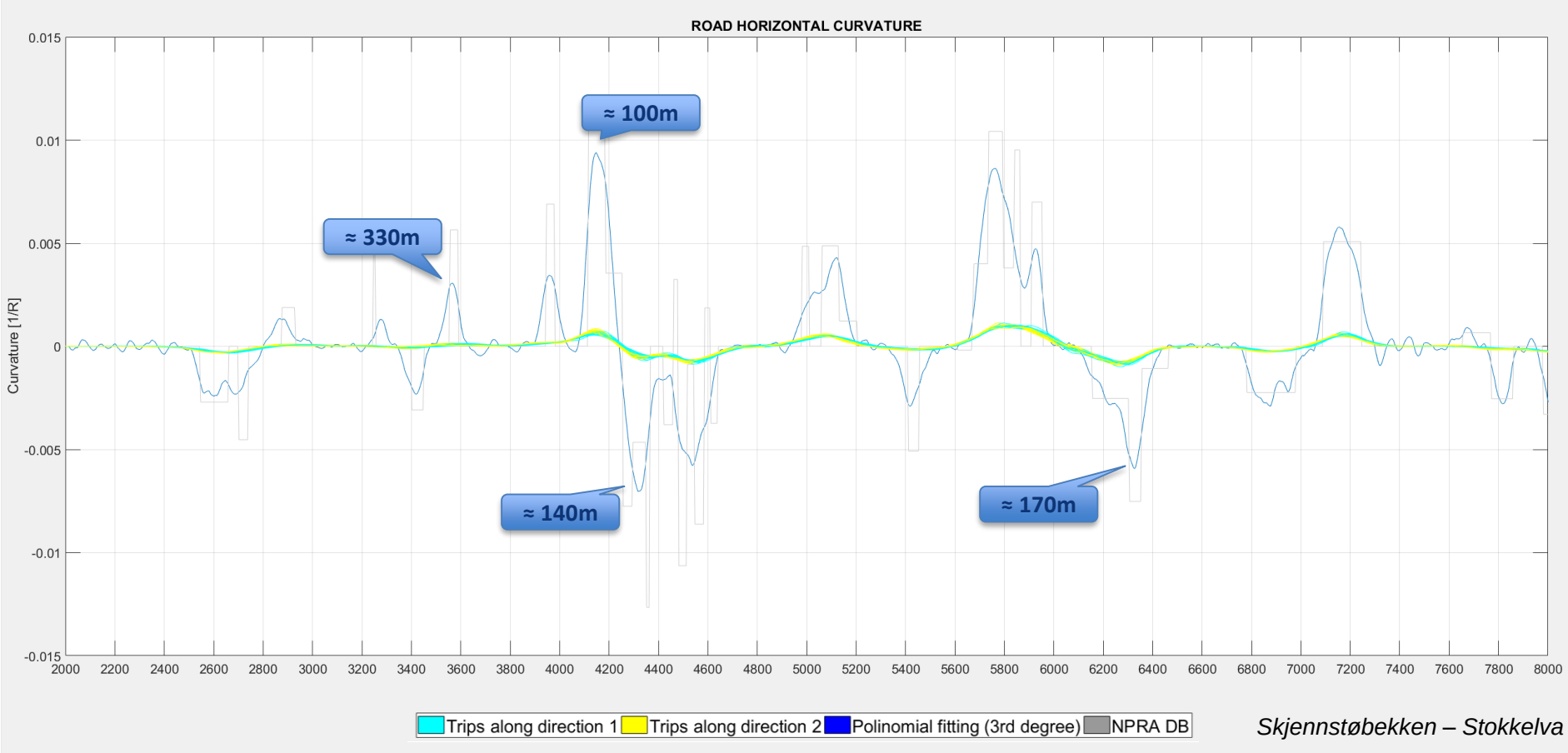
Results



Skjennstøbekken – Stokkelva

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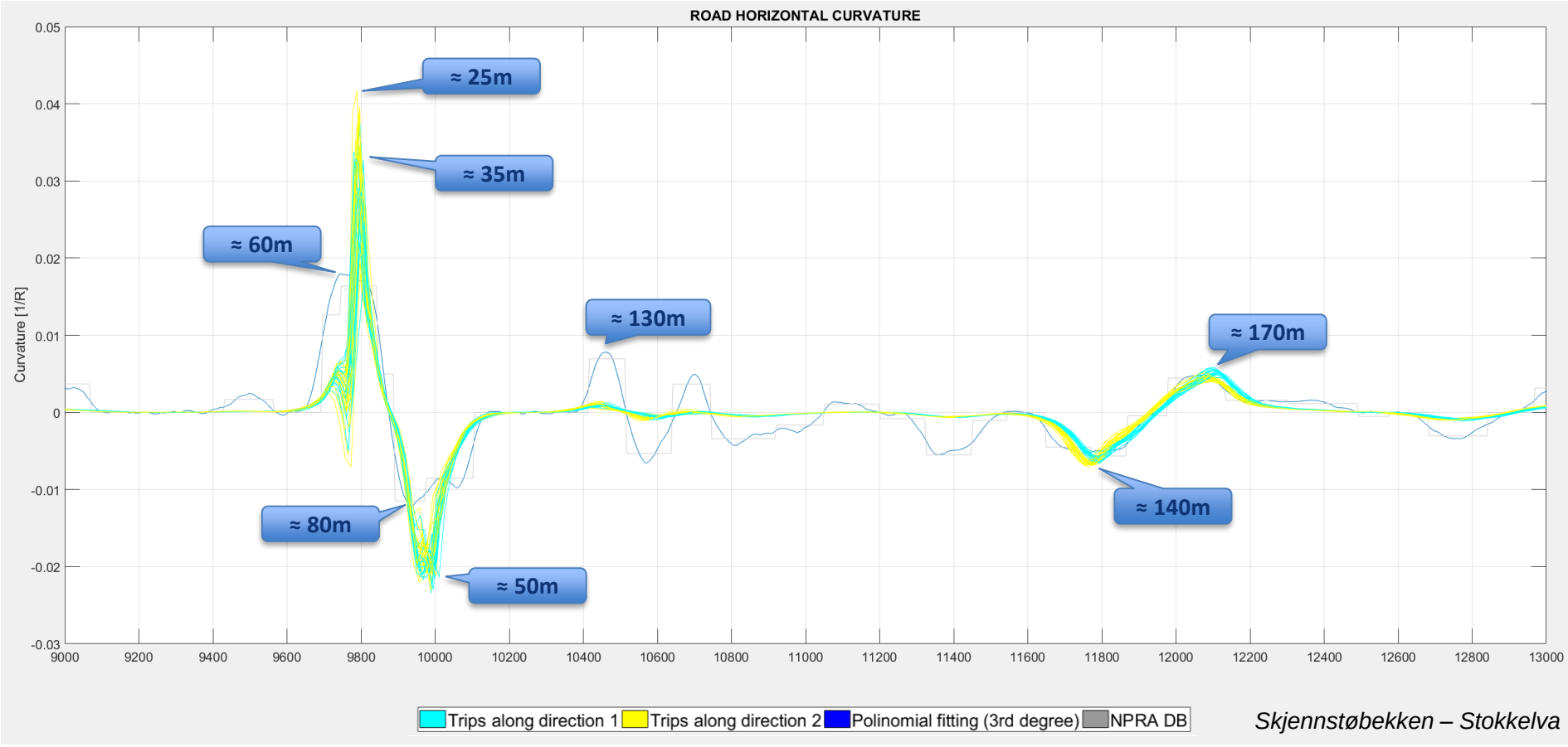
Results



Skjennstøbekken – Stokkelva

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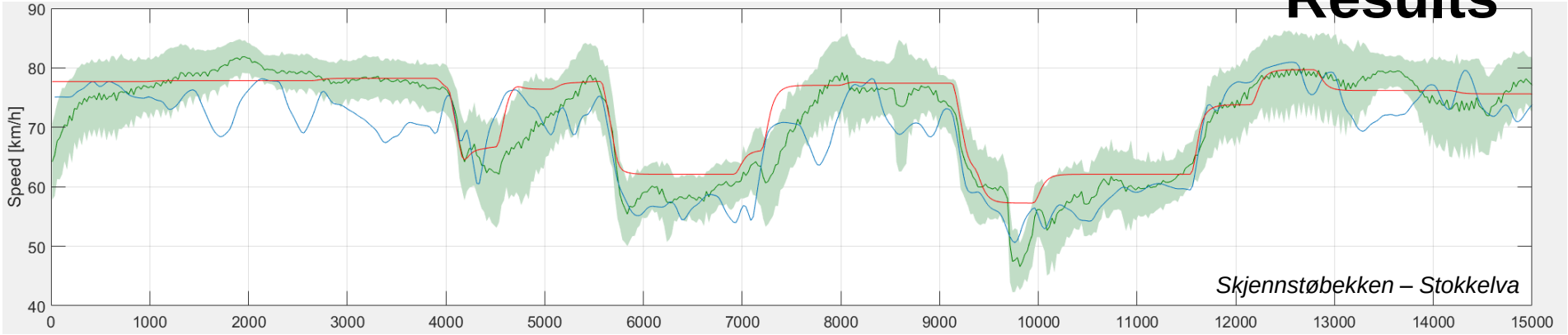
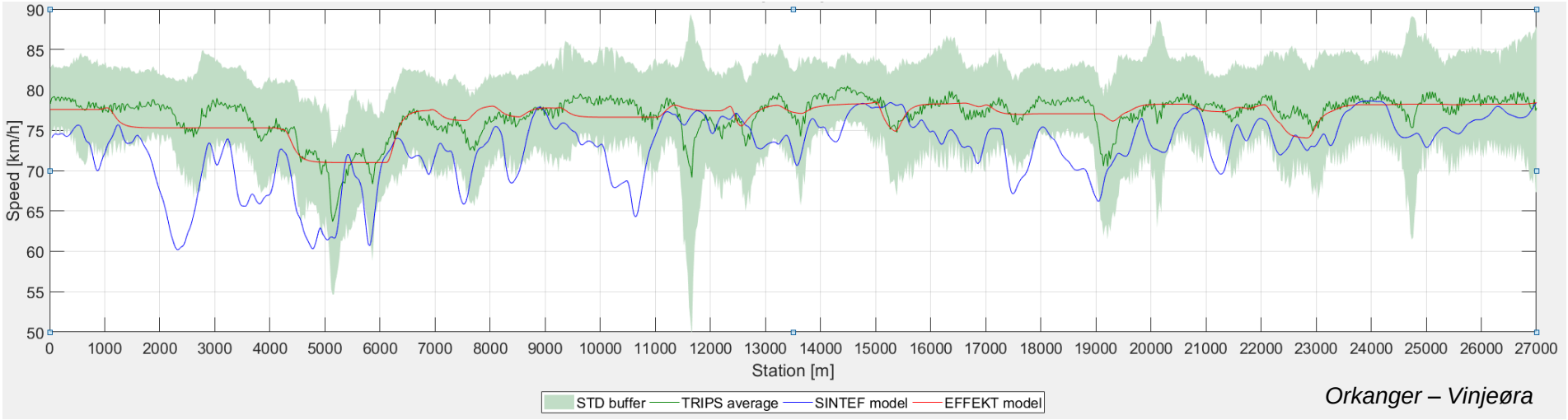
Speeds analysis between **speed models** and **operating speeds**

Results





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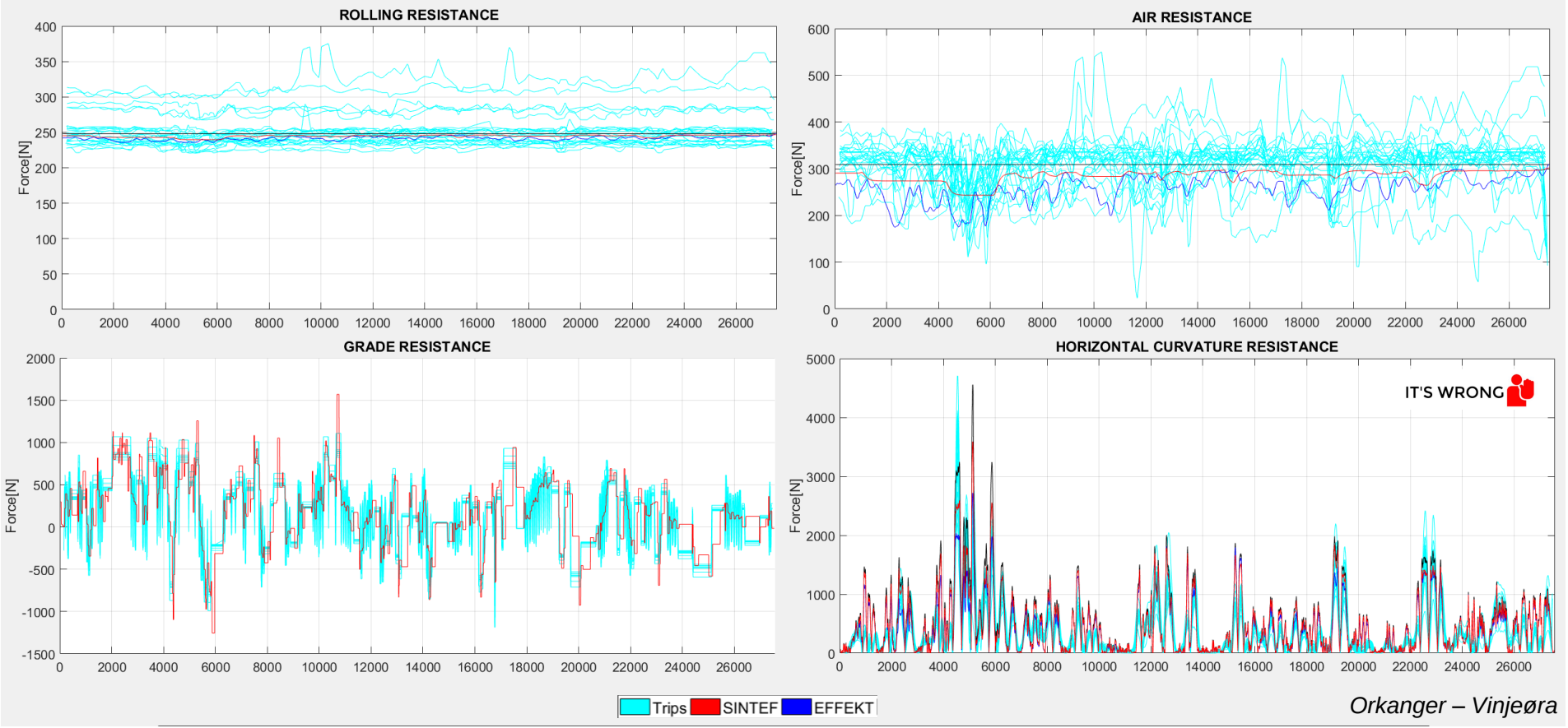
Results



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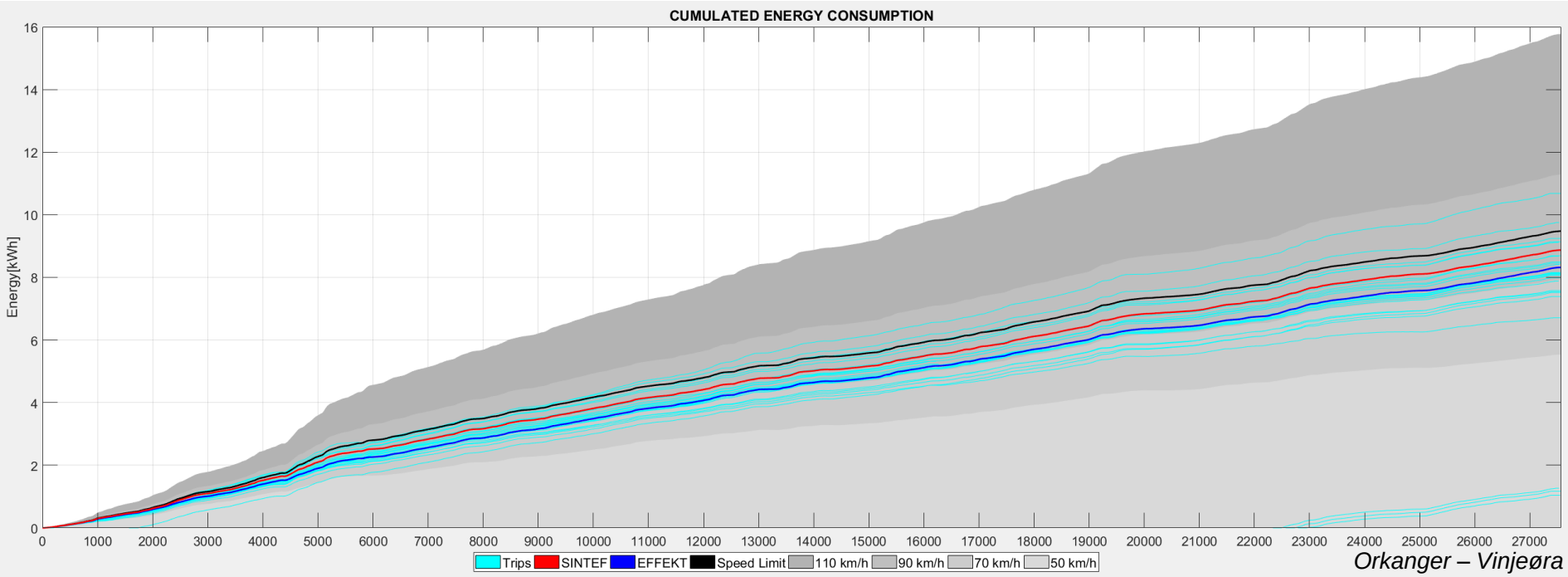
Results

- The energy module can give an overview of the energy demand of the desired track, based on constant speeds, PSL, modeled speed and actual trips, on both direction.



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The outcomes for the E39 as a project

E39 Energy Report

A **complete & high detailed evaluation** of the actual E39 in terms of energy demand.

New Designs Evaluation

An **energy comparison** between an **existing road** and a **new alignment** in the design stage.

Hotspots Identification

Identification of critical curves steep uphills and downhills or, more generally, **critical design combinations**.

Alignment Optimization

If implemented inside an **optimization process**, could help identifying **energy-optimized alignments**, also considering **small corridors**.


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The Timeline

Getting Inside

- Literature Review
- Connecting & Networking
- Definition of potential research objectives

Facing with the data

- Data acquisition
- Data processing
- Definition of standards:
  - Database Structure
  - Procedures
  - Algorithms

Model development

- Speed/Energy model testing
- Comparison with other existing models
- Comparison with currently adopted speed models in NPRA

Exploitation

- E39 Energy Report
- New Designs Evaluation
- Hotspots Identification
- Alignment Optimization

AUG 2015 → AUG 2016 | SEP 2016 → JAN 2017 | FEB 2016 → AUG 2017 | SEP 2017 → AUG 2018


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A Next Step?

The idea is to cooperate to create a unique tool that contains and harmonizes the different researches we developed separately.

Different codes, models, databases, beta-softwares or prototypes

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A Next Step?

GIUSEPPE MARINELLI
Energy-friendly Road Design

HREFNA RUN VIGNISDOTTIR
Life cycle assessment of road winter maintenance operations

GAYLORD KABONGO BOOTO
The effects of geometric design and technology diffusion on the overall environmental profile of big infrastructure projects

DIEGO MARIA BARBIERI
Use of Local Material for Road Construction

BABAK EBRAHIMI
Infrastructure performance viewer

REYN O'BORN
Mapping the environmental impact of road construction processes

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Are You in?


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Thank you!

Q&A

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