

Machine Learning @ SBB.

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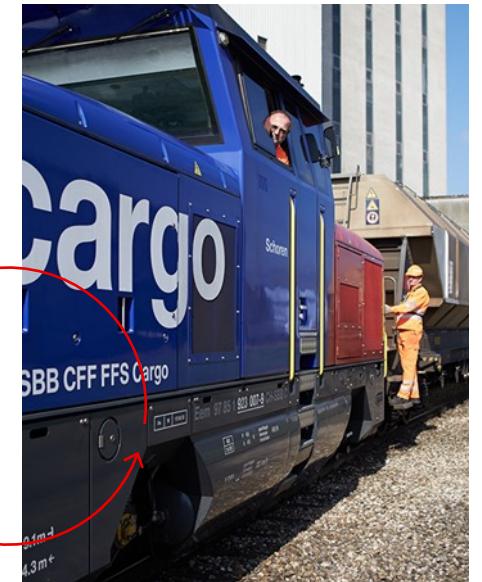
Analytics Service
22.11.2023

Agenda.

1. Introduction
2. Some projects in fast forward
3. Some projects in detail
 - Norman
 - Wheelset forecast
4. MLOps @ SBB



As an integrated railway, we keep Switzerland moving – every day.



Production
Passenger Services
11,260 trains/day

Market Passenger
Traffic
1.10M travellers/day

Real Estate
3,500 buildings

Infrastructure
3,265km of track

SBB Cargo
185,000 tonnes of
freight/day

Group-level units & specialist management units: Finance, Human Resources, IT, Communication, Corporate Development, Safety & Production Quality, Legal and Compliance, Public Affairs and Regulation

A few interesting figures.



93.1%
of trains on time,
regional differences



7,000
media enquiries, 250
press releases per year



11,260
trains on the network
every day



80.7 out of 100 points
customer satisfaction



804
stations and stops for
passenger traffic



CHF 5.63bn
annual purchasing
volume



413,000 GA
circulating

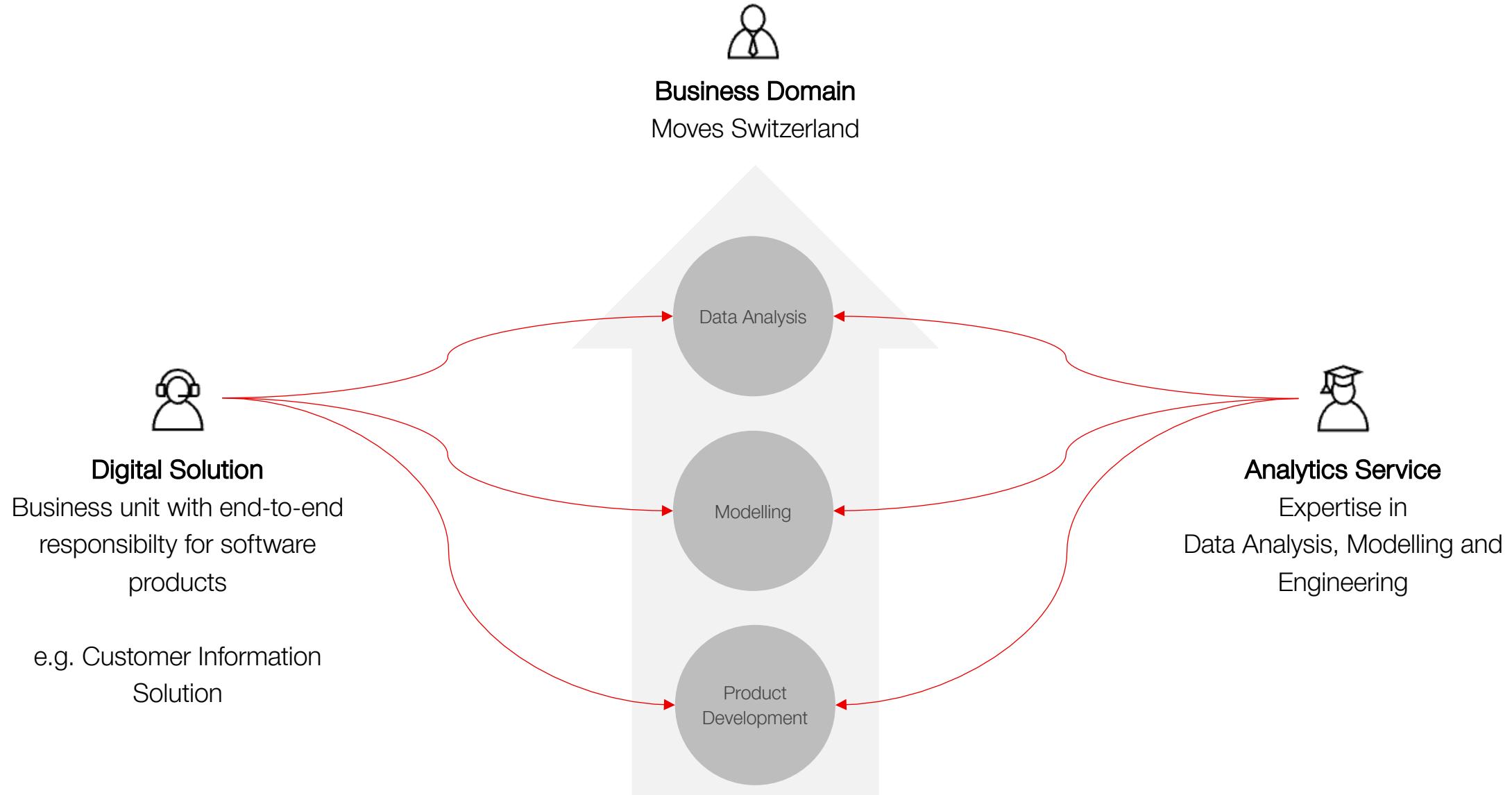


20,000
infrastructure
construction sites



656
multiple units,
108 power cars,
1,982 passenger coaches,
543 mainline locomotives

Analytics Service: Serving the Digital Solutions.



Some projects in fast forward.

Projects in cooperation between the Analytics Service and the specialist representative body.

Automatically map vegetation.



The **vegetation in the track area** must be checked regularly.

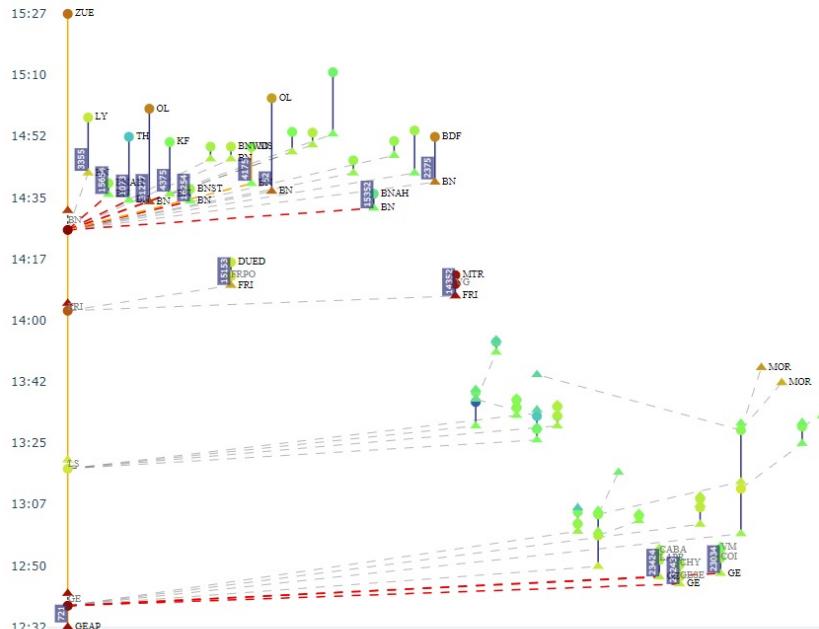
Automatic mapping of vegetation based on aerial photography.

Cost savings through more targeted use of vegetation control.

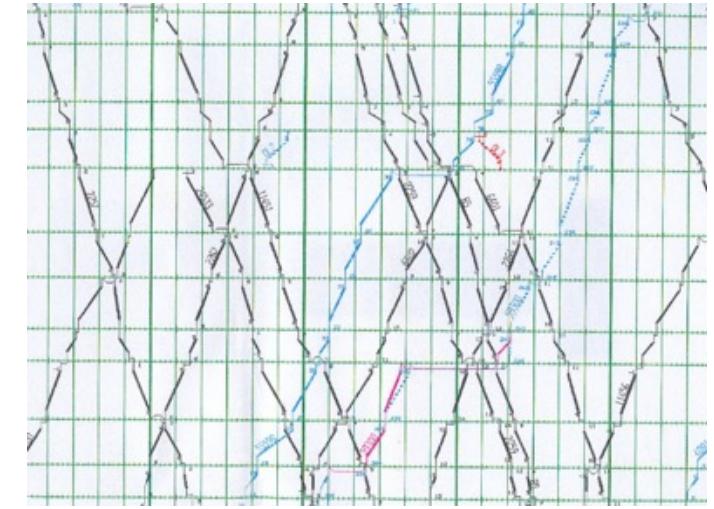
Visualise the spread of delays.



Delays spread due to the adherence to connections.

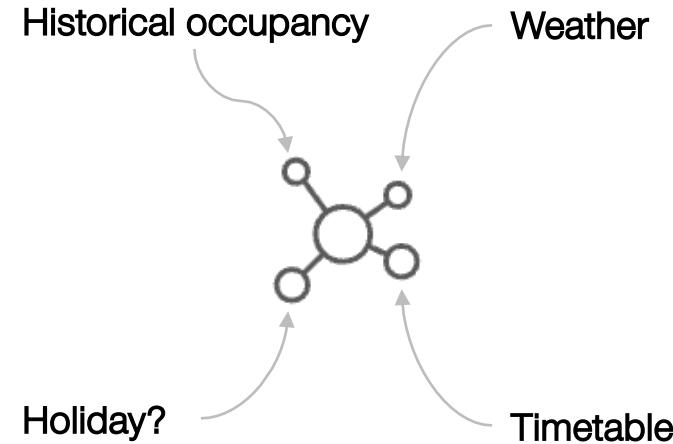


The delay propagation is modelled as a **graph** and **displayed visually**.



Buffer times for connections can be optimised during timetable planning.

Forecast occupancy of passenger trains.



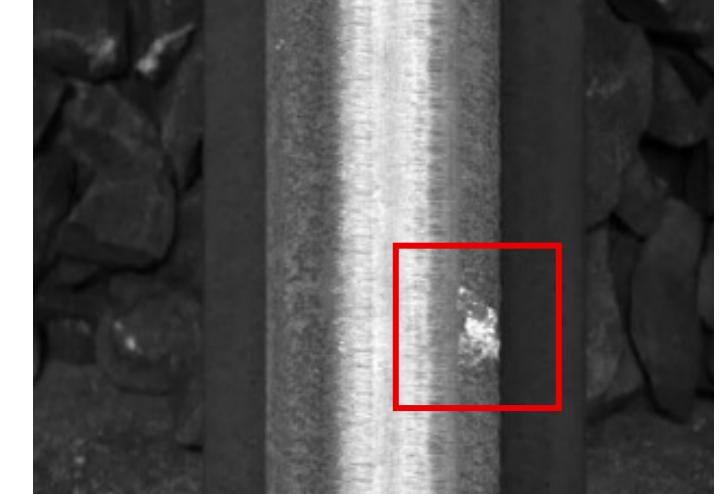
The passenger transport load is subject to high fluctuations.

The occupancy rate is statistically forecast **coach specific** on a **daily basis**.



Forecasts for customer information, capacity planning and pricing of **saver tickets**.

Automatically detect defective rails.

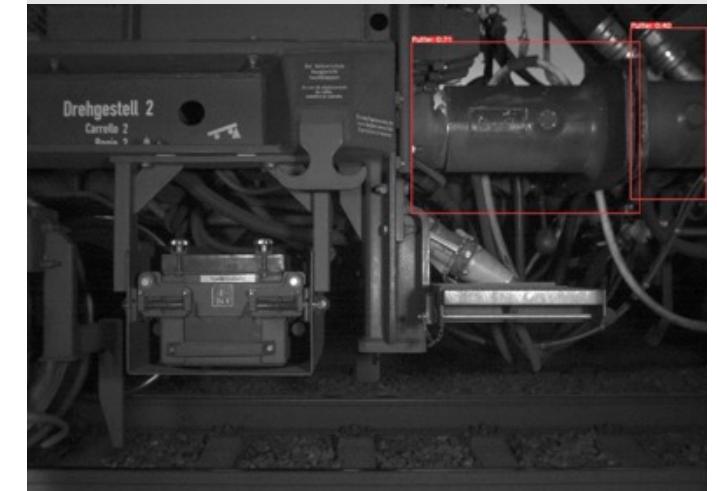
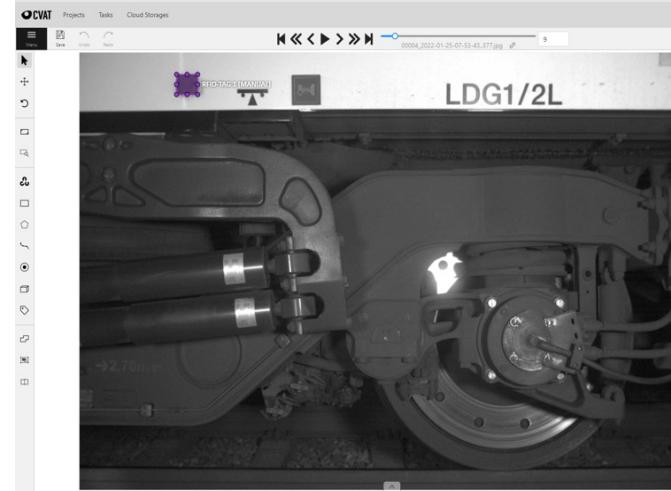


Manual **inspection of rails for damage** is dangerous, time-consuming and expensive.

Track damage is automatically detected on image material from **measurement and diagnostic runs**.

Greater **safety**, higher **quality** and reduced **effort** for track inspection.

Defect detection on passing trains.

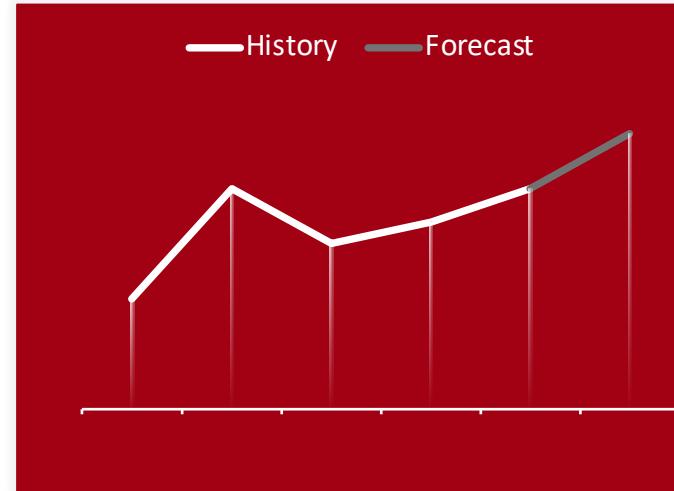


Cameras from Wayside Intelligence automatically **photograph trains** while they are in motion.

A machine learning model is trained with manually annotated images.

Automatic **image/train mapping** and **object recognition** enables condition-based maintenance.

Forecast net working capital.



SBB raises **liquidity** for its operating business on the capital market.

The **liquidity requirement per business unit** is automatically forecast.

This provides SBB Treasury with **decision support** when minimising interest.

Norman.

Natural Language Processing model for the corporate solution.

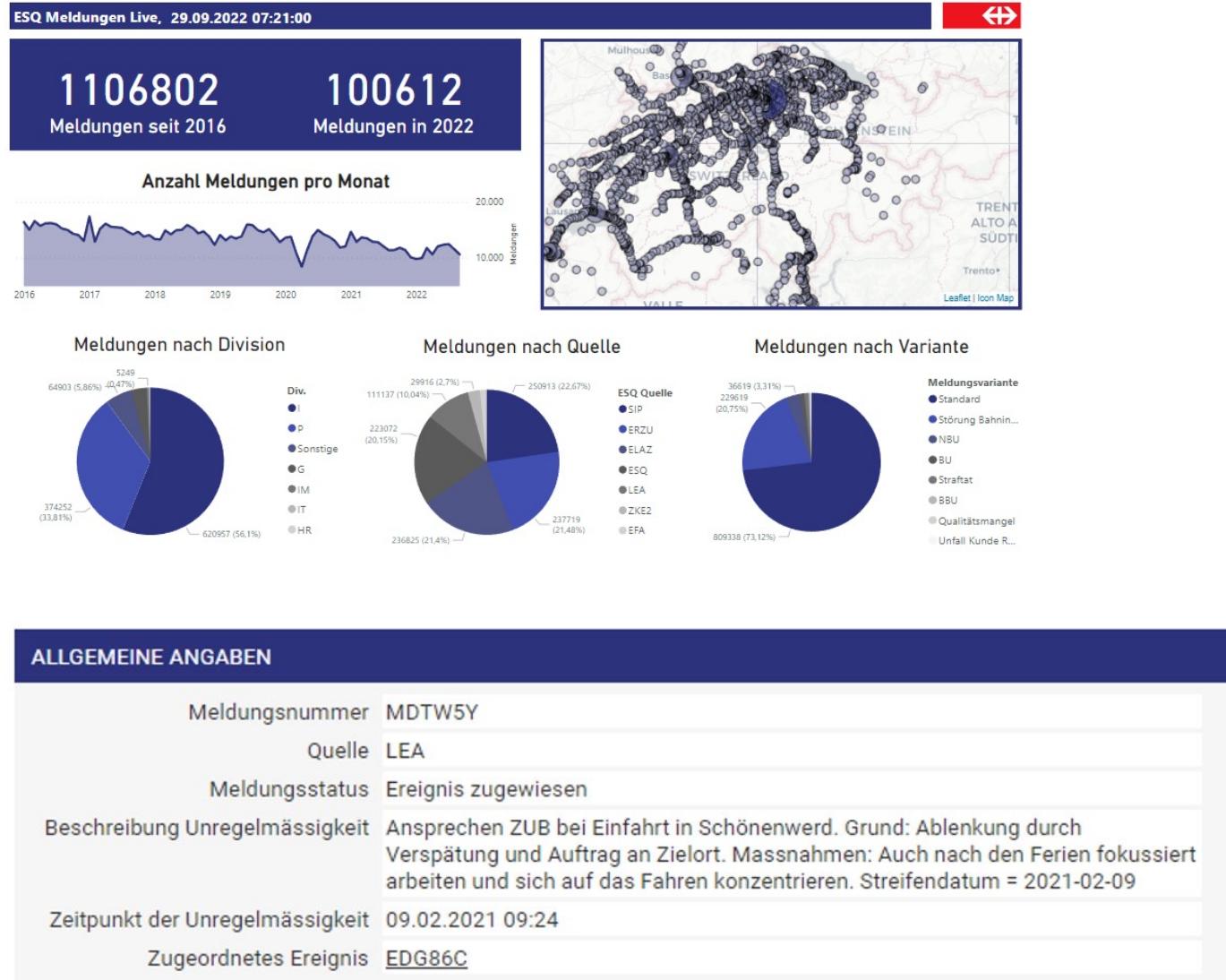
Norman. Challenge.

Challenge

Data

Solution

Results



Incidents safety and quality

Hundreds of safety and quality-relevant messages, called **ESQ messages**, are recorded every day.

These messages are processed manually by a team of experts:

- **Grouping** of messages for the same event
- Assignment of messages to **categories**

This manual work costs a lot of **experts' time**, carries the risk of **inconsistencies** and has the **potential for errors**.

Norman. Data sources.

Challenge

Data

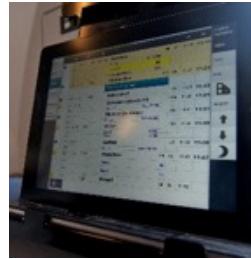
Solution

Results



ESQ

Incidents Safety and Quality



ALEA

Locomotive driver messages



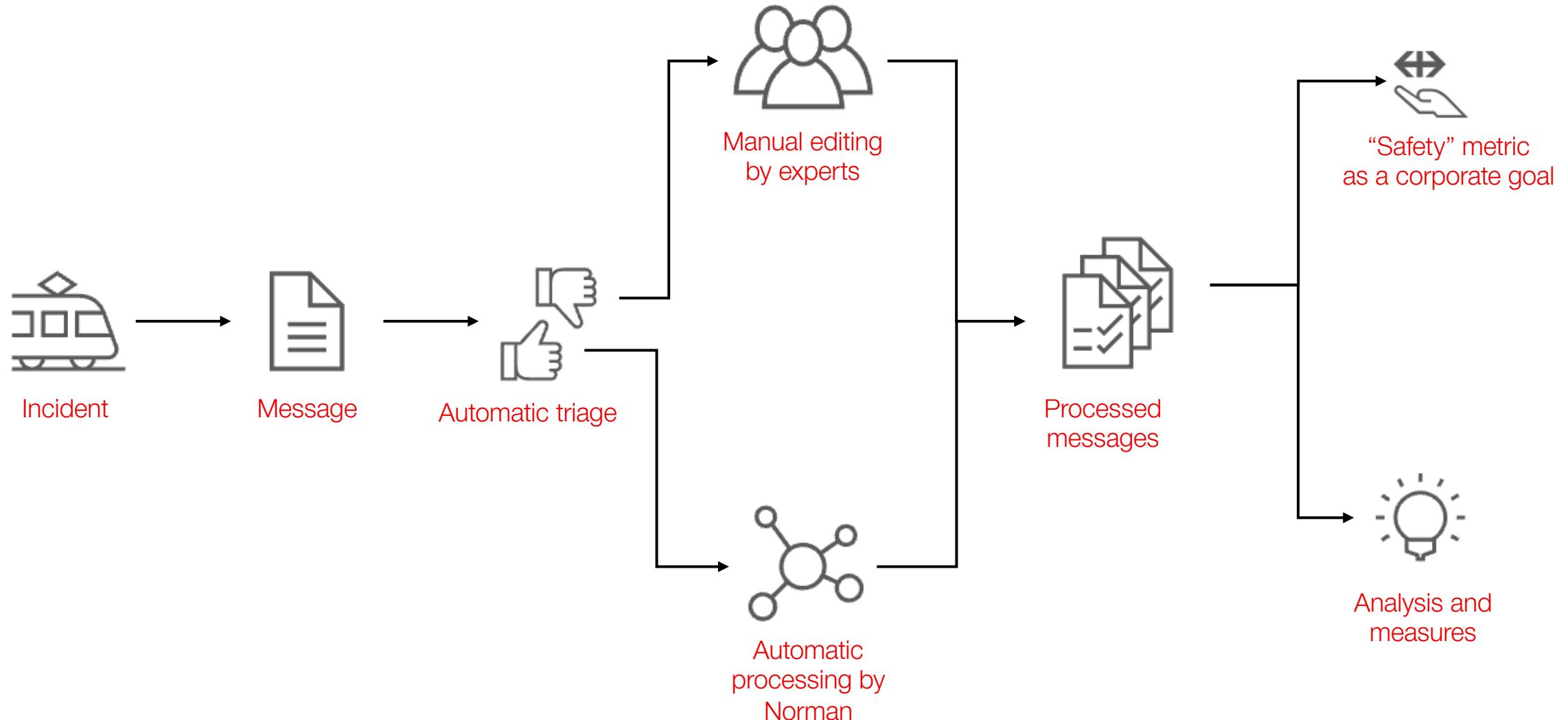
ELAZ

Messages from customer escorts

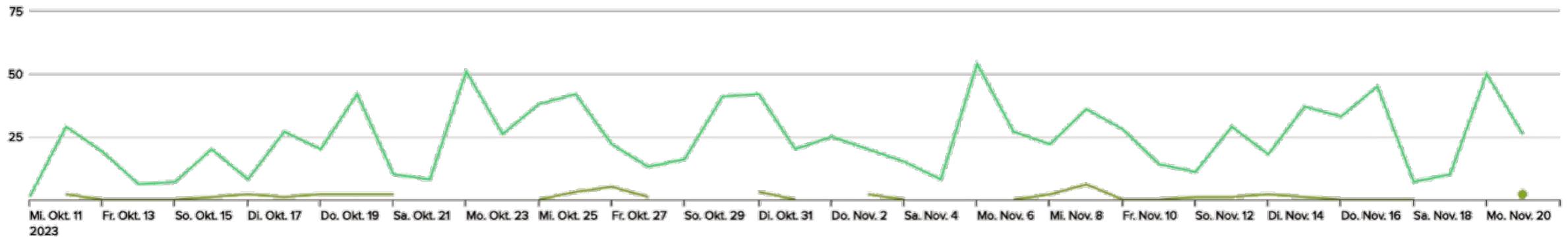


SIP

Infrastructure messages



valid_predictions per index per day



Fully operationalised

Norman has been in productive use since December 2021. The graph shows the number of messages processed per day.

Model Architecture

Distilbert Multilingual model
Multi-label classification

Model quality

Norman can handle 53% of the messages from LEA (train driver) and ELAZ (customer attendant).

Of these 53%, 98% are processed correctly
- in three national languages!



Wheelset forecast.

Predictive maintenance model for the rolling stock solution.

Wheelset forecast.



Wheelset reprofiling

Wheels must be reprofiled regularly. This includes a **grinding of the tread** in a reprofiling centre.

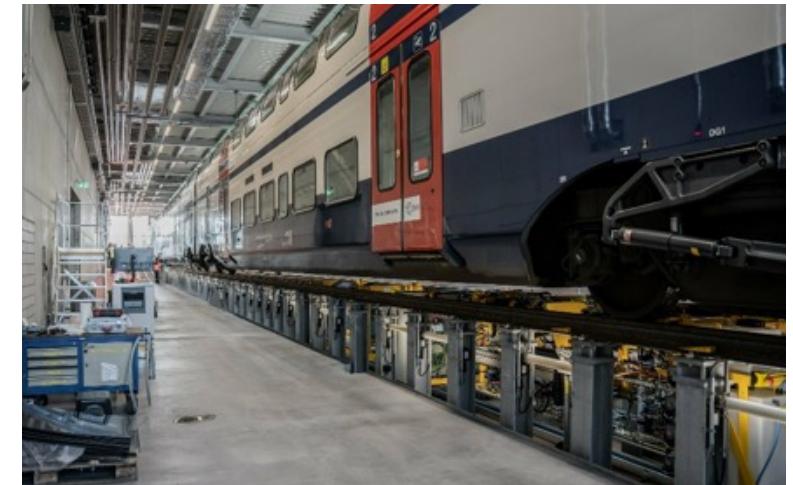
After some reprofiling, the wheelset needs to be replaced.



Wheel load checkpoints

Wheel load checkpoints measure the **out-of-roundness of wheels** as they pass over.

If too much out-of-roundness is measured, **reprofiling** must be carried out **immediately** to prevent damage to rolling stock and infrastructure.



Maintenance coordination

The **limited capacity of the service facilities** makes the coordination of reprofiling challenging.

Unscheduled reprofiling leads to **disruption and loss of efficiency** in maintenance coordination.

Predictive maintenance for wheelsets

Can unscheduled rolling stock withdrawals from service be prevented by an **automatic early warning system for tread defects?**

Data sources.



C2M data
SAP

Reports from maintenance

- When was which wheel ground?
- When was which wheelset replaced?



Wayside Intelligence
WIN API from ZKE

Wheel load checkpoints

- When and where did the measurement take place?
- How out of round is a wheel (dynamic coefficient)?

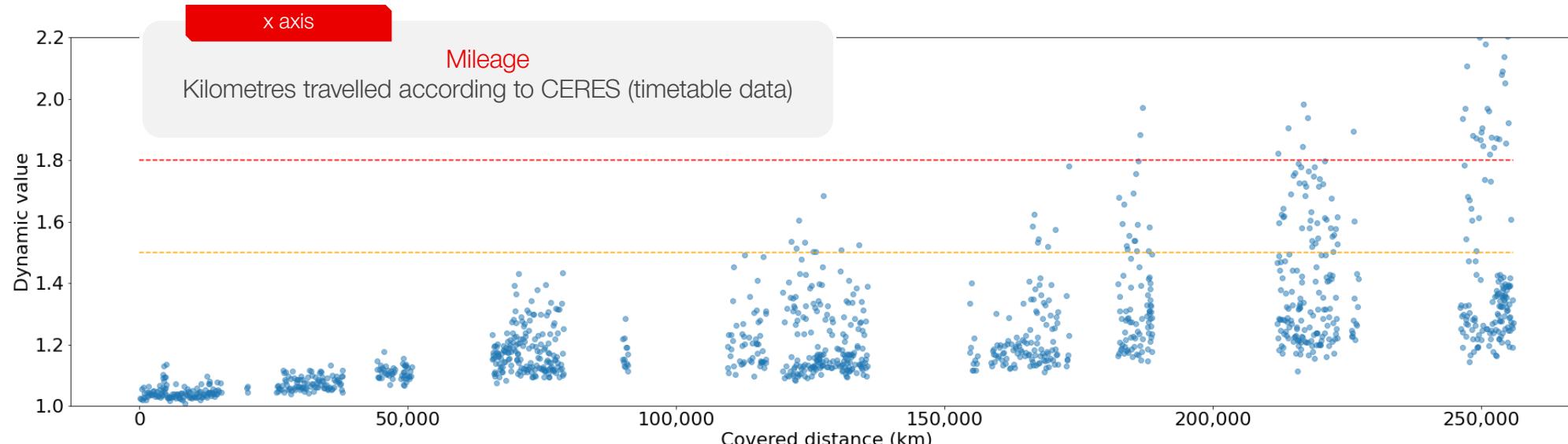
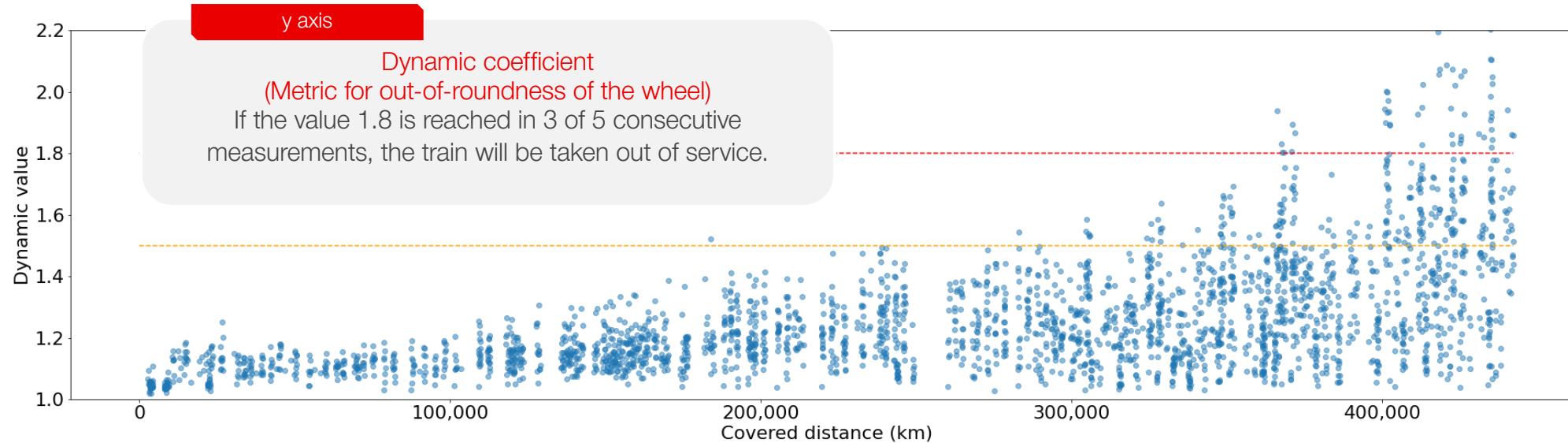


CERES
EAP (DSO BPS)

Timetable

- How many kilometres of driving are there between two measurements on a wheel load checkpoint?

Time series data.



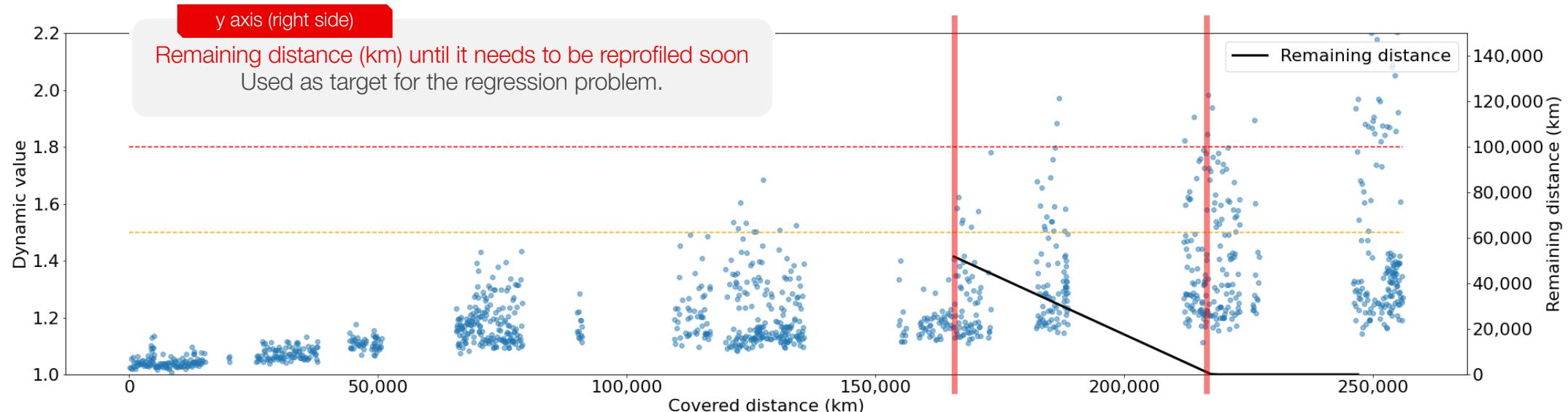
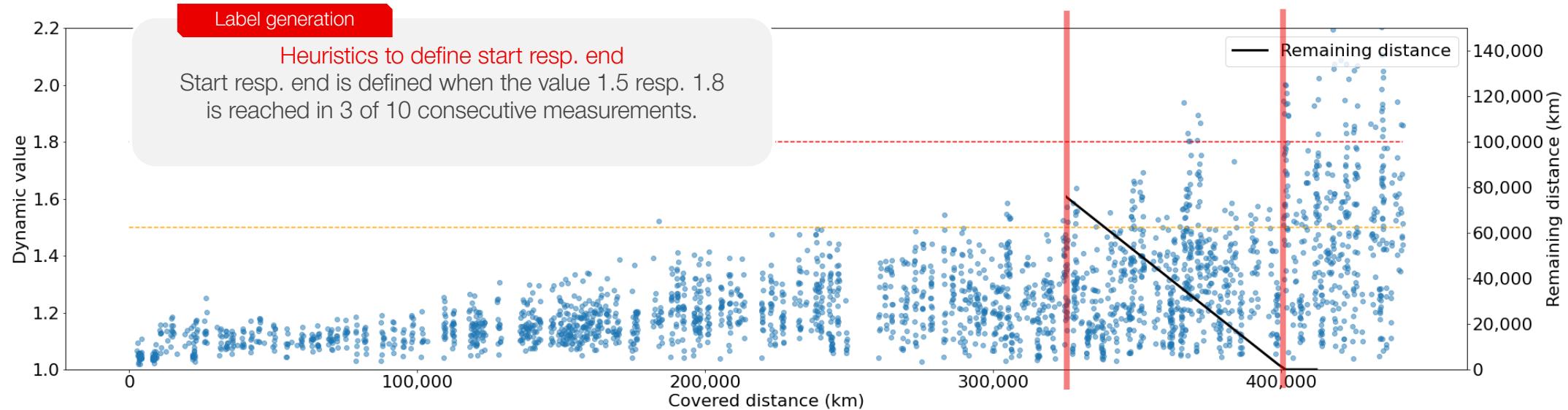
Wheelset forecast. Challenge.

Data

Challenge

Solution

Results



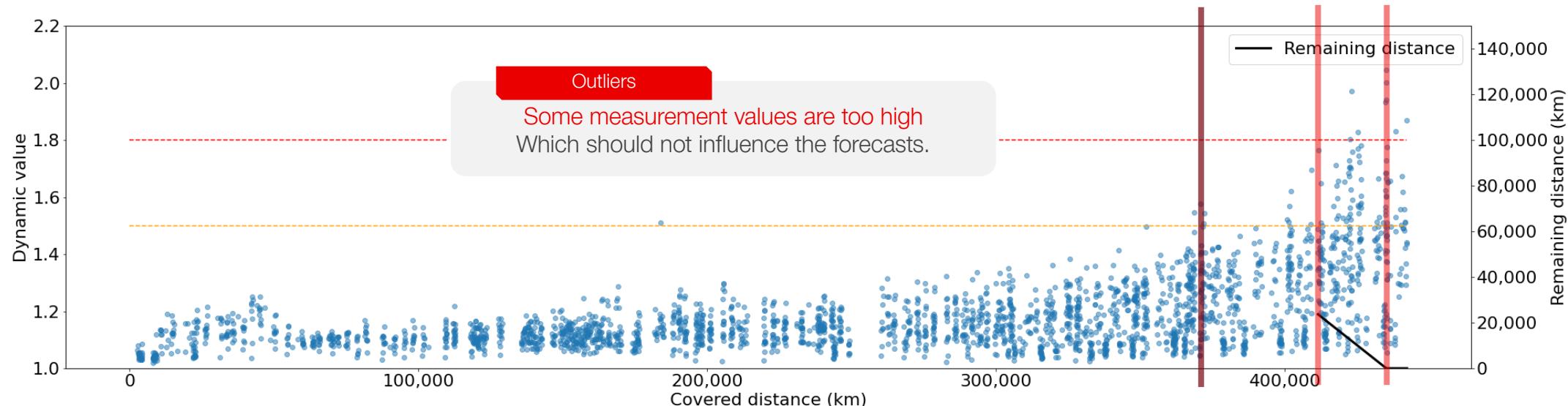
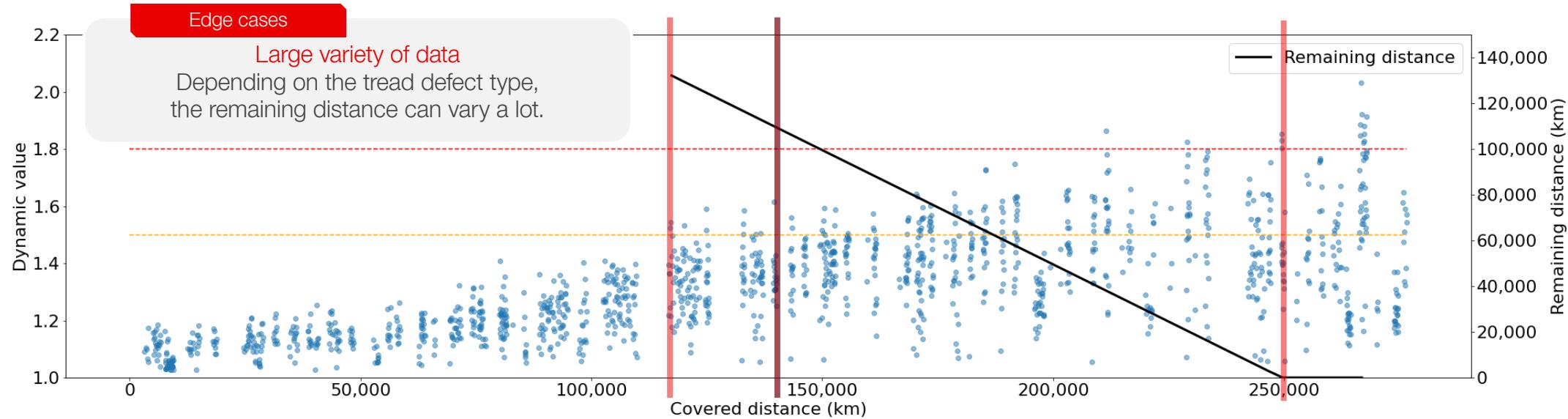
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Challenge

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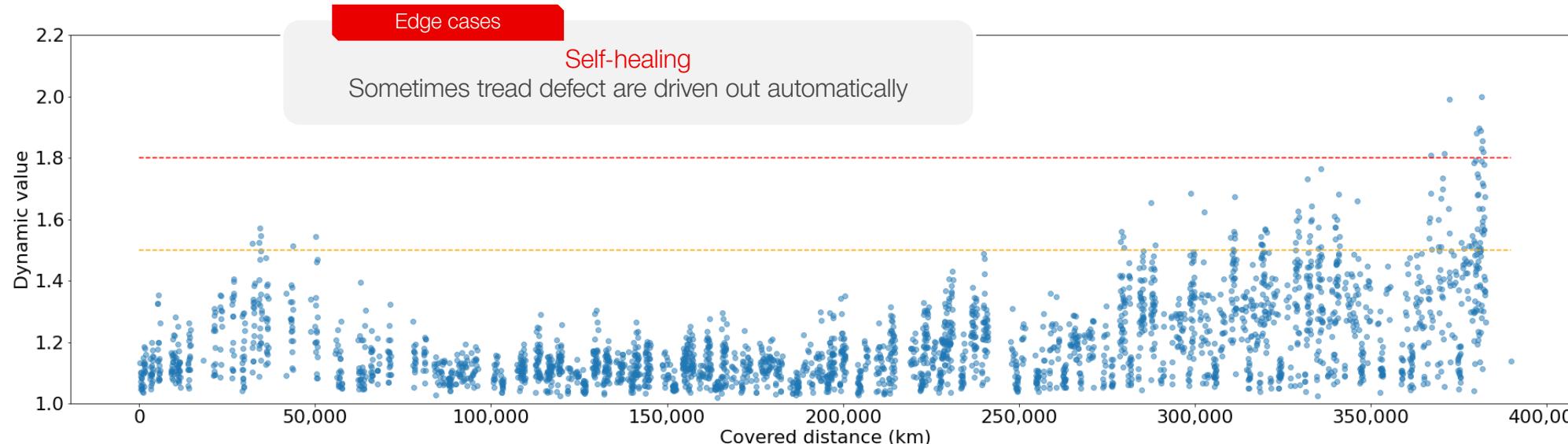
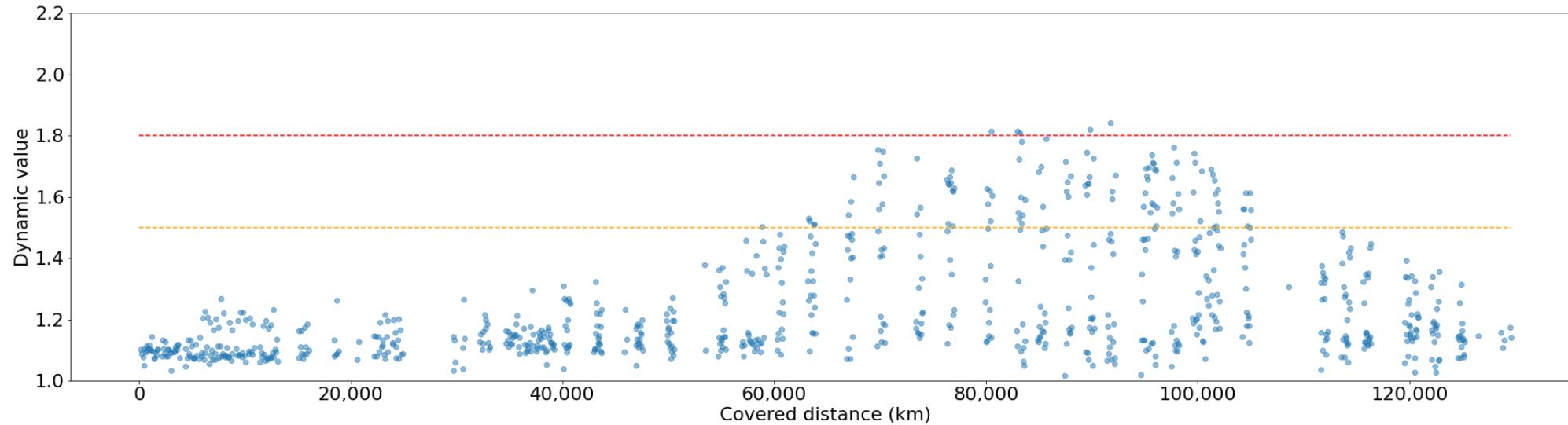
Wheelset forecast. Challenge.

Data

Challenge

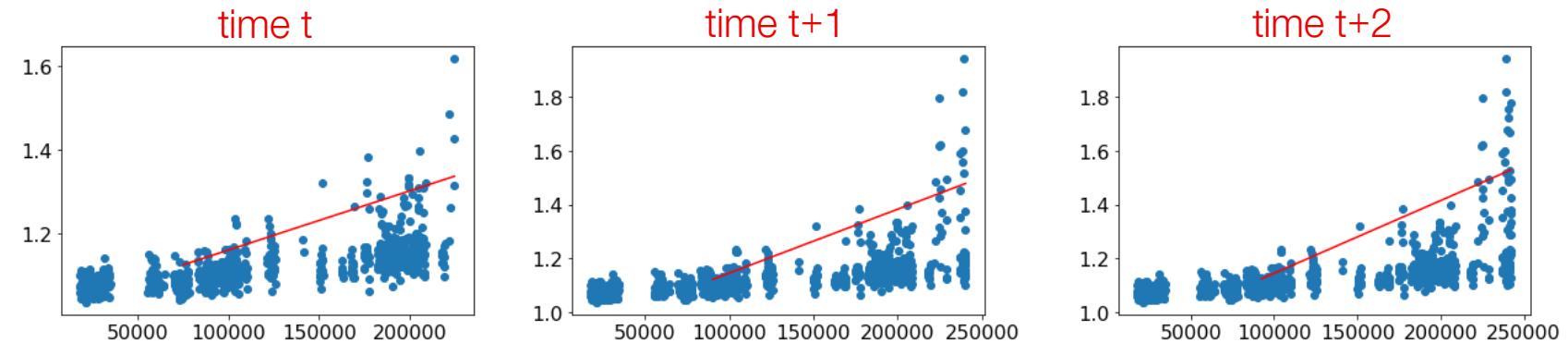
Solution

Results



Feature extraction

Fitting a quantile regression
using the **quantile 95%** with
the values of the **past 150,000 km**



Last value as feature

1.34

1.48

1.53

Modeling



- Using different quantiles and window sizes for feature extraction
- Stratified grouped k-fold cross validation
 - Stratified by the target (remaining distance)
 - Grouped by train (wheels of a train have similar dynamic value patterns)
- Important LightGBM parameter was to set decreasing monotonic constraints on all features

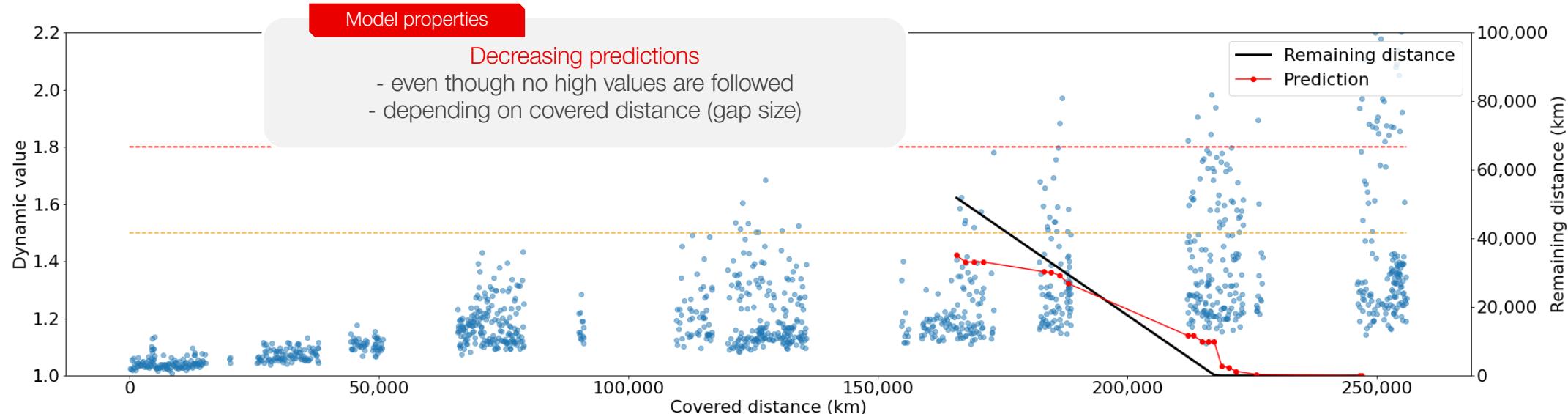
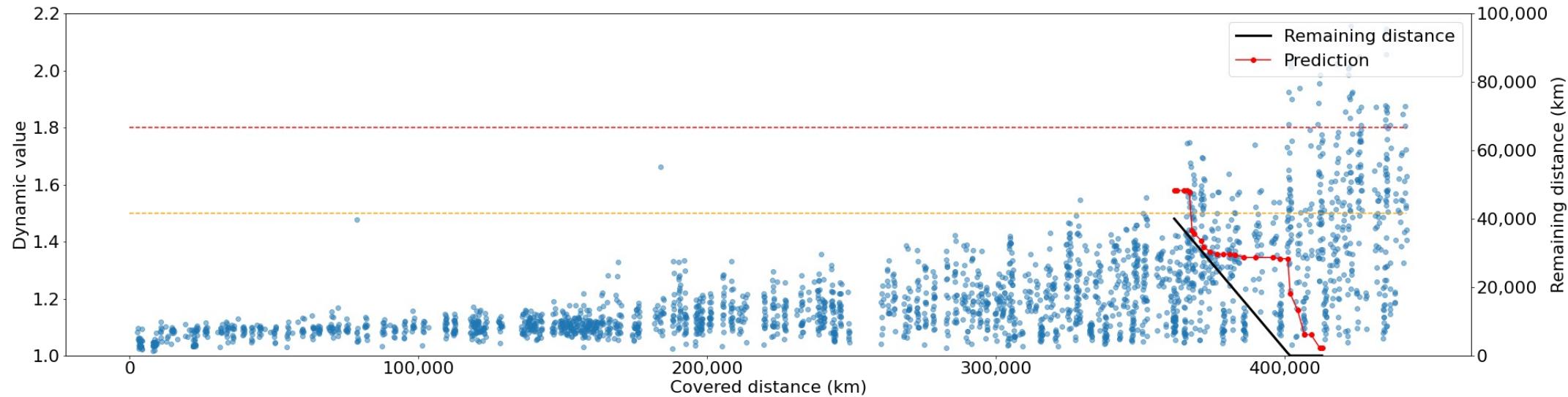
Wheelset forecast. Results.

Data

Challenge

Solution

Results





94 85 0514024-4 (RABe 514 (DTZ) / At1 514)

Sicht R0 andere Instandhaltung

R0 Planung

1 ausgewählt x |

R0 Planen

Drehgestellpos.

TDG1	TDG2
1 2	3 4

LDG1	LDG2
1 2	3 4

LRS1	LRS2	LRG2	LRS1
-	-	-	-

LDG2	LDG1
4 3	2 1

TRG1	TRG2
TRG2	TRG1

TDG2	TDG1
4 3	2 1

TRG1	TRG2
TRG2	TRG1

Radsatzpos.

TRG1	TRG2
TRG2	TRG1

TRG1	TRG2
TRG2	TRG1

TRG1	TRG2
TRG2	TRG1

Fähigkeit R0

-	-
-	-

-	-
-	-

-	-
-	-

-	-
-	-

Prognose R0

20. Mai 22	25. Feb. 23
24. März 22	17. Nov. 22

19. März 24	2. März 24
25. Juli 22	13. Mai 24

Reстауr km R0

10'188	144'201
41'750	89'263

367'528	348'301
25'840	388'006

Drucken, (mehr)

913	912	920	920
864	874	870	878

880	878	909	909
905	905	922	922

R0/R5

R0	R0
126'789	126'789

R0	R0
596'451	596'451

R0	R0
-	-

R0	R0
-	-

T913/14 (km)

213'925	213'925
596'451	596'451

T911/12 (km)

387'889	387'889
596'451	596'451

T910 (km)

-	-
-	-

T920 (km)

-	-
-	-

Masse&Spur

-	-
-	-

Bandagen (1)

false	false
false	false

false	false
false	false

false	false
false	false

false	false
false	false

Details

S1-R0 Meldungen

✉ 2021-12-08
RS aufgrund calipri Messung

Integration in vehicle calendar

The forecasts are displayed in the maintenance coordination application and serve as **decision support**.

Model quality

Thanks to the forecasts it possible to rate and compare wheel conditions which is needed for prioritization.





MLOps @ SBB.

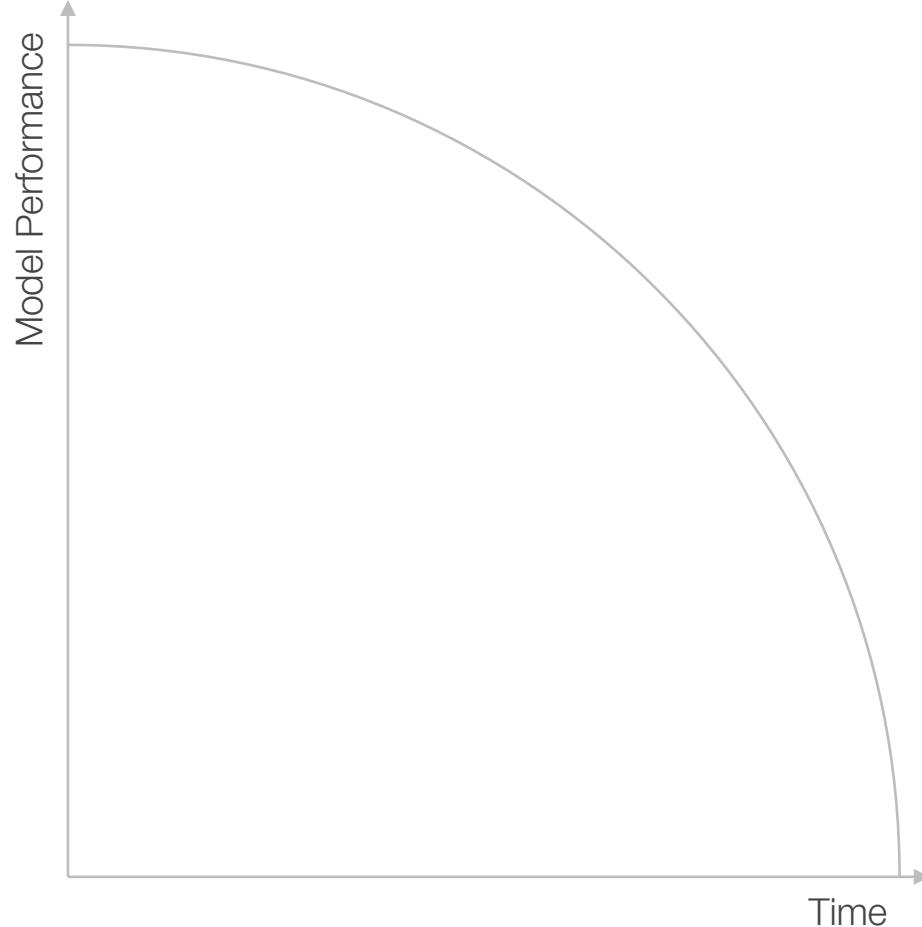
Operationalizing of Machine Learning Products.

Why MLOps?

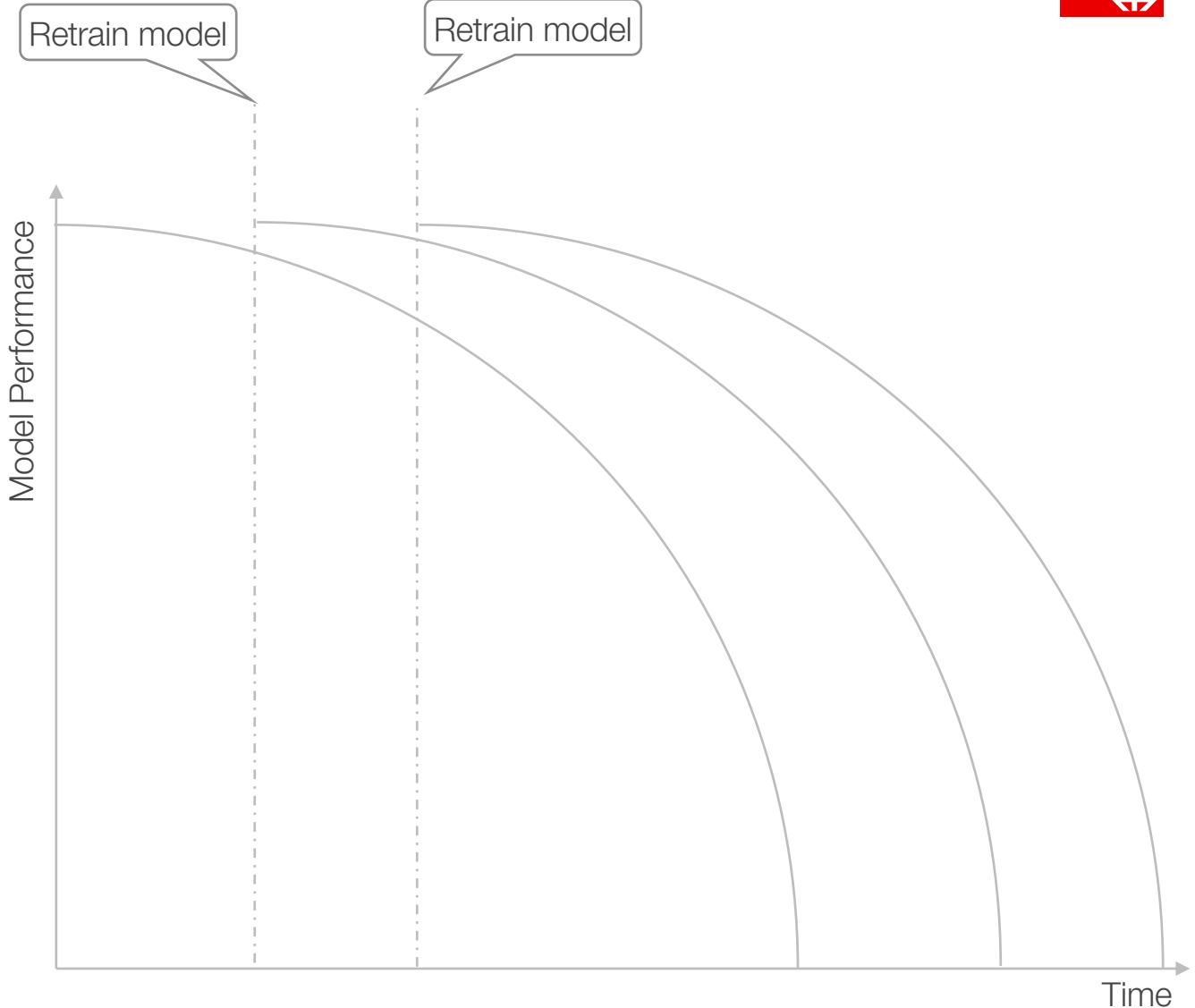
Persona	Wants	Frustrations	Needs
Data Scientist	Develop features and models	Putting my models into production is hard	Easy and fast way of bringing my models to production
Machine Learning Engineer	Put model into production	Rewriting research code for production is hard	Best practices for MLOps adhered to during exploration
Business Owner	Monitor model in production	Understanding what is going on in a machine learning system is hard	Simple tracking of data quality, data drift and model drift

Model drift.

Why models in production are hard.

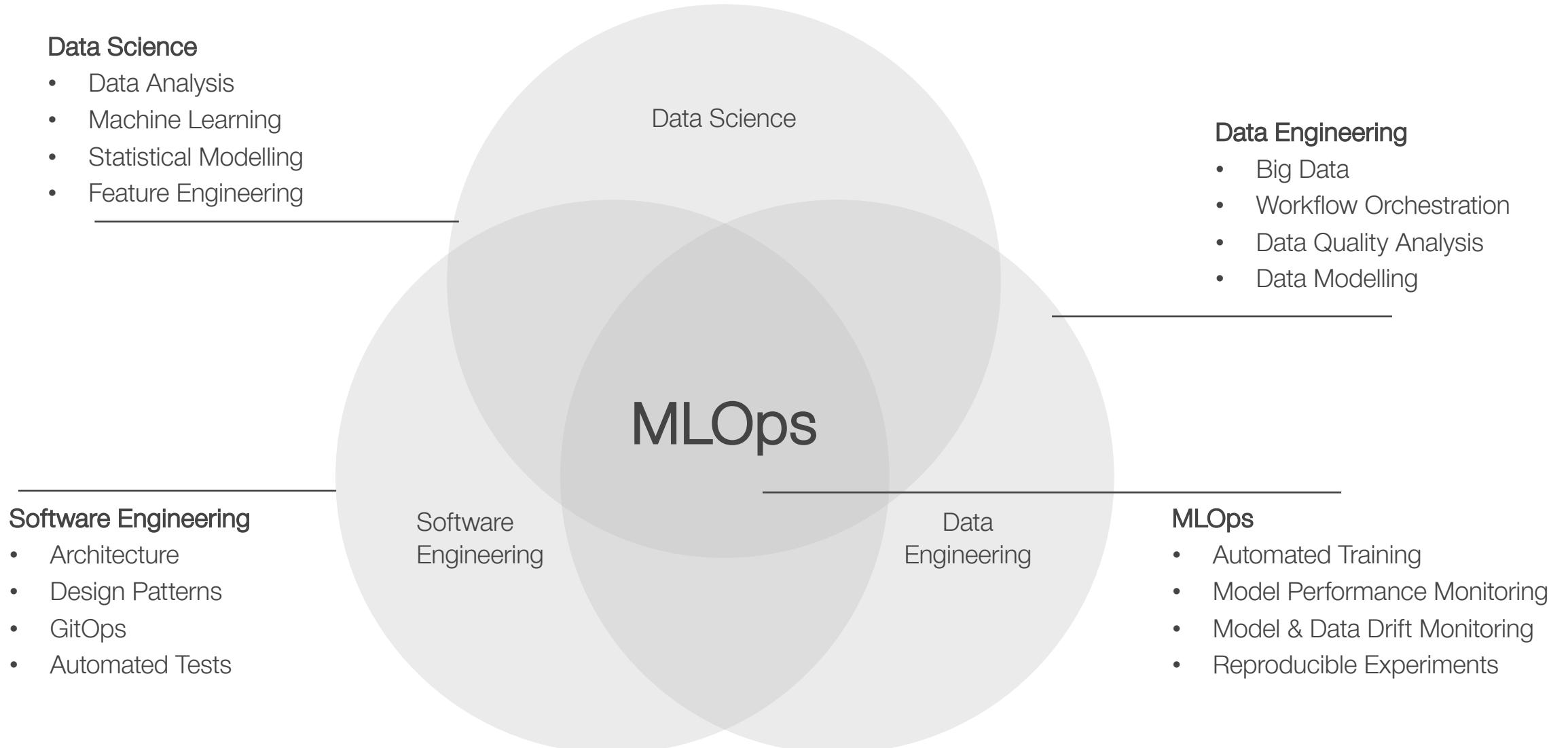


As the **modelled phenomenon changes**,
a model becomes less performant.

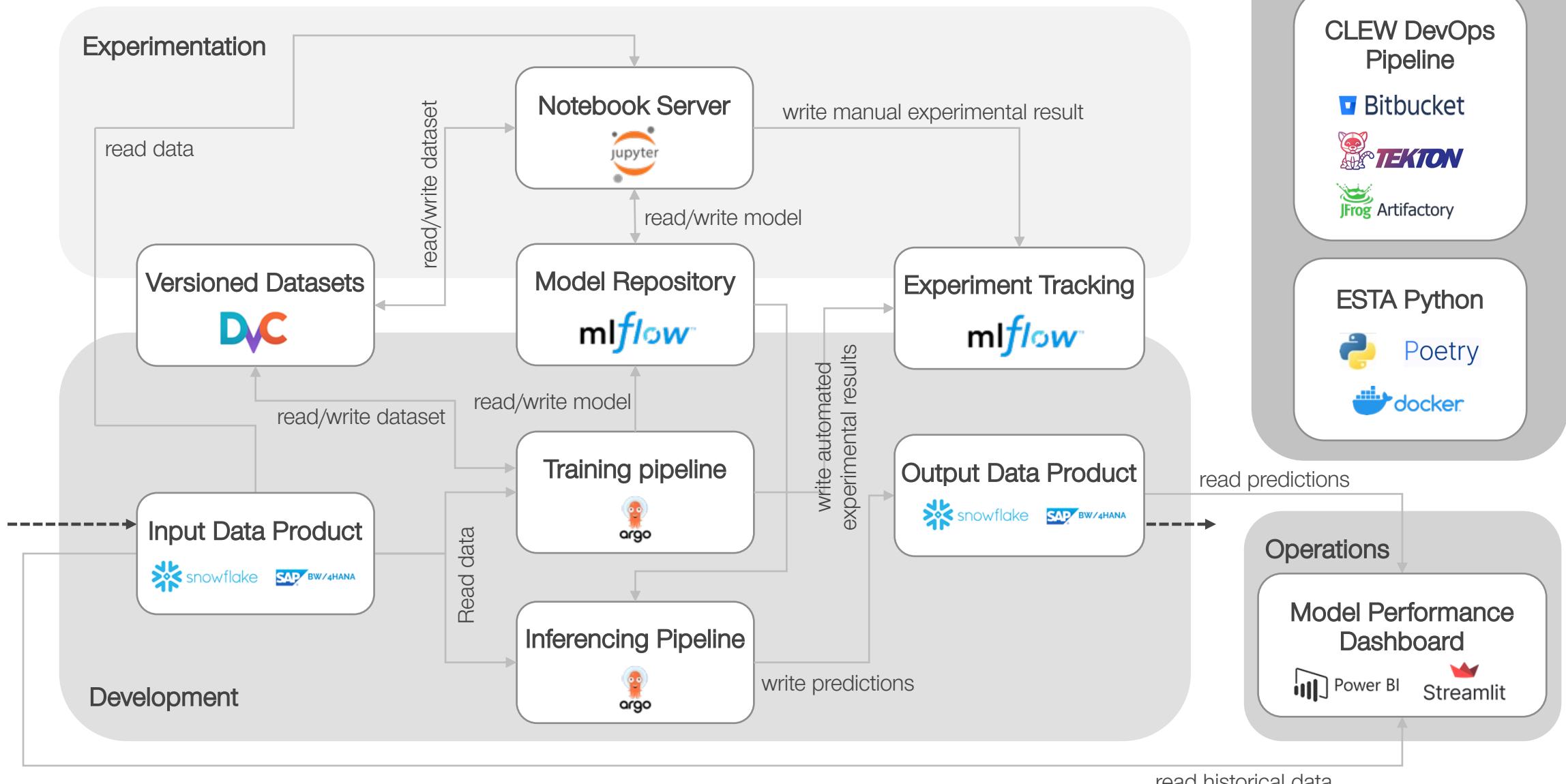


Periodic and automatic retraining **adapts the model to the current state of the phenomenon**, ensuring lasting performance.

MLOps: Models in production.



An overview of MLOps on EAP.



DevOps tooling.

WSL2

The **Windows Subsystem for Linux** runs a Linux Kernel in Windows and enables work in a Linux shell on a regular SBB Windows laptop.

Docker

Docker enables bundling programs and all their dependencies into containers that can be run on our container runtime.

VSCode

Visual Studio Code is an integrated development environment. With the **Remote Development Extension Pack** you can work with a Windows UI and WSL2 Linux.

pyenv

The Python version management tool **pyenv** enables multiple Python environments with different Python versions and dependencies installed in parallel.

Poetry

The Python dependency management tool **Poetry** enables repeatable installs by using lock files and enables semver-compliant version pinning.

pylint

Static code analysis for Python enables catching potential errors without running the code.

black

Automatic code formatting with **black** ensures all code is formatted the same.

pre-commit

The Python library **pre-commit** enables forcing code quality checks, unit tests and formatters to run automatically before each git commit. This ensures code quality.

OmegaConf

OmegaConf is a tool for managing configuration within Python programs.

click

Easily creating command line interfaces with Python is the goal of **click**. Argo Workflow steps are started as click commands.



Thank you, danke,
merci
& grazie.

Questions / Discussion.