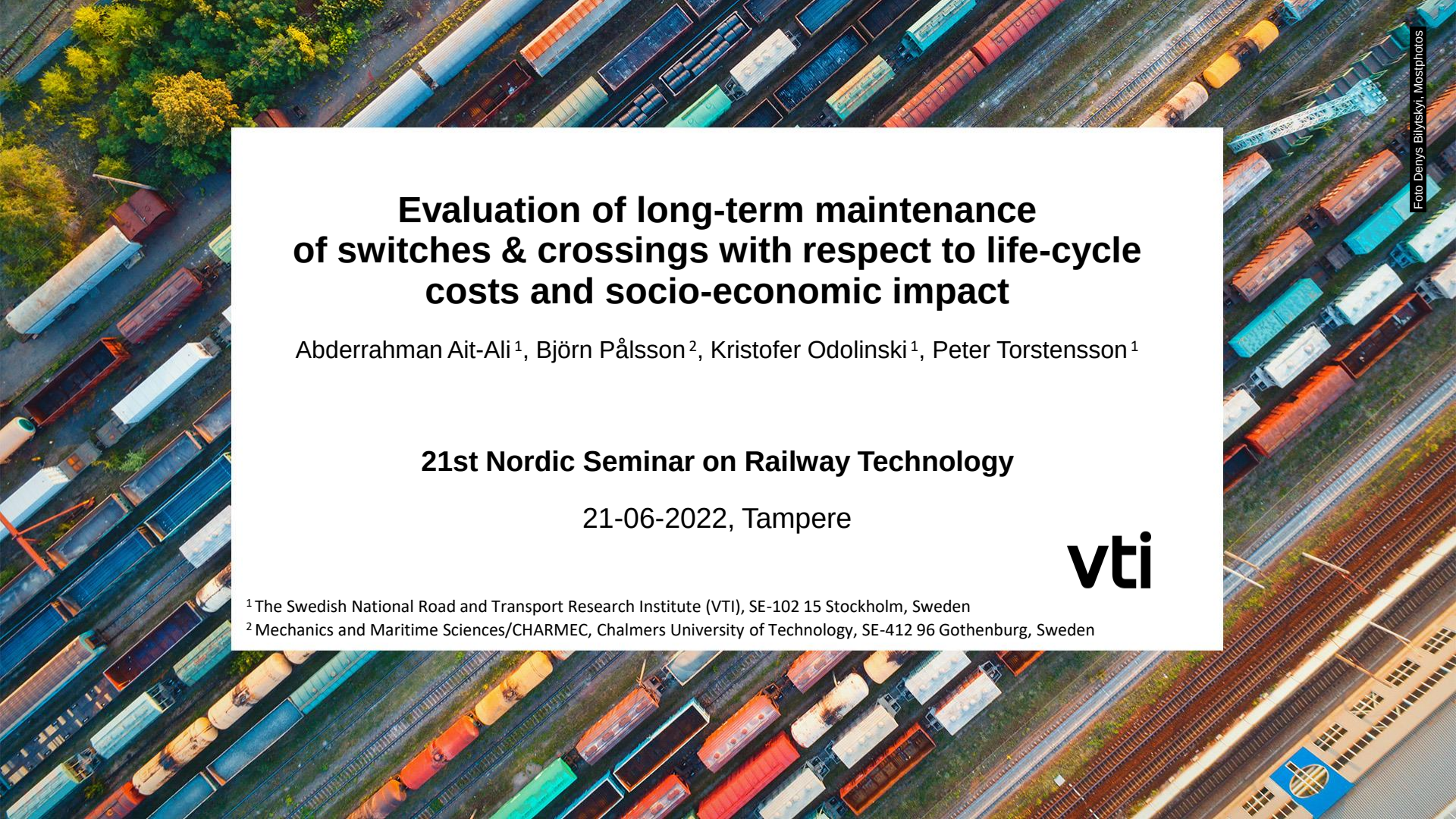

Evaluation of long-term maintenance of switches & crossings with respect to life-cycle costs and socio-economic impact

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21st Nordic Seminar on Railway Technology

21-06-2022, Tampere

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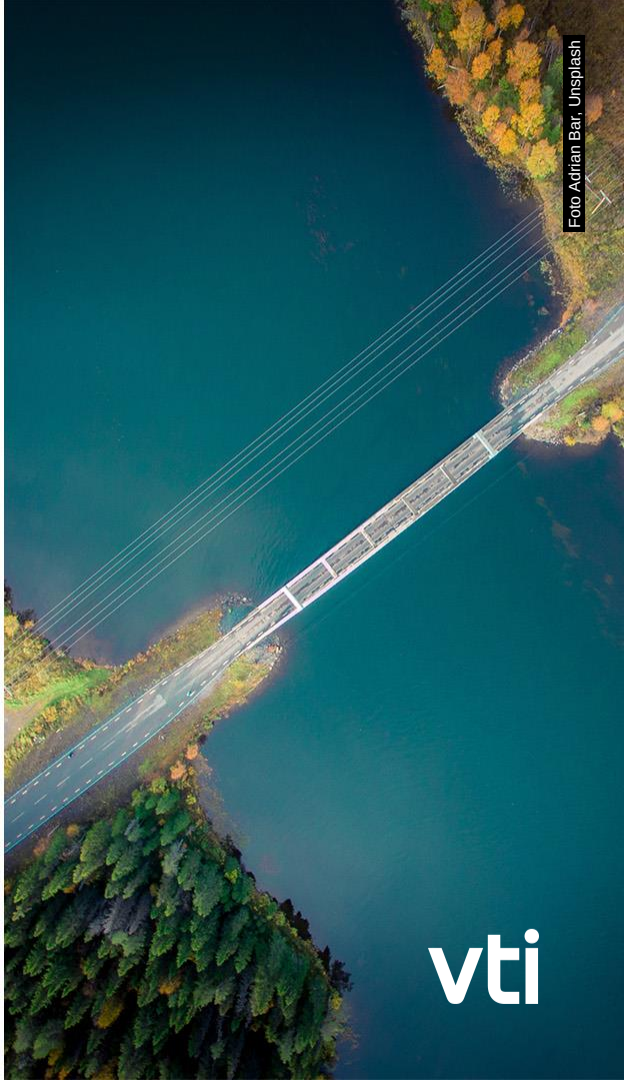
OUTLINE

1. Background
2. Focus & Aim
3. Methodology
4. Preliminary analysis
5. Conclusions



1. BACKGROUND

- **Maintenance of switches and crossings (S&Cs)** is a (necessary) requirement for good quality freight and passenger train services
- An **efficient** maintenance of S&Cs **minimizes the (socio-economic) costs** over the life cycle of the asset, i.e., LCCs
- LCCs are affected by
  - Train **traffic** (type of traffic, traffic volume, etc.)
  - Design of the **infrastructure** (type of switch, components, etc.)
  - **Maintenance** strategy
    - **What** measures (e.g., grinding, track direction) have been performed?
    - **When/How often** were the measures performed?

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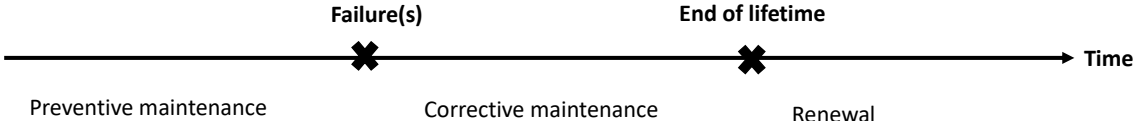
2. FOCUS & AIM

- The project focuses on **standard turnout S&Cs** and aims to analyze dependencies between
  - **Maintenance** strategies (with a focus on **rail grinding** and **track alignment**)
  - Expected **socio-economic effects** over the life cycle

Standard turnout



- The goal is to
  - Calculate LCCs of different **maintenance strategies (preventive/corrective)**
  - Find **more efficient** maintenance strategies for S&Cs

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2. METHODOLOGY

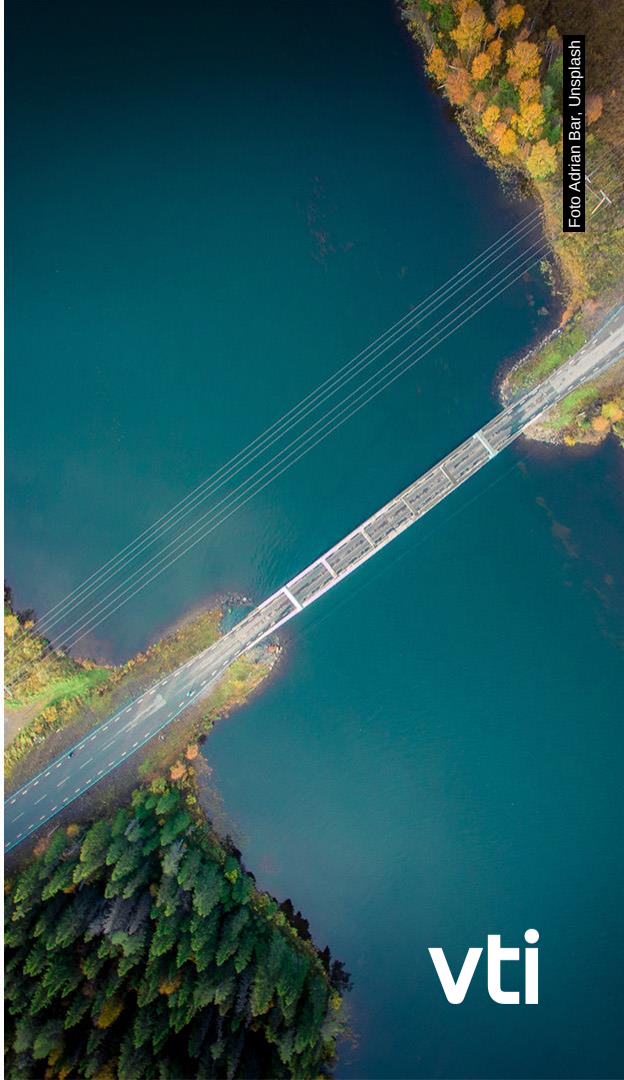
a) Overview

b) Mechanical simulation

c) LCC modeling

d) Maintenance strategies

e) Preventive & corrective measures



a) OVERVIEW

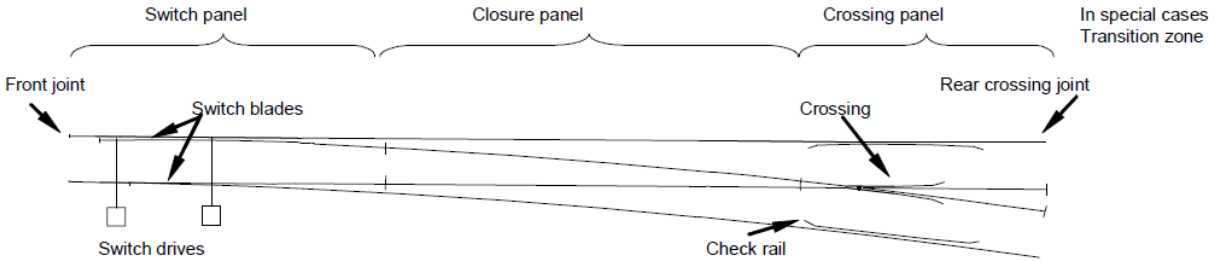
- The methodology is based on two main components:

  - **Component 1:** Simulation of the damage evolution in S&C for different maintenance strategies to investigate the relationship between maintenance status and damage development at S&C

  - **Component 2:** LCC modeling to calculate the socio-economic costs of a particular maintenance strategy over the S&C life cycle

b) MECHANICAL SIMULATION

- The dynamic vehicle-S&C **interaction** and resulting mechanical **damage** over time in S&C is investigated by means of **simulation**



- The goal is to investigate the relationship between:
  - the **maintenance** measures, i.e., track tamping & rail grinding

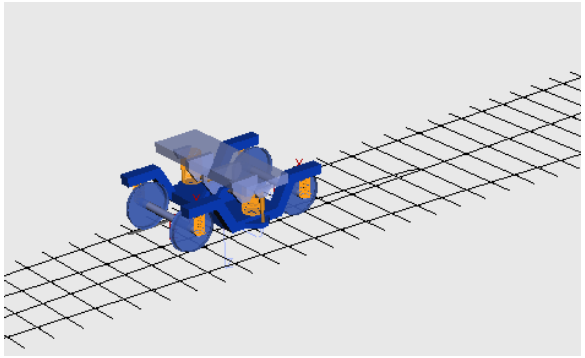
  &

  - the development of mechanical **damage**, i.e., in the form of track irregularity (misalignment) and contact geometry degradation

b) MECHANICAL SIMULATION

- Simulation of accumulated S&C damage using iterative Whole System Model scheme
- The simulations will be performed for different maintenance interventions to compare long-term performance

Dynamic vehicle-track interaction

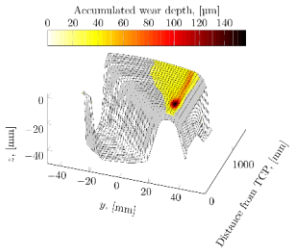


Simulation output

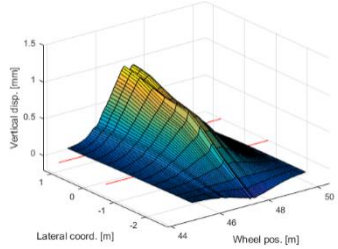
Updated damage state

Damage modelling

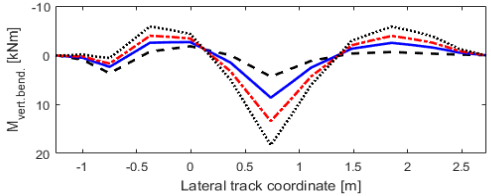
Running surface



Ballast settlement



Sleeper & crossing bending loads (fatigue risk)



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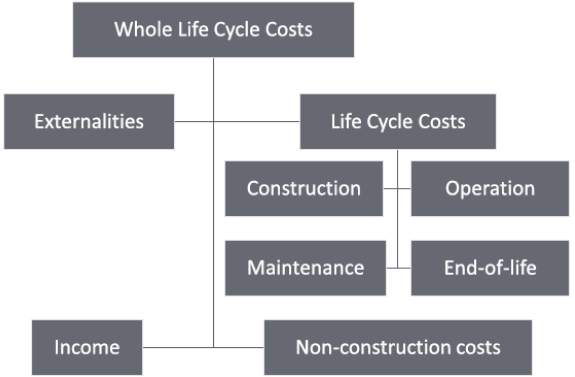
c) LCC MODELING

- LCCs cover different **phases** and **costs/benefits**, e.g.,
  - Maintenance, replacement and operations, etc.
  - Costs (labor, traffic loss, etc.) or benefits (increased traffic reliability, etc.)
- A model of the **total LCCs** (noted $TSEC$) is

$$TSEC = CML + LTP - GTP$$



Phase of the life cycle	Socio-economic costs (-) and benefits (+)	Notation
Maintenance (or replacement)	(-) Costs of material and labour	CML
	(-) Loss in potential traffic production	LTP
Operations	(+) Gain in future traffic production (quality)	GTP

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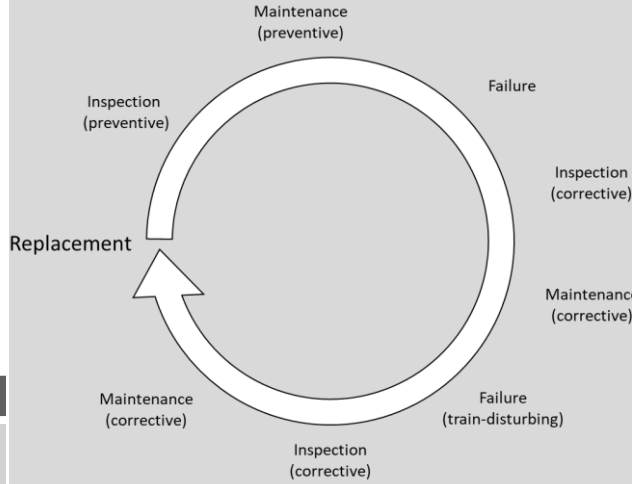
d) MAINTENANCE STRATEGIES

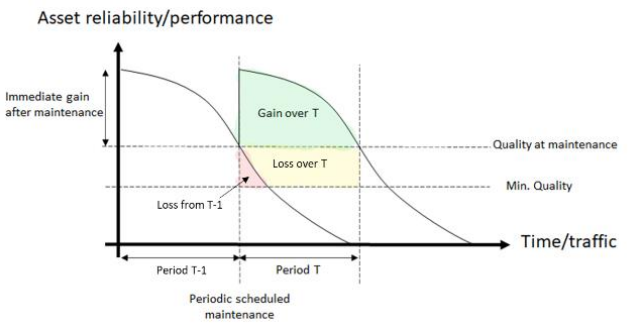
- The impact of maintenance and operations on LCCs are closely dependent on the adopted **maintenance strategy**
- Different strategies (preventive/corrective) have different **characteristics** (requirements & consequences)

Characteristic	Preventive (proactive)	Corrective (reactive)
Knowledge	Requires more knowledge about the assets (e.g., frequent inspections)	No knowledge is required
Traffic	Pre-planned and less expensive losses of traffic (e.g., maintenance windows)	Unplanned and more expensive losses of traffic (e.g., delay, accidents)
Work	Shorter and less expensive maintenance work (labour and material)	Longer and more expensive maintenance work (unplanned, time pressure, etc.)



e) PREVENTIVE & CORRECTIVE

- To model (among others) the relation between
  - (Performed) **preventive** measures
  - (Need for) **corrective** maintenance
- A regression analysis is performed
  - ***Corrective*** represent, e.g., #failures
  - ***Preventive*** represent, e.g., #preventive maintenance measures.
  - $\boldsymbol{X}$ holds selected important variables related to
    - Traffic (volume, type of traffic, axle load, etc.)
    - Infrastructure (type/model of S&Cs, etc.).



$$\boldsymbol{Corrective} = f(\boldsymbol{Preventive}, \boldsymbol{X})$$

3. PRELIMINARY ANALYSIS

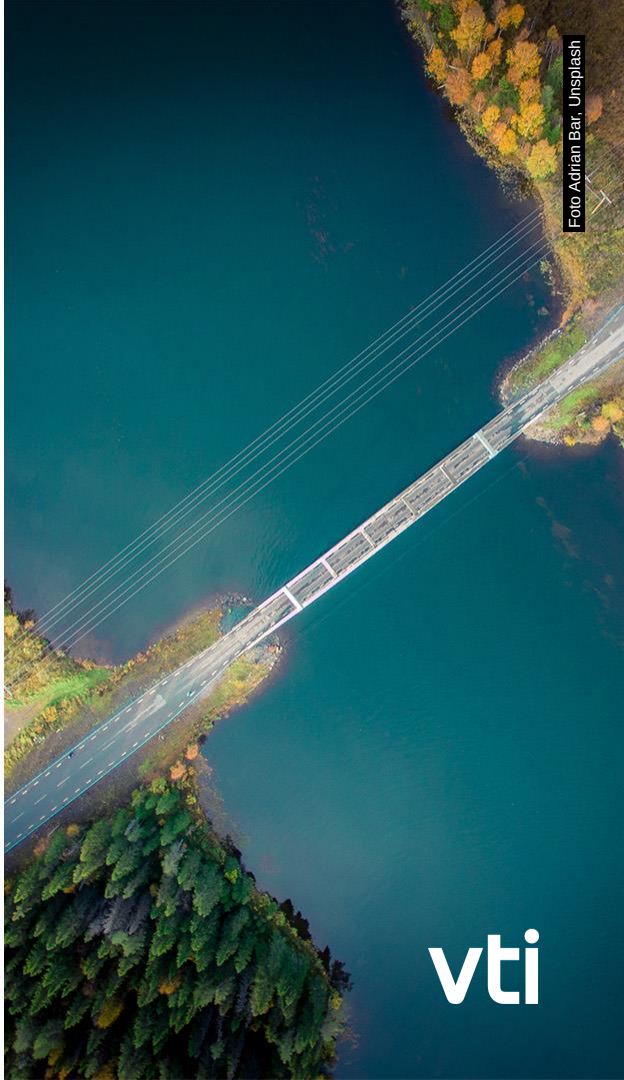
a) Databases

b) Data (& KOMBI)

c) Key S&C

d) Life cycle

e) Case study



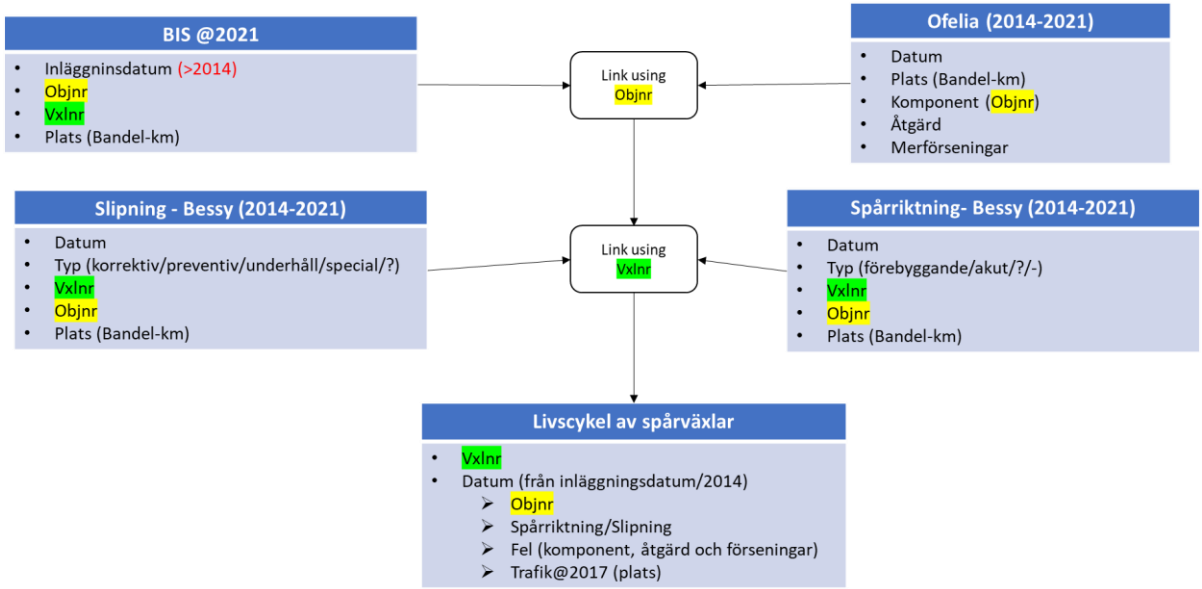
a) DATABASES

- The relevant databases are managed by **Trafikverket**
- Data are available for different assets, here **only related to S&C** are selected

Database	Content	Time (interval)
BIS	Infrastructure	In 2021, also in 2014
Bessy	Inspections	Between 2014 and 2021
Ofelia	Failures/delays	Between 2014 and 2021, also from 2003
Lupp	Train traffic	During 2017

a) DATA (& KOMBI)

Data(bases)	Main content (columns)
Infrastructure 2021 (BIS)	• Replacement date • Object number • S&Cs number and model • Location, track • Maximum allowed speed
Inspections 2014-2021 (Bessy)	• Date • S&Cs number and model • Location • Inspection type • S&Cs Component • Recommended action
Failures 2014-2021 (Ofelia)	• Date • Object number • S&Cs number and model • S&Cs Component • Location • Disturbed trains • Delay • Recommended action
Train traffic 2017 (Lupp)	• Departures & arrivals • Traffic type • Train vehicles • Train load & km



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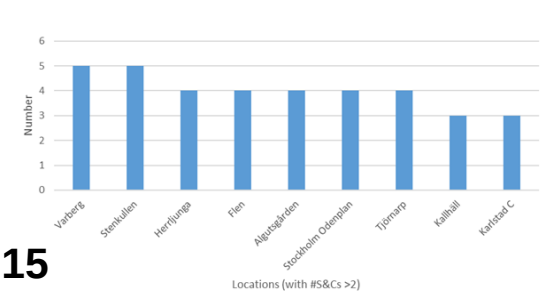
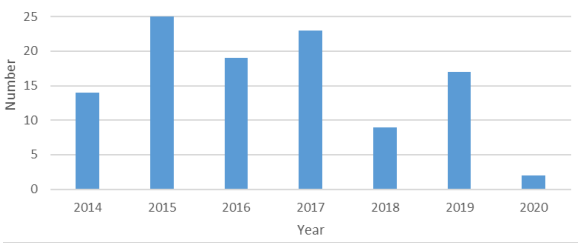
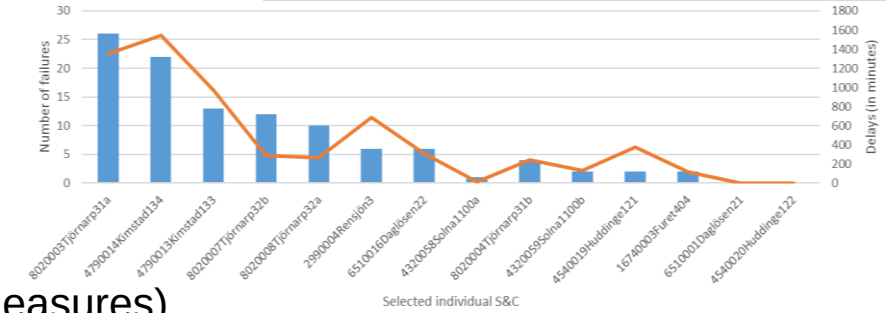
b) KEY S&C

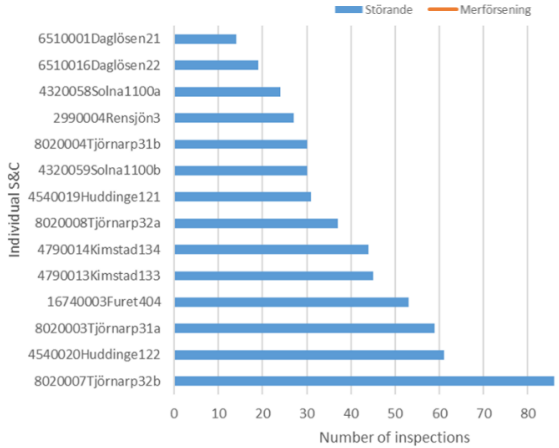
- Focus on model **60E-R760-1:15**
- **Spatiotemporal** distribution of S&Cs
- Focus on S&Cs **replaced in 2014**
- Failures and **delays** statistics
- **#observations** (inspections, maintenance measures)
- Train traffic

➔ Vxlnr 133 in Kimstad

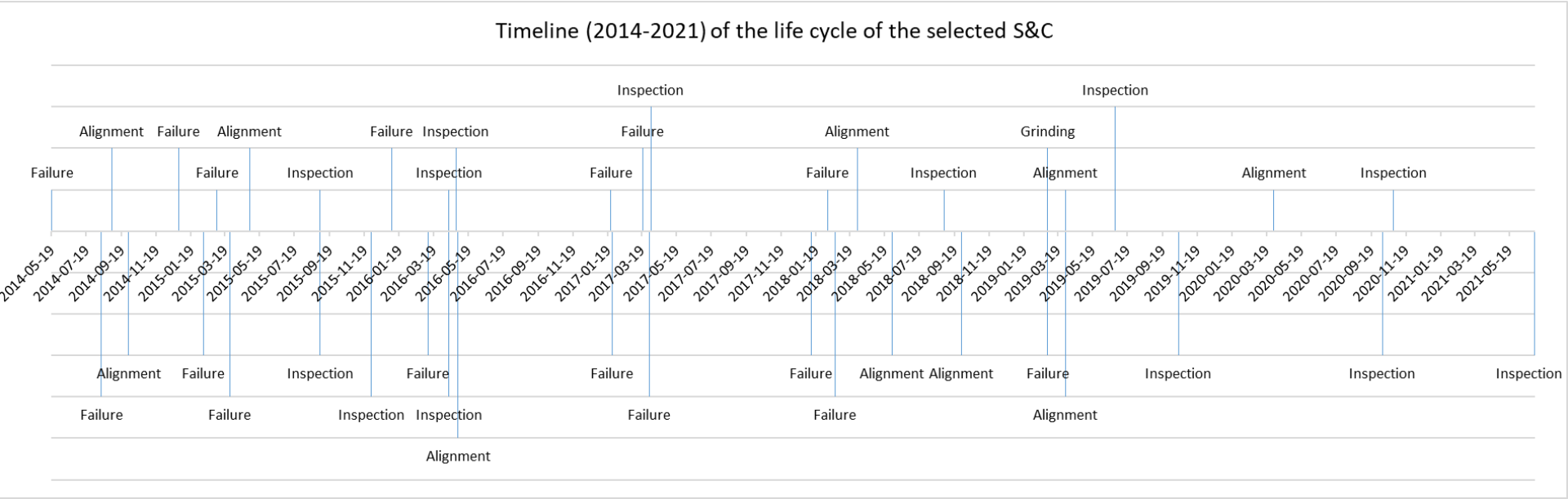








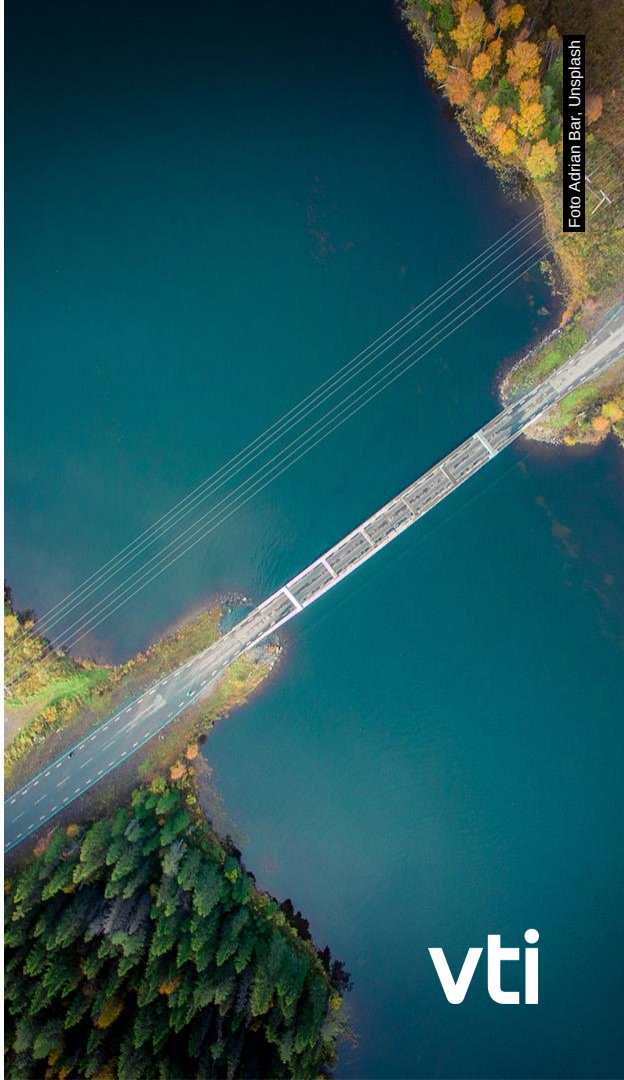
c) LIFE CYCLE (OF THE SELECTED KEY S&C)



4. CONCLUSIONS

a) Highlights

b) Next steps



a) HIGHLIGHTS

- A **methodology** combining different approaches (simulation, regression & LCA) for the evaluation of long-term maintenance of S&Cs
- Consideration of **socio-economic impacts** in the LCCs
- Linking different data sources into a **combined database** for use in similar LCC studies
- Identifying **key S&Cs** with regards to different characteristics (model, #obs, traffic, etc.)
- **Timeline** of selected S&Cs for LCA

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b) NEXT STEPS

- Mechanical **simulations**
  - Degradation of S&Cs
- **Regression** analysis
  - Effect of preventive measures on corrective maintenance
- **LCC model** combining the simulation results and regression output
  - Evaluation of the LCCs including the **socio-economic impacts**
  - Comparison of different **maintenance strategies for S&Cs**

Thank you for your attention!
Question?

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