Integrating Demand Data with Train Delay Models:

Socio-Economic Evaluation for Maintenance Planning

Abderrahman Ait-Ali (Linköping University - LiU & Swedish National Road and Transport Research Institute), Zohreh Ranjbar (Research Institutes of Sweden - RISE) & Martin Joborn (RISE & LiU)

EWGT 2025 | Edinburgh

2025-09-03

LINKÖPINGS UNIVERSITET

Agenda

1. Introduction
2. Literature review
3. Methodology
4. Case study
5. Conclusions

1. Introduction

a) Motivation
b) Research objectives

1.a) Motivation

- Punctuality is a key performance indicator for railways for
  - Customer satisfaction, i.e., passengers and freight transporters
  - Infrastructure management, e.g., maintenance
- Currently used indicators are predominantly train-centric
  - Example: RT + X minutes, i.e., % of trains arriving at the final station within X minutes of the scheduled time
  - However, these metrics overlook real impacts on passengers (and freight transporters), especially on congested time intervals and track sections

1.b) Research objectives

- To improve **delay evaluation** by integrating **ridership data**
- To assess **societal costs** by estimating **passenger delays** and using socio-economic valuation guidelines
- To illustrate the use in **maintenance planning** in a case study from Sweden

2. Literature review

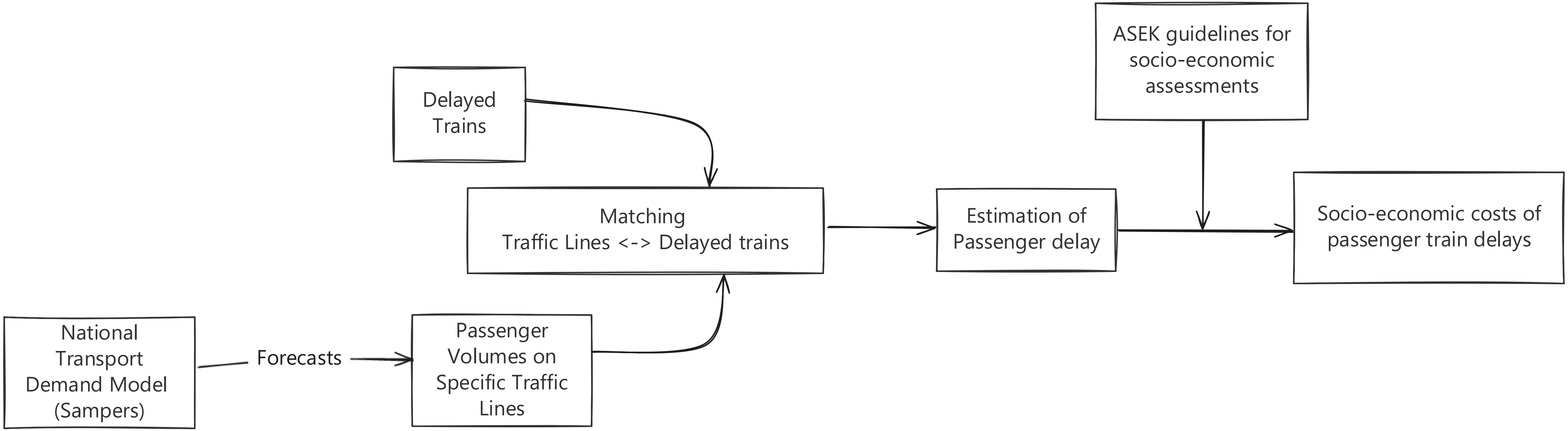
- **Several punctuality indicators** have been proposed and assessed in the existing literature, as discussed in Ait-Ali (2024)
  - Including passenger-centric variants thanks to the emergence of new automatic data collection systems (e.g., AFC, APC *)
- Socio-economic evaluation frameworks have been mainly used in assessing new infrastructure investments
  - Few studies have (passenger) delay assessment in these frameworks
- *Gap*: Operational evaluation framework integrating passenger delay assessment for planning maintenance activities

- * AFC – Automatic Fare Collection, APC – Automatic Passenger Counting

3. Methodology

a) Overview
b) Train load estimation
c) Delay assessment
d) Socio-economic evaluation

a) Overview


ASEK guidelines for socio-economic assessments
Delayed Trains
Matching Traffic Lines <-> Delayed trains
Estimation of Passenger delay
Socio-economic costs of passenger train delays
National Transport Demand Model (Sampers)
Forecasts
Passenger Volumes on Specific Traffic Lines

a) Train load estimation

- Use demand data from the (Swedish) national transport demand model
  - Passenger volumes on specific traffic lines $l \in L$

- Using stopping pattern similarity, the goal is to match
  - delayed trains $t \in T$ & the (closest/most similar) traffic line l

- Estimation of the number of **affected (alighting) passengers**

$$P_t = P_{argmax_l\, S(t,l)}$$

b) Passenger delay

- Builds on **delay contributions(*)** by Joborn and Ranjbar (2022)
  - (*) delay contribution Δ_t represents the contribution of disturbance d to the delay of disturbed train $t \in T(d)$

- Using load estimates, passenger delay is reformulated in terms of passenger delay-hours (over all disturbed trains t due to d)

$$PD_d = \sum_{t \in T(d)} P_t \, \Delta_t$$

- Associated with disturbances which facilitates the analysis of infrastructure-related traffic disruptions.

c) Socio-economic costs

- Values of cost parameters v_i are from the Swedish national guidelines for socio-economic valuations (aka. ASEK)
- Multiply passenger delay by the cost parameters

$$C_d = \sum_{i \in I} v_i . PD_{d,i}$$

Table 3. Parameters for socio-economic valuations of delay costs (Broberg and Wettergren, 2024).

Trip purpose	Type	Value-of-time (SEK per hour)	Delay cost parameter v_i (SEK per pax-min)
Business	National	331	19
	Regional	331	19
Private (work)	National	94	5.5
	Regional	89	5.2
Private (others)	National	94	5.5
	Regional	68	4.0

- Differentiation by trip
  - purpose (commuting, business, private)
  - type (national, local/regional)

3. Case study

a) Case Study – Southern Main Line
b) Data(sets)
c) Results

a) Southern Main Line

- 616 km, key corridor between **Stockholm and Malmö**
- High demand, mix of train types
- 9 300 disturbed trains, 5 200 delays (36% are infrastructure-related)

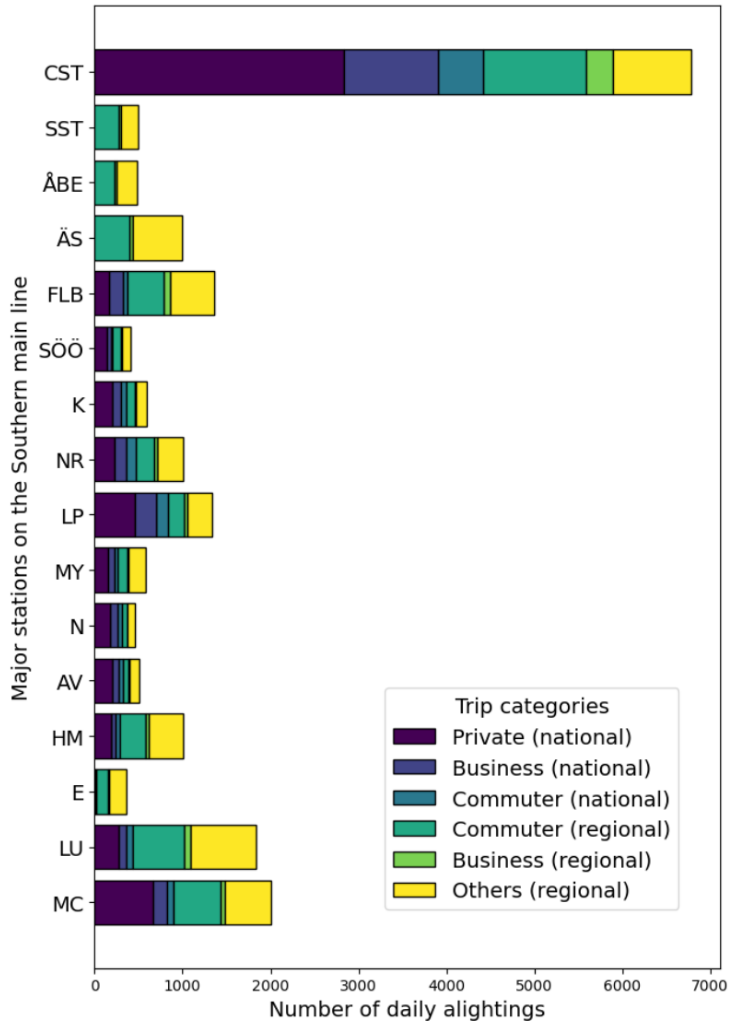
Table 1. Descriptive statistics from disturbance, delay and demand data.

Category	Description	Value
Disturbances	Disturbed trains in the dataset	9 300
	Total infrastructure-related failures (% of the total)	2 220 (36%)
Delay	Delayed trains, i.e., more than 5 min to the final station	5 200
	Average delay duration in minutes	15
Demand	Total number of daily alighting passengers	22 490
	Average (and standard deviation) per station	460 (1 040)

Southern main line (in black) and other connected lines from the Swedish rail network (Joborn and Ranjbar, 2022).

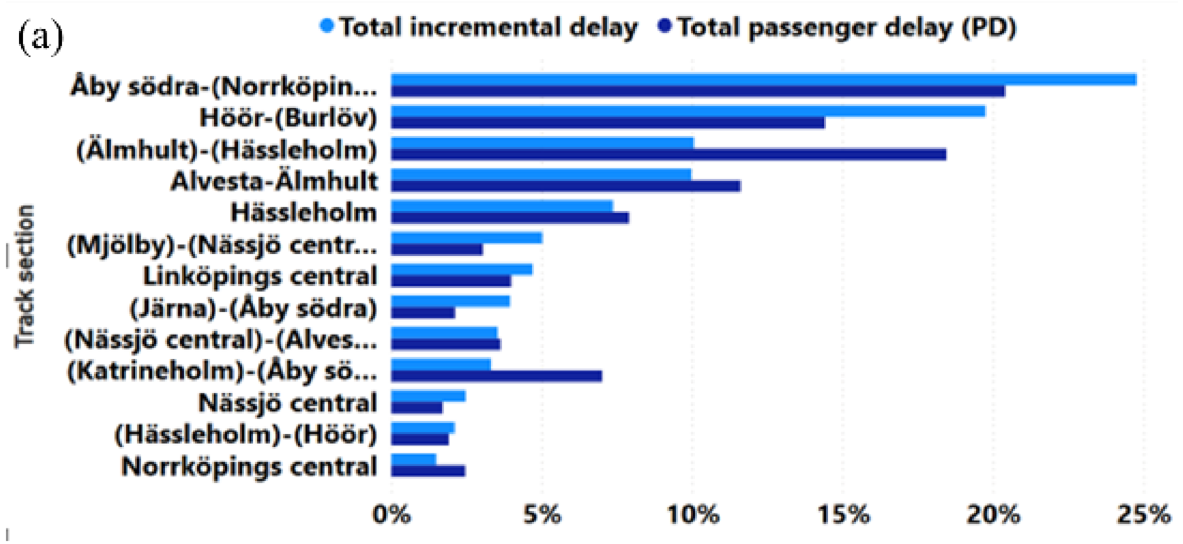
b) Data(sets)

- Traffic and delay data
  - Scheduled and actual timetable
  - Disturbances (time, cause, asset type, track section, etc.)
- National transport demand model
  - Passenger volumes, traffic line, trip types & purpose.
- Socio-economic guidelines
  - delay cost parameters (Broberg & Wettergren, 2024)

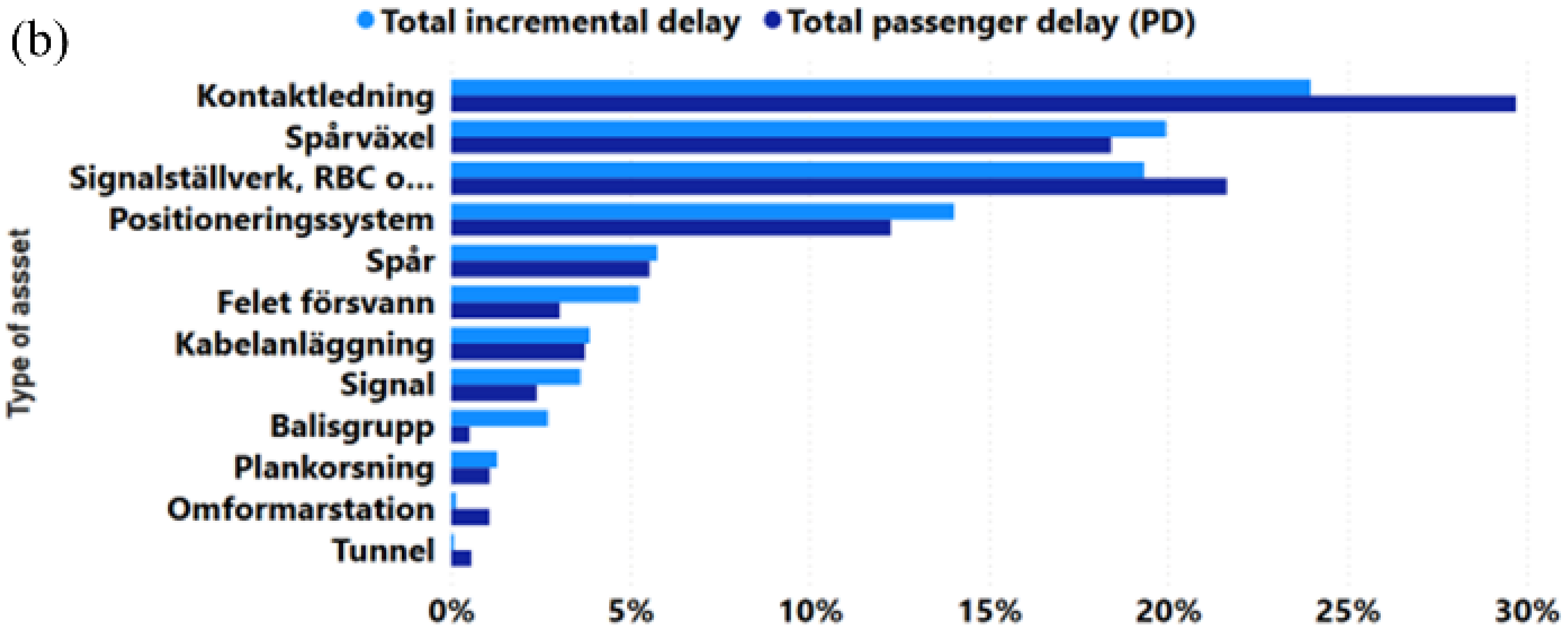


b) Results – per track section

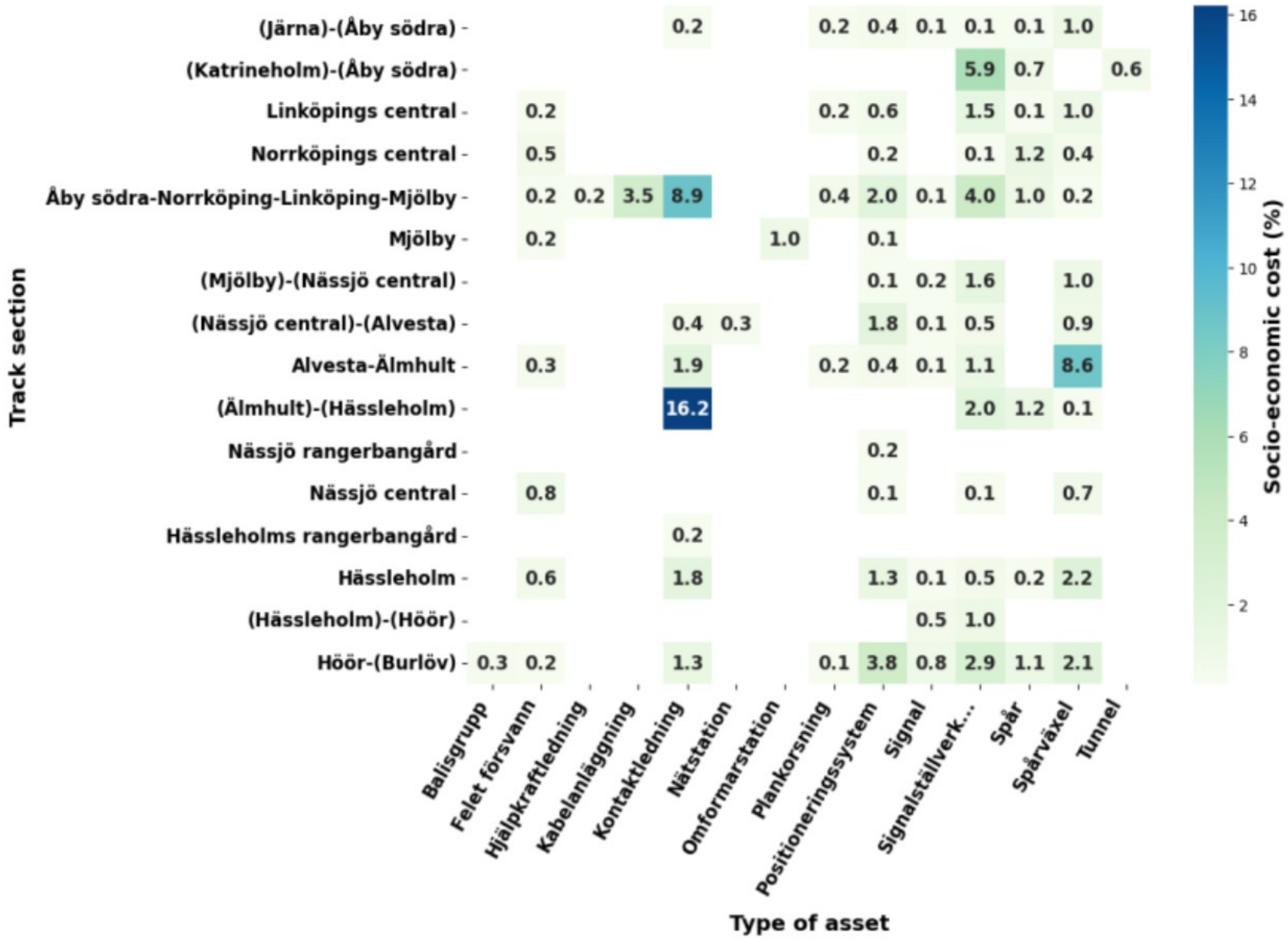
- Comparison (in %) between
  - the currently used **total incremental delay**, i.e., accumulation of primary delays (>3 min), and
  - the proposed **passenger delay** (based on delay increments),



b) Results – per asset type



b) Results – Societal costs (in %)



4. Conclusions

a) Discussion
b) Future works

LINKÖPINGS UNIVERSITET

a) Highlights

- Integration of demand data into delay metrics provides a more passenger-centric performance indicator
- Application to the Southern Main Line shows differences between traditional incremental delay and passenger-centric valuations, indicating potential for alternative (improved?) prioritizations
  - Comparative results (across sections/assets) reveal disparities between the current metric and the proposed passenger delay
- Monetary valuations can reveal infrastructure bottlenecks with higher societal costs (than train-centric metrics suggest)
  - Support prioritization of maintenance actions (what and where?)

b) Ideas/directions for future works

- Extend analysis to incorporate **time-dependent ridership** (peak/off-peak differences).
    - Replace forecasted demand with **observed passenger counting or fare (APC/AFC) data** where available.
- Perform **sensitivity analysis** on passenger load assumptions and delay propagation effects.
- Apply the framework to **multiple corridors** for broader validation and benchmarking.
    - Include **freight delay valuations** to capture full network performance impacts.

Thank you!

Question(s)?

Contact: abdai17@liu.se

LINKÖPINGS UNIVERSITET