Passenger Delay-Based Valuation of Railway Disturbances for Maintenance Prioritization

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Agenda

1. Introduction
2. Literature & research gap
3. Methodology
4. Case study
5. Conclusions

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Integrating demand data with train delay models: A socio-economic evaluation for maintenance planning

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Abstract

Railway punctuality remains a critical measure of service quality and operational efficiency. Traditional performance metrics, such as on-time performance and delay increments, inform about punctuality goals and guide maintenance planning, but they often overlook the passenger experience due to limited access to disaggregated demand data. This study integrates forecasted ridership data with delay evaluation models to assess passenger delays and their socio-economic impacts. By combining passenger-centric delay contributions with the Swedish framework for socio-economic evaluations, we enable a more informed prioritisation of maintenance interventions. A case study on the Southern Main Line in Sweden illustrates the methodology's potential to improve maintenance planning, highlighting its relevance for achieving data-driven improvements in train service reliability.

Keywords: Railway punctuality; passenger delay; socio-economic cost; ridership estimation; maintenance planning.

1. Introduction

Railway service reliability and punctuality are among the most important performance indicators for both passenger satisfaction and infrastructure management. Punctuality, often monitored using vehicle-centric measures, remains the most widely used indicator in operational practice (Goverde, 2005). In Sweden, these indicators are not only used for performance monitoring and contractual penalties, but also for planning maintenance activities on important railway infrastructure assets. For instance, train disruption hours, i.e., accumulated incremental delays, serve as one basis for prioritisation when maintenance plans are prepared; the infrastructure manager prioritises interventions based on locations and asset types contributing most to delays, see a review by Pettersson (2020) for Swedish railways.

However, existing approaches for punctuality and performance evaluation primarily focus on train-centric metrics, overlooking passenger-level impacts, in particular on congested time intervals and track sections. This gap can lead to

1. Introduction

- Railway punctuality is an important performance indicator (for customer satisfaction, infrastructure management, etc.)
- Currently used indicators are mainly train-centric (e.g., RT + X minutes)
- However, these metrics overlook real impacts on passengers (and freight transporters), especially on congested time intervals and track sections
- 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 & research gap

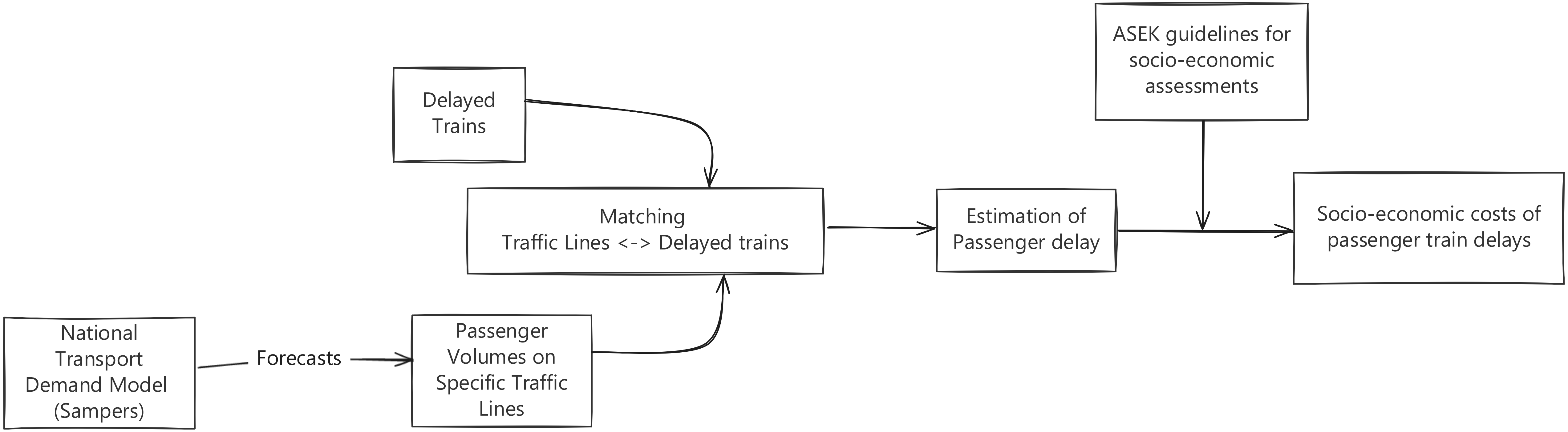
- **Several punctuality indicators** have been proposed/assessed in the existing literature
  - including passenger-centric variants thanks to the emergence of new automatic data collection systems (e.g., AFC, APC *)
- **Socio-economic evaluation frameworks** have been limited to the assessment of new infrastructure investments
  - Few studies have (passenger) delay assessment in these frameworks
- ***Gap***: Operational evaluation framework integrating passenger delay assessment (for planning railway 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 (score S), 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 ν_i are from the Swedish national guidelines for socio-economic valuations (aka. ASEK)
- Multiply passenger delay by the cost parameters

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

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 ν_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

× 3,5

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

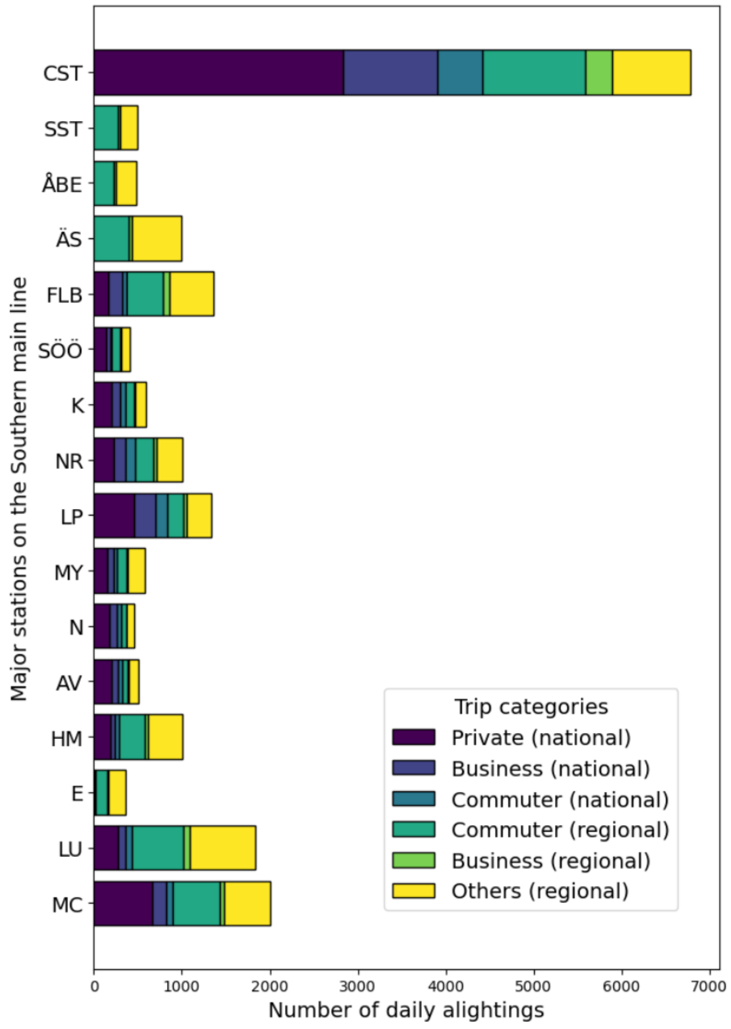
Southern main line (in black) and other connected lines from the Swedish rail network (Joborn and Ranjbar, 2022).

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)

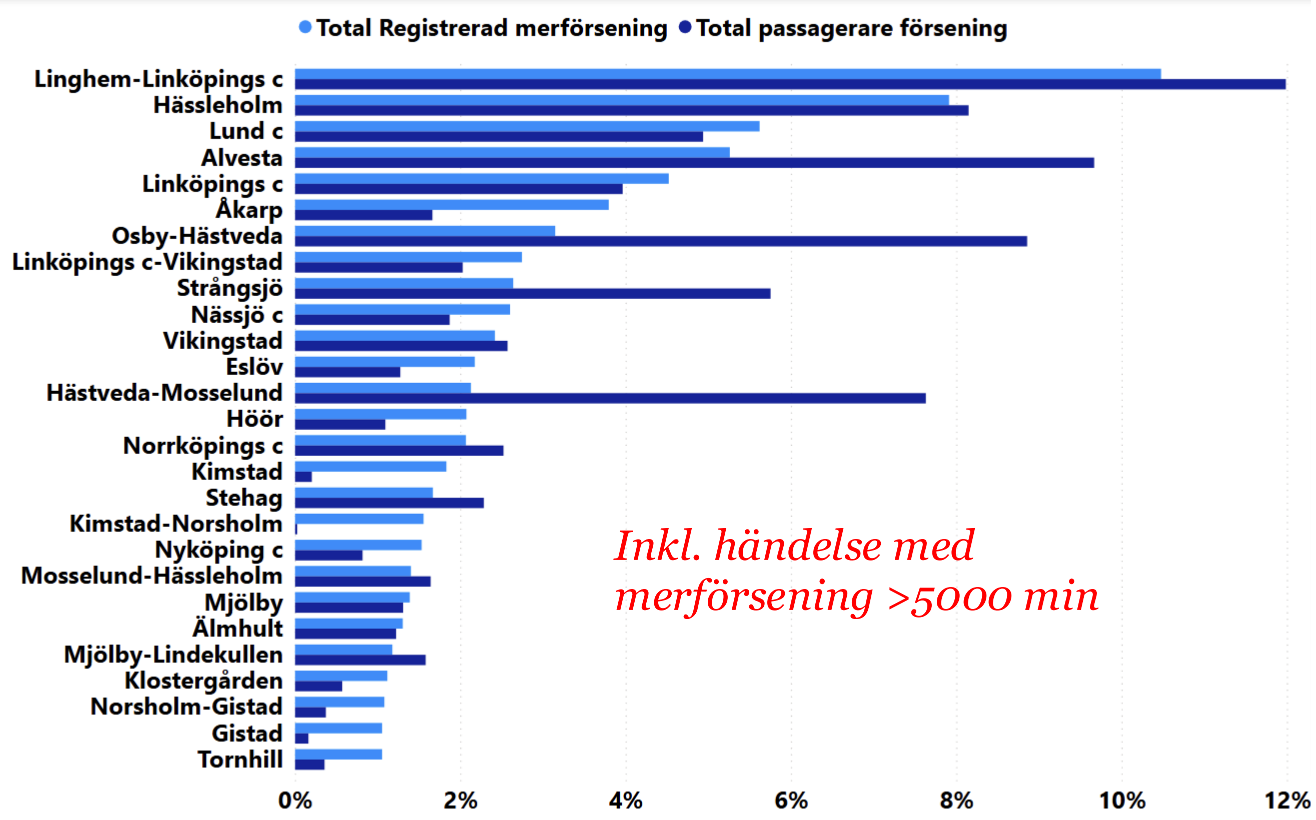
b) Data(sets)

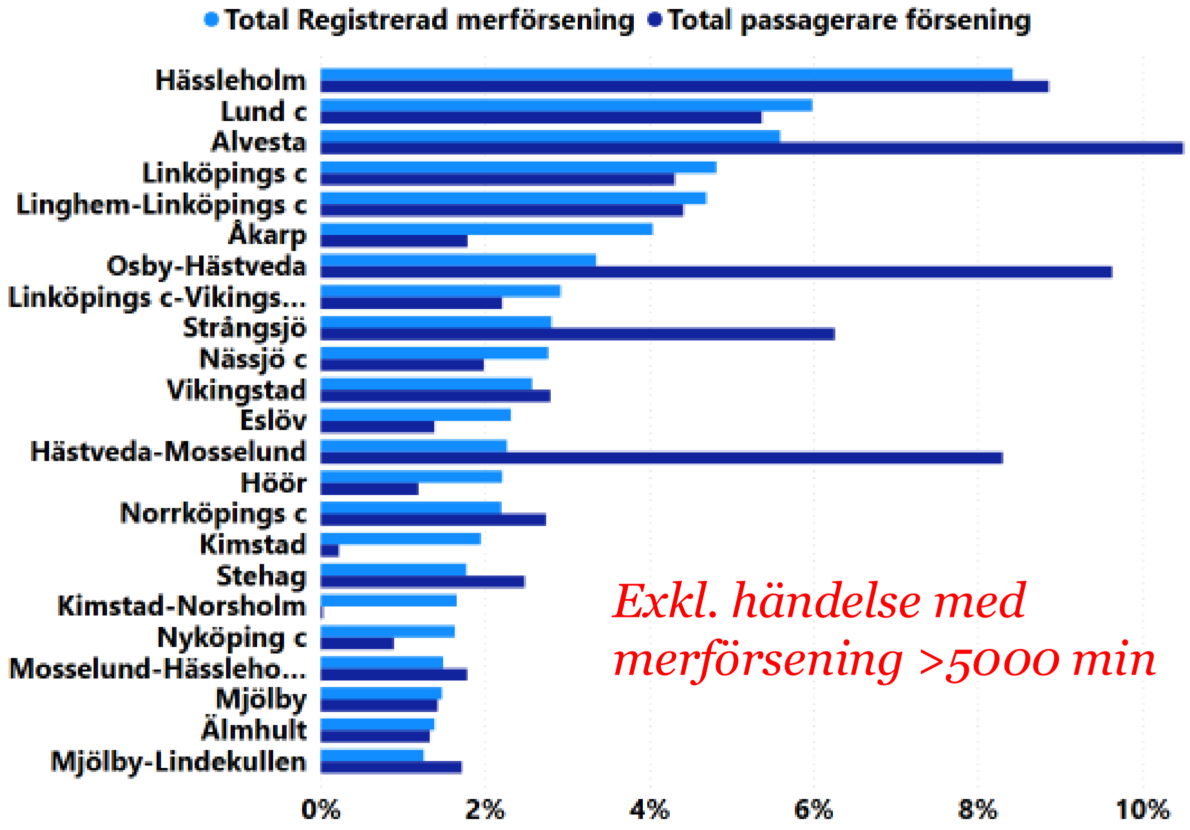
- Traffic and delay data
  - Scheduled and actual timetable
  - Disturbances (time, cause, asset type, track section, etc.)
- National transport demand data
  - Passenger volumes, traffic line, trip types & purpose.
- Socio-economic valuations
  - delay cost parameters (Broberg & Wettergren, 2024)



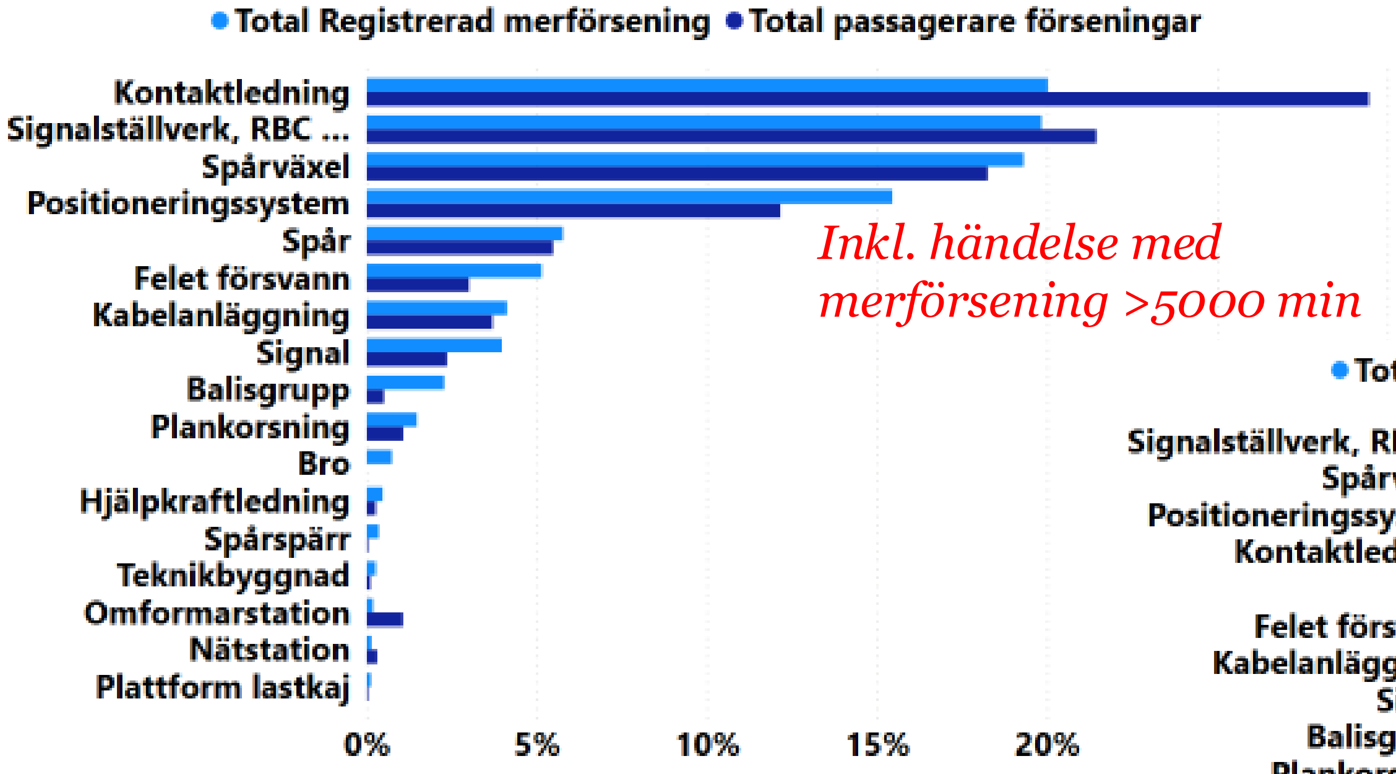
b) Results – comparison per location

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

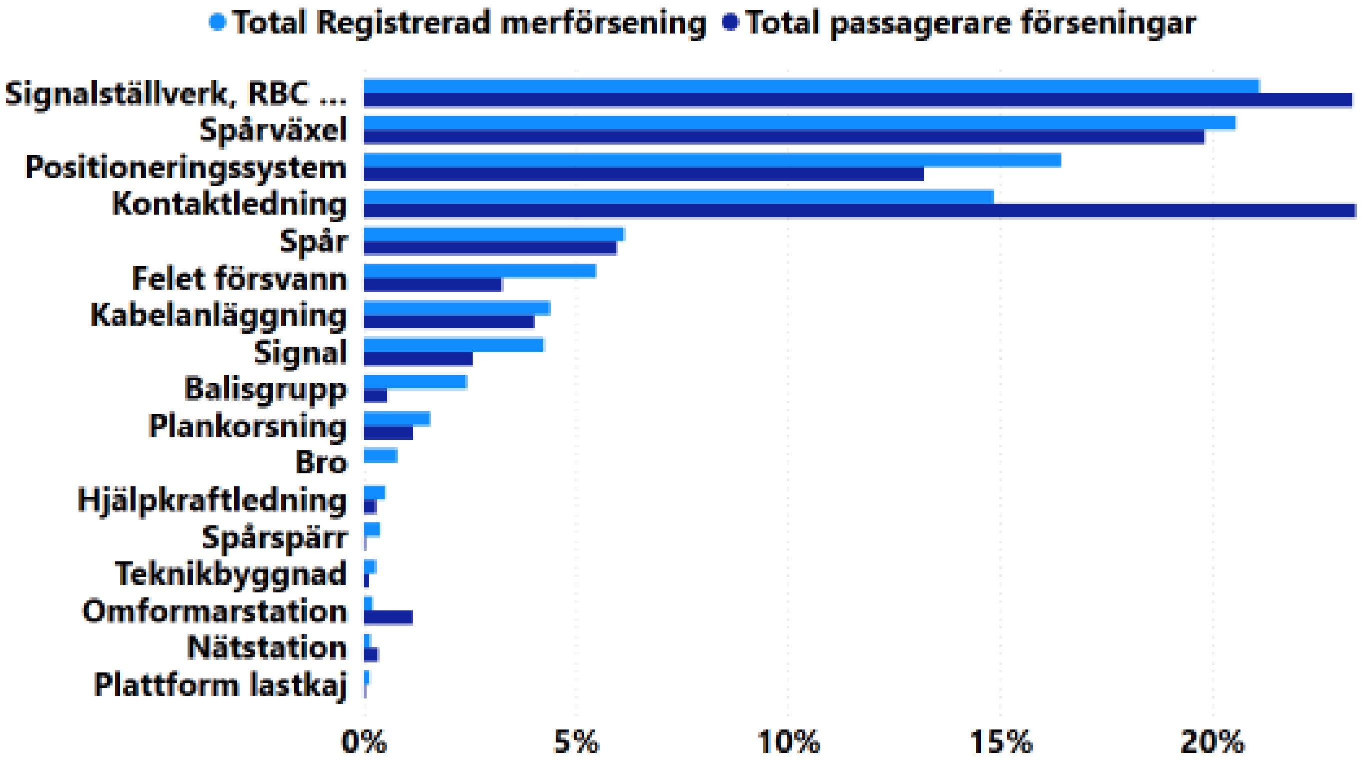




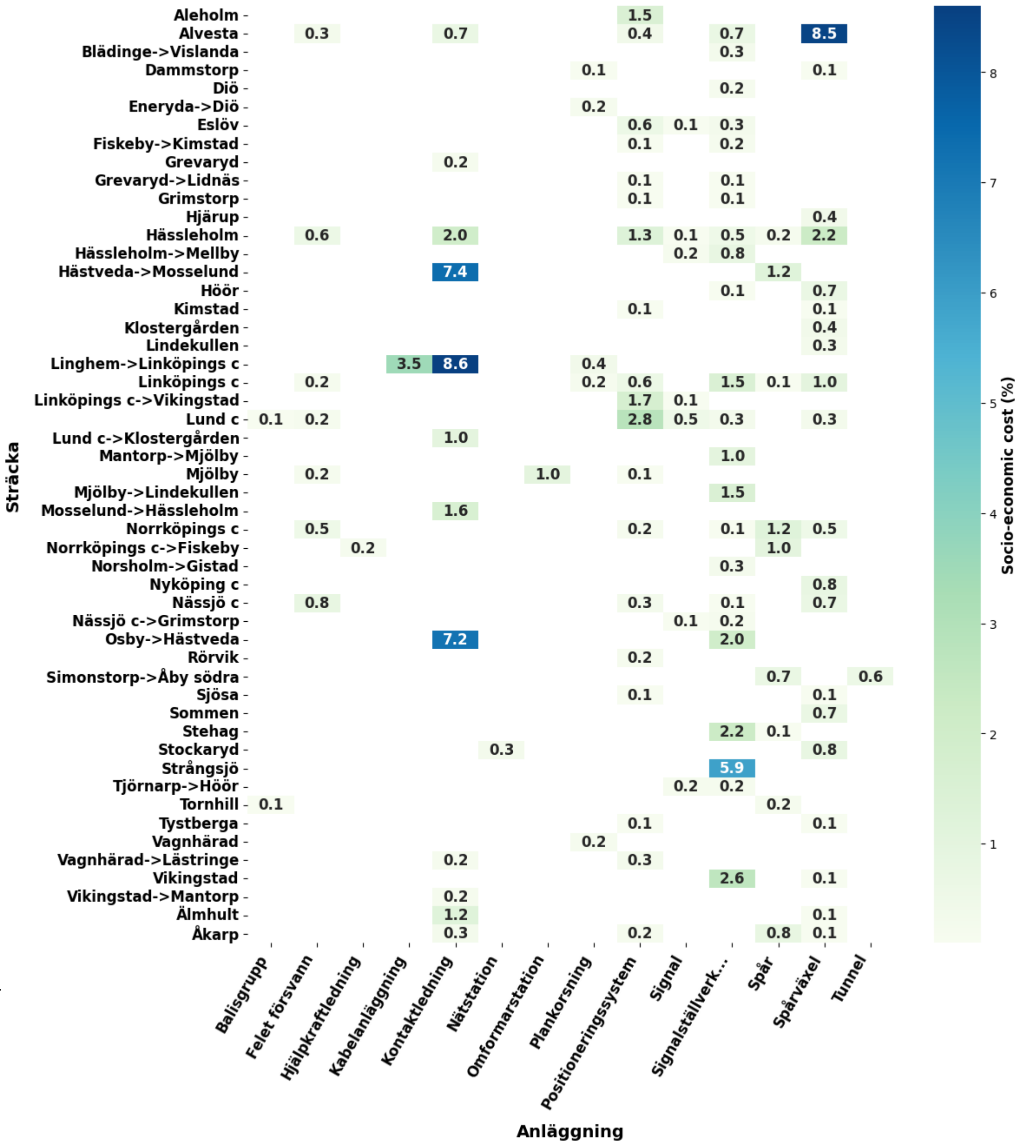
b) Results – comparison per asset type



Inkl. händelse med merförsening >5000 min



b) Results – total societal costs (in %)



4. Conclusions

- A more passenger-centric framework for valuation of disturbances
  - support prioritization of maintenance actions (what and where?)
- Application to the Southern Main Line shows differences between traditional incremental delay and passenger-centric valuations
  - indicating potential for alternative (improved?) prioritizations
- **Ideas/directions for future works**
  - Replace forecasted demand with observed passenger counting or fare (APC/AFC) data where available
  - Sensitivity analysis on passenger load assumptions and delay propagation effects
  - Apply to multiple corridors for broader validation and benchmarking, including freight delay valuations

Thank you!

Question(s)?

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