Salvetti PhD Award Winner

Compressed version of disputation presentation

Operation and maintenance performance of rail infrastructure:

Model and methods

Christer Stenström

Supervisors: Prof. Aditya Parida
Prof. Uday Kumar

Opponent: Prof. Rommert Dekker, Erasmus University, The Netherlands

Committee members: Prof. Ingrid B. Utne, NTNU, Norway
Prof. João C.E.J. Pombo, Instituto Superior Técnico, Portugal
Prof. Bjarne Bergquist, LTU, Sweden

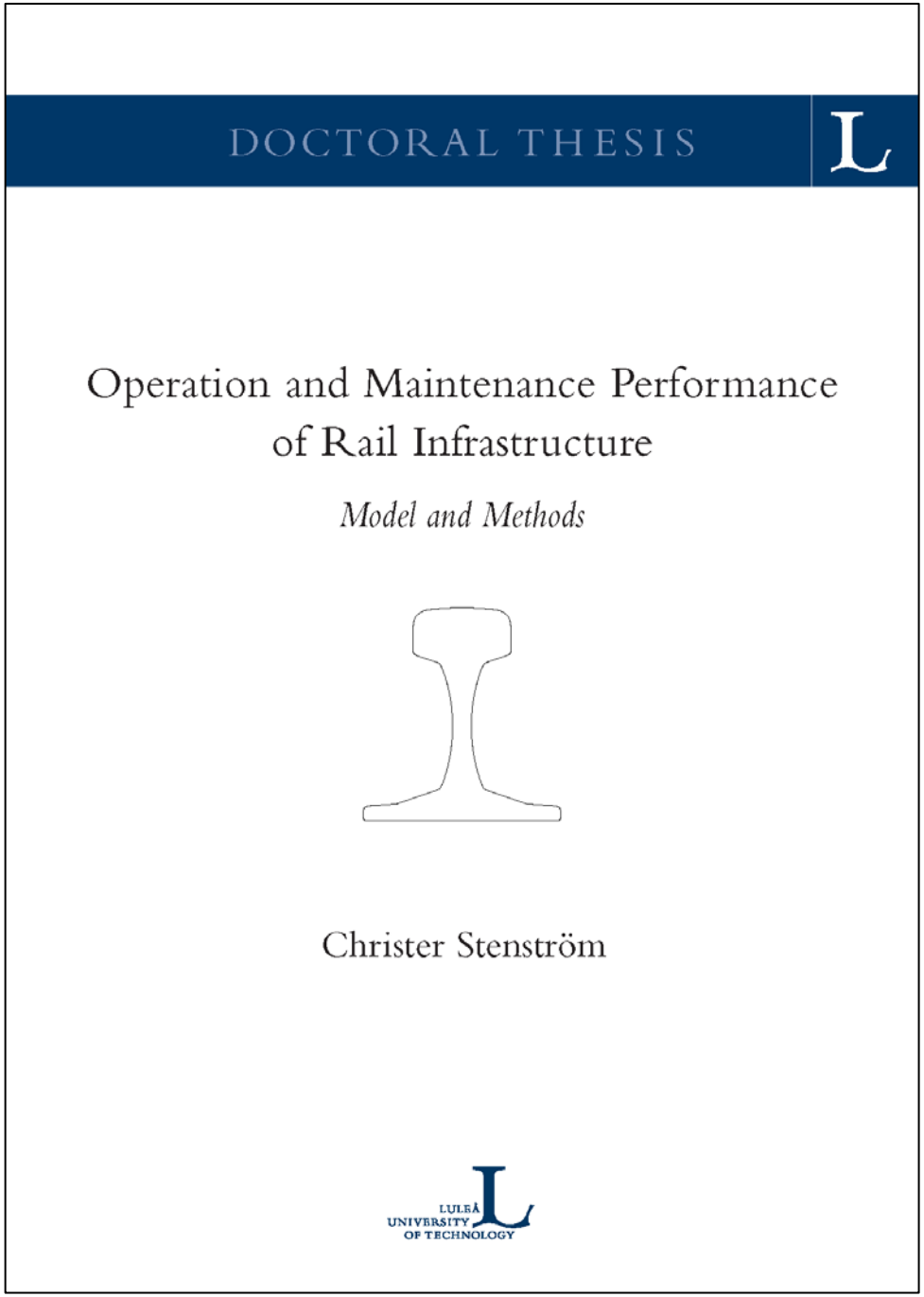
Operation and Maintenance Engineering
Luleå University of Technology, Sweden
2016 – 06 – 01

Division of Operation, Maintenance and Acoustics

JVTC LULEÅ RAILWAY RESEARCH CENTER
at Luleå University of Technology

Luleå University of Technology

Division of Operation, Maintenance and Acoustics



- From 2010-2014
- Funded by the Swedish Transport Administration (Trafikverket)
- On maintenance performance measurement
- Includes five journal papers, three in Web of Science (compilation thesis)
- Jointly with AUTOMAIN and BGLC EU-projects

Table of contents

Part I

Table of contents

Part II

Scope

- Operation and maintenance performance
- In terms of technical performance

Reliability:
How often items fail

Maintainability:
How hard it is to do maintenance

Supportability:
How fast an organisation can react on failures

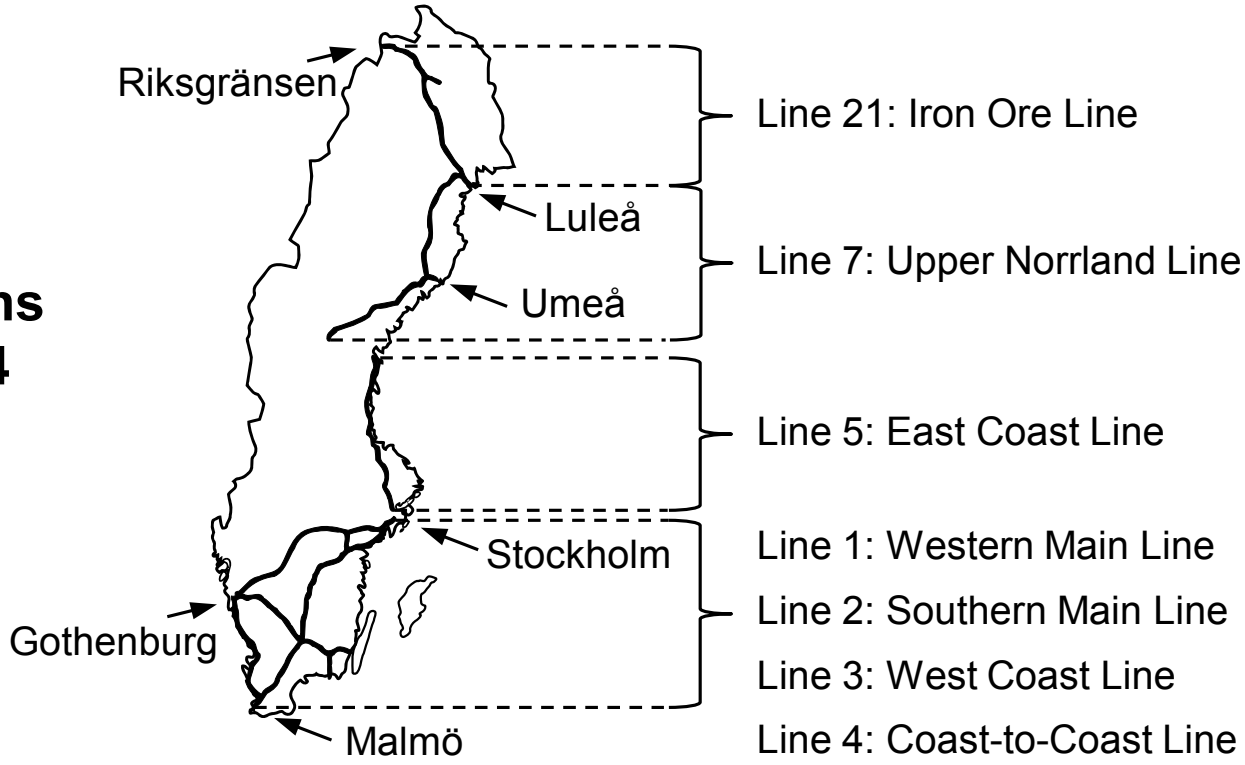
Failure

Availability:
The proportion of time a system is functioning

A key for capacity and credibility!

Data collection

7 lines
65 sections
2010-2014



1 year data (2013-14):

65	Sections
24 816	Failures
352 679	Inspections
52 854	Potential failures (= inspection remarks)
28 704	Rectified potential failures

Programming in Matlab

Table of contents

Part II

Paper A:

Stenström, C., Parida, A., Galar, D. and Kumar, U. (2013) **Link and effect model for performance improvement of railway infrastructure**, Journal of Rail and Rapid Transit

Paper B

Paper C

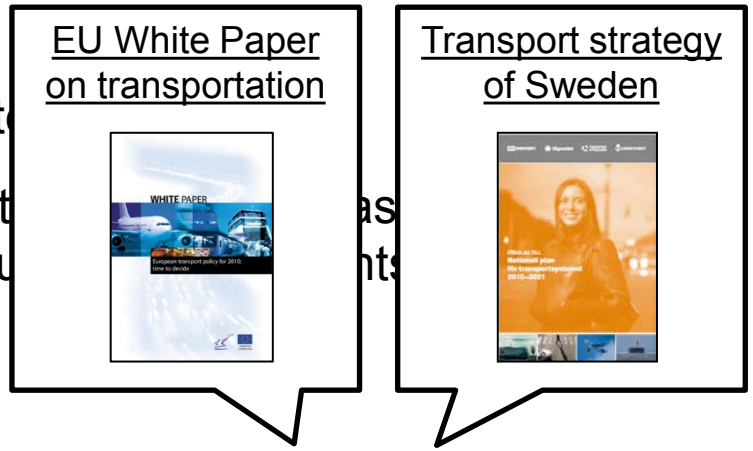
Paper D

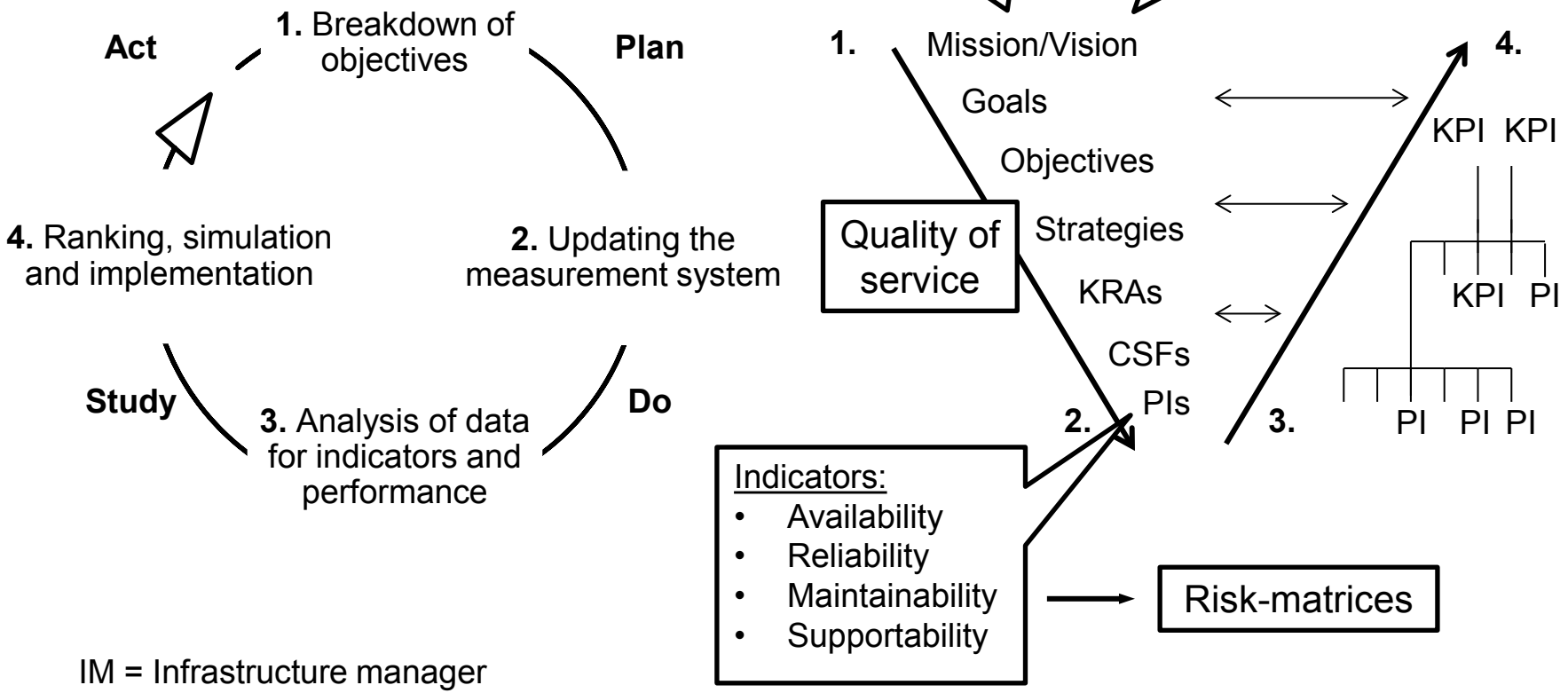
Paper E

MPM framework

Link and effect model

- For maintenance policy and maint
- Focus on: the components of strat as
  implementation issues and continu nts

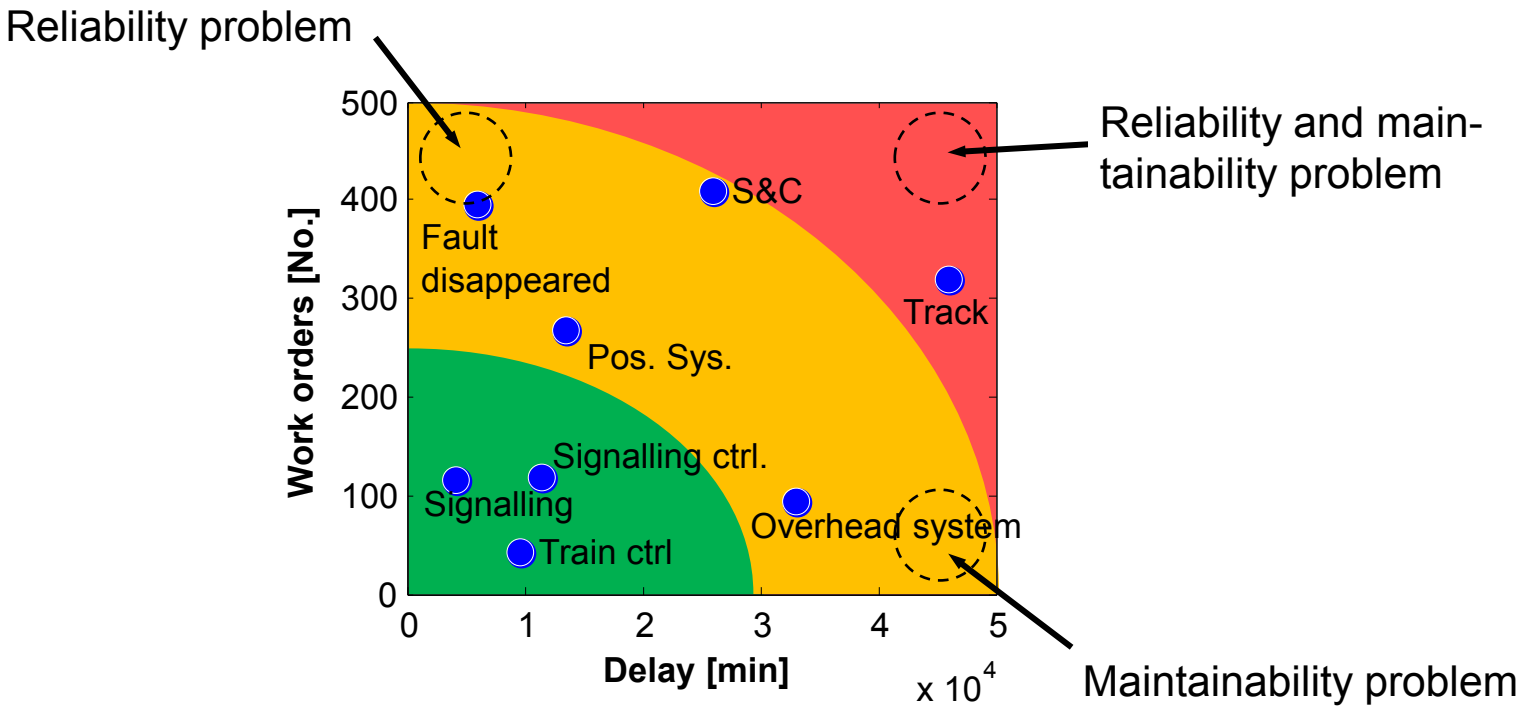




IM = Infrastructure manager
KRA = Key result area
CSF = Critical success factor

Case study

Probability-consequence matrix



At three levels:
System, subsystem and component.

(MIL-STD-1629A and ISO 31010)

Table of contents

Part II

KPIs

KPIs of rail infrastructure

- ~120 indicators mapped
- Comparison with EN 15341: Maintenance key performance indicators

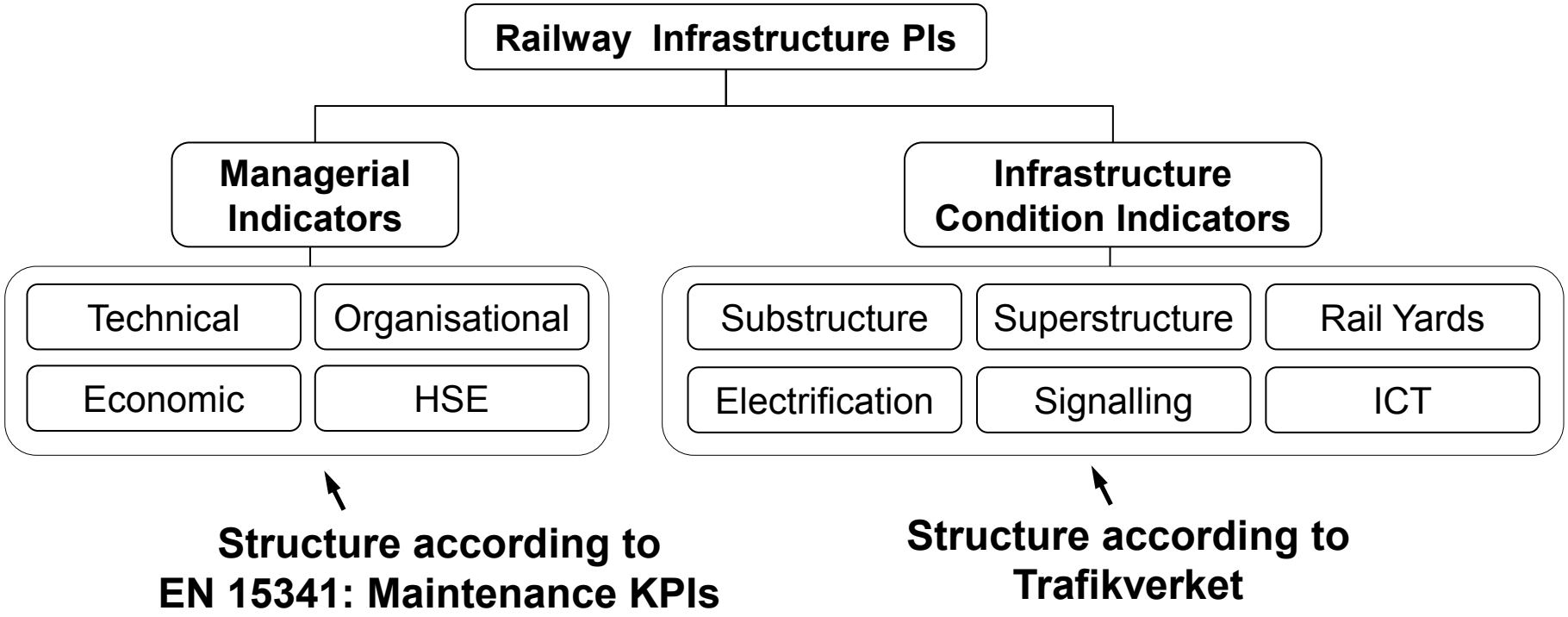


Table of contents

Part II

Paper A

Paper B

Paper C:

Stenström, C., Parida, A. and Kumar, U. (2016) **Measuring and monitoring operational availability of rail infrastructure**, To appear in: Journal of Rail and Rapid Transit

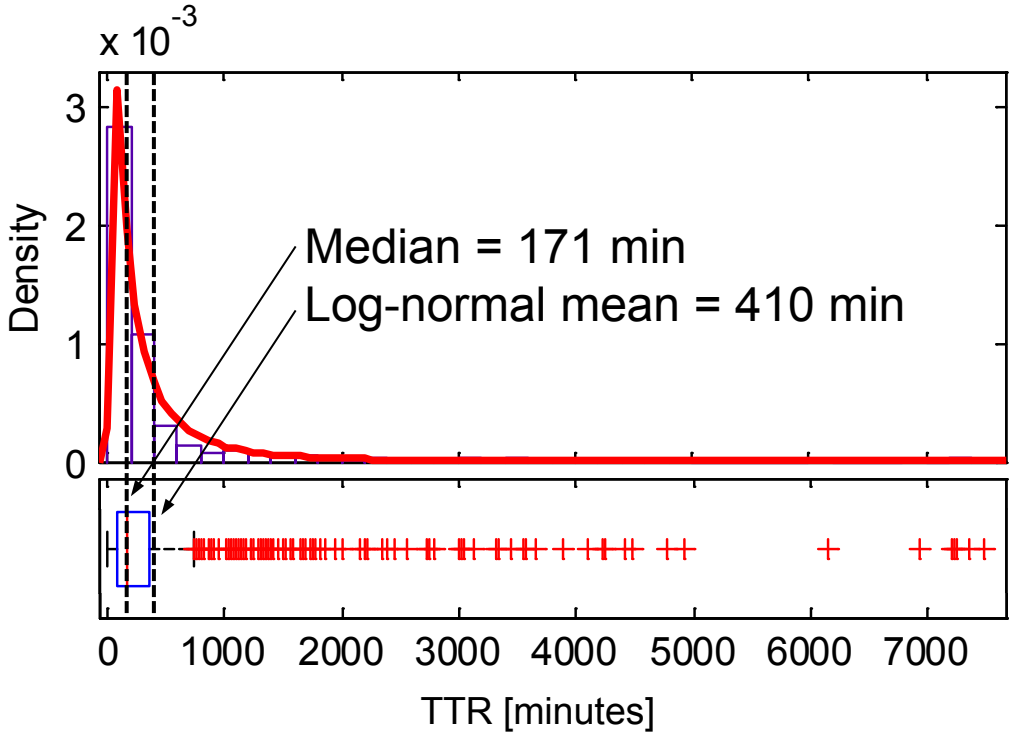
Paper D

Paper E

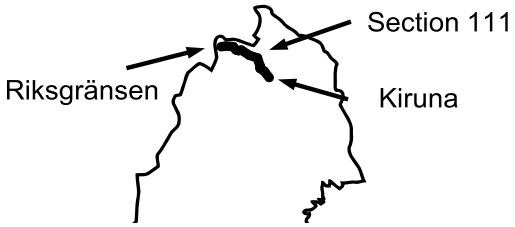
Availability performance

Availability of rail infrastructure

TTR = logistic time + repair time

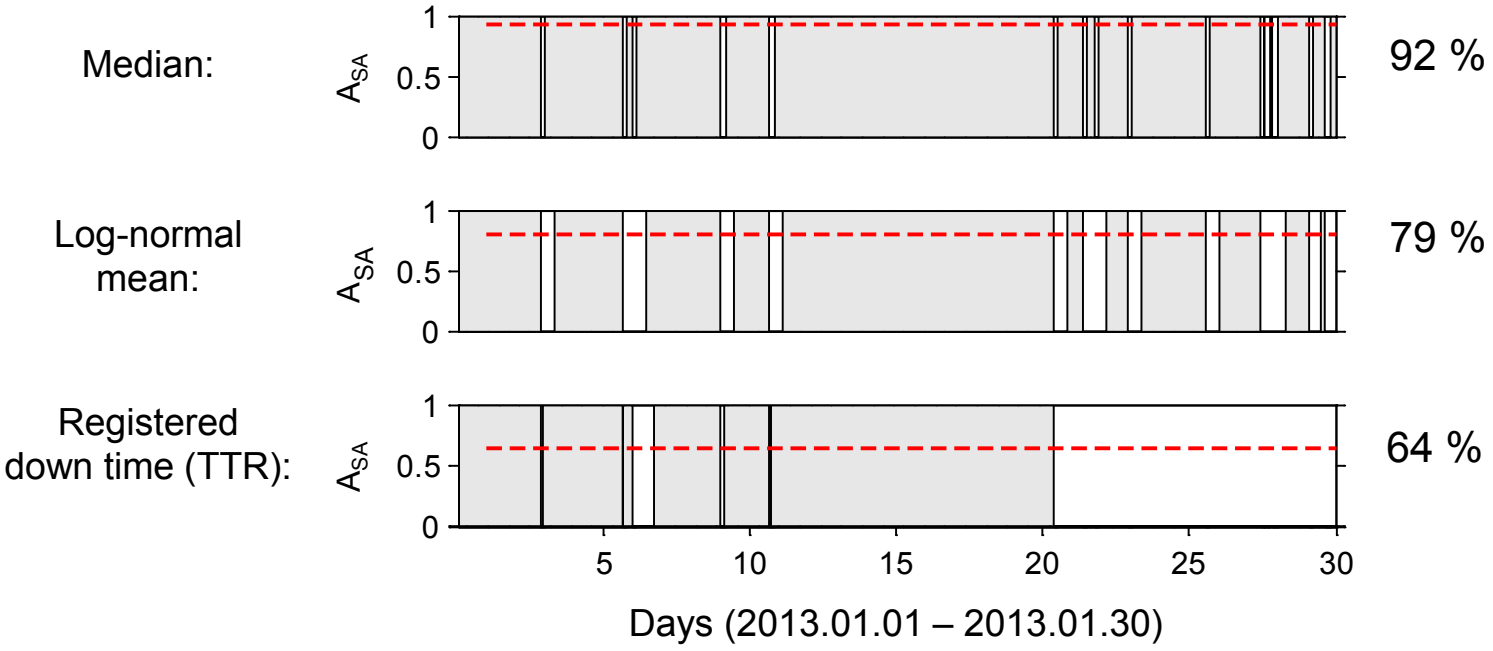


955 train-delaying failures
2010-14

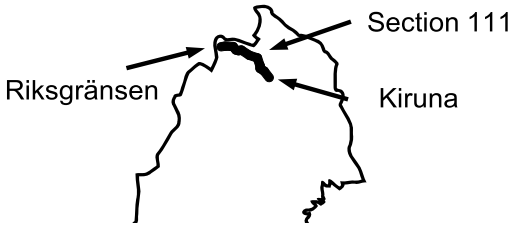


(TTR = Time to restoration)

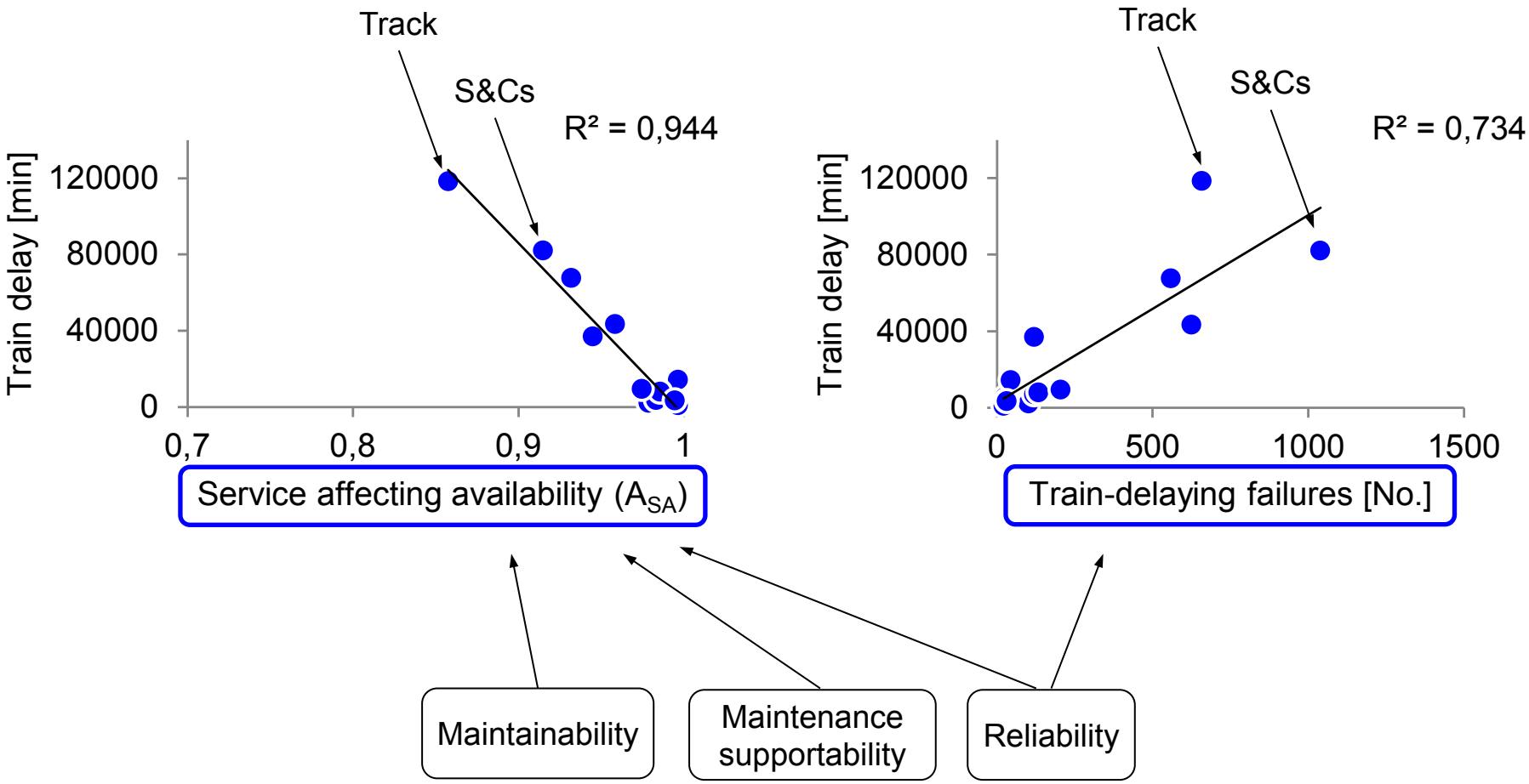
Availability of rail infrastructure



955 train-delaying failures 2010-14



(TTR = Time to restoration)



(S&Cs = Switches and crossings)

Table of contents

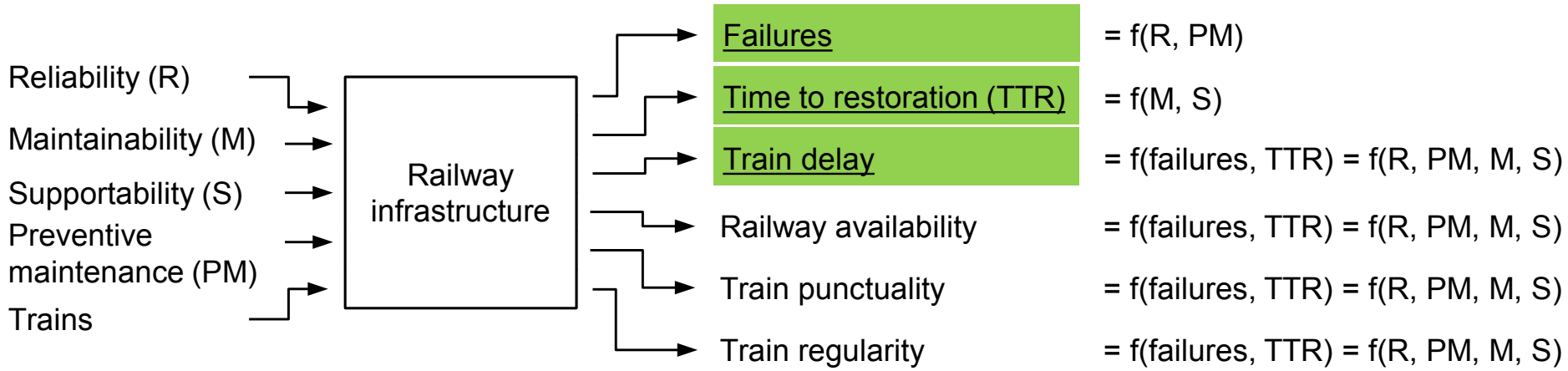
Part II

Composite indicator

Integrity index – A composite indicator

- Provides the big picture, easier to interpret than trying to find a trend in many separate indicators
- Used by World Bank, European Commission, UNESCO and OECD

Theoretical framework:



Time to restoration = Logistic time + Repair time

$$TTR = LT + RT$$

Procedure

Normalisation to switches & crossings and track length:

S&C failures (per S&Cs)	Linear assets failures [km^{-1}]	S&C delay (per S&Cs)	Linear assets delay [km^{-1}]	Logistic time (LT)	Repair time (RT)

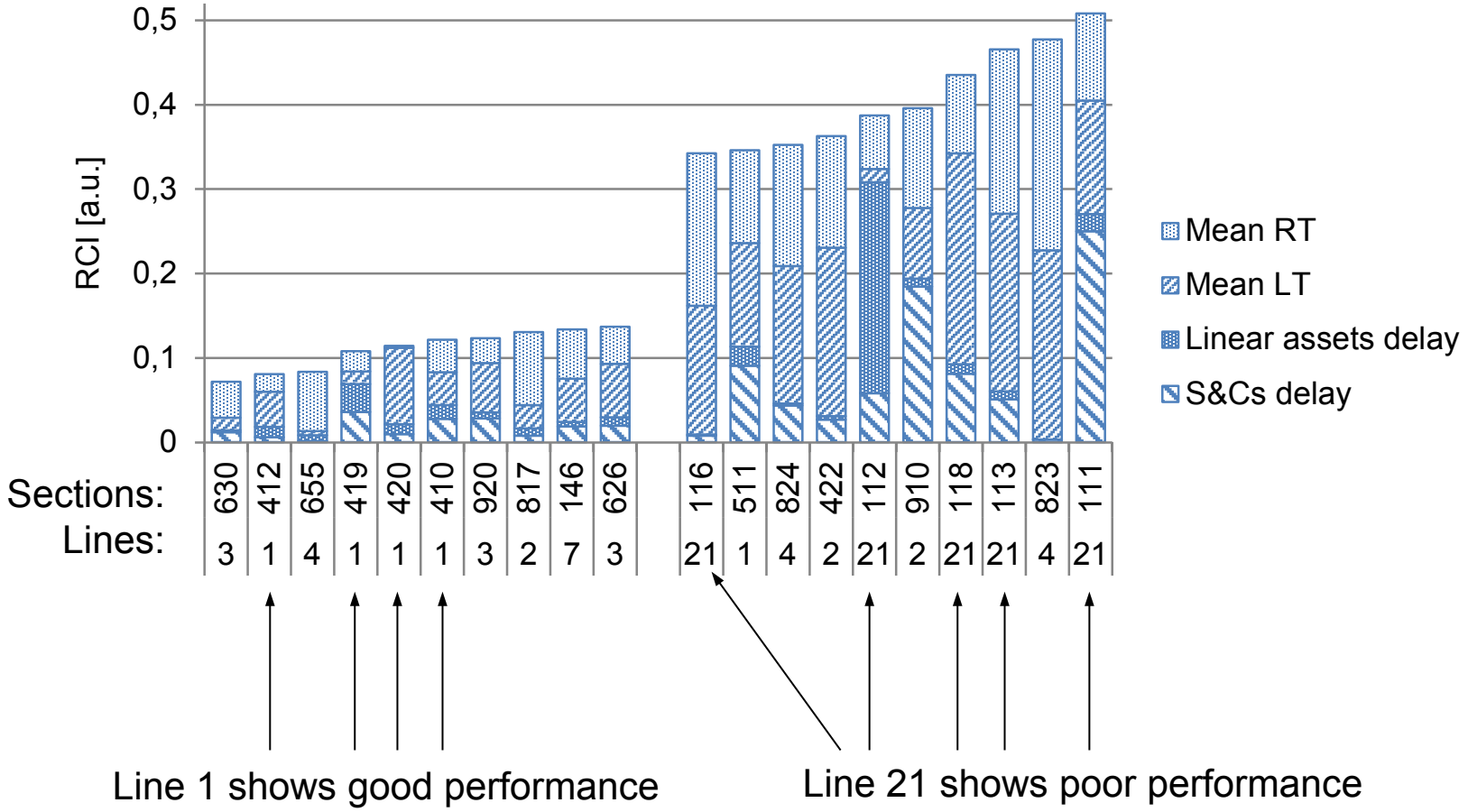
Normalisation of data range: Min-Max, Z-score and Rank

Weighting: Equal weighting, Correlation weighting, AHP and Reduced CI

Aggregation: Additive and geometric

$$Rank(CI_i) = Rank\left(\sum_{q=1}^{Q=6} w_q I_{qi}\right) = Rank\left(\sum_{q=1}^{Q=6} w_q \frac{x_{qi} - min(x_q)}{max(x_q) - min(x_q)}\right)$$

Results



LT = Logistic time = travel time
RT = Repair time
a.u. = arbitrary unit

Table of contents

Part II

Paper A

Paper B

Paper C

Paper D

Paper E:

Stenström, C., Parida, A., and Kumar, U., **Preventive and corrective maintenance: Cost comparison and cost-benefit analysis**, Structure and Infrastructure Engineering

Cost-benefit analysis

Comparison of corrective and preventive maintenance (CM and PM) costs

65 railway sections

CM

PM: Inspections

PM: Remarks

$$C_{Section} = \frac{1}{N}\left(C_{CM}^{S\&Cs} + C_{PMI}^{S\&Cs} + C_{PMR}^{S\&Cs}\right) + \frac{1}{M}\left(C_{CM}^{Track} + C_{PMI}^{Track} + C_{PMR}^{Track}\right)$$

No. of S&Cs

Track length

2 personnel

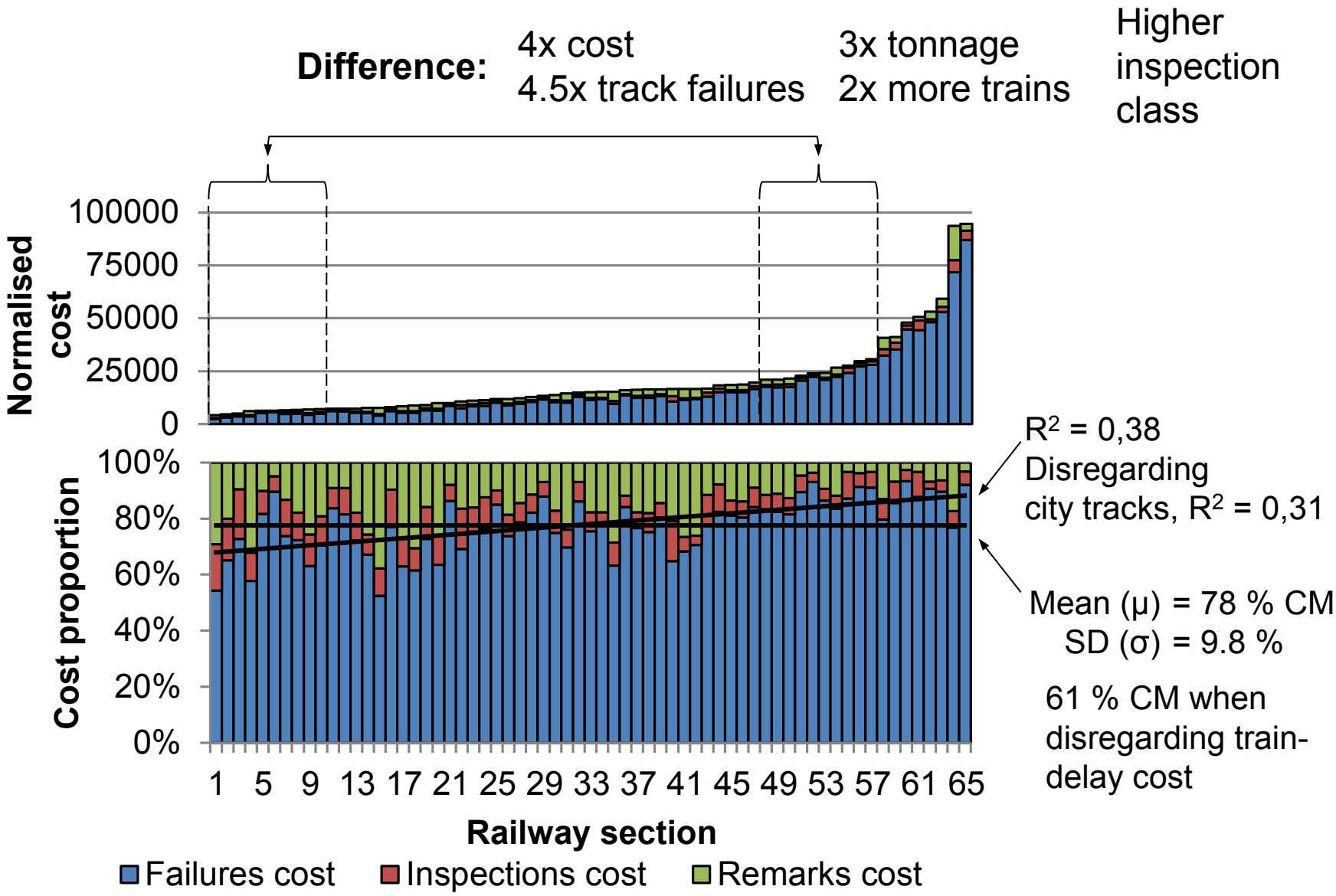
€100 / item

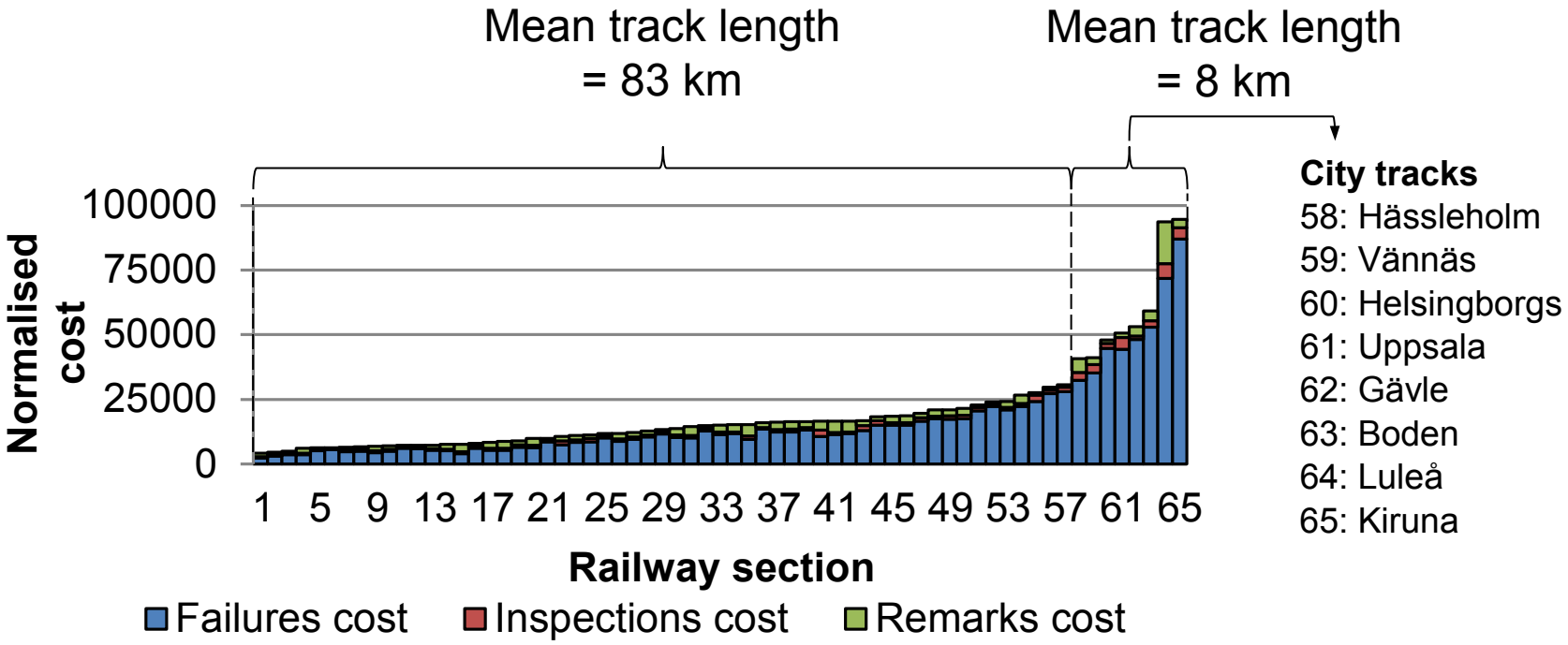
$$= \sum_{i=1}^{n}\left(n_{P,i}C_P\left\{2t_{LT,i} + t_{RT,i}\right\} + C_{M,i} + t_{DT,i}C_{DT}\right)$$

€100 / h

€53 / min

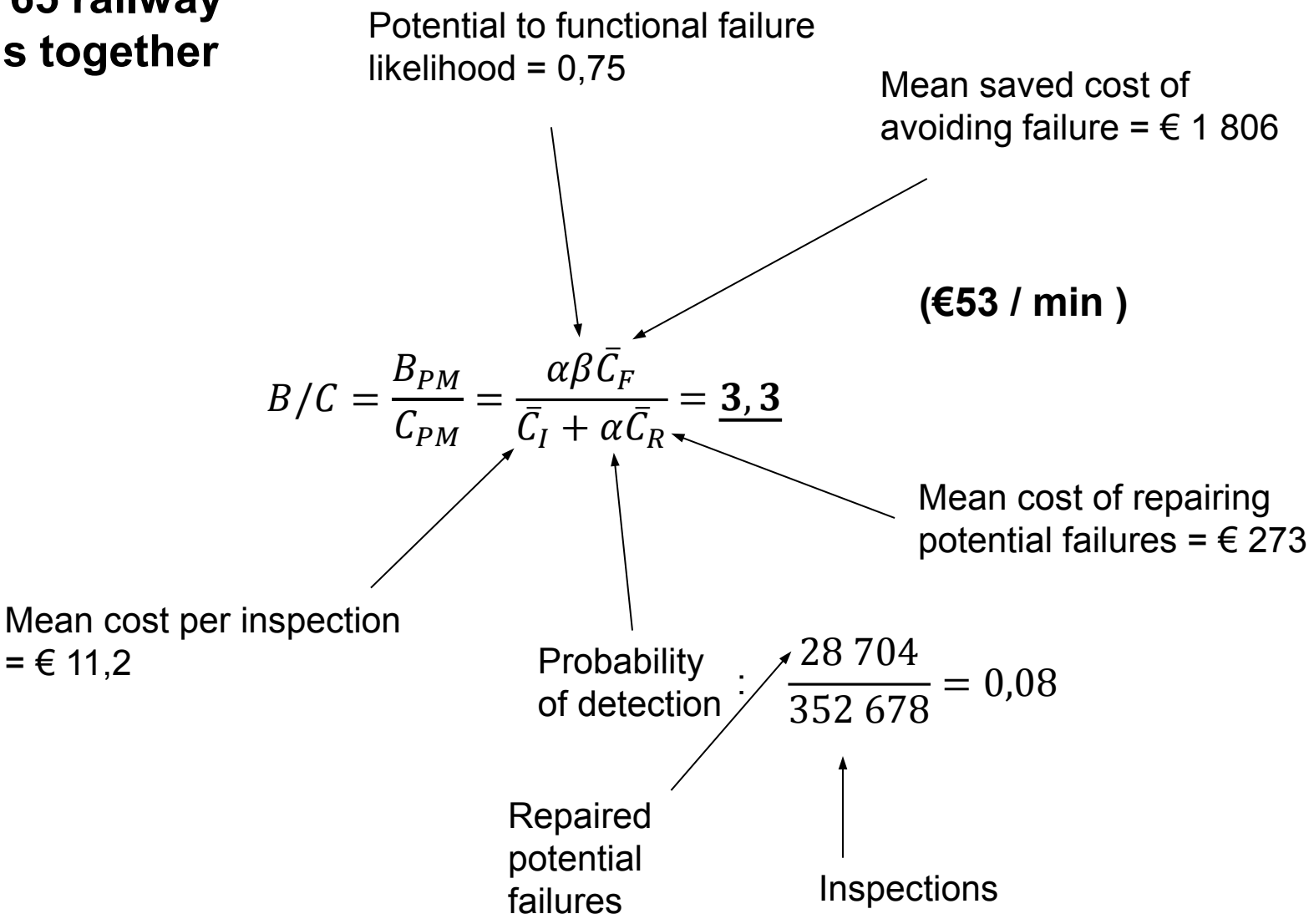
(S&Cs = Switches and crossings)


Difference:
4x cost
4.5x track failures
3x tonnage
2x more trains
Higher inspection class
Normalised cost
100000
75000
50000
25000
0
Cost proportion
100%
80%
60%
40%
20%
0%
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65
Railway section
Failures cost
Inspections cost
Remarks cost
R² = 0,38
Disregarding city tracks, R² = 0,31
Mean (μ) = 78 % CM
SD (σ) = 9.8 %
61 % CM when disregarding train-delay cost


Mean track length
= 83 km
Mean track length
= 8 km
City tracks
58: Hässleholm
59: Vännäs
60: Helsingborgs
61: Uppsala
62: Gävle
63: Boden
64: Luleå
65: Kiruna
Normalised cost
100000
75000
50000
25000
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65
Railway section
Failures cost
Inspections cost
Remarks cost

Cost-benefit analysis

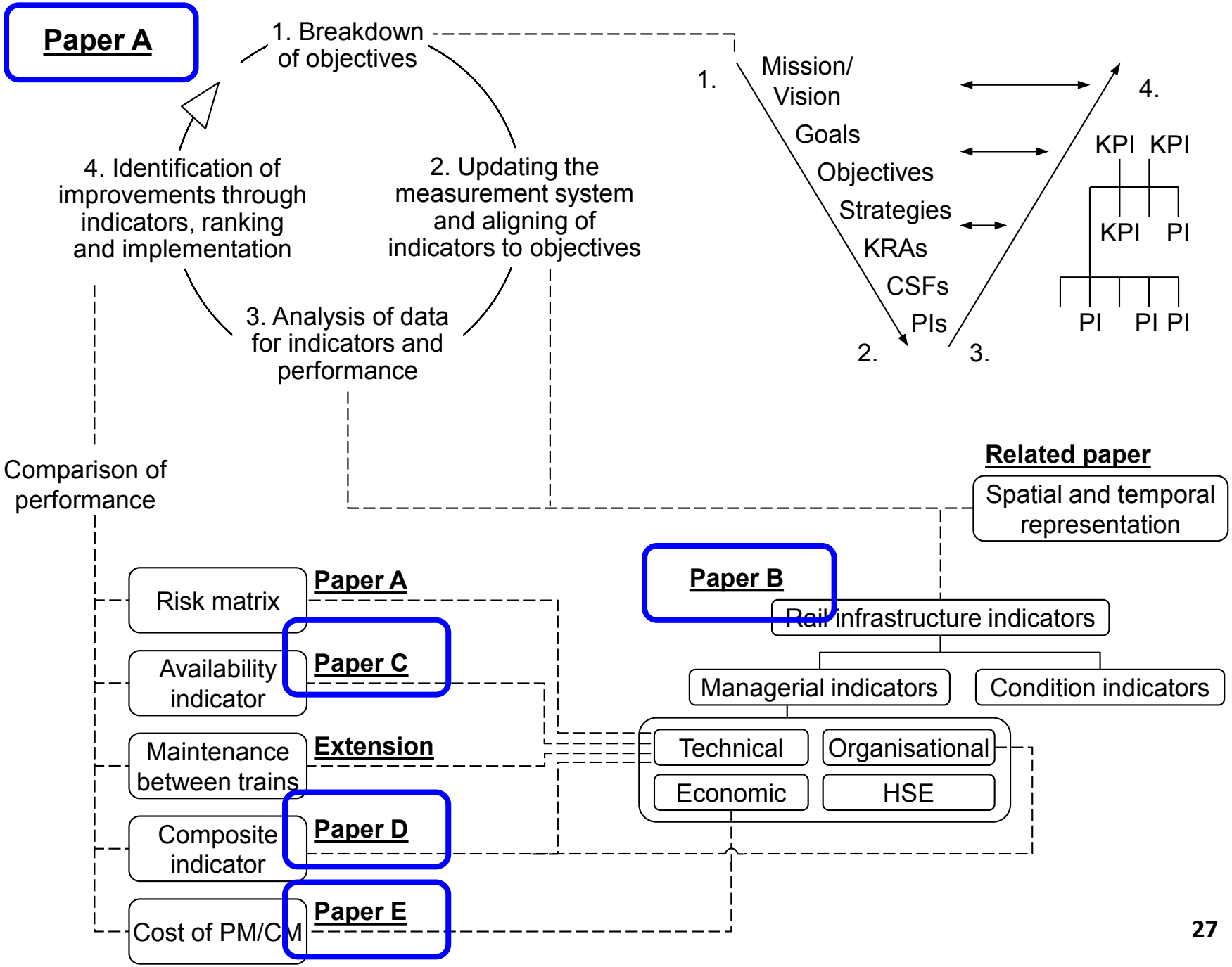
For the 65 railway sections together



(Potential failure = Inspection remark)

Table of contents

Part II


Paper A
1. Breakdown of objectives
2. Updating the measurement system and aligning of indicators to objectives
3. Analysis of data for indicators and performance
4. Identification of improvements through indicators, ranking and implementation
1.
Mission/ Vision
Goals
Objectives
Strategies
KRAs
CSFs
PIs
2.
3.
4.
KPI KPI
KPI PI
PI PI PI
Comparison of performance
Related paper
Spatial and temporal representation
Paper B
Rail infrastructure indicators
Managerial indicators
Condition indicators
Technical
Organisational
Economic
HSE
Risk matrix
Paper A
Availability indicator
Paper C
Maintenance between trains
Extension
Composite indicator
Paper D
Cost of PM/CM
Paper E

Thank you!

efnms
European Federation of National Maintenance Societies vzw

SALVETTI

HMS
Hellenic Maintenance Society
ΕΛΛΗΝΙΚΗ ΕΤΑΙΡΙΑ ΤΕΧΝΟΛΟΓΙΑΣ & ΔΙΟΙΚΗΣΗΣ ΣΥΝΤΗΡΗΣΗΣ

TRAFIKVERKET

Division of Operation, Maintenance and Acoustics

JVT
Luleå Railway Research Center