UIC HIGHSPEED Morocco 2023

HIGH-SPEED RAIL : THE RIGHT SPEED FOR OUR PLANET

Under the High Patronage of his Majesty King Mohammed VI

Session 1.1 Room Karam1
Economy / Rail business model

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DIRECTION VOYAGES SNCF /
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ONCF UIC

Session1.1 Economy / Rail business model Speaker Lists;

1

Mr.Friedemann Brockmeyer

Germany

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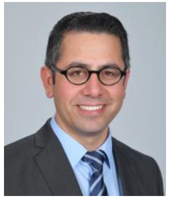

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11TH WORLD CONGRESS OF HIGH-SPEED RAIL

Marrakech, 7-10 MARCH 2023

How to build high-speed lines cheaper?

A holistic approach to improve cost effectiveness in the construction of new high-speed lines

Friedemann Brockmeyer
Partner, civity Management Consultants, Germany
Session1-1.1 Economy / Rail business model

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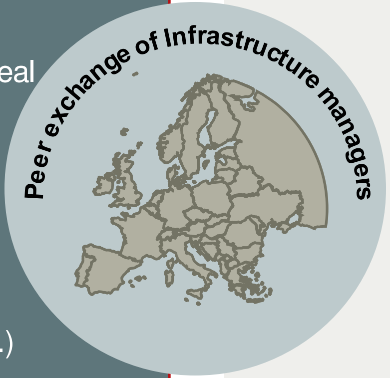
We have built a dedicated framework for high-speed rail; our cost model allows to initially narrow down specific components responsible for high CAPEX spending

Our approach is two-fold, and rests on a peer exchange established among European railway managers

Part 1: civity cost model

- Quantitative assessment of CAPEX sources for real high-speed capital projects
- Costs are benchmarked against data from more than 30 European projects
- Econometric approach to separate costs arising from concept vs. execution
- Unit rate analyses for most important structures (track, earthworks, tunnels, signalling system etc.)

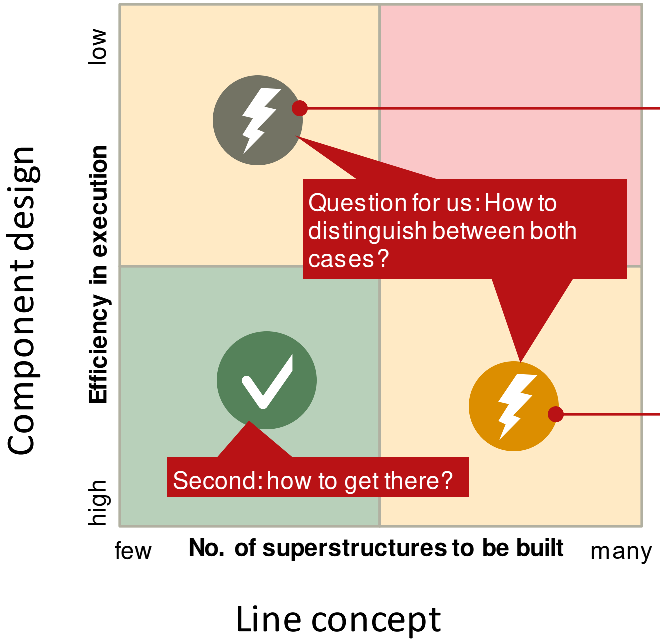


Part 2: exchange of good practices

- Focus on actual saving potentials that are transferable across infrastructure managers
- More than 20 interviews were conducted with ADIF, Bane NOR, DB, SBB, OEBB & Trafikverket
- Identification of good practices for two archetypical high-speed line types
- Illustration of the CAPEX impact for prioritising measures and as input for TCO analyses

Focus for today's talk

Five silver taps cost more than two made of gold – a holistic understanding is needed to discover saving potentials when benchmarking costs of high speed capital projects

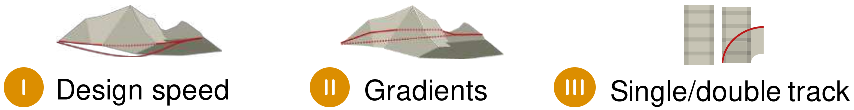


„Conventional" gold-plating

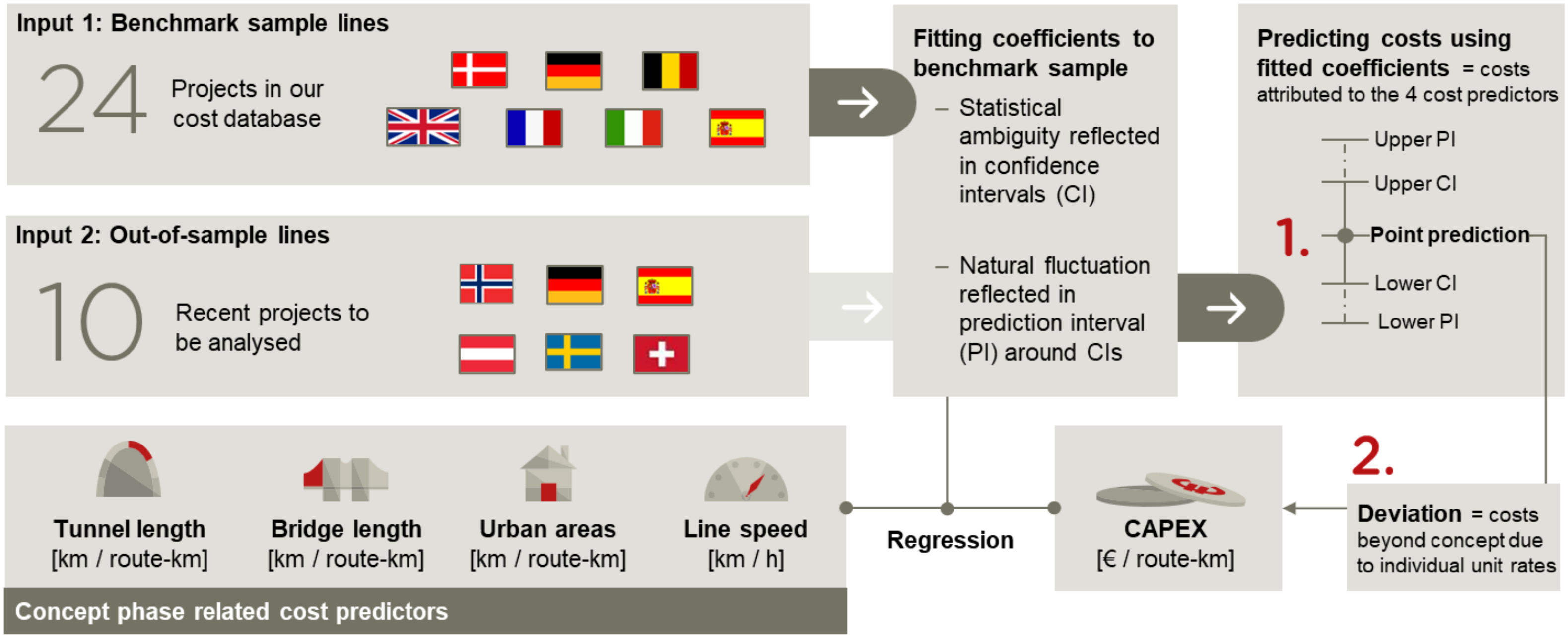
- Project specs that lead to expensive execution (observable as high unit rates for bridges, tunnels etc.)
- Yet, impact of high unit rates is limited if not many superstructures needed

„Ambitious concept" gold-plating

- Projects that do fairly well in execution (low unit rates for bridges, tunnels etc.)
- Yet, even the best executed tunnel costs more than the worst executed daylight zone, hence overall still high costs per route-km if concept is too ambitious.
- Three main drivers:

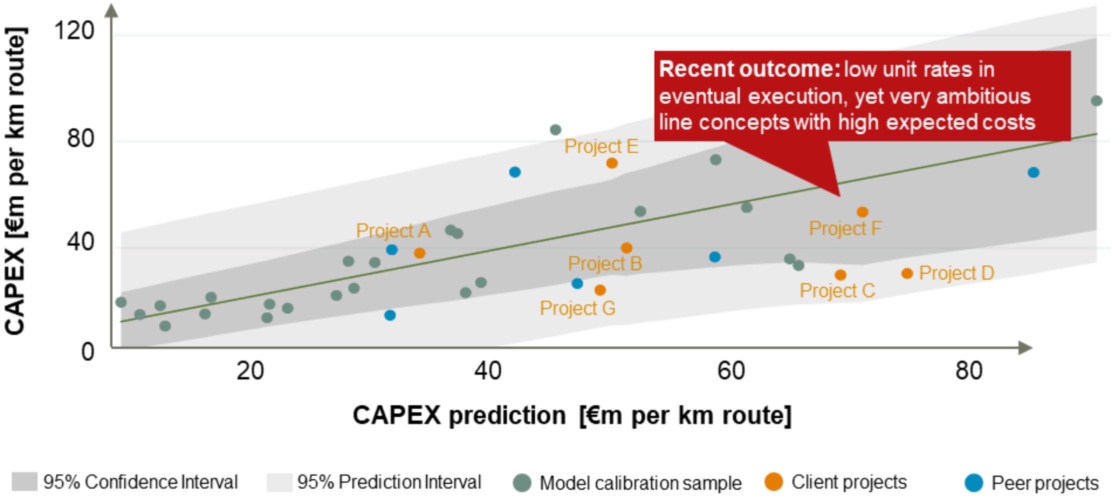


A regression allows us to separate observed CAPEX into a prediction component (if structures were build agnostically), and a deviation from it (due to actual efficiency)

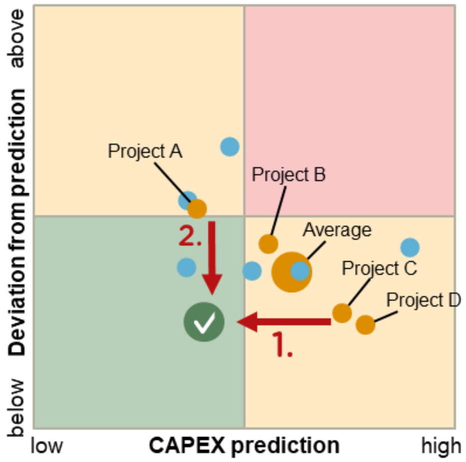


Study example: client's projects increasingly located in the lower right area, indicating rather ambitious concepts; civity identified specific saving potentials with peer group

Example study results (2021)



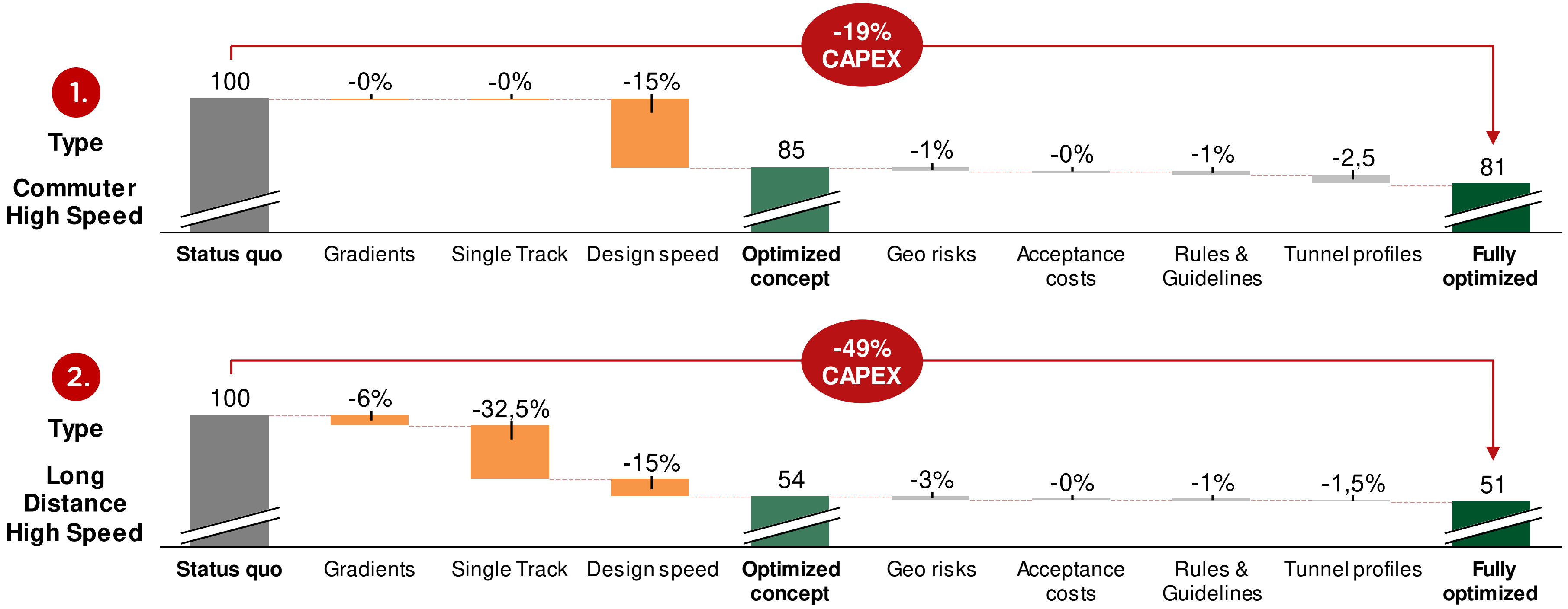
Note: OLS-regression estimated with model calibration sample, with out-of-sample prediction for client projects and peer projects. A point above the green line indicates that eventual costs exceed the costs we would expect considering the share of tunnels, bridges, urban fabric as well as the design speed. All costs normalised and inflation-corrected (2019 PPP-corrected price levels).



Peer project data underpinned assessment of client's potentials in both dimensions

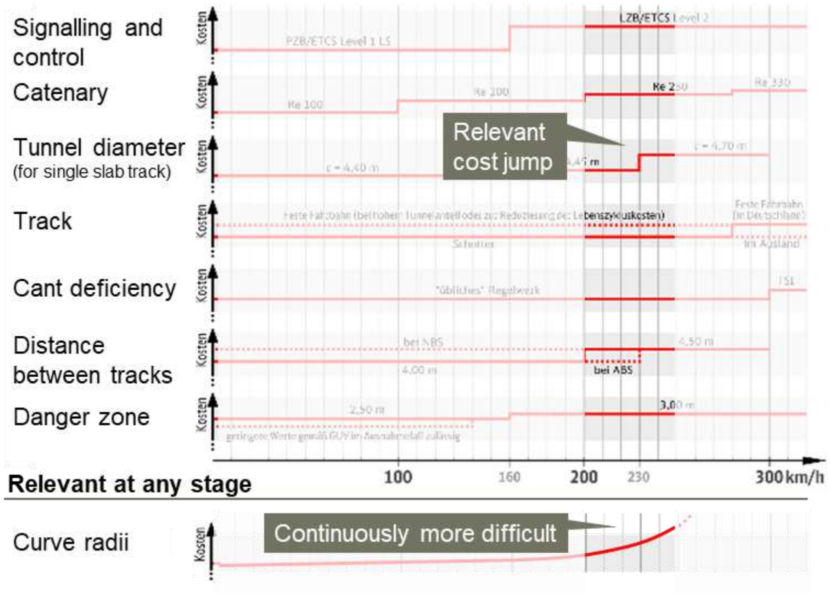
Overall, 12 cost drivers were studied in depth across a peer group of railway managers; all top three CAPEX drivers directly set bounds on the number/length of costly structures needed

Driver-specific measures identified: some lines could be constructed for half the effort from a pure CAPEX view – optimized concept responsible for majority of potentials

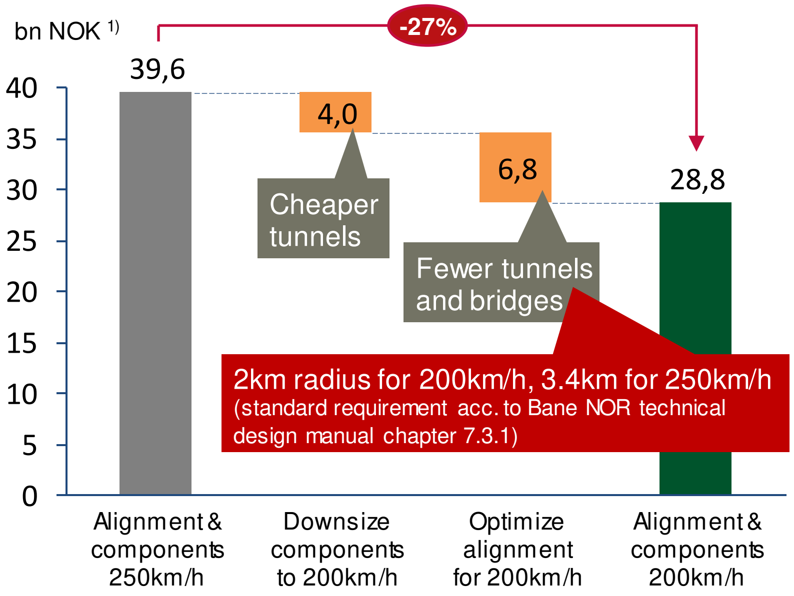


A reduction of design speed to 200km/h helps to align routes reasonably to the landscape for fewer expensive structures, while also their respective components can be further downsized

DB analyses (2021)



Vestfoldline concept study (2012)

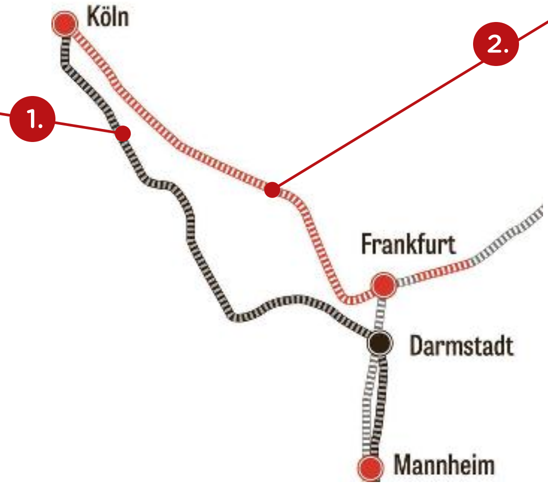


1) Price level as of 2011.

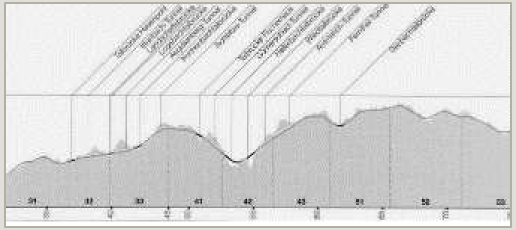
Keeping legacy lines in operation increases overall network capacity, enabling new lines in challenging terrain to be built as passenger-dedicated with much steeper gradients

Legacy line now and then

German Rail maintains the connection from Cologne to Frankfurt/Main with two lines



New high-speed line



a.k.a. „The Westerwald rollercoaster“ due to gradients up to 40‰

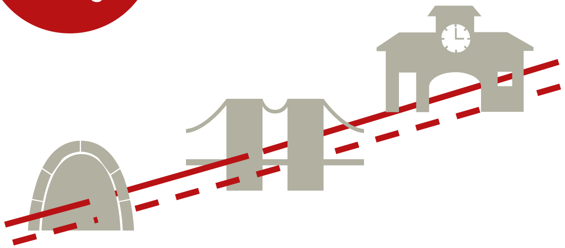
Image credits: Top left ; Bottom left ; Middle ; Top right ; Bottom right

Consider single-track enhancements in line with corresponding capacity requirements

ADIF Antequera – Granada line

Constructions prepared for a second track, just not rolled out yet

25% indicative saving

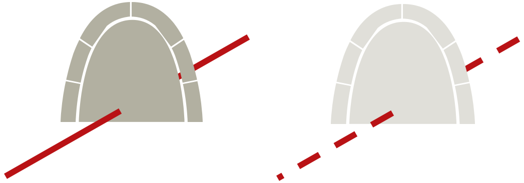


- Relevant investments in structures for second track already spent
- Flexibility for later upgrade to double track

ÖBB Karawankentunnel[2)]

Single track structures; construction for second track to be build separately if once required

40% indicative saving



- CAPEX spending in line with capacity needs
- No possibilities for passing trains on the entire segment

Promising new approaches: ADST

Alternate double–single track (ADST)

35% indicative saving

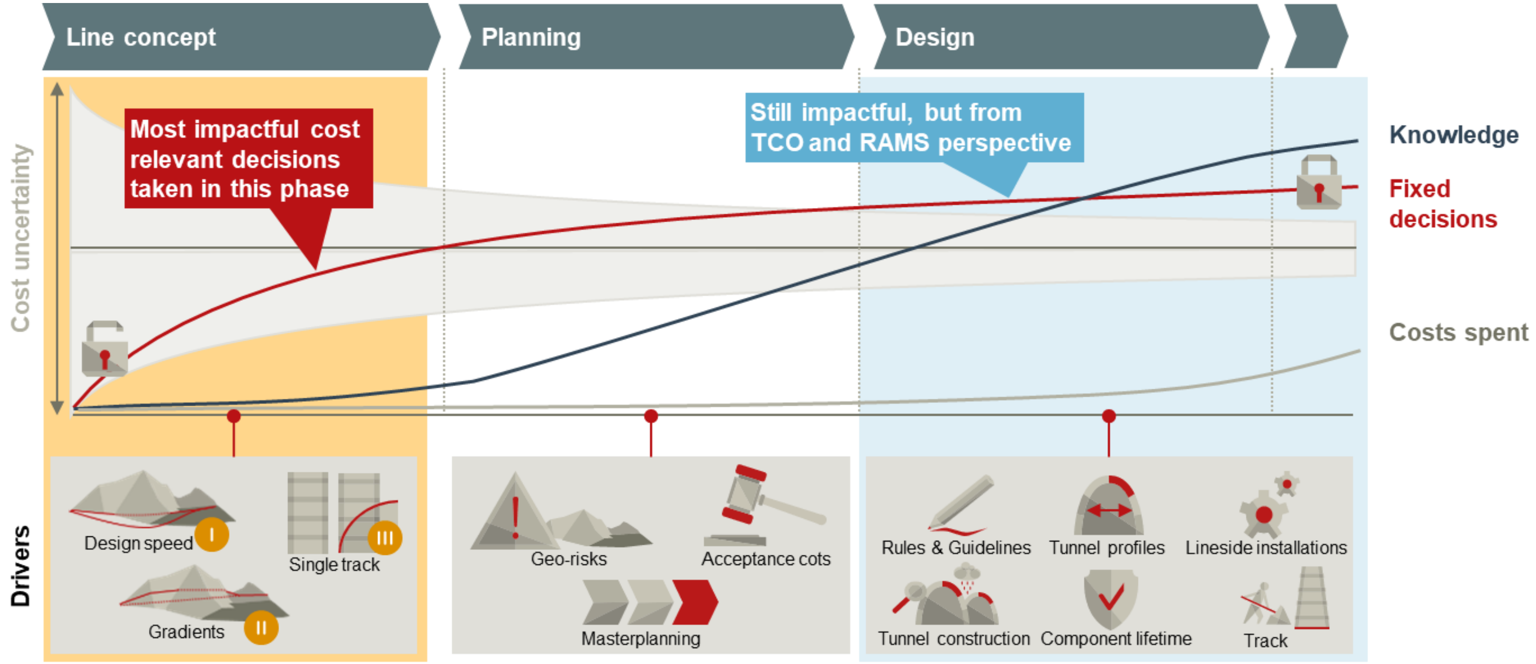
- single track where infra-structure is especially ex-pensive (tunnels/ viaducts)
- double track where it is cheaper

Suggested by a Spanish study[1)] for traffic demand up to 30 - 40 trains per day

- CAPEX spending in line with capacity needs
- Favourable for operations from a RAMS perspective

1) www.researchgate.net/publication/262773330_An_Alternate_Double-Single_Track_Proposal_for_High-Speed_Peripheral_Railway_Lines 2) here: double track demounted in favour of broader gauge

Most importantly, many design choices are already locked after the concept phase and their direct CAPEX impact is limited – instead, TCO/RAMS perspectives relevant for the latter



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Optimal Speed of High-Speed Lines

focus: maintenance costs & predictive maintenance

Dr. Hassan Alsalamat
Director Rolling Stock & Maintenance, Deutsche Bahn Engineering & Consulting, Germany
Session1-1.1 Economy / Rail business model

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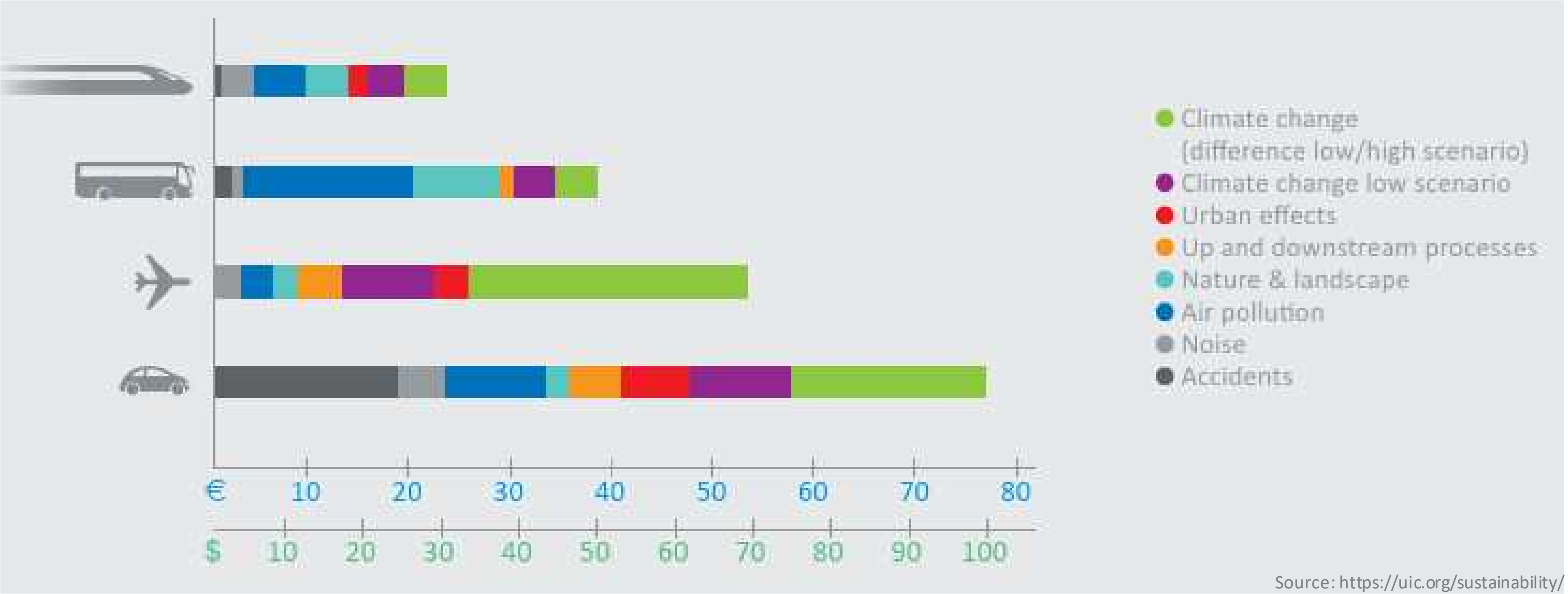
Railway is the most efficient transport form in comparison to Car, Bus and Aeroplane

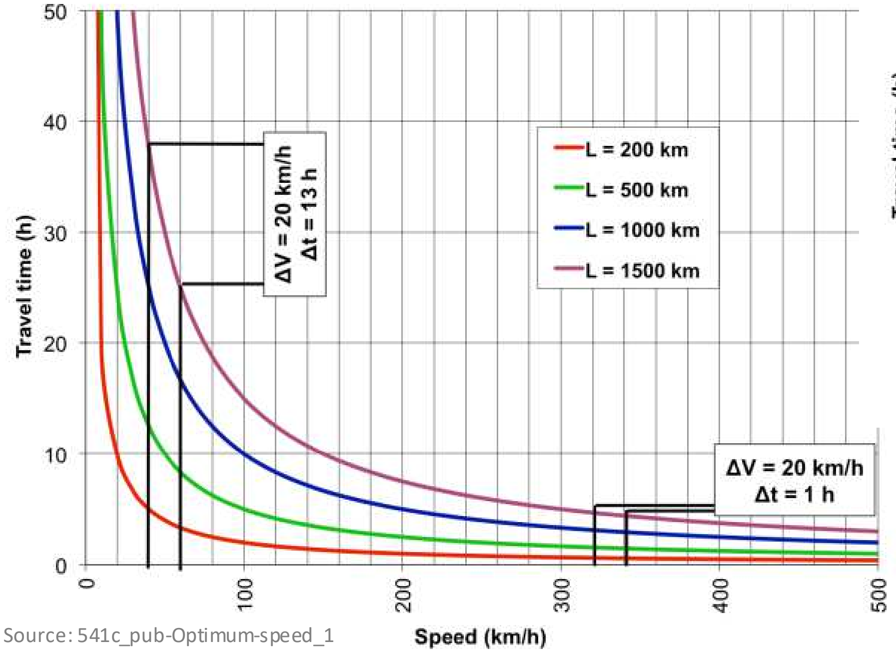
Average external costs per transport modes (per 1,000 passenger-kilometres)



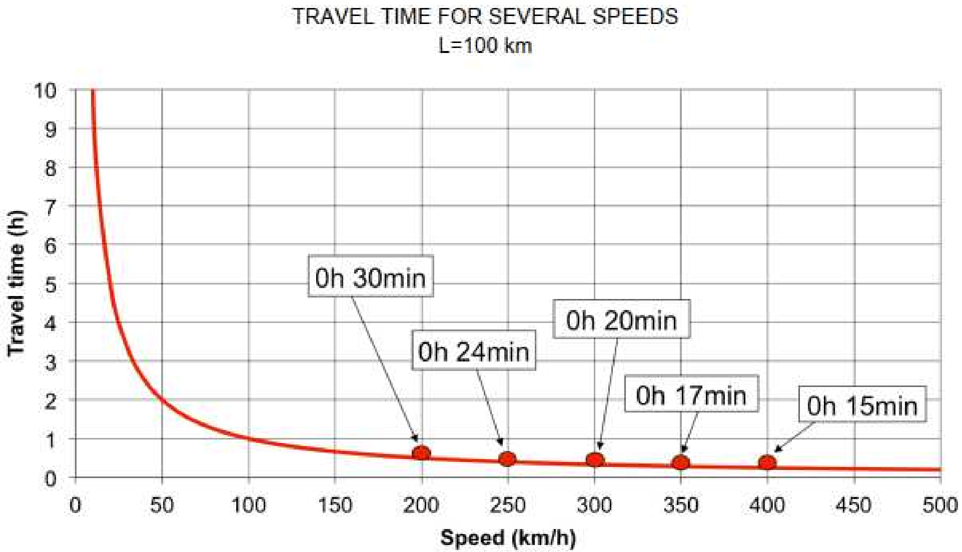
Source: https://uic.org/sustainability/

Speed efficiency regarding time reduction

Chose the right speed according to different factors

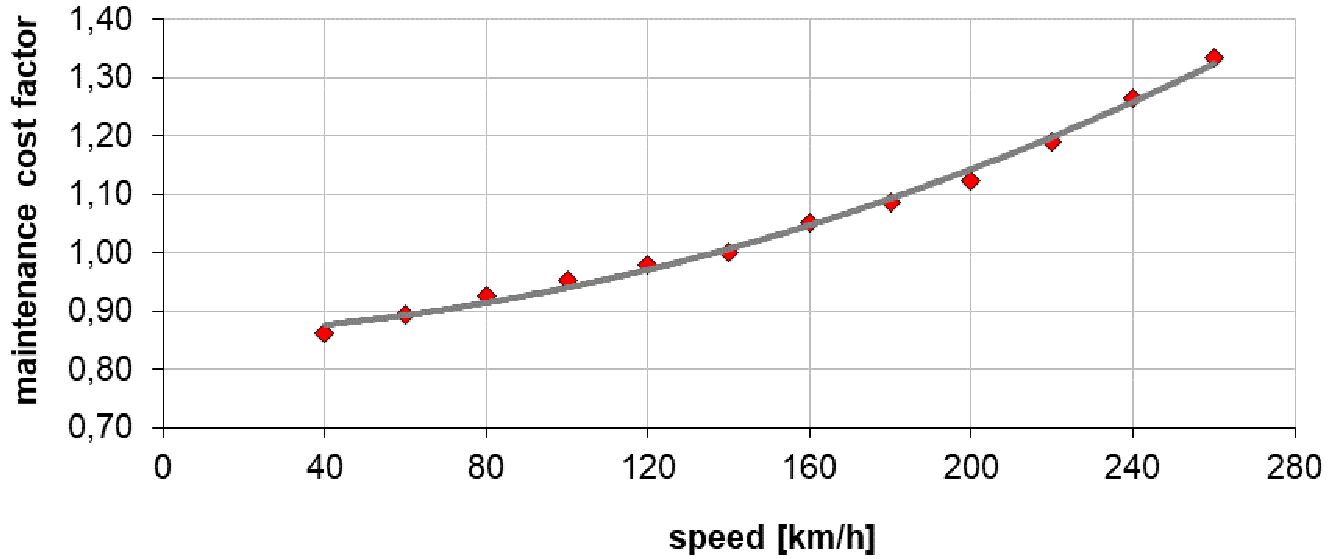


Source: 541c_pub-Optimum-speed_1



Maintenance cost of the track increase exponentially with the speed

We have to find the optimal speed for a an economically effective operation of high-speed lines

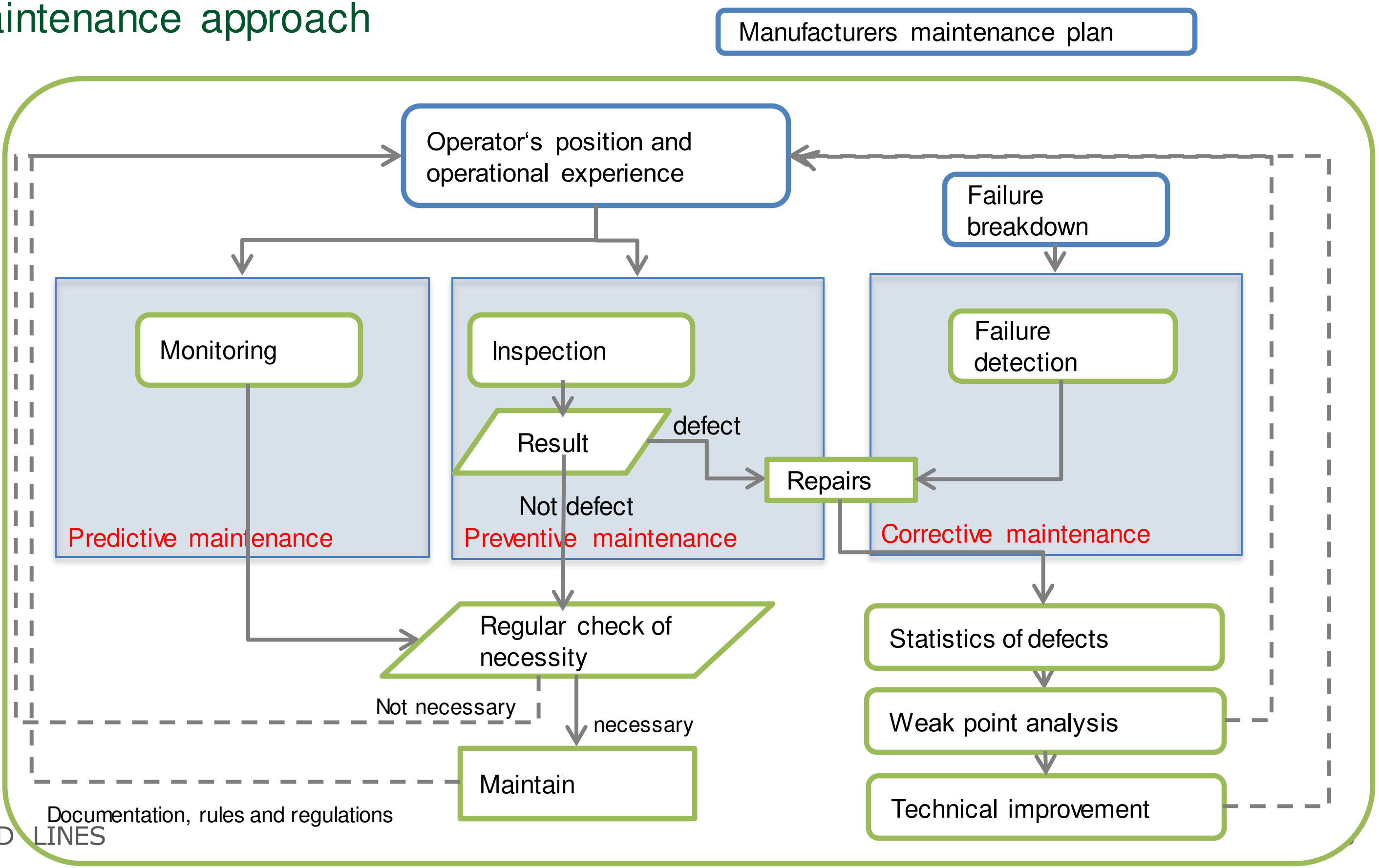


Source: Own Diagramm

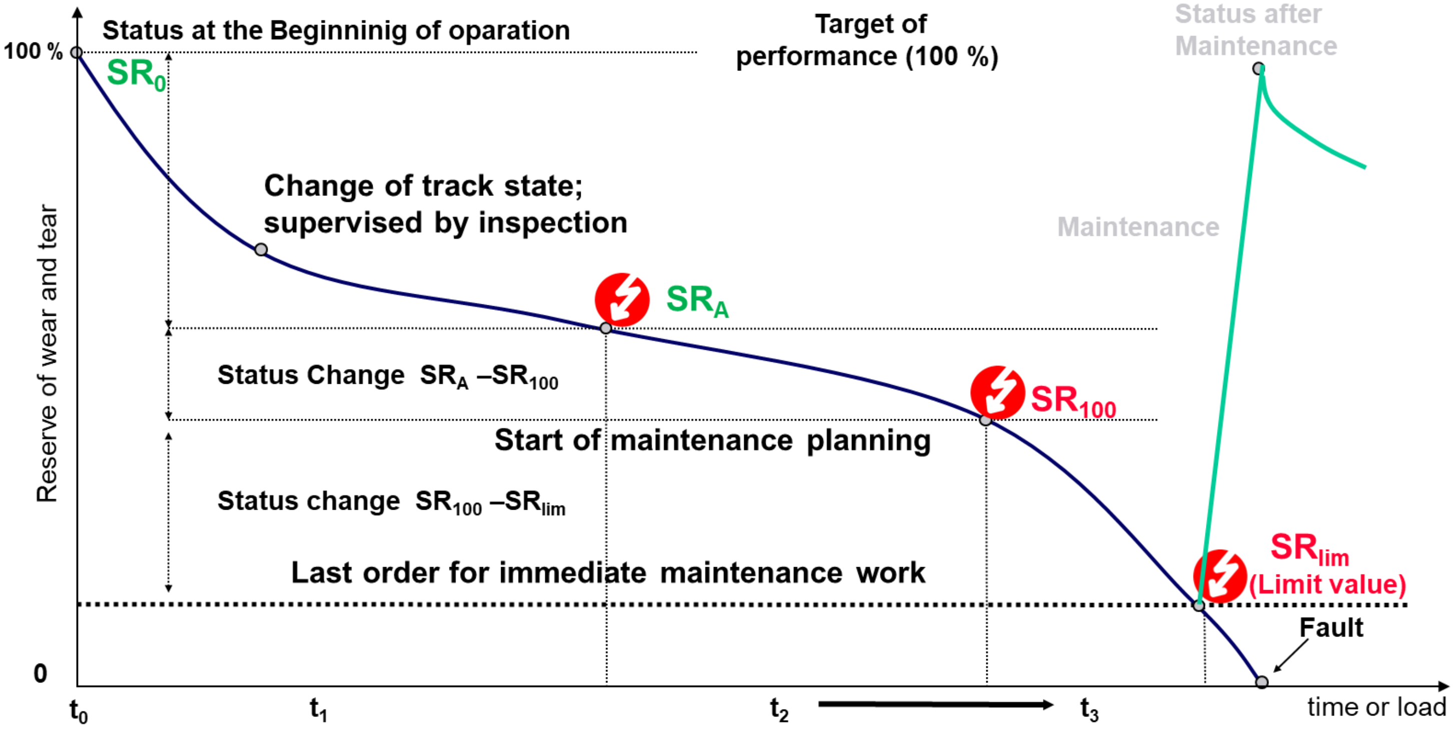
Choosing the right maintenance approach

Minimize the operational disruptions through predictive maintenance

- The maintenance focus will be on the left (predictive maintenance) and middle (preventive maintenance) parts of the diagram for maintenance approach. The right part (corrective maintenance) will be minimized as far as possible



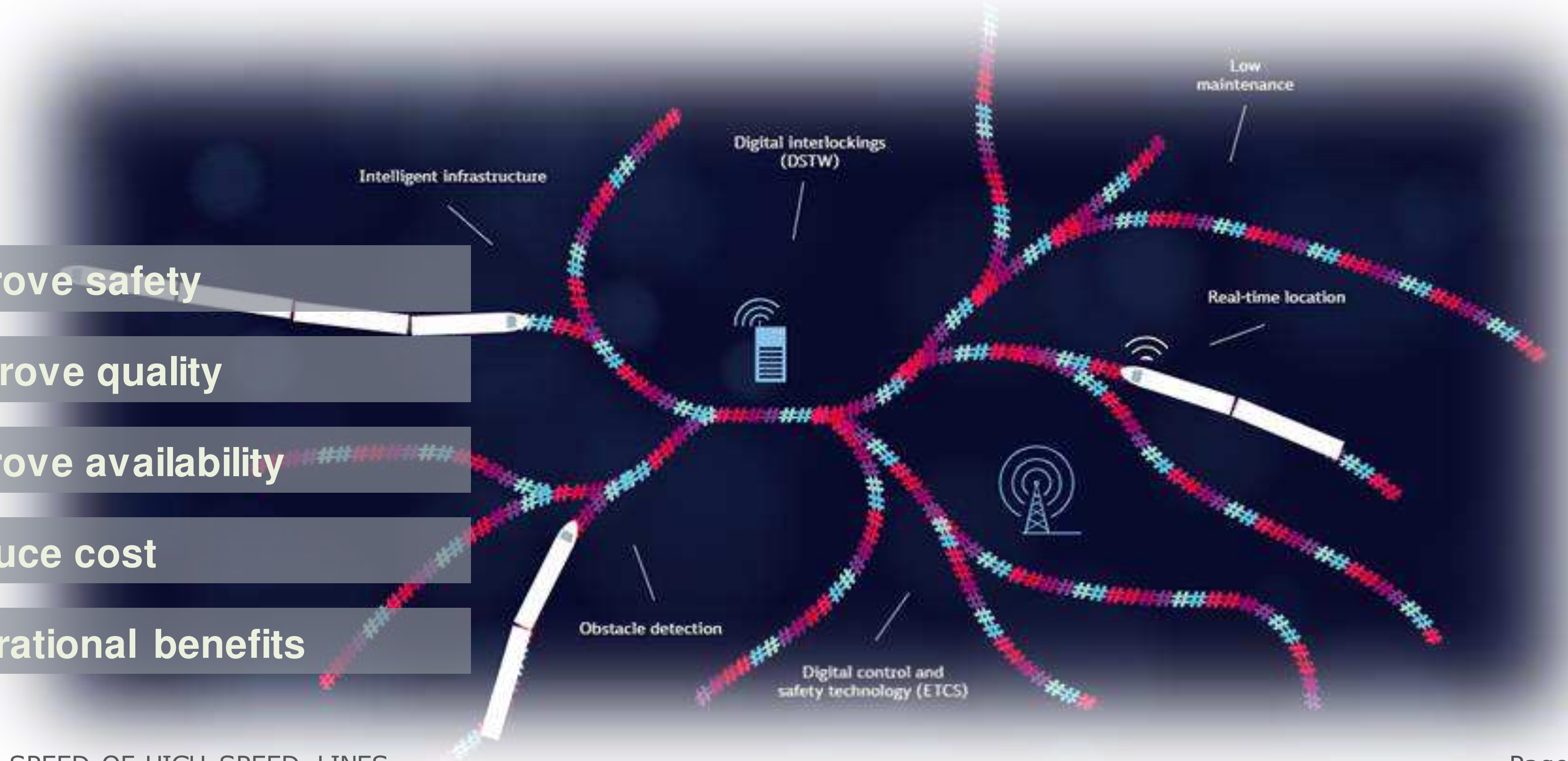
Finding the optimum of inspection or maintenance and repair effort and system performance



SR: Falt and reaction limits

Condition Monitoring is a key factor:

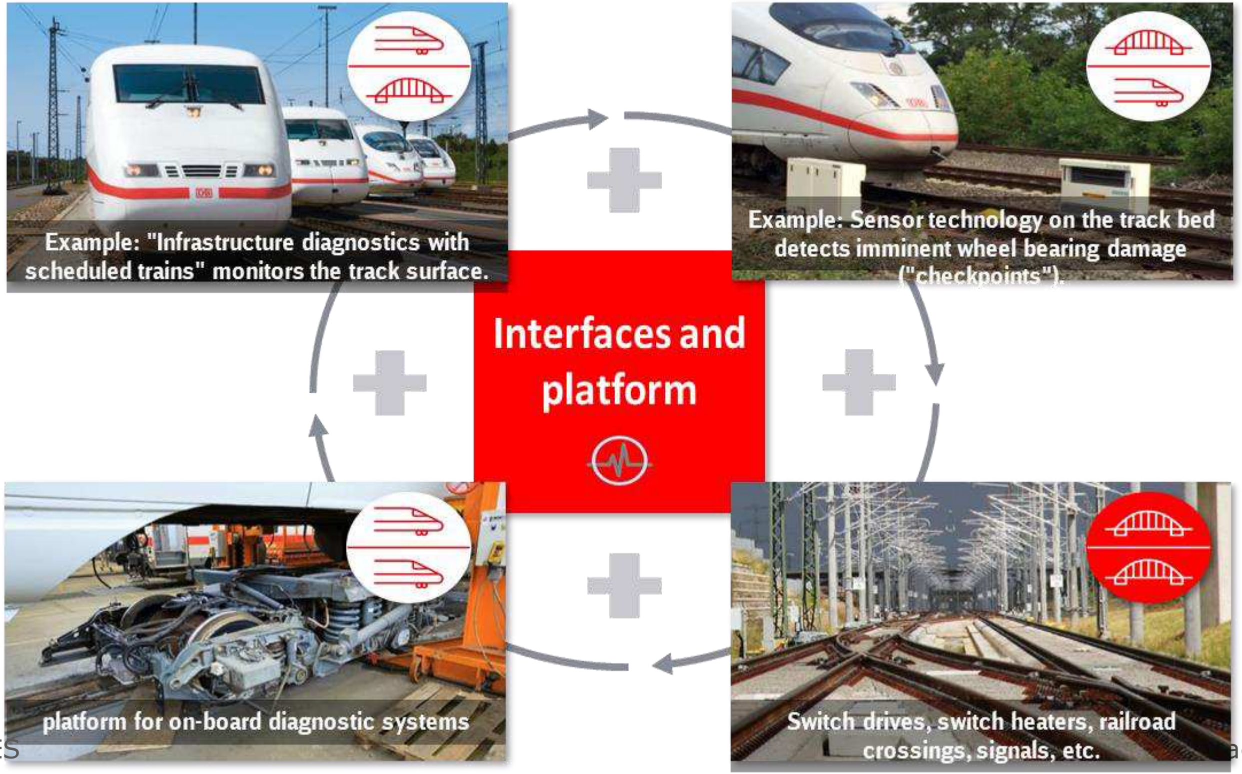
- Improve safety
- Improve quality
- Improve availability
- Reduce cost
- Operational benefits



The use of a unified platform for the whole asset management system is beneficial for vehicle and infrastructure maintenance within DB

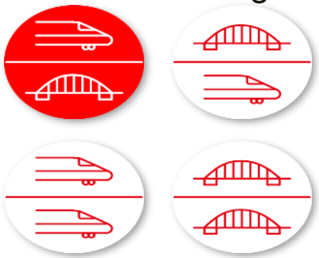
Way side or train borne asset 4 cluster monitoring systems:

- ❖ Train - Infra
- ❖ Infra - Train
- ❖ Train - Train
- ❖ Infra - Infra



The use of a unified platform for the whole asset management system is beneficial for vehicle and infrastructure maintenance

Vehicle monitoring Infrastructure



Scheduled train and test train systems

- Infrastructure diagnostics from a scheduled train (track, overhead line)
- Regular inspection by self-propelled track recording cars (complete range of track geometry and vehicle responses)

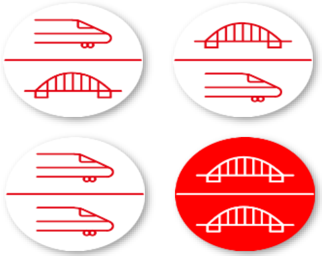
- Continuous monitoring of the track geometry from the scheduled train and concise preparation of the measurement results for asset officers
- Separate analyses for measurements in switch zones
- Ability to equip railway vehicles in scheduled operations
- Driving comfort analyses, identification of infrastructure or vehicle errors

Benefits/Reference

- Continuous monitoring of track geometry quality in the network
- The condition forecast for track geometry quality makes it possible to specifically plan route repairs (direct supply to the asset officers).
- Checks to assess repair quality and sustainability
- Use of a measurement system for different vehicle series

The use of a unified platform for the whole asset management system is beneficial for vehicle and infrastructure maintenance

Infrastructure self-monitoring



Infrastructure systems

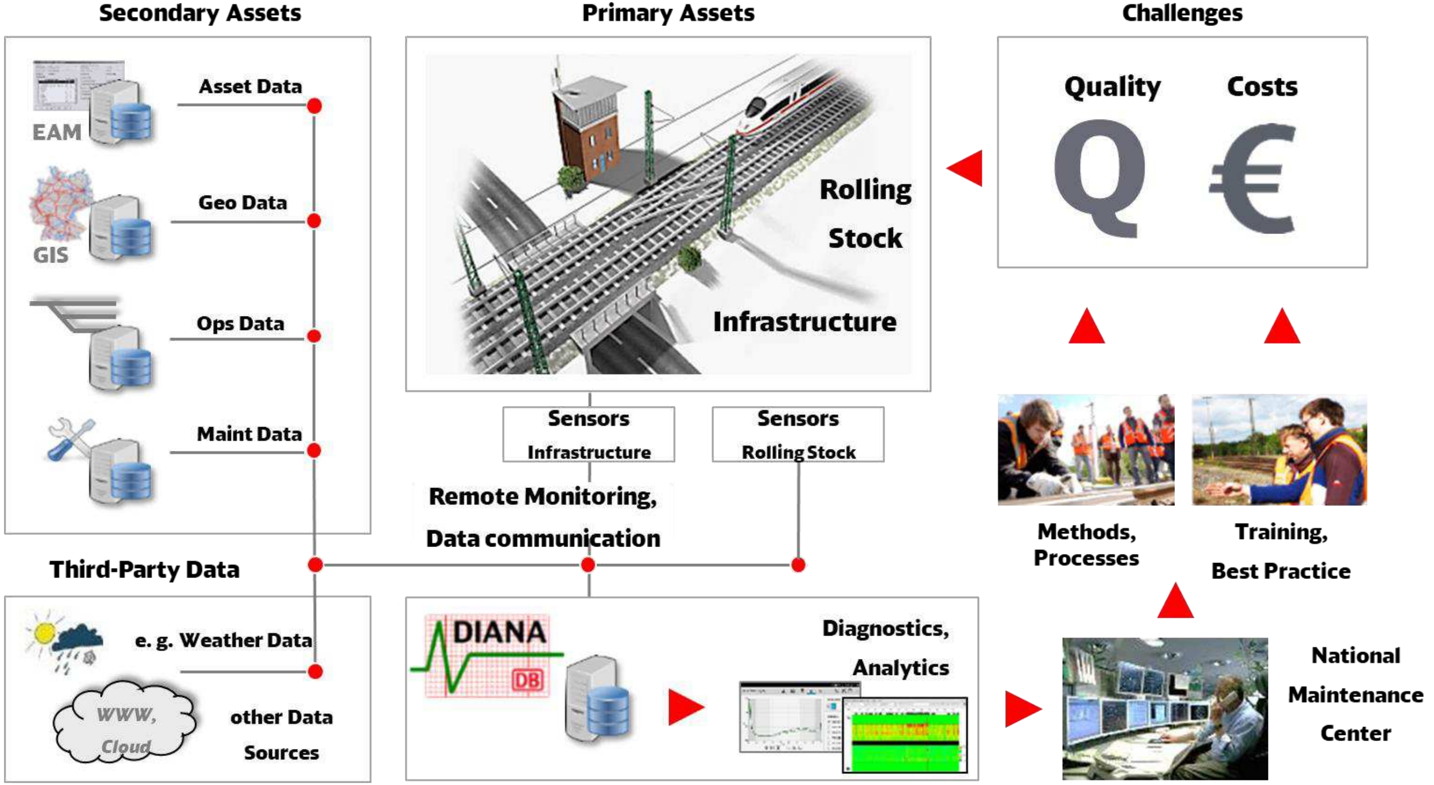
- Point diagnostics
- Switch heater monitoring and control
- Railroad crossing diagnostics

- Monitoring and diagnosis of infrastructure components within the portfolio for the following equipment types: switches, switch heaters and railroad crossings.

Benefits/Reference

- Faster fault repair
- Preventing wear and tear
- Forecasts for imminent incidents
- Adapter available for existing solutions
  - voestalpine
  - Strukton
- Additional equipment types possible
- Dependency analysis

Integration: as many as possible data from different sources for optimized maintenance



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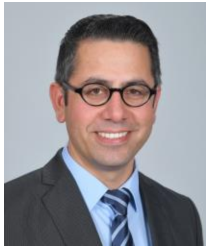

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Demand Analysis in High Speed Rail (HSR): calibration of run choice model on the relationship Rome-Milan (Italy)

Francesco, Russo
Full Professor, DIIES-Università Mediterranea di Reggio Calabria, Italy
Session1-1.1 Economy / Rail business model

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Motivation

- Agenda 2030 for Sustainable Development - Goal 9 – Statement 9.1: “.. infrastructure to support economic development and human well-being, with a focus on affordable and equitable access for all”
- Support decision-makers in evaluation of investments in HSR lines and of operative services planning

Objective

- HSR travel demand models simulating the run choice among existing alternatives by users
- Procedure for the identification of users’ choices on the dimension of the run

Actvities

- Choice set construction and individual choice identification
- Specification, calibration and validation of run choice models on the Rome-Milan relationship

Travel demand models

- **Disaggregated** (single user)
- **Aggregated** (group of users)

Demand flows
from traffic counts
(Cascetta & Nguyen, 1988)

Demand models' parameters
from traffic counts
(Cascetta & Russo, 1997)

Consistent demand and
supply models' parameters
from traffic counts
(Russo & Vitetta, 2011)

Research contribution

Demand models' parameters
from travel costs
(e.g. variation of travel tickets, …)

HSR demand components

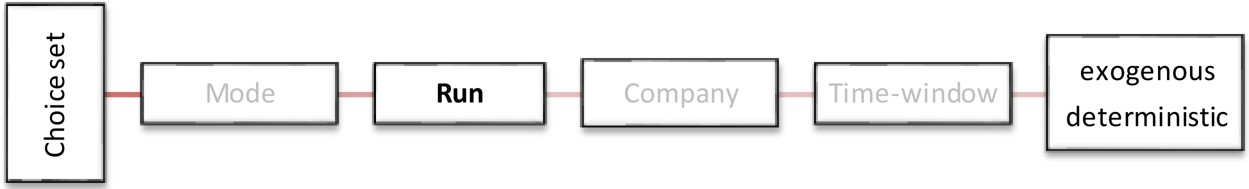
Diverted	from other modes	e.g. shift from air/auto to HSR	endogenous factor
	from other rail services	e.g. shift from Intercity to HSR	
Induced	direct	e.g. changes of trip frequency, destination or related activity pattern	
	indirect	e.g. increase of mobility due to change in life-style and land use	exogenous factor
Economy-based		e.g. decrease/increase of the overall mobility due to economy trends	

(Ben-Akiva et al., 2010)

Four-step procedure (users' run choices)

- Choice set generation
- Choice identification
- Choice model specification
- Choice model calibration

Choice set generation



- Choice set of runs of HSR service, selecting runs exogenously according to deterministic criteria.

Choice identification

- **Step 1**: Individual changes of ticket costs

  $\Delta \mathbf{C}_{k+1}(r,w)=\mathbf{C}_{k+1}(r,w)-\mathbf{C}_{k}(r,w)$

  $c_k(r,w) = \{ 0, \text{ if } \Delta \mathbf{C}_{k+1}(r,w)=0 \; ; 1, \text{ if } \Delta \mathbf{C}_{k+1}(r,w)\neq 0 \}$

- **Step 2**: Number of changes in ticket costs

  $N_k(r) = \Sigma_w \, c_k(r,w) \leq N_k$

  $N_k = \Sigma_r \, N_k(r)$

- **Step 3**: Identification of chosen run r by user i: r(i)

  $r(i): N_k(r) \neq 0$

  w = ticket cost; r = run; k = day

Choice model specification

- Random Utility Model (RUM):

$$p^i_r(\beta) = \text{Prob}\,(U^i_r(\beta) > U^i_{r'}(\beta))\ \forall\, r' \neq r,\ r \in R$$

- Logit model specification:

$$p^i_r(\beta) = \exp\,(V_r(\beta)) / \Sigma_{r'=1 \dots n} \exp\,(V_{r'}(\beta))$$

Choice model calibration

$$\boldsymbol{\beta}^* = \max \ln L(\boldsymbol{\beta})$$

$$L(\boldsymbol{\beta}) = \Pi_{i=1 \dots n}\,(N_k(r) / N_k)\ p^i_r(\boldsymbol{\beta})$$

Rome-Milan HSR relationship (Italy)

1. Aggregate survey (time series)
Steps: A-B-C

2. Disaggregate survey (users' choice)
Steps A-B-C-D-E

A. Daily ticket costs survey

B. Daily ticket costs coding

C. Changes of ticket costs

D. Users' choice identification

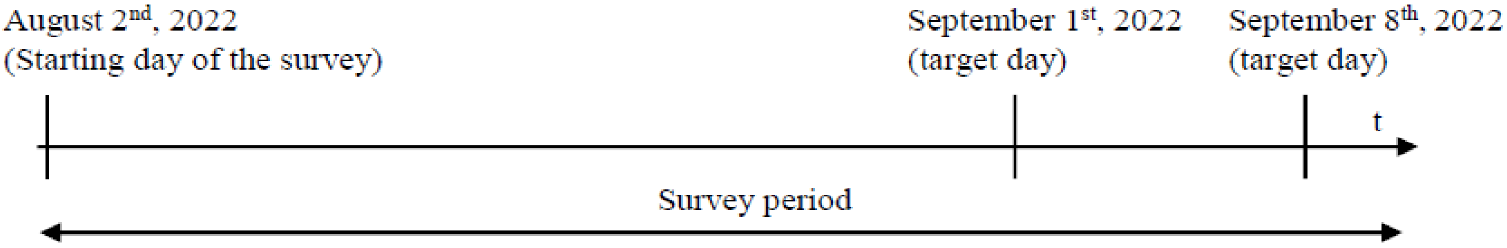
E. Choice model calibration

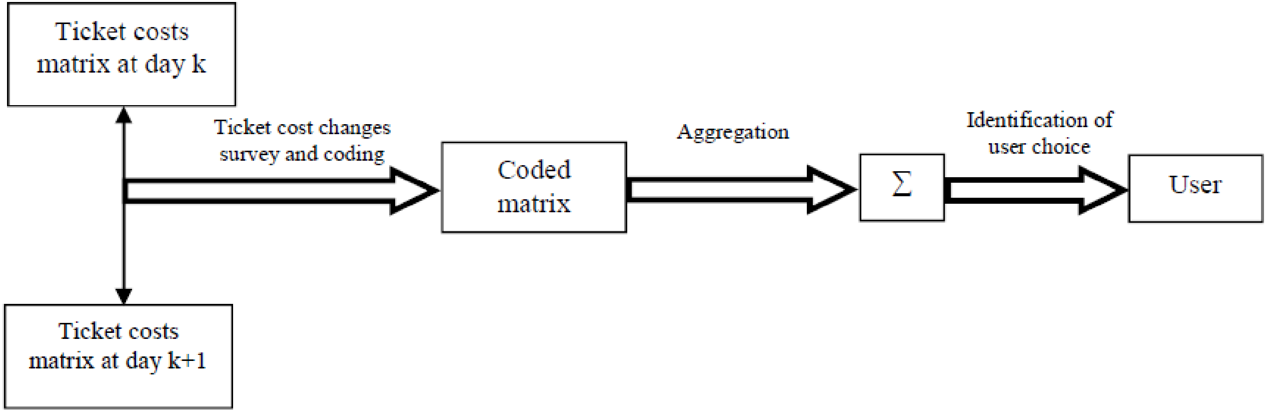
❖ Rome-Milan (477 km)

Trenitalia	33 run/day
Italo NTV	32 run/day
Flows 2008 (Trenitalia)	1,0 mln pax
Flows 2018 (Trenitalia)	3,6 mln pax

2. Disaggregate survey (users' choice)
Steps A-B-C-D-E

D. Users' choice identification





E. Choice model calibration

β_{stop}	β_{time}	$\beta_{penalty}$	$\beta_{cost\leq7}$	$L(\mathbf{0})$	$L(\beta^*)$	ρ^2	$\bar{\rho}^2$
4,53	-12,47	0,45	-0,01	-21,96	-21,05	0,04	-0,10

- stop, number of intermediate stops between the departure and arrival stations
- time [h], travel time from the origin to the destination, calculated as the difference between arrival time and departure time at the stations
- penalty [h], difference between Desired Arrival Time (DAT) and the run arrival time at the station (given a DAT)
- cost≤Q [€], (average) ticket cost associated to a run available in the Q(=7) days preceding the target day (i.e. users who choose inside the Q days before the target day)
- $\rho^2 = 1 - (\ln L(\boldsymbol{\beta}^*)) / (\ln L(\mathbf{0}))$
- $\bar{\rho}^2 = 1 - (\ln L(\boldsymbol{\beta}^*) - N_\beta) / (\ln L(\mathbf{0}))$

- **Main results**
  - Estimation of demand models' parameters from travel costs
  - Procedure for the identification of users' HSR run choice from evolution tickets' costs
  - Experimentation on the Milan-Rome relationship (Italy)

- **Advantages**
  - Effort reduction in surveys' execution, quite expensive in terms of time and cost, with automatic extraction and storage of users' choices
  - Use of reverse assignment calibration according to assigned distributions of available seats

- **Limitations**:
  - Hybrid nature procedure: aggregate for attributes and disaggregate for observed choices of users
  - Unknown number of users that "caused" the change of the ticket cost (unknown "weight" associated to observed choice)

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Track Access Charge reductions to promote rail traffic growth: two possible European approaches

Speaker: G. Sitongia (RFI, Italy)

Session1: 1.1 Economy / Rail business model

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APPLYING TAC REDUCTIONS IN A REGULATED MARKET

IMs elaborate a Track Access Charge (TAC) for the provision of the basic service which is set at **direct cost** of operating the train service and, if the market can bear this, **mark-ups**. To guarantee competition and therefore to achieve the modal shift, IM could set **discounts on the TAC**, bearing in mind the following constraints:

Non-discrimination for different RUs that perform services of an equivalent nature

Balancing costs and revenues (including government funding and other revenues) over a multi-year period

In order to plan services efficiently, RUs need to know the **TAC sufficiently in advance**

Compatibility of traffic increases with the infrastructure **capacity** and with the expected **transport plan**

IM would need to have a **more commercial and not just an administrative approach**: considering the constraints, applying discounts in a regulated market is not easy!

TAC REDUCTIONS: LEGAL FRAMEWORK

Directive 34/2012 Art. 33 «Discounts»

IMs may introduce schemes available to all users of the infrastructure, for specified traffic flows, granting **time-limited** discounts to encourage the development of **new rail services**, or discounts encouraging the use of **considerably underutilised** lines. Discounts may relate only to charges levied for a **specified infrastructure section.** Discount schemes shall be applied in a **non-discriminatory manner** to any RU

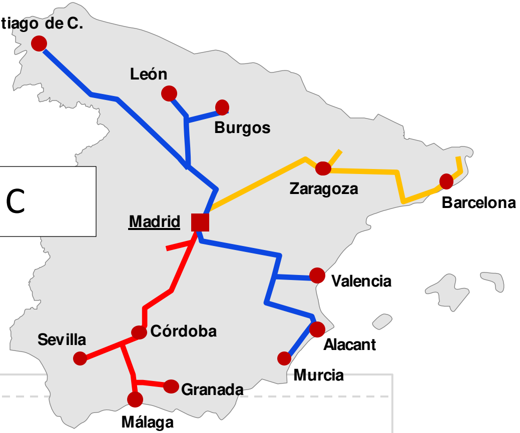
Rail Sector Act (Law 38/2015)

- The IM must set a reference traffic and a target traffic (higher) for each line.
- For each line, it also sets the maximum amount of the bonus applicable if the reference traffic is exceeded.

Decision ART 96/2015 e 140/2017

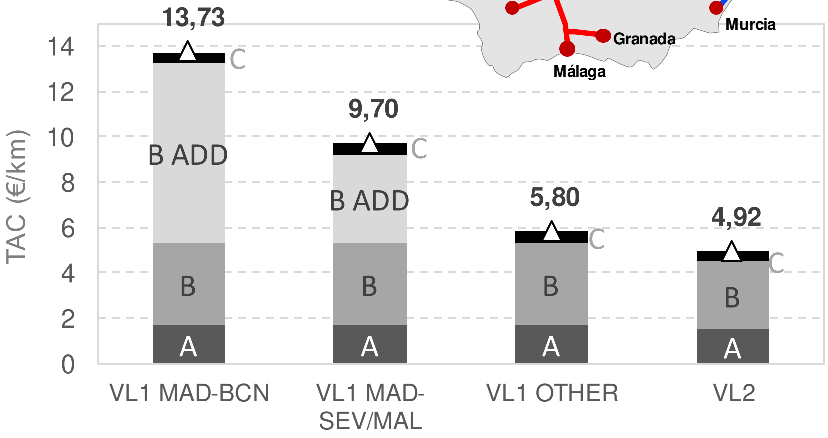
- The IM must identify the train paths to be discounted (catalogue)
- IM submits the catalogue to Regulatory Body (ART) 40 days before publication
- IM publishes the catalogue 9 months before the start of the annual timetable, if approved by ART

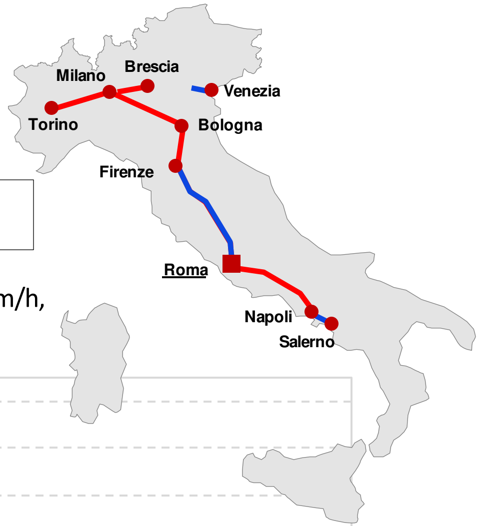
TRACK ACCESS CHARGE FOR HIGH SPEED SERVICES IN SPAIN AND ITALY



$$TAC = A + B + B_{ADD} + C$$

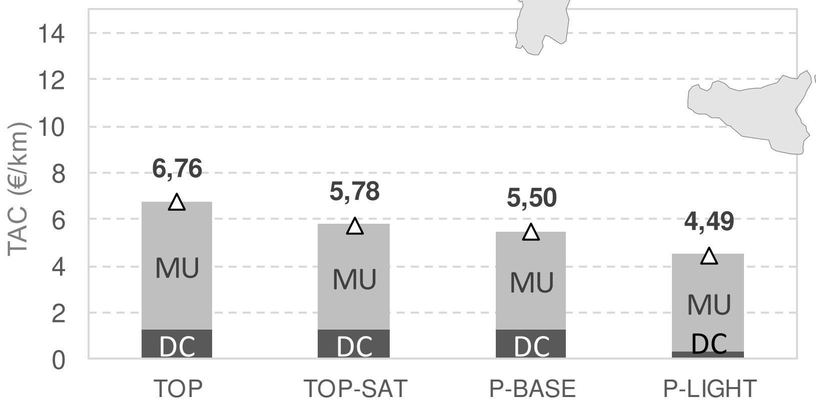
Hp: 450 seats offred





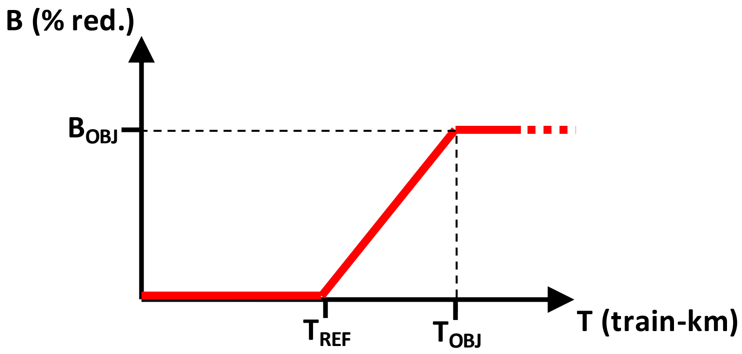
$$TAC = DC + MU$$

Hp: Weight < 500t, Op. Speed >150 km/h, Single composition



Source: Elaborated by the authors from ADIF, ADIF AV and RFI NS 2023

REDUCTION SCHEMES FOR HIGH SPEED SERVICES IN SPAIN



- T_{REF} [trainkm] is the <u>reference traffic</u> (set by IM according to the situation pre-existing or its foreseeable evolution)
- T_{OBJ} [trainkm] is the <u>target traffic</u> (determined by IM according to its expectations of market)
- B_{OBJ} [%] is the <u>target bonus</u> percentage applicable when the target traffic is reached and exceeded.

If there are more RUs:

- the traffic increase [trainkm] due to RU (**I_{RU}**) can be calculated:

$$I_{RU} = (T - T_{REF}) \cdot \frac{T_{RU}}{T}$$

- The discount [€] that the RU will receive (**D_{RU}**) on that section will be:

$$D_{RU} = B \cdot \left(TAC_{RU} \cdot \frac{I_{RU}}{T_{RU}}\right)$$

Note: if the traffic increases each IF will receive the bonus. This implies that no bonus is given to the RU that takes traffic from a competitor (if the total traffic is stable).

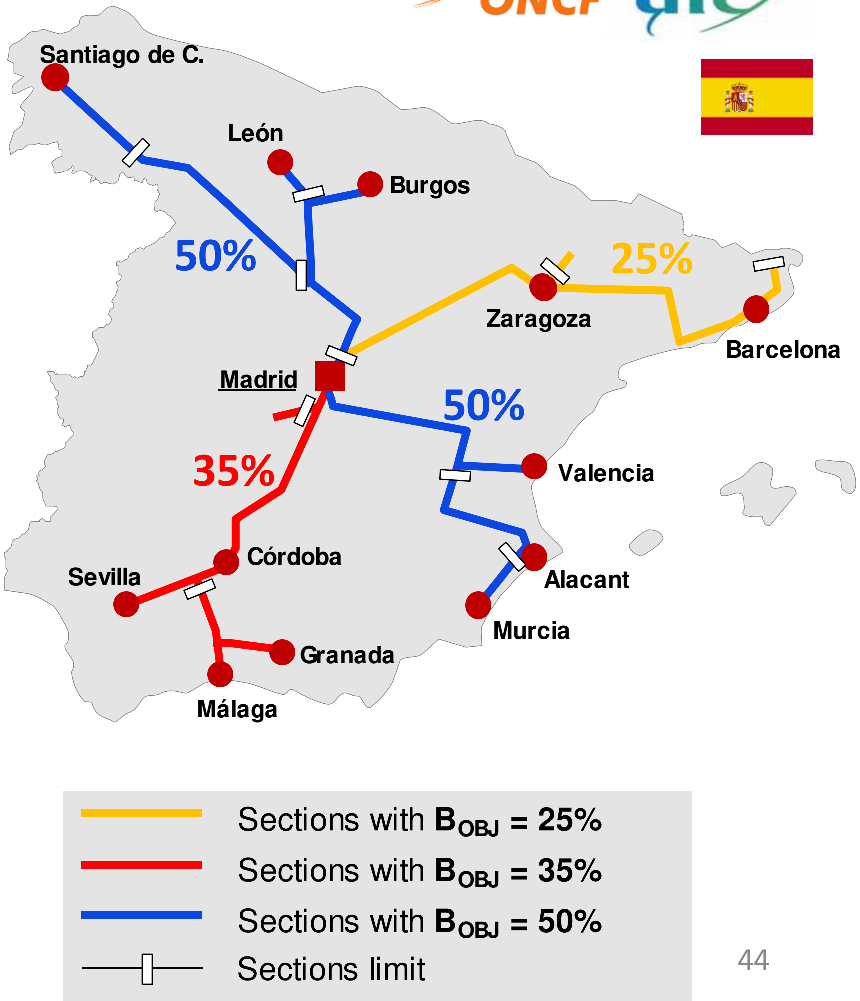
BONUS VALUE IN SPAIN

The Infrastructure Managers (ADIF AV and ADIF) have identified 13 sections of the High-Speed lines for which T_{REF}, T_{OBJ} and B_{OBJ} are provided for each market segment (VL1, VL2, VL3 etc.)

The map shows the sections with the corresponding the B_{OBJ} bonus target

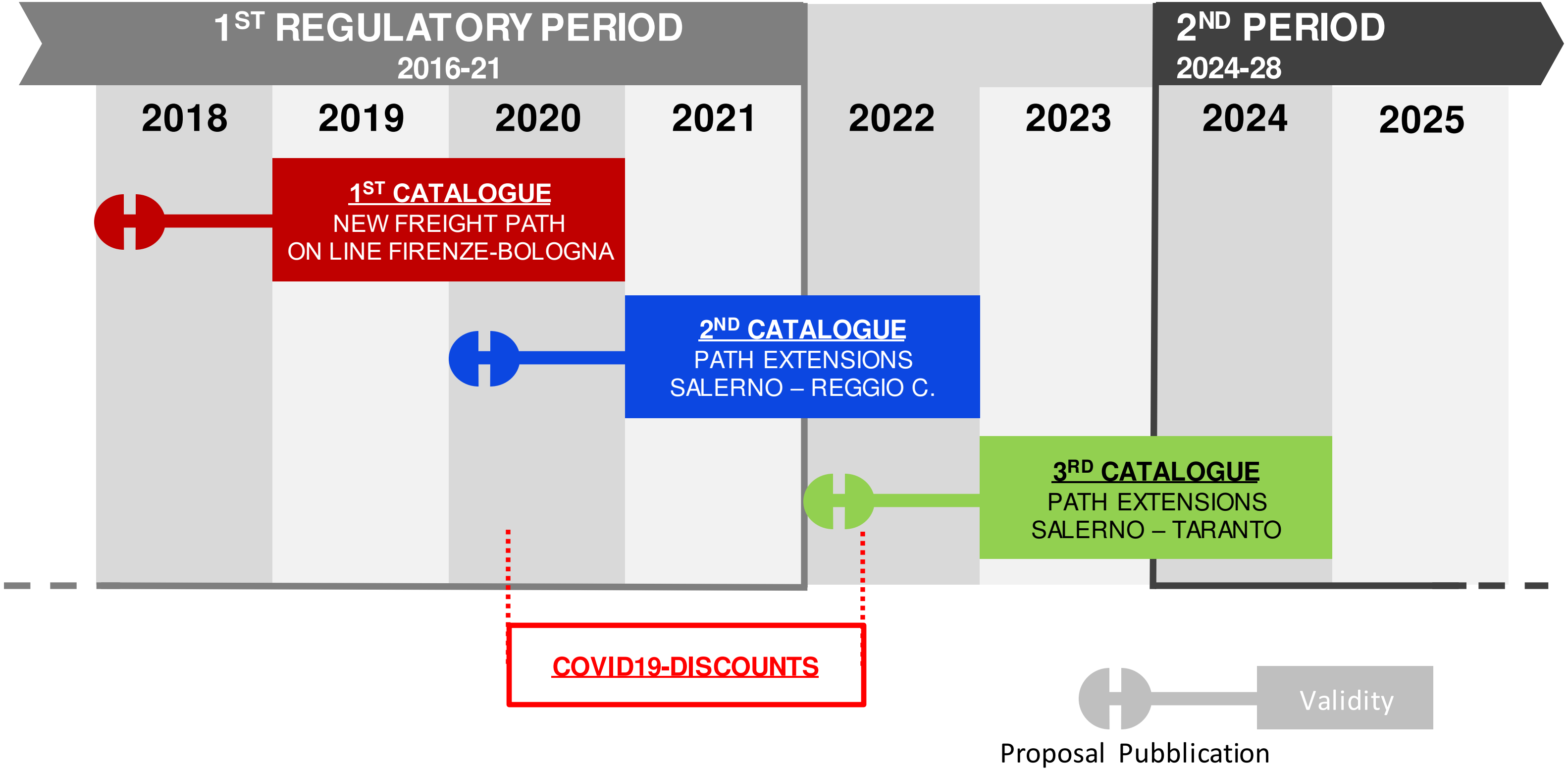
B (%) will apply to **modes A and B of the TAC**

Section	T_{REF} [mln Tr-km] VL1	T_{OBJ} [mln Tr-km] VL1	B_{OBJ}
050 Madrid – Frontera Francia	16,72	18,39	**25%**
010 Madrid – Sevilla	8,71	9,57	**35%**
040 Madrid – Valencia	9,07	9,98	**50%**
…	…	…	…

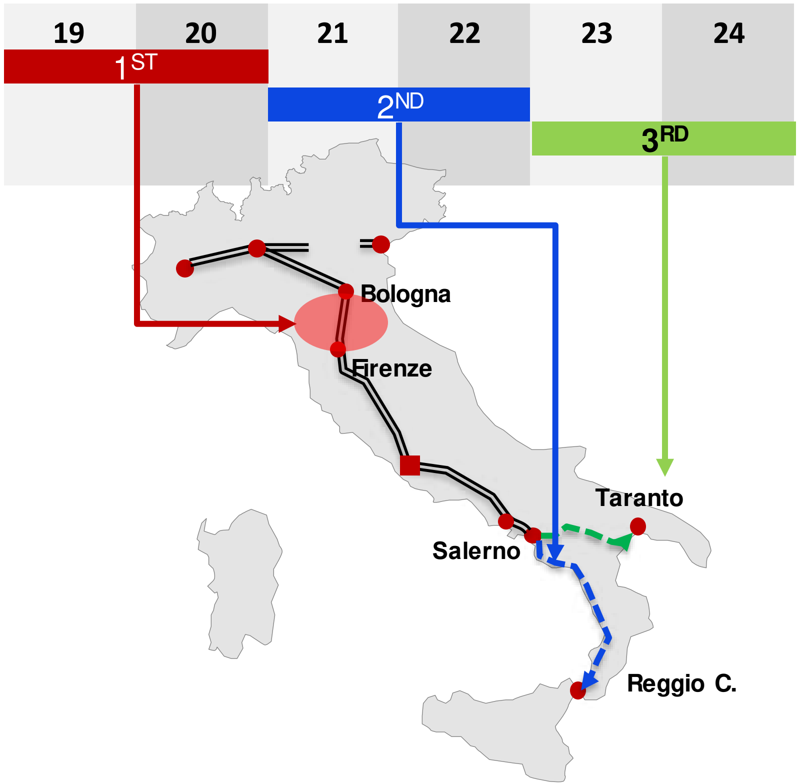


REDUCTION SCHEMES FOR HIGH SPEED SERVICES IN ITALY

For each catalogue, RFI has set the amount of the discount equal to that of the entire MU component



DISCOUNTS ARE TIME-LIMITED AND OFFERED FOR LINES/PATH



1ST CATALOGUE

- 2 paths per day/direction
- Only for **freight** using HS Line between Bologna and Firenze in the night-time
- Encourage **non-existent traffic**, ensure an **adequately gabarit route** during adjacent line TCR

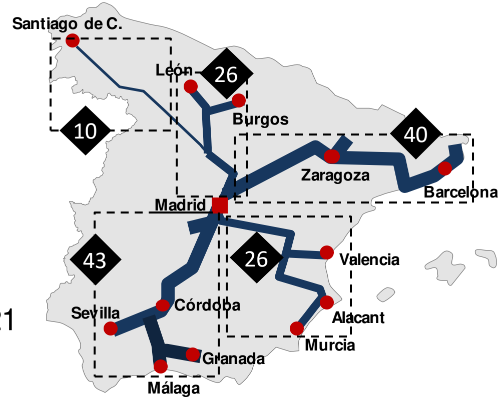
2ND CATALOGUE

- 4 paths per day/direction from Salerno to **Reggio Calabria**.
- RUs get a bonus if they extend any existing high-speed path originating from Milan/Venice
- Encourage **new rail services** and **competition** in a new market

3RD CATALOGUE

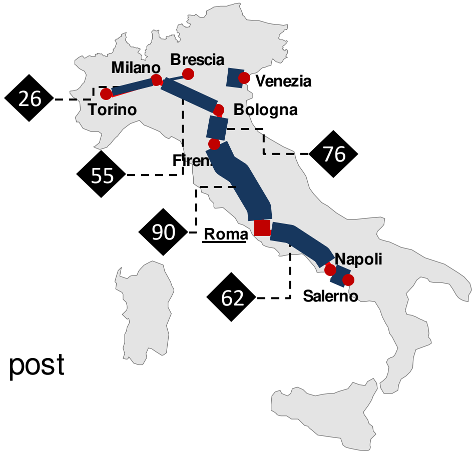
- 2 pre-arranged paths per day/direction from Salerno to **Taranto** (in agreement with Local and Central Authorities).
- RUs get a bonus if they extend specific existing high-speed path.
- Encourage **new rail services** and **competition**

COMPARING TWO APPROACHES



Discounts on HS lines

Amount 1,5 mln € yr 2021



Discounts on HS trains running on conv. lines

Amount 7 mln € (2 post covid discount) yr 2021

The amount of the discount is established by the IM on objective criteria (use of the lines) and is open to any RUs	Discount is guaranteed to any RUs using paths in the catalogue. If they are not enough, priority criteria are applied
The discount is activated only if certain traffic thresholds are exceeded, which ensure C=R	The train paths in the catalog are additional and not substitutes for the estimated multi-year traffic, which guarantees C=R
Capacity available across the entire network	The paths included in the catalog are checked with respect to the infrastructure capacity, even in urban nodes

Source: Elaborated by the authors from ADIF, ADIF AV NS 2023, CNMC «Informe anual del sector ferroviario» (2021) and RFI NS 2023
Maps: Average daily trains per line

UIC HIGHSPEED Morocco 2023

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A THIRD POSSIBLE APPROACH: NEW-COMER BONUS

France (2020/21) set up a process to request differentiated TAC for new-comer RUs for a limited period of time (2 years + 1 year)

Transport Authority **controls** and **validate** the whole process

RU — **Request** of differentiated TAC

DOSSIER

- O/D OFFER PROJECT
- TRAIN-KM VOLUME
- FILL RATE
- FORECAST TURNOVER
- LEVEL AND TYPE OF CHARGE
- PROVISIONAL 5 YEARS RESULTS

IM — **Analysis** of dossier and **offer** of differentiated TAC

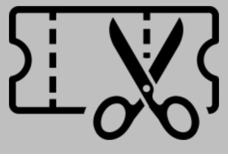
The discount is considered **non-discriminatory** if it corrects a situation of objective and transitory difference between the new-comer and the existing operators. The extent of the reduction is justified by the IM based on the revenue differential induced by the "ramp-up" phase.

Trenitalia, a new-comer RU on the Paris-Lyon route, has obtained a reduction:

- **37%** for the 1st y (2022);
- **16%** for the 2nd y (2023);
- *8% for the 3rd y (tbe).*

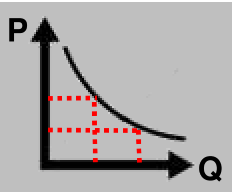
Source: Elaborated by the authors from SNCF Réseau NS 2023, Autorité de régulation des transports «Avis n° 2022-036 du 17 mai 2022»

CONCLUSIONS AND CONSIDERATIONS



Discounts exist in some TAC systems, but with **relative impact**. In other sectors (e.g., aviation) they are an important tool for traffic development. TAC Discount can support **the start of the competition** in HS services.

In addition to **discounts**, it would also be possible to implement a **tariff policy** in agreement with the State to support traffic development. While the discounts are designed to give a temporary boost to a market that needs to start up, the tariff policy is used to identify the right price level to reach a traffic target in a more structural way.



It is essential that the IM understands the **business of the companies** and the **intermodal competition** both to implement the discounts and for the tariff policies. In any case, it is necessary for the IM to know the price **elasticity of demand**. For non-existent services, it may be necessary to assume elasticity.

THANK YOU

RFI RETE FERROVIARIA ITALIANA GRUPPO FERROVIE DELLO STATO ITALIANE

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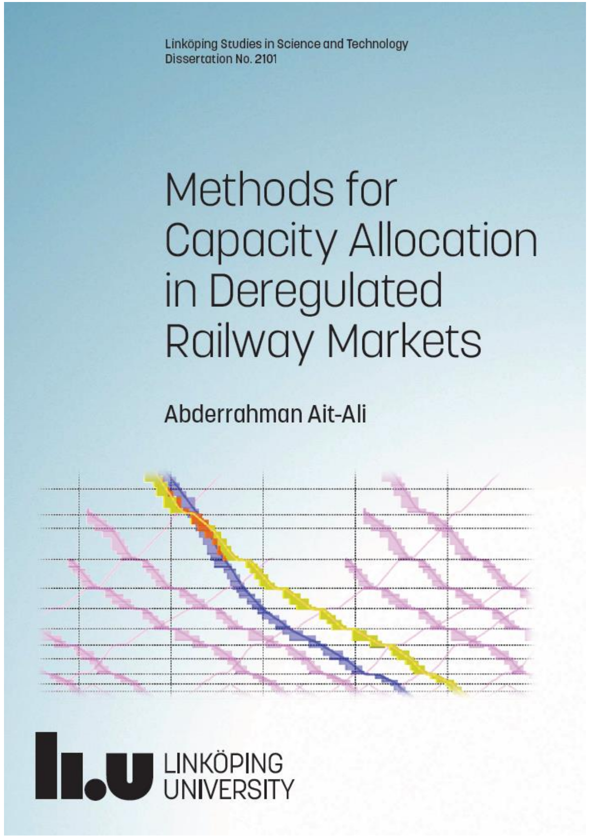
Methods for Capacity Allocation in Deregulated Railway Markets

Abderrahman, Ait-Ali
Researcher, VTI & Linköping University, Sweden
Session1-1.1 Economy / Rail business model

ONCF UIC

Outline

1. Motivation
2. Objectives
3. Methodology
4. Results
5. Conclusions



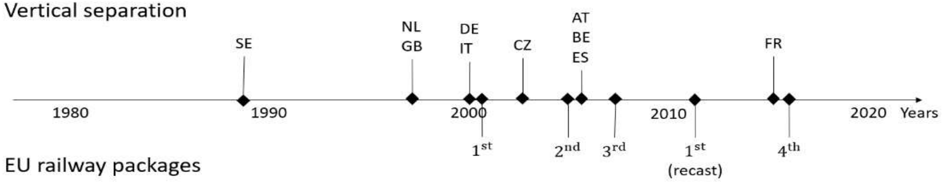
1. MOTIVATION OF THE PROJECT

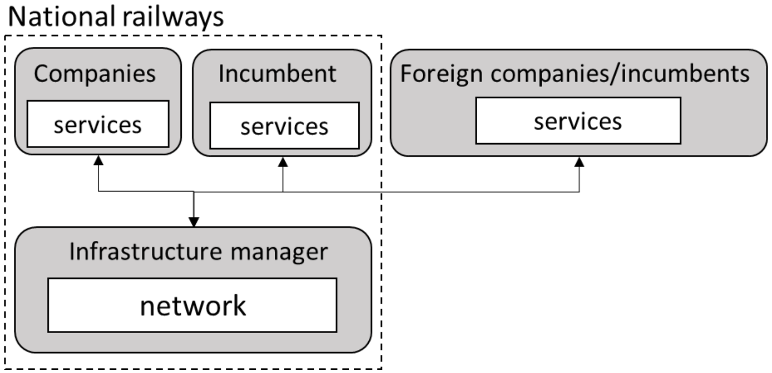
Major reforms in European railways, i.e., vertical separation, followed by deregulation.

Before the reforms, capacity allocation was internally performed within a monopolistic company (supposedly) aimed at finding efficient* timetables.

Now (after the reforms), capacity allocation should be transparent (clear and fair) and (still) efficient**.

(*) set by the company, e.g., max. profit or min. cost
(**) set by the legislation, e.g., min. social costs





2. OBJECTIVES

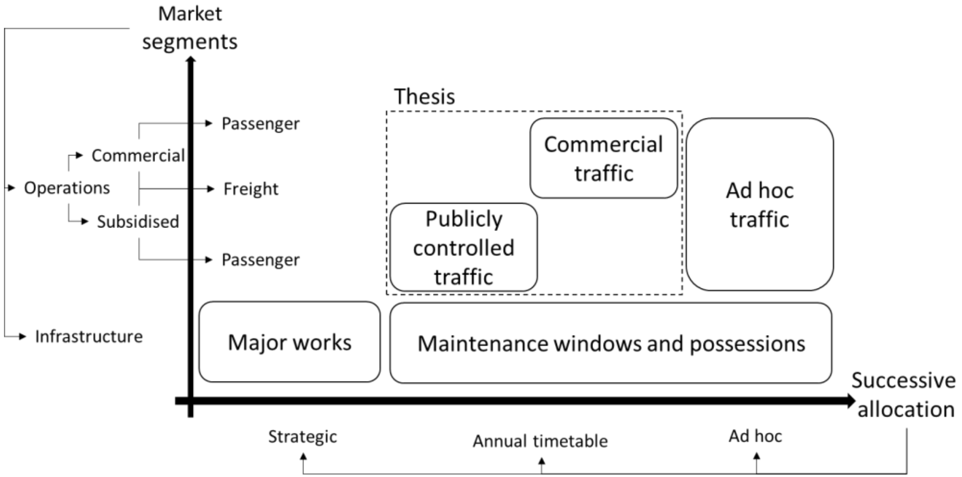
Objective 1. What capacity allocation is used in current deregulated markets?

O2. How can capacity conflicts be more efficiently resolved between commercial and subsidized traffic?

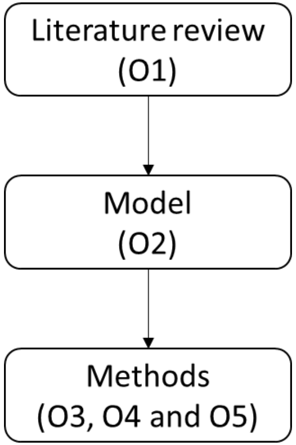
O3. Is actual subsidized traffic supply efficient according to the guidelines for cost-benefit analysis?

O4. How can mathematical optimization be used to improve the traffic supply?

O5. How much demand data is needed for more accurate policy decisions?



3. METHODOLOGICAL APPROACH



Top-down research methodology:

Review of (European) railway markets and their capacity allocation

Build a model for successive capacity allocation in a segmented deregulated market

Develop methods for the allocation model, i.e., solutions, data and parameters

	Research methodology		
Research methods	**Literature**	**Model**	**Methods**
Qualitative text analysis	P1		
Cost benefit analysis (CBA)		P2	P3
Mathematical programming			P4 and P5
Passenger flow simulation		P2	P3 and P5
Data analysis	P1	P2	P3, P4 and P5

4. RESULTS (PART 1 OF 2)

Paper 1. European Railway Deregulation: An overview of market organization and capacity allocation

https://doi.org/10.1080/23249935.2021.1885521

- Overview of deregulated railway markets in Europe
- Currently used ways to solve capacity conflicts

Paper 2. Pricing commercial train path requests based on societal costs

https://doi.org/10.1016/j.tra.2019.12.005

- Pricing commercial train paths using marginal social costs
- Assessment of social costs for commuter traffic

4. RESULTS (PART 2 OF 2)

Paper 3. Are commuter train timetables consistent with passengers' valuations of waiting times and in-vehicle crowding?

https://doi.org/10.1016/j.tranpol.2021.11.025

- Optimal frequencies for commuter traffic (based on demand)
- PTA's implicit valuation for waiting time and crowding

Paper 4. A disaggregate bundle method for train timetabling problems

- Improved method for solving train timetabling problems

https://doi.org/10.1016/j.jrtpm.2020.100200

Paper 5. The value of additional data for public transport origin–destination matrix estimation

https://doi.org/10.1007/s12469-021-00282-0

- Value of additional data for better estimates of travel demand

5. CONCLUSIONS

European railway reforms brought new challenges to capacity allocation, but legislation provides opportunities for adopting market-based methods

Some methods are proposed in this project to reduce the research gap in the rail sector, versus other sectors

Further research demand

- Further experimentations (demonstrators, prototypes) to gain more insights into, e.g., legislation, digitalization
- Complementary and extension works, e.g., ad hoc capacity allocation, reserve capacity, robustness, maintenance

THANK YOU

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