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G7 Transport Academic Workshop

Transport Systems Resilience: Research Activities in MOST

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MOST - Italian Center for Sustainable Mobility/
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Wednesday, 10th April 2024 - Aula Magna "Carassa e Dadda"
Politecnico di Milano, Bovisa Campus, Milan (Italy)

Outline

- Introducing MOST and spokes research
- Transportation resilience and reliability research in MOST
- Spoke 4: Resilience in Rail Transport (Line and Station)
- Spoke 7: Resilience of Transport Systems Networks
- Spoke 8: MaaS, Mobility Services and Social Resilence

The MOST in numbers

STAFF FROM PARTNERS 696 Researchers	INVESTMENT 378 M€ (2023-2025)	RECRUITING PLAN 574 Young researchers
INFRASTRUCTURE PROJECTS 147M€ Spokes research projects	OPEN CALLS 32 M€ Calls devoted to external entities	FLAGSHIP PROJECTS 68 M€ Calls Devoted to the partners of the Center

The Italian Center for Sustainable Mobility

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It is based on the **collaboration 49 among public and private parties (research institutions and industry)**

24 Universities + National Res. Council

- Consiglio Nazionale delle Ricerche
- Politecnico di Bari
- Politecnico Milano 1863
- Politecnico di Torino
- Università degli Studi di Bergamo
- Alma Mater Studiorum Università di Bologna
- UNIMORE Università degli Studi di Modena e Reggio Emilia
- Università degli Studi di Napoli Federico II
- Sapienza Università di Roma
- Università degli Studi di Brescia
- Università degli Studi di Milano Bicocca
- Università degli Studi di Cagliari
- Università degli Studi di Cassino e del Lazio Meridionale
- Università degli Studi Firenze
- Università di Genova
- Università Politecnica delle Marche
- Università degli Studi di Padova
- Università degli Studi di Palermo
- Università di Parma
- Università degli Studi di Napoli Parthenope
- Università di Pisa
- Università degli Studi Mediterranea di Reggio Calabria
- Università del Salento
- Università degli Studi di Salerno
- Università di Torino

Regions covered by MOST

9 Spoke-Leader entities

24 Private partners

- a2a Life Company
- Ferrari
- Pirelli
- accenture
- Ferrovie dello Stato Italiane
- Posteitaliane
- Almaviva
- Fincantieri
- snam
- Angel
- FNM la vita in movimento
- Stellantis
- autostrade per l'italia
- Hitachi
- teoresi group
- Avio Aero A GE Aviation Business
- Intesa Sanpaolo
- Iveco
- brembo
- ThalesAlenia Space
- Leonardo
- eni
- Lutech
- UnipolSai Assicurazioni

MOST Centro Nazionale per la Mobilità Sostenibile

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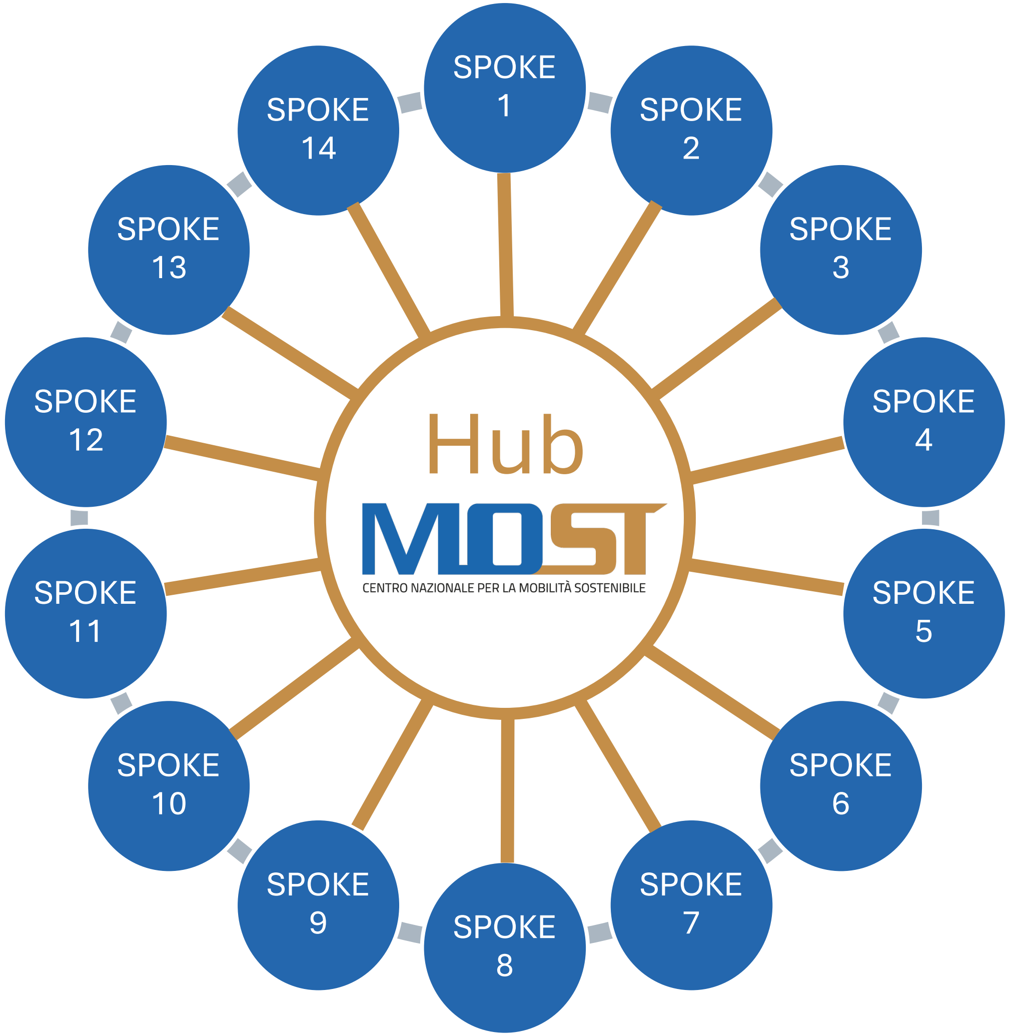
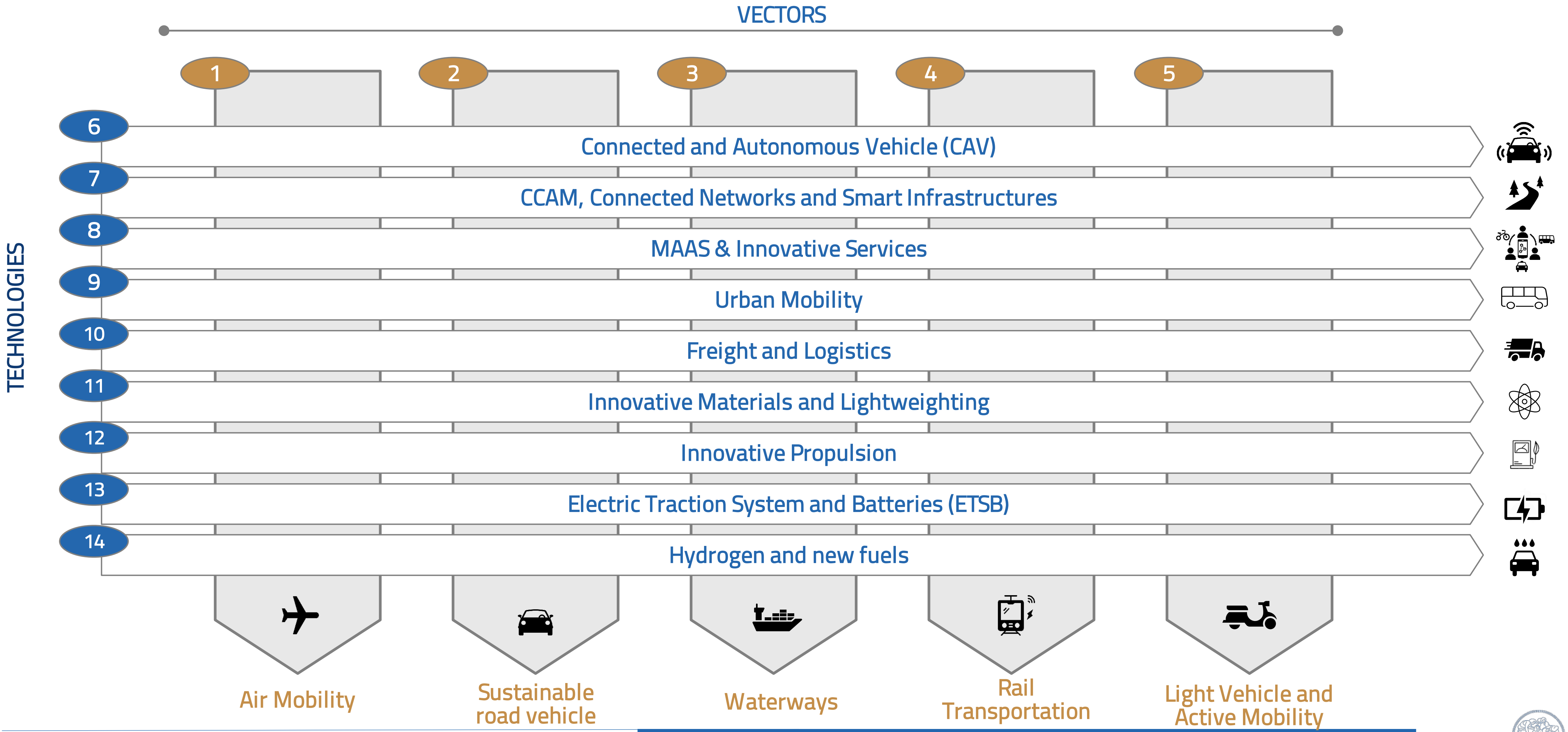
The MOST's Hub& Spoke model

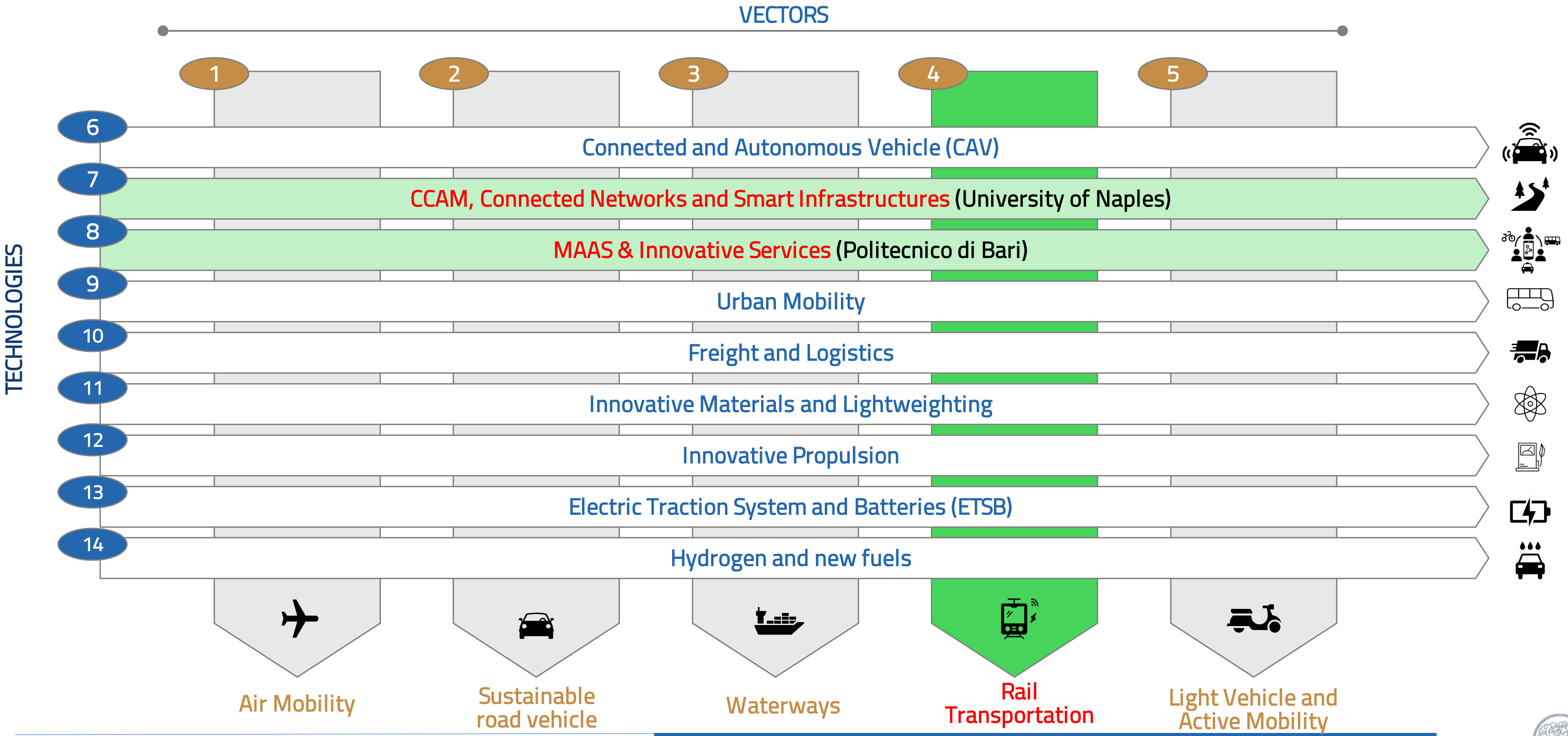
14 **Spokes** develop their specific research plan, set up the research infrastructures, recruit young researchers, manage the open calls for projects and disseminates the outcomes from local to international audience.



The spokes research topics



The spokes research topics and resilience



SPOKE 4 – Railway Transportation

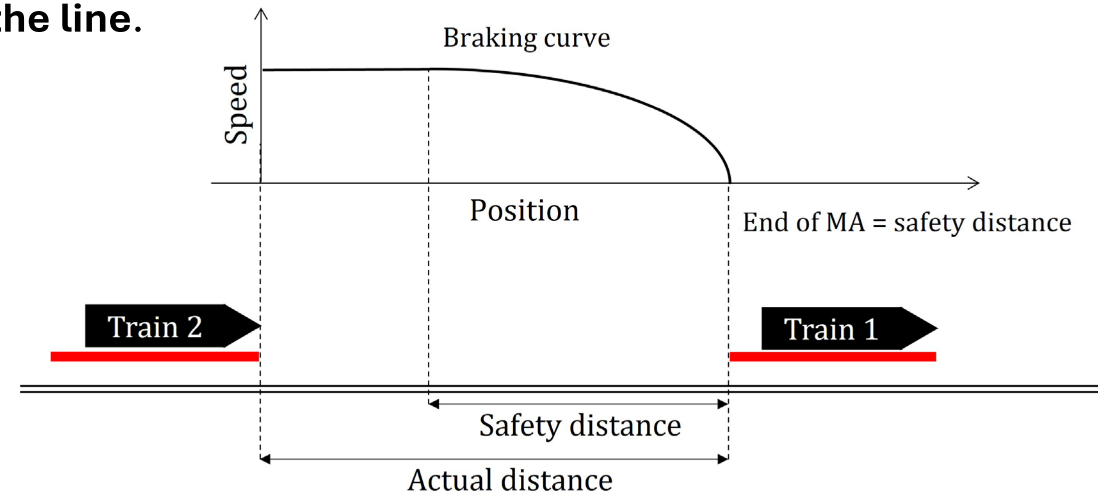
From the spoke 4 we consider two goals related to resilience and reliability and then to increase the attractivity of rail transport:

- **increase the capacity** of the existing rail-track network;

- **ensure high resilience** of the traffic regulation of the railway service with respect to disturbances and disruption to traffic regularity.

Rail Signalling Technology

Railway signalling is composed by ground-based systems (**RBC**, Radio Block Center in ETCS) distributed along the network, that sends the Movement Authority (**MA**) to the on-board unit of the vehicles, that communicates its **current position along the line**.



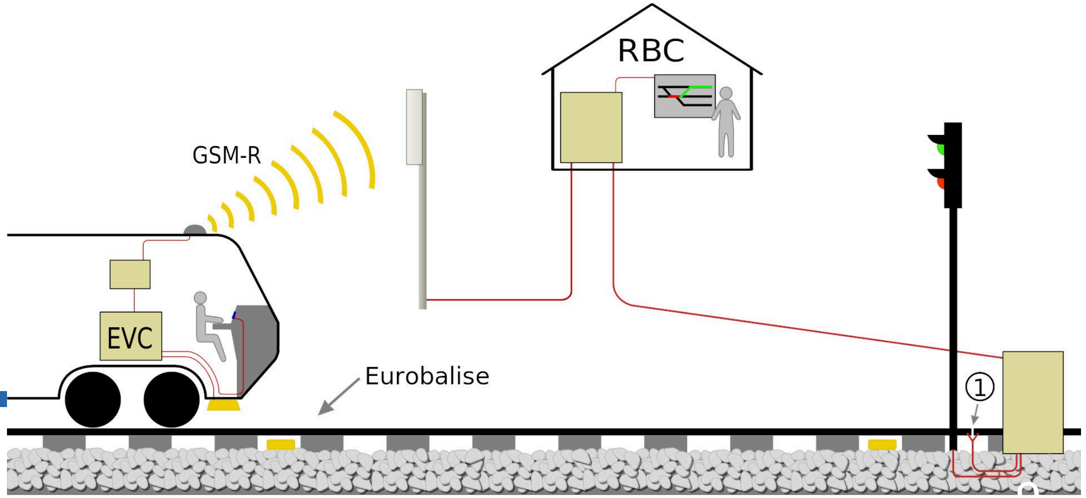
Moving block technology

It relies on the definition of **areas around each train**, travelling together with it, that can't be occupied by other vehicles.

Its working principle is based on the precise knowledge of the **train position and speed**, which allows instantaneously evaluate the **absolute distance** to be maintained from the vehicle ahead, to guarantee the **safety** of the network.

Moving block reaction to hazardous operational scenarios

- loss of train integrity
- loss of communication with RBC
- interruption of vehicle circulation
- unexpected track occupation



Methodology

Currently, there are no true **MVB** system implemented in railway networks.

Barriers to its application are:

- ensure safety and resilience of the system
- long-term testing
- complexity of the system

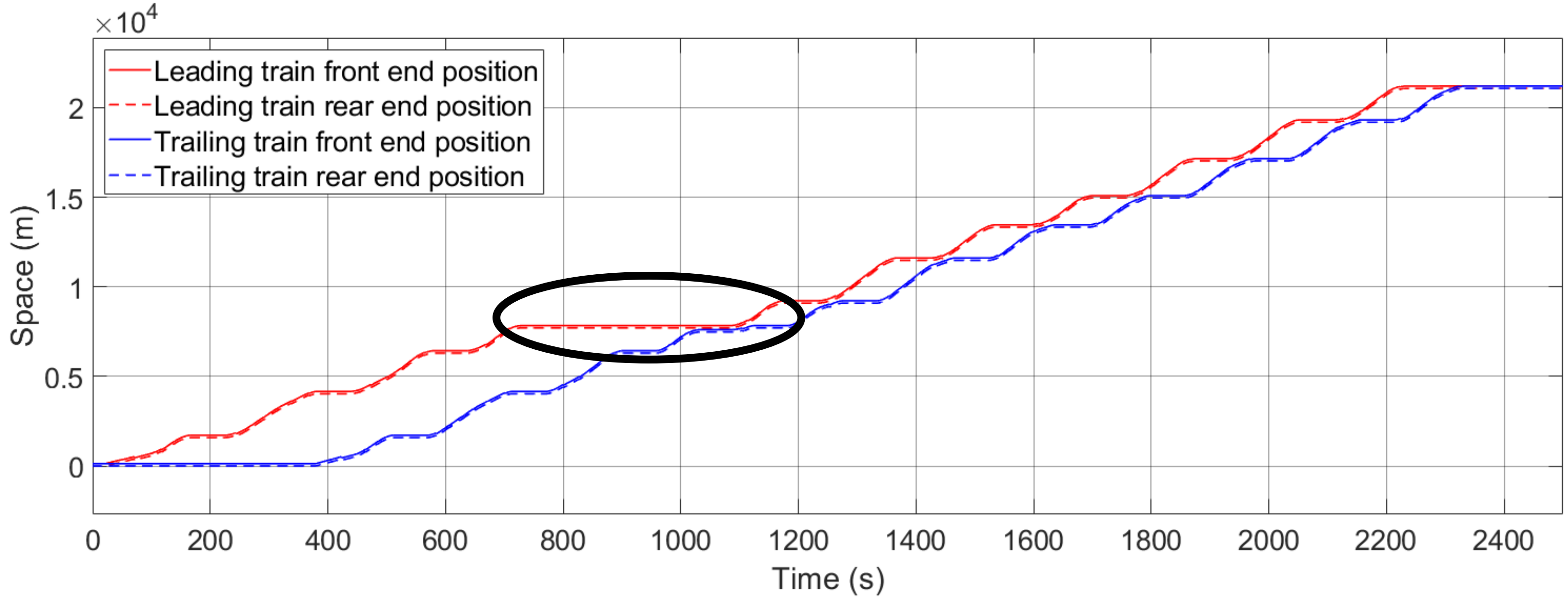
To **boost MVB implementation**, two research trajectories have been following:

Hardware in the Loop (HiL) test bench

Multi-layer network digital twin

Hardware in the Loop (HiL) test bench

This activity develops a HiL test bench aiming at **“zero on-site testing”** able to test sub-systems and overall system performances and resilience.



In case of **anomalous stopping time** of the leading train, the **MVB** approach allows for a **7% faster** service completion than **FXB (Fixed Block).**

Expected benefits of HiL:

- guarantee even **higher safety standards**
- **reducing the costs and time** required for system development, testing, validation and homologation
- help the **increase** of the Italian railway **transport capacity** through cutting-edge signalling technologies
- contribute to the **digitalization** of the railway network, with attention to **cybersecurity** issues

Multi-layer network digital twin

Three different layers:

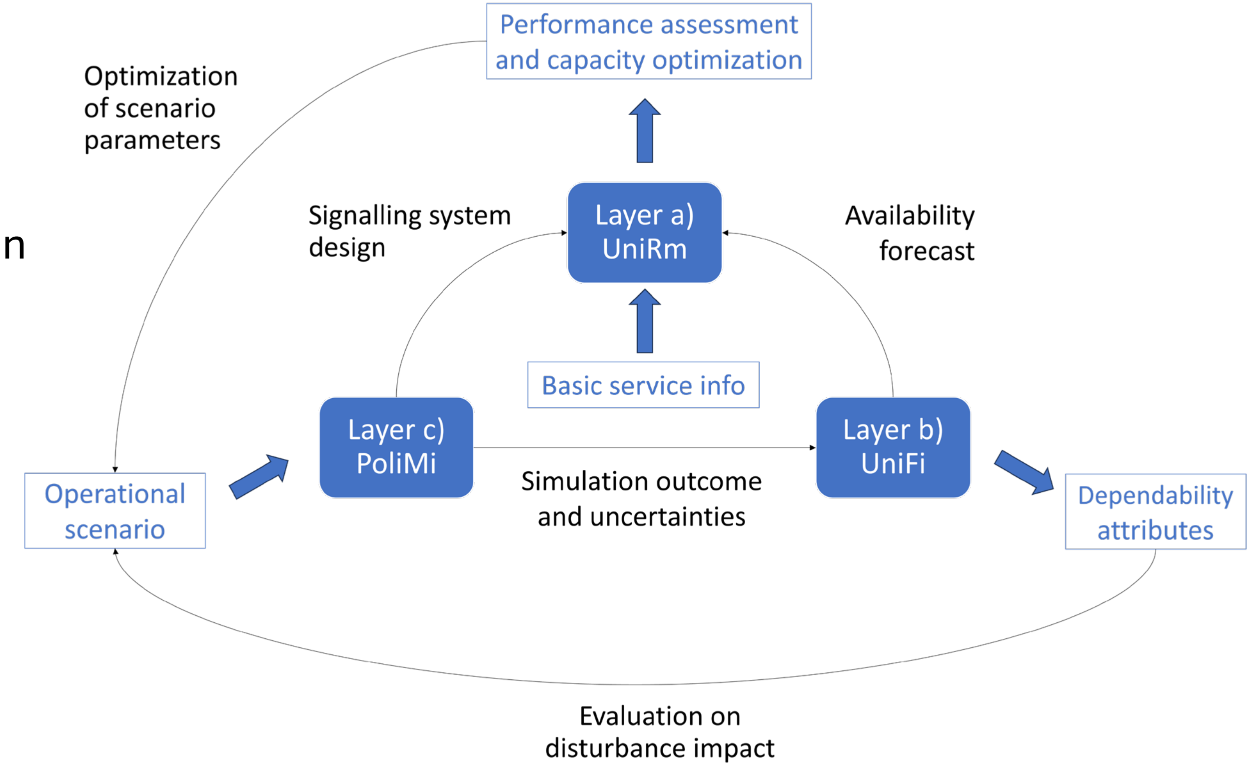
a)Macro-level performance evaluation

b)Meso-level for system dependability evaluation

c)Micro-level train and signalling system dynamic simulation

The multi-layer approach is used to propagate disturbing effects from local operational condition to higher level (regional/national).

In this way, it is possible to manage the complexity of the railway network, considering local dynamic aspects and traffic disruption events, moving away from the point where the disturbance occurs.



Regularization of rail traffic within large station areas

Railway traffic often experiences perturbation from the ideal conditions that lead traffic perturbations ranging from delays to more severe disruptions.

Providing an effective response to perturbations aims at:

1. Maintaining service regularity
2. Reduce passengers' inconvenience
3. Optimise resource utilization
4. Reduce time for operation recovery

A tool that can be employed towards these goals is the **real-time management** of train movement for perturbation response

Goals and scope

Optimization of the railway traffic within large station areas with the aim of minimizing the delay propagation among trains and promptly recovering the nominal conditions after unexpected events.

Two kinds of events must be accounted for:

Disturbances	Relatively small scale, can be resolved with traffic management	Disruptions	Larger scale, require the reorganization of railway resources

Problem referred to as **Train Timetable Rescheduling** (TTR) problem.

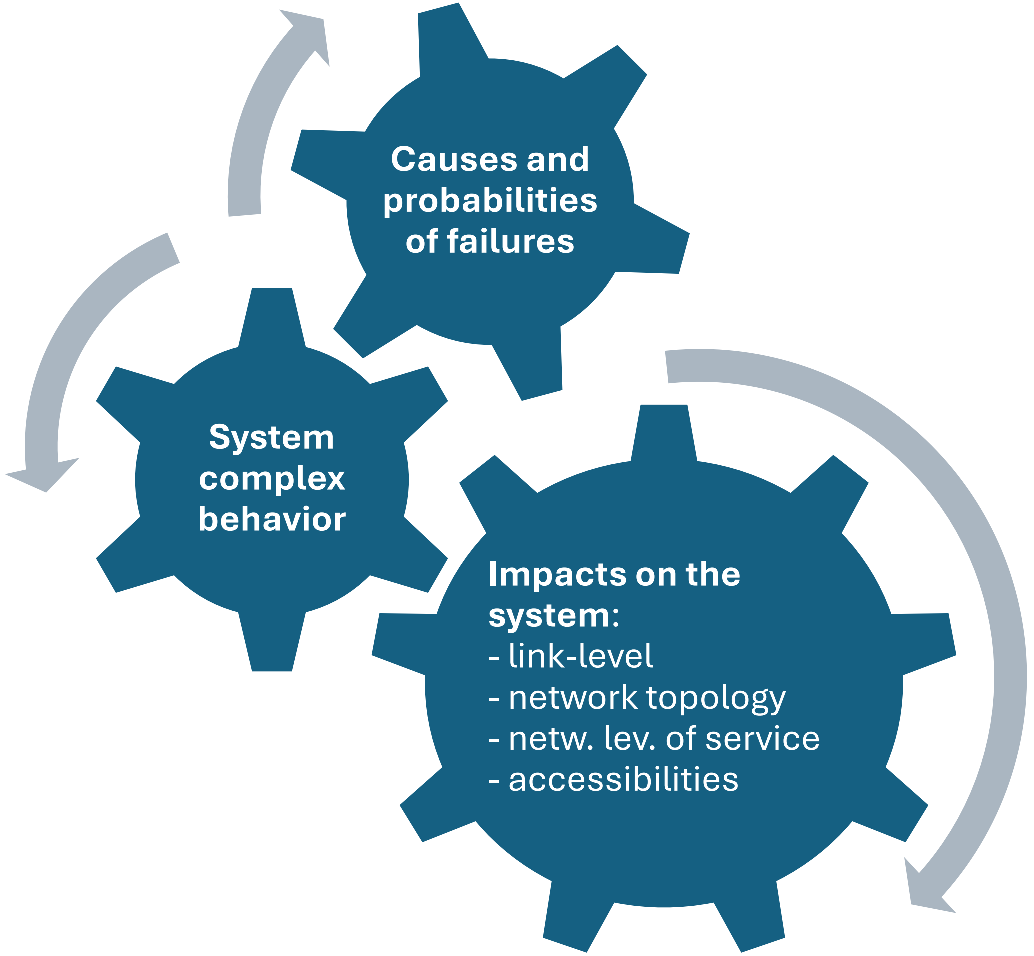
In addition to traditional TTR, we also include **re-platforming** as a mean for managing railway traffic.

Moreover, the application in terminal stations proposes additional challenges, both at modelling and optimization level.

Spoke 7: Resilience of transportation systems

Some activities of Spoke 7 focus on how complex transportation systems resist/adapt to failures

- **Characterization of failures** (causes, probabilities, forecasting, early monitoring)
- **Characterization of transportation systems** (supply, demand, interactions and equilibrium)
- **Methods** to compute vulnerability, reliability, resilience and impacts at different levels



Research in Failures Identification

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- **Climate, environment and other natural disasters**
  - extreme weather events
  - landslides
  - earthquakes
  - sea-level rise and increased risk of flooding

- **Transfer of risk maps at a network level**
  - Associating cause-dependent failure probability distributions to the links of the national transportation network

Research in Failures Identification

- **Ageing and maintenance**
  - Prevent disasters
  - Programming maintenance of aged infrastructures

<u>Activities</u>:

✓Massive (and affordable) **methods** to characterize the **status of the national inventory**

✓Identification of the national strategic network

✓Structural Health Monitoring and Sensing capabilities

Research in Failures Identification

- **System operation and congestion**
  - Special events and unusual travel demand load
  - Late arrival of a scheduled service
  - Traffic stops and queues backpropagation

- **Identify the probability of occurrence at different links of the network**
- **Short, medium, and long-term forecasting**
- **Sensing and early monitoring**

Methodological aspects

Asset inventory approaches are inadequate for complexity

- Can be used for investigating causes and characterizing probability profiles of failure for network elements

Network-level and simulation approaches are required

- Topology-based approaches (network analysis) are limited since generally: i) are based on binary inputs (on/off); ii) consider the supply side only
- Level of service approaches: i) are based on continuous inputs, as residual capacity; ii) accommodate the demand (or the unmeet one)

Appropriate performances

indicators should be chosen

- Accessibility works well since considers both the demand and supply, it can embed the network (re)equilibration and the demand elasticity, as well as socioeconomic and territorial attributes
- Indicators (accessibility) must be computed with consistent and common approaches (e.g. random utility models)

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Spoke 7 Research agenda

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Strategical level

- **Consensus on definitions**:
  vulnerability, reliability, and resilience concepts, specifically defined for transportation networks
- **Harmonization of approaches**:
  network-level, simulation-based, equilibrium-consistent (dynamic process for resilience), ...
- **Harmonization of methodological/computational tools** (e.g., Montecarlo simulation, sensitivity analysis, other methods for dealing with uncertainty, ...)
- **Consensus and harmonization on indexes** (e.g., accessibility and its correct definition and computation method)

Local level (national)

- **Identification of the strategic network**
  vulnerability method, looking for (combination of) rare but unacceptable events)
- **Identification of the minimal reliable network,** that ensures acceptable degraded performances in the short-term; reliability method, considering failures with their probability profiles
- **Identification of strategic and reliable policies to maintain the performance** of the strategic and reliable national networks
- **Identification of resilience indexes** for the national networks (current, minimal reliable, and strategic), applying dynamic process approaches

Spoke 8 – MaaS & Innovative Services

Mobility as a Service & Transport System Resilience

Mobility as a Service framework can contribute to **unveil resilience properties** (if any) of transport supply by its embedded information system:

- In case of service disruption users need to know **how to reach the destination** (i.e. re-planning the journey);
- MaaS can support users in **feeding/updating their choice sets** according to their needs assuming the disrupted context (X^{th} best alternative; route, means of transport, ...)
- Big Data Analysis, IoT, AI, behavioural models, ML can support MaaS and then **reduce the uncertainty** by continuously monitoring the transport scenarios and defining alternative plans to be proposed

Spoke 8 – MaaS & Innovative Services

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Transport System Resilience & Equity

Are the solutions to improve transport resilience **equitable** according to the population groups or communities' needs?

Mobility is a resource, a richness: equitable resilience should take into account issues of social vulnerability and differentiated access to mobility also in case of disruptions

Can we **quantitatively** measure equity? (harmonization of measures needed)

For ex:

- Gini Based index
- Theil index (within, between, within+between)
- Atkinson index

Can we **design network** according to both transport resilience and social resilience? (define common problem formulations and minimum level of equity)

For ex:

NDP based on the optimization of Theil equity indexes

NDP using Gini based index as problem constraint

Crucial aspects in transportation systems

- **Transportation Systems**
  - are complex
  - behave non-linearly
  - several feedbacks between different components
    - Transportation supply (networks)
    - Transport demand (people and goods)
    - Demand/supply interaction
  - **Interconnect different sub-systems**
    - Physical / Infrastructural assets
    - Technological layers
    - Service layers
    - Socio-Economic layer

I don’t mind about the disruption I do mind about how to finalize my trip!

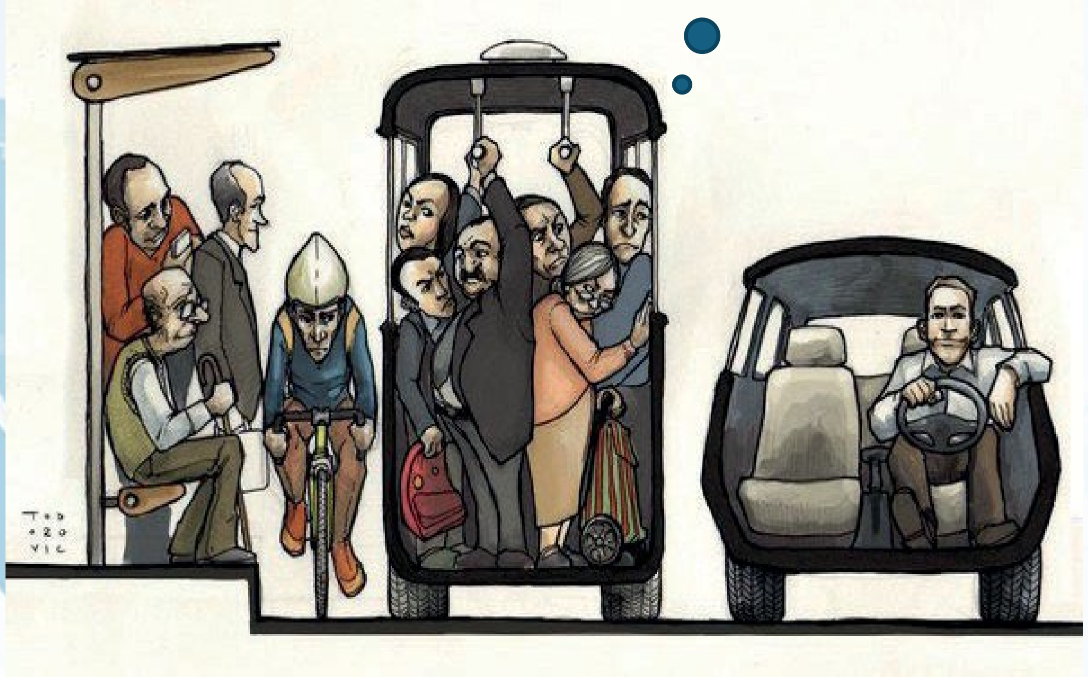

Image from : «Justicia Urbana», di Fabian Todorovic

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