C4R

Capacity for Rail

Operations for Enhanced Capacity: An overview

C4R 2nd Dissemination Event, Brussels, November 2016

Egidio Quaglietta
SP3 Lead

Network Rail

SEVENTH FRAMEWORK PROGRAMME

SP3: Operations for enhanced capacity

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- The project should pave the way for an **affordable** railway infrastructure (low maintenance and rapid construction) and operations concept that is **resilient** to extreme weather and other hazards, designed for **automated** maintenance and operations (e.g. automated coupling, brake testing), and **adaptable** to different route characteristics including (very) high speed. At the same time, it should contribute to an **increase of capacity** of freight transport.

An Overview of SP3

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SP3 will contribute to the project by paving the way for:
1. Operations that are **resilient** to extreme weather and other hazards;
2. **Automated** maintenance and operations;
3. **Adaptable** solutions for different route characteristics including (very) high speed;
4. An increase of **capacity** of freight transport.

WP1 Capability trade-offs To test appropriate and **adaptable** strategies for **capacity** enhancement (Links with SP1, SP2, SP5)	**WP2 Models and simulations** Understand the implications of different operational strategies on **resilience**, **capacity,** potential for **automated** solutions and requirements for **adaptability** (Links with all SPs)	**WP3 Optimal strategies** Development and testing of new strategies for **resilient** operations. Solutions for **automated** operations. (Links with SP4, SP6)	**WP4 Data modelling and architecture** Development of data management and integration approaches that support information flow in **resilient** operations, **automated** maintenance and operations (Links with SP4)

Development of innovative and cost effective technologies for collecting real-time data on the train operation (**WP4**)
Development of innovative solutions for traffic capacity computation for freight and passengers based on data gathering, analysing and utilising processes (**All**)
Determination of data requirements and models to improve rail punctuality and level of service (**WP2**, **WP3**, **WP4**)
Longer trains and/or high-speed freight (**WP2**)
Development of joint requirements and testing for incident management plans (**WP3**)

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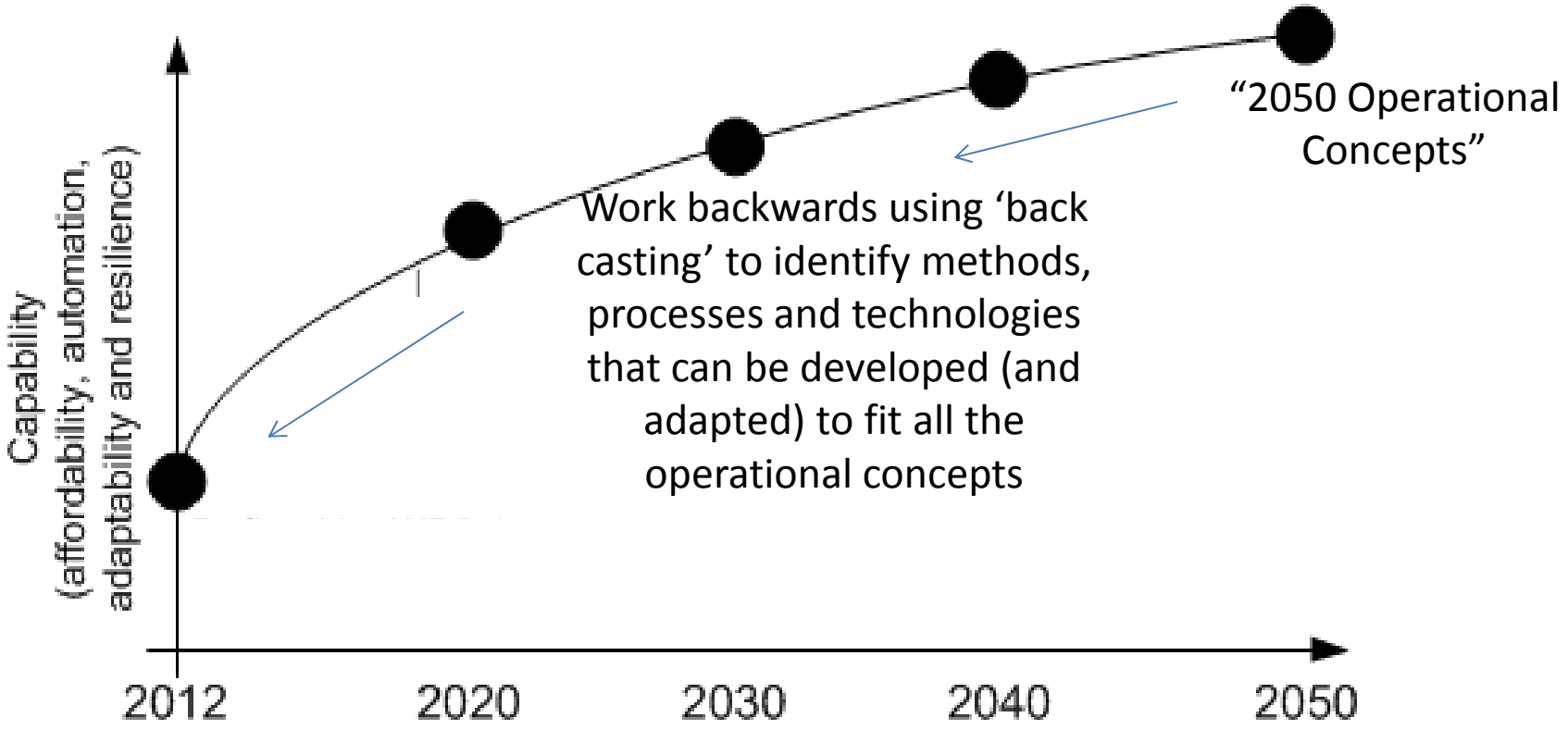
Developing Operational Concepts



Capability Trade-Off Analysis Tool

Capacity for Rail

Capability Status Representation

Current

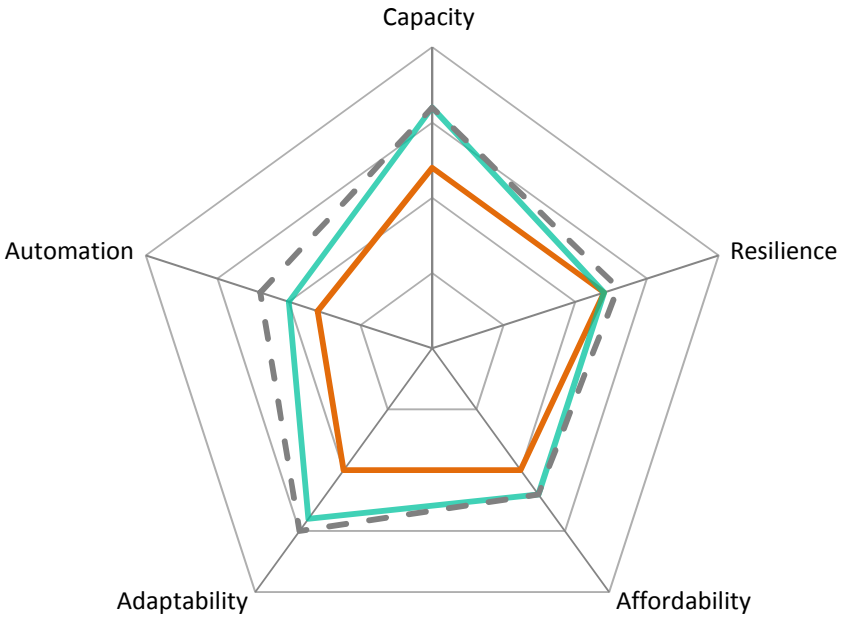
Future

Innovation Representation

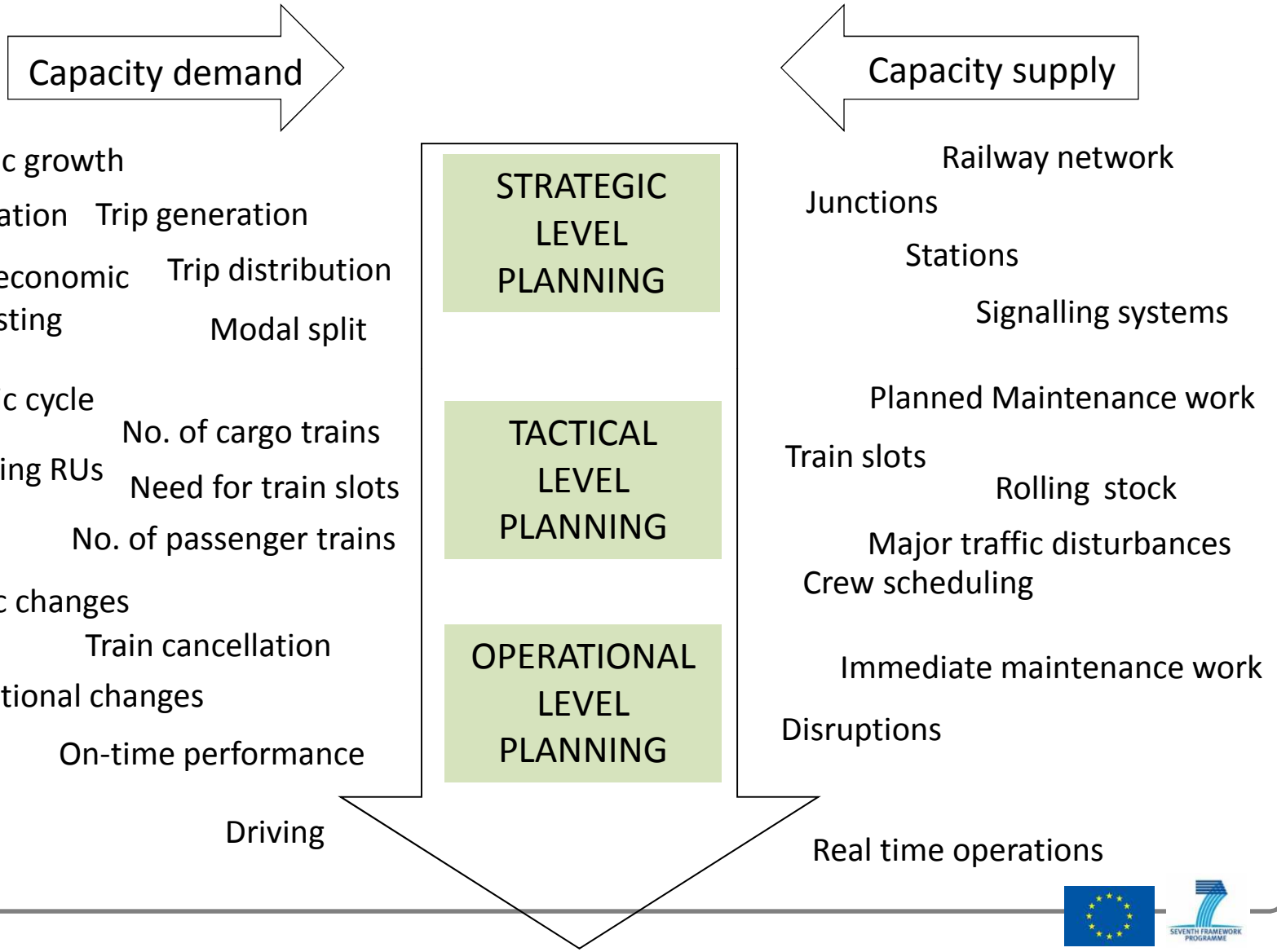
Calculation of Outcomes

Outcome Measures

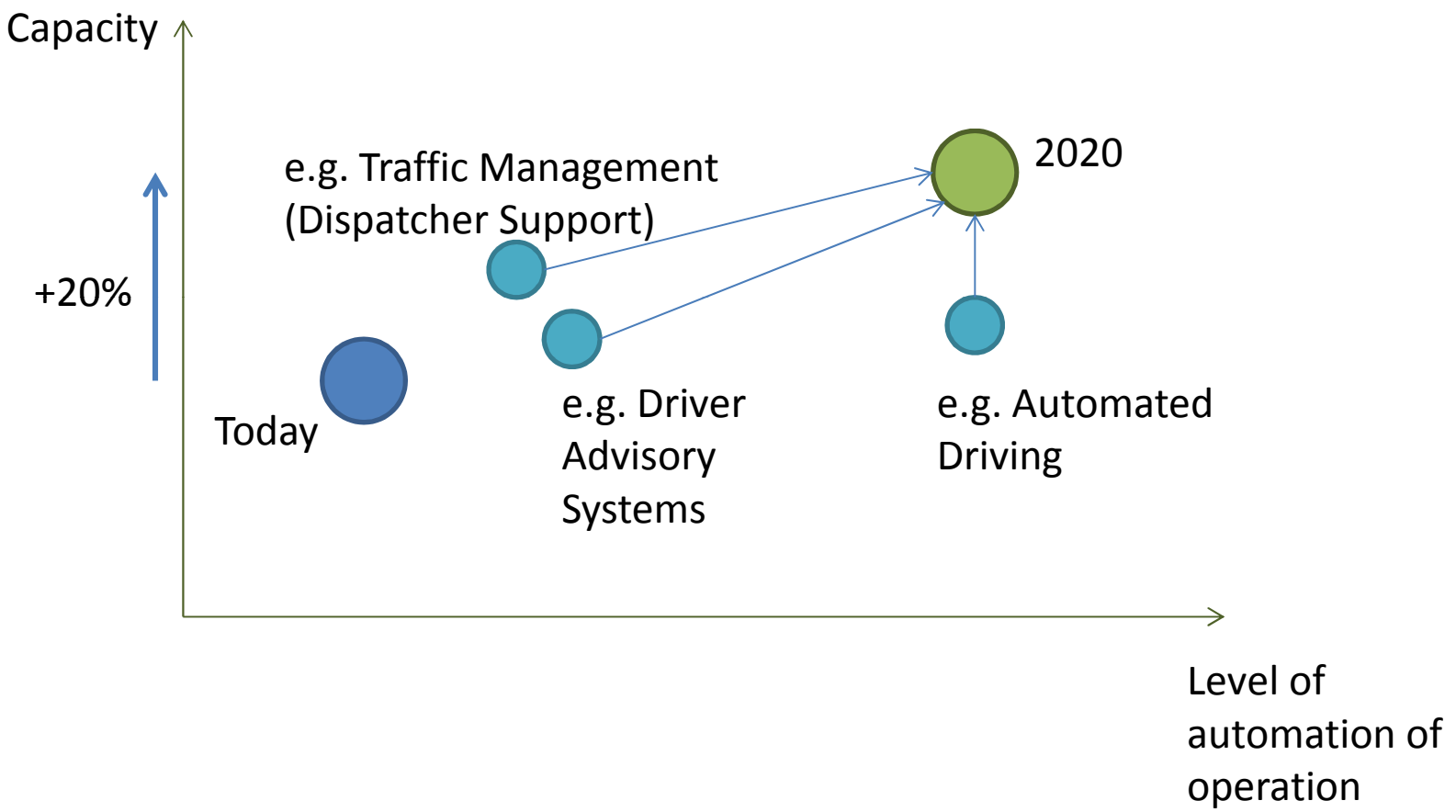
Visualisation of Outcomes



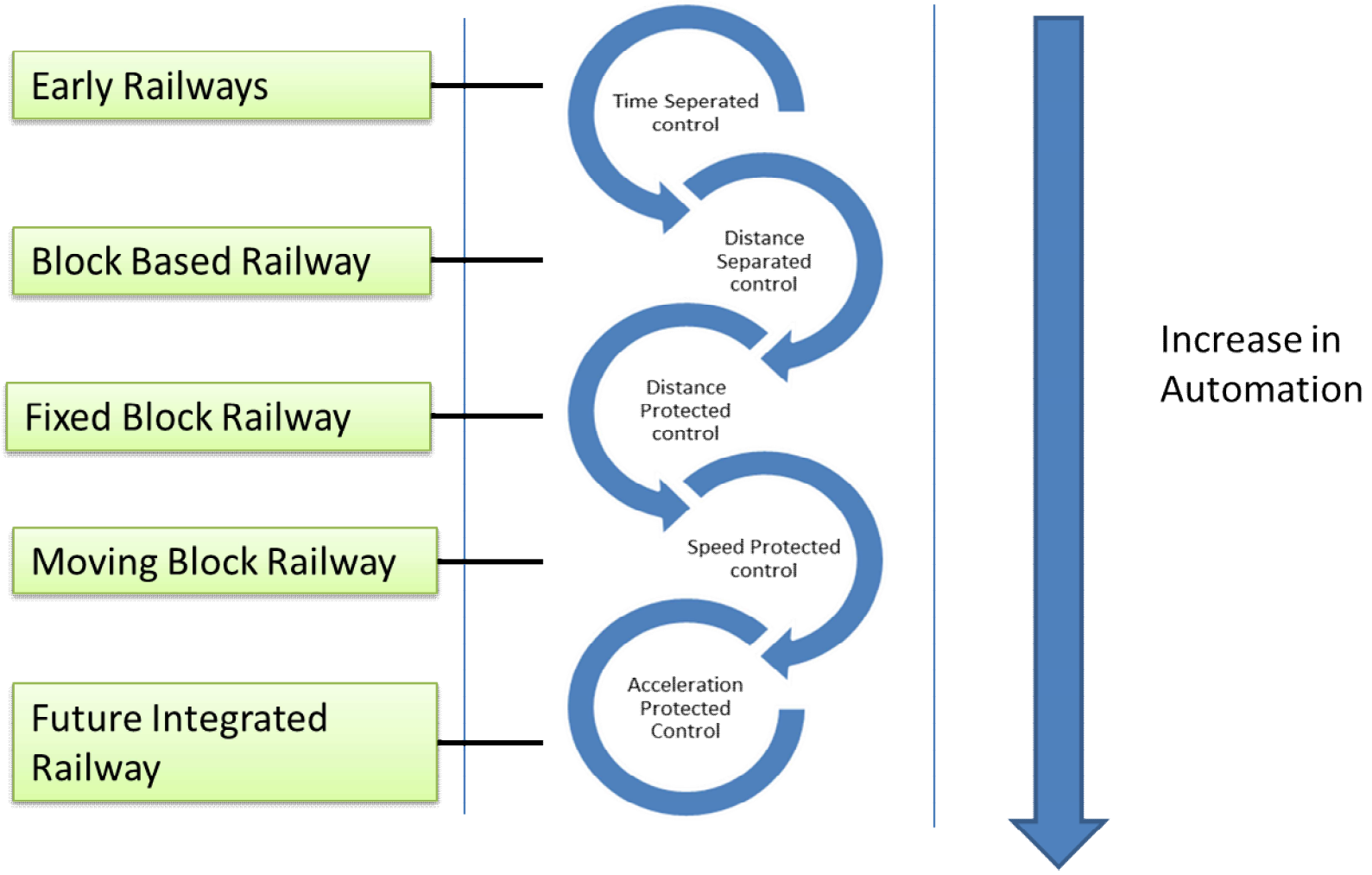
Modelling Framework



Capacity increase through automation



Automation Progression



Moving towards automation

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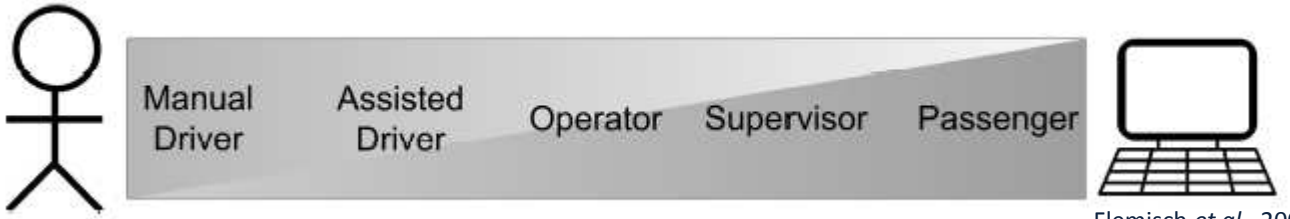
Automation can be viewed as a spectrum, from completely manual operation through to completely autonomous operation. From the perspective of the driver, for example:



Flemisch *et al.*, 2008

Or, from the system perspective (Smith, 2013):

1. No automation;
2. Function-specific automation (limited automation of specific functions);
3. Combined-function automation (automation of two or more connected control functions);
4. Limited self-driving (autonomous within certain limits, e.g. environmental conditions);
5. Full self-driving (safety responsibility lies completely with autonomous systems).

Big Data Approach

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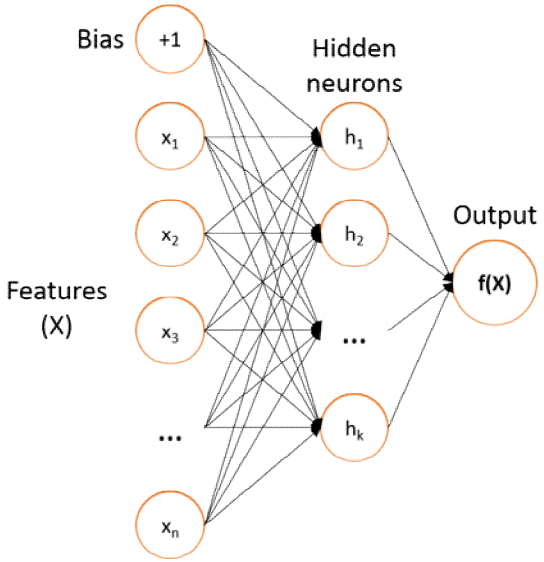
Large amounts of data generated by travelling trains + **Large number of models to be managed** = **Big Data problem**

State-of-the-art machine learning algorithm based on Extreme Learning Machines (ELM) adapted for typical Big Data architectures

Implementation of the algorithm for Apache Spark (state-of-art in-memory computing tool for Big Data) on Apache Hadoop



Spark

THE APACHE SOFTWARE FOUNDATION apache.org

hadoop

SP3 Team

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IK INSTYTUT KOLEJNICTWA

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SP3 WP3.1 Capability Trade-Offs Analysis Tool

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Egidio Quaglietta

Network Rail

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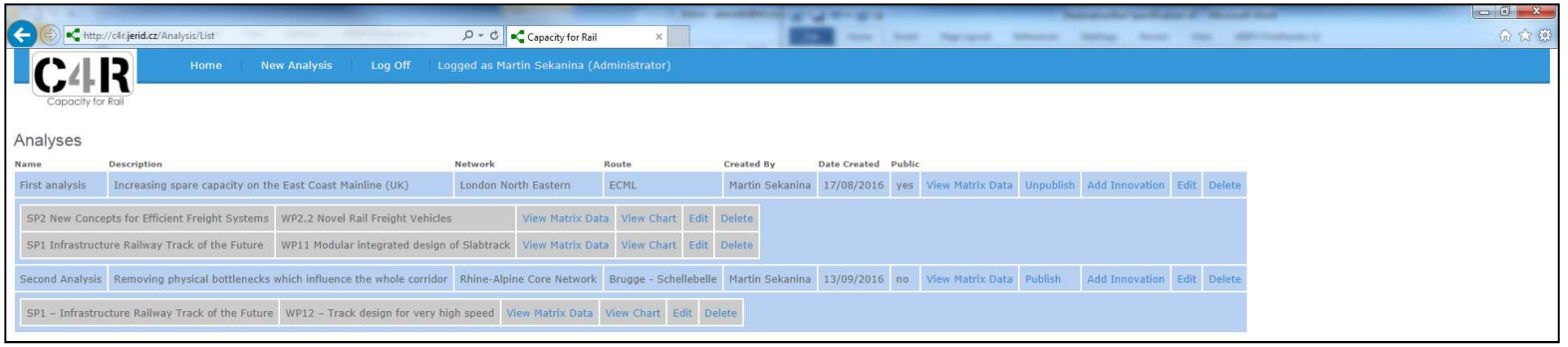
Capability Trade-Offs Analysis Tool

A web-based **Decision Support Tool** to identify **options/ innovations** which deliver greater capacity using:

- **Whole systems approach**
- **Current and future** railway capabilities
- **Trade-offs and interactions** between capabilities



Capability Trade-Off Analysis Tool

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Capability Status Representation

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Calculation of Outcomes

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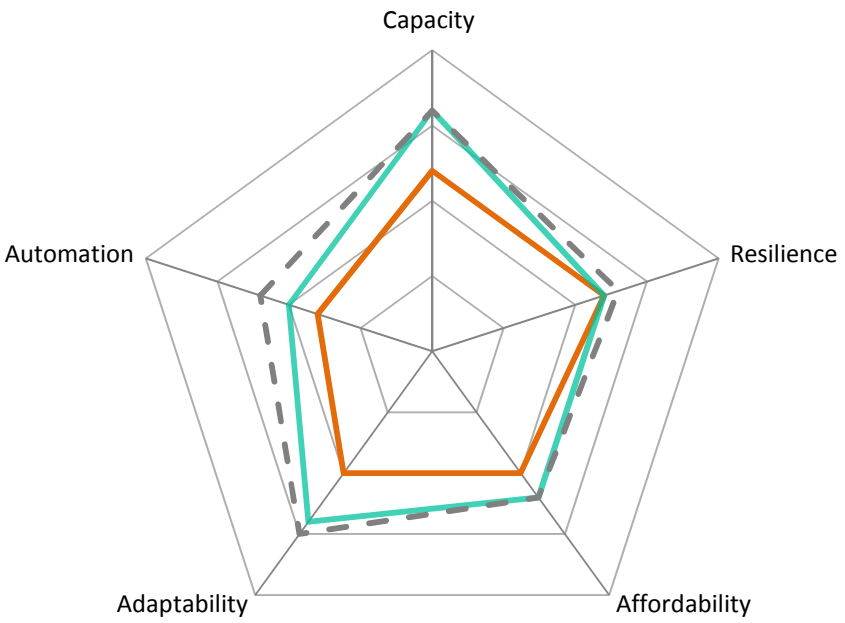

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System set-up

The user is guided to enter **components** of the railway system for the **"current"** state….

Infrastructure	Track	Number of lines	Up	1
			Down	2
		Track Loading Gauge		GC
		Permitted Axel Load (tonne)		22.8 - 24.1
		Rail Support		Ballast
		Line Speed	Up	200 - 250
			Down	200 - 250
		Layout	Level Crossings	Yes
			Junctions	Grade Seperated
			Minimum Curvature	Single Lead / Flat / Grade Seperated
			Max Gradient	
			Station/ junction Spacing (Ave Km between stations and/or junctions)	
		Number of Swtiches & Crossings		
	Railway Electrification Infrastructure	Type		
	Structures	Bridges		
		Culverts		
		Earthworks		
		Tunnels		
	Signalling	Signalling Type		
		Longest Block Length (km)		
		Headway		
	Station (expandable - for each station)	Platform	Length (m)	
			Number	
		Type		
		Terminal Platforms	Turnaround Time	
			no. of platforms	
		Platform Information		
		Ticketing Facilities		
Operations	Automation	Type		
	Train positioning	Type		
		Traffic Heterogeneity		

Capability Status Representation

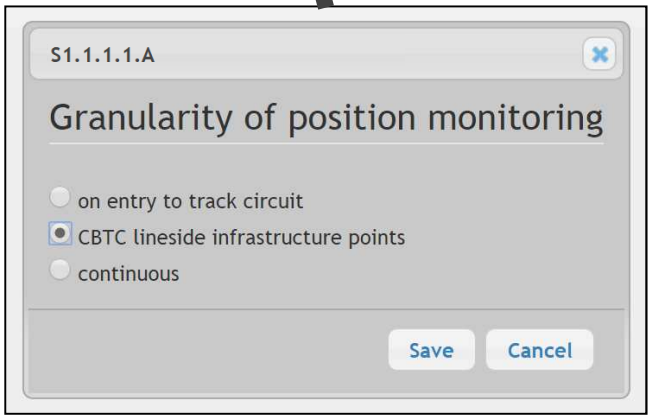
F1 Control operations	F1.1 Control traffic flow	F1.1.1 Deliver effective real time operation plan	F1.1.1.1 Monitor train positions	S1.1.1.1.A Granularity of position monitoring on entry to track circuit -- not selected --
			F1.1.1.2 Compare train positions to schedule	S1.1.1.2.A Speed with which comparison can be made hours -- not selected --
				S1.1.1.2.B Coverage of network that can be compared regional -- not selected --

…This automatically populates the capability status values for the **“current”** railway…

Capability Status Representation

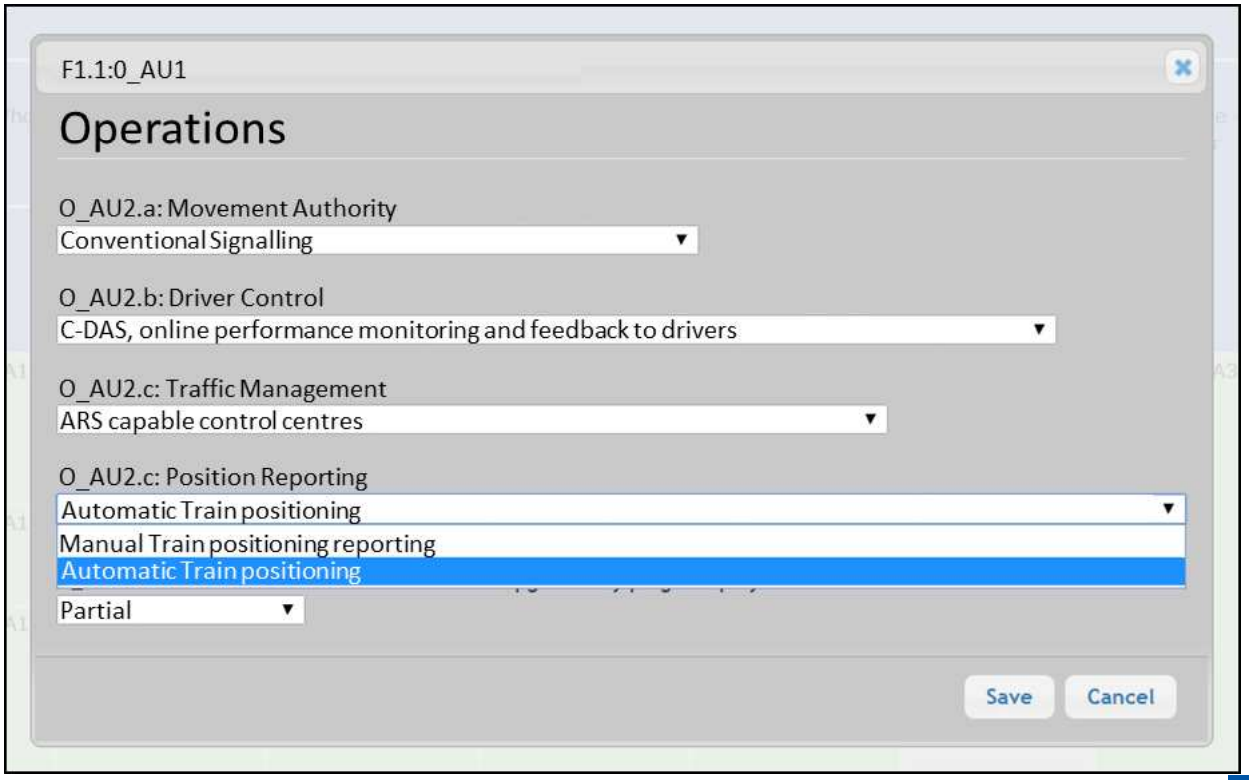
F1	F1.1	F1.1.1	F1.1.1.1	S1.1.1.1.A
Control operations	Control traffic flow	Deliver effective real time operation plan	Monitor train positions	Granularity of position monitoring
				on entry to track circuit
				CBTC lineside infrastructure points
			F1.1.1.2	S1.1.1.2.A
			Compare train positions to schedule	Speed with which comparison can be made
				hours
				hours
				S1.1.1.2.B
				Coverage of network that can be compared
				regional
				-- not selected --

…The user then chooses the **"future"** railway capabilities.



System and Capability Status Inputs

The tool includes **structured questions** to evaluate the rail system with regards to the other high-level goals…



- Upgrades to the railway system **required** to overcome the challenges (such as low line speed).
- **Dependencies** may exist; meaning the full benefit of upgrades may not realised.
- Further changes to capabilities maybe needed.

The CTA Tool characterises capabilities impact on capacity in look-up tables.

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Examples of dependencies for line speed within the tool

- E.g. Line Curvature

Curvature/Speed limit Table		Speed Limit (kph) restricted options					
minimum radius of curvature (m)	< 200	< 50					
	200 - 600	< 50	50 - 80				
	600 -1110	< 50	50 - 80	80 - 100			
	1110-3700	< 50	50 - 80	80 - 100	100 - 150		
	3700-10000	< 50	50 - 80	80 - 100	100 - 150	150 - 200	
	10000 - 20000	< 50	50 - 80	80 - 100	100 - 150	150 - 200	200-250

Current

Future

- E.g. Removal of permanent speed restrictions

Level Crossing/Speed limit table		Speed Limit (kph) restricted options					
Associated level crossing Permanent speed restriction	None	< 50	50 - 80	80 - 100	100 - 150	150 - 200	200-250
	< 50	< 50					
	50 - 80	< 50	50 - 80				
	80 - 100	< 50	50 - 80	80 - 100			
	100 - 150	< 50	50 - 80	80 - 100	100 - 150		
	150 - 200	< 50	50 - 80	80 - 100	100 - 150	150 - 200	

Current

Future

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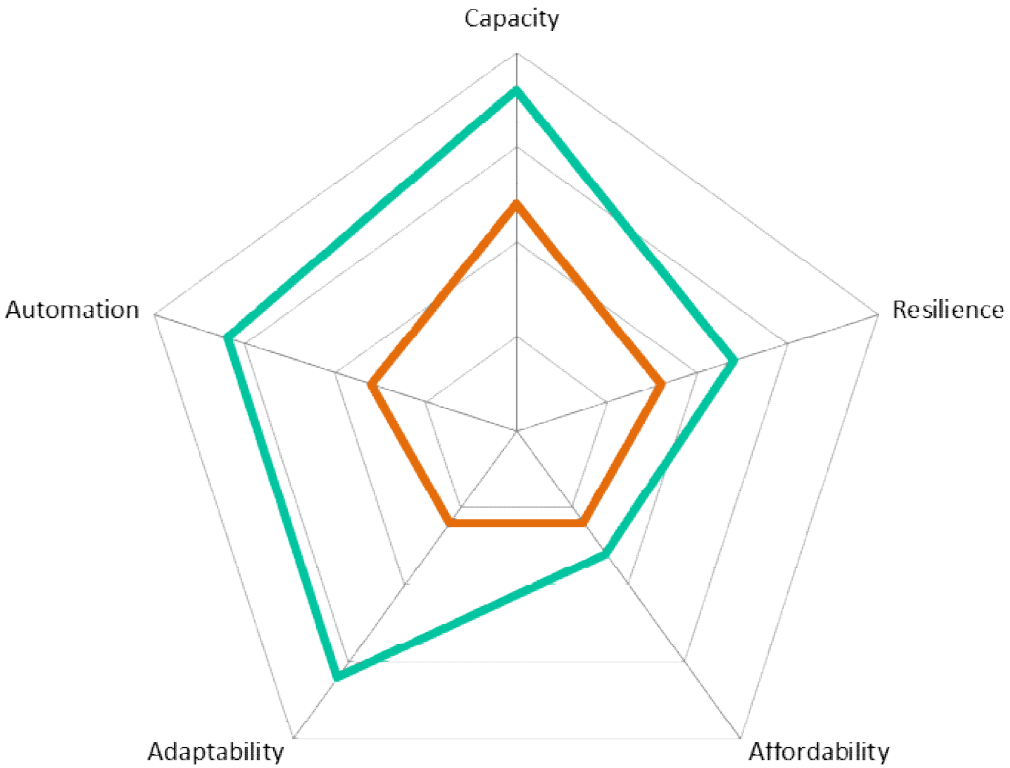
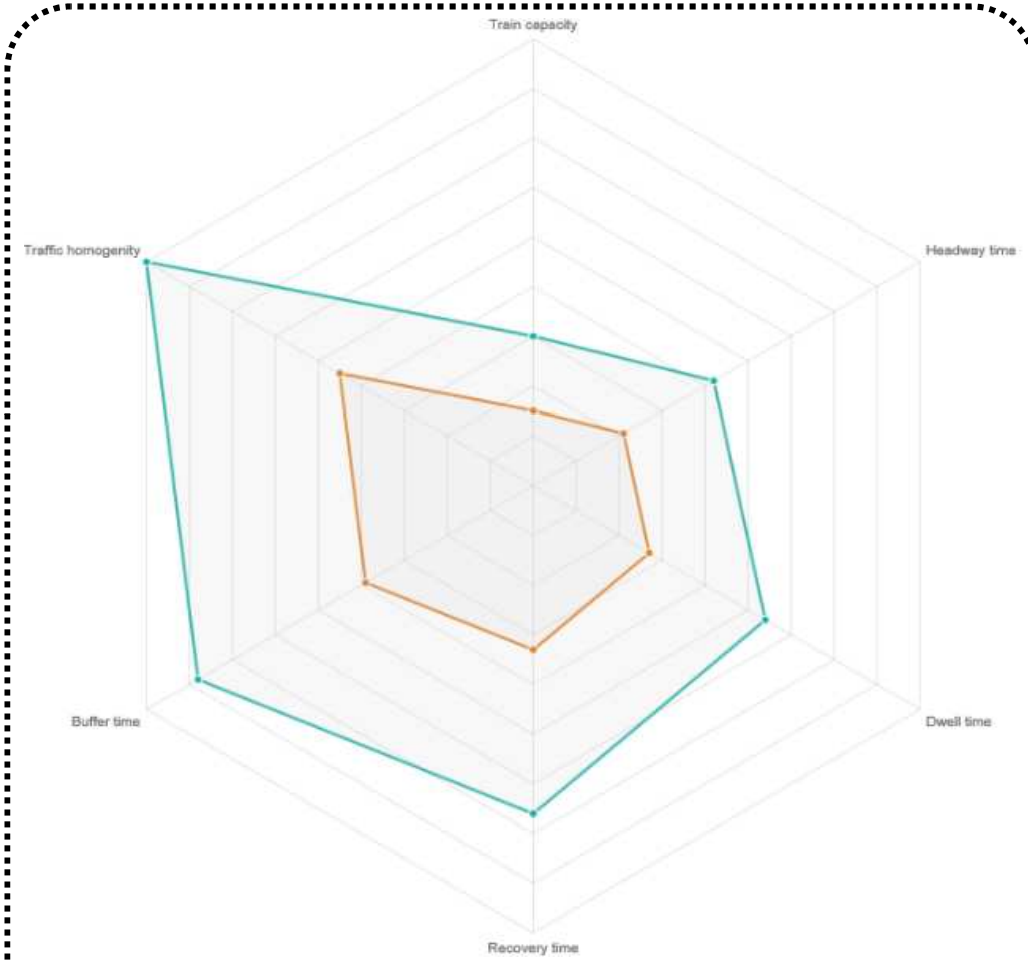
The output of the tool is a spider diagram for the 5 high-level goals

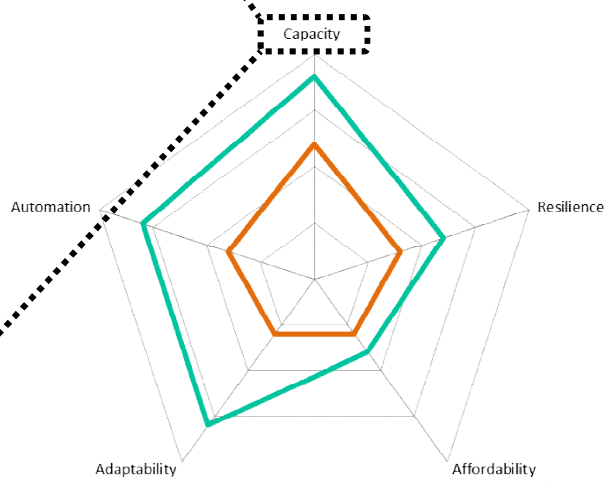


Visualisation of Railway Capabilities

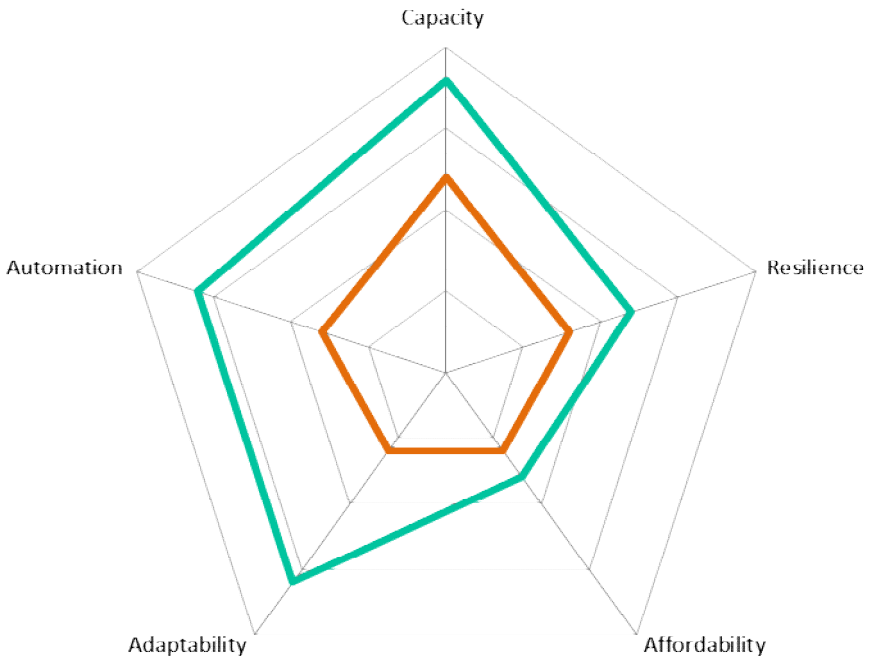


Visual break-down of Capacity

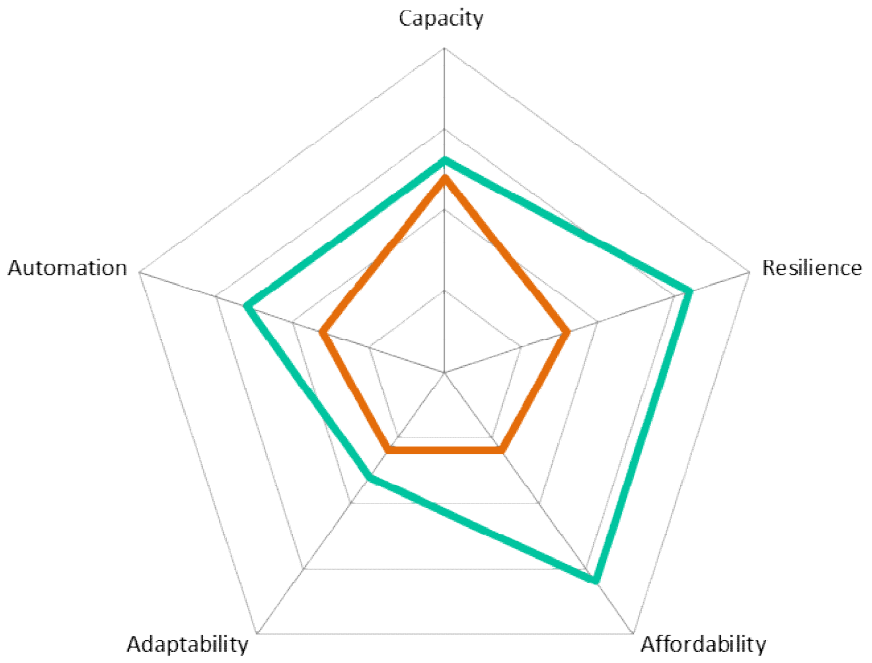
The tools provides a visualised break-down of capacity.



The tool provides a comparison of different upgrades/innovations



Innovation 1



Innovation 2

Capacity Trade-Off Analysis Tool

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- The CTA tool provides **an overview of the extent to which improvements contribute** to the move from the current status of a railway towards a **desired future railway**.
- It expresses the outcome in terms of the **5 high-level objectives: capacity, affordability, automation, adaptability and resilience.**
- It allows railway infrastructure managers to **identify solutions** for increasing capacity using a **whole-system approach.**

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SP3 WP3.3 – Optimal Strategies for disruption management

C4R 2nd Dissemination Event, Brussels, November 2016

Paola PELLEGRINI
WP3.3 Lead

IFSTTAR

Objectives of WP3.3

Optimal Strategies (Extreme Situations)

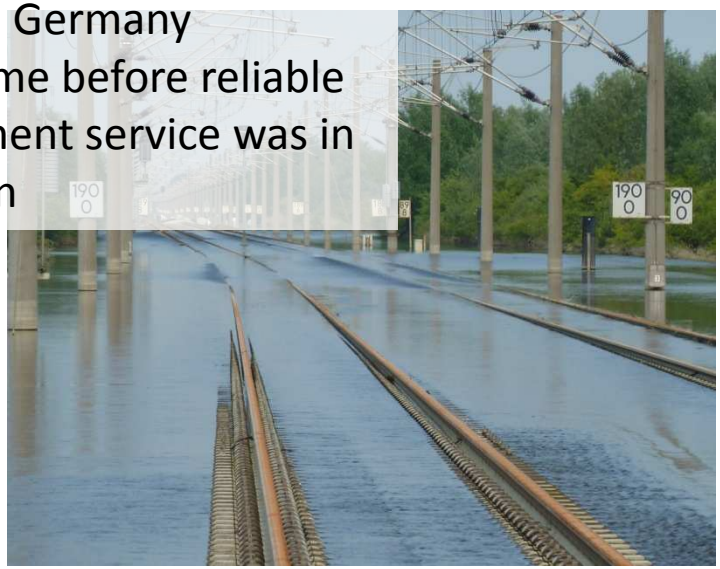
Review of operational strategies in use or being developed and the outcomes when different strategies are employed

- **D3.3.1: Description of optimal strategies for automatic traffic management, decision support and customer information**
- **D3.3.2: Requirements for incident management plans**

Ash cloud affecting Air traffic
Railway had difficulties in providing adequate replacement services

Source: theguardian.com

Floods in Germany
A long time before reliable replacement service was in operation



Source: DB Mediathek

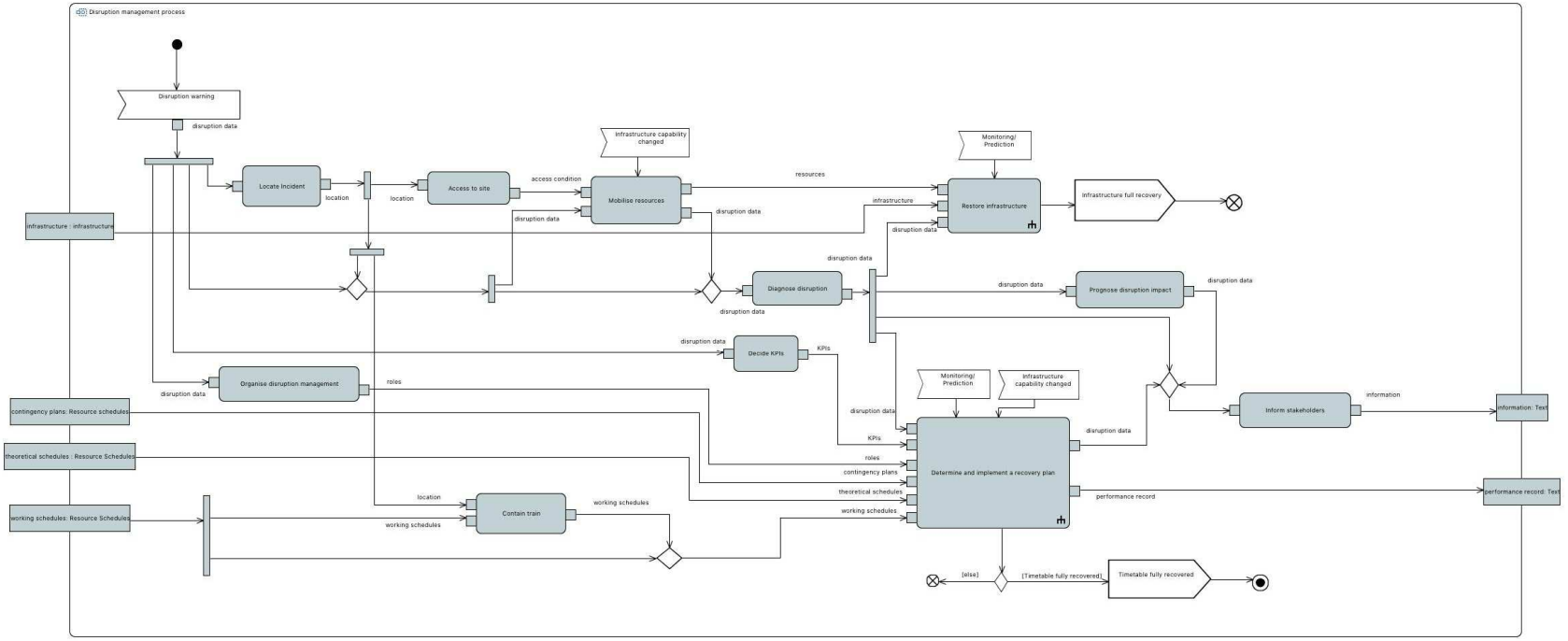
Disruption management process

The process has been formalised through **SysML activity diagrams**

SysML is a **standardised and open source** modelling language for system engineering

SysML allows specifying

- abstract system requirements
- main system's structures
- activity flows and data exchanges



Benefits of the SysML formalisation

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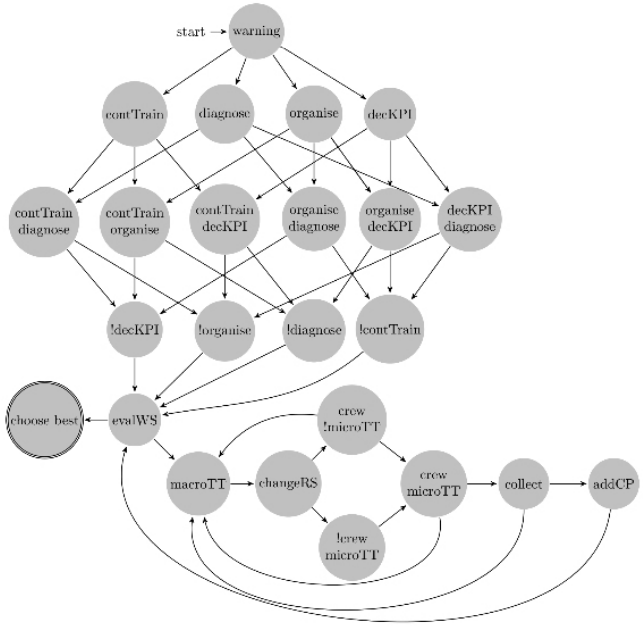
Definition of a **unified framework** for the disruption management process throughout Europe

- Network Rail, Trafikverket, ADIF and SNCF could validate the model and specify country-specific procedures

Ease of translation of the activity diagrams into state graphs to check the main properties of the **system's behaviour**



Possibility of analysing the **level of automation** currently implemented and envisaged

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Traffic Management and Automation

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Increase efficiency of railway operations

Allow supporting railway traffic managers' decisions

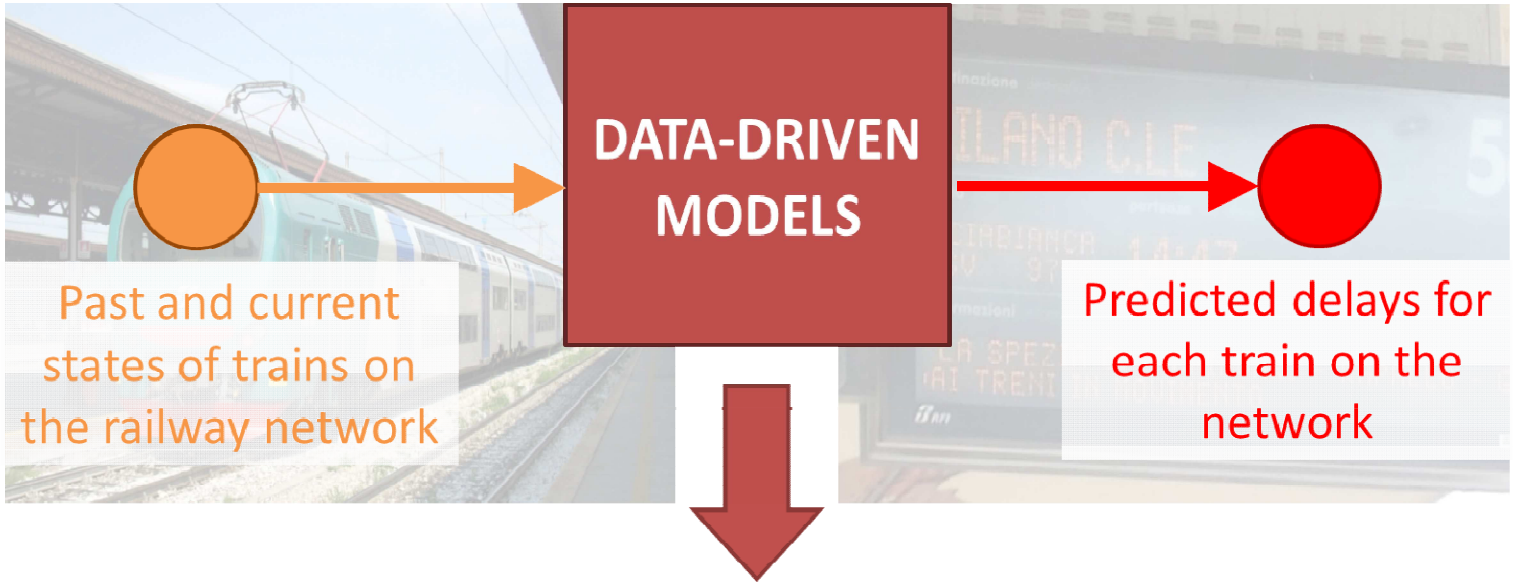
Increasing Automation in TMS

Helps dealing with inherent complexities of railway operations

Improve disruption management processes

Automated tools based on Data Mining techniques and Big Data technologies can be used to deliver more accurate predictions of the future state of a railway network, in particular regarding Train Delay Predictions

Disruption and Delay Prediction



Exploit large amounts of historic "Train Movements" data from TMSs (arrivals, departures, etc.) and look at the past states of the trains over the railway network in order to build a model able to predict future delays of trains by means of data-driven methodologies

Big Data Approach

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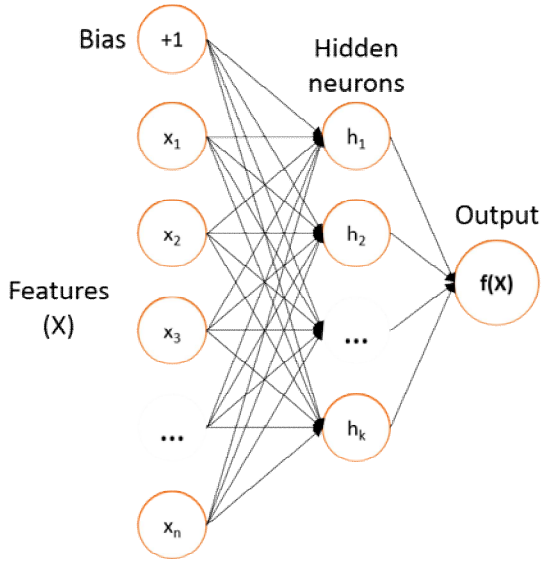
Large amounts of data generated by travelling trains + **Large number of models to be managed** = **Big Data problem**

State-of-the-art machine learning algorithm based on Extreme Learning Machines (ELM) adapted for typical Big Data architectures

Implementation of the algorithm for Apache Spark (state-of-art in-memory computing tool for Big Data) on Apache Hadoop



Spark

THE APACHE SOFTWARE FOUNDATION apache.org

hadoop

Expected Benefits

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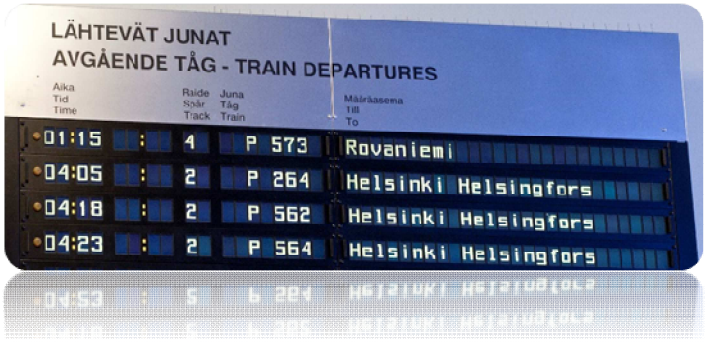
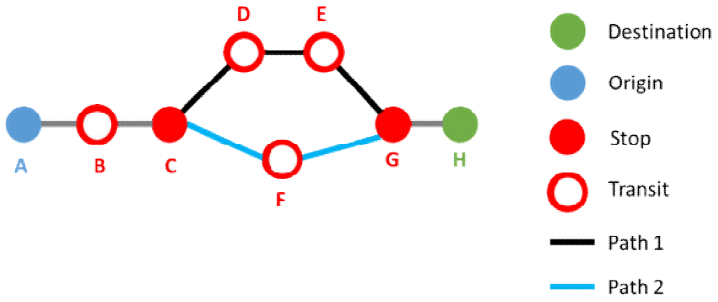
- Improved Passenger Information Systems, increasing the perception of the reliability of train passenger services and, in case of service disruptions, providing valid alternatives to passengers looking for the best train connections
- Improved Freight tracking systems, estimating goods' time to arrival correctly so to improve customers' decision-making processes
- Improved Timetable planning, providing the possibility of updating the train trip scheduling to cope with recurrent delays
- Improved Delay management (rescheduling), allowing traffic managers to reroute trains so to utilize the railway network in a better way



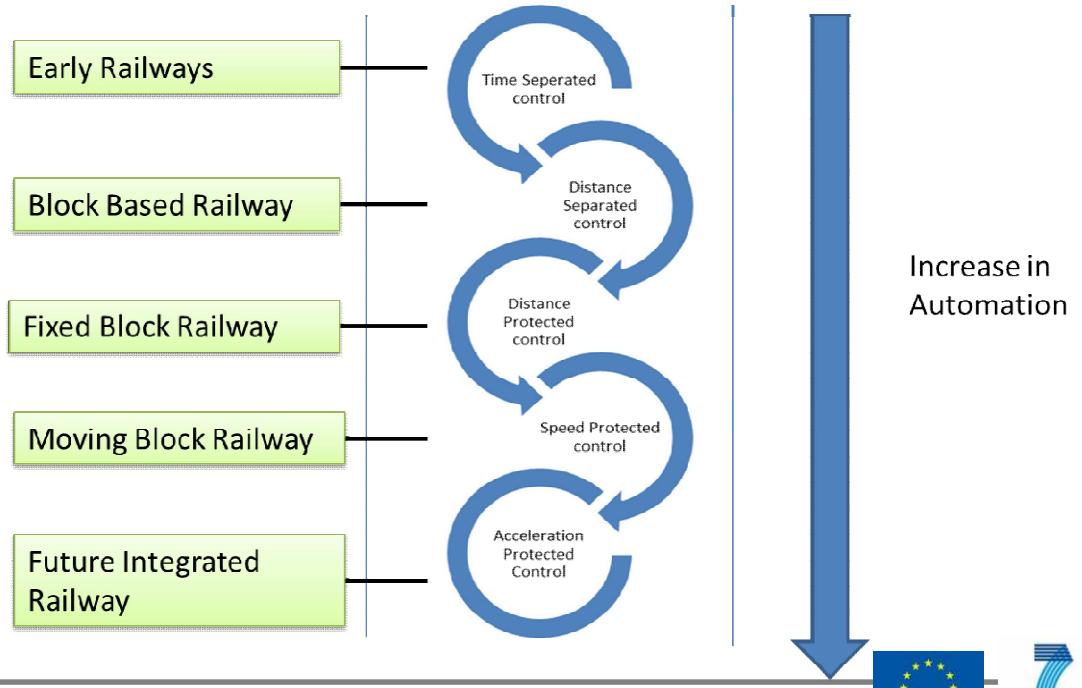


Automation Progression

The use of Big Data Analysis for disruption and delay prediction is a promising approach for **automation improvement**

Other propitious contexts for such an improvement can be identified

This will allow the study of suitable **technological advancements**



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SP3 WP3.4 – Data Modelling and Architecture

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Egidio Quaglietta,
Network Rail

UNIVERSITY OF BIRMINGHAM

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WP3.4 - Data Modelling and Architecture

Develop a data architecture that is able to provide ubiquitous data for railway operations and supporting applications

- Understand the data exchange and integration requirements of railway operations;
- Provide extensions to existing data notations that support operational data;
- Develop new data model supporting autonomous data exchange and reasoning;
- Develop appropriate architectural frameworks for distributed processing in railway operations.

Focus of Activities

Activities focussed on 3 backcast storyboards, giving continuous threads through individual tasks:

- Storyboard 1 – single source, multi-scaled infrastructure data for operations and simulation;
- Storyboard 2 – Data integration as a driver for effective usage of cross-mode capacity;
- Storyboard 3 – Real-time data in support of cross-border and cross organisational operations.

Data Modelling State of the Art

Review of existing models, standards and open data curation / provisioning w.r.t. the requirements of the storyboards

- Supports targeted development activity for demonstrations:
  - Current “best practice” e.g. XML;
  - Next generation models e.g. Ontology;
  - Linked Open Data.
- Presented in D3.4.1.

Improved Situational Awareness

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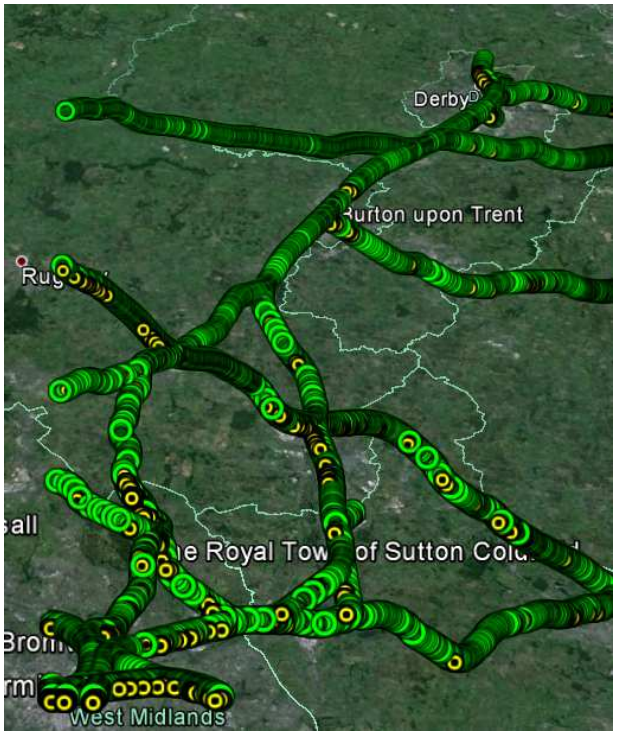
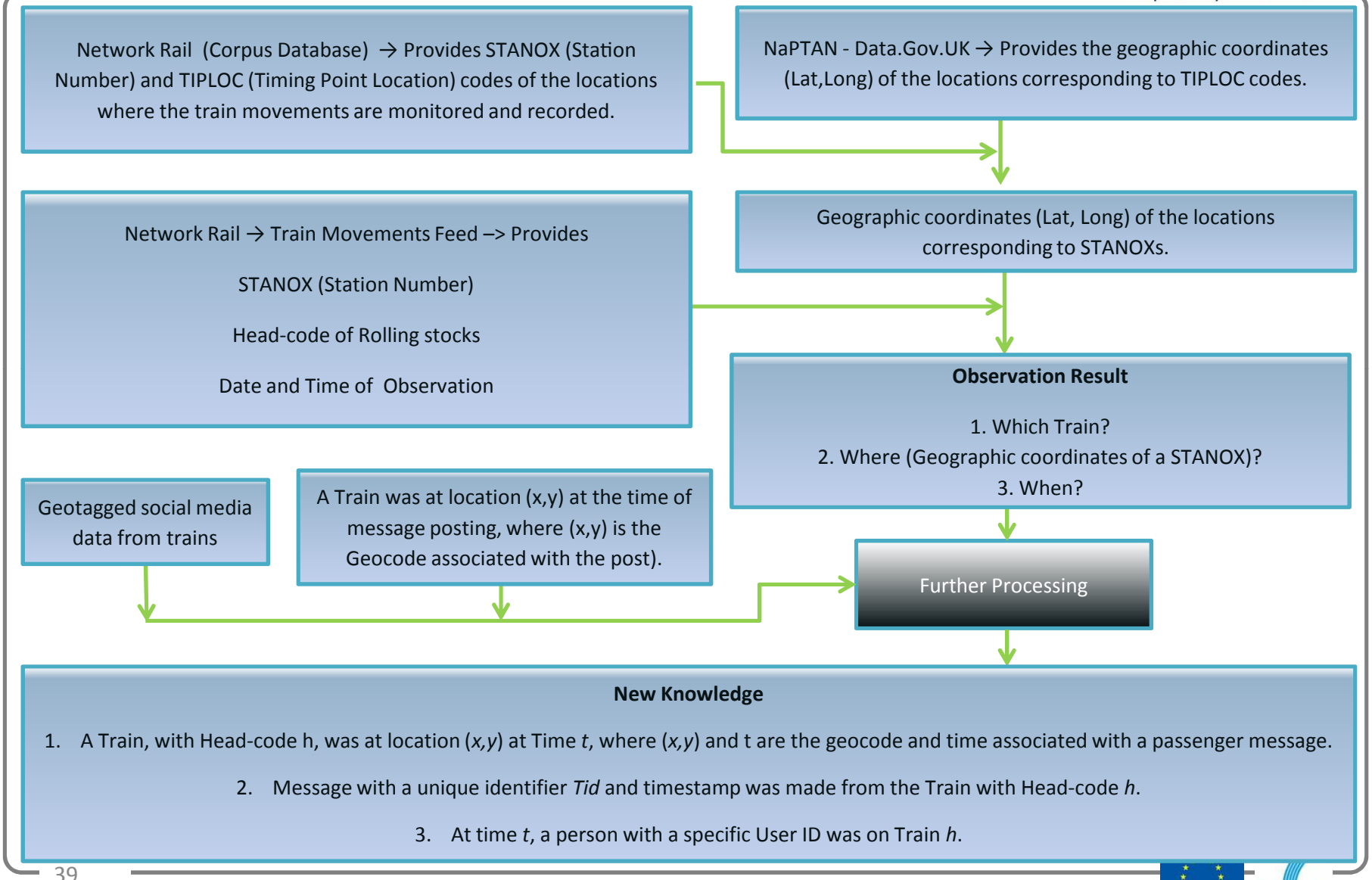
Extra information during disruption using crowdsourced data

- Leveraging open information on evolving situation from social media
  - Anonymisation and privacy
  - Content mining
  - Geolocation
  - Trustworthiness
- Understanding operational impacts
  - Management of the network
  - Informing travellers



Data Fusion Approach



Semantic Web Data Models

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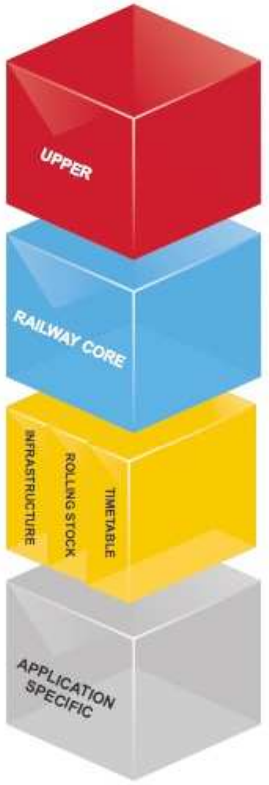
Railway Core Ontology (RaCoOn):



- Support semantic web applications for rail;
- Integrate with external models for multimode:
  - Transit ontology (timetables, networks);
  - Linked NaPTAN (access points);
  - Public transport services ontology.
- Bring in data from other domains to support operations (link to SP4):
  - Semantic Sensor Network, SSN (sensor / RCM data);
  - W3C provenance, PROV-O (understanding of data origins).

Maximising on Multimode

Keeping passengers moving during disrupted operations

- Understanding the data available and the models used
- Understanding the geographical relationships
  - Combining official and open transport network data
- Passenger comfort, improved use of capacity, feeding of long-distance modes