C4R

Capacity for Rail

System assessment and migration

Dissemination, Brussels – 3rd of November 2016

Jonathan PARAGREEN and SP 5 partners

SEVENTH FRAMEWORK PROGRAMME

SP5 content

Capacity for Rail

- Objectives
- Results achieved up to now
  - Scenarios (WP5.3)
  - Cost-benefit analysis (WP5.4)
  - Demonstration (WP5.5)
- Next steps

C4R breakdown structure

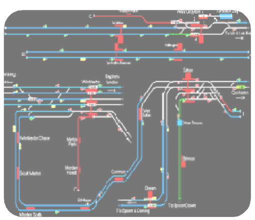
Capacity for Rail

SP1 - Infrastructure

Transversal approach for infrastructure solutions for conventional mixed traffic and VHS, integrated monitoring and power supply, reduced maintenance, highly reliable S&Cs

SP2 - Freight

Longer trains, lower tare loads, automatic coupling, enhanced braking. Modern, automated, intelligent, fully integrated system for efficient, reliable, freight operations

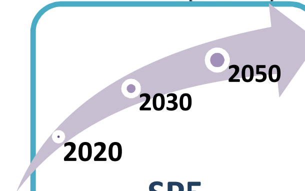


SP3 - Operation and capacity

Traffic capacity computation for freight and passengers, models and simulators for planners: capacity generation, traffic flow, resilience to perturbations, ability to recover from disturbance, computerized real time info to customers and operators at any time.

SP4 - Advanced monitoring

Integration of Advanced Monitoring Technologies in the design and built-in process for an easier-to-monitor (self monitoring) infrastructure with low cost and low impact inspection.



SP5

Migration

State of art

Scenarios for smooth migration from now to 2050

Assessment of the full sustainability of the developed solutions

Demonstration

Recommendations

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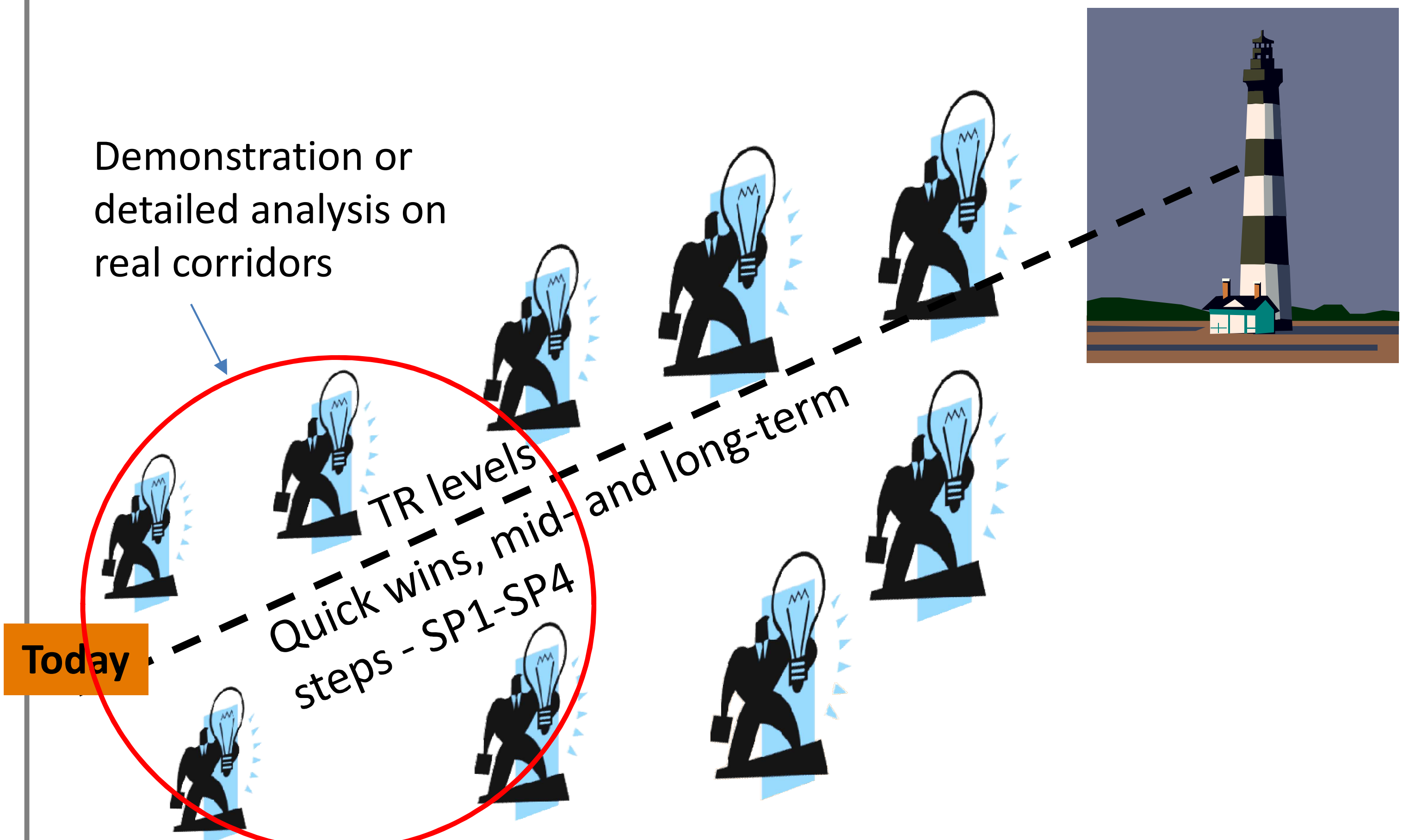
C4R Capacity for Rail

Visions and the steps to reach

Vision 2050 (SP5)

How does the railway system look like?

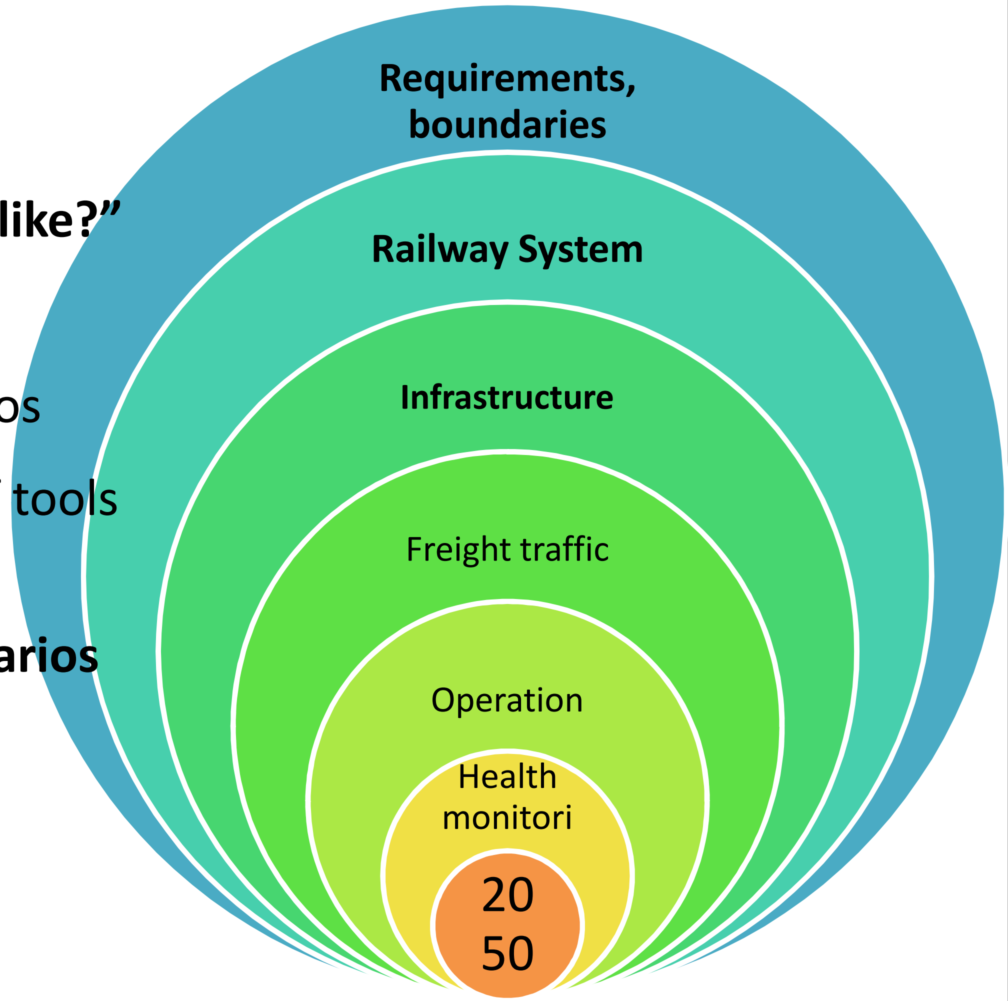


SP5 looks for the system

Capacity for Rail

System approach

- Identification of **visions , future requirements and boundaries**
- **"How does the railway 2050 look like?"**
- Identification of necessary steps
- Development of migration scenarios
- Identification and improvement of tools for assessment
- **Assessment of technologies/scenarios**
- **Identification of optimal capacity enhancement scenarios**
- **Demonstration**



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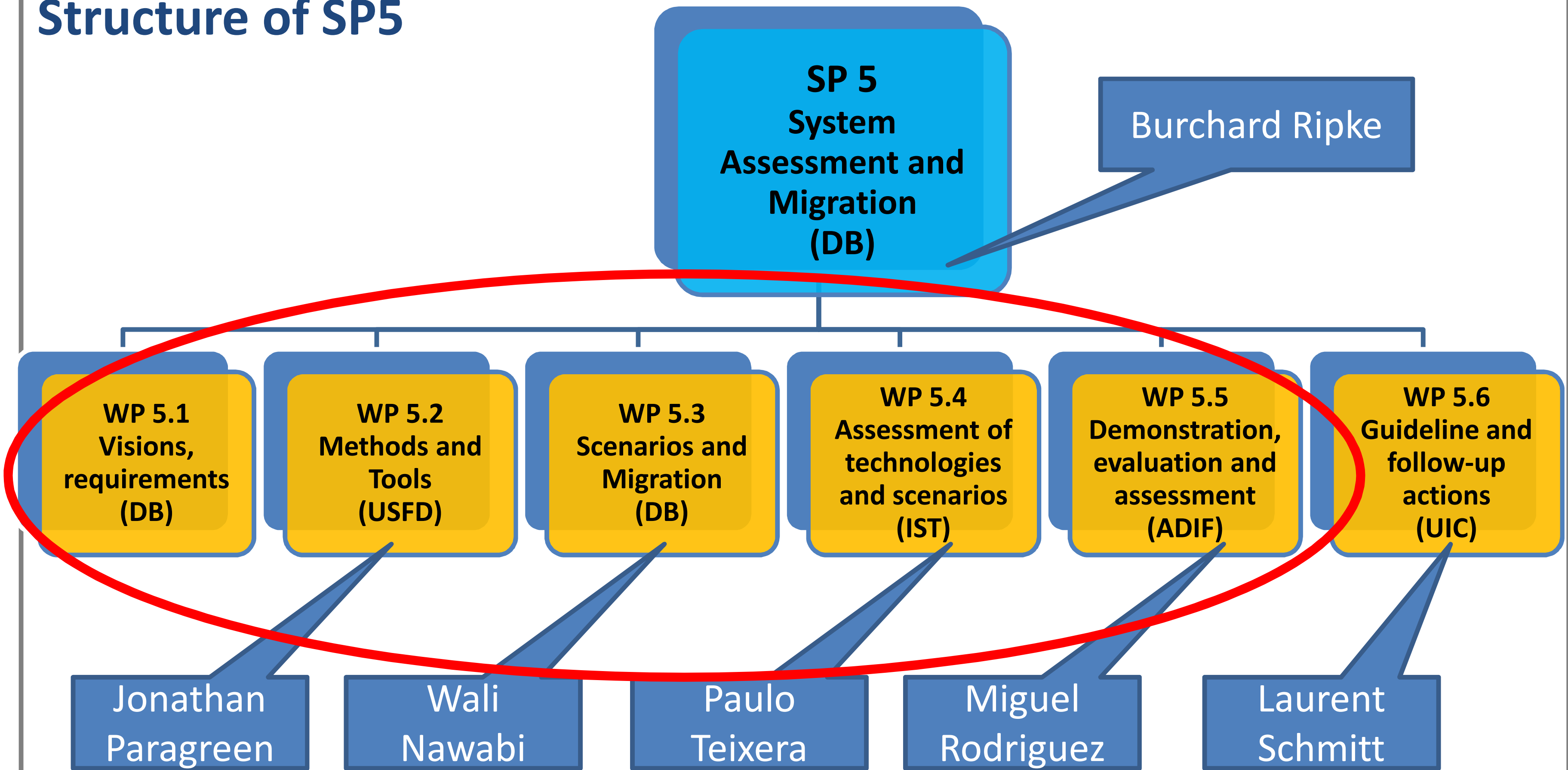
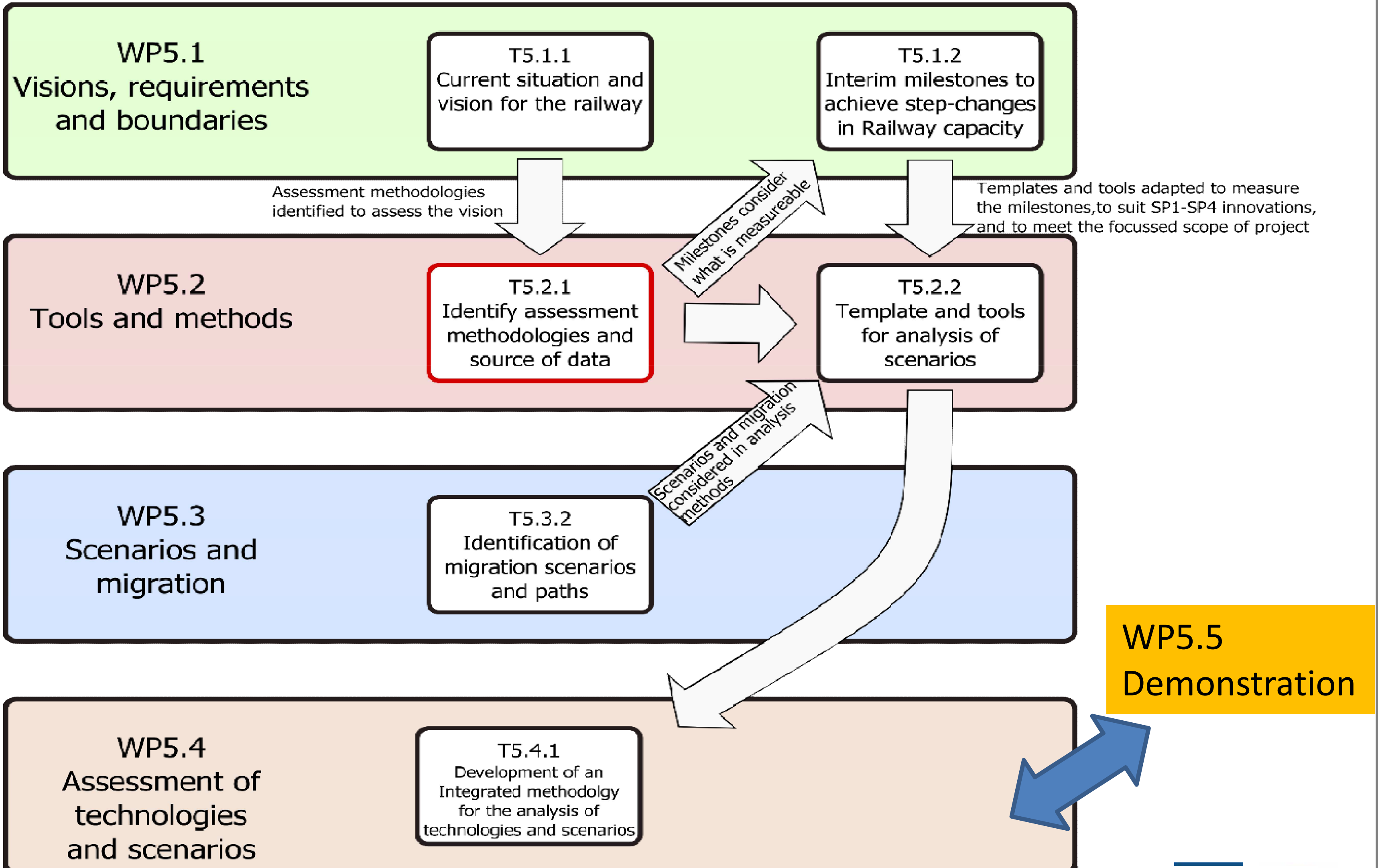
SP5 consist of 6 WP

Structure of SP5



Context of WPs within SP5



SP5 – Achieved results

Work Package 5.3 – Scenarios

Wali NAWABI

DB NETZE

WP 5.3 looks for corridors and migration scenarios

Leader: IK – moves to DB
Partner: UIC, TRV, Systra, DB, NR, ADIF, TRL, IST, TCDD, ERFTC

Objectives

Based on the innovation of other sub-projects and results from WP5.1 and 5.2 this work package will

- select real sites/corridors for migration,
- identify (global) migration scenarios and paths,
- select migration scenarios/paths for validation and assessment for selected sites/corridors
- These migration scenarios will be considered assessed in a global sustainable approach, including their financial, social and environmental impacts.

Vision

The Vision represents the overarching aims and aspirations for the railway system as reflected in European Union and National Long-term strategies for Rail. The vision describes the railway which meets the demands of the scenarios developed and defined by representative bodies given specified drivers.

Drivers

In the Capacity4Rail project the drivers are, along with the Vision, the potential socio- economic or environmental futures against which the needs and use of the railways will be considered.

Technology

A technology is an innovation or identified technology developed from SP1-SP4 in the Capacity4Rail project which is to be assessed against the baseline case.

Scenario

A scenario is a potential ‘combination of situations’ that the future railway may be required to cope with, including the characteristics of railway routes (infrastructure, local climatic conditions & variations, operations, bottlenecks etc) and particular combinations of overarching drivers. *For example, to meet the vision of doubling freight capacity by 2050 with the socio-economic driver of increased urbanisation, one scenario might be “24hr freight operations in urban areas”.*

Migration

The migration path is the implementation of a specific technology to achieve a vision. For example a migration path to address the vision of doubling capacity may be “highly reliable slab track which requires minimal maintenance and interventions over its lifetime”.

Path

A path is a timeline of migrations and combination of technologies within a scenario for a particular case study.

Case study

Case studies are used to assess the migration path technologies.

The case study will compare a technology against a baseline case for a specific geographical location or route, and the physical characteristics of that route/location, and traffic characteristics can be applied to assess the impact of the innovation and how far it goes towards achieving the target.

Aim of the C4R project

To offer an **affordable increase of capacity**, **availability** and **performance** to the railway system, by developing a **holistic view** on the railway as a system of interacting technical components driven by **customer demand**

The capacity issue is addressed in three different ways

- A more efficient use of existing resources, by optimizing **operating strategies**, enhancing traffic planning, improving transshipment procedures and improving automation and operational procedures to reduce the time needed to recover from traffic disruption.
- A reduction of the non-operational capacity-consumers, through the **design** of resilient, reliable and low-maintenance **infrastructure** and **vehicles**, non-intrusive **inspection**, fast renewal and construction **processes**.
- An increase of the performance of existing resources, through significant improvements of wagons maneuverability and equipment to answer **freight customers' needs** for **higher Reliability and performance**.

Necessary steps to reach the vision 2050

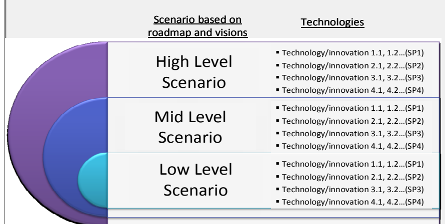
The project is developing a **vision** and identifies the requirements of the railway system in 2030/2050. **"How does the railway 2050 look like?"**
→ to identify the **visions**, **future requirements** and **boundaries** (technical, economical, operational, environmental or social economics).

Identifying the **technologies** and their development/ implementation steps necessary to move towards the targeted vision, the project is developing in an system approach, **innovative concepts of**:

- Infrastructure design and construction **(SP1)**,
- Operation management, incident recovering and freight operations, with a particular focus on transshipment and improved specifications for rolling stock **(SP2 and SP3)**
- Maintenance including advanced monitoring **(SP4)**

Approach for the scenarios

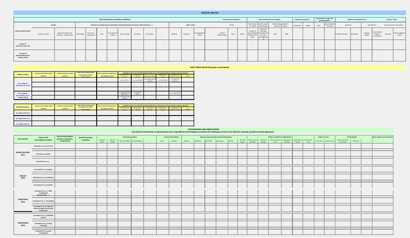
Definition of scenarios based on requirements and common visions (roadmap)



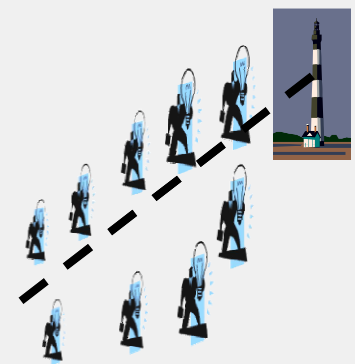
- Generic scenarios
- Specific scenarios

Baseline analysis: Selection and description of real sites and corridors

Analysis of the capacity constraints on the selected corridors (2nd step)



Definition of Migration paths to 2030/2050



Requirements and the steps to reach the vision 2050

Approach for the scenarios

- Scenarios set up from the C4R innovations and their key parameters related to the capacity enhancement.
- High level scenarios with top targets: generic scenarios with respect to SP1-SP4 innovations in comparison to the actual situation and standards.
- Specific scenarios derived from the bottlenecks of the selected corridors (2nd step)…to cope with situations we are not able to control.
- Firstly, to define top targets and requirements (roadmap and defined KPI's).
- Secondly, to define specific parameters with respect to each SP.
- By determining the top targets as well as the specific parameters different scenarios are taken into account, which consist of the Baseline (current situation, 2015), Scenario 2030 and Scenario 2050 → Migration path
- Finally, to indicate the impact of the technical parameters on the 5 key aspects and contribution to the project targets; also combinations of innov.

Possible approach for definition of the scenarios

Firstly, to define top targets and requirements (roadmap and defined KPI's)

Top targets for Scenarios

Targets for Scenarios with respect to SP1				
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**	**Source**

- Baseline 2015
- Scenario 2030
- Scenario 2050

Exemplary for SP1 – Infrastructure

Top targets for Scenarios

Targets for Scenarios with respect to SP1				
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**	**Source**
LCC (NPV, €)	100%	-	80%	DoW
Shorter timeslots for maintenance MTTR (hours)	100%	50%	-	DoW - WP5.3 KPI's
Specific CO2 emissions (incl. embodied)		50%	-	SP5
Resilience to severe weather conditions (mesured by infrastructure down-time)			<50%	SP5

Approach for the scenarios

Secondly, to define specific technical parameters with respect for each SP

Example for SP1 – Infrastructure

Specific Parameters for Scenarios with respect to SP1 to SP4							
Parameters	**Baseline**	**Scenario 2030**	**Scenario 2050**	**Source**	**Name/title/type of the concerned Innovation**	**TRL of the concerned innovation**	**Contribution to the parameter/target by another SP**
Specific Parameters for Scenarios with respect to Infrastructure (SP1)							
Max speed (HS) [km/h]	300-350		400	SP1 (WP1.2) (DoW)			
Mixed traffic in HS/VHS lines	??						
Max axle load [t/axle]	22,5	25	30	SP2			

indicating the TRL for migration issue

incl. other SP's contributing to the target/parameter!

Approach for the scenarios

Finally, to indicate the impact of the technical parameters on the 5 key aspects

Exemplary for SP4 – Monitoring

Parameters	Baseline	Scenario 2030	Scenario 2050	Source	Name/title/type of the concerned Innovation	TRL of the concerned innovation	Contribution to the parameter/target by another SP
Specific Parameters for Scenarios with respect to Infrastructure (SP4)							
Reliability of infrastructure, reduction of track Unavailability (e. g. disruptions due to late weather warning)	100%	150%	150%	C4R target (KPI, reg. SP4)			
Inspection and Maintenance costs	100%	80%	70%	C4R target (KPI, reg. SP1)			
Maintainability of Infrastructure	100%	120%	150%	assumed			
Energy harvesting	100%	120%	140%	assumed			

Impact on							
affordability	adaptability	automation	resilience	capacity	infrastructure	operation	environment
+		++	+	++	++	++	+
+	+	++		+	+	+	
+		+	+	+	+	+	
+		+				+	++

Targets, Parameters and KPI

Top targets for Scenarios with respect to SP1			
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**
LCC (NPV, €)	100%		80%
Shorter timeslots for maintenance MTTR (hours)	100%	50%	-
Specific CO2 emissions by 2030 with respect to 1990, including embodied carbon		50%	-
Unavailability/Disruptions due to EW events (measured by infrastructure down-time); innovative design of infrastructure being resilient to severe weather conditions	100%	40%	80%

Legend
++ strong positive | + noticable positive | o insignificant | - noticable negative | -- strong negative

Specific Parameters (technical objectives) for Scenarios with respect to SP1				Impact of the innovation/technology on													
				Affordability				Adaptability			Resilience		Automation			Capacity	
Parameters	Baseline	Scenario 2030	Scenario 2050	TARGET Decrease of Infrastructure LCC	TARGET Decrease of Train operating costs	TARGET Decrease of specific CO2 emissions	TARGET Elimination of operating noise problem sites	TARGET Seamless train movement	TARGET Interoperability	TARGET Infra capability to respond to new operational requirements from traffic demand	TARGET Reduction of train delays (MDT) due to EW	TARGET Reduction of train delays (MDT) due to Infrastructure failures	TARGET Reduction of track unavailability by using AMS	TARGET Automated Freight System by 2050	TARGET Track unavailability due to inspection	TARGET Capacity for passenger traffic	TARGET Capacity for freight traffic
				infrastructure LCC	train operational costs	CO2 emissions incl. carbon emissions	noise & vibration	Adaptability of freight wagons to cope with different freight containers	bundling of freight rolling stock	ability to change operational parameters with small interventions	perturbations due to flooding and low temperatures	perturbations due to infrastructure failures	Advanced Monitoring System (AMS) integration	Co-modal transhipment and interchange/logistic	inspection time	increase in overall passenger capacity to meet capacity required for 50% shift of medium distance passenger road traffic to rail	increase in overall freight capacity to meet capacity required for 50% of road freight over 300 km to rail
Modular integrated design of new concepts for infrastructure - Innovative New Slab Track (WP 1.1)				+	o	-	+	o	o	+	+	+	o	o	o	+	+
Reliability (MTBF)	100%		200%	x								x					
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year	x								x				x	x
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x							x	x					
Unavailability due to inspection - (MDT)	100%	50%	20%	x								x				x	x
Maintainability/Installation of track (MTTR)	100%		50%	x							x	x				x	x
Flexible system										x							
CO2 embodied emissions	100%		50%			x											
Low noise and vibration	compared to track system on the selected	-5 dB(A)	-10 dB(A)				x										
Innovative High Speed Track (WP 1.2)				+	o	o	o	o	o	o	o	o	o	o	o	o	o
Optimisation of design (same LCC while increasing maximum speed)				x													
Innovative S&C (WP 1.3)				+	o	o	o	o	o	+	+	+	o	o	+	+	+
Reliability of S&C (MTBF)	100%		200%	x								x			x		
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year	x								x				x	x
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x						x	x						
Unavailability due to inspection - (MDT)	100%	50%	20%	x								x			x	x	x
Maintainability/Installation of track (MTTR)	100%		50%	x		x				x	x	x				x	x

Targets and Parameters for SP1

Top targets for Scenarios with respect to SP1			
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**
LCC (NPV, €)	100%		80%
Shorter timeslots for maintenance MTTR (hours)	100%	50%	-
Specific CO2 emissions by 2030 with respect to 1990, including embodied carbon		50%	-
Unavailability/Disruptions due to EW events (measured by infrastructure down-time); innovative design of infrastructure being resilient to severe weather conditions	100%	40%	80%

Legend

++ strong positive **+** noticable positive **o** insignificant **-** noticable negative **--** strong negative

Specific Parameters (technical objectives) for Scenarios with respect to SP1				Impa[…]						
				Affordability				Adaptability		
				TARGET Decrease of Infrastructure LCC	TARGET Decrease of Train operating costs	TARGET Decrease of specific CO2 emissions	TARGET Elimination of operating noise problem sites	TARGET Seamless train movement	TARGET Interoperability	Infra […] resp[…] o[…] requir[…] tra[…]
Parameters	**Baseline**	**Scenario 2030**	**Scenario 2050**	infrastructure LCC	train operational costs	CO2 emissions incl. carbon emissions	noise & vibration	Adaptability of freight wagons to cope with different freight containers	bundling of freight rolling stock	abilit[…] o[…] paramet[…] int[…]
Modular integrated design of new concepts for infrastructure - Innovative New Slab Track (WP 1.1)				+	o	-	+	o	o	+
Reliability (MTBF)	100%		200%	x						
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year	x						
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x						
Unavailability due to inspection - (MDT)	100%	50%	20%	x						
Maintainability/Installation of track (MTTR)	100%		50%	x						
Flexible system										
CO2 embodied emissions	100%		50%			x				
Low noise and vibration	compared to track system on the selected	-5 dB(A)	-10 dB(A)				x			
Innovative High Speed Track (WP 1.2)				+	o	o	o	o	o	o
Optimisation of design (same LCC while increasing maximum speed)				x						
Innovative S&C (WP 1.3)				+	o	o	o	o	o	+
Reliability of S&C (MTBF)	100%		200%	x						
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year	x						
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x						
Unavailability due to inspection - (MDT)	100%	50%	20%	x						
Maintainability/Installation of track (MTTR)	100%		50%	x		x				

Targets and Parameters for SP2

Top targets for Scenarios with respect to SP2				
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**	**Source**
Capacity requirements for freigth [tonne-kilometres]	100%	130%	160%	SP2 - standard
	100%	150%	180%	SP2 / SP5 / D-Rail - WP low
	100%	210%	300%	SP2 / SP5 / D-Rail - WP high
Noise pollution [dB(A)]		-5	-10	SP5 (noise e. g. from brake)
Transport-related greenhouse gas [tonne/tonne-kilimetres]	xx%	50%	50%	SP5
Specifiy energy consumption [Megajoule/tonne-kilometres]	72%	50%	50%	SP5
Absolut energy consumption [Megajoule/tonne-kilometres]	94%	50%	50%	SP5
Exhaus emision (Nox and PM10) [/tonne-kilometres]	xx%	60%	60%	SP5
Standardized loading gauge (on RCF)	G2 and P/C 410	G2 and P/C 432	GC and P/C 432	SP2
Customer's Cost for Rail Freight Transport (referred to road freight)		-20%	-50%	SP2
Severe weather conditions tbd	tbd	tbd	tbd	see SP3
Winter (snow) resilience				
water (rain) resilience				
storm (wind) resilience				

Legend

++ strong positive | + noticable positive | o insignificant | - noticable negative | -- strong negative

Specific Parameters for Scenarios with respect to SP2									Impa					
									affordability				adaptabilit	
									TARGET Infrastructure LCC	TARGET Train operating costs	TARGET Specific CO2 emissions	TARGET Noise levels	TARGET Seamless train movement	TARGET Interoperability
Parameters	**Baseline**	**Scenario 2030**	**Scenario 2050**	**Source**	**Expected results**	**Name/title/type of the concerned Innovation**	**TRL of the concerned innovation (Migration)**	**Contribution to the parameter/target by another SP**	infrastructure LCC	operational costs	carbon emissions	noise & vibration	No access restriction to any corridor segment	bundling of freight rolling stock
Infrastructure									-	+	++	-	++	o
Max speed [km/h]	100	120	160	SP2						x	xx	-		
Max. axle load on RCF [t]	22,5	25	30	SP2						x	xx	-	xx	
Max. meter load on RCF [t]	8,0	8,0	8,3	SP2					-	x	x	-	xx	
Max. loading gauge wagon load	G1	G2	G2	SP2					o	x	x	-	xx	
Max. loading gauge inter modal	P/C 400	P/C 432	P/C 450	SP2					o	x	x	-	xx	
Novel rail freight vehicles: Wagons									o		+	+	o	o
Automatic couplers [%]	2	50	100	SP2						x				
Running gear brakes	Cast brakes	50% LL Brakes	disc brakes	SP2						x	x	x		
Electronic brake control [%]	0	40	100	SP2						x	x	x		
Novel rail freight vehicles: Locomotives									o	+	-	o	++	o
Duo Locos [%]	2	40	80	SP2						x	-			
Tractive effort [kN] 4-axl loco	300	350	400	SP2						x				
Novel rail freight vehicles: Train performance									o	+	++	o	++	++
Max. train length [m]	740	835	1.050	SP2						xx	xx		xx	xx
Bundling of trains in some corridors	0	2x750m	2x1000m	SP2						xx	xx		xx	xx
Max train weight [t]	2.200	4.400	10.000	SP2						xx	xx		xx	
Novel rail freight vehicles: Wagon performance									-/x	++	++	-/x	++	++
Wagon Load - max axle load	22,5	25	30	SP2		Baseline Habbins								
Tare weight per wagon meter index	100	98	93	SP2		Lighter wagons			x	x	x	x	o	o
Load weight per wagonmeter	100	117	150	SP2		Higher axle load			-	xx	x	-	o	o
Intermodal container wagon - max axle load	22,5	22,5	25	SP2		Baseline Sggmrss								
Tare weight per wagon meter index	100	98	93	SP2		Lighter wagons			x	x	x	x	o	o
Load weight per wagonmeter	100	101	115	SP2		Higher axle load			-	xx	x	-	o	o
Intermodal trailer wagon - max axle load	22,5	22,5	25	SP2		Baseline Sdggmrs								
Tare weight per wagon meter index	100	98	93	SP2		Lighter wagons			x	x	x	x	o	o
Load weight per wagonmeter	100	101	115	SP2		Higher axle load			-	xx	x	-	o	o
Co-modal transhipment and									o	++	++	o	o	o
Marshalling yard automation	5%	50%	100%	SP2										
Feeder trains	Diesel	50% Duo-locos linear	100% Duo-locos linea	SP2						xx	xx			
Co-modal transhipment and									o	++	o	o	o	+
End-point lines	100%	75%	50%	SP2						xx				
Linear with inter mediate stops	0%	25%	50%	SP2						xx				
Terminal performance	None automated	Some automated	Fully automated	SP2						xx				x
High Speed Freight									o	o	o	o	o	o
Network	National post	International post and parcel	International post and parcel	SP2										

Approach for the scenarios

Combination of innovations and migration paths

Physical constraints of the selected route (hot spot) related to capacity*	C4R innovations to cope with the constraints (what can be influenced by C4R innovations)	Strong impact on C4R targets (qualitatively guess by the concerned SP)	TRL of the concerned innovation (reg. Migration)	Additional contribution by other SP's innovation (considering of TEN-T projects already planned)	TRL of the concerned innovation (reg. Migration)	Scenarios based on combination of innovations to solve the existing constraints	Overall impact (assessment of the benefits based on the outcomes from WP5.4 and SP3**)
			2016/2030/2050		2016/2030/2050		
Infrastructure constraint (conventional track system): big delays, high Maintenance activities and costs	**SP1 Infrastructure - Innovative New Slab Track**	Reduction of infrastructure LCC; Reduction of train delays due to Infrastructure; Increase of capacity for passenger & freight;	TRL of the innovative new slab track (SP1)	SP4: use of sensing technology, pre-failure detection (based on improved real-time data), reduced infrastructure (Maintenance) costs	TRL of the innovative sensors (SP4);	SP1 + SP4: Innovative New Slab Track combined with embedded sensor	SP3: capacity simulation, capability trade-offs model, linked with CBA results
Infrastructure: capacity constraint, big delays, low Availability	**SP1 Infrastructure - Innovative High Speed Track**	Reduction of infrastructure LCC	TRL of the innovative high speed track (SP1)	SP2: Novel freight vehicles (e. g. train length, bundling of trains)	TRL of the innovative vehicle (SP2);	SP1+SP2: Innovative High Speed Track with novel rail freight vehicles	SP3: capacity simulation, capability trade-offs model, linked with CBA results
constraints on a track section (e. g. bridges): disruptions (extreme weather), no Monitoring of structural health, high Maint. & inspection activities, low Reliability	**SP4 Non-intrusive innovative monitoring techniques**	Reduction of infrastructure LCC; Reduction of train delays due to IF (& EW); Increase of capacity for passenger & freight; Reduced unavailability (MDT) by using AMS	TRL of the innovative sensors (SP4)			SP4 + SP?: Innovative sensors combined with...	SP3: capacity simulation, capability trade-offs model, linked with CBA results

Regarding the assessment of technologies and scenarios

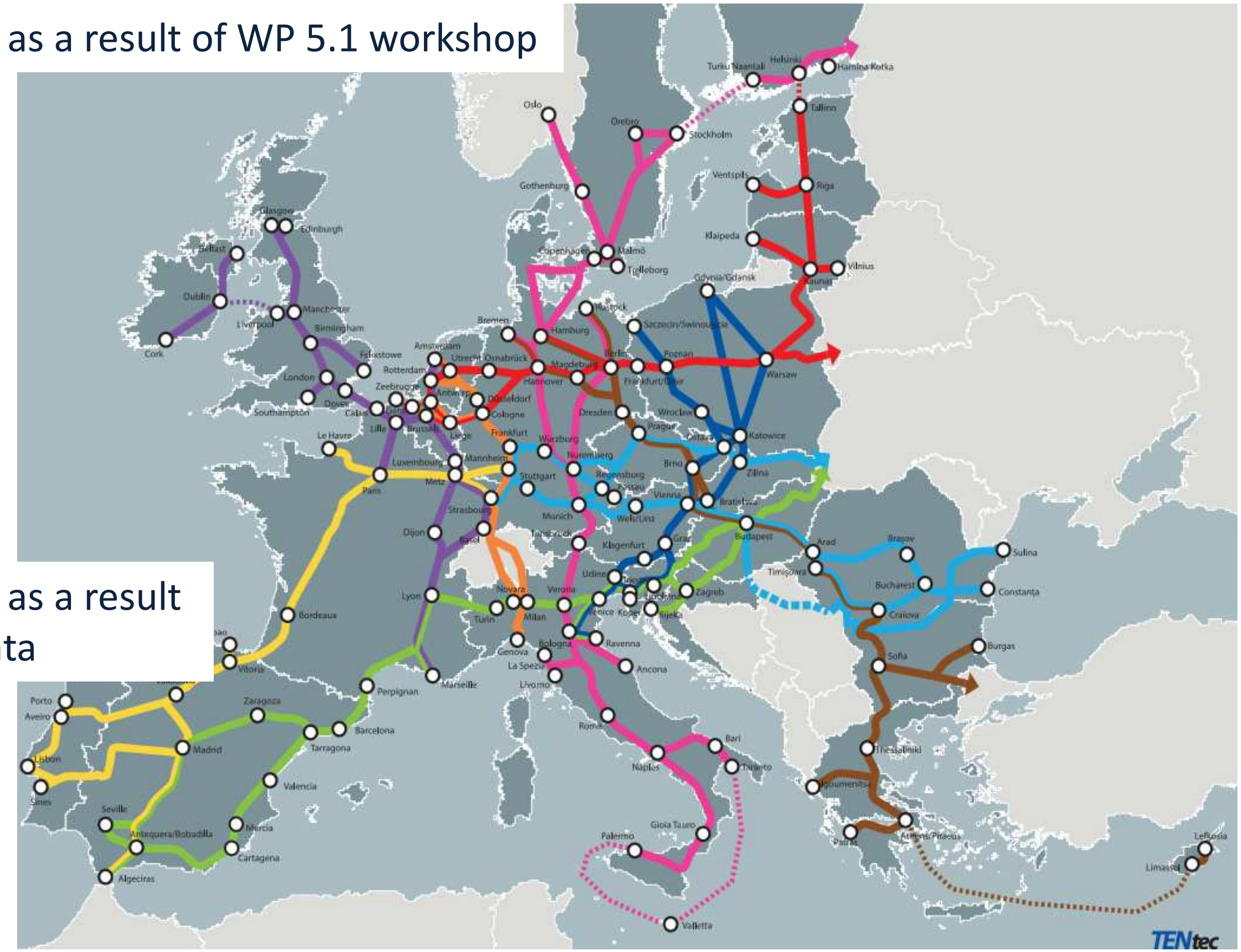
- Need for definition of assessment criteria
- These scenarios will be **assessed** with respect **to capacity and resilience of operation** in SP3. Beside the impact on Capacity & Resilience of operation these scenarios will also assessed with respect to the targets Affordability, Automation, Adaptability (by Multi Criteria Assessment and CBA).
- Not intended to assess each innovation. It is not aimed to show that each target/parameter is assessed and achieved (we assess what we can do). The focus should be to evaluate the **impact of the innovations** on the C4R targets by considering their cost-effectiveness contributing to the capacity enhancement. Optimal combination of solutions can be identified from their cost/capacity/resilience ratios.

  Each innovation will have different aims – tackling different C4R priorities – and different TRL levels. Therefore the availability and accuracy of cost, reliability, availability, safety and capacity data will be different.

Freight Corridors in Europe

- Key Corridors as a result of WP 5.1 workshop
  - Pink
  - Green
  - Purple
  - Red

- Key Corridors as a result of corridor data
  - Green
  - Orange



SP5 – Achieved results

Work Package 5.4 – Assessment

INTEGRATED METHODOLOGY FOR THE ANALYSIS OF SCENARIOS AND MIGRATION

P. TEIXEIRA
F. FRANCISCO
C. LOMBARDI
TÉCNICO LISBOA

Outline

- Methodologies Overview
- Multi-Criteria Analysis (MCA)
- Cost Benefit Analysis (CBA)
- Required input data

Methodologies Overview

- Two complementary methodologies:

MULTI-CRITERIA ANALYSIS + COST-BENEFIT ANALYSIS

Multi-Criteria Analysis

- Impact of technologies and scenarios is measured against a set of targets derived from the vision for the 2030/2050 European rail network
- Each target must be associated with a measurable criterion

Cost-Benefit Analysis

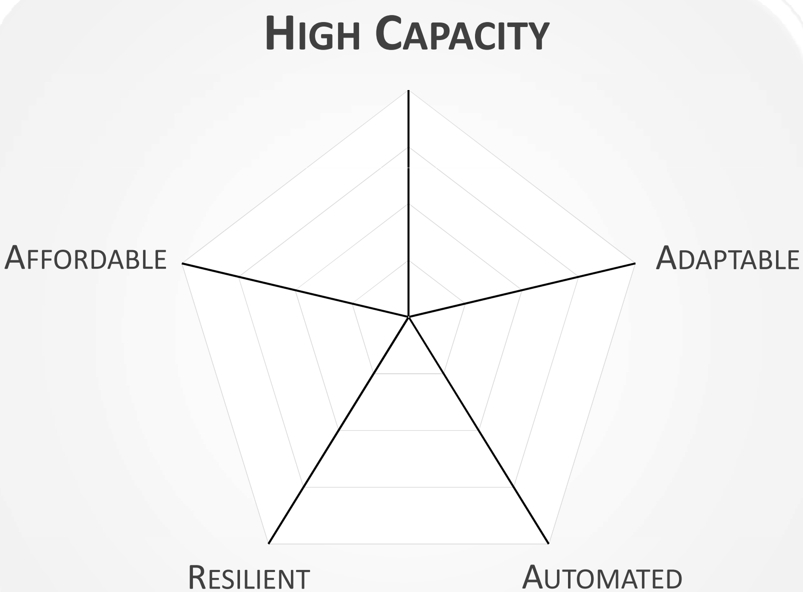
- Established method for appraisal of investments
- Allows for an estimate of the economic impacts.

Methodologies Overview

OUTPUTS

Multi-Criteria Analysis

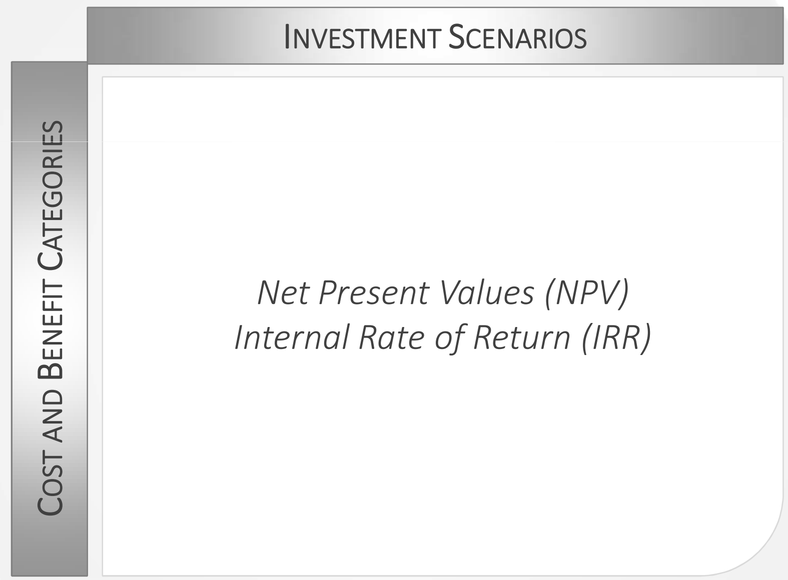
Impacts towards Vision for 2030/2050



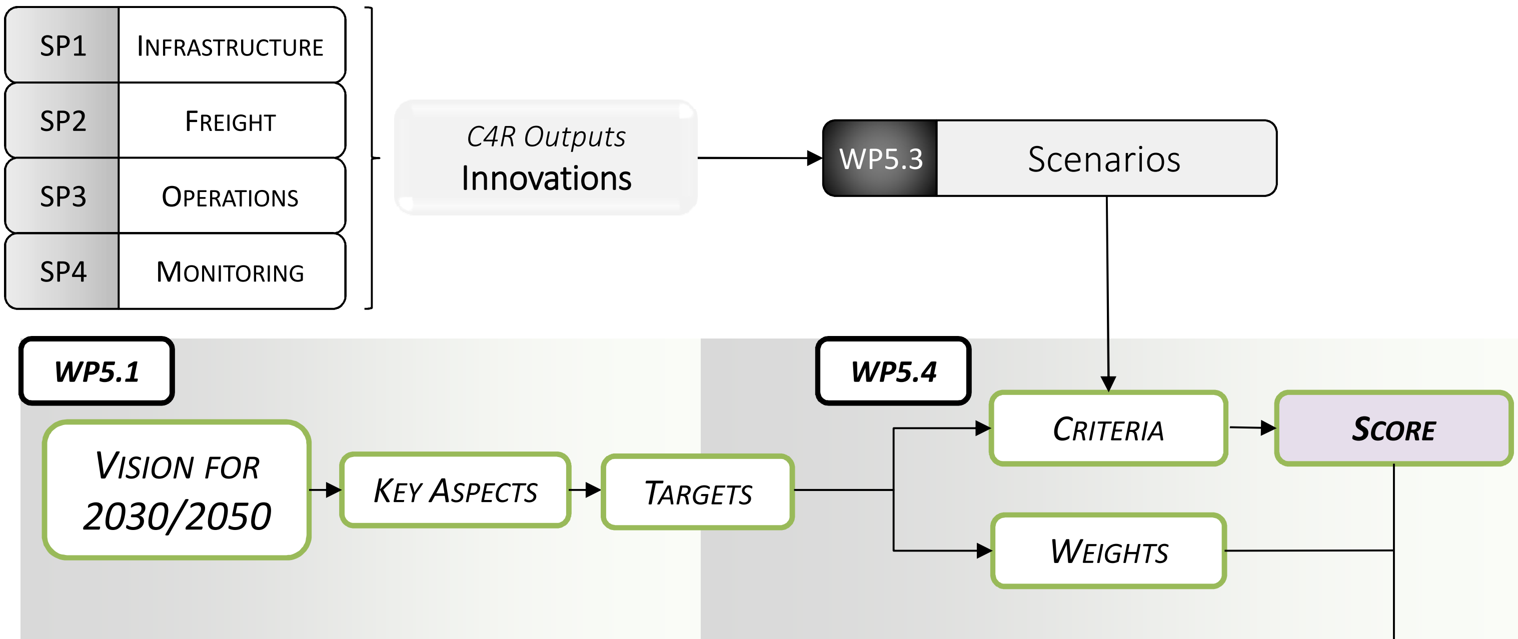
+

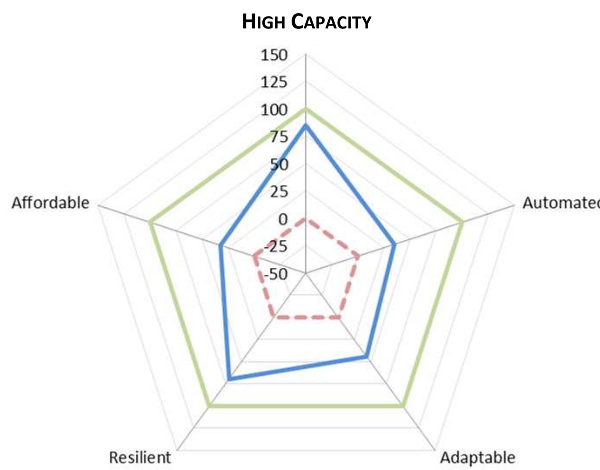
Cost-Benefit Analysis

Socio-economic appraisal



MCA Procedure





	Affordability	Adaptability	Resilience	Automation	High Capacity
Baseline	0	0	0	0	0
Score	32	44	70	35	85
Vision	100	100	100	100	100

MCA Targets

Capacity for Rail

1. Affordability	**T1.1.**	20% decrease in infrastructure Life-Cycle Cost (LCC) by 2050
	T1.2.	50% decrease in Train Operating Costs (TOC) by 2050
	T1.3.	50% decrease in specific CO_2 emissions, including embodied carbon, by 2030
	T1.4.	Elimination of operating noise problem sites by 2050
2. Adaptability	**T2.1.**	Freight rolling stock adaptable to cope with different freight containers by 2050
	T2.2.	Fully interoperable bundling of freight rolling stock by 2050
	T2.3.	Infrastructure adaptable to new operational requirements from traffic demand by 2050
3. Resilience	**T3.1.**	80% reduction of train delays due to Extreme Weather events by 2050
	T3.2.	80% reduction of train delays due to Infrastructure Failures by 2050
4. Automation	**T4.1.**	Automated rail freight system by 2050
	T4.2.	50% reduction of track unavailability due to monitoring & inspections by 2050
5. High Capacity	**T5.1.**	100% increase in overall freight capacity by 2050
	T5.2.	100% increase in overall passenger capacity by 2050

SEVENTH FRAMEWORK PROGRAMME

CBA Approach: Overview

- Perform Cost-Benefit Analysis (CBA) on the application of C4R innovations to rail corridors.
- Features of this CBA:
  - Wide geographic scope
  - Dozens of individual projects
  - Technologies still under development
  - Input data scattered, inconsistent and incomplete
- Not reasonable to expect the level of detail usually associated with the CBA of a single project

CBA Approach: Overview

- Need an approach focused on the **variables potentially changed by the innovations**
- Needs to be simple enough that the amount of data is manageable
- Specifically:
  - Approach should be based on whatever information is available to establish baseline
  - Variables that are not significantly changed should not be included in analysis
- Must allow sensitivity and probabilistic analyses

CBA Approach: Investment Levels

- Incremental approach with 3 investment levels:

Baseline

No investment besides maintenance or replacement of End Of Life items

TEN-T Investments

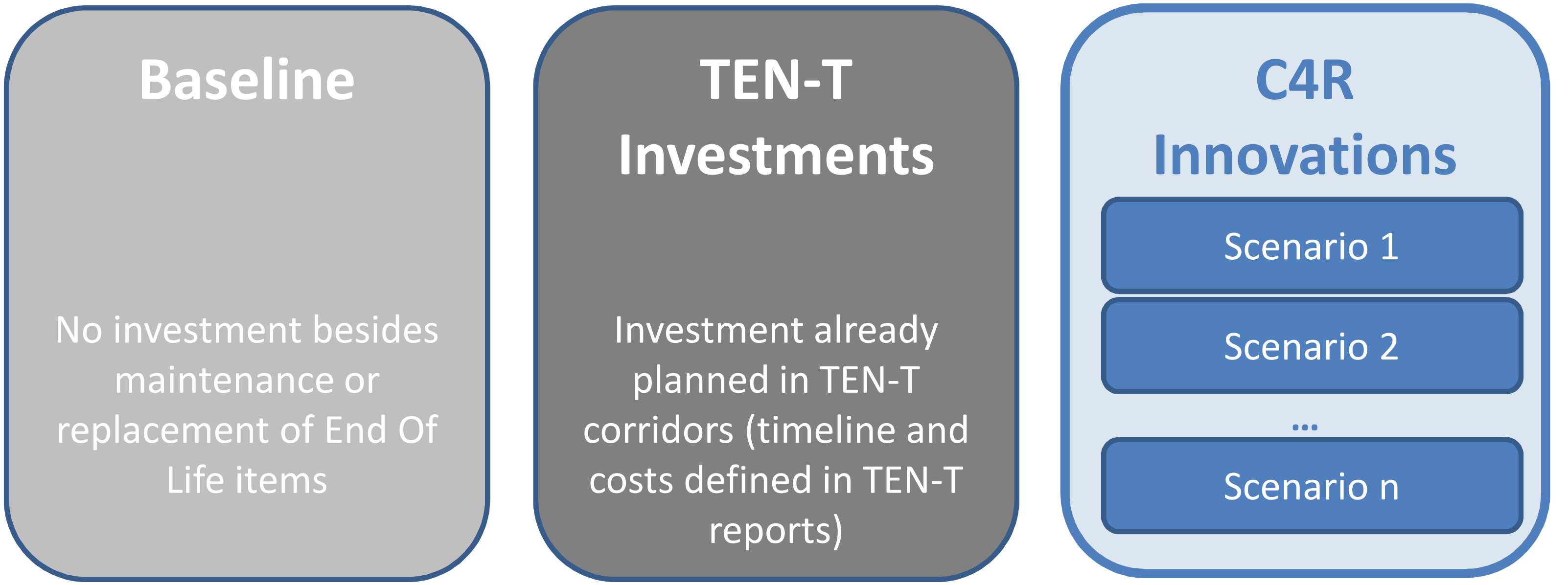
Investment already planned in TEN-T corridors (timeline and costs defined in TEN-T reports)

C4R Innovations

Introduction of new technologies from C4R project

CBA Approach: Investment Levels

- Incremental approach with 3 investment levels:



CBA: Reference Values

- Reference Values, CBA Boundaries
  - CBA boundaries from EC guidelines

CBA Boundaries				
Time horizon	40	years		
Year 1	2016			
Economic Boundary Conditions				
Price base year	2015			
Social discount rate	4,00%			
Shadow price conversion factor	0,95			

Case Study: Input Data

- Infrastructure Data:

	Year	Length	Number of Tracks	Switches and Crossings Density	Max Train Length	Max Axle Load	Capacity			
							Block Length	Buffer Time	Crossing Buffer	Supplement for Maintenace
		km		1/km	m	T/axle	km			h/track
									Baseline	
S5 Stockholm - Mjölby	2015	239	2	0,14			15	5%	0%	5
S5 Stockholm - Orëbro	2015	227	2	0,14			15	5%	0%	5

Maintenance Costs						Passenger		Freight	
Track Fixed	Track Variable	S & C Fixed	S & C Variable	Monitoring track	Monitoring S&C	Av. Speed	Time	Av. Speed	Time
€/(year·km	€/(MGT·km)	€/year	€/(MGT·	€/(year·km)	€/(year·km)	(km/h)	(h)	(km/h)	(h)
30000	130	10500	130			124	1,93	50	4,78
30000	130	10500	130			153	1,48	49	4,60

CBA: Reference Values

Capacity for Rail

- Reference trains assigned to each investment level

Freight Train 1

400 m length
22,5 T/axle wagons

Freight Train 2

750 m length
22,5 T/axle wagons

Freight Train 3

750 m length
25 T/axle wagons

Baseline

Max. Length: 400 m
Max axle load: 22,5 T/axle

TEN-T Investments

Siding extensions and signaling upgrades, complete 2020

Max. Length: 750 m
Max axle load: 22,5 T/axle

C4R Innovations

Slab track instalation, complete 2025

Max. Length: 750 m
Max axle load: 25 T/axle

SEVENTH FRAMEWORK PROGRAMME

CBA: Tool

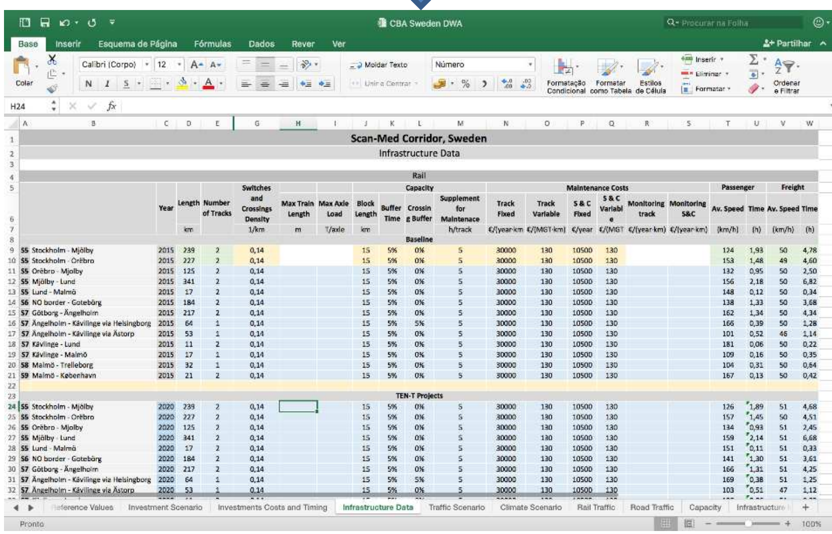
Capacity for Rail

Reference Values

Infrastructure Data

Traffic Scenario

Investment Scenario



Excel tool for automatic CBA computation of each Scenario

CBA Results: NPV, IRR

Comparison of Scenarios

Sensitivity Analysis

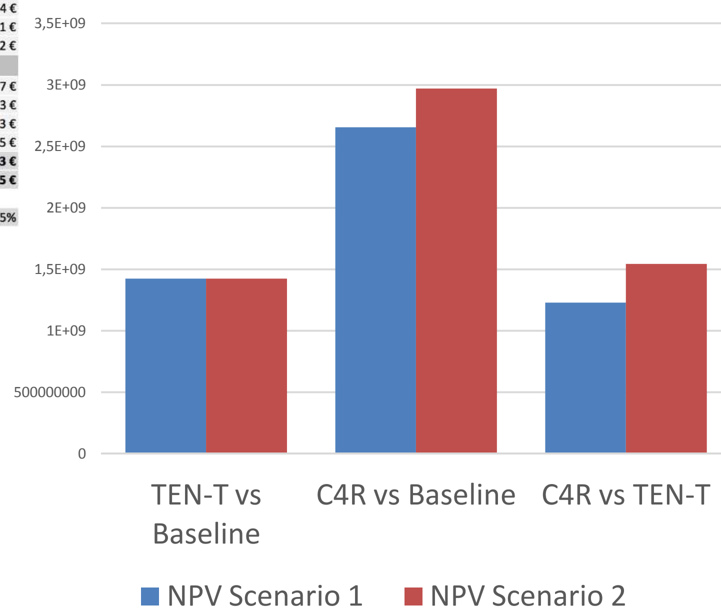
Probabilistic Analysis

CBA: Comparison of Scenarios

- Alternative scenarios can be directly compared

	Net Cost		
	TEN-T vs Baseline	**C4R vs Baseline**	**C4R vs TEN-T**
Infrastructure			
Investment	1 314 884 568 €	4 541 002 833 €	3 226 118 265 €
Maintenance	2 809 010 €	-654 360 868 €	-657 169 878 €
Total Financial Cost	**1 317 693 578 €**	**3 886 641 965 €**	**2 568 948 387 €**
Total Economic Cost	**1 251 808 899 €**	**3 692 309 867 €**	**2 440 500 967 €**

	Net Benefit		
	TEN-T vs Baseline	**C4R vs Baseline**	**C4R vs TEN-T**
Consumer Surplus			
Value of Time			
Passenger Time Savings	395 993 538 €	908 411 345 €	512 417 807 €
Freight Time Savings	48 734 650 €	404 813 297 €	356 078 647 €
Delays	431 922 329 €	329 287 903 €	-102 634 426 €
Producer Surplus			
Rail Passenger Operating Costs	-444 093 212 €	-1 195 958 430 €	-751 865 218 €
Rail Freight Operating Costs	548 848 403 €	1 395 091 907 €	846 243 504 €
Road Passenger Operating Costs	838 243 708 €	2 255 614 049 €	1 417 370 341 €
Road Freight Operating Costs	829 777 053 €	2 188 956 495 €	1 359 179 442 €
Externalities			
Rail Passheger GHG Emissions	-3 108 652 €	-8 371 709 €	-5 263 057 €
Rail Freight GHG Emissions	9 604 847 €	13 515 390 €	3 910 543 €
Road Passenger GHG Emissions	*8 382 437 €*	22 556 140 €	14 173 703 €
Road Freight GHG Emissions	12 627 042 €	33 310 208 €	20 683 165 €
Total Economic Benfits	**2 676 932 142 €**	**6 347 226 594 €**	**3 670 294 453 €**
NPV	**1 425 123 242 €**	**2 654 916 728 €**	**1 229 793 485 €**
Internal Rate of Return	8,66%	7,75%	6,95%



	Net Cost		
	TEN-T vs Baseline	**C4R vs Baseline**	**C4R vs TEN-T**
Infrastructure			
Investment	1 314 884 568 €	3 745 037 244 €	2 430 152 676 €
Maintenance	2 809 010 €	-429 765 254 €	-432 574 264 €
Total Financial Cost	**1 317 693 578 €**	**3 315 271 990 €**	**1 997 578 412 €**
Total Economic Cost	**1 251 808 899 €**	**3 149 508 391 €**	**1 897 699 491 €**

	Net Benefit		
	TEN-T vs Baseline	**C4R vs Baseline**	**C4R vs TEN-T**
Consumer Surplus			
Value of Time			
Passenger Time Savings	395 993 538 €	753 704 357 €	357 710 819 €
Freight Time Savings	48 734 650 €	367 006 682 €	318 272 033 €
Delays	431 922 329 €	294 199 934 €	-137 722 395 €
Producer Surplus			
Rail Passenger Operating Costs	-444 093 212 €	-1 195 958 430 €	-751 865 218 €
Rail Freight Operating Costs	548 848 403 €	1 395 091 907 €	846 243 504 €
Road Passenger Operating Costs	838 243 708 €	2 255 614 049 €	1 417 370 341 €
Road Freight Operating Costs	829 777 053 €	2 188 956 495 €	1 359 179 442 €
Externalities			
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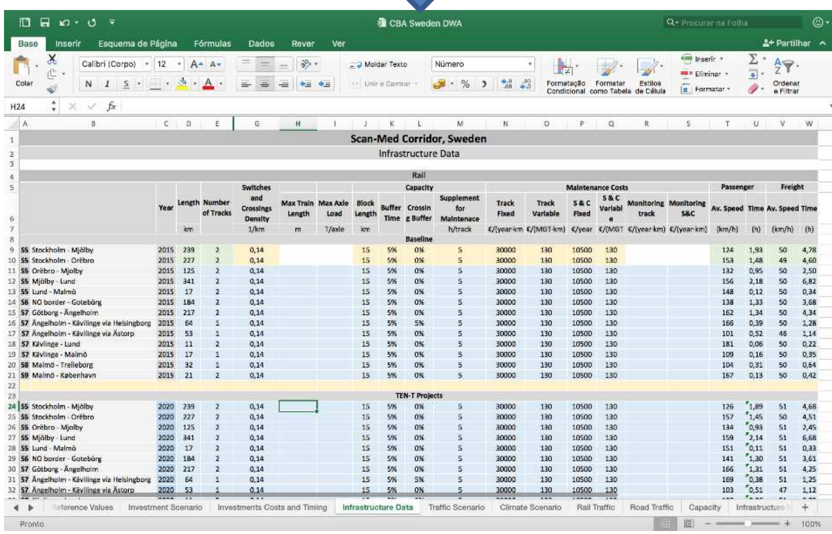
Road Freight GHG Emissions	12 627 042 €	33 310 208 €	20 683 165 €
Total Economic Benfits	**2 676 932 142 €**	**6 119 625 023 €**	**3 442 692 882 €**
NPV	**1 425 123 242 €**	**2 970 116 633 €**	**1 544 993 390 €**
Internal Rate of Return	8,66%	8,68%	8,71%

CBA: Probabilistic Analysis

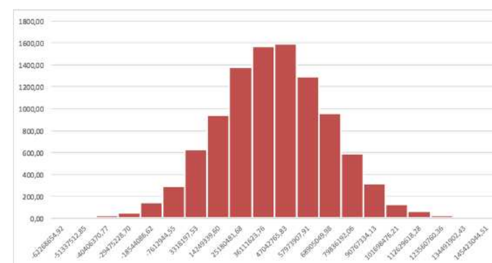
Random value generators for critical variables

Choice of an appropriate probability distribution



Script for results generation

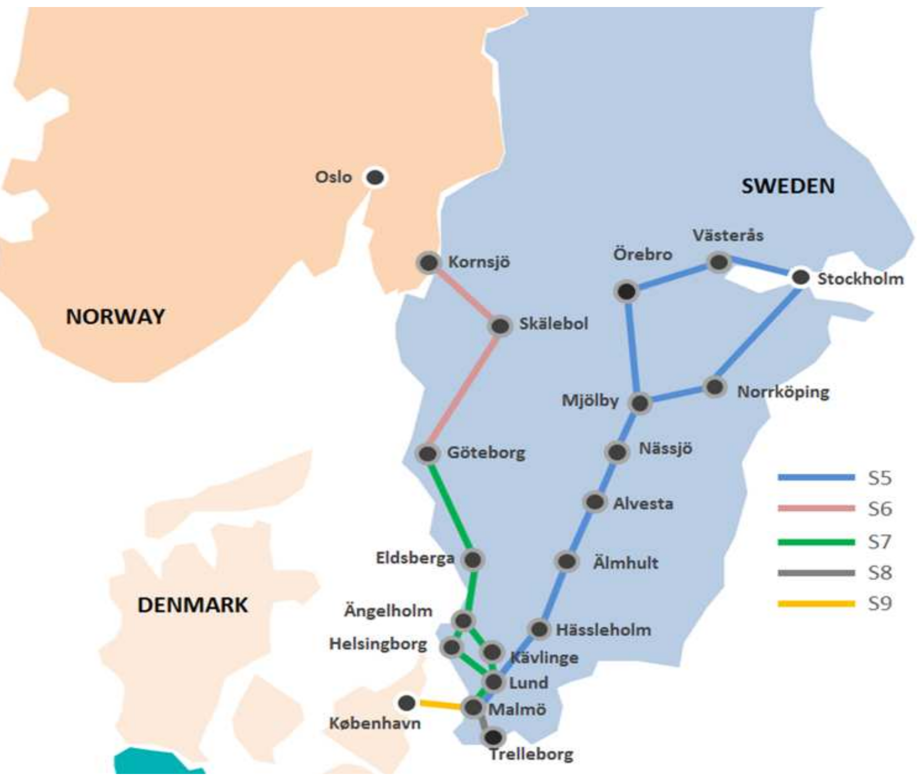
Post-processing



Case Study:
Swedish section of Scan-Med corridor

Capacity for Rail

- **Approach approved and tool available for testing and validation (Swedish case study)**



D30 fx

	A	B
1		**Scan-Med Corridor, Sweden**
2		Corridor Overview
3		
21		
22		**Rail Corridor Segmentaion**
23	**S5**	Stockholm - Mjölby
24	**S5**	Stockholm - Orëbro
25	**S5**	Orëbro - Mjolby
26	**S5**	Mjölby - Lund
27	**S5**	Lund - Malmö
28	**S6**	NO border - Gotebörg
29	**S7**	Götborg - Ängelholm
30	**S7**	Ängelholm - Kävilinge via Helsingborg
31	**S7**	Ängelholm - Kävilinge via Ästorp
32	**S7**	Kävlinge - Lund
33	**S7**	Kävlinge - Malmö
34	**S8**	Malmö - Trelleborg
35	**S9**	Malmö - København
36		
37		
38		**Road Corridor Segmentation**
39	**S5**	Stockholm - Helsingborg (E4)
40	**S5**	Helsingborg - Malmö (E20)
41	**S6**	NO border - Gotebörg (E6)
42	**S7**	Göteborg - Helsingborg (E20)
43	**S8**	Malmö - Trelleborg (E22)
44	**S9**	Malmö - København (E20)
45		
46		
47		
48		

Overview | Reference Values | Investment Scenario | Infrastructure

CBA: Required Input Data

Reference Trains		
Reference Passenger Trains	Average load	**Minimum implementation:** one global reference train for each investment level **Intermediate implementation:** one reference train for each investment level per corridor section **Maximum implementation:** several reference trains and setting of traffic mix per section
	Average gross weight	
	Operating costs per passenger·km	
	GHG emissions per passenger·km	
Reference Freight Trains	Average load	
	Average gross weight	
	Operating costs per T·km	
	GHG emissions per T·km	

CBA: Required Input Data

Reference Road Vehicles		
Reference Passenger Car	Average load	**Minimum implementation:** one global reference train for each investment level **Intermediate implementation:** one reference train for each investment level per corridor section **Maximum implementation:** several reference trains and setting of traffic mix per section
	Operating costs per passenger·km	
	GHG emissions per passenger·km	
Reference Freight Truck	Average load	
	Operating costs per T·km	
	GHG emissions per T·km	

CBA: Required Input Data

Infrastructure Data		
General data	Section length	All data per section for • current technology, • **after TEN-T investments** and • **after effect of each relevant C4R innovation or set of innovations**
	Number of tracks	
	Maximum train length	
	Maximum axle load	
	S&C density	
Capacity	Block length (section of track where a single train is allowed at a time)	
	Buffer time & crossing buffer	
	Supplement for maintenance	
Speeds	Passenger trains average speed	
	Freight trains average speed	

CBA: Required Input Data

Infrastructure Data		
Track maintenance costs	Fixed maintenance costs, €/(year·km)	All data per section • for current technology, • **after TEN-T investments** and • after effect of each **C4R innovation** or set of innovations
	Variable maintenance costs, €/(MGT·km)	
S&C maintenance costs	Fixed maintenance costs, €/(year·km)	
	Variable maintenance costs, €/(MGT·km)	
Monitoring costs	Fixed monitoring costs, €/(year·km)	
	Variable monitoring costs, €/(MGT·km)	

CBA: Required Input Data

Investment Scenario		
Baseline	Planed renewals (track and S&C) **<u>or</u>** date of last renewal and expected life span of existing lines	
	Cost of renewals (track and S&C)	
TEN-T projects	List of projects with costs and dates (directly from TEN-T reports)	
C4R scenario	Installation costs	For each C4R innovation or set of innovations
	Date of implementation (expected TRL 8/9)	
	Migration scenario - Set of innovations to be introduced, geographical scope and time frame for installation	For each C4R scenario

CBA: Required Input Data

Traffic Scenario		
Baseline	Current rail traffic split by passengers and freight in trains or passengers and T per unit time	All data per section
	Traffic projections for maintenance of current conditions (at least 1 data point)	
TEN-T projects	Diverted and generated traffic projections as result of TEN-T investments	
C4R scenario	Diverted and generated traffic projections as result of C4R investments	All data per section for each C4R scenario

SP5 – Achieved results

WP 5.5 Demonstration, evaluation and assessment

Miguel RODRÍGUEZ-PLAZA

adif

WP5.5

WP5.5: Demonstration, evaluation and assessment

M12-M24

Task 5.5.1
Development of demonstration plans

Lead : ADIF

M12-M24

Task 5.5.2
Safety and Risk assessment for the demonstrators according to CSM

Lead : ADIF

M24-M36

Task 5.5.3
Laboratory demonstrations

Lead : ADIF

It was agreed to merge D5.5.1 and D5.5.2 into a single document

M30-M36

Task 5.5.4
On track demonstrations

Lead : ADIF

M30-M246

Task 5.5.5
Demonstrations in virtual reality

Lead : DB

M40-M48

Task 5.5.6
Final evaluation and assessment of the project innovations

Lead : DB

4 OBJECTIVES

- To carry out **test-scale demonstrations** on infrastructure or in laboratories or demonstration in virtual environment of the innovations proposed in the different subprojects.
- To **evaluate the technical results** of the demonstrations.
- To combine this results with the scenarios evaluation to perform **a global assessment of the innovations proposed** in the project.
- To perform **safety and risk assessment** for the demonstrators according to **Common Safety Method** (**CSM**).

The demonstrators play a crucial role in CAPACITY4RAIL as they enable the assessment of the innovations developed in the project, which will serve to identify room for improvement and will guide their further development.

Methodology for Demonstrations activities in order to archive D 5.5.1 and 5.5.2.

Capacity for Rail

General information about partners

- Ask for information about the tasks in which SP5 partners will be involved.
- Total PM dedicated to demonstration activities.

Questionnaire 1

- The scope of this questionnaire is to find out what are the different demonstration activities that have been detected in C4R.

Validations of Demonstrations activities

- Some new demonstrations activities were proposed

Questionnaire 2

- This Demonstration Activities Questionnaire is intended to determine the scope, resources, and schedule necessary to carry out the demonstration activities foreseen in C4R WP5.5

Deliverable WP5.5

D 5.5.1 & D 5.5.2 Test Plan Demo and Risk Assessment

Actual submission date: 30/08/2016

In order to obtain homogeneous information regarding the planned demonstrators, it was decided to prepare two questionnaire templates, with a different degree of detail.

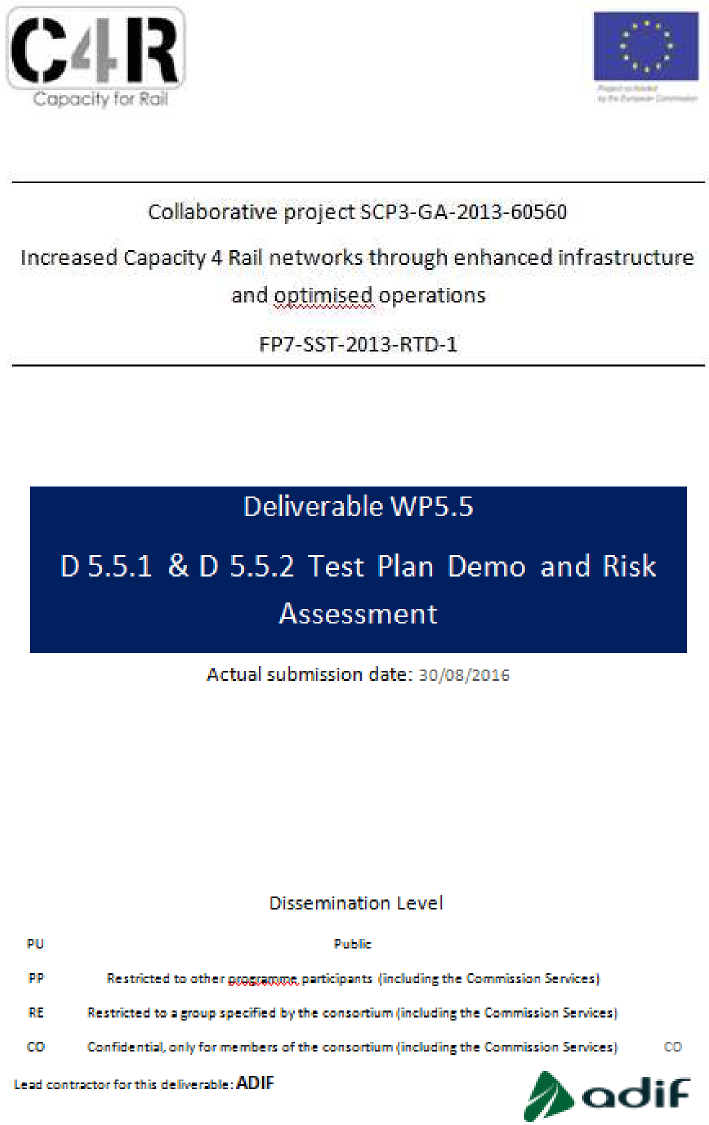
Questionnaire 1

The first questionnaire was aimed at identifying the demonstrators that were envisaged in each SP and to collect preliminary information about what was intended to be tested, which TRL would be achieved, approximate budget and other general information.

Questionnaire 2

Second questionnaire is much more complete as it is aimed at collecting all the information needed to build a detailed plan of the demonstrators which includes the description of the facilities, the tests to be carried out, the monitoring strategy and the data obtained from it as well as permits, risks and contingency plans, among others

WP 5.5 Deliverable


C4R
Capacity for Rail

Collaborative project SCP3-GA-2013-60560

Increased Capacity 4 Rail networks through enhanced infrastructure and optimised operations

FP7-SST-2013-RTD-1

Deliverable WP5.5

D 5.5.1 & D 5.5.2 Test Plan Demo and Risk Assessment

Actual submission date: 30/08/2016

Dissemination Level

PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	CO

Lead contractor for this deliverable: ADIF

adif

Deliverable 5.5.1 and 5.5.2 was delivered on September 2016.

A great effort was made in order to define the demonstration activities that can be undertaken in due time and that results are available well before the end of the project.

WORK PACKAGE	DEMONSTRATION	LEADER	PARTNERS	TRL
WP11	Construction of prototypes for tests (Slab track)	ACCIONA	UoH, VFS	TRL7(lab. real scale)
WP11	Fatigue tests of complete systems (track box) or key sensitive elements	CEDEX	ADIF	TRL4 (laboratory)
WP11	Line test of prototypes under revenue service by RFF, if technically accepted by RFF and the National Safety Authority. (Slab track)	RFF	ACCIONA	TRL7 (on-track)
WP12	Verification by full scale tests. Long term behaviour test at 400 kph	CEDEX	ADIF	TRL4 (lab. real scale)
WP12	Assessment of the effects of mixed traffic.	CEDEX	ADIF	TRL4 (lab. real scale)
WP12	Full scale testing of an existing bridge susceptible to high vibrations.	KTH	ADIF, INECO, CEDEX, SYSTRA	TRL3 (lab. reduced scale)
WP13	Innovative solutions for S&C will be tested in new field installations: improved S&C design, monitoring solutions, new materials…	TRV	DB,TCDD, TATA, VAE,VCSA	TRL7 (on track)
WP24	Assess the performance of the newly designed fully integrated rail freight systems using even-based simulation methods	UNEW	KTH, DICEA	TRL3 (simulation)
WP32	Demonstration of capacity enhancements	LIU	ADIF, TRV, NR, UNEW, TUD	TRL3 (simulation)
WP34	Proof of concept for data modeling and architecture	UoB	NR, UIC, ADIF, DB, TRV, SYSTRA, UNEW	TRL3 (simulation)
WP42	Demonstration of innovative monitoring concepts in the laboratory	UoB	ADEVICE, UU, REFER	TRL4 (laboratory)
WP43	Validation at laboratory level of the monitoring system		ACCIONA, CEMOSA, ADEVICE, DB, TCDD, REFER, UPORTO	TRL4 (lab reduced scale)
WP43	Real scale validation in track box (CEDEX) of the monitoring system implemented in SP1		ACCIONA, CEMOSA, ADEVICE, DB, TCDD, REFER, UPORTO	TRL4 (ab real scale)
WP43	Validation in a real validation pilot together with other project developments. This demonstration will be coordinated with SP1.		ACCIONA, CEMOSA, ADEVICE, DB, TCDD, REFER, UPORTO	TRL7 (on-track)
WP44	Demonstration of retro-fitting		DB, TRV,REFER, ASTS, OG, UOB, UPORTO, ACCIONA, CEMOSA	TRL7
WP55	Demonstrations in virtual reality	DB		TRL4

WP 5.5

C4R
Capacity for Rail

Initial stage.

List of demonstration activities according to DoW.

SEVENTH FRAMEWORK PROGRAMME

WP 5.5

Capacity for Rail

Final stage.

SP	WP		Partners involved
		DEM of new prototypes of Slab Track; LAB-Rail track accelerated testing at CEDEX (1:1 scale)	
1	1.1	Demo of new prototype of Slab Track **(1st prototype)**	CEDEX
			ACCIONA
			SYSTRA
1	1.1	Demo of new prototype of Slab Track **(2nd prototype)**	CEDEX
			ACCIONA
			VSCA
		Related task	
1	1.1.3	Full design of prototypes of new concepts for infrastructures	ACCIONA
1	1.1	Lab-testing of a innovative rail section	UoH
	4.3	Real-scale tests of embedded RFID sensor tags (with SP1 - CEDEX) - Later	
		VHST	
1	1.2	DEM-Laboratory, Track for VHS very high speed; Rail track accelerated testing	CEDEX
			ADIF
			VFS
1	1.2	Other DEM-activity/task associated: DEM-Full scale testing of an existing bridge susceptible to high vibrations	ADIF
			INECO
		Switches and crossing	
1	1.3	Decisions tool for S&C maintenance based on track recording car information	TCDD
			TRV
1	1.3	Using wireless technology to S&C monitoring	TCDD
			TRV
1	1.3	New material for S&C crossing in service	VCSA(Chalmers, UoH,
1	1.3	Material validation data for wear map	UoH
1	1.3	Laser measurements of S&C frog nose	UoH
1	1.3	Innovatiove technology to remove snow in turnouts	TRV
		Embebbed RFID + Innovative monitoring sensors	
4	4.3	In-lab tests of embedded RFID sensor tags	CEMOSA
			ADEVICE
			ACCIONA
4	4.3	Real-scale tests of embedded RFID sensor tags (with SP1 - CEDEX)	CEMOSA
			ADEVICE
			ACCIONA
4	4.3	Lab demonstration of innovative monitoring sensors	UPORTO
4	4.3	Real scale tests of innovative monitoring sensors	UPORTO
		DEM of retro-fitting	
4	4.4	In-lab and on-track validation tests	DB
			ACCIONA
			UPORTO
			REFER
		DEM-Virtual reality	
5	5.5.5	DEM-Virtual reality; Impact of new technologies developed in the project.	DB (IST)
			USFD
		Other DEM	
5	5.5	DEM-Coordination-Planning-Report-Assessment	

List of demonstrators approved within SP5-WP5.5

SEVENTH FRAMEWORK PROGRAMME

WP 5.5 Demonstrators

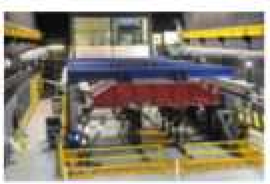
WP	Code	Demonstration	Leader/ Partners
1.2	DEM 1.2.1	Track for very high speed, including mixed traffic. In situ test.	CEDEX / INECO, ADIF, ACCIONA, VOSSLOH, IST
1.1	DEM 1.1.1	New Prototype of Slab Track	CEDEX, ACCIONA, SYSTRA, VSCA
1.3	DEM 1.3.1	Develop decision tool for S&C maintenance based on track recording car information	TCDD /Trv
1.3	DEM 1.3.2	Using wireless technology to make measurement in S&Cs, preferable acceleration	TCDD/(WP4, Trv)
1.3	DEM 1.3.3	Installing a new material for crossing in service S&C	VCSA/(Trv, UoH, Chalmers)
1.3	DEM 1.3.4	Material validation data for wear map	UoH /(Chalmers, VAE, VSCA)
1.3	DEM 1.3.5	Laser measurements for S&C crossing	UoH
1.3	DEM 1.3.6	New innovative technology to remove snow in turnouts	TRV
4.3	DEM 4.3.1	In-lab tests of embedded RFID sensor tags	CEMOSA /ADEVICE

List of demonstrators approved and described in depth in the deliverable.

WP 5.5

Depicts the geographical locations of the demonstrators

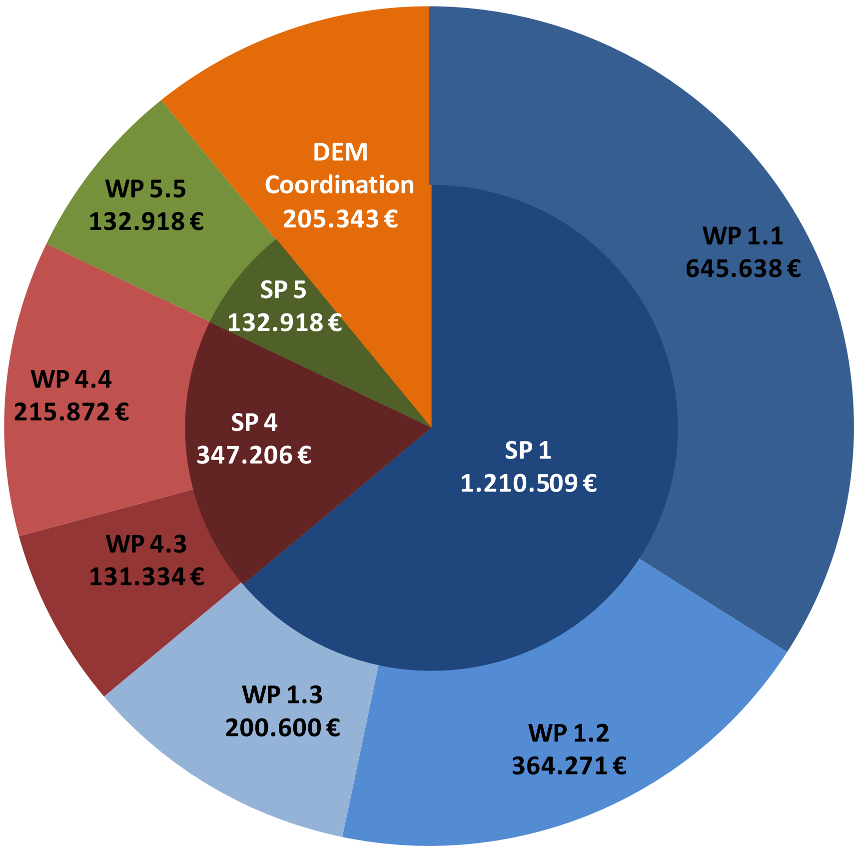
Capacity for Rail



WP 5.5 *Scheduled implementation of the demonstrators*

WP	CODE DEMO	DEMONSTRATOR	2015 10	2015 11	2015 12	2016 01	2016 02	2016 03	2016 04	2016 05	2016 06	2016 07	2016 08	2016 09	2016 10	2016 11	2016 12	2017 01	2017 02	2017 03	2017 04	2017 05	2017 06	2017 07	2017 08	2017 09
1.2	1.2.1.	Track for Very High Speed											■	■	■	■	■	■	■							
1.1	1.1.1.	Prototyping and testing two new slab track concept																	■	■	■	■	■	■		
1.3	1.3.1.	Develop decision tool for S&C maintenance based on track recording car information												■	■	■	■	■								
1.3	1.3.2.	Using wireless technology to make measurement in S&Cs, preferable acceleration									■	■	■	■	■	■	■	■	■	■	■	■				
1.3	1.3.3.	Installing a new material for crossing in service S&C				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
1.3	1.3.4.	Material validation data for wear map										■	■	■	■	■	■	■	■	■						
1.3	1.3.5.	Laser measurements of S&C frog nose										■	■	■	■	■	■	■	■	■	■	■	■	■	■	
1.3	1.3.6.	New innovative technology to remove snow in turnouts												■	■	■	■	■	■	■	■					
4.3	4.3.1.	Embedded sensors in precast concrete elements				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			

WP 5.5 Demonstration Budget



Budget distribution among SPs and WPs.

SP5 – Next steps

- **Interviews with SP1, SP2, SP3 and SP4**
  - Gathering of data necessary for CBA and MCA
- **Completion of corridor analysis**
- **Compilation of data necessary for CBA**
- **Cost-Benefit Analysis**
- **Monitoring and assessment of demonstration**
- **Guideline for further research and development**

C4R Capacity for Rail

Thank you for your kind attention

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SEVENTH FRAMEWORK PROGRAMME