C4R

Capacity for Rail

Migration strategies for innovative track solutions 2030/2050

Workshop & Training, Paris –15th of March 2017

Burchard RIPKE and SP5 partners

SEVENTH FRAMEWORK PROGRAMME

Outline

- Boundaries and demands on the future railway
- Multi Criteria Assessment and Cost Benefit Analysis to identify suitable innovations
- Scenarios and migration from now to 2030
- Next steps

C4R breakdown structure

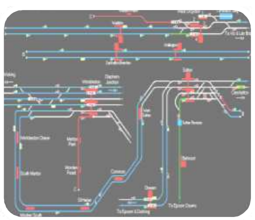
Capacity for Rail

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

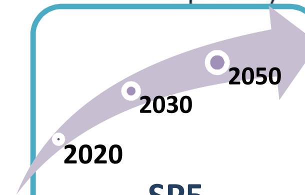


SP3 - Operation and capacity

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 migra-tion from now to 2050

Assessment of the full sustainability of the developed solutions

Demonstration

Recommen-dations

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The key targets of C4R

Capacity for Rail

- Increased capacity is the ultimate goal, but not necessarily deliver directly by all SP's

Capacity

- Multiple levels/views of capacity

  - System capacity
  - Infrastructure utilisation
  - Rolling stock utilisation

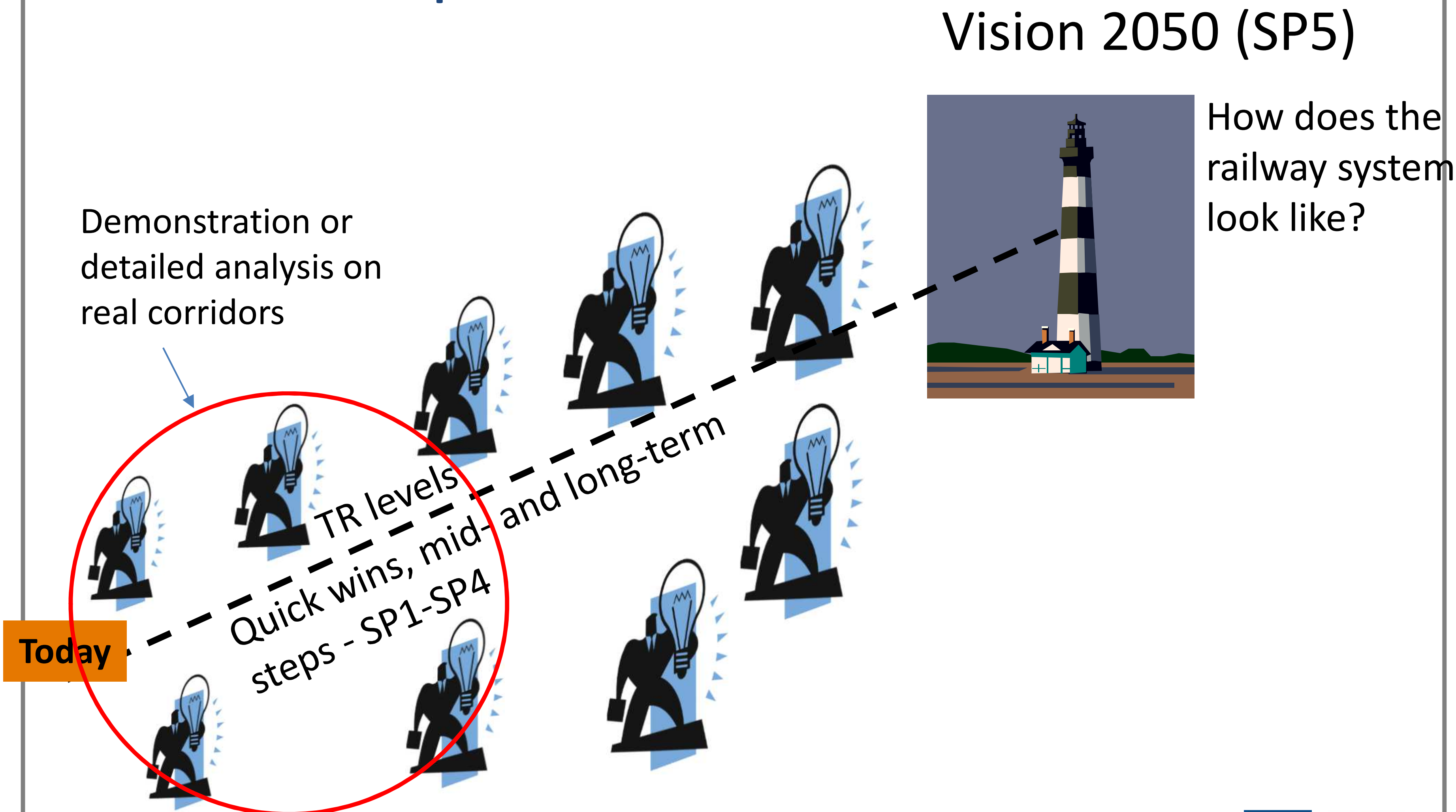
- Whatever changes, **safety is axiomatic**
- Need to deliver high **quality** (e.g. punctuality) throughout

Adaptable | **Affordable** | **Automated** | **Resilient**

- All SPs contribute to capacity through innovations affecting one or more goals

C4R Approach

Visions and the steps to reach



Visions

Extraction of visions

- **24h/7day - Infrastructure**
- **Modular infrastructure** which is adaptable to further requirements (I)
- **Adaptable and predictive maintenance strategies** (M,I)
- **High speed freight trains** with up to 200 km/h (F, I)
- **Each 15 minutes runs a passenger train** on more than 30 % of the network (I, O)
- **Cross-border interoperability** across Europe through the creation of a single standard for railway signalling (S)
- **No catenary** – power supply by conductor rails and fuel cells (I, F, P)
- **Long trains with up to 1400 m** with a single or two locomotives (F,I)
- **Trains know and report their parameters** like length or axle load (M,O)
- **50 % shift** from road to rail (O,S)

Future boundaries and demands

Boundaries for the future railway

Boundaries - EU	2015	2030	2050
Passenger capacity	100%	130%	200%
Freight capacity	100%	130-210%	160-300%
Modal shift road-rail	0%	25%	50%
Greenhouse gas emission	100%	80%	50%
Noise pollution	100%	95%	90%

Boundaries - Germany	2015	2030	2050
Passenger capacity	104%	119%	-
Freight capacity	108%	143%	-
Modal shift road-rail	> 1%	> 5%	-

Future boundaries and demands

C4R
Capacity for Rail

Demands on the future railway with respect to the track

Demand	2015	2030	2050
Timeslots for maintenance - MTTR	100%	50%	
Planned & unplanned unavailability - MDT	100%	50%	< 1h/d/a
Specific CO2 emissions (incl. embodied)	100%	80%	50%
Resilience to severe weather conditions (measured by infrastructure down-time)	100%	<75%	<50%
LCC (NPV)	100%	90%	80%

Innovative track constructions are necessary to fulfil the demands

Where? | **Which construction?** | **When?**

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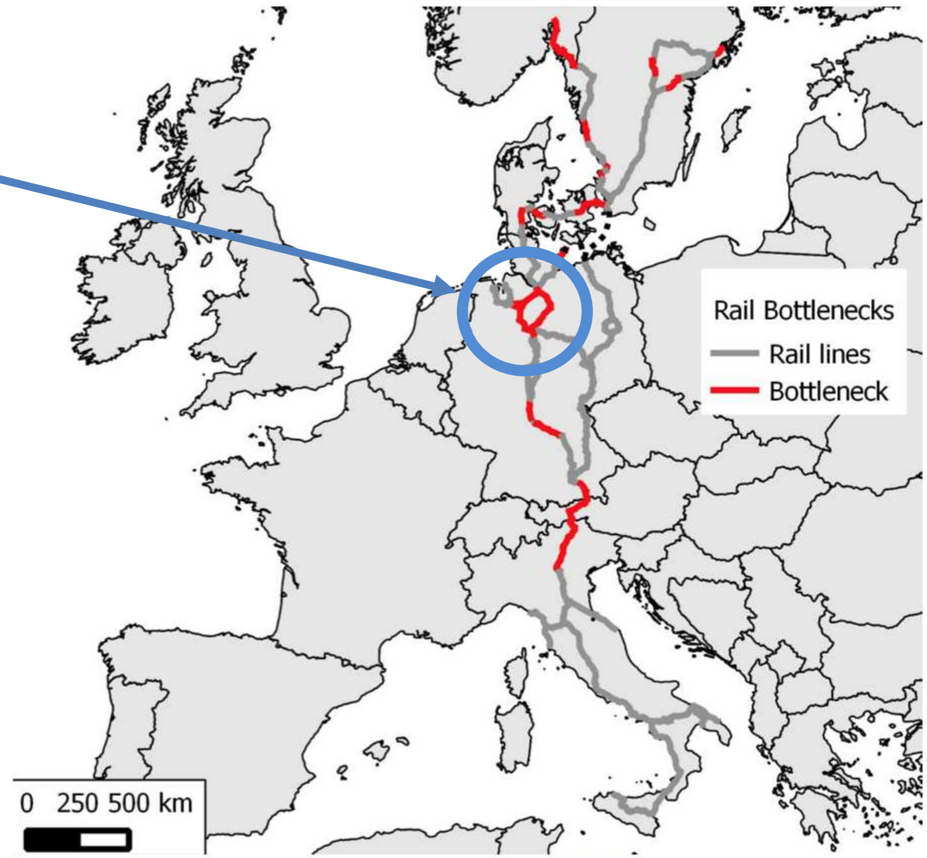
Bottleneck analysis - rail

C4R
Capacity for Rail

RFC 3: ScanMed – Corridor

Hamburg - Uelzen



Source: Information from national authorities (Trafikverket, Trafikstyrelsen, BMVI, BMVIT).

The red marked sections contain physical bottlenecks which influence the whole corridor

Source: SWIFTLY GREEN: Mapping of the current status of the Stockholm-Palermo corridor

Critical sections

Specific requirements

Section	Number of trains 2016	Number of trains 2030	Number of trains 2030 - HHV
Hamburg - Uelzen	141	187	**> 260**
Uelzen - Hannover	120	159	**> 221**

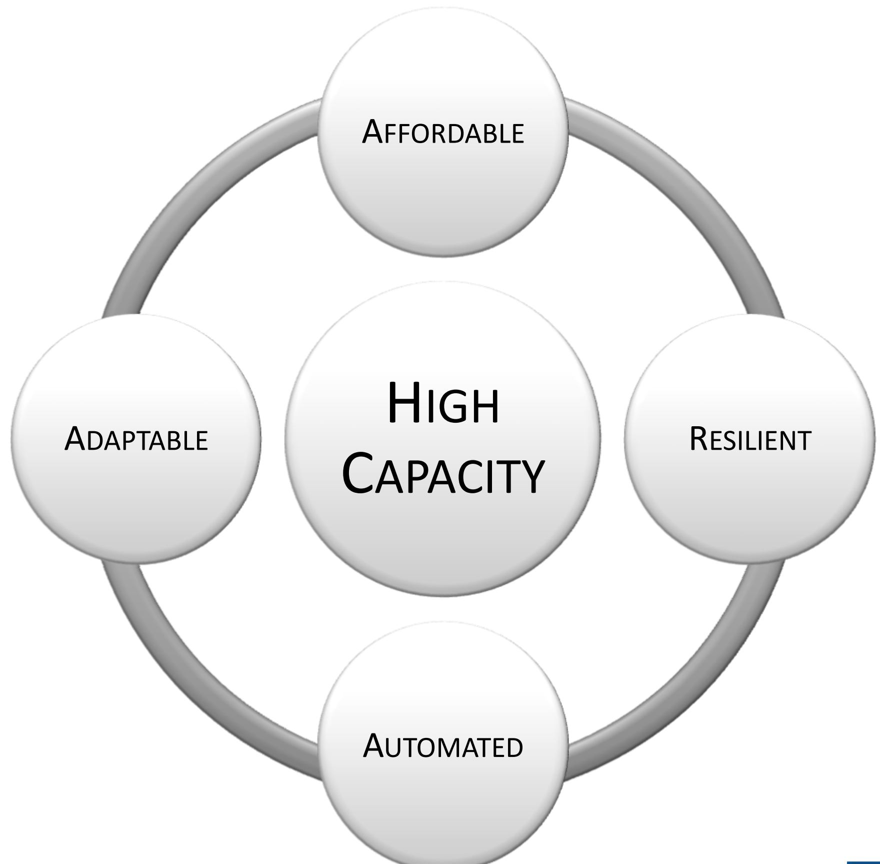
Strong increase in number of trains per day in individual sections of RCF

- Ports - Hafen Hinterland traffic
- Industrial areas and big cities

Objective of C4R

How to develop and to assess an affordable, resilient, automated, adaptable and high-capacity railway system

5 key aspects



Methodologies Overview

C4R Capacity for Rail

Complementary methodologies

Multi-Criteria Analysis (MCA) + Cost-Benefit Analysis (CBA)

Multi-Criteria Analysis (MCA)

- 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 (CBA)

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

+

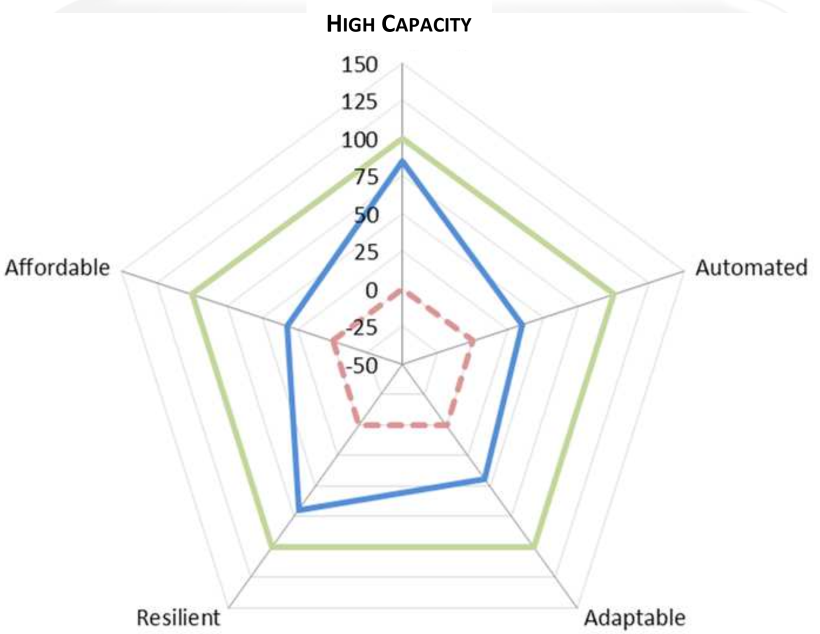
Capacity assessment in SP3

Methodologies Overview

Capacity for Rail

OUTPUTS

MULTI-CRITERIA ANALYSIS
Impacts towards Vision for 2030/2050



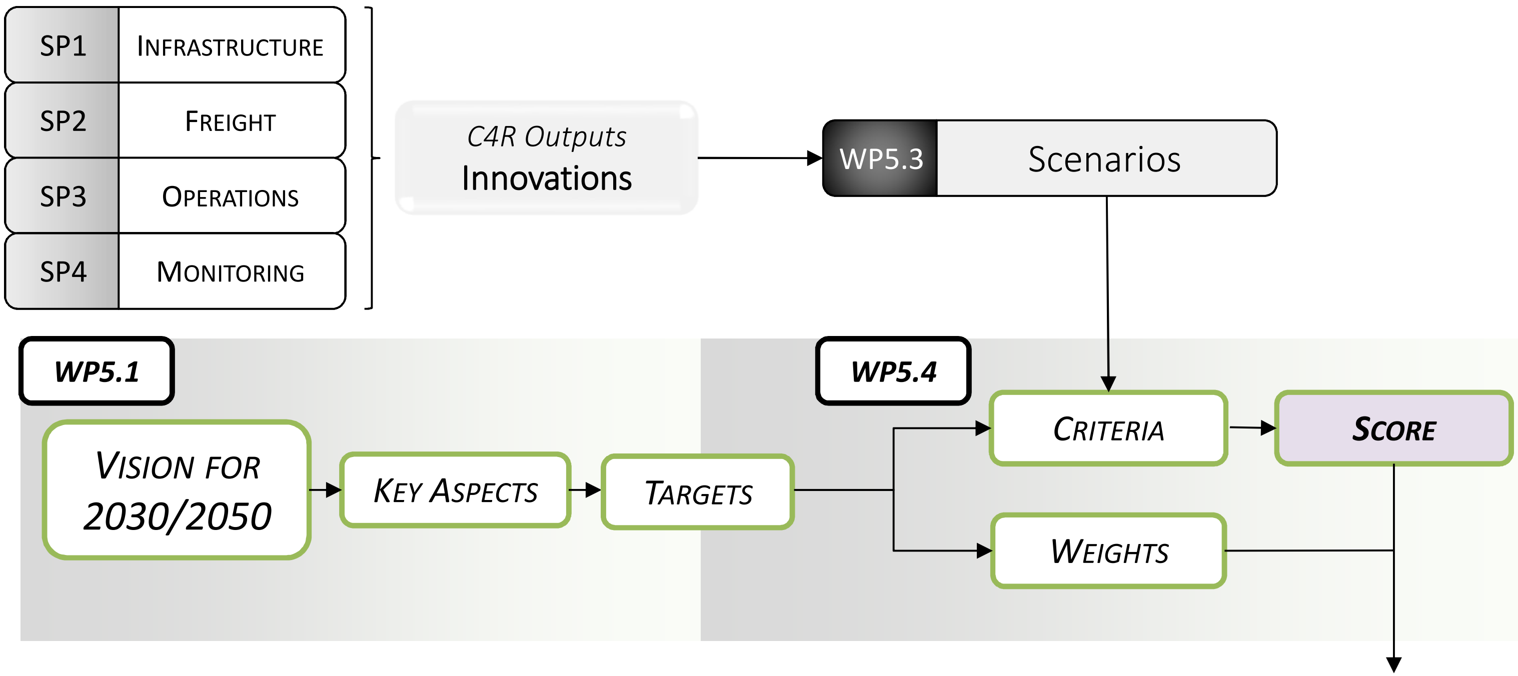
COST-BENEFIT ANALYSIS
Socio-economic appraisal

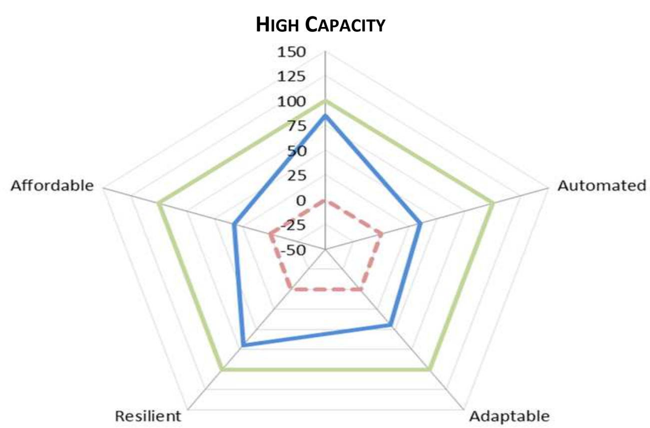
INVESTMENT SCENARIOS

COST AND BENEFIT CATEGORIES

Net Present Values (NPV)
Internal Rate of Return (IRR)

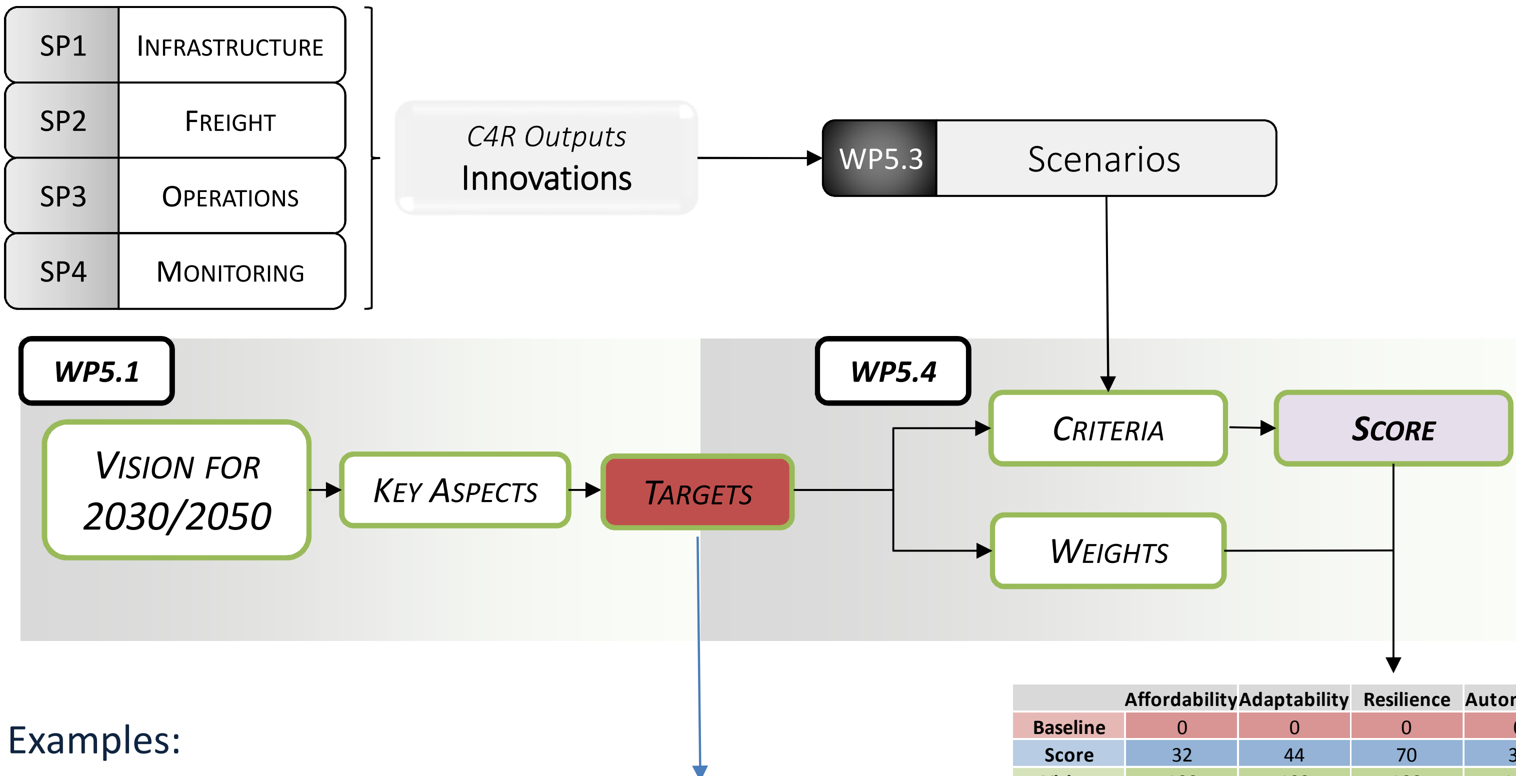
MCA Procedure





	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 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

- Examples:

Key aspect: Affordability

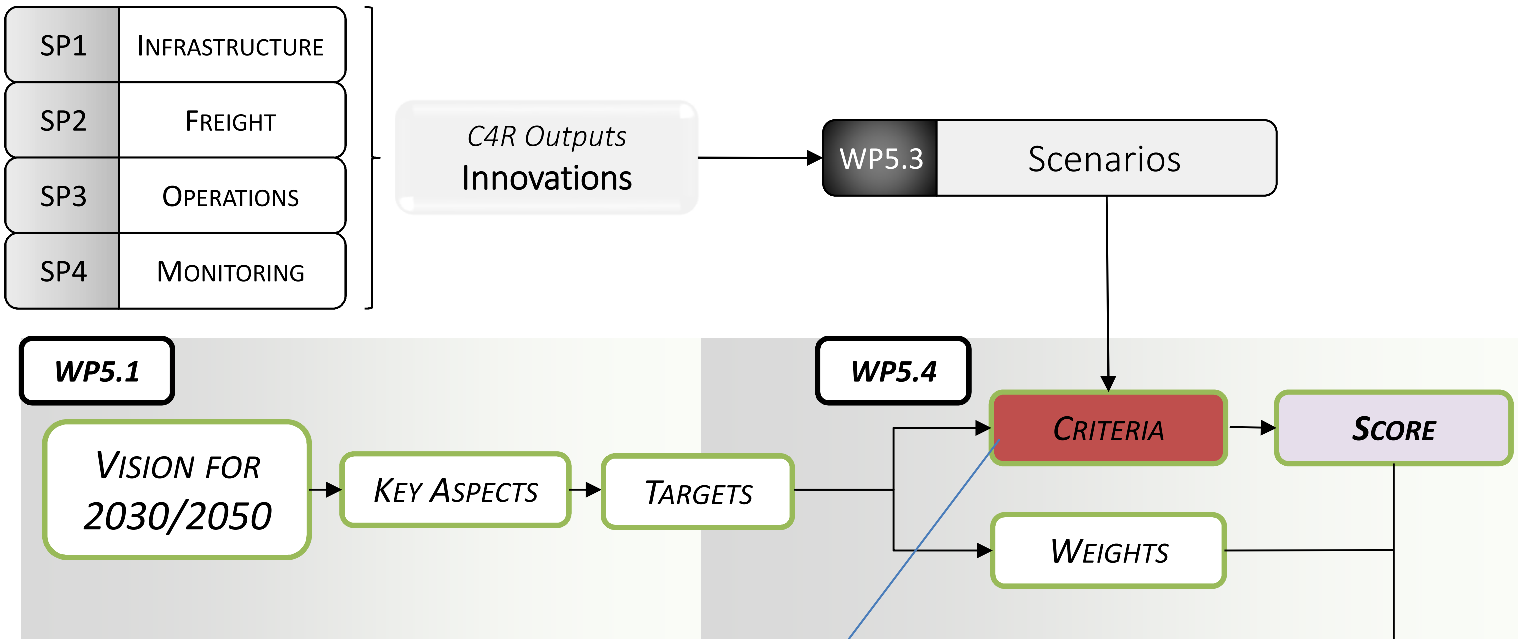
Targets:

- 20% decrease in infrastructure LCC
- 50% decrease of RU operating costs by 2050
- 50% decrease in C02 emissions
- ……

MCA Targets

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

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

- Examples:

T1.1	20% decrease in infrastructure Life-Cycle Costs (LCC) by 2050
Criterion	Comparison of infrastructure life-cycle costs, between baseline and innovation scenarios (NPV)
Scoring Scale	Linear scale, with Score = 100 for 20% decrease regarding baseline scenario
Inputs	Unit costs for procurement, operation, inspection, maintenance and unavailability; RAMS parameters

Resilient Adaptable

MCA Procedure

Capacity for Rail

- The scoring of scenarios is to be made through a set of templates provided by WP.5.2. (e.g. LCC template;)
  - Scored according to the change relative to the baseline based on a linear (or non-linear) scale:

Score < 0	Technology or scenario worst than baseline
Score = 0	Technology or scenario with no change relative to baseline
0 < Score < 100	Score measures relative distance of technology or scenario between baseline and fulfilment of target
Score = 100	Target is fulfilled
Score > 100	Target milestone is exceeded

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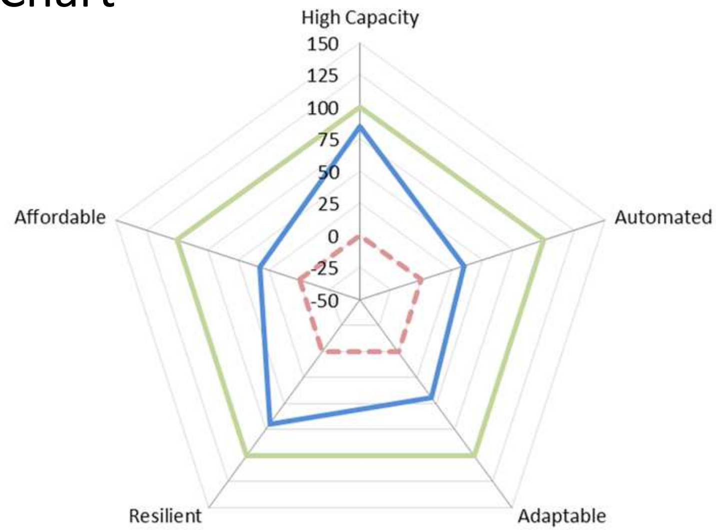
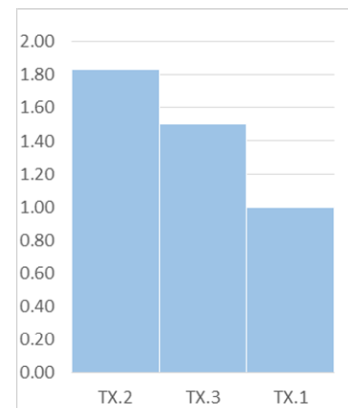
MCA Target Weighting

- Weighed average provides score for each key aspect that can be plotted on a Spider Chart

Basic Scale Computation			
	TX.2	TX.3	TX.1
TX.2		1	4
TX.3			3
TX.1			

Attractiveness Scale		
	Basic	Normalised
TX.2	4	**1.67**
TX.3	3	**1.50**
TX.1	0	**1.00**





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

CBA Approach: Overview

Capacity for Rail

Wide geographical scope

Dozens of individual projects

- Slab track A-B
- Slab track B-C
- New wagons
- Monitoring A-B
- ...

Technologies under development

TRL 9?

Scattered and incomplete input data

- Infrastructure Data
- Traffic demand data
- ...

Cost-Benefit Analysis

- Focus on variables potentially changed by innovations
- Simple enough for amount of data to remain manageable
- Allow sensitivity and probabilistic analysis

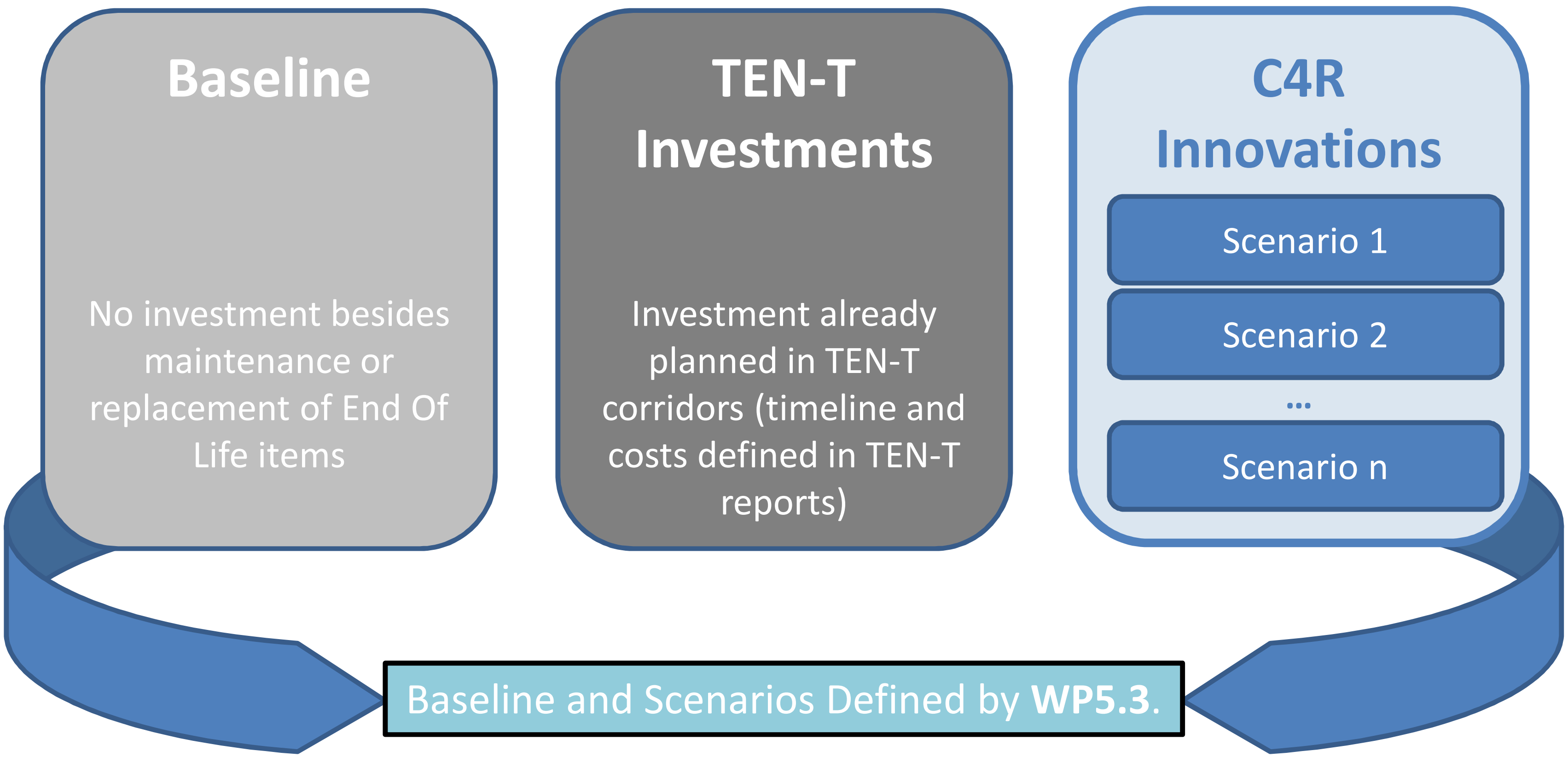
CBA Approach: Investment Levels

- Incremental approach with 3 investment levels:

Baseline	TEN-T Investments	C4R Innovations
No investment besides maintenance or replacement of End Of Life items	Investment already planned in TEN-T corridors (timeline and costs defined in TEN-T reports)	Introduction of new technologies from C4R project

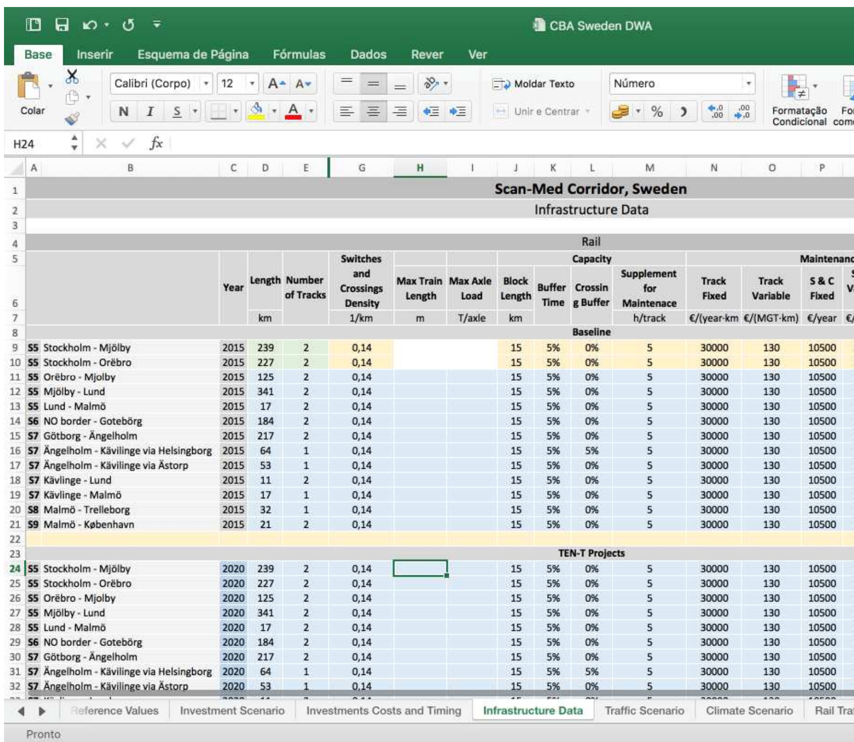
CBA Approach: Investment Levels

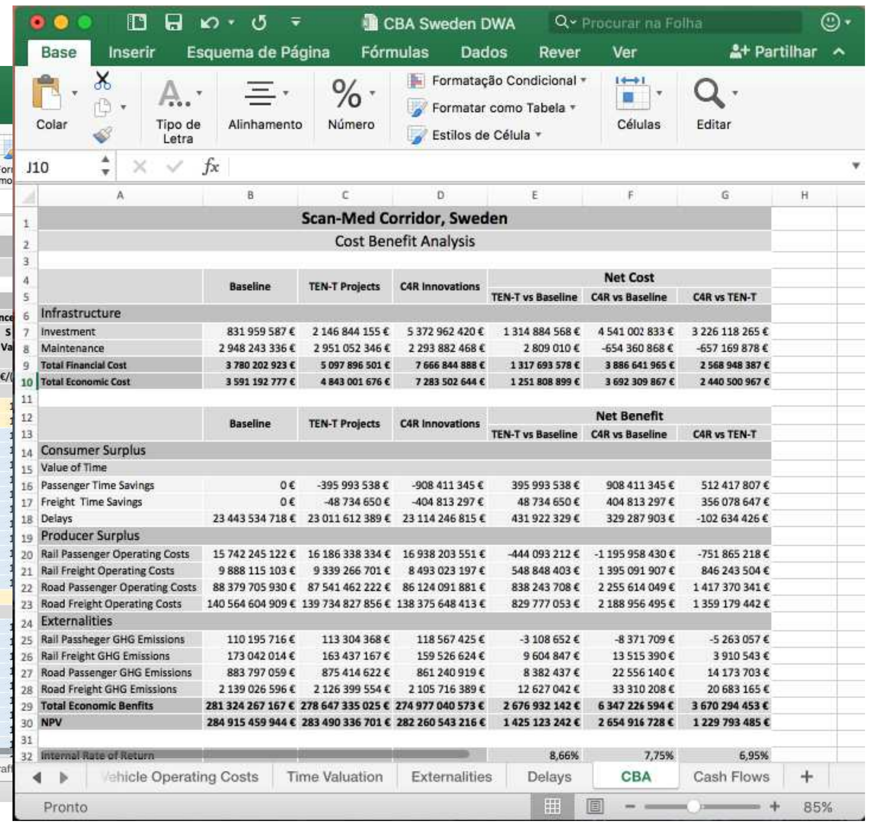
- Incremental approach with 3 investment levels:



CBA Tool

- Excel tool automatically computes CBA from defined input data
- Allows comparison of scenarios, sensitivity and probabilistic analysis

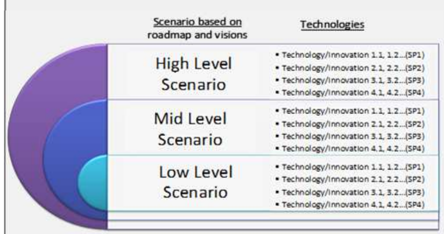




Scenarios

Approach for the scenarios

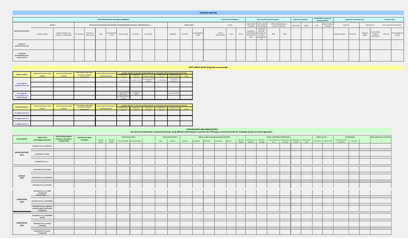
Definition of **scenarios** based on **roadmap** and **C4R Innovations**



Generic scenarios

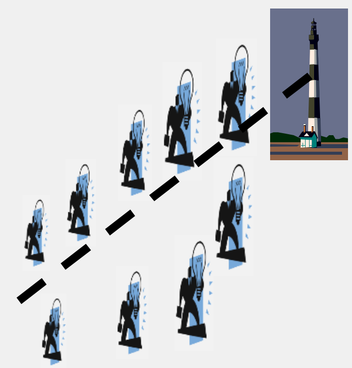
Baseline analysis Selection and description of real sites and corridors

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



Specific scenarios

Definition of migration paths to 2030/2050



Requirements and the steps to reach the vision 2050

C4R Capacity for Rail

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

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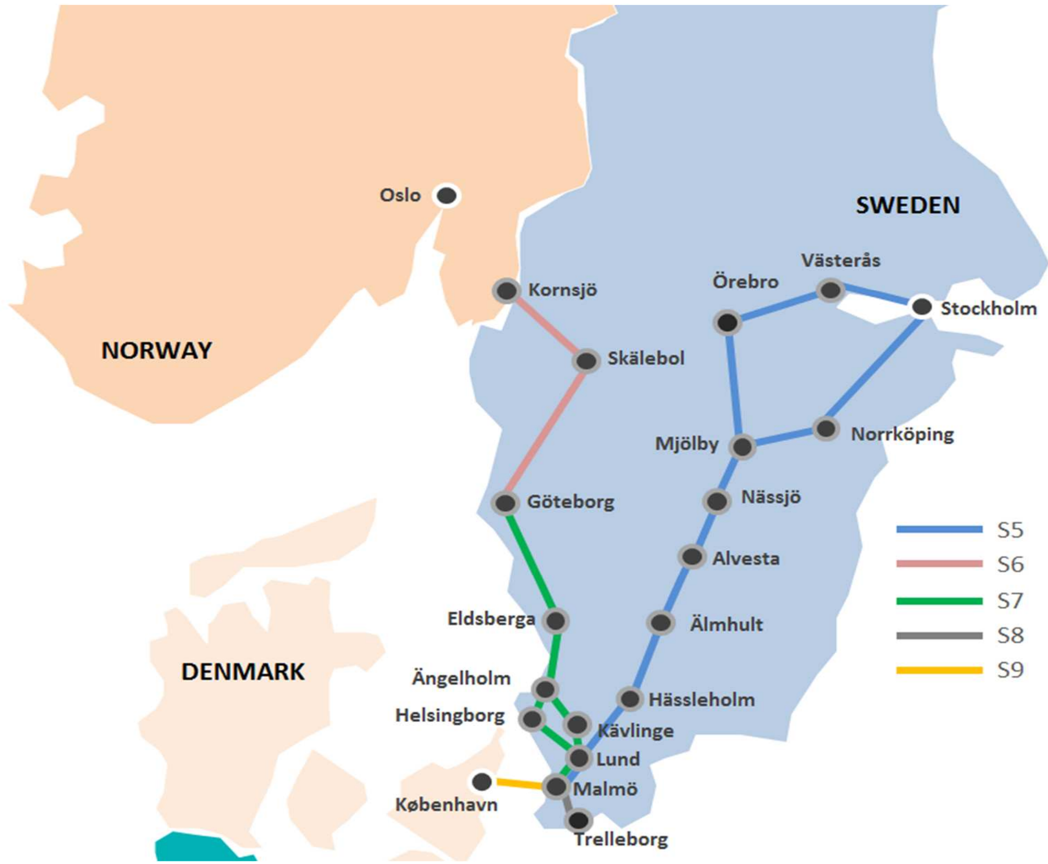
Investment Scenario Example

e.g. Scenario i

Introduction of slab-track (SP1) Swedish network

Introduction of new freight wagons (SP2) Swedish network

Introduction of new monitoring systems (SP4) Swedish network



Investment Scenario Example

Introduction of slab-track (SP1) Mjölby-Malmö

Introduction of new Switches & Crossings (SP2) Mjölby-Malmö

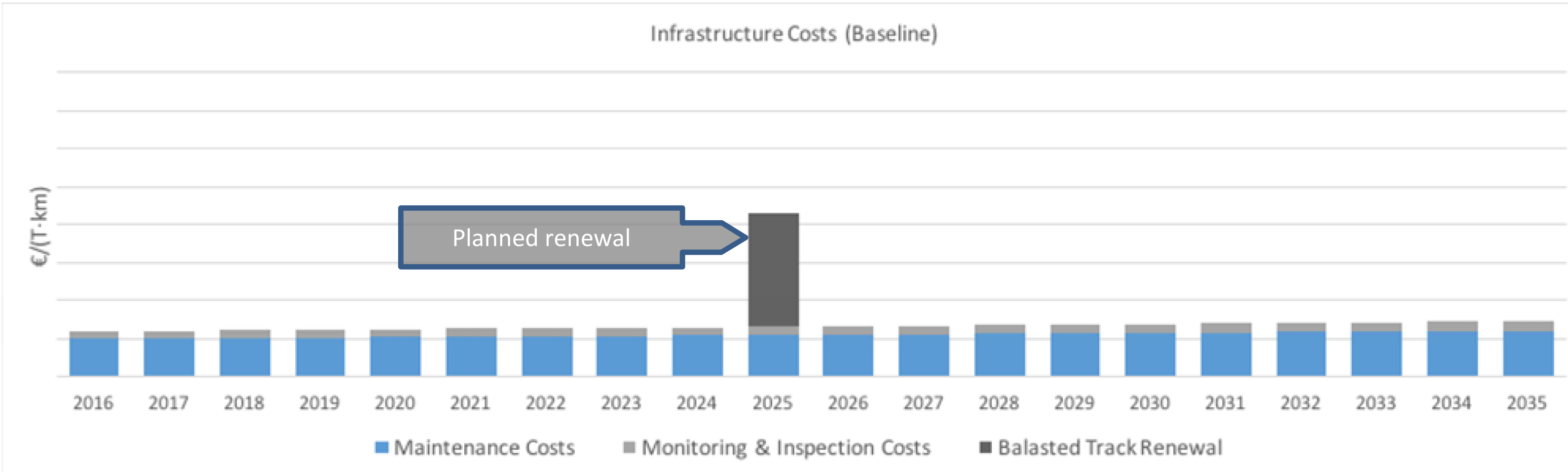
Introduction of new freight wagons (SP2) Stockholm-Malmö

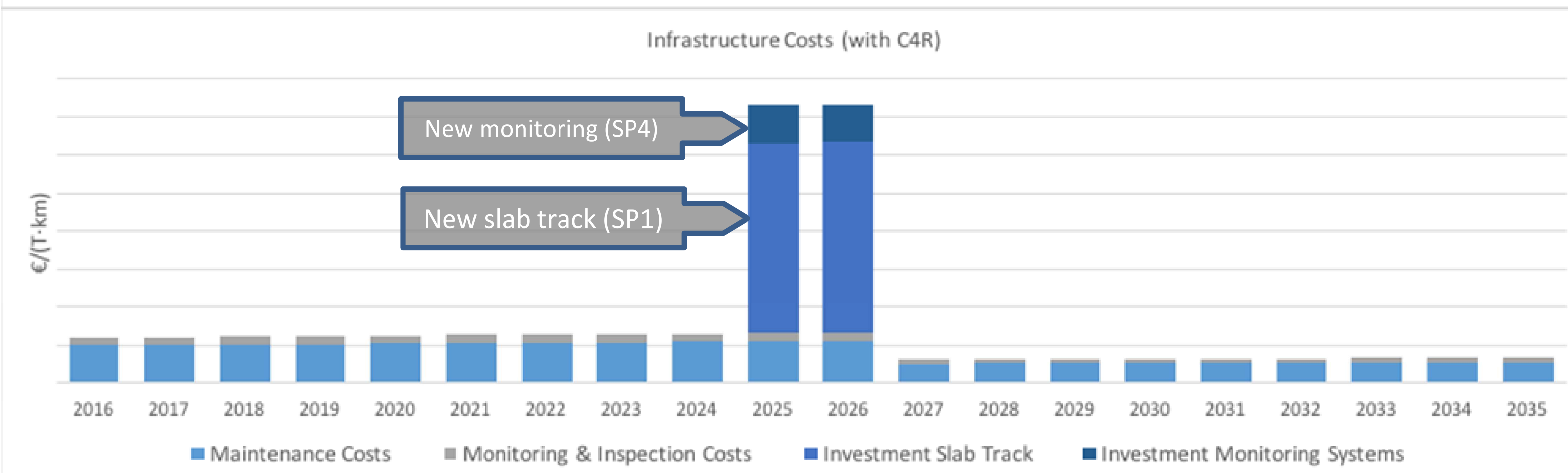
Introduction of new monitoring systems (SP4) Lund-Göteborg

e.g. Scenario ii

CBA Tool: Output Example

- Multitude of outputs can be extracted:



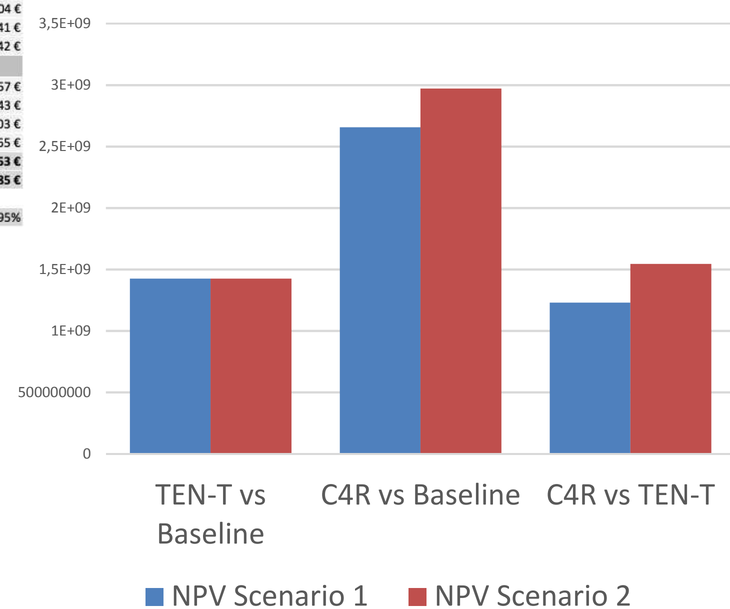


CBA: Comparison of Scenarios

- 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 €
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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%

Capacity for Rail

CBA - Results

Scan-Med Corridor, Sweden						
Cost Benefit Analysis						
	Baseline	TEN-T Projects	C4R Innovations	Net Cost		
				TEN-T vs Baseline	C4R vs Baseline	C4R vs TEN-T
Infrastructure						
Investment	0 €	371 003 700 €	895 217 385 €	371 003 700 €	895 217 385 €	524 213 686 €
Maintenance	7 090 184 255 €	6 616 914 964 €	5 864 080 545 €	-473 269 291 €	-1 226 103 711 €	-752 834 420 €
Total Financial Cost				**-102 265 592 €**	**-330 886 325 €**	**-228 620 734 €**
Total Economic Cost				**-97 152 312 €**	**-314 342 009 €**	**-217 189 697 €**
	Baseline	TEN-T Projects	C4R Innovations	Net Benefit		
				TEN-T vs Baseline	C4R vs Baseline	C4R vs TEN-T
Consumer Surplus						
Value of Time						
Passenger	25 132 813 388 €	24 722 200 298 €	24 295 475 769 €	410 613 090 €	837 337 619 €	426 724 529 €
Freight	8 339 391 859 €	8 927 948 522 €	8 752 693 236 €	-588 556 663 €	-413 301 378 €	175 255 286 €
Producer Surplus						
Rail Passenger Operating Costs	16 271 871 980 €	17 462 338 041 €	18 324 637 349 €	-1 190 466 061 €	-2 052 765 369 €	-862 299 308 €
Rail Freight Operating Costs	10 027 166 001 €	9 853 008 094 €	9 367 842 108 €	174 157 906 €	659 323 893 €	485 165 987 €
Road Passenger Operating Costs	88 379 705 930 €	86 894 314 317 €	86 894 314 317 €	1 485 391 613 €	1 485 391 613 €	0 €
Road Freight Operating Costs	140 564 604 909 €	139 133 575 163 €	139 133 575 163 €	1 431 029 746 €	1 431 029 746 €	0 €
Externalities						
Rail Passheger GHG Emissions	113 903 104 €	122 236 366 €	128 272 461 €	-8 333 262 €	-14 369 358 €	-6 036 095 €
Rail Freight GHG Emissions	175 475 405 €	172 427 642 €	163 937 237 €	3 047 763 €	11 538 168 €	8 490 405 €
Road Passenger GHG Emissions	883 797 059 €	868 943 143 €	868 943 143 €	14 853 916 €	14 853 916 €	0 €
Road Freight GHG Emissions	2 139 026 596 €	2 117 250 057 €	2 117 250 057 €	21 776 540 €	21 776 540 €	0 €
Total Economic Benfits				**1 753 514 588 €**	**1 980 815 391 €**	**227 300 803 €**
NPV				**1 850 666 900 €**	**2 295 157 400 €**	**444 490 500 €**
Internal Rate of Return				4,27%	4,58%	5,49%

- Results presented divided into categories and investment levels, with comparisons between them

Next steps - Demonstration

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

4.4 Monitoring of track sections with innovative sensors DB

5.5 Visualisation of bottlenecks, migration and assessement DB

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

Next steps - Assessment

- *Workshops with SP1, SP2 about scenarios and data for CBA*
- *Completion of corridor analysis*
- *Compilation of data necessary for CBA*
- *Cost-Benefit Analysis*
- *Monitoring and assessment of demonstration*
- *Guideline for further research and development*

Thank you for your kind attention

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ADIF

University of Lisbon

University of Sheffield

TRL

TCDD

COMSA

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