Migration strategies for innovative track solutions 2030/2050
Workshop & Training, Paris –15th of March 2017

Burchard RIPKE and SP5 partners
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

**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
The key targets of C4R

- Increased capacity is the ultimate goal, but not necessarily deliver directly by all SP’s
- Whatever changes, safety is axiomatic
- Need to deliver high quality (e.g. punctuality) throughout
- All SPs contribute to capacity through innovations affecting one or more goals

Multiple levels/views of capacity
- System capacity
- Infrastructure utilisation
- Rolling stock utilisation
Visions and the steps to reach

Vision 2050 (SP5)

How does the railway system look like?

Demonstration or detailed analysis on real corridors

Today

TR levels Quick wins, mid- and long-term steps - SP1-SP4
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

<table>
<thead>
<tr>
<th>Boundaries - EU</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger capacity</td>
<td>100%</td>
<td>130%</td>
<td>200%</td>
</tr>
<tr>
<td>Freight capacity</td>
<td>100%</td>
<td>130-210%</td>
<td>160-300%</td>
</tr>
<tr>
<td>Modal shift road-rail</td>
<td>0%</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>Greenhouse gas emission</td>
<td>100%</td>
<td>80%</td>
<td>50%</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>100%</td>
<td>95%</td>
<td>90%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boundaries - Germany</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger capacity</td>
<td>104%</td>
<td>119%</td>
<td>-</td>
</tr>
<tr>
<td>Freight capacity</td>
<td>108%</td>
<td>143%</td>
<td>-</td>
</tr>
<tr>
<td>Modal shift road-rail</td>
<td>&gt; 1%</td>
<td>&gt; 5%</td>
<td>-</td>
</tr>
</tbody>
</table>
Demands on the future railway with respect to the track

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

Innovative track constructions are necessary to fulfil the demands

**Where?**  
**Which construction?**  
**When?**
Bottleneck analysis - rail

RFC 3: ScanMed – Corridor

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

<table>
<thead>
<tr>
<th>Section</th>
<th>Number of trains 2016</th>
<th>Number of trains 2030</th>
<th>Number of trains 2030 - HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamburg - Uelzen</td>
<td>141</td>
<td>187</td>
<td>&gt; 260</td>
</tr>
<tr>
<td>Uelzen - Hannover</td>
<td>120</td>
<td>159</td>
<td>&gt; 221</td>
</tr>
</tbody>
</table>

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

- Affordable
- Resilient
- High Capacity
- Adaptable
- Automated
Methodologies Overview

Complementary methodologies

**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

**OUTPUTS**

**MULTI-CRITERIA ANALYSIS**
Impacts towards Vision for 2030/2050

**COST-BENEFIT ANALYSIS**
Socio-economic appraisal

**INVESTMENT SCENARIOS**

- Net Present Values (NPV)
- Internal Rate of Return (IRR)
MCA Procedure

WP5.1
VISION FOR 2030/2050

C4R Outputs
Key Aspects

WP5.2
Targets

WP5.3
Scenarios

WP5.4
Criteria

Weights

Score

Affordability    Adaptability    Resilience    Automation    High Capacity

Baseline 0 0 0 0 0
Score 32 44 70 35 85
Vision 100 100 100 100 100

High Capacity

Affordable

Automated

Resilient

Adaptable
Key aspect: Affordability

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

Examples:

- Key aspects:
  - Affordability
- Targets:
  - 20% decrease in infrastructure LCC
  - 50% decrease of RU operating costs by 2050
  - 50% decrease in C02 emissions
  - ......

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Affordability</th>
<th>Adaptability</th>
<th>Resilience</th>
<th>Automation</th>
<th>High Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Score</td>
<td>32</td>
<td>44</td>
<td>70</td>
<td>35</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Vision</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
### MCA Targets

<table>
<thead>
<tr>
<th></th>
<th>Affordability</th>
<th></th>
<th>Adaptability</th>
<th></th>
<th>Resilience</th>
<th></th>
<th>Automation</th>
<th></th>
<th>High Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>T1.1.</strong> 20% decrease in infrastructure Life-Cycle Cost (LCC) by 2050</td>
<td></td>
<td><strong>T2.1.</strong> Freight rolling stock adaptable to cope with different freight containers by 2050</td>
<td></td>
<td><strong>T3.1.</strong> 80% reduction of train delays due to Extreme Weather events by 2050</td>
<td></td>
<td><strong>T4.1.</strong> Automated rail freight system by 2050</td>
<td></td>
<td><strong>T5.1.</strong> 100% increase in overall freight capacity by 2050</td>
</tr>
<tr>
<td></td>
<td><strong>T1.2.</strong> 50% decrease in Train Operating Costs (TOC) by 2050</td>
<td></td>
<td><strong>T2.2.</strong> Fully interoperable bundling of freight rolling stock by 2050</td>
<td></td>
<td><strong>T3.2.</strong> 80% reduction of train delays due to Infrastructure Failures by 2050</td>
<td></td>
<td><strong>T4.2.</strong> 50% reduction of track unavailability due to monitoring &amp; inspections by 2050</td>
<td></td>
<td><strong>T5.2.</strong> 100% increase in overall passenger capacity by 2050</td>
</tr>
<tr>
<td></td>
<td><strong>T1.3.</strong> 50% decrease in specific CO₂ emissions, including embodied carbon, by 2030</td>
<td></td>
<td><strong>T2.3.</strong> Infrastructure adaptable to new operational requirements from traffic demand by 2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>T1.4.</strong> Elimination of operating noise problem sites by 2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MCA Procedure

- Vision for 2030/2050
  - Key Aspects
  - Targets
  - Criteria
  - Score

| SP1 | Infrastructure |
| SP2 | Freight |
| SP3 | Operations |
| SP4 | Monitoring |

WP5.1

- C4R Outputs (Innovations)
- WP5.3 Scenarios

WP5.4

- Affordability
- Adaptability
- Resilience
- Automation
- High Capacity

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

Example:

- 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
MCA Procedure

- 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:

<table>
<thead>
<tr>
<th>Score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0</td>
<td>Technology or scenario worst than baseline</td>
</tr>
<tr>
<td>0</td>
<td>Technology or scenario with no change relative to baseline</td>
</tr>
<tr>
<td>0 &lt; Score &lt; 100</td>
<td>Score measures relative distance of technology or scenario between baseline and fulfilment of target</td>
</tr>
<tr>
<td>100</td>
<td>Target is fulfilled</td>
</tr>
<tr>
<td>&gt; 100</td>
<td>Target milestone is exceeded</td>
</tr>
</tbody>
</table>
MCA Target Weighting

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

<table>
<thead>
<tr>
<th></th>
<th>TX.2</th>
<th>TX.3</th>
<th>TX.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Scale Computation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TX.2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TX.3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TX.1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attractiveness Scale</th>
<th>Basic</th>
<th>Normalised</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX.2</td>
<td>4</td>
<td>1.67</td>
</tr>
<tr>
<td>TX.3</td>
<td>3</td>
<td>1.50</td>
</tr>
<tr>
<td>TX.1</td>
<td>0</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Affordability</th>
<th>Adaptability</th>
<th>Resilience</th>
<th>Automation</th>
<th>High Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Score</td>
<td>32</td>
<td>44</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>Vision</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
CBA Approach: Overview

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**
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:
  
  **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**
  
  Scenario 1
  Scenario 2
  ...
  Scenario n

Baseline and Scenarios Defined by WP5.3.
CBA Tool

• Excel tool automatically computes CBA from defined input data

• Allows comparison of scenarios, sensitivity and probabilistic analysis
Approach for the scenarios

Definition of scenarios based on roadmap and C4R Innovations

Baseline analysis
Selection and description of real sites and corridors

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

Definition of migration paths to 2030/2050

Generic scenarios

Specific scenarios

Requirements and the steps to reach the vision 2050
### Scenarios

**Approach for the scenarios**

Combination of innovations and migration paths

<table>
<thead>
<tr>
<th>Physical constraints of the selected route (hot spot) related to capacity*</th>
<th>C4R innovations to cope with the constraints (what can be influenced by C4R innovations)</th>
<th>Strong impact on C4R targets (qualitatively guess by the concerned SP)</th>
<th>TRL of the concerned innovation (reg. Migration)</th>
<th>Additional contribution by other SP’s innovation (considering of TEN-T projects already planned)</th>
<th>TRL of the concerned innovation (reg. Migration)</th>
<th>Scenarios based on combination of innovations to solve the existing constraints</th>
<th>Overall impact (assessment of the benefits based on the outcomes from WP5.4 and SP3**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure constraint (conventional track system): big delays, high Maintenance activities and costs</td>
<td>SP1: Infrastructure - Innovative New Slab Track</td>
<td>Reduction of infrastructure LCC; Reduction of train delays due to Infrastructure; Increase of capacity for passenger &amp; freight;</td>
<td>TRL of the innovative new slab track (SP1)</td>
<td>SP4: use of sensing technology, pre-failure detection (based on improved real-time data), reduced infrastructure (Maintenance) costs</td>
<td>TRL of the innovative sensors (SP4);</td>
<td>SP1 + SP4: Innovative New Slab Track combined with embedded sensor</td>
<td>SP3: capacity simulation, capability trade-offs model, linked with CBA results</td>
</tr>
<tr>
<td>Infrastructure: capacity constraint, big delays, low Availability</td>
<td>SP1: Infrastructure - Innovative High Speed Track</td>
<td>Reduction of infrastructure LCC</td>
<td>TRL of the innovative high speed track (SP1)</td>
<td>SP2: Novel freight vehicles (e.g. train length, bundling of trains)</td>
<td>TRL of the innovative vehicle (SP2);</td>
<td>SP1+SP2: Innovative High Speed Track with novel rail freight vehicles</td>
<td>SP3: capacity simulation, capability trade-offs model, linked with CBA results</td>
</tr>
<tr>
<td>constraints on a track section (e.g. bridges): disruptions (extreme weather), no Monitoring of structural health, high Maint. &amp; inspection activities, low Reliability</td>
<td>SP4: Non-intrusive innovative monitoring techniques</td>
<td>Reduction of infrastructure LCC; Reduction of train delays due to IF (&amp; EW); Increase of capacity for passenger &amp; freight; Reduced unavailability (MDT) by using AMS</td>
<td>TRL of the innovative sensors (SP4)</td>
<td></td>
<td></td>
<td>SP4 + SP7: Innovative sensors combined with...</td>
<td>SP3: capacity simulation, capability trade-offs model, linked with CBA results</td>
</tr>
</tbody>
</table>
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

e.g. Scenario ii

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
CBA Tool: Output Example

- Multitude of outputs can be extracted:
CBA: Comparison of Scenarios

- Alternative scenarios can be directly compared
• Results presented divided into categories and investment levels, with comparisons between them
### Next steps - Demonstration

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

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

- 4.4 Monitoring of track sections with innovative sensors
- 5.5 Visualisation of bottlenecks, migration and assessment
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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UIC