TD 2.8: Virtually Coupled Train Sets

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Agenda

- Virtual Coupling – Goals and Vision
- System Concept (D6.1)
  - Functional Layer Structure
  - Main Functions and Two-Stage Implementation Approach
- Performance and Safety (D6.2)
  - Parameter Study
  - Relative Braking Distance vs. Absolute Braking Distance
- Project Outlook – Next Tasks
- Conclusions
The Goals of Virtual Coupling

- Increase line capacity by reducing the headway
- Increase operational flexibility by ensuring interoperability
- Improve the use of the existing station platforms by utilization of several platform tracks
- Reduce costs by:
  - Adding on-board equipment and electronic systems instead of new tracks or heavy changes in the infrastructure
  - Reducing maintenance cost in relation with best use of the line

- Increasing competitiveness with respect to road transportation
Virtually Coupled Train Sets (VCTS) - The Concept

Paradigm Change “Breaking the wall”: From absolute to relative braking distance

Utilization of safe platoon and consist management for two or more consists of any train type:

- Real-time distance, speed and acceleration supervision through on-board sensors
- Permanent T2T-communication of current train dynamics, trajectories and braking capabilities to enable cooperative movement
- Safe distance control with traction/braking control units
- To the external systems the VCTS is seen as one train that follows the rules of the underlying signaling system.

➢ New Elements in VCTS System: Sensors, Controls, T2T-Communication, Platoon Management
VCTS – Functional Layer Structure

Functional VCTS Implementation

**Tactical Layer: Platoon Management**
The tactical layer is in charge of coordinating the movement of the trains composing the platoon from the instance a joining request is received until the platoon is dissolved, including unexpected events and degraded modes.

→ On-the-fly manoeuvres (possibility to optimise with respect to time/energy/...)

**Operational Layer: T2T-Communication, Sensors, Controls**
The operational layer manages the local movement of each train assuring that commands established by the tactical layer are safely executed.

→ Regulation of headway with respect to safety limits and stability
VCTS Implementation – Stage 1

Replacement of mechanical coupler by virtual coupler: Builds upon the established procedure of portion working, i.e. joining and dividing trains during operation.

- Executing safe distance control utilizing sensors and communication (full operational layer)
- Coupling of identical vehicles in standstill as scheduled in timetable
- Basic platoon management, cooperative headway control manoeuvres (tactical layer)
- Decoupling in standstill as scheduled in timetable
- Similar to conventional operation, communication via lead consist for the whole platoon, basic interaction with interlocking (variable platoon length with gaps)
VCTS Implementation – Stage 2

Introduction of individual VCTS modules with additional functionalities
→ Smooth and efficient operation with on-the-fly manoeuvres – some examples:

- Executing safe distance control utilizing sensors and communication (full operational layer)
  → unchanged from Stage 1

- Coupling of identical vehicles in standstill as scheduled in timetable
  → Coupling of different vehicle types, coupling on-the-fly, unscheduled dynamic coupling

- Basic platoon management, cooperative headway control manoeuvres (tactical layer)
  → Calling at multiple platforms

- Decoupling in standstill as scheduled in timetable
  → Decoupling on-the-fly, unscheduled dynamic decoupling

- Similar to conventional operation
  → Interaction with TMS (e.g. to minimise delay by unscheduled coupling), switches and interlocking (advanced routing)
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VCTS – Performance and Safety

- VCTS has the potential to improve rail operations by combining benefits that usually contradict each other:
  - Capacity
  - Flexibility
  - Robustness

- For D6.2, we focussed on the capacity (S2R key performance indicator)
  - Reduced coupling and decoupling time (D6.2 studies: 10 - 40 % improvements for the IMPACT Scenarios High speed and Regional [2,3])
  - Paradigm shift from absolute to relative braking distance (RBD)

What is RBD? The required distance between trains that guarantees safe braking to standstill

→ How large is the RBD?
Relative Braking Distance – Parameter Study

In an ideal world, ...

- without delays (communication, control and brake force application) and
- 100 % precision (measurement and control),

... RBD is zero.

- Both trains travel at the same speed and follow the same braking curve until standstill. Thus, the distance between both trains never changes.

But what happens to RBD in reality?
Factors of influence: Latencies, accuracy of speed/distance measurement, braking capabilities, speed level, ...
Exemplary Comparison of Relative and Absolute Braking Distance

<table>
<thead>
<tr>
<th>Service [3]</th>
<th>(\alpha) in m/s²</th>
<th>(v_0) in km/h [3]</th>
<th>(\Delta t_{RD}) in s</th>
<th>(\Delta s_{inacc}) in m</th>
<th>(\Delta v_{inacc}) in km/h [4]</th>
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</thead>
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<tr>
<td>High Speed</td>
<td>-0.75</td>
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<td>3</td>
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<tr>
<td>Regional</td>
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<td>3</td>
<td>15</td>
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<tr>
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<tr>
<td>Freight</td>
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<td>100</td>
<td>8</td>
<td>15</td>
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</tr>
</tbody>
</table>

Assumptions and boundary conditions

- **Absolute Braking Distance**
- **Relative Braking Distance**
  (reaction delay, distance and speed inaccuracy and an additional 15 % safety margin)
Project Outlook – Next Tasks [5]:

D7.1 – Technical Feasibility Analysis (ongoing)
▪ Identification of critical aspects in VCTS implementation concerning:
  – Technological and operational subsystems
  – General obstacles
▪ Mitigation measures
▪ Introduction strategy:
  – Proof of concept with a demonstrator
  – Enabling near-term implementation of Stage 1 with minimum complexity

D7.2/3 – System Requirement Specification
D7.4 – System Impact Analysis
D7.5 – Analysis of the Business Model

Preliminary illustration by DLR from draft of Deliverable 7.1
Conclusions

- VCTS can increase capacity, flexibility and robustness of a line without major infrastructural changes due to:
  - Decreased headway and coupling times
  - Efficient and dynamic manoeuvres
  - Interoperability by coupling between any train types

- A safe realisation of VCTS is possible with the right system design and control mechanisms.

- VCTS is not tailored to a single signalling system. Thus, it is fully compatible with the Single European Rail Area (SERA) framework.

➢ VCTS – increasing competitiveness with respect to the road transportation by enabling more efficient freight and passengers transportation over the railway network.
Thank you for your attention!

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Project Website: https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-3
References

[1] X2Rail-3 (No 826141) - D6.1 - Virtual Train Coupling System Concept and Application Conditions - 2020, Canesi, S. (Lead Author), Deliverable.


