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Approaches for a more sustainable railway which require driving assistance systems or ATO

Michael Nold
12.12.2024

Motivation

Initial Situation according [1]**:**

- GoA 4 remains, most likely, until middle term on special applications, because of technical issues.
- GoA 2 can be realized earlier.

The presentation focus on:

- Driving assistance systems or GoA 2 and their potential for various optimizations and how they can help reach sustainable goals.

Approaches for a **more sustainable railway** which require driving assistance systems or ATO

Energy efficient driving	**Dynamic mechanical coupling at cruising speed**	**Slipping**

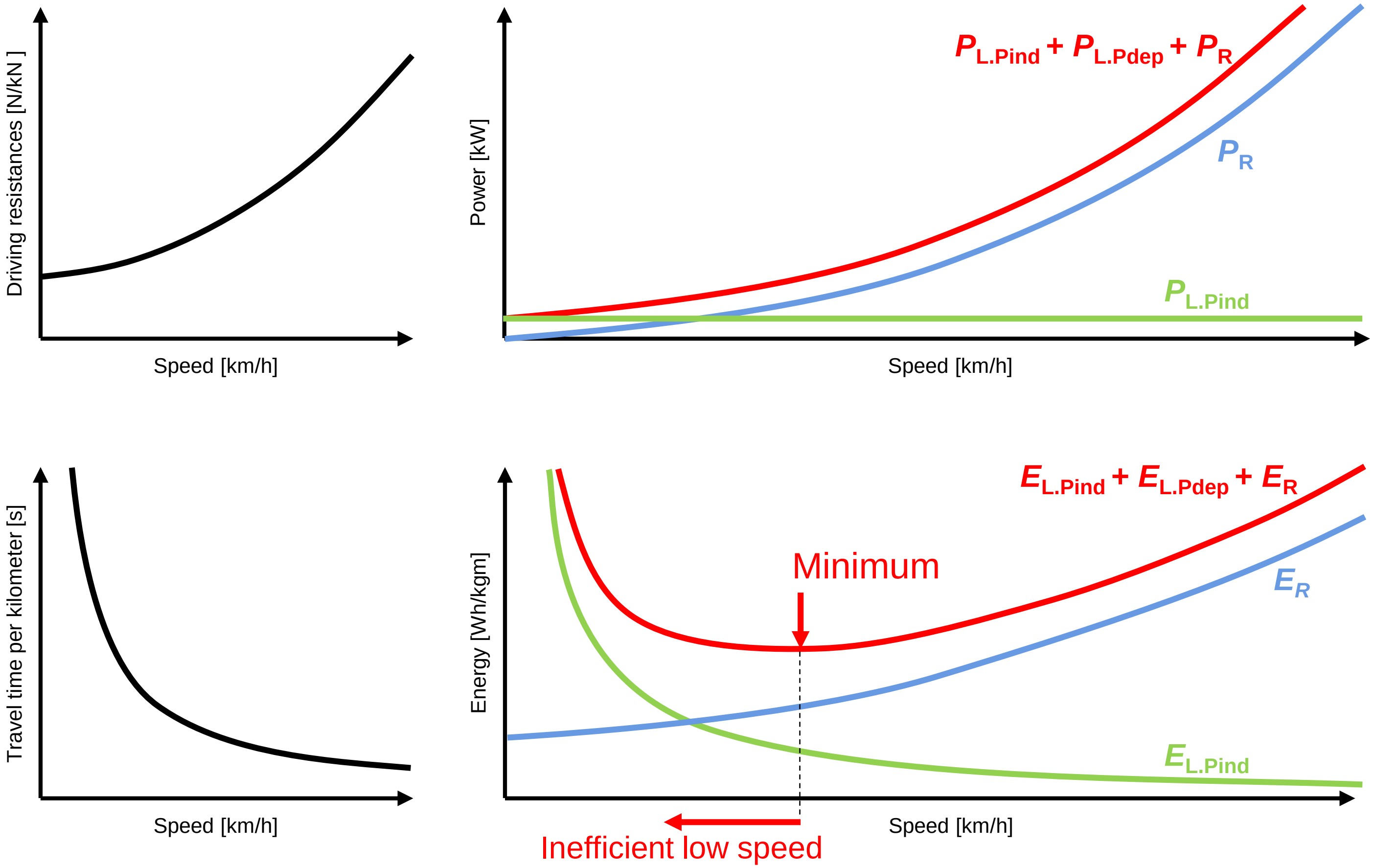
Is energy efficient driving slow driving?

At constant speed, the energy consumption arise due:

- Driving resistances P_R
- Components/auxiliaries/ comfort system

➢ **The minimum depends on the vehicle and the section of the route.**

➢ **Driving too slowly increases energy consumption.**
➔ Energy efficient driving is complex



Source / References: [1], [3], [9]

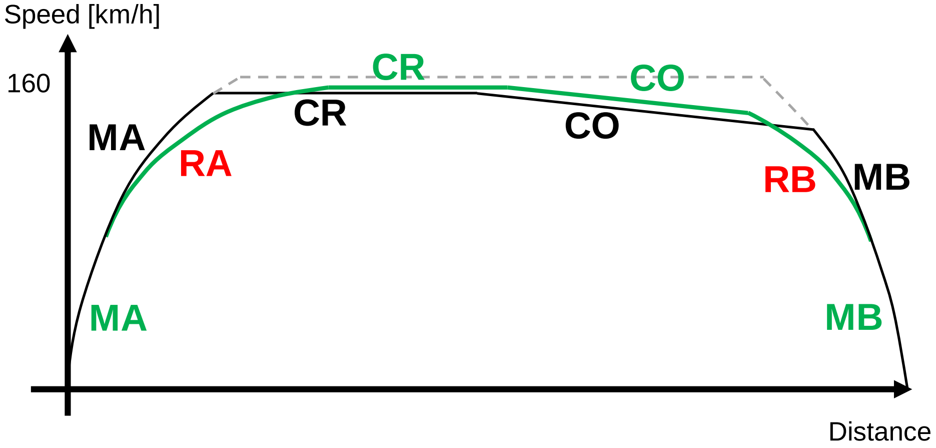
How is the energy efficient trajectory?

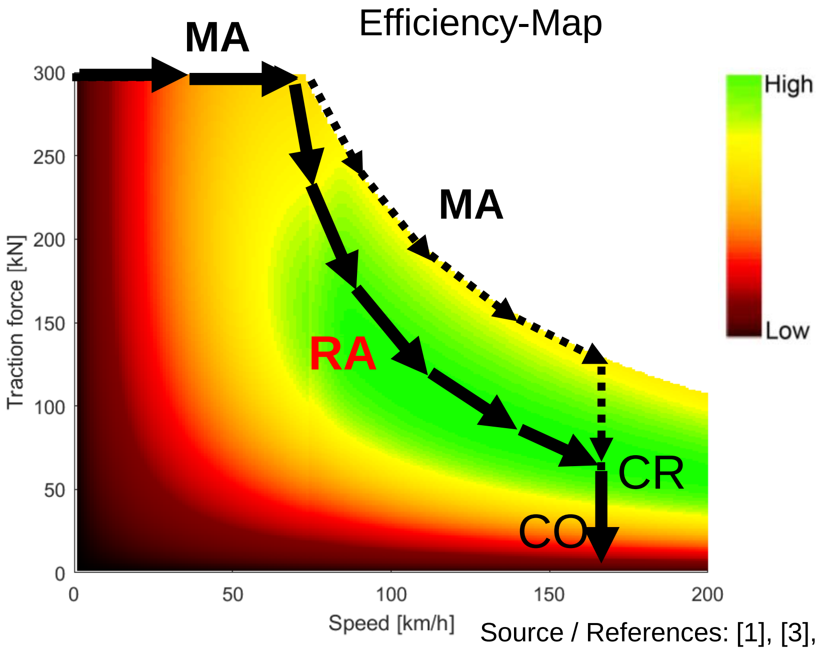
- Due to simplified modelling, it is often assumed that energy-efficient trajectory consists of only 4 modes.
  - **MA** Maximal acceleration
  - **CR** Cruising (constant speed)
  - **CO** Coasting (zero traction)
  - **MB** Maximal service braking

- By modelled correctly, it immediately becomes clear that energy-efficient trajectory consists of 2 additional modes → 6 modes.

  ➔ Two additional modes arise 2 additional modes → 6 modes.
  - **RA** Reduced acceleration
  - **RB** Reduced braking

  ➔The trajectory changes



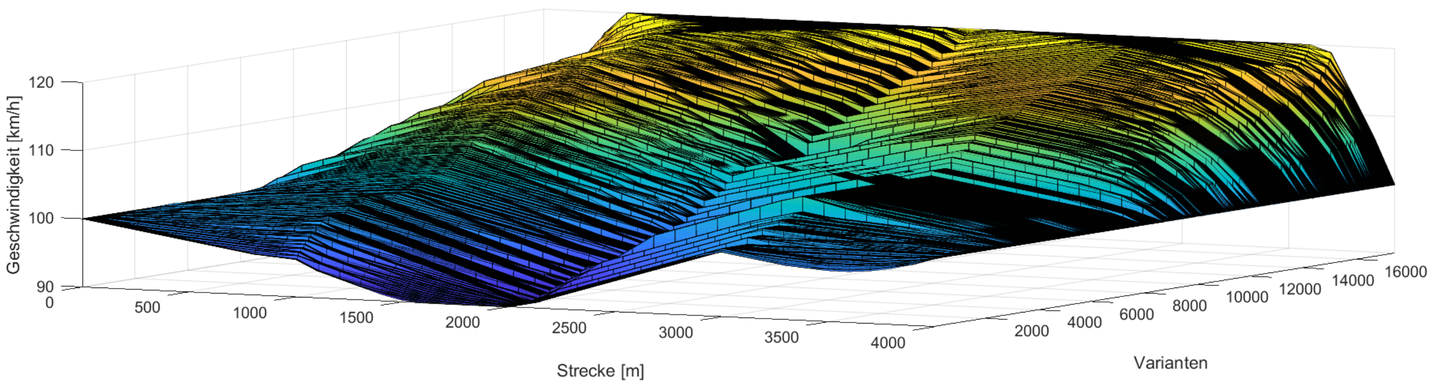


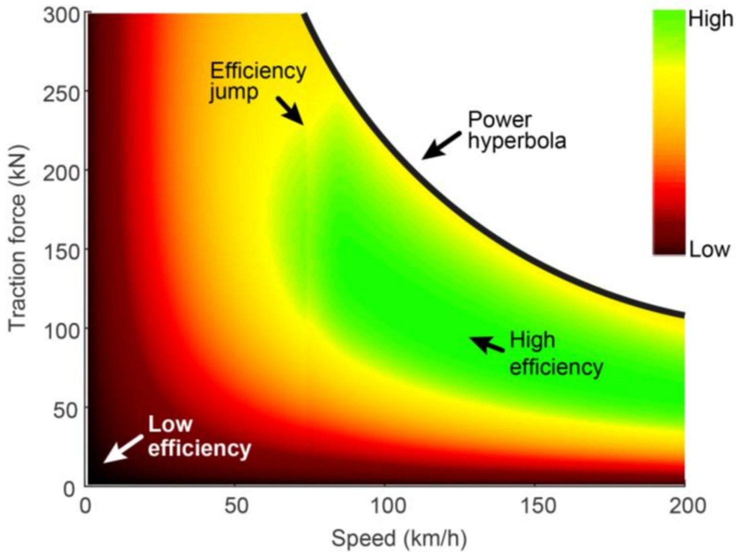
Source / References: [1], [3], [9]

Energy (3/3)
What is energy-efficient driving?

- Energy-efficient driving is not as slowest as possible. It requires an varying trajectory along the reduce and have to considered, vehicle specific details, line detiles and the timetable with it network effects.
- Energy-efficient driving requires speed and traction force that varies along the route with change in very short intervals and with high precision.

➢ **Assistance systems for energy-efficient driving are required to keep it manageable for the driver.** Otherwise, there is a risk that the driver will no longer be able to concentrate on safety and line.



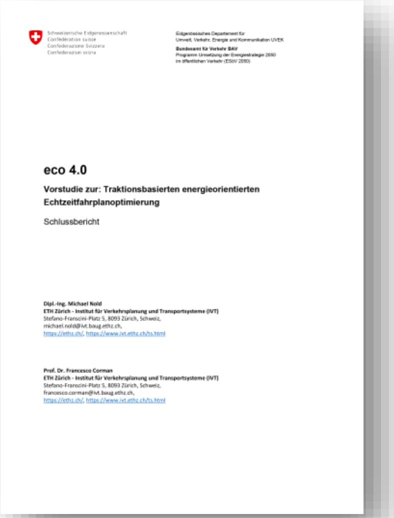


Source / References: [1], [3], [9]

Further Information's

About, e.g.:

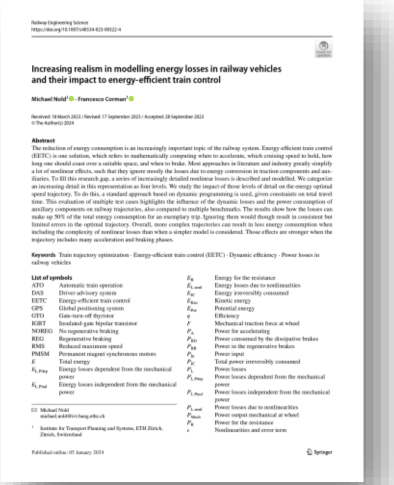
- Modelling vehicle energy flows
- Classification in levels
- Levels impact
- Simulation and handle the programming of Energy efficient train control


eco 4.0

Vorstudie zur: Traktionsbasierten energieorientierten Echtzeitfahrplanoptimierung

Schlussbericht

Nold, M., and Corman, F. (2020) eco 4.0 Vorstudie zur: Traktionsbasierten energieorientierten Echtzeitfahrplanoptimierung. Bundesamt für Verkehr, 257. https://doi.org/10.3929/ethz-b-000462144


Increasing realism in modelling energy losses in railway vehicles and their impact to energy-efficient train control

Nold, M., and Corman, F. (2024) Increasing realism in modelling energy losses in railway vehicles and their impact to energy-efficient train control. Railway Engineering Science 32, 257. ISSN: 2662-4753. https://doi.org/10.1007/s40534-023-00322-4

Approaches for a **more sustainable railway** which require driving assistance systems or ATO

Driving assistance sys. or GoA 2 required

Energy efficient driving

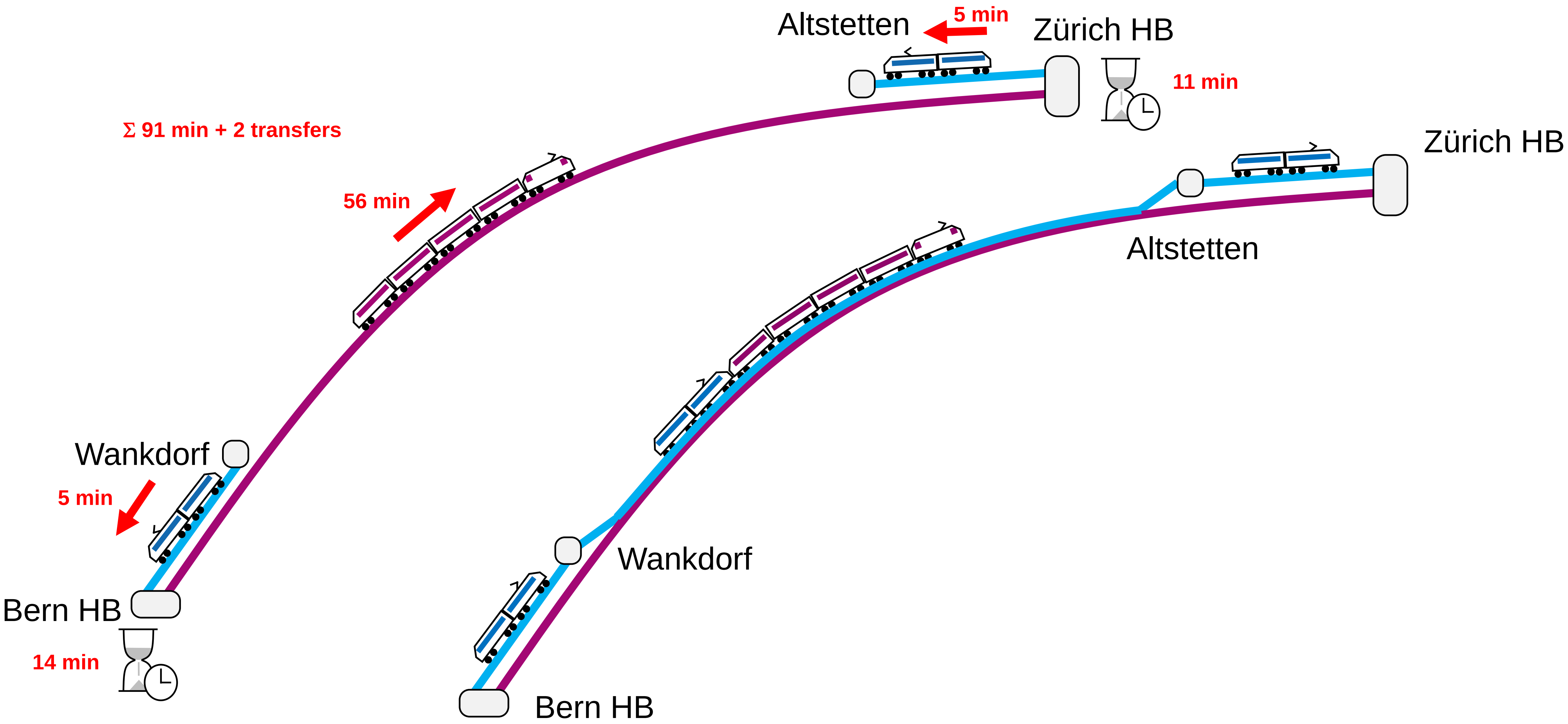
Dynamic mechanical coupling at cruising speed

Slipping

✓ **Reduction of energy consumption**

Dynamic train unit coupling and decoupling at cruising speed (1/3)

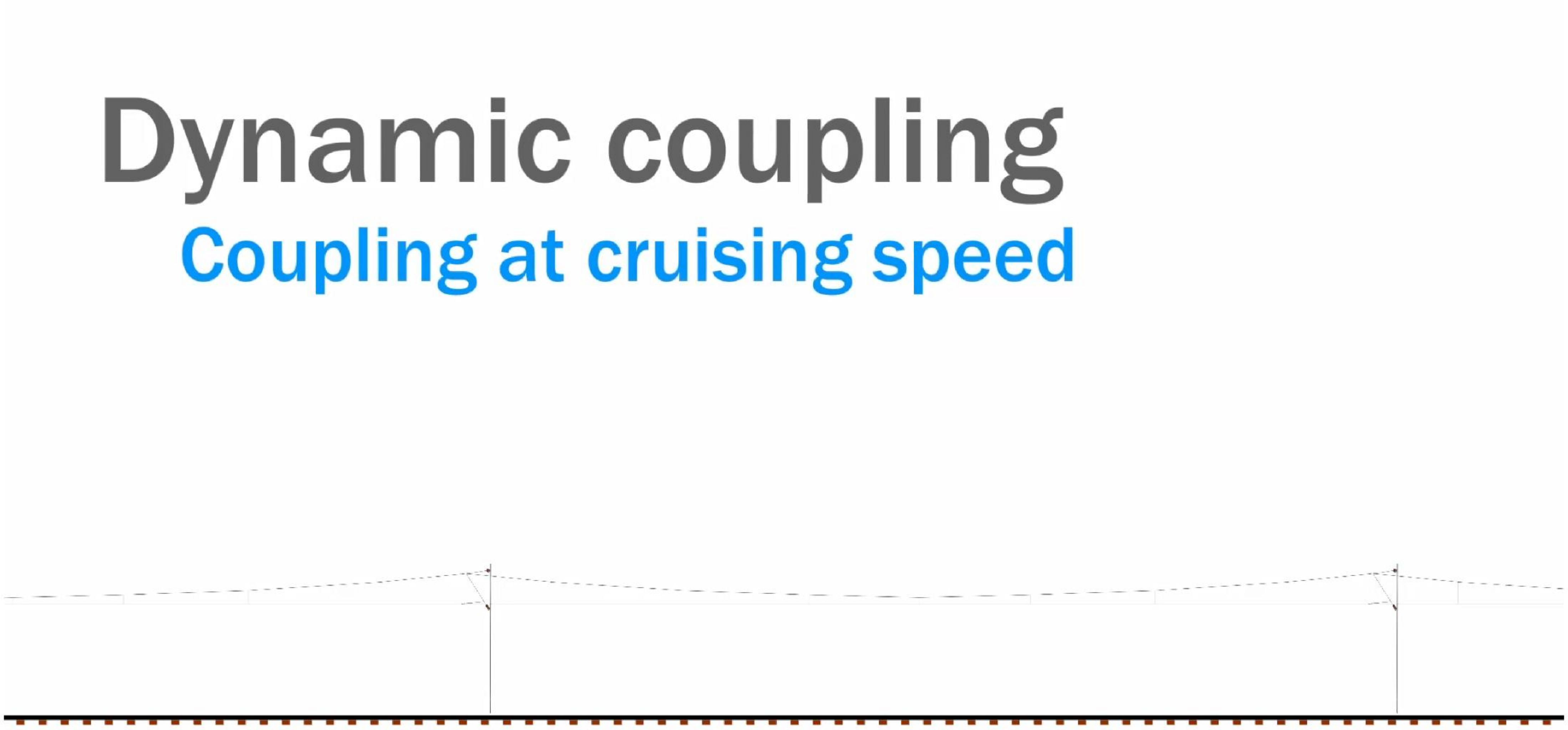
Problem & Possible application



Source / References: [2], [5]

Dynamic train unit coupling and decoupling at cruising speed (2/3)

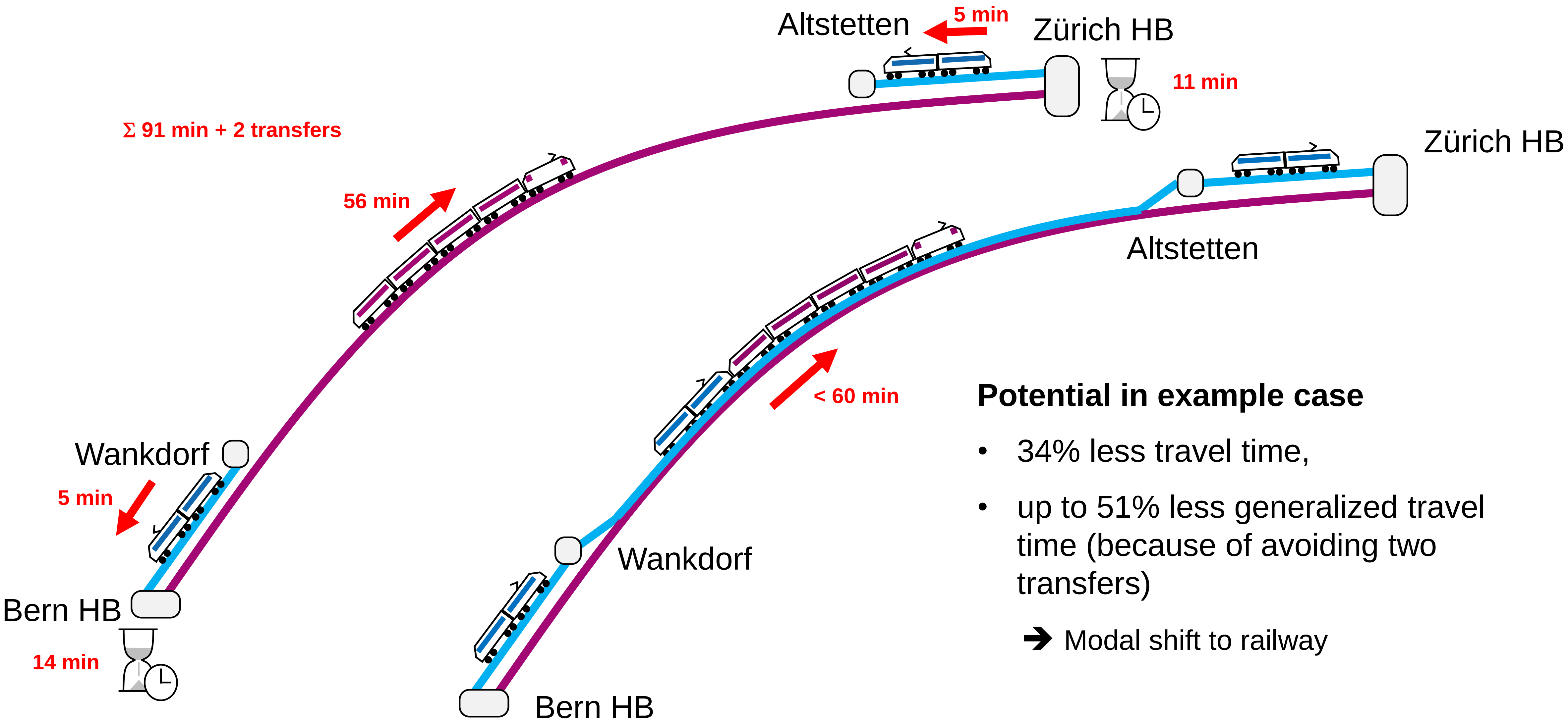
Technology - Coupling support device



Source / References: [7]

Dynamic train unit coupling and decoupling at cruising speed (1/3)

Possible application



Potential in example case

- 34% less travel time,
- up to 51% less generalized travel time (because of avoiding two transfers)

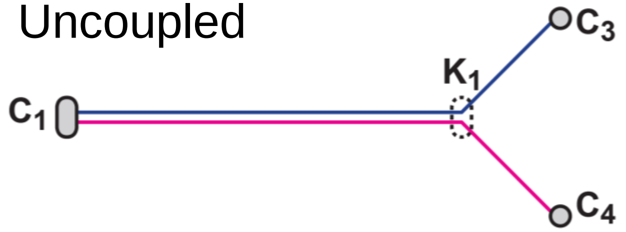
➔ Modal shift to railway

Source / References: [2], [5]

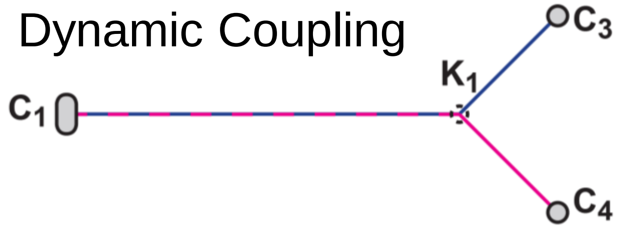
Dynamic train unit coupling and decoupling at cruising speed (3/3)

Topologies & Interoperability

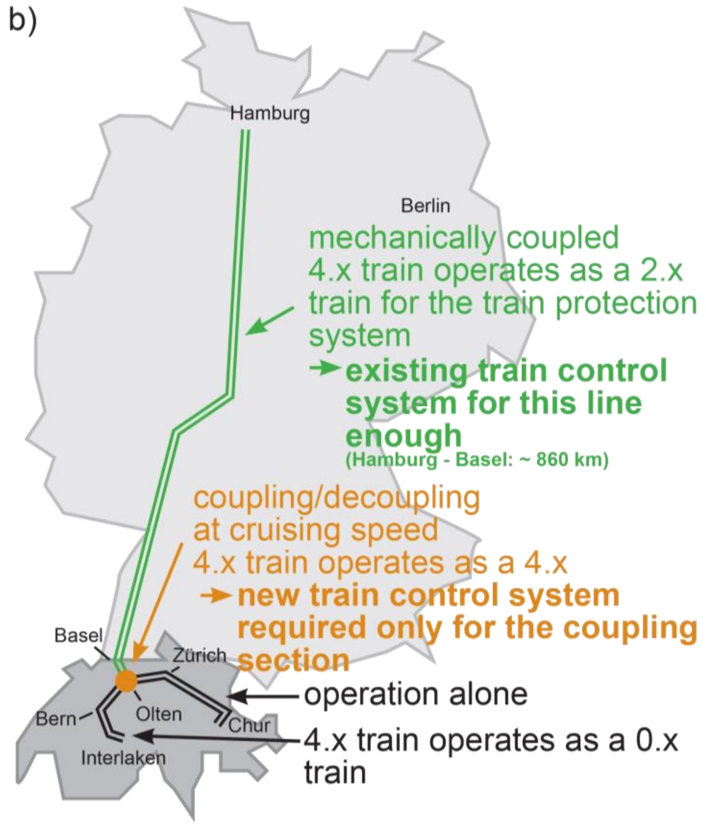
Uncoupled



Dynamic Coupling



Dynamic Coupling

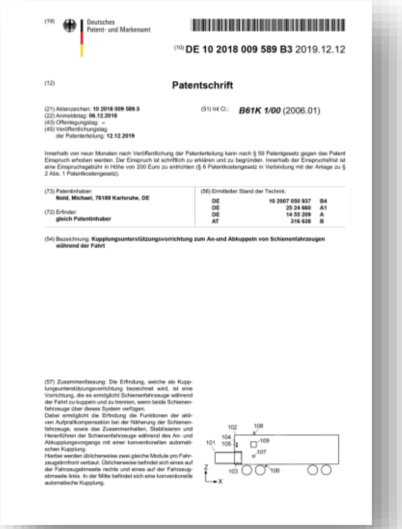


Source / References: [2]

Further Information's

About, e.g.:

- Technology Coupling support device
- Generation of coupling
- Coupling phases and simulation
- Impact on Topologies and demand
- Research Agenda



Deutsches Patent- und Markenamt

DE 10 2018 009 589 B3 2019.12.12

Patentschrift

B61K 1/00 (2006.01)

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Journal of Rail Transport Planning & Management

Dynamic train unit coupling and decoupling at cruising speed: Systematic classification, operational potentials, and research agenda

Michael Nold, Francesco Corman

Nold, M. & Corman, F. (2021) Dynamic train unit coupling and decoupling at cruising speed: Systematic classification, operational potentials, and research agenda. Journal of Rail Transport Planning & Management 18. ISSN: 2210-9706. https://doi.org/10.1016/j.jrtpm.2021.100241

Approaches for a **more sustainable railway** which require driving assistance systems or ATO

GoA 4 can increase the benefits

Driving assistance systems or GoA 2 required

Energy efficient driving

Dynamic mechanical coupling at cruising speed

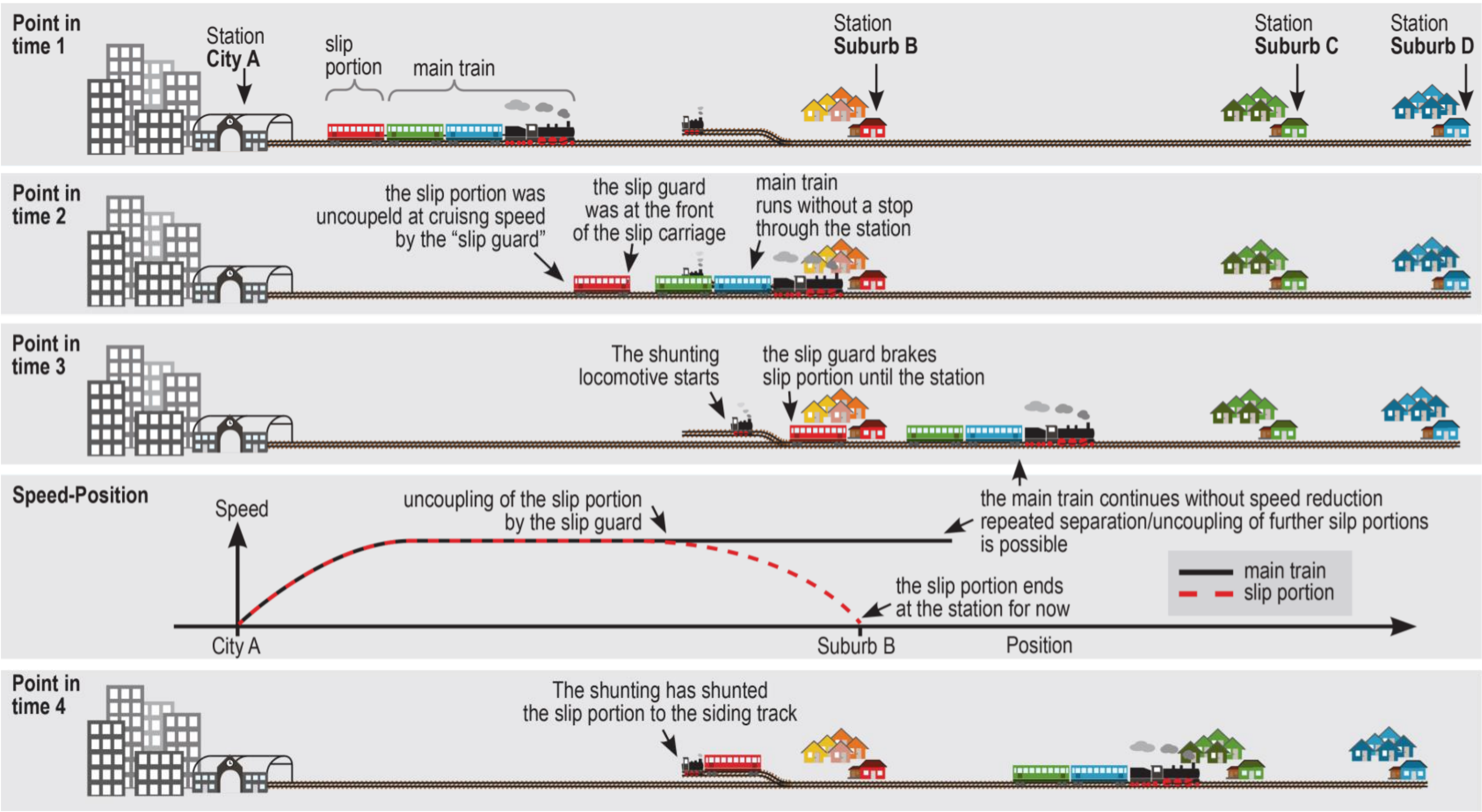
Slipping

✓ **Reduction of energy consumption**

✓ **Increased capacity usage**

✓ **Travel time reduction**

Slipping (1/3)
History



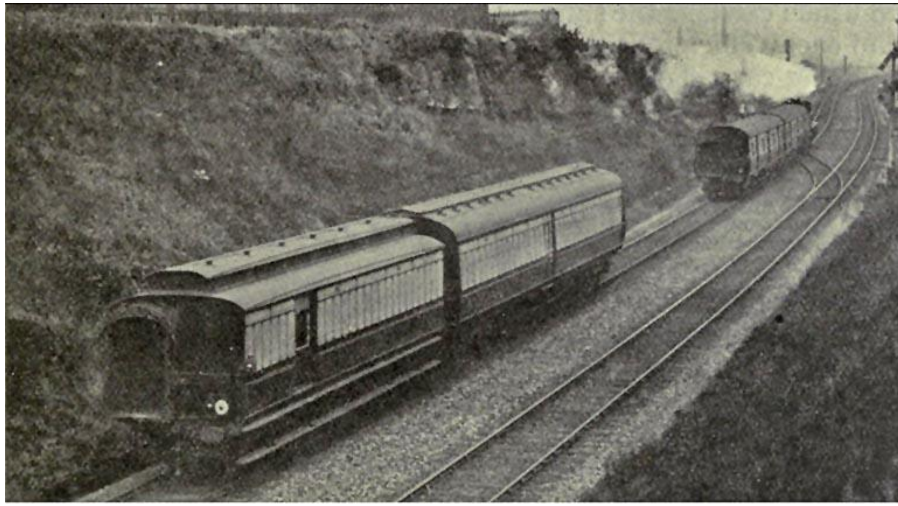
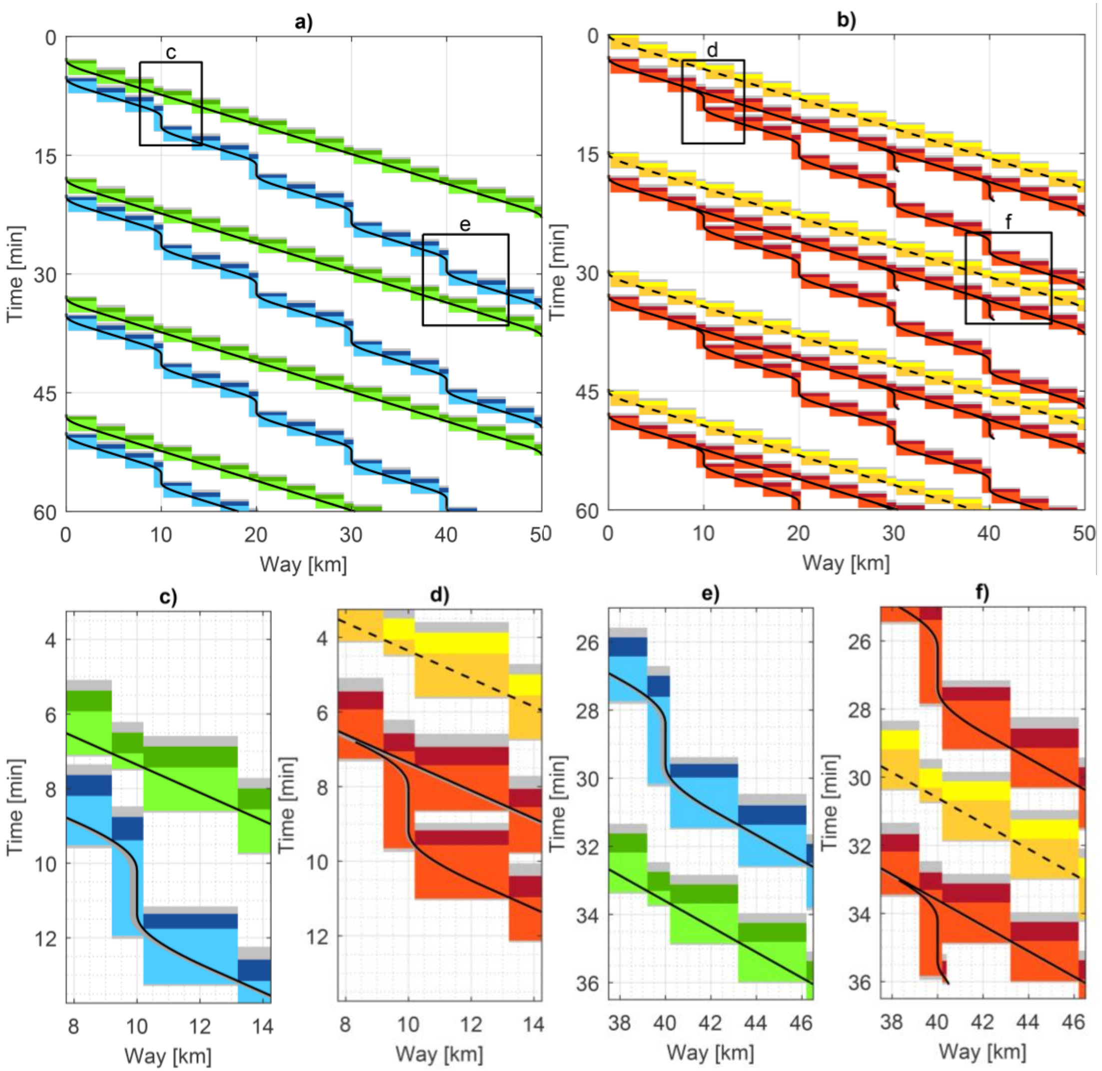


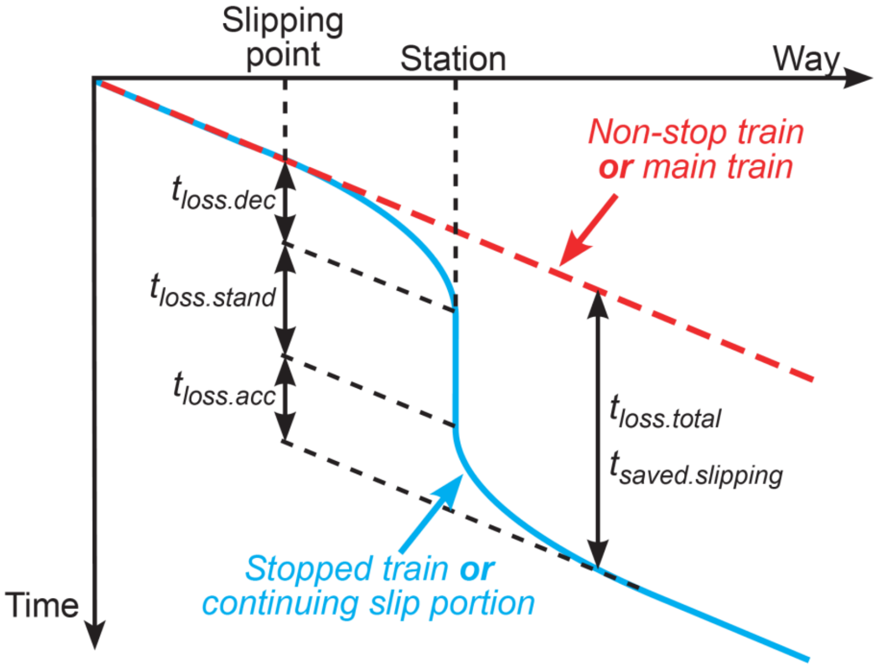
Photo-Source: Wikipedia

- ➔ **Train separation it something old**
- ➔ **Use railcars instead of coaches required**
- ➔ **Usage of assistance system or ATO useful**

Source / References: [10]

Slipping (2/3)
Capacity





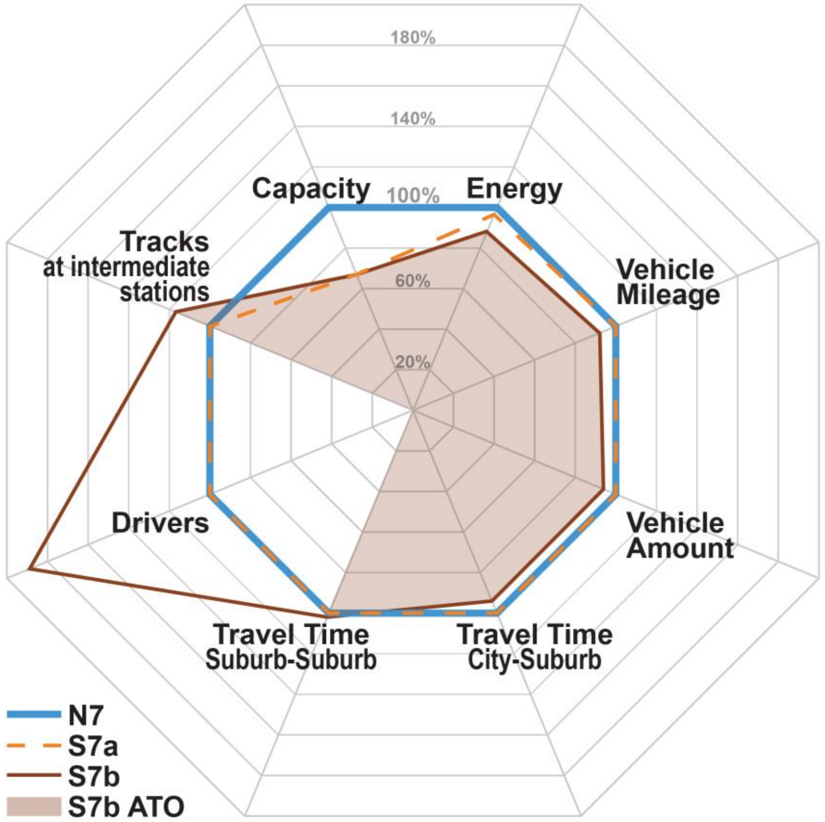
➔ Here: +50 % more trains

Source / References: [10]

Slipping (3/3)
Potential

Significant improvements by focusing on one goal **OR** **Slight simultaneous improvements**

- Higher capacity usage (+50 % possible)
- Energy Saving by (-65 % in extrem cases)
  - Avoiding losses due to decelerations/accelerations
  - Avoiding vehicle front/rear resistance due to coupling of vehicles.
  - Optimized vehicle size along the trip (portion size).
  - Enabling lower and homogenous speed (by the same travel time).
- Travel time reductions (-30 % for some relation)
- Less transfers
- Less vehicle millage
- …



Source / References: [10]

Slipping

Further Information's

About, e.g.:

- System analysis - e.g.:
  - Scenarios
  - Timetable
  - Drivers
  - Energy
  - Capacity
  - Vehicle circulation
- Station topology & shunting

Nold, M., and Corman, F. (2024) Train separation at cruising speed, how it can improve current railway operations. Journal of Rail Transport Planning & Management 30. 100451 ISSN: 2210-9706. doi: https://doi.org/10.1016/j.jrtpm.2024.100451

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Train separation at cruising speed, how it can improve current railway operations

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ARTICLE INFO

Keywords:
Slipping
Dynamic coupling
Railway operations
Energy
Travel time
Capacity
Decoupling at cruising speed

ABSTRACT

This paper systematically reviewed the slipping operation, which is a train separation at cruising speed. For this, we describe the historical and operational background of the operation scenario practiced for over 100 years. Based on the concept of slipping, we discuss the holistic potential to improve current railway operations, considering travel time saving, energy saving, the increase of capacity utilization, station topology, driver requirements, and vehicle usage. Finally, a simulation of a theoretical urban railway line with several scenarios quantifies the magnitudes of the improvements. Based on the slipping test cases, one parameter can improve enormously, e.g., up to −65 % energy saving, −33 % capacity usage, and travel time reductions. Otherwise, slipping can slightly improve several parameters simultaneously.

1. Introduction

Research and engineering have several approaches to improving performance of railway systems. A few approaches focus on reducing the travel time (Nold, 2018a), buffer time and routing (Dewilde et al., 2014), or the impact of delay (Cacchiani et al., 2014). Other approaches aim to reduce energy consumption (Nold, 2018b), (Nold and Corman, 2024), (Wang et al., 2020). Finally, other approaches aim to increase capacity utilization (Goverde et al., 2013). However, most approaches often optimize only one of these main focus topics and neglect or narrow focus on the others. For example, a speed reduction reduces, in most lines, energy consumption and increases travel time. Most of the characteristics are conflicting with each other, and unless changes in the boundary constraints, unconventional ideas, or new technologies, it is difficult to improve multiple characteristics at once.

In this work, we study the potential of train separation at cruising speed. This is effectively a simpler version of dynamic coupling (Nold and Corman, 2021). A view in history shows that train separation at cruising speed is not only an idea of the future; instead, it was already practiced in the past and called *slipping*. Furthermore, similar approaches are used for today's railway operations. Due to this, we take a look at the history and derive new potential from it. Many technological developments allow to resolve some of the drawbacks and limitations that were characteristics of this specific operation. Those are now currently studied in the literature and assumed coming into industry soon, like trains with high degree of automation (GoA4, for instance) (Wang et al., 2022), automation in signaling, small motorized coaches (Althaus and Staub, 2020) or train units, such as EMU, safe movements under relative braking distance (virtual coupling) (Quaglietta et al., 2020), (Quaglietta et al., 2022). We believe that the potential of slipping, in specific demand constellations (large center and many suburban centers connected to that; and strongly directional flows of passengers) can deliver good performance. In fact, it will address indicators such as transfer penalties (Wardman and Hine, 2000), total travel time (or

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Approaches for a **more sustainable railway** which require driving assistance systems or ATO

GoA 4 can increase the benefits

Driving assistance systems or GoA 2 required

Energy efficient driving

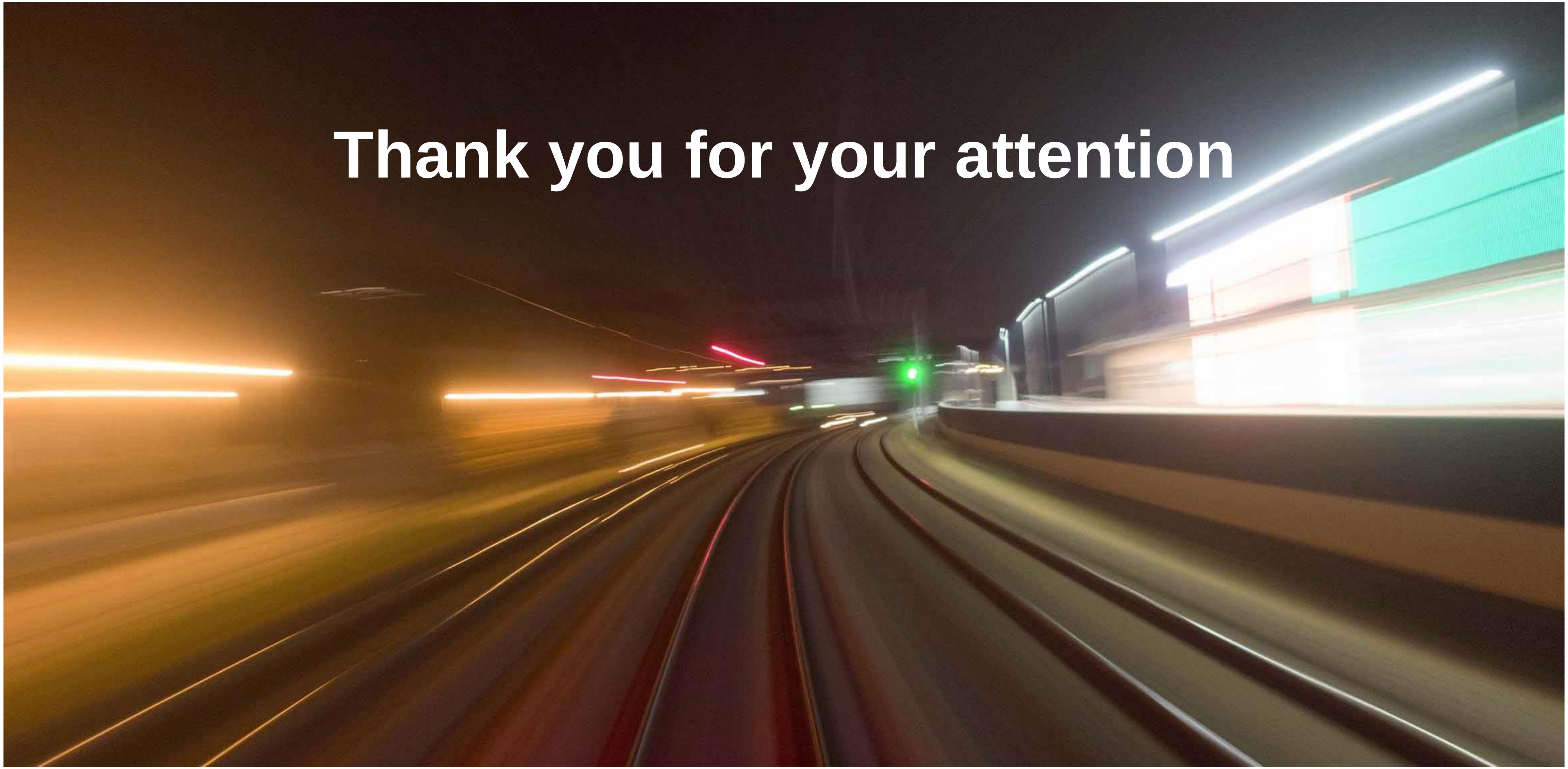
Dynamic mechanical coupling at cruising speed

Slipping

✓ **Reduction of energy consumption ➔ Less CO_2, less power plants, …**

✓ **Increased capacity usage ➔ Minimization of space requirements**

✓ **Travel time reduction ➔ Modal shift to rail**


Thank you for your attention

References

[1] Nold, M., Corman, F. (2020) eco 4.0 - Vorstudie zur: Traktionsbasierten energieorientierten Echtzeitfahrplanoptimierung. https://doi.org/10.3929/ethz-b-000462144

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