Technical-economical comparison of Maglev and High Speed Systems
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2. Comparison of the Technology between Wheel-on-Rail and Maglev
3. System Comparison
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Basis of the LCC Analysis

Life-cycle phases

- Development
- Construction
- Prototype
- Test
- Serial-Production
- Initial Operation
- Operation
- Termination of Operation
- Waste disposal

Determination and development of LCC

Cost determination
Cost development
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Basis of the LCC Analysis

Cost Matrix Model

Cost Types

Technical structure

Life-cycle phases

Cost type: Failure Costs

Life-cycle: Operation

Component Propulsion System

Cost Element:
Failure costs of the propulsion system in the operation phase of the life cycle.
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Basis of the LCC Analysis

Simplified LCC Model for the comparison of Railway Systems
Comparison of the Technology between Wheel-on-Rail and Maglev Technique

<table>
<thead>
<tr>
<th>Type of guided system</th>
<th>Function of carrying guiding and propulsion</th>
<th>Load Effect</th>
<th>Mechanically stressed due to carrying (static load)</th>
<th>Track maintenance costs in percentage of initial capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel-on-rail</td>
<td>Through contacts</td>
<td>High point load Heavy wear</td>
<td>5000 $\text{i} \ 10000 \text{ kg/cm}^2$ (approx.) $^{1) \ 2)}$</td>
<td>2,6 $\text{i} \ 4,5$</td>
</tr>
<tr>
<td>Maglev (Transrapid)</td>
<td>No contact</td>
<td>Low area load Little wear</td>
<td>1 $\text{ kg/cm}^2$ (approx.) $^{3)}$</td>
<td>0,2 $\text{i} \ 0,5$</td>
</tr>
</tbody>
</table>

1) Passenger coach and ICE end power car respectively
2) Mean additional dynamic element for wheel-on-rail approx. 30%
3) Mean additional dynamic element for maglev approx. 10%
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Comparison of the Technology between Wheel-on-Rail and Maglev Technique

Alignment Parameters

Transrapid
(Propulsion integrated in guideway)

Wheel-on-rail
(Propulsion in the train)

gradient (max 10%)

gradient (max 4%)
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Comparison of the Technology between Wheel-on-Rail and Maglev Technique

Curve radius

ICE

Transrapid

300 km/h

2825 m at 400 km/h

Transrapid

ICE

Transrapid

200 km/h

1590 m

1400 m

705 m
### Technical-economical comparison of Maglev and High Speed Systems

**Comparison of the Technology between Wheel-on-Rail and Maglev Technique**

Crest and Sag of the High Speed Systems

<table>
<thead>
<tr>
<th></th>
<th>Wheel/Rail System ICE3</th>
<th>Maglev Transrapid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crest</td>
<td>Sag</td>
</tr>
<tr>
<td>Vertical Acceleration</td>
<td>0,5 m/s²</td>
<td>0,6 m/s²</td>
</tr>
<tr>
<td>Design Speed 200 km/h</td>
<td>6.400 m</td>
<td>5.200 m</td>
</tr>
<tr>
<td>300 km/h</td>
<td>14.400 m</td>
<td>11.700 m</td>
</tr>
<tr>
<td>330 km/h</td>
<td>17.400 m</td>
<td>14.200 m</td>
</tr>
<tr>
<td>400 km/h</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>450 km/h</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
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Comparison of the Technology between Wheel-on-Rail and Maglev Technique

Guideway

At grade guideway Typ III

Elevated guideway Typ II

Elevated guideway Typ I
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System Comparison

Mass balance

- Magnetic drive, etc. Hovering frame Levitation/guiding system; Eddy-current brake; Electrical equipment 46%
- Equipment 11%
- Passengers 11%
- Bodywork 27%
- Batteries 5%

Length of vehicle: 129 m

Cost balance

- Magnetic drive, etc. Hovering frame Levitation/guiding system; Eddy-current brake; Electrical equipment 54%
- Equipment 16%
- Assembly/Commissioning 5%
- Bodywork 22%
- Batteries 3%

Total mass: 318 t (247 t unladen)$^2$$^3$)

Number of seats (standard config.): 446 (approx. 36t)$^1$

Number of sections: 5 (approx. 64 t/car)

Specific mass per seat: 0,63 t/seat

---

1) 80 kg per person with luggage
2) Laden mass (passengers and equipment)
3) Basis configuration of TR 08
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System Comparison

Mass balance

- Running gear Energy Supply Propulsion (7%)
- Onboard control Aux. groups 48%
- Equipment 18%
- Passengers 7%
- Bodywork 27%

Cost balance

- Running gear Energy Supply Propulsion (13%)
- Onboard control Aux. groups 44%
- Equipment 26%
- Assembly/Commissioning 10%
- Bodywork 20%

Total mass: 442 t (408 t unladen)
Number of seats (standard config.): 415 (approx. 33 t)
Number of cars: 8 (approx. 55 t/car)
Specific mass per seat: 0.99 t/seat

1) 80 kg per person with luggage
2) Laden mass (i.e. including passengers)
### System Comparison

#### Vehicle

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Wheel on Rail System</th>
<th>Maglev System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carriages/Sections per Train</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Seats</td>
<td>415 (+ 24 in the dining car)</td>
<td>446</td>
</tr>
<tr>
<td>Operational speed</td>
<td>300 km/h</td>
<td>450 km/h</td>
</tr>
<tr>
<td>Max. engine power</td>
<td>8000 KW</td>
<td>25000 KW</td>
</tr>
<tr>
<td>Net weight of the train</td>
<td>409 t</td>
<td>247 t</td>
</tr>
<tr>
<td>Weight / Seat</td>
<td>Approx. 930 kg</td>
<td>Approx. 550 kg</td>
</tr>
<tr>
<td>Total length of train</td>
<td>200m</td>
<td>128 m</td>
</tr>
<tr>
<td>Width</td>
<td>2,95 m</td>
<td>3,70 m</td>
</tr>
<tr>
<td>Heigth</td>
<td>3,89 m</td>
<td>4,16 m</td>
</tr>
<tr>
<td>Axel load</td>
<td>17 t (2,1 t/m)</td>
<td>2,2 t/m</td>
</tr>
</tbody>
</table>
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System Comparison

Subsystems for Maglev and Wheel/Rail System

Energy Supply

Vehicle

Propulsion

Signal & Control System
System Comparison

Comparison of general system structure

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Maglev</th>
<th>Wheel on rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>Maglev vehicle</td>
<td>Vehicle</td>
</tr>
<tr>
<td></td>
<td>Vehicle-OCS</td>
<td>incl. Propulsion components and OCS</td>
</tr>
<tr>
<td>Operations control system</td>
<td>Operation center, control facilities, Radio facilities</td>
<td>Signal box, ETCS</td>
</tr>
<tr>
<td>Propulsion/Conductor rail</td>
<td>Substation (incl. current converter),</td>
<td>Overhead catenary</td>
</tr>
<tr>
<td></td>
<td>Incoming current converter, Intermediate circuit, Braking chopper,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inverter, Output converter,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Track cable, Stator windings,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feeder rail</td>
<td></td>
</tr>
<tr>
<td>Energy supply</td>
<td>Power Station, local energy network (3~ 110 kV 50 Hz), High voltage</td>
<td>Power station, railway energy supply network</td>
</tr>
<tr>
<td></td>
<td>converter, 3~ 20 kV 50 Hz</td>
<td>(1~ 110 kV 16,7 Hz), Substation</td>
</tr>
<tr>
<td>Guideway</td>
<td>At grade, elevated</td>
<td>At grade</td>
</tr>
</tbody>
</table>
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System Comparison

![Graph comparing Transrapid and ICE 3 runs](image)
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System Comparison

![Acceleration vs Speed Graph]

- **Rail systems**
  1. ICE 3
  2. Class-425 EMU
  3. Class-145 + 5 double-deck coaches
  4. Class-146 + 5 double-deck coaches
  5. Metrorapid (DU airport – DUI Hbf.)
  6. ICE-T (class 411)

1. $V_{\text{max}} = 200 \text{ km/h}; \bar{a} = 0.41 \text{ m/s}^2$
2. $a = 0.27 \text{ m/s}^2$
3. $a = 0.46 \text{ m/s}^2$
4. $a = 0.78 \text{ m/s}^2$
5. $a = 0.32 \text{ m/s}^2$
6. $a = 0.23 \text{ m/s}^2$

( $\bar{a}$ : mean acceleration)
## System Comparison

### Energy consumption

<table>
<thead>
<tr>
<th></th>
<th>Wheel/Rail</th>
<th>modified MAGLEV</th>
<th>MAGLEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>running time including timetable reserves</td>
<td>32 min.</td>
<td>32 min.</td>
<td>21 min.</td>
</tr>
<tr>
<td>Design Speed</td>
<td>300 km/h</td>
<td>246 km/h</td>
<td>450 km/h</td>
</tr>
<tr>
<td>Energy supply</td>
<td>Substation 15 kV</td>
<td>Substation 20 kV</td>
<td>Substation 20 kV</td>
</tr>
<tr>
<td>Traction energy consumption</td>
<td>62,2 GWh/a</td>
<td>44,1 GWh/a</td>
<td>89,6 GWh/a</td>
</tr>
<tr>
<td>secondary energy consumption</td>
<td>6,2 GWh/a</td>
<td>13,2 GWh/a</td>
<td>13,2 GWh/a</td>
</tr>
</tbody>
</table>
Identification of the Quantity and Cost Frameworks

Cost Structure of the system comparison

**Investment Costs**

*Infrastructure costs*
- Land requirement
- Guideway / track
- Power supply
- Propulsion/feeder
- Operation control system
- Noise protection

*Vehicle Costs*

*Other Costs*
- Facilities
- Planning costs

**Operational Costs**

*Personnel costs*

*Energy Costs*

*Maintenance Costs*
Identification of the Quantity and Cost Frameworks

Comparison of the Investments Costs

<table>
<thead>
<tr>
<th>Cost Group</th>
<th>Mio. €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land requirement</td>
<td>0</td>
</tr>
<tr>
<td>Guideway/track</td>
<td>0</td>
</tr>
<tr>
<td>Propulsion/feeder</td>
<td>0</td>
</tr>
<tr>
<td>Power supply</td>
<td>0</td>
</tr>
<tr>
<td>Operation control system</td>
<td>0</td>
</tr>
<tr>
<td>Other costs</td>
<td>0</td>
</tr>
<tr>
<td>Vehicle</td>
<td>0</td>
</tr>
<tr>
<td>Total investment</td>
<td>0</td>
</tr>
</tbody>
</table>

ICE

Transrapid (with cost reduction)

Transrapid (without cost reduction)
Identification of the Quantity and Cost Frameworks

Comparison of Personnel Costs
Identification of the Quantity and Cost Frameworks

Comparison of Maintenance Costs

Total
Vehicle
Guideway
Stations
Operation Control System
Energy Supply
Propulsion Energy Supply Feeder

Maglev Maintenance Costs
ICE Maintenance Costs
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System Comparison

- Maintenance costs
- Energy costs
- Operation materials
- Operation personnel
- Total

Costs are in Millions of euros:
- Maglev
- ICE
Analysis of the LCC

Periodic Cost Development
Analysis of the LCC

Total Cost Development for Maglev and for Rail
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Noise emission

<table>
<thead>
<tr>
<th>Speed</th>
<th>S-Bahn</th>
<th>Transrapid 07</th>
<th>ICE 1+2</th>
<th>TGV-A</th>
<th>Transrapid 07</th>
<th>ICE 1+2</th>
<th>TGV-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 km/h</td>
<td>80</td>
<td>72</td>
<td>84</td>
<td>85</td>
<td>75</td>
<td>88</td>
<td>91</td>
</tr>
<tr>
<td>200 km/h</td>
<td>86</td>
<td>88</td>
<td>92</td>
<td>92</td>
<td>86</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>250 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>450 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Technical-economical comparison
of Maglev and High Speed Systems

### Journey time Comparison

<table>
<thead>
<tr>
<th>Journey time</th>
<th>Distance [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times to/from terminals:</td>
<td>Maglev and WoR: 35 min</td>
</tr>
<tr>
<td>Aircraft</td>
<td>80 min</td>
</tr>
</tbody>
</table>

**ICE 3** 300 km/h  
**Maglev 450 km/h**  
**Aircraft**  

Graph showing journey times vs. distance for ICE 3, Maglev, and Aircraft.
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System Comparison

Hourly performance of carriers

<table>
<thead>
<tr>
<th>Capacity (passenger per hour) vs Headway [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maglev, 10 sections</td>
</tr>
<tr>
<td>Wheel-on-Rail, two ICE 3</td>
</tr>
<tr>
<td>Maglev, 5 sections</td>
</tr>
<tr>
<td>Wheel-on-Rail, one ICE 3</td>
</tr>
<tr>
<td>B777-300</td>
</tr>
<tr>
<td>A 320</td>
</tr>
</tbody>
</table>
Summary of Evaluation

Potential Cost Savings of the High Speed Maglev System

High Speed Maglev System has Lower Costs than the Wheel-on-Rail System

High Speed Maglev System has Lower Maintenance Expenses than the Wheel-on-Rail System

High Speed Maglev System has Lower Life Cycle Costs than the Wheel-on-Rail System

Environmentally Compatible Operation

Macro-economical Benefits