Analysis of German diesel operated regional railway lines' patterns with regard to the application of battery and fuel cell electric trains

**Johannes Pagenkopf**, Mathias Böhm, Jan Lucas Haas, Horst Friedrich
DLR (German Aerospace Center) - Institute of Vehicle Concepts (FK)
Berlin, Germany

Railways Conference 2018
Sitges, 4\textsuperscript{th} Sept. 2018
Background

FCEMU & BEMU

• In regional railway transport, BEMU (Battery Electric Multiple Units) and FCEMU (Fuel Cell Electric Multiple Units) emerge as new drivetrain alternatives to classic DMU and EMU for use on non-electrified lines

• Benefits of FCEMU/BEMU (against DMU / EMU):
  • Less noise, no exhaust & CO₂ emissions at point of use
  • High(er) drivetrain efficiency
  • no trackside electrification (costs, right-of-way issues)

• Drawbacks (to be solved):
  • No broad operational experiences gained so far
  • range-constrained (right picture)
  • Long refuelling (FCEMU) or recharging times (BEMU)
Aim
Assess BEMU and FCEMU suitability by means of a line analysis (for Germany)

• Why line analysis? → A comprehensive BEMU/FCEMU comparison requires to consider technical, economical and infrastructural aspects.

• The concrete line and electrification profile largely determines the suitability of BEMU and FCEMU:
  • Electrification degree
  • Number of electrified start & terminus stations
  • Position and length of non-electrified sections
  • Dwelling times at start/terminus stations
  • Operational profile (timetable, trains per hour/direction)
  • Local H₂ production potential
  • Potential to equip further electrification islands/sections

Only about 60% of tracks in Germany are electrified

Source: https://geovdbn.deutschebahn.com/isr
Methods

- Data on 469 German regional railway lines which are diesel operated today were used.

- **Line definition:** Train running once from start to terminus station on a regional railway operated route.

- Data derived from publicly available sources (Streda.X Infrastrukturregister, railway atlas, electronic timetable, public transport authorities,…)

- Derived data:

<table>
<thead>
<tr>
<th>Attributes and characteristic values</th>
<th>Stations</th>
<th>Timetable</th>
<th>Operations (current)</th>
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</thead>
<tbody>
<tr>
<td>Basic line and route data:</td>
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<tr>
<td>- federal state in charge</td>
<td>- number of stations</td>
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<tr>
<td>- diesel line subnetwork affiliation</td>
<td>- average distance between stations (km)</td>
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<tr>
<td>- route number (German: Kursbuchstrecke)</td>
<td>- driving time (min)</td>
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<tr>
<td>- number of RB (regional train) / RE (regional express train) service</td>
<td>- dwell time at terminus station* (min)</td>
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<tr>
<td>- name of start and terminus station, itinerary</td>
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<tr>
<td>- line length (km)</td>
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<td></td>
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<tr>
<td>- max. velocity (km/h)</td>
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<table>
<thead>
<tr>
<th>Electrification</th>
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</thead>
<tbody>
<tr>
<td>- position of electrified line sections (km)</td>
<td>- railway operator</td>
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<tr>
<td>- electrification degree by line</td>
<td>- railway class in service</td>
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<tr>
<td>- start or terminus station electrified</td>
<td>- train kilometers (km/h)</td>
</tr>
</tbody>
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* incomplete due to partly missing data
Results (I) – General line patterns
Attributes analysed and exemplary observations

- Diverse pattern in terms of
  - Line length
  - Average station distances
  - Journey/(Driving time) time
  - Average velocity

- 75% of lines:
  - Line lengths: shorter than 93 km
  - Station distances: less than 8.0 km
  - Driving times: less than 99.3 min
  - Average velocities: lower than 65.1 km/h
Results (II) – Electrification patterns

• OHC (overhead catenary) electrified sections (red) are concentrated mainly around start and terminus stations (top right figure)

• 57% of all lines (269) are electrified by less than 1/10 (bottom left figure)

Grouped frequency of OHC electrification degrees

Example of a diesel sub-network (East Brandenburg Lot 2)
Results (III) – Electrification degree vs. length of longest non-electr. section

• Line classification by number of start and terminus stations equipped with overhead catenary (0 ▲, 1 +, 2 ◆)

• 77 % of lines have maximum non-electrified sections lengths of < 80 km

[The falling red dot curve indicates cases where a non-electrified secondary line leads into an electrified line at start/terminus station (500 m electrified length assumed in general)]

All lines’ OHC electrification degree and length of longest non-electrified section of each line (n=469)
Results (IV) - Implications to the suitability of BEMU and FCEMU

- Lines with < 80 km non-electrified single section: generally suited to BEMU, but full battery recharging must be possible
- 26% of lines have both start and terminus stations electrified (and offer therefore good premises for BEMU)
- FCEMU (currently 600 – 1000 km range) can be deployed on all investigated lines (provided, the timetable allows refueling during daytime if required)
- Future outlook: BEMU-tailored new direct lines (EMU with battery operation on short non-electrified branches)
Conclusions

- Dataset of 469 currently German diesel operated lines was set up

- Line and electrification patterns were analysed

- BEMU and FCEMU based line suitability criteria can be investigated line by line and diesel (sub-)network by network

- Diverse pattern in terms of line lengths (5-445 km), electrification degree (80 % electrified by < 30%) and electrification patterns

- Outlook: Further parameters to be included (e.g. track-profile, energy demand, detailed rosters)
Thank you for your attention.

German Aerospace Center - DLR
Institute of Vehicle Concepts | Vehicle Systems and Technology Assessment |
Rutherfordstraße 2 | 12489 Berlin

Johannes Pagenkopf, M.Sc.
+49 (0)30 67055-7957 | Johannes.Pagenkopf@dlr.de
www.DLR.de/FK