New electric locomotives for the UK
- TRAXX UK with Last Mile feature
- Technology outlook

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# Contents

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Freight forecast &amp; UK electrification</td>
</tr>
<tr>
<td>2</td>
<td>Application of electric locomotives in the UK</td>
</tr>
<tr>
<td>3</td>
<td>The TRAXX UK with Last Mile</td>
</tr>
<tr>
<td>4</td>
<td>The multi-engine diesel locomotive</td>
</tr>
<tr>
<td>5</td>
<td>Outlook</td>
</tr>
<tr>
<td>6</td>
<td>Summary</td>
</tr>
</tbody>
</table>
Freight traffic 2030 forecast* overlaps with the existing and future electrified lines – but only partially.

Questions:

- How can the electrified lines be used for freight traffic?
- Where are the missing links for freight? Example: Felixstowe – Ipswich – Peterborough

*) Rail freight demand forecasts to 2030, MDS Transmodal Limited, October 2011
A look across the Channel: Electric traction is dominant for freight throughout Europe, also on major corridors

**Typical speeds for freight with E-locos:**
- 80 – 120 km/h

**Typical trains:**
- One loco + 1’600 tons on 12‰ (1:83)
- Two locos + 3’400 tons on 12‰ (1:83)

**Future:** 2’200 ton intermodal trains (matching the max train lengths of 700 to 750 m)
Long haul diesel traction is not competitive in Germany
Energy costs for diesel locos are 2x higher than for electric locos

- Diesel traction has 2x higher energy costs for the same train load
  - Maxima*: 3’600 kW diesel → 2’900 kW at the wheel
  - TRAXX: 5’600 kW at the wheel
- Δ cost for diesel loco**: approx. 300 k€/loco/year

*) The Maxima is one of the most powerful diesel locos in Europe
**) With 1’595 ton train weight, 100’000 km/year

Energy costs in €/train-km (speed 100 km/h)

- 1 kWh = 0.0934 €
diesel = 0.958 €/l

Maschen
(Hamburg)

Munich
## Contents

1. Freight forecast & UK electrification
2. Application of electric locomotives in the UK
3. The TRAXX UK with Last Mile
4. The multi-engine diesel locomotive
5. Outlook
6. Summary
E-locos have much more power at the wheels and are suited for mixed freight and high speed passenger traffic.

- **Electric locos**
  - 4-axle configuration
  - 5’600 kW at the wheels
  - Operate at 80 – 120 km/h also on grades
  - Suited for mixed traffic with passenger trains

- **Diesel locos**
  - 6-axle configuration
  - Approx. 2’000 kW at the wheels
  - Operate at lower speeds, particularly with heavy loads and on steep grades
  - Require dedicated tracks if speeds are low
4-axle E-locos can haul 1’400 to 1’600 tons at 80 km/h, also on the 13‰ (1:77) grades up to Beatock Summit.
An E-loco + 1’500t can easily run at 60 mph (96 km/h)
Running simulations: Daventry – Coatbridge Terminal at max 60 mph

<table>
<thead>
<tr>
<th>Max permitted speed</th>
<th>Effective speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 mph (96 km/h)</td>
<td>Speed drops slightly to 50 mph (80 km/h)</td>
</tr>
</tbody>
</table>

Actual timetable:
- 2 hours, 8 min.

Traveling time with an electric loco:
- 1 hour, 43 min. at max 60 mph (96 km/h)
An E-loco + 1’500t can also run at 75 mph (120 km/h)

Running simulations: Daventry – Coatbridge Terminal at max 75 mph

Actual timetable:
- 2 hours, 8 min.

Traveling time with an electric loco:
- 1 hours, 29 min. at max 75 mph (120 km/h)

*) loss of approx. 2.5 min.
Operation can be overall at 100 km/h with 2’400 tons load

... with an additional pushing loco for the section up to Beatock Summit

A single loco can haul 2’400 tons at 100 km/h on 5‰ continuously (and up to approx. 7‰ dynamically)

This train can continue at 100 km/h up to Beatock summit on 13‰ with an additional pushing loco

The above procedure is standard practice in Switzerland on the Gotthard line between Erstfeld and Göschenen (26‰, 300 m curves)
Contents

1  Freight forecast & UK electrification
2  Application of electric locomotives in the UK
3  The TRAXX UK with Last Mile
4  The multi-engine diesel locomotive
5  Outlook
6  Summary
An electric locomotive for the UK can be derived from the European TRAXX Locomotive Platform → TRAXX UK

<table>
<thead>
<tr>
<th>TRAXX UK, Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track gauge</td>
</tr>
<tr>
<td>Wheelset arrangement</td>
</tr>
<tr>
<td>Max. speed</td>
</tr>
<tr>
<td>Catenary voltage</td>
</tr>
<tr>
<td>Power at the wheel</td>
</tr>
<tr>
<td>Starting tractive effort</td>
</tr>
<tr>
<td>Braking effort</td>
</tr>
<tr>
<td>Last Mile diesel engine</td>
</tr>
<tr>
<td>Power Last Mile (at the wheel)</td>
</tr>
<tr>
<td>Starting tractive effort, Last Mile</td>
</tr>
<tr>
<td>Service weight</td>
</tr>
<tr>
<td>Train heating</td>
</tr>
<tr>
<td>Length over buffers</td>
</tr>
<tr>
<td>Bogie wheelbase</td>
</tr>
<tr>
<td>Wheel diameter (new/worn)</td>
</tr>
<tr>
<td>Drive system</td>
</tr>
<tr>
<td>ATP systems</td>
</tr>
<tr>
<td>Standards</td>
</tr>
<tr>
<td>Radio remote control, shunting</td>
</tr>
</tbody>
</table>

Key Features

- Meets the UK loading gauges
- Designed for freight and passenger
- Low track and P2 forces with fully suspended drive and short axle base
- Full power regeneration of braking power → 10% average energy savings
- Integrated Last Mile functionality for operation into non-electrified terminals
- Loco available in two versions:
  - Operation in UK only
  - Operation UK - Eurotunnel - France
The TRAXX UK is a member of the TRAXX Platform
… with adaptations to meet the UK requirements

TRAXX AC
15 and 25 kVAC

TRAXX DC
3 kVDC

TRAXX MS
15/25 kVAC & 1.5/3 kVDC

TRAXX DE
diesel-electric

Italy, Spain, Poland

Benelux, Italy, Poland

North – South Corridors

> 1550 sold TRAXX locomotives
> 1450 TRAXX locomotives in operation
The TRAXX UK is the **missing link** within the TRAXX Platform for the UK and cross-border services to France

**TRAXX Corridors**

- Different corridors
- Different safety systems
- Different applications, heavy freight and high speed passenger services

**Electric locomotive types:**

- TRAXX AC
- TRAXX MS
- TRAXX DC

**TRAXX UK**

**Catenary systems:**

- 15 kV AC
- 3 kV DC
- 25 kV AC
- 1.5 kV DC
The **dc-link** of the traction converter is the common interface for adding power sources and loads.
The TRAXX UK is available with a small diesel engine + battery allowing Last Mile operation w/o a shunting loco.

**Electric operation**
- Full power of 5.6 MW at the wheels.
- Max speed 140 for freight, 160 km/h for passenger services.

**Diesel for Last Mile**
- Standard industrial engine
- Stage IIIB exhaust emissions
- Intelligent power control

**Drive system**

**Traction converter**

**Energy storage**
- Battery boost

**Energy flow**
The Last Mile feature is an add-on to TRAXX locomotives … for seamless operation into short branch lines, sidings and terminals

**Last Mile Feature:**
- Full 300 kN tractive effort under catenary and with Last Mile Diesel engine with Stage IIIIB exhaust emissions standards
- Robust industrial diesel engine adapted to the needs of railway applications → low life-cycle costs
- Non-stop transition between electric and Last Mile operation

→ The Last Mile feature opens the door to new logistic concepts in rail freight distribution

![Industrial diesel engine used for Last Mile](image)
The Last Mile functionality provides the same tractive effort as under catenary → seamless operation

Last Mile: Same train load at lower speed!

1’600 tons on 12‰ (1:83)

Last Mile operation

Electric operation under catenary

1’600 tons on 0‰
The Last Mile feature allows to serve destinations without the need of shunting locomotives \( \rightarrow \) new logistic concepts

The electric loco with Last Mile can distribute freight along mainlines …
- addressing small terminals w/o shunting locos
- with high acceleration for stop-and-go traffic

Non electrified siding  \( \xrightarrow{\text{Hub/terminal}} \) Electrified mainline

Electrified mainline  \( \xrightarrow{\text{Non electrified siding}} \) Non electrified siding

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<table>
<thead>
<tr>
<th></th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Freight forecast &amp; UK electrification</td>
</tr>
<tr>
<td>2</td>
<td>Application of electric locomotives in the UK</td>
</tr>
<tr>
<td>3</td>
<td>The TRAXX UK with Last Mile</td>
</tr>
<tr>
<td>4</td>
<td>The multi-engine diesel locomotive</td>
</tr>
<tr>
<td>5</td>
<td>Outlook</td>
</tr>
<tr>
<td>6</td>
<td>Summary</td>
</tr>
</tbody>
</table>
Low cost, robust industrial diesel engines can replace single engines → substantial reduction of life-cycle costs

Locomotive power: 2’000 to 4’800 hp

Diesel engine #1

Diesel engine #2

Diesel engine #3

Diesel engine #4

Train heating

Auxiliaries

Traction motor

Other loads

All engines fulfill the Stage IIIB standard

Energy flow bi-directional

Energy flow uni-directional
Industrial engines fulfill Stage IIIB exhaust emissions much more easily than large engines – at low fuel consumption.
The BR 245 of the German Railways has four high speed engines, with low exhaust emissions → Stage IIIB

Features:
- **Diesel exhaust emissions:** Fulfills Stage IIIB standards
- **Engine control:** Fuel savings with automatic start/stop functionality
- **Applications:** passenger and freight services

4x Caterpillar C18 engines
The BR 245: The 5% reduction in fuel consumption leads to cost savings of $1\text{M€}$/loco per locomotive over 20 years!

**Fuel savings**
- Selective engine control, start-stop feature $\rightarrow$ 5%
- Inherent higher efficiency compared to large & legacy medium speed engines $\rightarrow$ 5 to 10%

**Other savings**
- Up to 50% lower service and maintenance costs
- No obsolescence due to very large engine market
- High availability: Diesel engine is a replaceable module

In 20 years calculated as NPV:
- **Savings of 1 M€ fuel costs (1’100 tons CO$_2$)**
  - 150’000 km/year
  - Comparison of TRAXX with single engine (MTU 16V4000) and 4x C18
  - Fuel cost of 1,23 € / Liter with an assumed escalation of 3% per year
## Contents

1. Freight forecast & UK electrification
2. Application of electric locomotives in the UK
3. The TRAXX UK with Last Mile
4. The multi-engine diesel locomotive
5. Outlook
6. Summary
Dual-powered locos for full electric and diesel traction

The ALP-45DP as an example, however with a high axle load of 32 tons

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**Dual-powered loco for North America**

- BoBo configuration
- 32 tons axle load
- 4 MW electric power at the wheels
- 2x 2100 hp (3100kW) diesel engine power
Is a dual-powered locomotive feasible for the UK?

There are severe limitations due to limited axle load and loading gauge.

### The 4-axle DP locomotive

- There is a choice of either …
  
  a) Approx. 3.5 MW electric power + ~700 kW diesel power at the wheels (1 MW diesel engine), or
  
  b) 5.6 MW electric power + 200 kW Last Mile power at the wheels (230 kW engine + battery)

- 5.6 MW at the wheels is needed in mixed mainline traffic → b) solution of TRAXX UK

- Future development in next 20 years: To increase the Last Mile power to ≥500 kW with new batteries, fuel cells, etc.

### The 6-axle DP locomotive

- It is questionable to fit 5.6 MW electric power and a minimum of 2’000 kW (2’600 hp) diesel engine power into one locomotive …
  
  - technically, and
  
  - at a reasonable price, LCC.

- Also, it is questionable from point of view of energy consumption to carry the additional weight of a heavy diesel engine under long stretches of catenary operation.

- Conclusion: The electrification of missing links for freight may be the better solution
Summary, #1

- There is a large overlap of electrification with traffic forecasts, however, there are important missing links of electrification to increase the potential of freight services with electric locomotives.

- Electric locomotives have compared to diesel locos...
  - a much higher traction power, and
  - a much higher tractive effort above 30 km/h
  and are therefore suited for mixed freight and high speed passenger traffic ...
  - with faster train acceleration, lower energy costs, and
  - higher speed of operation at 80 to 120 km/h

- Examples: On the West Coast Mainline (over the Beatock Summit)
  a single electric loco can haul ...
  - 1’400 to 1’600 tons at up to 120 km/h (dropping over a short distance to 80 km/h)
  - up to 2’400 tons at 100 km/h with an additional pushing loco used only on the section of higher gradient up to Beatock Summit
Summary, #2

- The TRAXX UK is an electric loco available in two versions:
  - For UK only on 25 kV AC for freight and passenger services, max. 200 km/h
  - For UK-Channel Tunnel-Northern France for freight services

- The TRAXX UK is available with Last Mile …
  - for operation without catenary into terminals, sidings and short branch lines* without the need of a shunting loco.
  - for new logistic concepts of freight distribution.

- Modern locos have a traction converter with a dc-link which is the common interface for electric, diesel and energy storage devices
  - This allows to combine electric traction with diesel engines and batteries (energy storage devices) → Example: The Last Mile of the TRAXX UK consists of small diesel engine + battery boost.
  - In the future we expect further developments with new batteries, fuel cells etc, which increase the capability of Last Mile and lead to further energy savings.

*) The section Felixstowe - Ipswich with Last Mile is hardly realistic due to long travelling time of >1h
Summary, #3

- State-of-the-art locomotive design permits to use small robust industrial diesel engines fulfilling Stage III B exhaust emission standards. The benefits are ...
  - Lower fuel consumption of 5 to 15% compared single and legacy engines
  - Lower maintenance; no obsolescence due to large market of engine spares

- Future dual-powered locomotives for the UK?
  - The requirement of full electric power (5.6 MW) under catenary and the limitations of axle load and loading gauge leads to following result:

  4-axle locomotive: The best choice is a high power electric locomotive (5.6 MW at the wheel) with a Last Mile capability for short distance operation without catenary.

  This loco can be used both for freight and passenger services (200 km/h) for increased economies of scale and max. versatility. In addition it has overall low P2 forces (low track access costs). \( \textbf{This is the objective of the TRAXX UK.} \)

  6-axle locomotive: It is questionable if such a locomotive is technically and commercially feasible for the UK. \textbf{Alternative:} electrification of missing links!?
The Power of TRAXX - Thank You!