High-Power locomotives for Indian Railways

28.10.2017

Camille Thill

BOMBARDIER
the evolution of mobility

- Most successful platform in Europe with more than **2000** sold locomotives
- Homologated for up to **20** countries
- **Last mile diesel engine** for electric locomotives enables new logistic concepts
- **High productivity** also because of high traction performance and high energy efficiency

Locomotives – proven and innovative

Bombardier Transportation has been a pioneer in Locomotive Technologies

BBC Baureihe 120

- **World's first AC electric locomotive (introduced in 1979)**
- **High Starting TE (340 kN) and power at wheel (5.6 MW)**
- **Originator of all modern locomotive families**

AEG 12X

- **Most powerful 4 axle loco in the world (7.2 MW @wheel)**
- **Universal Locomotive for mixed traffic**
- **World's first locomotive to be equipped with IGBT Propulsion**

TRAXX 1/2

- Well **proven product platform**
- **1'700 locomotives** in commercial service
- High **reliability and availability**
- MDBF over **500.000 km**

TRAXX 3
Platform Development

- Improvement of **energy efficiency**
- **LCC optimizations**
- Heavy train loads / increased **tractive effort**
- Homologation for **more international Corridors**
- **Energy Optimization**
- Implementation of **innovative features**:
  - Last Mile Diesel
  - Last Mile Battery
  - Radio Remote Control for Shunting
  - Condition based/modular maintenance
- Upgrade for **Norms & Standards** (TSI LOC/PAS 2015)

TRAXX AC3 freight	*TRAXX* AC3 passenger	*TRAXX* MS 3	*TRAXX* DC 3
▪ Last Mile ▪ Single axle drive ▪ AC15/25 kV ▪ Eco mode ▪ WTB UIC	▪ Fully suspended drive system ▪ WTB DOIC ▪ Passenger functionalities	▪ 15/25 kV, 3 kV&1.5 kV ▪ Freight and passenger ▪ Last Mile	▪ 3/1.5 kV DC ▪ Italy ▪ Last Mile

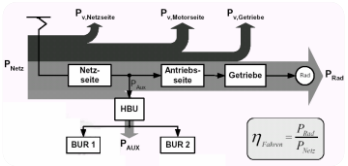
BOMBARDIER
the evolution of mobility

Innovation Management @ LOC
TRAXX – Game Changing Innovations

MyBTfleet - Maintenance Efficiency

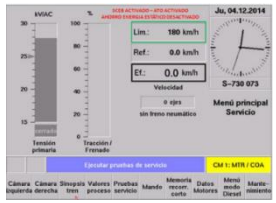
The proven TRAXX platform combined with BT`s service experience reduces the maintenance costs and provides savings each year.

Energy Efficiency



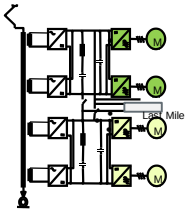
Approx. 2 % higher energy efficiency than comparable locomotives results in a savings of 4'000 to 8'000 € per year per locomotive.

Bombardier Efficient Driving System



Driver Assistant system provides recommendations to the driver to optimize train run with at min. energy within the timetable. Expected energy savings approx. 15 %.

Eco mode



Eco mode saves around 2% energy by switching off traction motors individually when full traction force is not required. Savings of 2'000 €/year/locomotive.

High Power Last Mile

All new TRAXX 3 locomotive types will be equipped with a Last Mile functionality to bridge non-electrified sections – thus allow more efficient production concepts.

High Availability

Top quality and standardized building blocks combined with the experience of 500 TRAXX locomotives in full will lead to a MDBF of more than over 600'000 km/loco/year → 15'000 € savings/loco//year.

Radio Remote control for Shunting

The TRAXX 3 can be equipped with a radio remote control for shunting which will increase the operational efficiency by up to 15'000 €/loco/year.

Condition-Based Maintenance

TRAXX 3 is ready for modular & condition-based maintenance (CBM), i.e. the locomotive itself requests the replacement of parts in due time (>200 signal are treated by a specific CBM computer).

BOMBARDIER
the evolution of mobility

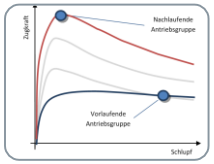
Bombardier TRAXX:
The most advanced Locomotive Platform for Europe

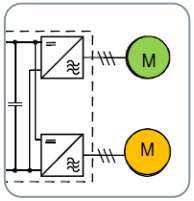
Transnational Railway Applications with eXtreme fleXibility

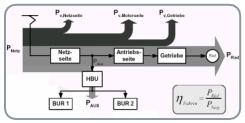
Technical Data	
Loco Axle Configs.	BoBo, CoCo
Power/Axle	Up to 1600 kW/axle (Cont. Power Rating)
Starting Tractive Effort/Axle	Up to 85 kN/axle (Flat Top)
Axle Load	≤ 22.5 tonnes (Europe, South Africa) ≤ 25 tonnes (China, Russia/CIS)
Length	18.9 m (BoBo) ≤ to 23.8 m (CoCo)
ATP Systems	ETCS Baseline 3.6
Power Configurations	Fully Electric Fully Diesel Electric + Last Mile Dual Mode

Key Features

- ECO Mode
- Advanced Adhesion control
- Condition Based Maintenance
- Modular Maintenace Program

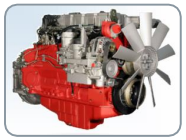


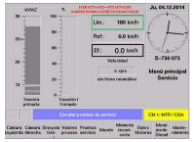




Key Options

- High Power Last Mile
- Bombardier Efficient Driving System
- Remote Control Shunting





BOMBARDIER
the evolution of mobility

Locomotives designed by BT are the backbone of India's modern electric Locomotive fleet.

WAP-5*
160 km/h
4000 kW

WAG-9*
100 km/h
4500 kW

* Designed simultaneously in 1993/94 with many commonalities by Bombardier, previously Adtranz, previously ABB Transportation, in Australia, Germany and Switzerland

Change of gear ratio

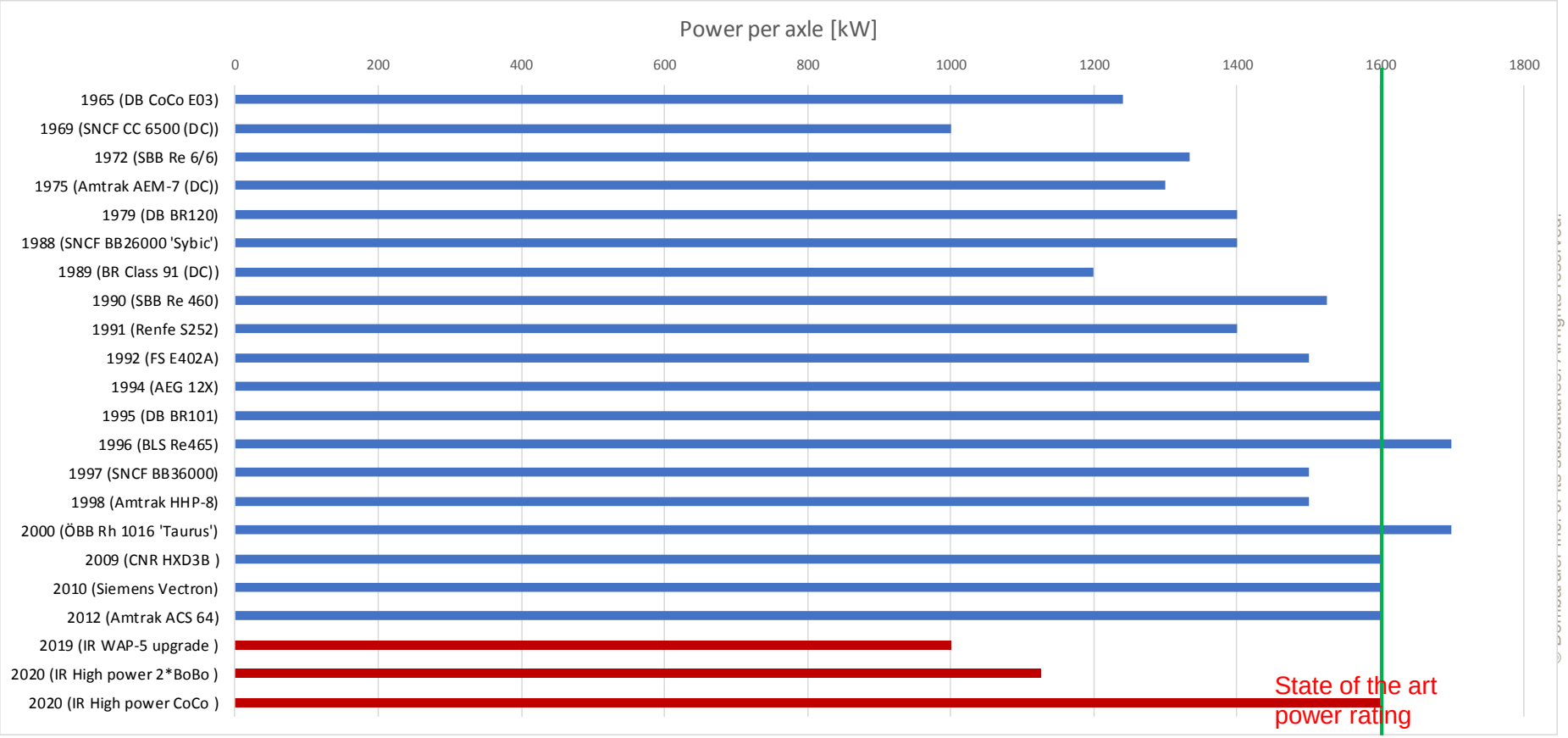
WAP-7
140 km/h
4500 kW

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways
Actual locomotive specifications from IR

	DFC West	High Speed	Upgrade WAP-5
Power	7000	8000-9000 kW	8000
Configuration	CoCo	CoCo or 2*BoBo	2*BoBo
Tractive effort	589 kN	400 kN	400 kN
Max speed	120 km/h	200 km/h	200 km/h
Power / axle	*1170 kW*	*1500 … 1000 kW*	*1000 kW*

High-Power locomotives for Indian Railways
Power per axle of High-Power locomotive designs (*1)



<u>Conclusion</u>: Axle power of 1600 kW has been state-of-the-art for 2 decades in Europe and for about 1 decade in China.

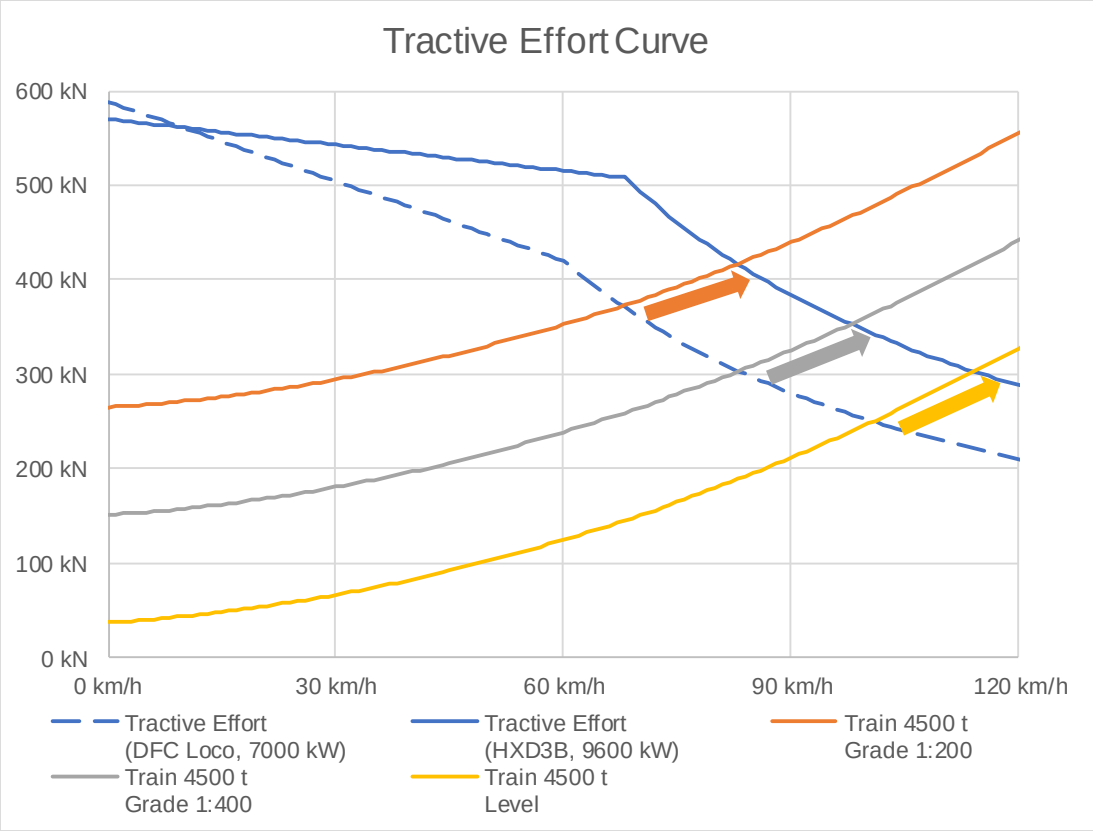
Should India stay behind?

*1) Several of these are multi-purpose locomotives operating freight and 200 km/h passenger trains

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways
Freight applications – Performance comparison

Current situation (typical)	Europe	China	India
kW/ton (freight trains)	3	2-3	< 1



Increasing the locomotive power provides better acceleration, raises the train speed on level track and allows maintaining a higher speed on grades.

Diagram compares 7000 kW freight locomotive with heavy 6-axle locomotive HXD3B (9600 kW) designed for China, hauling a 4500 t **container** train

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways
High-speed passenger operation

Current situation (typical)	Europe	China	India
kW/ton (passenger trains)	10	10	< 5

Operational aspects for passenger trains:

Europe : 12 - 14 coaches @ 47 t : 560 - 650 t → approx. 10 kW/t

India : 24 coaches @ 50 t: 1200 t & same criteria → 12000 kW, not achievable with 6 ax

Consider following parameters:

- Line speed profile, Number of stops, Future perspective (new lines, increased line speed)
- Sensitivity of travel time to variation of power for envisaged trains and lines.

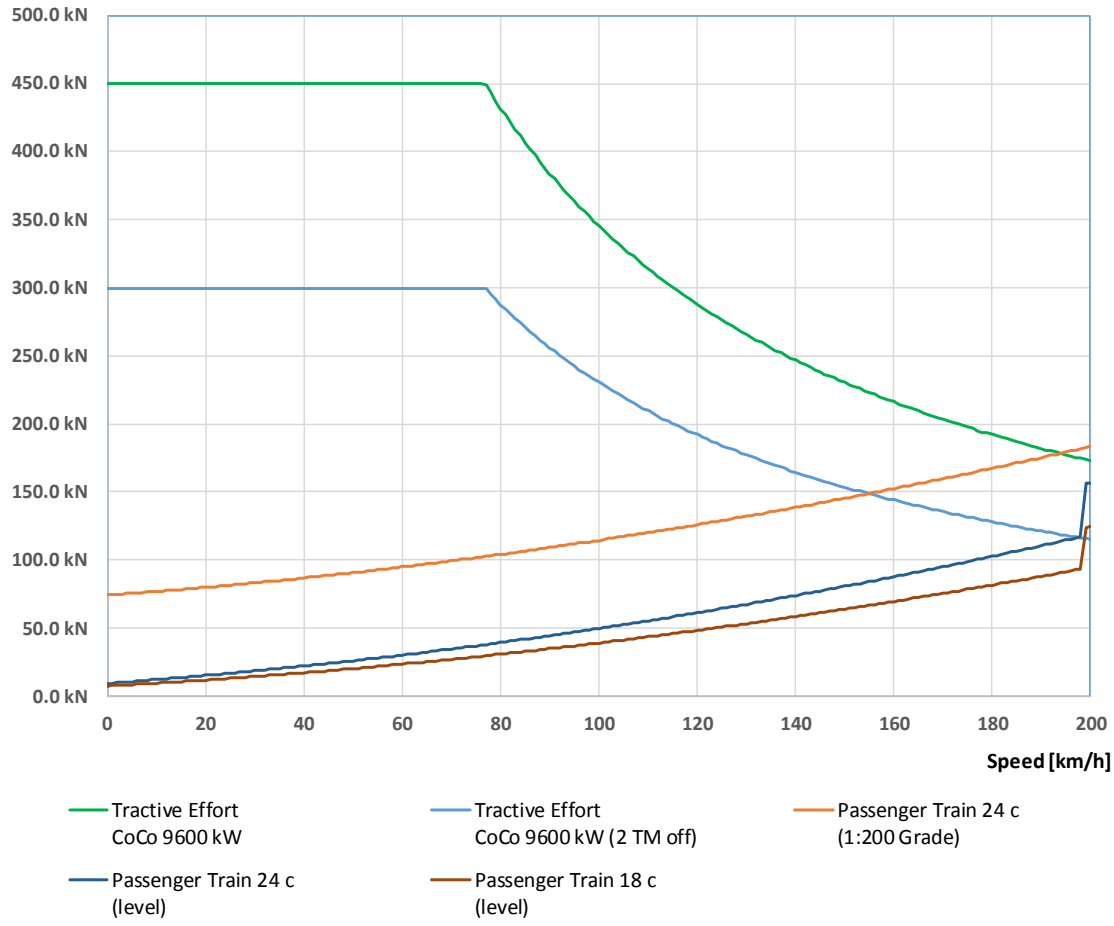
Then:

→ Decide for an economic, highly efficient High-Power CoCo, and IF necessary, limit train length somewhat for ensuring travel time or forecasted line throughput
OR

→ for a much more expensive 2*BoBo (in one consist or distributed at both train extremities for bi-directional operation), but if so, then with 8/6 * CoCo power, to achieve max. benefit

High-Power locomotives for Indian Railways
Passenger train performance of high-power CoCo (9600 kW)

Traction effort / train resistance diagram



- Easy acceleration to 200 km/h with 24 coach train on level track
- Maintaining V> 190 km/h on 1:200 grades
- Maintaining V> 195 km/h with 2 TM off on level track and 200 km/h with 18-coach train

Note: Resistance increment at max speed represents effort needed for residual acceleration of 0.1 km/h/s

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways
“Universal locomotive” proposal (1)

Bombardier suggests to Indian Railways the study of a multi-purpose locomotive

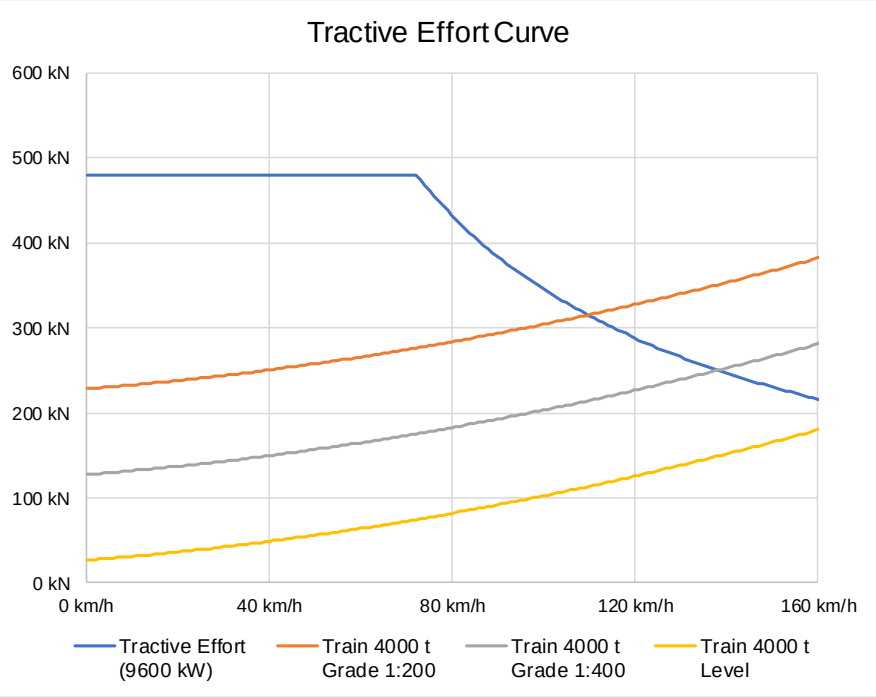
- Design basis: High-power High-speed CoCo design
- Axle load: max 21.5 t
- Use fpr consideration: Heavy non high-speed passenger trains (160 km/h)
  AND Medium-heavy fast freight trains
- Re-gearing for Vmax = 160 km/h (fully suspended drive with **low unsprung mass,** better than WAP-5)
- Benefits for IR:
  One locomotive type for different applications, thus simplifying:
  - driver training
  - training for maintenance
  - spare parts logistics

  and improving:
  - operational flexibility to react to a varying demand,
  - line capacity in mixed traffic (more similar speed for P and F trains)
  - transportation times of perishable or urgent freight
- Tractive effort & train running resistance **diagram** of 4000 t freight pls see next page

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways "Universal locomotive" proposal (2)

Tractive effort of 9600 kW locomotive
4000 t train (BOXN) running resistance diagram



Locomotive may replace all dc locomotives and substitute them by 1 for 2, reducing maintenance cost to far below 50% and improving IR's energy balance thanks to regenerative braking

Multi-purpose locomotives in Europe

SBB Re 6/6
8000 kW/140 km/h

Euro Shuttle
7000 kW/160 km/h

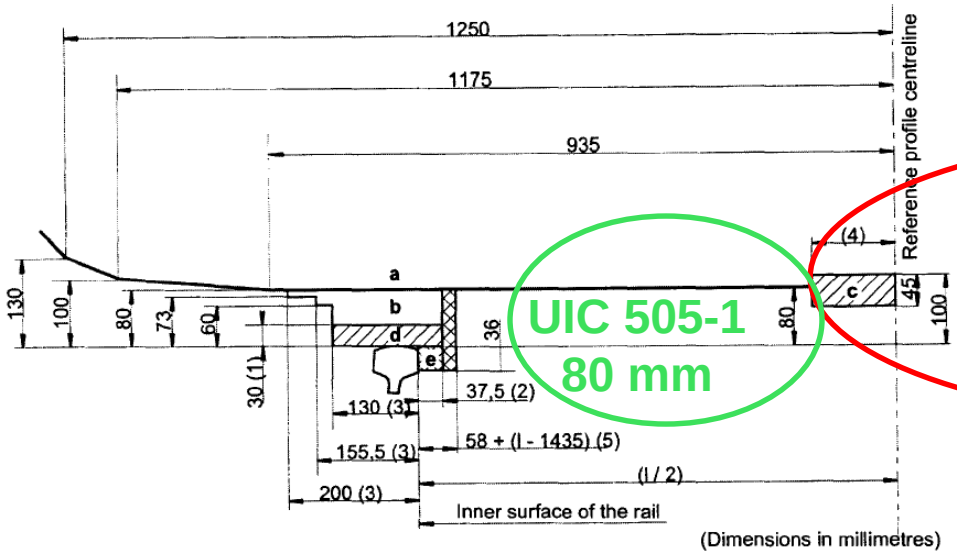
BLS Re465
7000 kW/200 km/h

Should India stay behind?

BOMBARDIER
the evolution of mobility

High-Power locomotives for Indian Railways
Challenges met by locomotive designers (1)

1. Clearance to top of rail: 102 mm requested against 70 to 80 mm in other countries



100 mm only close to centre line due to Signal transmission in France/Belgium from raised track contact strips (”crocodile”)

2. Severe definition of “nominal” conditions (22.5 kV permanent voltage, simultaneous with extreme temperatures) for nominal power definition, leading to higher initial cost

3. Higher than usual temperature margins requested for magnetic components
(beyond international standards)

High-Power locomotives for Indian Railways
Challenges met by locomotive designers (2)

4. Unsubstantiated line current harmonics limitations
   → cost for large filter components; induced additional losses → add. electric energy cost

	Interference Current	Limit
1.0	Psophometric current	10.0 A
2.0	DC component	4.7 A
3.0	Second Harmonic component (100 Hz) and 83.33 Hz component	8.5 A
4.0	1400 Hz up to 5000 Hz	400 mA
5.1	>5000 Hz up to 32000 Hz	270 mA
5.2	39500 Hz up to 43500 Hz	270 mA

IR do not provide operating frequencies of those track circuits effectively installed but define 3 large frequency ranges, which do not allowing selection of any non-harmful converter operating frequencies without further costly technical measures.

→ **Dedicated designs** needed for India (no reuse of components proven abroad)

High-Power locomotives for Indian Railways Recommendations

For optimizing asset management and providing huge benefits for the freight and passenger operation, the new generation of locomotives should have following features:

- Efficient and economic CoCo architecture enabling high power per axle to minimize investment cost per kW
- Using readily available and world-wide proven concepts and components to reach high performance, availability and reliability levels.
- Ensure low track forces via low unsprung mass thanks to fully suspended drives, allowing wide-range locomotive operation for passenger and freight services.
- Continuous operation of Hotel Load inverters (thanks to regenerative braking) for bridging neutral sections, thus ensuring uninterrupted power supply to coaches

Procurement of new electric locomotives could be supported by

- Partnering in Locomotive assembly
- Alternative financing of locomotives
- Services for Rolling Stock like CBM (Condition Based Maintenance) using Digitalization

High-Power locomotives for Indian Railways
Locomotive Manufacturing/Assembly ...

Actual situation

- Traditional Indian factories operate at capacity limit and there is a recognized lack of electric locomotives to serve entire transportation demand (need of approx. 100 additional locomotives/year has been estimated not long ago)
- Needs of IR for new locomotives are increasing further due to rapid electrification, traffic expansion and necessary replacement of oldest locomotives (approx. 50/year, that may be replaced by about 20 – 30 new ones)

Way out

- BT‘s India strategy is focused on bringing wide-reaching benefits for railways and the community at large, and is in line with the “Make in India” initiative
- Locomotive assembly may be performed in additional facilities (similar to Dankuni) and in existing industrial facilities, like BT’s manufacturing facility in Savli (Gujarat)
- Best in class manufacturing technology will further optimize assembly procedures and improve delivery rates
- Industrial Cooperation agreements can be made with IR to improve asset handling knowledge

High-Power locomotives for Indian Railways
… and Provision of Maintenance Services

Actual situation

- Maintaining a large variety of locomotive types with different technologies may end up in the future in a huge challenge for all workshops and their logistics services

Way out

- Latest locomotive contracts already include maintenance contracts with the respective suppliers
- Introduction of state-of-the-art maintenance technologies to ensure highest possible fleet availability and reduce cost per locomotive operating hour
- Creation of state of the art spare part Logistic systems to be provided by the supplier
- Introduction of a Maintenance Management System like MyBTfleet to communicate and integrate all different data and applications that refer to IR's fleet, helping IR to monitor the fleet efficiently and increase availability

Bombardier TRAXX INDIA:
Highly Modular Platform for all Indian Traffic Applications

Key Features

- ECO Mode
- Advanced Adhesion control
- Condition Based Maintenance
- Optimised Unsprung Mass
- Universal Architecture enabling varied functionality

Technical Data	
Loco Axle Configs.	BoBo (Single Cab Powerhead), 2xBoBo (Double Unit) CoCo (Single Unit)
Power/Axle	Up to 1600 kW/axle
Starting Tractive Effort/Axle	Heavy Haul Freight: ≤ 98 kN/axle Mixed Traffic: ≤ 80 - 85 kN/axle Passenger : ≤ 70 - 75 kN/axle
Axle Load	Passenger/Mixed Traffic: 19.5 t – 21.5 t Heavy Haul Freight: 22.5 t – 25 t
Max. Operating Speed	Heavy Haul Freight: ≤ 120 km/h Mixed Traffic: ≤ 160 km/h Passenger : ≤ 200 km/h

BOMBARDIER
the evolution of mobility

BOMBARDIER

the evolution of mobility