

# Co-Co LOCOMOTIVE

## Electric Dynamic performance

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Issued Date: 06/08/2025

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Revision Date:

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# REVISION HISTORY

Rev. No	Revision Info	Date
00	First Issue	06/08/2025

# INTRODUCTION

THE PRESENT DOCUMENT:

- DETAILS THE LOCOMOTIVE EFFORT-SPEED CHARACTERISTICS
- PRESENTS THE KINEMATIC AND DYNAMIC CALCULATION DATA FOR THE 25kV POWER SUPPLY
- SHOWS THE LOCOMOTIVE DYNAMIC PERFORMANCE AND THE RUN TIME ON THE BİLECİK-KARAKOY LINE FOR THE MAXIMUM PERFORMANCE EVALUATION
- SHOWS THE LOCOMOTIVE DYNAMIC PERFORMANCE AND THE AVERAGE RMS MOTOR TORQUE AND DUTY CYCLE ON THE ULUKIŞLA – BOĞAZKÖPRÜ LINE FOR THE LIFETIME EVALUATION OF THE DRIVELINE COMPONENT
- SHOWS PERFORMANCE IN LMM MODE.

# EFFORT-SPEED CHARACTERISTICS

@ Average wear wheel Diameter

The mechanical characteristics are based on the main customer requirements:

- Max Effort at wheels  $\geq 500$  kN
- Continuous traction effort at wheels  $\geq 350$  kN
- Max Power at wheels  $\geq 7200$  kW

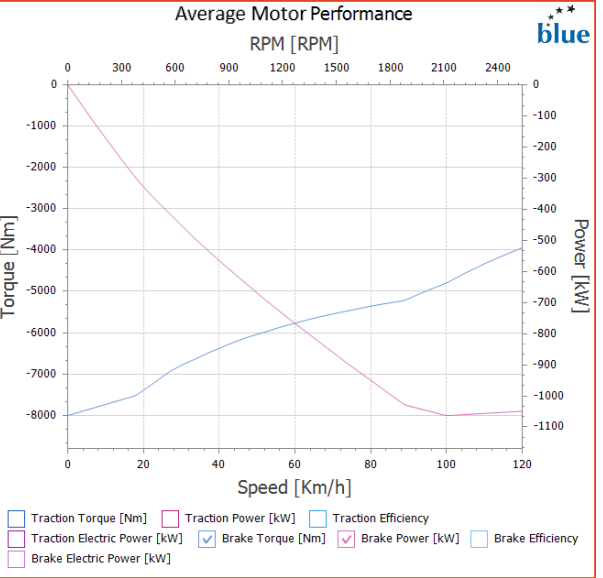
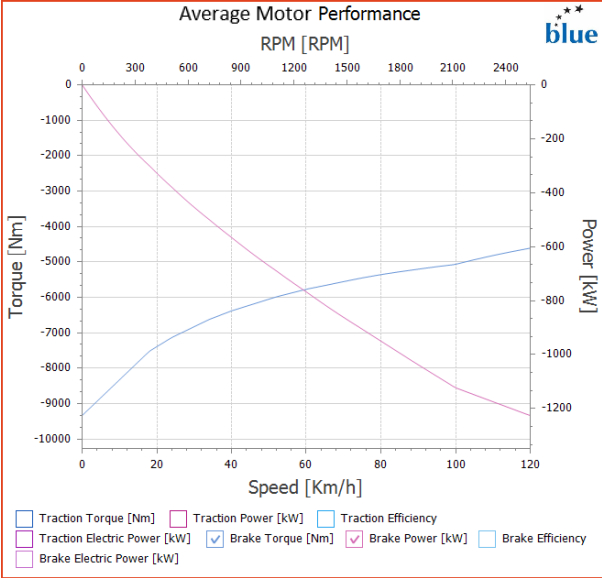
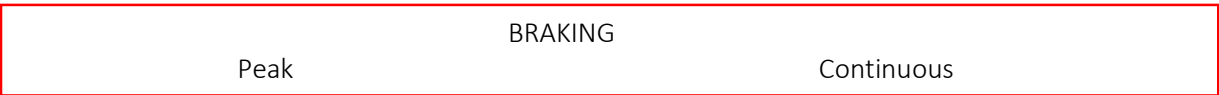
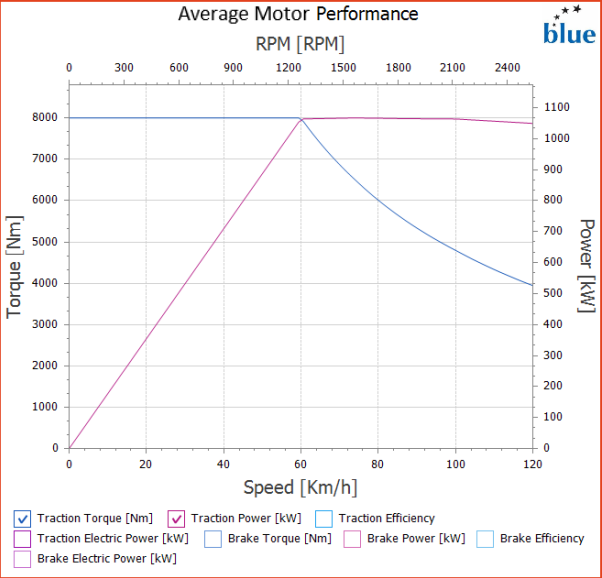
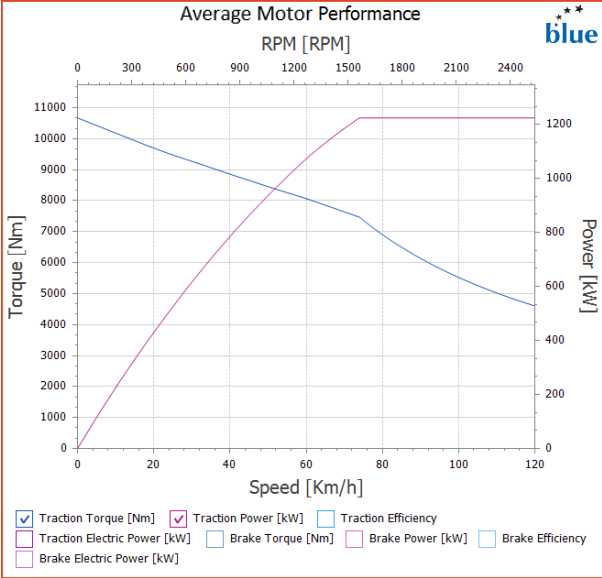
Following the E5000 traction motor performance presentation and other industry standards for Co-Co locomotives, the following option has been analysed :

		Electric supply	
Effort and Power at wheel, half worn ( $\Phi = 1200$ mm)	Unit	Motoring	Braking
MAX PEAK EFFORT	(kN)	500	438
MAX PEAK POWER	(kW)	7200	7200
MAX CONTINUOUS EFFORT	(kN)	375	375
MAX CONTINUOUS POWER	(kW)	6400	6400

DRIVE-LINE DATA - ELECTRIC SUPPLY

Gear ratio = 4.82      Gearbox efficiency = 0.98

	Unit	Motoring	Braking
MAX PEAK TORQUE	(Nm)	10700	9337
MAX PEAK POWER	(kW)	1250	1225
MAX CONTINUOUS TORQUE	(Nm)	8000	8000
MAX CONTINUOUS POWER	(kW)	1050	1050



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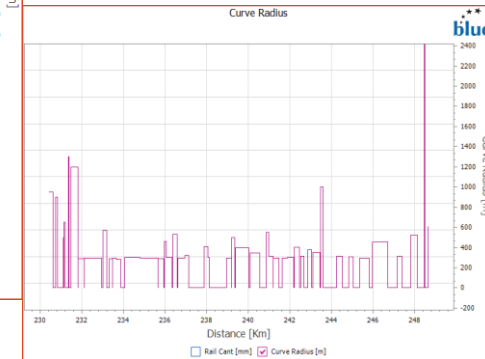
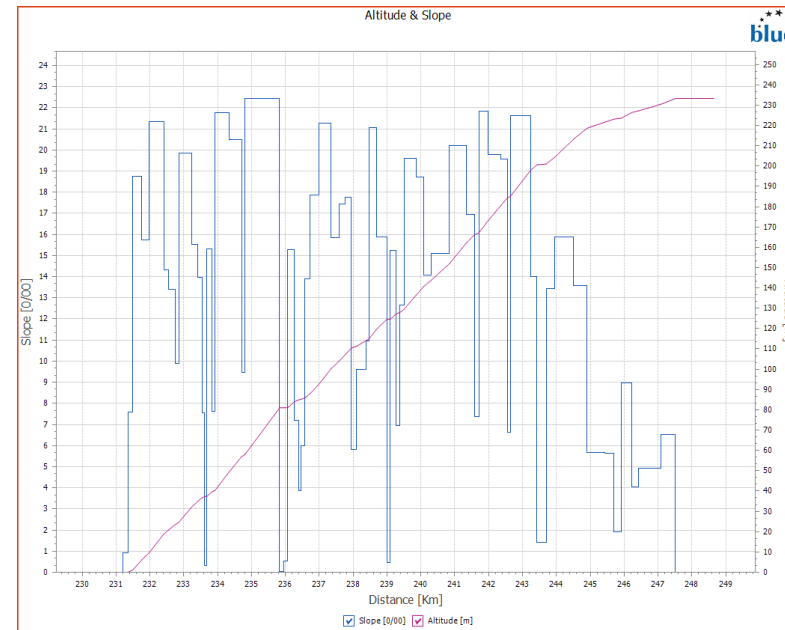
### ELECTRIC SUPPLY - MAX PERFORMANCE CALCULATION INPUT DATA

#### TRAIN DATA (1750 tons payload)

LOCOMOTIVE MASS	135 t
LOCOMOTIVE ROTATING MASS	15%
LOCOMOTIVE FRONT AREA	13 m <sup>2</sup>
LOCOMOTIVE C <sub>x</sub>	0.8
CONVERTER EFFICIENCY	0.97
LOCOMOTIVE AUXILIARY LOAD	150 kW
TRAIN BUS POWER SUPPLY	800 kW
HAULED TRAIN CARS NUMBER	20
CAR WEIGHT (4 AXLES)	80.3 t
CARS ROTATING MASS	13.8 %
TOTAL TRAIN C <sub>x</sub>	2.466
DEAD TIME FOR TORQUE INCREASE	2

#### REFERENCE LINE DATA – BILECIK to KARAKOY

- ☐ One stop in Yayla (60 sec stop)
- ☐ Curve data included.
- ☐ Maximum speed Bilecik to Yayla 70 km/h, Yayla to Karakoy 65 km/h



# Co-Co LOCOMOTIVE

## Electric Dynamic performance

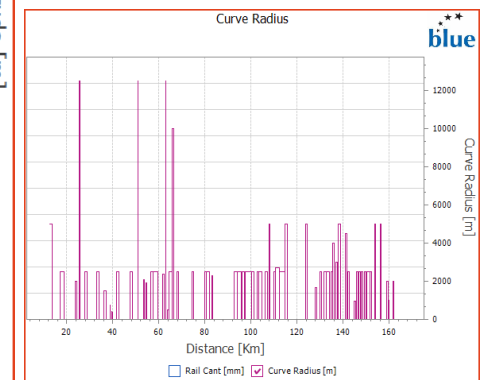
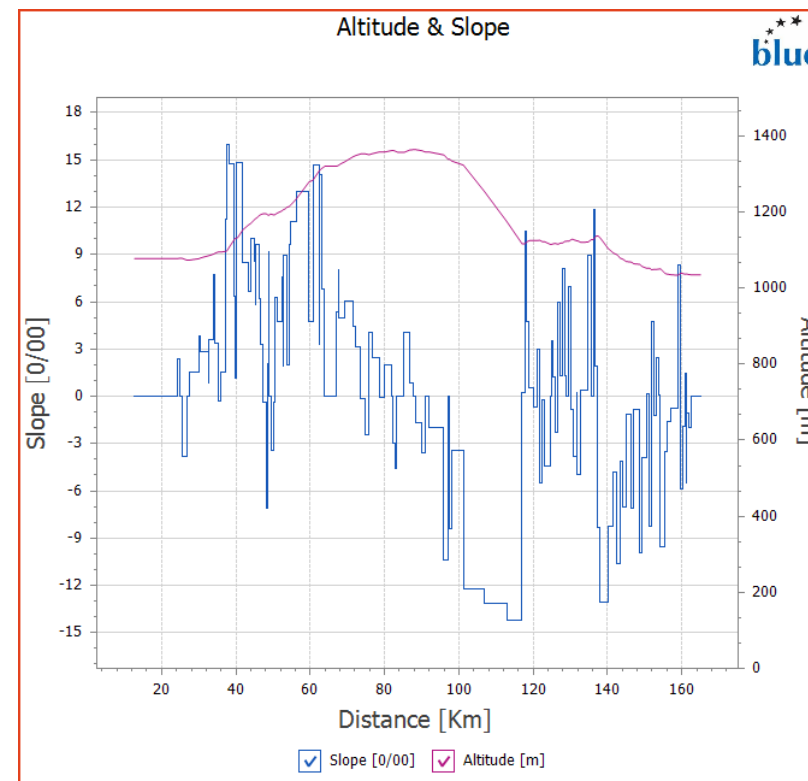
### AVERAGE PERFORMANCE CALCULATION INPUT DATA – ELECTRIC SUPPLY

#### TRAIN DATA (1750 tons payload)

LOCOMOTIVE MASS	135 t
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TOTAL TRAIN Cx	2.466
DEAD TIME FOR TORQUE INCREASE	2

#### REFERENCE LINE DATA – Ulukışla – Boğazköprü

- ☐ Nr. 7 stations (60 sec stop)
- ☐ Curve data included.
- ☐ Maximum speed 160



# Co-Co LOCOMOTIVE

## Electric Dynamic performance

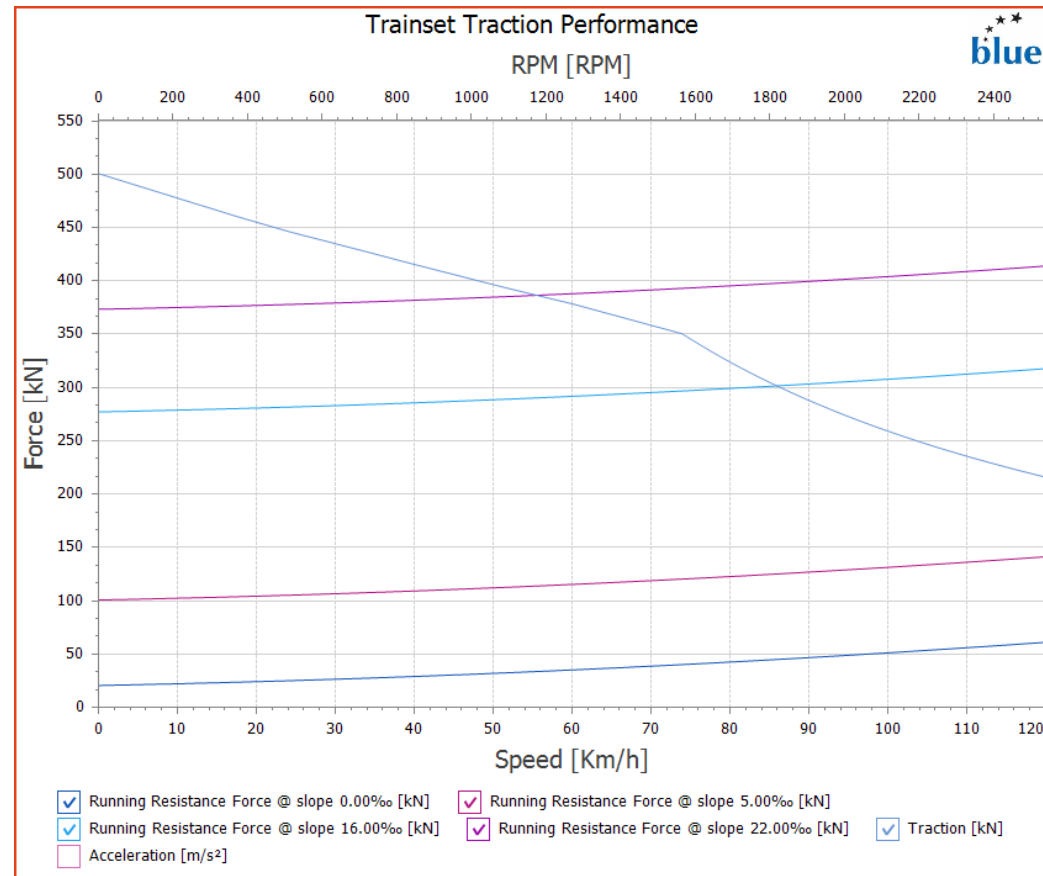
### PERFORMANCE CALCULATION – ELECTRIC SUPPLY

MAXIMUM SPEED ON VARIOUS SLOPES AND STRAIGHT TRACK

Payload 1500 t - Residual acceleration 0.05 m/s<sup>2</sup>

Calculated with peak motor mechanical characteristics

SLOPE (%)	MAX SPEED (km/h)
Flat	120
5 ‰	116
16 ‰	61
22 ‰	17



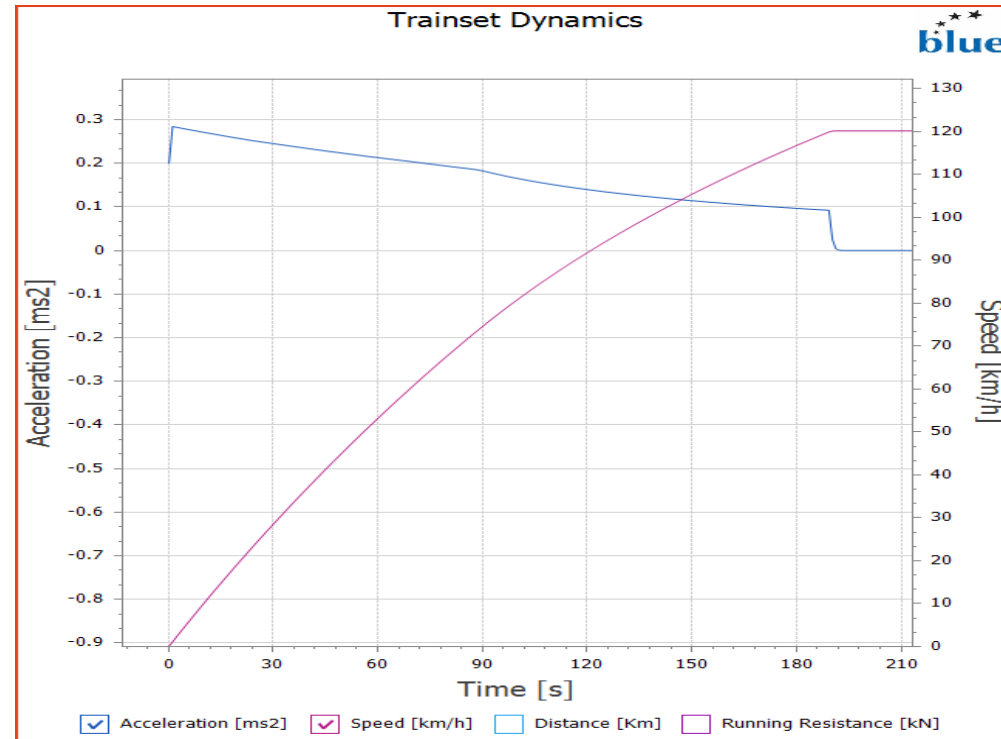
## PERFORMANCE CALCULATION – ELECTRIC SUPPLY

STARTING AND AVERAGE ACCELERATION ON STRAIGHT AND FLAT TRACK

Payload 1500 t

Calculated with peak motor mechanical characteristics

SPEED RANGE	AVERAGE ACCELERATION (m/s <sup>2</sup> )
0 (starting)	0.28
0 to 40 km/h	0.26
0 to 120 km/h	0.18



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### MAX. PERFORMANCE CALCULATION – ELECTRIC SUPPLY

#### RUN CALCULATION ON THE BILECIK-KARAKOY LINE – 1250, 1500 and 1750 tons PAYLOAD

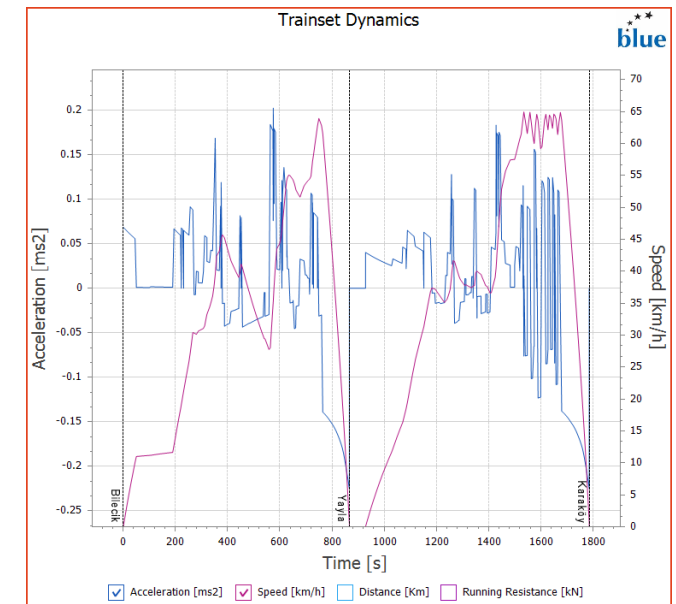
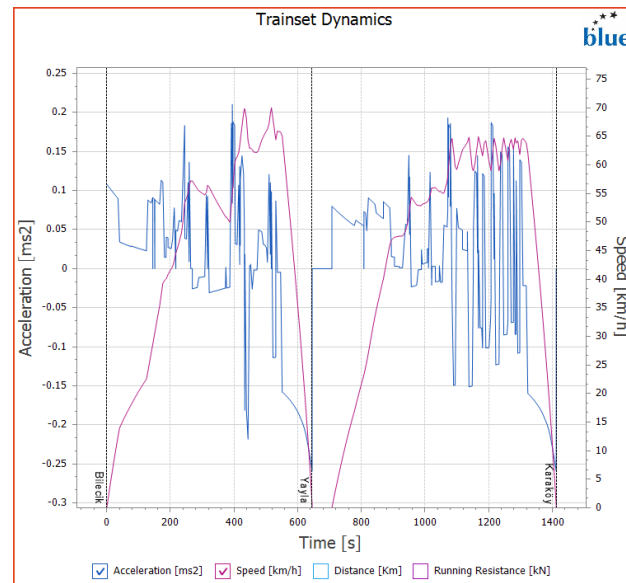
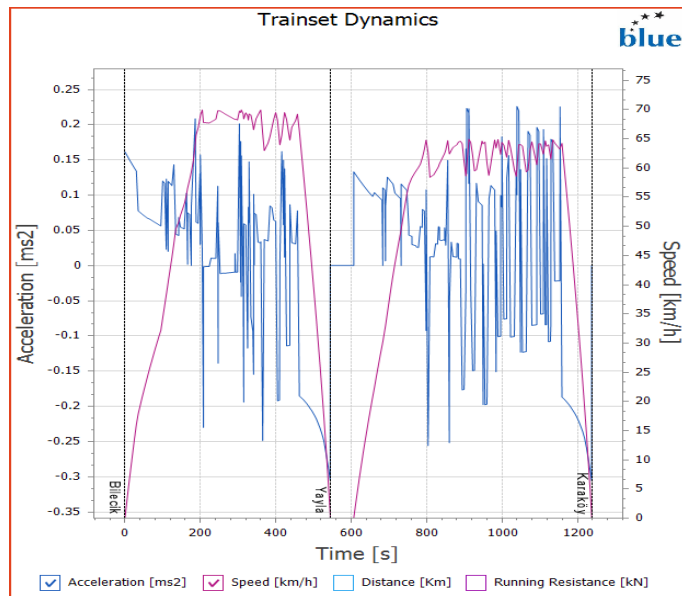
The run calculation has been performed using the peak traction curve, «all out» handle and pure ED braking.

The Torque and Speed curves vs. time are being used as input for the traction chain max. temperature capability verification.

PAYLOAD (tons)	MISSION TIME (sec)	AVERAGE SPEED (km/h)	AVERAGE RMS MOTOR TORQUE (Nm)	AVERAGE PANTOGRAPH POWER (kW)
1250	1237	49	7134	4250

PAYLOAD (tons)	MISSION TIME (sec)	AVERAGE SPEED (km/h)	AVERAGE RMS MOTOR TORQUE (Nm)	AVERAGE PANTOGRAPH POWER (kW)
1500	1412	43	7643	4184

PAYLOAD (tons)	MISSION TIME (sec)	AVERAGE SPEED (km/h)	AVERAGE RMS MOTOR TORQUE (Nm)	AVERAGE PANTOGRAPH POWER (kW)
1750	1785	34	8406	3772



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## Electric Dynamic performance

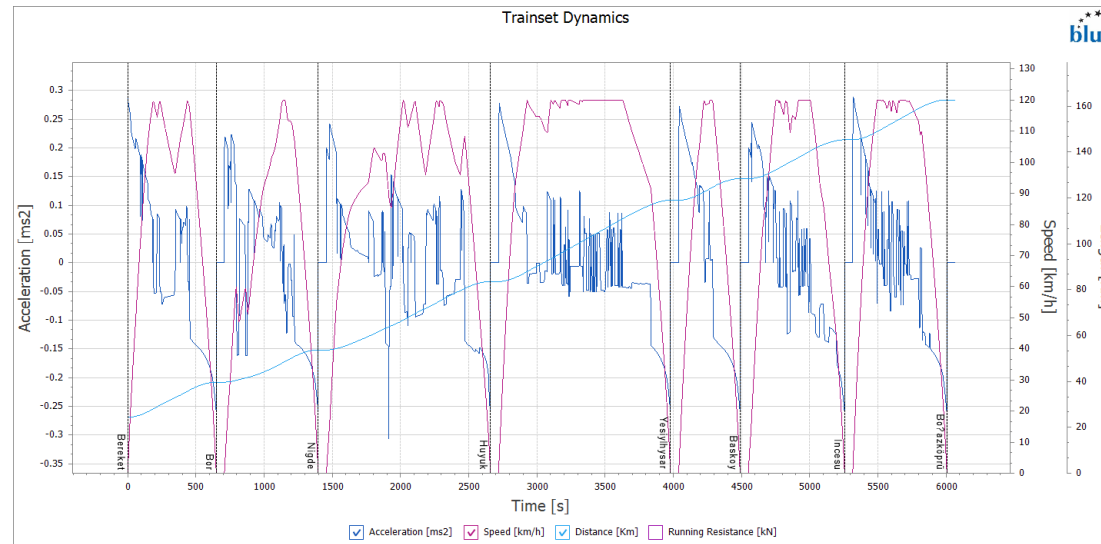
### AVERAGE PERFORMANCE CALCULATION – ELECTRIC SUPPLY

RUN CALCULATION ON THE Ulukışla – Boğazköprü LINE (ED Brake Only, All Out, coasting zero torque ) – 1500 tons PAYLOAD

The run calculation has been performed using the peak traction curve, «all out» handle, coasting at 0 torque and pure ED braking. Auxiliary Loads are 150kW

The Torque and Speed curves vs. time are being used as input for the traction chain average temperature capability and mechanical wear verification.

PAYLOAD (tons)	MISSION TIME (sec)	AVERAGE SPEED (km/h)	AVERAGE RMS MOTOR TORQUE (Nm)	AVERAGE PANTOGRAPH POWER (kW)
1500	6066	82	4956	1988



Motor Torque Range	% of time	Average Speed (Kmh)
From 10602 to 8000 Nm	10.4%	34.8
From 8000 to 5000 Nm	27.7%	90.3
From 5000 to 1000 Nm	30.0%	110.4
From 1000 to 0 Nm	31.9%	68.6

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## Electric Dynamic performance

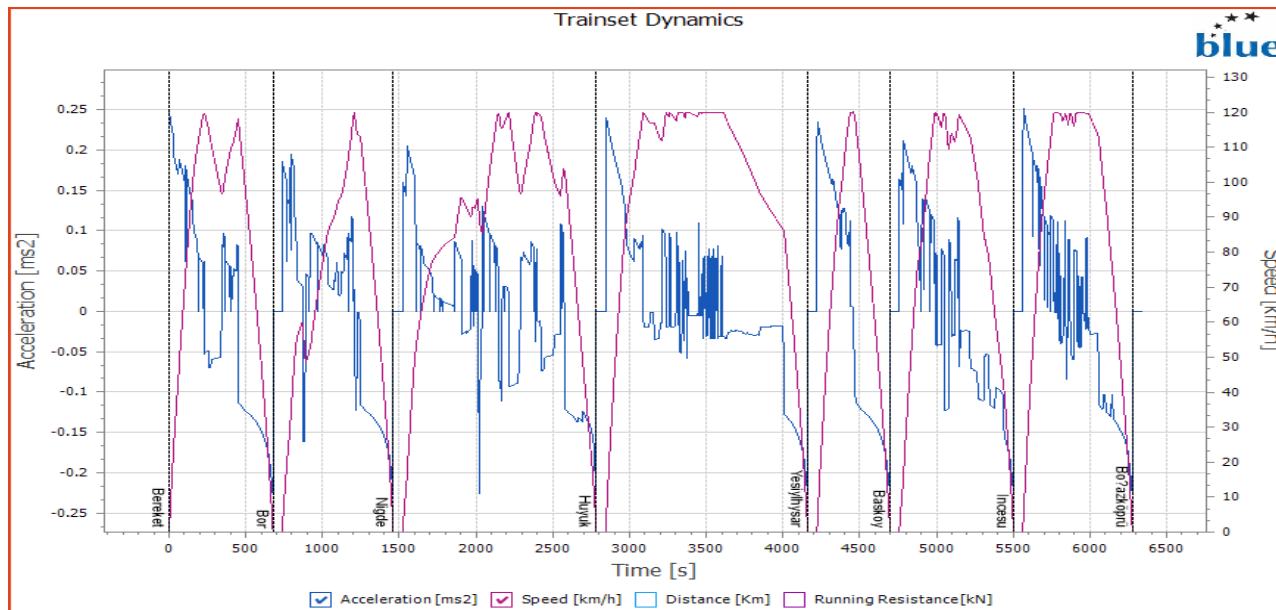
### AVERAGE PERFORMANCE CALCULATION – ELECTRIC SUPPLY

RUN CALCULATION ON THE Ulukışla – Boğazköprü LINE (ED Brake Only, All Out, coasting zero torque ) – 1750 tons PAYLOAD

The run calculation has been performed using the peak traction curve, «all out» handle, coasting at 0 torque and pure ED braking. Auxiliary Loads are 150kW

The Torque and Speed curves vs. time are being used as input for the traction chain average temperature capability and mechanical wear verification.

PAYLOAD (tons)	MISSION TIME (sec)	AVERAGE SPEED (km/h)	AVERAGE RMS MOTOR TORQUE (Nm)	AVERAGE PANTOGRAPH POWER (kW)
1750	6258	79	5244	2102



Motor Torque Range	% of time	Average Speed (Kmh)
From 10602 to 8000 Nm	11.8%	34.1
From 8000 to 5000 Nm	31.1%	86.2
From 5000 to 1000 Nm	42.7%	112.2
From 1000 to 0 Nm	14.5%	111.1

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### PERFORMANCE CALCULATION – ELECTRIC SUPPLY

#### SLOPE / TRAIN MASS TABLE

The slope / train mass tables are calculated considering straight tracks.

The speed is calculated as the maximum speed which is possible to be achieved with a residual acceleration of  $0.05 \text{ m/s}^2$ .

The payload is the mass of the hauled train (the locomotive mass is not included).

Peak traction curve

Slope Payload (ton)	0.0‰	2.5‰	5.0‰	10.0‰	15.0‰	20.0‰	22.0‰	25.0‰	27.7‰	30.0‰
250	120	120	120	120	120	120	120	120	120	120
500	120	120	120	120	120	120	120	120	112	106
750	120	120	120	120	120	103	97	89	83	78
1000	120	120	120	120	99	83	78	67	53	41
1250	120	120	120	102	83	62	50	31	14	
1500	120	120	116	89	68	32	17			
1750	120	120	104	79	43					
2000	120	111	94	66	20					
2250	120	102	85	47						

Continuous traction curve

Slope Payload (ton)	0.0‰	2.5‰	5.0‰	10.0‰	15.0‰	20.0‰	22.0‰	25.0‰	27.7‰	30.0‰
250	120	120	120	120	120	120	120	120	120	120
500	120	120	120	120	120	120	114	105	99	93
750	120	120	120	120	108	91	86	79	73	69
1000	120	120	120	107	87	73	68	62		
1250	120	120	117	91	73	60				
1500	120	120	103	79	62					
1750	120	109	92	69						
2000	119	99	83	62						
2250	111	91	76							

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**Electric Dynamic performance**

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## SUMMARY OF RESULTS – 1500T PAYLOAD

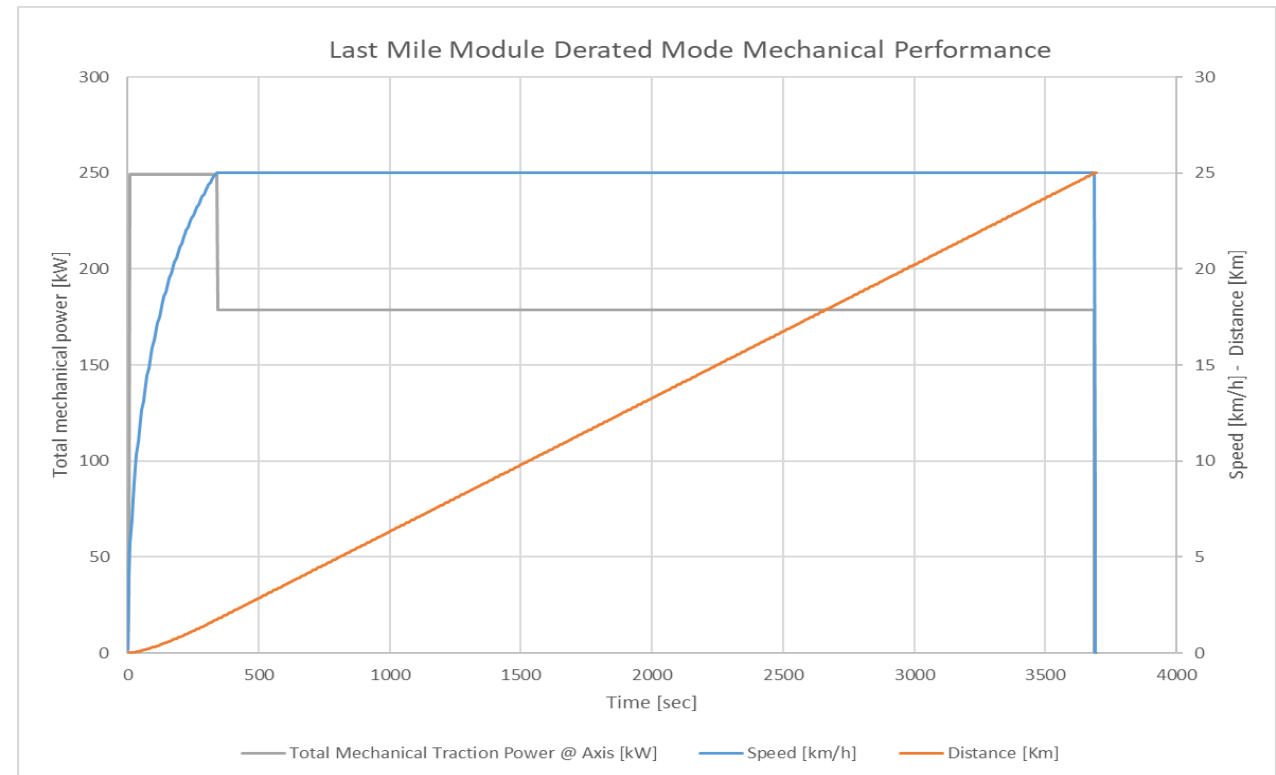
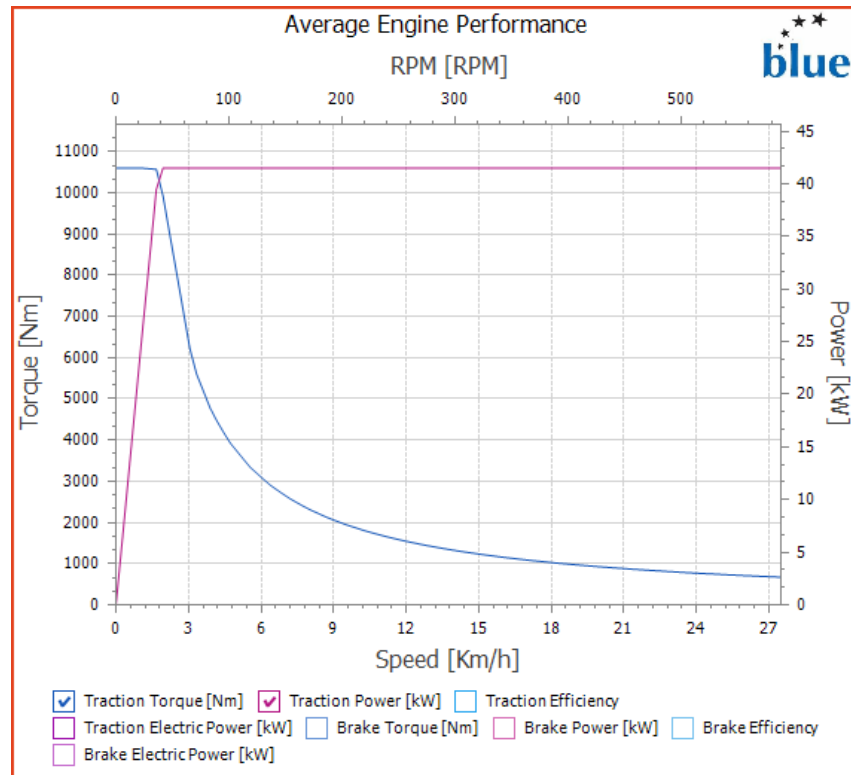
Max Speed on 16 ‰ slope (km/h)	Starting Acceleration (m/s <sup>2</sup> )	Average Acceleration 0-40 km/h (m/s <sup>2</sup> )	Average Acceleration 0-120 km/h (m/s <sup>2</sup> )	Bilecik-Karakoy Run time (sec)	Bilecik-Karakoy average speed (km/h)	Ulukisla – Bogazcopru Run time (sec)	Ulukisla – Bogazcopru Average speed (km/h)	Ulukisla – Bogazcopru RMS torque (Nm)
61	0.28	0.26	0.18	1412	43	6066	82	4956

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### PERFORMANCE IN LMM MODE

The most severe mission for the LMM is to supply the propulsion of the locomotive with a 1500 t payload train for maximum 25 km at the constant speed of 25 km/h. During LMM mode, 6 traction motors will be powered.

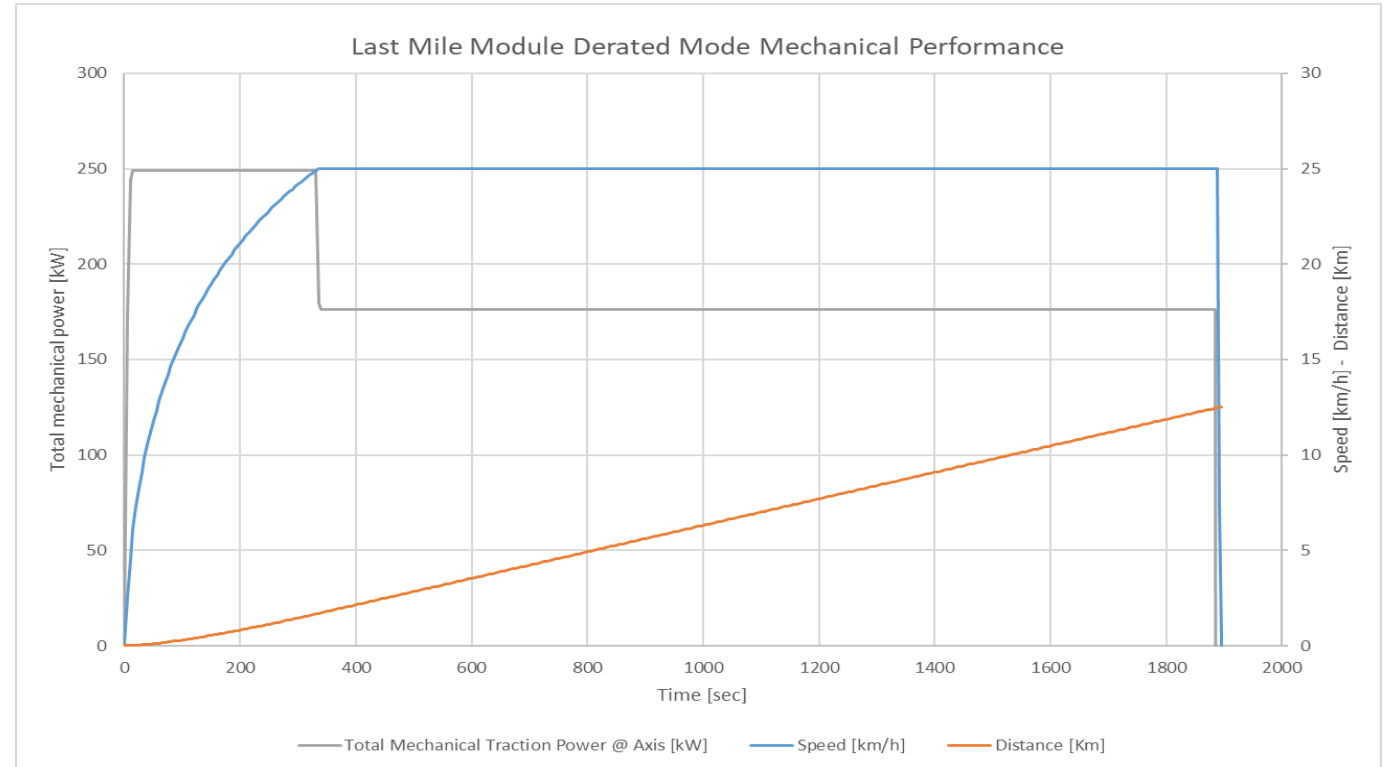
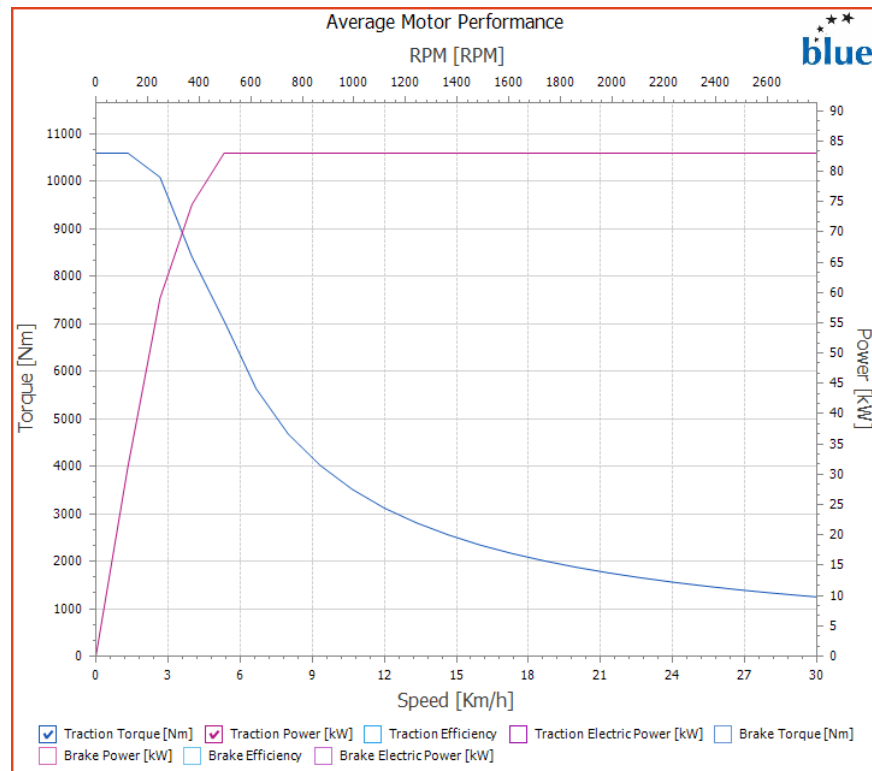


Maximum traction motor mechanical characteristics in LMM

Mechanical Power vs Time

### PERFORMANCE IN DEGRADED LMM MODE (1 LLM WORKING)

The most severe mission for the LMM is to supply the propulsion of the locomotive with a 1500 t payload train for maximum 12.5 km at the constant speed of 25 km/h. During Degraded LMM mode only 3 traction motors will be powered.



Maximum traction motor mechanical characteristics in Derated LMM

Mechanical Power vs Time

## **TEMPERATURE CALCULATION ON ROUTE PROFILES**

The data in numeric format are shown in the document TCL-2\_BC21.

- The temperature calculation for the evaluation of the lifetime of the traction motor and the mechanical life of the rolling elements of the drive-line has to be executed using the load profile in page 5 (Ulukışla-Boğazköprü , 1750 t train) repeated till when the temperature steady state is reached.
- The temperature calculation for the evaluation of the maximum stress of the traction motor and the maximum mechanical of the rolling elements of the drive-line must be executed using the load profile in page 4 (BILECIK-KARAKOY uphill, 1750 t train).

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THANK YOU!