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OPEUS_

Modelling and strategies for the assessment and Optimisation of Energy Usage aspects of rail innovation

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Shift2Rail

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1	Newcastle University	UNEW	UK
2	SAFT SAS	SAFT	FR
3	Union Internationale des Chemin de Fer	UIC	FR
4	Union Internationale des Transport Public	UITP	BE
5	Universitaet Rostock	UROS	DE
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EXECUTIVE SUMMARY

The work presented in this deliverable D3.1 has been carried out in the framework of the collaboration agreement between OPEUS and the S2R Members project FINE1 (Grant agreement No. 730818).

The document summarises the main service profile and related data defining the boundary conditions for the reference scenarios (urban, regional, high speed and freight) to be used in the modelling activities of the project. The contents of this document have been produced by a combination of the information generated by previous projects (e.g. Roll2Rail), the existing draft standard prEN50591 and the joint effort of the OPEUS-FINE1 group.

Specifically, the following service profiles and data have been defined:

1. Urban
    a. Suburban
    b. Metro
    c. Tram
2. Regional
    a. Regional 160
    b. Regional 140
3. High speed
    a. High speed 300
    b. High speed 250
    c. Intercity
4. Freight

1 Introduction

As indicated in the DOA, this deliverable focuses on the definition of the boundary conditions for the reference scenarios to be used in the modelling activities of the project. The emphasis is on the identification and definition of suitable duty cycles for each of these scenarios. Specifically, the following are being considered:

1. Urban
2. Regional
3. High speed
4. Freight

The work presented in this deliverable D3.1 has been carried out in the framework of the collaboration agreement between OPEUS and the S2R Members project FINE1 (Grant agreement No. 730818). Section 2 provides an overview of the reference scenarios and the general characteristics of the rolling stock used in each of these. Sections 3, 4, 5 and 6 describe the scenarios for urban, regional, high speed and freight applications defined by their corresponding agreed/standardised duty cycles. Section 7 introduces the structure of the input parameter matrix and section 8 summarises the main conclusions of this deliverable.

2 Reference scenarios overview

The work carried by previous EU-funded projects such as RailEnergy and CleanER-D has resulted in standardised duty cycles which are incorporated into a standard (CEN/CENELEC, 2014). The Roll2Rail project (Grant agreement H2020-636032)[1] recently published a report defining a number of service sub-categories for each main reference profile or scenario. These include maximum speed, average distance between stations and type of rolling stock used. The results of Roll2Rail (2016) indicate that approximately 80% of all European traffic measured in train-km uses electric traction.

In addition, the data resulting from this project shown in Table 2 related to the annual service specifies the distance covered by rolling stock in each of the categories as an average of current vehicle age distribution. This value could be increased if optimisation approaches were to be introduced to the rolling stock availability and maintenance regimes. For each sub-service category included in Table 2, a reference speed profile or duty cycle is defined representing the typical service provided which might include station stops and gradients. However, given the diversity of services across Europe it is simply not possible to have a universal profile. Instead, representative synthetic profiles are used. The current prEN50591 standard "Specification and verification of energy consumption for railway rolling stock" (CEN/CENELEC, 2014) includes these representative profiles which have been included in Table 2.

The standard only considers the inclusion of altitude profiles (gradients) for freight mainline services as a way to assess the capability of locomotives to overcome them. However, for the purpose of Shift2Rail related research, no gradients are considered in order to facilitate a valid comparison between energy estimations. Similarly, the standard does not consider the effects of tunnels although these increase the driving resistance of high speed traffic in particular.

Travel time included in prEN50591 has been simulated and validated as part of Roll2Rail (2016). Specifically, all out mode with maximum power was simulated to

[1] New Dependable Rolling Stock for a more Sustainable, Intelligent and Comfortable Rail Travel in Europe (Roll2Rail)

obtain the minimum travel time. A time plan recovery margin was then added to define the operational travel time. This considers reserve time allowances to accommodate an energy optimise profile as well as typical operational conditions without introducing delays. Leaflet 451-1 (UIC, 2000) defines a range of time plan recovery margins for different service categories (Table 1). A minimum of 5% recovery time has been suggested for Shift2Rail research purposes.

	Maximum speed [km/h]				
	≤ 140	141-160	161-200	201-250	>250
Recovery margin as % of journey time	3%	4%	5%	6%	7%

Table 1. Timetable recovery margins (UIC, 2000)

Main Service	Sub Service Category	Max. Speed [km/h]	Distance between stations [km]	Station dwell time [min]	Route length [km]	Operational travel time [h:min:sec]		Annual service [km]	Km-share [%]	Traction system	S2R TDs	remarks
						High power	Low power					
High Speed	High Speed 300	300	150	3	300	01:47:00	01:53:00	400,000	5	electrical	TD1.1	
	High Speed 250	250	75	3	300	02:03:00	-	350,000	3	electrical		250km/h and 2 add. stops
	Intercity	200	28	2-3	250	02:39:00	-	200,000	3	Mostly electrical		
Regional	Regional 160	160	15	1-3	250	02:57:00	-	150,000	9	Mostly electrical	TD1.1	160km/h and 7 add. stops
	Regional 140	140	5	1-2	70	01:09:00	-	100,000	17	Electrical &Diesel		
Urban	Suburban	120	3.6	1	40	00:43:00	-	100,000	18	electrical		
	Metro	80	1	0.5	20	00:37:30	-	140,000	13	electrical	TD1.1	OSIRIS
	Tram	50	0.4	0.5	-	-	-	90,000	13	electrical	TD1.1	OSIRIS
Freight	Freight Mainline	120	50	1-5	300	04:17:15	-	100,000	15	Mostly electrical	TD5.5	No elevation for Shift2Rail
	Freight Shunting	40	-	-	37	04:32:00	-	30,000	4	Diesel	TD5.4	CleanER-D

Table 2. Overview of service categories and their main characteristics (CleanER-D, 2011; CEN/CENELEC, 2014; OSIRIS, 2014; Roll2Rail, 2016)

3 Urban service profile

The suburban service profile consists of three distinct sub-categories, namely: Suburban, metro and tram. Their characteristics are detailed in the following sub-sections.

3.1 Suburban

A typical suburban service profile is defined in prEN50591 (Fig. 1). This type of service usually involves traffic on high capacity electrified routes connecting suburbs with large city centres at speeds varying from 80 to 120 km/h and distance between stops of 3.6km on average.

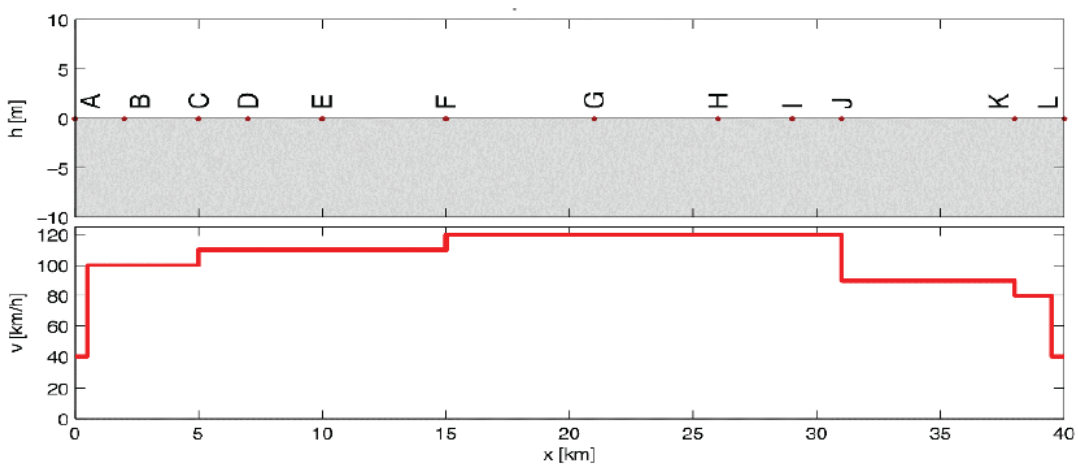

Fig. 1. Standard suburban profile (CEN/CENELEC, 2014)

The data related to this profile is summarised in Table 3

station	Distance [km]	Speed limit [km/h]	arrival [hh:mm:ss]	stop	departure [hh:mm:ss]
A	0.0	40		1:00	00:00:00
	0.5	100		1:00	
B	2	100		1:00	
C	5	100		1:00	
D	7	110		1:00	
E	10	110		1:00	
F	15	120		1:00	
G	21	120		1:00	
H	26	120		1:00	
I	29	120		1:00	
J	31	90		1:00	
K	38	80		1:00	
	39.5	40			
L	40		00:43:00	1:00	

Table 3. Suburban profile data (CEN/CENELEC, 2014)

3.2 Metro

The Metro profile is not included in the current version of the prEN50591 standard but it was proposed as part of OSIRIS (2014) and updated during Roll2Rail (2016). It represents fast services within large urban areas covering routes with stops separated by an average of 1km at speeds ranging from 60 to 80 km/h.

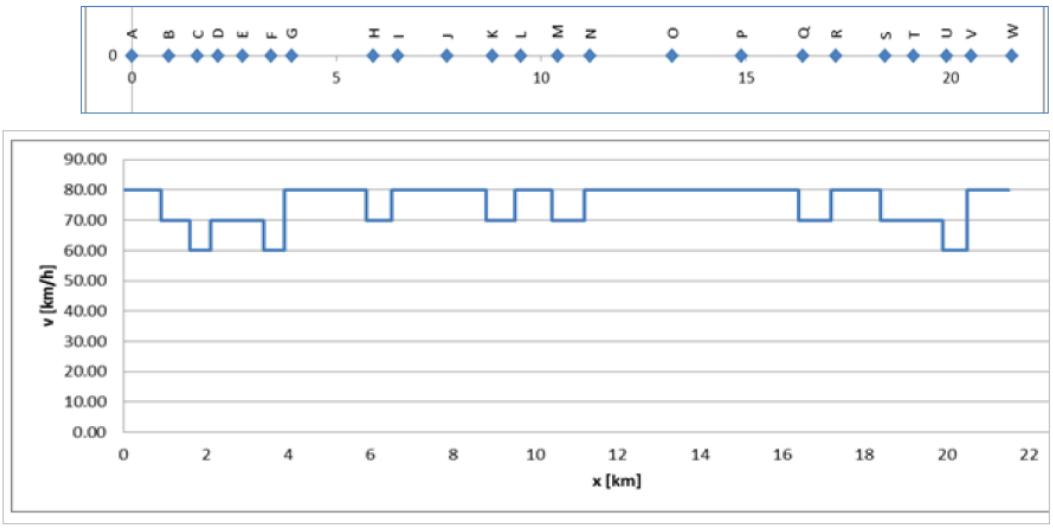

Fig. 2. Standard metro profile (OSIRIS, 2014; Roll2Rail, 2016)

The data related to this profile is summarised in Table 4

Station	Distance [km]	Speed limit [km/h]	stop
A	-	80	00:00:00
B	0.9	70	00:00:30
C	1.6	60	00:00:30
D	2.1	70	00:00:30
E	2.7	70	00:00:30
F	3.4	60	00:00:30
G	3.9	80	00:00:30
H	5.9	70	00:00:30
I	6.5	80	00:00:30
J	7.7	80	00:00:30
K	8.8	70	00:00:30
L	9.5	80	00:00:30
M	10.4	70	00:00:30
N	11.2	80	00:00:30
O	13.2	80	00:00:30
P	14.9	80	00:00:30
Q	16.4	70	00:00:30
R	17.2	80	00:00:30
S	18.4	70	00:00:30
T	19.1	70	00:00:30
U	19.9	60	00:00:30
V	20.5	80	00:00:30
W	21.5	80	00:00:30

Table 4. Metro profile data (OSIRIS, 2014; Roll2Rail, 2016)

3.3 Tram

As in the Metro case, the Tram profile is not included in the current version of the prEN50591 standard but it was proposed as part of OSIRIS (2014) and updated during Roll2Rail (2016). It represents services within urban areas covering partially segregated or non-segregated routes with stops separated by an average of 0.4 km at speeds up to 50 km/h.

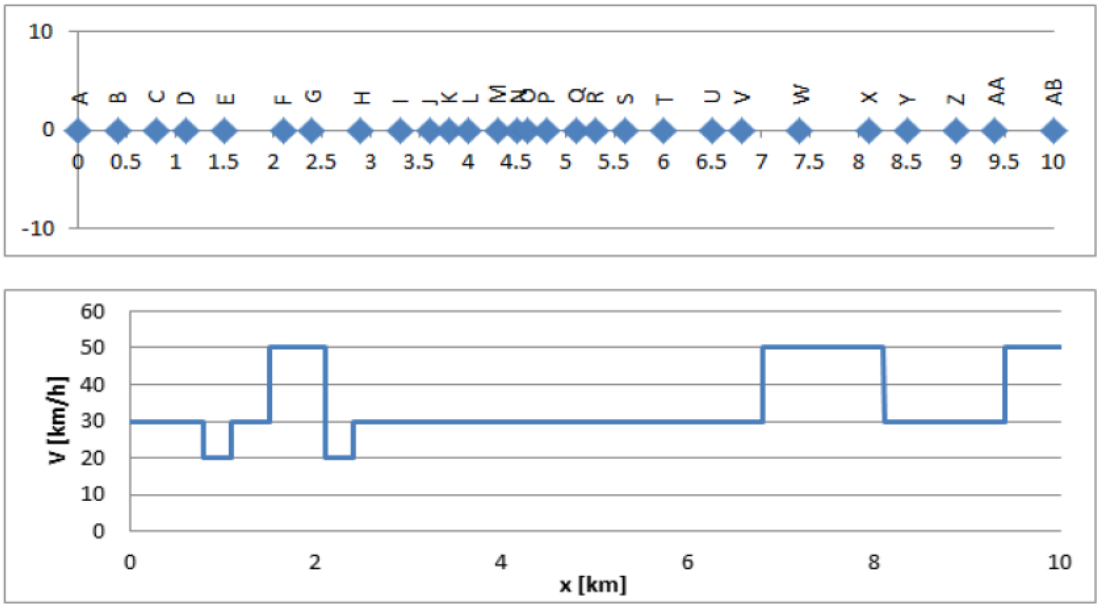

Fig. 3. Tram standard profile (OSIRIS, 2014; Roll2Rail, 2016)

The data related to this profile is summarised in Table 5

Station	Distance [km]	Speed limit [km/h]	Stop
A	-	30	00:00:00
B	0.4	30	00:00:30
C	0.8	20	00:00:30
D	1.1	30	00:00:30
E	1.5	50	00:00:30
F	2.1	20	00:00:30
G	2.4	30	00:00:30
H	2.9	30	00:00:30
I	3.3	30	00:00:30
J	3.6	30	00:00:30
K	3.8	30	00:00:30
L	4	30	00:00:30
M	4.3	30	00:00:30
N	4.5	30	00:00:30
O	4.6	30	00:00:30
P	4.8	30	00:00:30
Q	5.1	30	00:00:30
R	5.3	30	00:00:30
S	5.6	30	00:00:30
T	6	30	00:00:30
U	6.5	30	00:00:30
V	6.8	50	00:00:30
W	7.4	50	00:00:30
X	8.1	30	00:00:30
Y	8.5	30	00:00:30
Z	9	30	00:00:30
AA	9.4	50	00:00:30
BB	10	-	00:00:30

Table 5. Tram profile data (OSIRIS, 2014; Roll2Rail, 2016)

4 Regional

The regional service profile consists of two variants, namely: Regional 160 and regional 140. Their characteristics are detailed in the following sub-sections.

4.1 Regional 160

This category was newly created as part of the Roll2Rail project (Roll2Rail, 2016). It represents fast regional services ideally suited for modern EMUs/DMUs characteristics. The speed profile or duty cycle of this sub-category is based on the intercity profile as defined in prEN50591 with a reduced speed of 160km/h and the inclusion of additional stations, specifically stations C, G, I, J, L, N and P on Fig. 4 and Table 6 at an average distance of 15km. the lead spectrum for this type of service is predominantly similar to that of intercity services. Roll2Rail (2016) results show that in the regional 160 case, there is a stronger representation of time share at 160km/h.

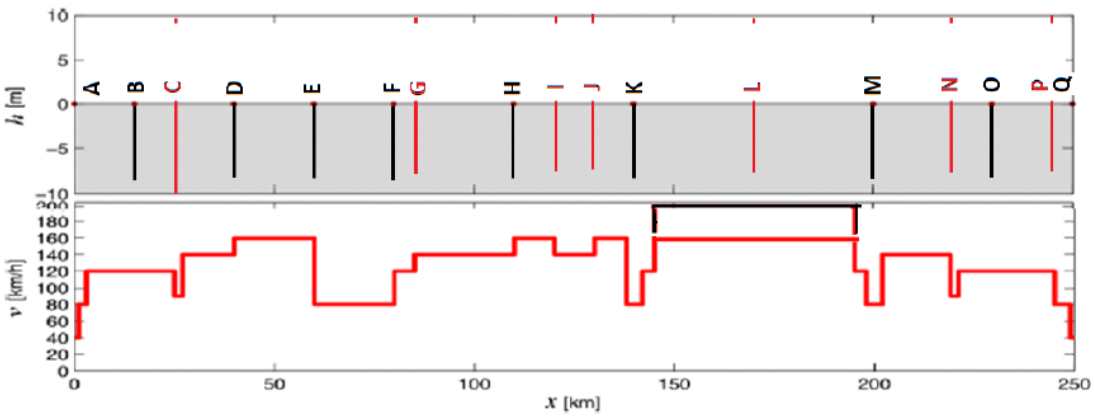

Fig. 4. Regional 160 service profile (CEN/CENELEC, 2014)

The service data for Regional 160 is summarised below

Station	Distance [km]	Speed limit [km/h]	Stop
A	-	40	00:03:00
	1	80	
	3	120	
B	15	120	00:02:00
C	25	90	00:01:00
	27	140	
D	40	160	00:02:00
E	60	80	00:02:00
F	80	120	00:03:00
G	85	140	00:01:00
H	110	160	00:02:00
I	120	140	00:01:00
J	130	160	00:01:00
	138	80	
K	140	80	00:03:00
	142	120	
	145	160	
L	175	160	00:01:00
	195	120	
	198	80	
M	200	80	00:02:00
	202	140	
N	219	90	00:01:00
	221	120	
O	230	120	00:02:00
P	245	80	00:01:00
	249	40	
Q	250	40	00:03:00

Table 6. Regional 160 profile data (CEN/CENELEC, 2014; Roll2Rail, 2016)

4.2 Regional 140

This is defined according to the regional profile in prEN50591 and in the same way as for the suburban application (CEN/CENELEC, 2014). The service covers 13 stations separated by 5km (average) on mostly non-electrified routes at 80 to 140km/h.

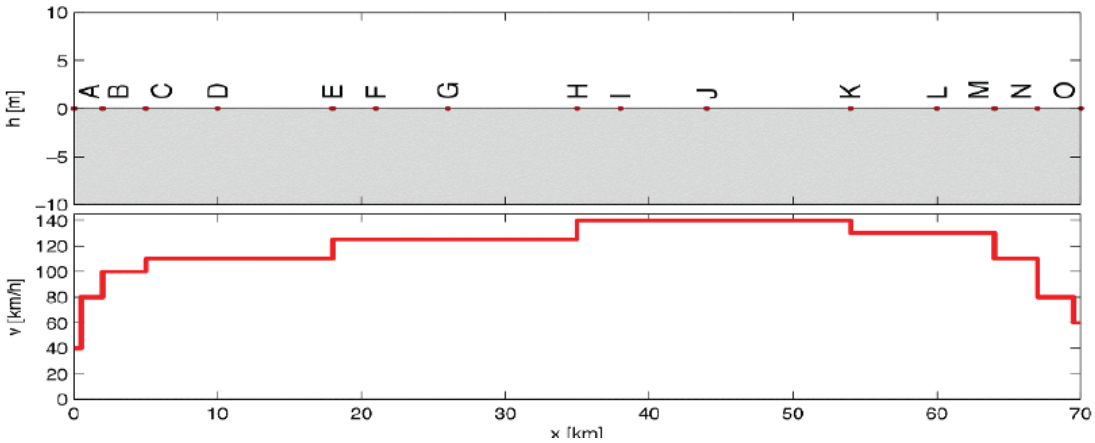

Fig. 5. Regional 140 service profile (CEN/CENELEC, 2014)

Station	Distance [km]	Speed limit [km/h]	Arrival [hh:mm:ss]	Stop	Departure [hh:mm:ss]
A	0.0	40		2:00	00:00:00
	0.5	80			
B	2	100		1:00	
C	5	110		1:00	
D	10	110		1:00	
E	18	125		2:00	
F	21	125		1:00	
G	26	125		1:00	
H	35	140		2:00	
I	38	140		1:00	
J	44	140		1:00	
K	54	130		2:00	
L	60	130		1:00	
M	64	110		1:00	
N	67	80		1:00	
	69.5	60			
O	70		01:01:00	2:00	

5 High speed

Similar to the situation described for the regional application (section 4), the high speed service profile consists of two variants per se plus a third associated one, namely: High speed 300, high speed 250 and intercity respectively. Their characteristics are detailed in the following sub-sections.

5.1 High speed 300

This service profile corresponds to the high speed profile defined in the standard, which represents a line with a maximum speed of 300 km/h for more than half of the total length of the route linking to upgraded lines with service speeds of up to 200-220 km/h (CEN/CENELEC, 2014). The profile also includes one single stop representing the very high distance between stops (150 km) typical of this sort of service e.g. Spanish and French high speed networks. The standard considers in addition the usual and frequent transition of high speed services over conventional lines to provide connectivity across the main nodes of the network.

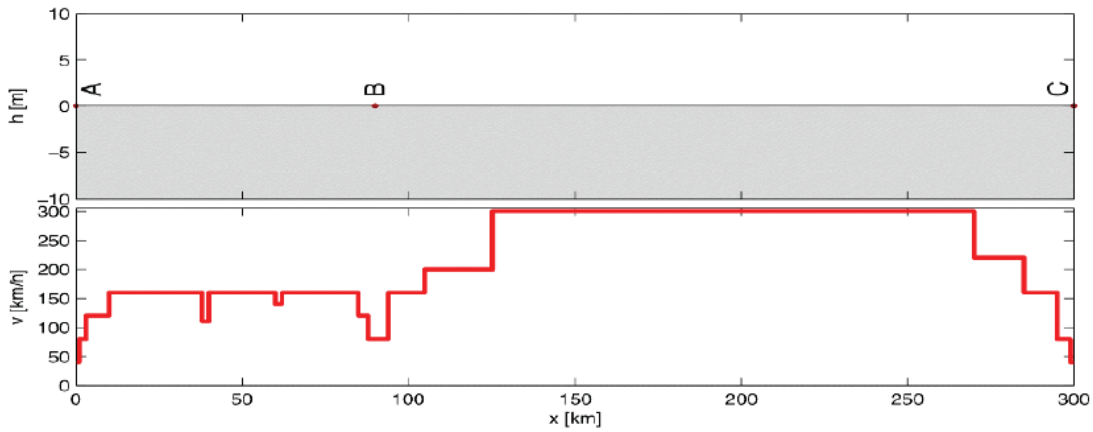

Fig. 6. High Speed 300 service profile (CEN/CENELEC, 2014)

Station	Distance [km]	Speed limit [km/h]	Arrival [hh:mm:ss]	Stop	Departure [hh:mm:ss]
A	0.0	40		3:00	00:00:00
	1	80			
	3	120			
	10	160			
	38	110			
	40	160			
	60	140			
	62	160			
	85	120			
	88	80			
B	90	80	00:42:00	3:00	00:45:00
	94	160			
	105	200			
	125	300			
	270	220			
	285	160			
	295	80			
	299	40			
C	300		01:47:00	3:00	

Table 7. High Speed 300 profile data (CEN/CENELEC, 2014)

5.2 High Speed 250

This profile has been proposed by the Roll2Rail project (Roll2Rail, 2016) to represent the growing traffic in Europe (e.g. Germany, Switzerland, Belgium, Netherlands, Poland) characterised by service speeds of up to 250 km/h. For simplicity purposes, the service profile is based on the high speed 300 with a reduced speed to 250 km/h and the addition of two further intermediate stations at 170km (station C) and 240 km (station D).

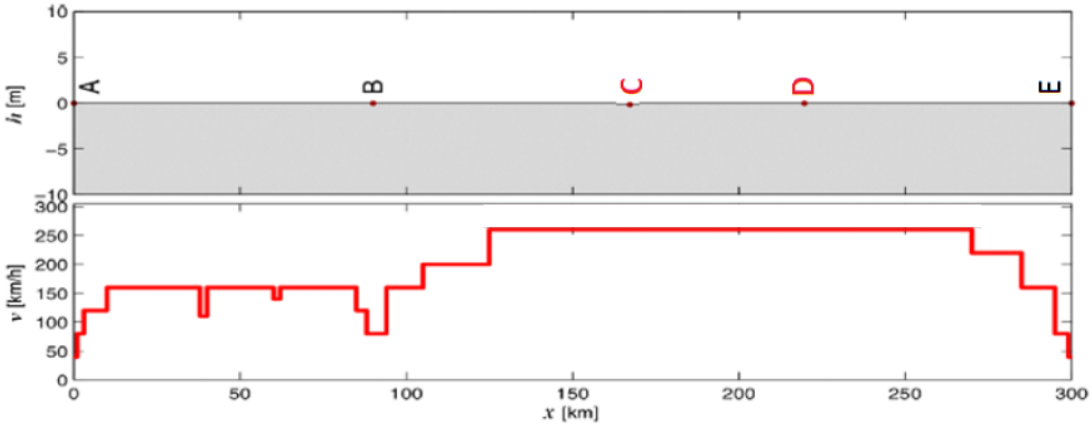

Fig. 7. High speed 250 service profile (Roll2Rail, 2016)

Station	Distance [km]	Speed limit [km/h]	Stop
A	0.0	40	3:00
	1	80	
	3	120	
	10	160	
	38	110	
	40	160	
	60	140	
	62	160	
	85	120	
	88	80	
B	90	80	3:00
	94	160	
	105	200	
	125	250	
C	170	250	3:00
D	240	250	3:00
	270	220	
	285	160	
	295	80	
	299	40	
C	300		3:00

Table 8. High speed 250 profile data (Roll2Rail, 2016)

5.3 Intercity

This service profile is included within the high speed grouping but follows the specific definition in the standard, where eight stops are included with different stopping times and at various speeds between stations with an overall maximum of 200km/h (CEN/CENELEC, 2014).

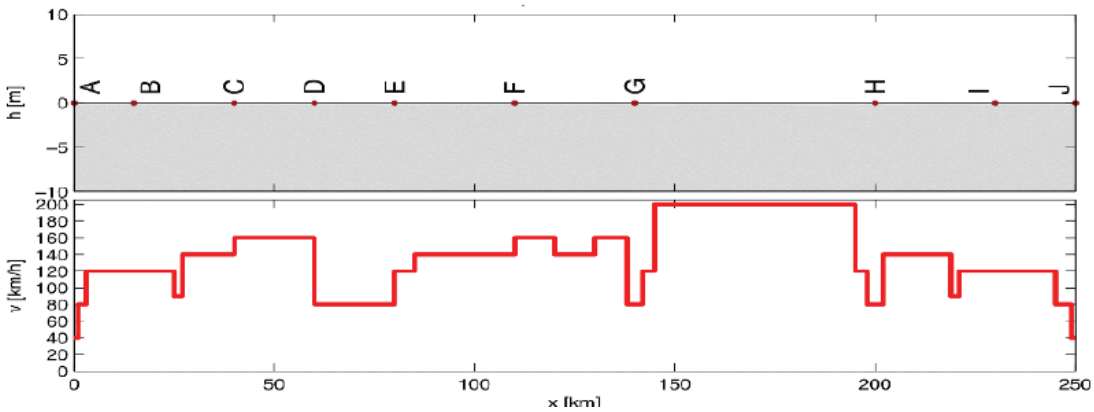

Fig. 8. Intercity service profile (CEN/CENELEC, 2014)

Station	Distance [km]	Speed limit [km/h]	Arrival [hh:mm:ss]	Stop	Departure [hh:mm:ss]
A	0.0	40		3:00	00:00:00
	1	80			
	3	120			
B	15	120	00:11:00	2:00	00:13:00
	25	90			
	27	140			
C	40	160	00:28:00	2:00	00:30:00
D	60	80	00:40:00	2:00	00:42:00
E	80	120	00:59:00	3:00	01:02:00
	85	140			
F	110	160	01:18:00	2:00	01:20:00
	120	140			
	130	160			
	138	80			
G	140	80	01:36:00	3:00	01:39:00
	142	120			
	145	200			

	195	120			
	198	80			
H	200	80	02:04:00	2:00	02:06:00
	202	140			
	219	90			
	221	120			
I	230	120	02:23:00	2:00	02:25:00
	245	80			
	249	40			
J	250	40	02:39:00	3:00	

Table 9. Intercity profile data (CEN/CENELEC, 2014)

6 Freight

The service profile for mainline freight operation is defined in prEC50591 describing it over a 300km line with three planned stops and two additional ones related to traffic management (red signal stops). This profile is the only one to include altitude reflecting the realities of European long distance freight services (CEN/CENELEC, 2014).

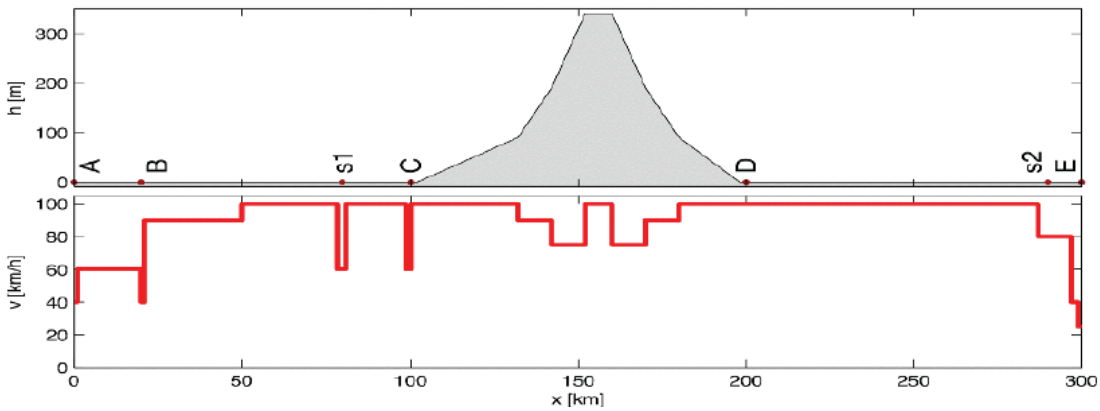

Fig. 9. Freight mainline service profile (CEN/CENELEC, 2014)

Station	Distance [km]	Height (m)	Speed limit [km/h]	Arrival [hh:mm:ss]	Stop	Departure [hh:mm:ss]
A	0.0	0	40		3:00	00:00:00
	1	0	60			
	18	0	60			
B	20	0	40	00:24:00	2:00	00:26:00
	21	0	90			
	50	0	100			
	78.5	0	60			
s1	80	0	60	01:12:00	1:00	01:13:00
	81	0	100			
	98.5	0	60			
C	100	0	100	01:29:00	5:00	01:34:00
	102	0	100			
	132	90	90			
	142	190	75			
	152	340	100			
	160	340	75			
	170	190	90			
	180	90	100			
	198	0	100			
D	200	0	100	02:51:00	5:00	02:56:00
	287	0	80			
s2	290	0	80	03:59:00	1:00	04:00:00
	292	0	80			
	297	0	40			
	299	0	25			
E	300	0	40			

Table 10. Freight mainline profile data (CEN/CENELEC, 2014)

7 Topologies, components and parameters

As part of the joint work between OPEUS and its Shift2Rail members project FINE1, an agreed selection of six topologies has been proposed as follows:

- T01 electric traction chain AC power supply;
- T02 electric traction chain AC power supply E-Transformer;
- T03 electric traction chain DC power supply;
- T04 bi-current traction chain;
- T05 diesel electric traction;
- T06 diesel hydraulic/ mechanical traction

Of these, only topologies T01, T02 and T03 will be simulated during the lifetime of OPEUS. Representative diagrams of all six topologies are included in Appendix A.

Similarly, 24 components and 312 parameters associated with these topologies have been proposed to be simulated for practical purposes, as indicated in Table 11. A separate live excel document is being used to collected the corresponding values from the relevant Shift2Rail members.

id	component	id	component
C00	Vehicle	C15	Line inductor
C04	Gearbox	C16	ESS battery
C05	Induction motor	C17	DLC Converter
C06	Synchronous motor	C18	ESS-DLC
C07	Motor converter (basic-semi-conductors)	C19	e-transformer
C08	Motor converter (SiC)	C22	Auxiliary converter-DC link connected
C09	Rheostat converter	C23	Electrical auxiliary-DC link
C10	Rheostat	C24	Auxiliary converter-connected to transformer link
C11	DC intermediate circuit-absorption	C25	Electrical auxiliary-transformer link
C12	Line converter	C26	Battery converter
C13	Transformer	C27	Battery consumption-on board power supply
C14	ESS battery converter	C28	Infrastructure

Table 11. Selection of components to be simulated as part of OPEUS

8 Conclusions

This deliverable D3.1 summarises the main service profile and related data defining the boundary conditions for the reference scenarios (urban, regional, high speed and freight) to be used in the modelling activities of the project. The contents of this document have been produced by a combination of the information generated by previous projects (e.g. Roll2Rail), the existing draft standard prEN50591 and the joint effort of the OPEUS-FINE1 group.

9 References

CEN/CENELEC (2014) *European Standard CLC/TS 50591:2013 Specification and verification of energy consumption for railway rolling stock*.

CleanER-D (2011) *D7.2.1 Detailed Specification: Parameters definition* (Grant agreement No FP7 - 234338).

OSIRIS (2014) *D1.8 Definition of Generic Duty Cycles/Operational Modes* (Grant agreement No FP7 – 284868).

Roll2Rail (2016) *D8.2 Energy calculation methodology, boundary conditions, and link with Shift2Rail targets* (Grant Agreement No. H2020 – 636032).

UIC (2000) *Leaflet 451-1 timetable recovery margins to guarantee timekeeping*.

10 Appendix A

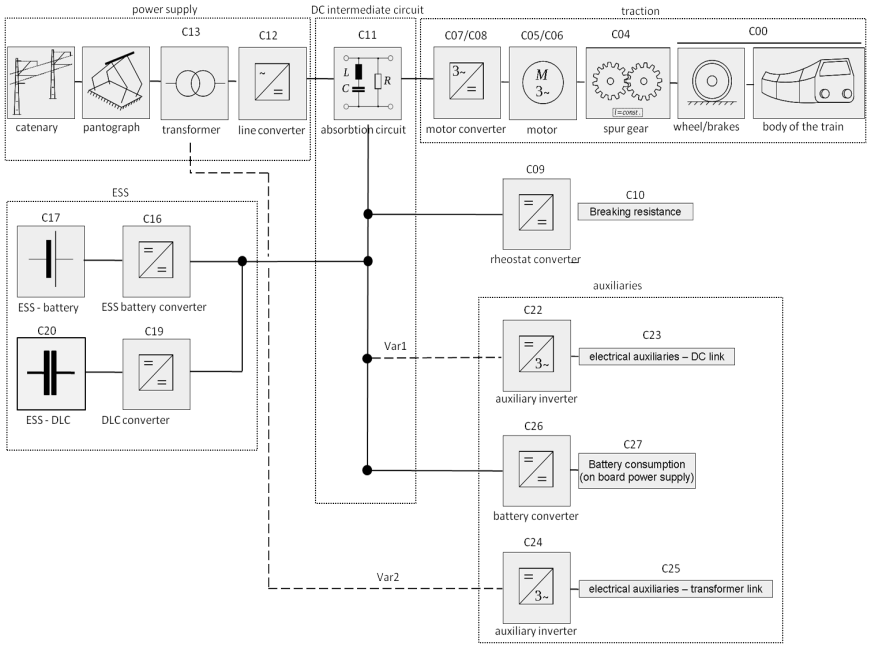

Fig. 10. Appendix A_T01 Electric traction chain AC power supply (25kV@50Hz, 15kV@16.7Hz)

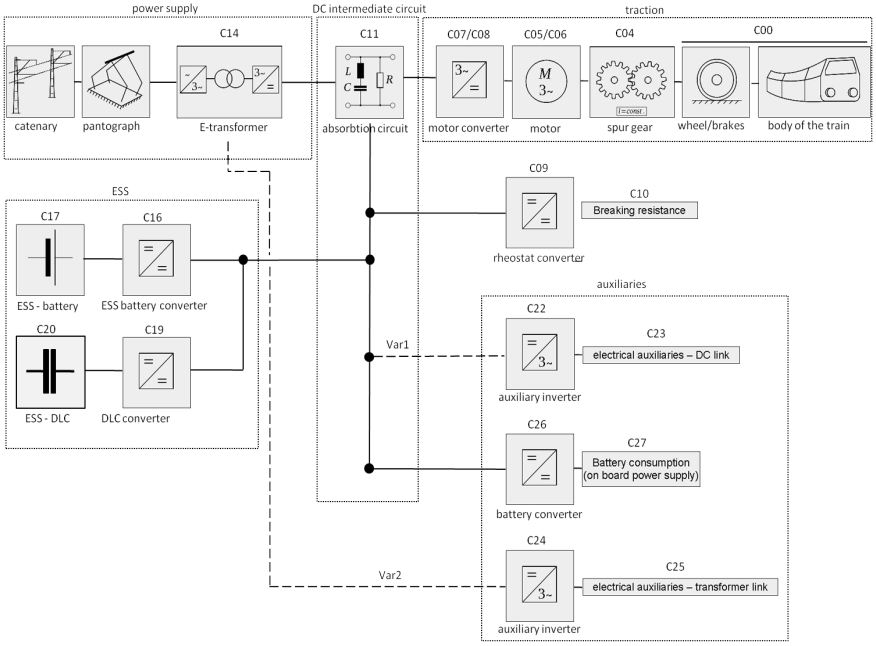

Fig. 11. Appendix A_T02 Electric traction chain AC power supply E-transformer (25kV@50Hz, 15kV@16.7Hz)

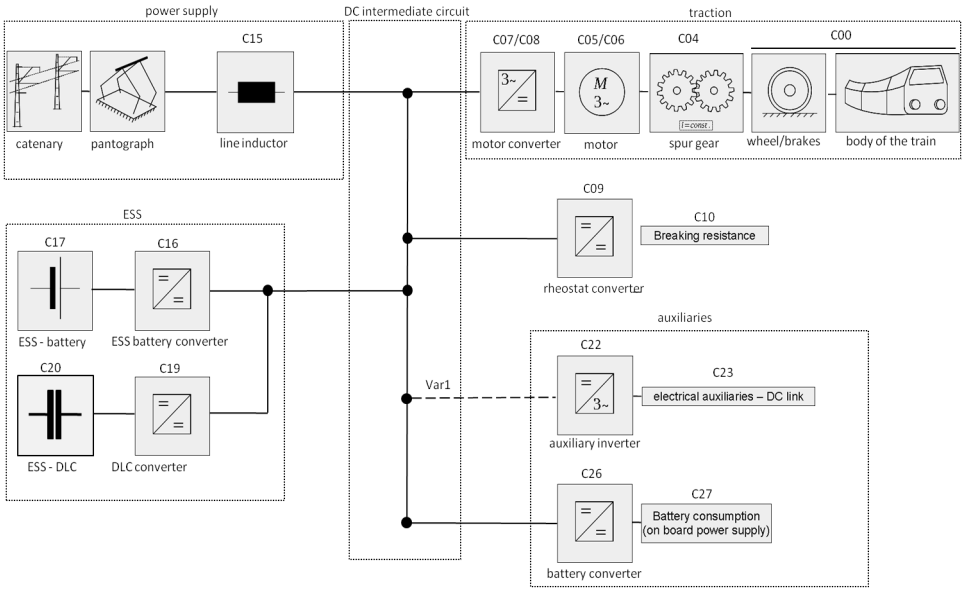

Fig. 12. Appendix A_T03 Electric traction chain DC power supply (750V, 1.5kV, 3kV)

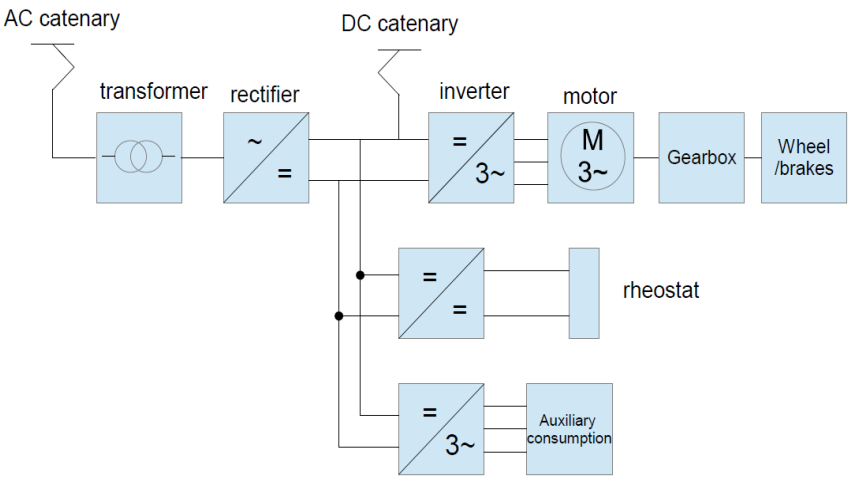

Fig. 13. Appendix A_T04 bi-current traction chain

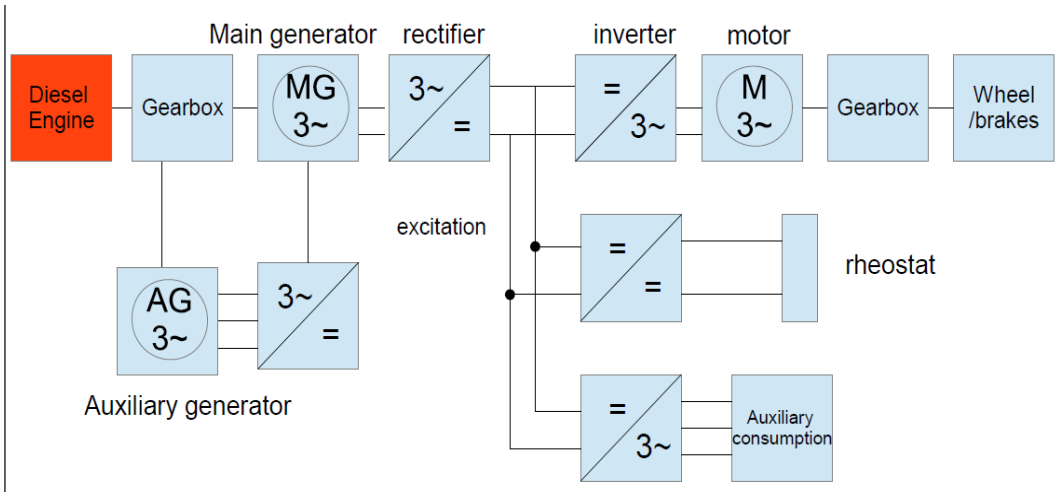

Fig. 14. Appendix A_T05 Diesel electric traction

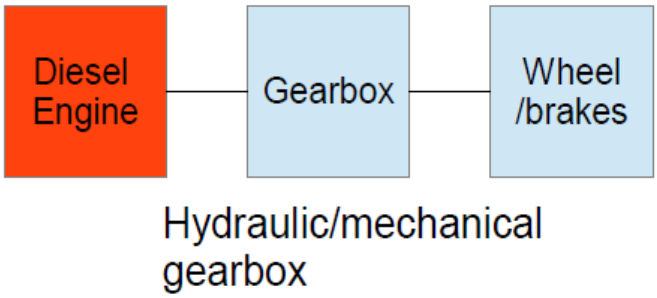

Fig. 15. Appendix A_T06 Diesel hydraulic/Mechanical traction