Project no. TIP5-CT-2006-031415

INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D1.1.1 Database of representative vehicles and characteristics from participant countries

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Issue 1

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Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. Executive Summary

One of the key objectives of SP1 is to verify that the technical solutions developed in Innotrack to reduce infrastructure costs have successfully addressed the root causes within the railway system and are suitable for a wide range of present and future traffic conditions across Europe

WP 1.1 is to gather the vehicle characteristic information that would enable Innotrack to ensure that any technical solutions are suitable for present and future traffic with the wide range of vehicle characteristics possible in Europe.

To help achieve this objective, this report provides the deliverable D1.1.1: “Database of representative vehicle types and characteristics from participant countries.” The collection of European railways vehicle data from the countries of partner organisations was planned in two stages using two forms which were designed in consultation with representatives from the other Innotrack work packages.

The first form, which was to be completed for this report, was for recording summary data on the range of representative vehicles that are used in the participant countries that should be taken into account in Innotrack’s assessment of track deterioration. This included vehicles which are representative of vehicles most commonly used in service, key new vehicle designs proposed for use in service in the next 5 -20 years and vehicles or vehicle defects which produce most damage of the infrastructure. The second form, which was not for completion at this stage, is for gathering far more detailed data for selected representative European vehicles.

A database of summary vehicle data has been developed which should help to enable the vehicles team to select representative European vehicles. It is clear, however, that the gathering of the more detailed data and vehicles models required is not going to be easy either due to commercial sensitivities or just a lack of adequate data in some instances. It is proposed that, where commercial sensitivities exist, some manufacturers could carry out track degradation modelling themselves and provide the output data to the Innotrack team. The Innotrack team could then develop and tune generic models which give the same output data as the commercial modelling has predicted.

2. Introduction

The objectives of SP1 are;

1. To categorise the key degradation conditions chosen by the participating Infrastructure Managers
2. To determine the root causes of these degradation conditions by modelling at an appropriate level
3. To develop a relational database of information developed in SP1 and SP6
4. To verify that the technical solutions have successfully addressed the root causes within the railway system context, and are suitable for a wide range of present and future traffic conditions across Europe

WP 1.1 is to gather the vehicle characteristics that would enable Innotrack to ensure that any technical solutions are suitable for present and future traffic with the wide range of vehicle characteristics that exist in Europe.

To enable WP1.1 of Innotrack to provide its deliverables, and in this instance D1.1.1: “Database of representative vehicle types and characteristics from participant countries,” the collection of European railways vehicles data was planned in two stages using two forms which were designed in consultation with representatives from the other Innotrack work packages.

The main subject of this report is the gathering of summary vehicle data of representative vehicles from the railways of partner countries. Form 1 (Annex 1) was for recording summary data on the range of representative vehicles that are used in the participant countries that should be taken into account in Innotrack’s assessment of track deterioration. This included:

1. vehicles which are representative of vehicles most commonly used in service
2. key new vehicle designs proposed for use in service in the next 5 -20 years
3. vehicles or vehicle defects which produce most damage of the infrastructure.

Form 1 was to be completed by the partner organisations for each selected vehicle, providing as much of the required data as possible. This data was to enable the Innotrack vehicles team to identify a selection of around 22 vehicles that could be representative of the characteristics of the full range of European railway vehicles.

Form 2 (Annex 2) was developed and distributed at the same time as Form 1 to identify data that could be required for the detailed modelling and analysis using the selected representative European vehicles in the work for the other Innotrack work packages. Although the detailed Form 2 was sent out with Form 1 this was only to illustrate the data that could eventually be required for modelling vehicle track forces and track deterioration.

3. Vehicle Characteristics Data

3.1 Gathering of Data

3.1.1 Summary Vehicles Data

Form 1 (Annex 1) was for recording summary data on the range of representative vehicles that are used in the participant countries that should be taken into account in Innotrack's assessment of track deterioration.

This included:

1. vehicles which are representative of vehicles most commonly used in service
2. key new vehicle designs proposed for use in service in the next 5 -20 years
3. vehicles or vehicle defects which produce most damage of the infrastructure.

It was proposed that the railway vehicles might include:

- Electric Multiple Units (EMUs) - 2 vehicles – with high or low yaw stiffnesses for high or lower speeds
- Locomotives - 2 vehicles - Freight Co-Co and Higher Speed Bo-Bo
- Trailer Coach - 2 vehicles – New and Old or high speed and standard service
- Diesel Multiple Unit standard or articulated
- Double Decker Train
- High Speed Train – Tilting and non-tilting
- Freight wagons - 2 vehicles – 4-axle and 2 -axle

This could have given around 14 vehicles from each country plus examples of particularly damaging vehicle as well as older designs that still had significant life.

The Form 1 was to be completed for each selected vehicle, providing as much of the required data as possible. This data was to enable the Innotrack vehicles team to identify a selection of around 22 vehicles that could be representative of the characteristics of the full range of European railway vehicles.

Where data for particular countries was not made available or all the required data not specified then the vehicles team sought for representative vehicles or additional data in Jane's World Railways and railway internet sites.

3.1.2 Detailed Vehicles Data

Form 2 (Annex 2) was developed at the same time as Form 1 to identify data that could be required for the detailed modelling and analysis using the selected representative European vehicles in the work for the other work packages. Although the detailed Form 2 was sent out with Form 1, this was only to illustrate the data that could eventually be required for modelling vehicle track forces and track deterioration.

The exact data gathered is dependent on the type of modelling required by SP2-6. However, it seemed clear that a broad selection of representative vehicles, which allow a range of vehicle masses, unsprung masses and yaw stiffnesses, would be required:

- Suburban Multiple Units - 4 designs
- High Speed Trains - 2 designs
- Pendolino type tilting vehicles - 2 designs
- Locos - 4 designs
- Coaches - 2 designs
- Freight Wagons - 4 designs
- Other (novel bogies) - 2 designs
- New train proposals - 2 designs

Making a total of at least 22 generic / representative vehicles

3.2 Results of Summary Data

Summary vehicle characteristic information was provided by some of the participant countries and additional data was added to this during December 2006and January 2007. A spreadsheet of data obtained for the representative vehicles of each country, which forms the deliverable for D1.1.1, is given in Annex 3. This data may be updated as the results from the Infrastructure Managers' workshops become available as they may identify particularly damaging vehicles and defects which WP1.1 should include in its assessment and modelling.

A comprehensive range of rolling stock has been obtained which identifies representative vehicles of all types including new and old designs, high and low speeds, light and heavy axleloads, and low and high yaw stiffness bogies. Although the Czech Republic and Spain have been able to provide some very helpful train data, only Sweden, Austria and UK which have been able to provide any data on bogie suspensions, yaw stiffness and the potential availability of vehicle dynamics models.

The data included in this spreadsheet with some additional available data is to be included in the Innotrack information databases.

In order to ensure that the range of vehicle models finally employed in SP1 is representative of the pan-European vehicle fleet, it is proposed to use 'generic' vehicle models to represent the range of key parameters identified from the database. Thus it may be established, for example, that 'typical' modern European EMUs have unsprung masses, primary yaw stiffnesses etc within a particular range of values. A generic EMU model can be quickly modified to represent the low, average and high end of this range of values allowing prediction of the range of conditions under which infrastructure must perform on a Europe-wide basis. Use of generic vehicle models has a number of advantages:

- They can be used to represent a range of conditions rather than a single vehicle type
- They avoid the need to obtain commercially sensitive vehicle models of current rolling stock
- They can easily be modified to extrapolate to future vehicle design
- Their validity can quickly be checked by comparison with results from existing detailed vehicle models

Generic vehicle models will not, of course, fully replicate the exact behaviour of an individual vehicle type and the level of modelling for which they are employed should be carefully considered. However, wheel-rail forces are generally dependent on a relatively small number of vehicle parameters (for example vehicle mass, primary yaw stiffness and bogie wheelbase). Recent UK experience has shown that such generic models can be used successfully to represent a wide range of modern passenger vehicles. This is undoubtedly aided by the fact that such vehicles generally use common suspension arrangements and are (relatively) linear. What is less clear at this stage is whether this approach can be extended to common freight vehicles suspensions. These are generally reliant on complex and non-linear friction damping arrangements. It is proposed that MMU should conduct a brief investigation into the validity of using 'generic' models to represent these vehicle types.

3.3 Representative European Railway Vehicles

Once all the remaining data from Infrastructure managers has been assembled and analysed then a final selection of representative European Railway vehicles can be made. These should include different ages, speeds and weights of vehicles. However the selection will be dependent on how easily the detailed data and associated vehicle models (or outputs from vehicle models) might be obtained from railways and manufacturers.

The first stages in achieving this deliverable will be achieving agreement on the types of modelling that is to be carried out within Innotrack and to identify the representative European vehicles for which detailed data is obtainable. As a preliminary assessment, examples of potential vehicles that could be selected have been listed in Annex 4. This demonstrates that we do have summary data for a sufficient range of vehicles out of which the European representative vehicles could be selected. Annex 4 is only given to demonstrate a potential list of representative vehicles that might be selected.

The issue of future vehicle design requires some further consideration. There is some evidence (at least in the UK) that the trend is to procure heavier, stiffer and more powerful vehicles and this has important implications for the future performance requirements of European rail infrastructure. It is proposed to carry out some further investigations in this area to establish trends, perhaps covering a 30 year time span (i.e. the typical life of a vehicle, but looking back 15 years and forward 15 years). This would allow the modelling tasks to represent this important aspect of future infrastructure performance more fully.

4. Conclusions

1. A database of summary data for representative vehicles has been assembled and is presented in this report.
2. The range of vehicles selected covers the full range of vehicles that might be required for selecting the European railway vehicles required for infrastructure damage modelling in Innotrack.
3. Only very few of the responses received so far for vehicle characteristics indicate the existence of dynamics models or the availability of detailed data.
4. Where detailed vehicle data is commercially sensitive, manufactures may be asked to carry out modelling work themselves and to provide the output results. The Innotrack team could develop generic models which produced the same outputs as provided by the manufacturers from their modelling work.

5. Annexes

Annex 1: Form 1 – Vehicles Characteristics – Summary Data

WP1.1 **Vehicle Characteristics**

Please identify between 10 - 20 vehicles which are representative of the full range of current and future trains operating on your national rail infrastructure. This should include key examples of damaging vehicles or defects. For each representative vehicle please complete Form 1

Form 1: Summary Data **Draft** **1.1**

Vehicle: (e.g.: Class 150)

Country:

Comments to Andrew Jablonski and Julian Stow
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					Vehicle					
	Vehicle	***Example***								
SA1	Vehicle Type		Select:-	DMU	EMU	Inter City	Trailer Coach	Freight Wagon	Loco	Other
SA2	Date vehicles represented by this vehicle entered service	*1992-96*								
SA3	Reason for selection		Select:-	Common	Damaging**	Important	Representative of many vehicles			Other
SA4	Car Body (Laden)									
	Vehicle Body									
SB1	Mass									kg
SB2	Vehicle Length (over buffers)									m
	Bogie/Suspension									
SC1	Wheel Diameter									mm
SC2	Number of axles (including wheel arrangement)	*Bo-Bo Co-Co*								
SC3	Any suspension information (Bogie yaw stiffness?)		Select:-	Low < 15		Medium 15 - 25		High > 25		MNm/rad
SC4	Unconventional Vehicle?		Select:-	Tilting		Articulated		Steering Bogie	Other	
SC5	Does a vehicle dynamics model exist for this vehicle?		Select:-	Yes		No		Don't Know		
SC6	If yes, what is the format of the model?	*VAMPIRE*								
	Power/Braking									
SD1	Power Type (if applicable)		Select	Diesel		AC Electric		DC Electric	Other	
SD2	Power/axle at rail									kW
SD3	Max service braking rate									m/sec2
	Notes:									
					Operational Characteristics					
	Service									
SE1	Maximum service speed (tare)									km/hr
SE2	Maximum service speed (laden)									km/hr
SE3	Routes Operated		Select:-	Suburban	Freight	Inter City	High Speed	Mixed Traffic	Other	
SE4	Number of similar vehicles in operation									
SE5	Representative of % of national fleet									%
	Damaging Vehicles/Defects									
SF1	If damaging vehicle** - description of problem on vehicle and effect on infrastructure									
	Options - wheel ovality?							>		mm
	- flats?							>		mm
	- high axleload?									kg
	- high unsprung mass?									kg
	- high yaw stiffness?									MNm/rad
	- other?									
	Notes:									
										Version 1.1 31.10.06

Annex 2: Form 2 – Vehicles Characteristics – Detailed Data

WP1.1 Vehicle Characteristics

This data is only to be provided when requested for specific vehicles

It could be required for the development of vehicle dynamics models for specific representative vehicles once the feedback from the Vehicle Characteristics data (Form 1) has been analysed.

Form 2: Detailed Data

Draft 1.1

Vehicle: (e.g.: Class 150)

Country:

Comments to Andrew Jablonski and Julian Stow
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	Vehicle	
	Mass	
VM1	Wheelset	kg
VM2	Bogie (Frame +Equipment – sprung mass)	kg
VM3	Car Body (Tare)	kg
VM4	Car Body (Laden)	kg
	Moment of Inertia	
	Wheelset	
VI1	Yaw	kg m2
VI2	Pitch	kg m2
VI3	Roll	kg m2
	Bogie Frame	
VI4	Yaw	kg m2
VI5	Pitch	kg m2
VI6	Roll	kg m2
	Body (Tare)	
VI7	Yaw	kg m2
VI8	Pitch	kg m2
VI9	Roll	kg m2
	Body (Laden)	
VI10	Yaw	kg m2
VI11	Pitch	kg m2
VI12	Roll	kg m2
	Location of Centre of Gravity	
VG1	Bogie	m above rail level
VG2	Car Body (Tare)	m above rail level
VG3	Car Body (Laden)	m above rail level
	Stiffnesses	
	Primary Suspension	
VS1	Vertical	N/m
VS2	Lateral	N/m
VS3	Longitudinal	N/m
	Secondary Suspension	
VS4	Vertical	N/m
VS5	Lateral	N/m
VS6	Longitudinal	N/m
	Bushes	
VS7	Radial	N/m
VS8	Axial	N/m
VS9	Tilt	Nm/rad
VS10	Rotation	Nm/rad
	Anti-roll bars	
VS11	Stiffness (+geometry)	Nm/rad
	Bumpstops	
VS12	Stiffness (as a non-linear characteristic if available)	N/m

	Damping	
	For each damper:	
VD1	Damper Rate	N/m/s
VD2	Damper Rate (Before blow-off)	N/m/s
VD3	Damper Rate (After blow-off)	N/m/s
VD4	Damper Blow-off Force	N
VD5	Damper Series Stiffness	N/m
	(Any other significant sources of damping within the bogie should be included eg rubber components, friction characteristics.)	
	Geometry	
VG4	The wheelbase, bogie centres and positions of all suspension components must be known. Usually found from:	
	Vehicle general arrangement drawing	
	Bogie general arrangement drawing	
	Primary suspension general arrangement drawing	
	Secondary suspension general arrangement drawing	
	Bogie sub-assembly drawings if useful	
	Wheels /Wheel profiles	
VW1	New	m,m
VW2	Worn – measured at various mileages between newly turned and wear limit	m,m
VW3	Wheel diameter	m
VW4	Wheel roughness	
VW5	Wheel material	
VW6	Wheel hardness	
VW7	Allowed wheel diameter differences - on bogie	mm
VW8	Allowed wheel diameter differences - on vehicle	mm
	Notes:	
	Operational Characteristics	
	Linespeed	
VL1	Maximum service speed	km/hr
VL2	Typical Service Speed (if different)	km/hr
VL3	Maximum Cant defficiency	
VL4	Speed over through routes (where requested for SP4)	
VL5	Speed over diverging route (where requested for SP$)	
	Vehicle operational characteristics (for each vehicle)	
VO1	Traction characteristics	kN
VO2	Number of powered axles / vehicle	
VO3	Braking characteristics	kN
VO4	Number of braked axles / vehicle	
VO5	Minimum curve radius	m
	Traffic Pattern	
VT1	Number of trains / day over example routes	
VT2	Types of vehicles in a train	
VT3	Train Consists	
	Damaging Vehicles/Defects	
VSF1	If damaging vehicle** - detailed description of problem on vehicle and effect on infrastructure	
	Notes:	
		Version 1.1 31.10.06

Annex 3: Vehicles Characteristics Database – Summary Information of Representative EU Vehicles

Country	Class	Date	Type	Power	Output Power	Wheelset	Speed	Axleload	Length	Max Tractive	Number	Total No. of	Suspension	Wheel
				Type	Continuous kW	Arrangement	km/h	tonne	m	Effort kN	of Type	Similar		Diameter
Austria	1016/1116	1999-	Electric Loco	25kV AC 50Hz 1116 is dual voltage with 15kV	6,400	Bo-Bo	230	21.75	19.28	300/loco	400	500 in EU; 48% of electric loco fleet		1150
Austria	4023/4024 /4124	1996-2006	EMU (similar to some DB DMUs)	15kV	1,440	Bo-2-2-2-Bo	140	116t tare 137t tare	66.87 total	27.5/axle	140	similar to some DB DMUs	Bogies: Bombardier type KTD140 for driving bogies at either end, JLD140 for non driving "Jacobs"-bogies at articulations; bogie wheelbase: 2300mm driving bogies, 2800mm intermediate bogies	Driving 760 Trailer 690
Austria	1144	1974-1995	Electric Loco	15kV	5,200	Bo-Bo	160	21	16	51/axle	210	represents 27% of Electric Loco fleet		1300
Austria	1822	1993	Electric Loco	15kV/3kV DC		Bo-Bo	140	20.6	19.3	250/loco continuous		5	Bogie wheeelbase 2700mm, with steering wheelsets: "SLM Schiebelager Antrieb" - bogie pivot pitch: 11000mm / ?	1100
Austria	2016	2001-2003	Diesel Loco	Diesel Electric (AC motors)	1,600	Bo-Bo	140	20	19.28	58.75/axle	100	represents 40% of Diesel Loco fleet	Medium Yaw stiffness	1100
Austria	4020-7020-6020	1978-1987	EMU		1200kW	Bo'Bo'+2'2'+2'2'	120	127.4 total	23.1	29.25	119	represents 55% of EMUs		950
Austria	5022	2003-2005	DMU (2 car articulated)	Diesel	630kW	Bo' (2') Bo'	120	70.3 total	41.7 total		20	represents 16% of DMU fleet	articulated DMU, driving bogies at both ends	770
Austria	5047	1987-1995	Diesel Railcar	Diesel hydraulic	419kW	2'Bo'	120	43.7 total	25.42	68	100	(+5 double ralcars, 5147) represents 84% of railcars & DMUs		
Austria	Bmz 21 71	1978	Passenger Coach				160	42	26.4		100	500 around Europe; 100 represents 10% of OBB long distance coaches		
Austria	Bmpz 29-91		Passenger coach Inter City				200	49.4	26.4		80	~10% of coaches	steering wheelsets	920

Country	Class	Date	Type	Power	Output Power	Wheelset	Speed	Axleload	Length	Max Tractive	Number	Total No. of	Suspension	Wheel
				Type	Continuous kW	Arrangement	km/h	tonne	m	Effort kN	of Type	Similar		Diameter
Austria	Bmpz I 21-73	1980-85	Passenger Coach				160	37 total	26.4		502	(+149 pilot coaches) #44% of coaches		840
Austria	Sgnss 455 2	1999	Freight Wagon			4 axle	120 100@22.5t	90t laden	19.74		20		Y25Lssd	920
Austria	Hbbins 24 70	1993-94	Freight Wagon			2 axle	120 100@22.5t	45t laden	15.5		150	total of 1000 similar type	UIC standards double link suspension	920
Austria	Habbinss 28 70	2000-01	Freight Wagon			4 axle	120 100@22.5t	90t laden	23.27		200	+80 similar	Y25Lssd	920
Austria	Ris 35 39	2000-01	Freight Wagon			4 axle	120 tare 100 laden	80t laden	21.7		1		Y25Css	920
Czech Rep.	Class 151	1978	Electric Loco	3kV DC	4,000kW	Bo'Bo	160	82t	16.74	227kN	12	+14 150s at 140km/h		1250
Czech Rep.	Class 163	1984-91	Electric Loco	3kV DC	3,060kW/ 3480kW peak	Bo'Bo	120	85	16.8	250kN	102	+ 20 162s @140km/h		1250
Czech Rep.	Class 240/242	1968-81	Electric Loco	25kV	3,080kW	Bo'Bo'	120	85	16.44	213kN	114	19.3% of locos		1250
Czech Rep.	Class 181/182	1961-62	Electric Loco	3kV DC	2,790kW	Co'Co'	90	120t	18.8	200kN	135		Damaging	1250
Czech Rep.	363	1980	Electric Loco	3kV DC/25kV	3060/3400kW	Bo'Bo'	120	85	16.8	217kN	116			1250
Czech Rep.	451,452	1961-75	EMU 4-car	3kV DC	2 motor cars/unit; 165kW/axle	Bo'Bo'+2'2'+2'2'+ Bo'Bo'	100	184t total	24	150kN	46		Damaging	1000
Czech Rep.	Class 750, 753, 754	1975	Diesel Loco	Diesel	1325-1476kW	Bo'Bo	100	74.4	16.5	186kN	134			1000
Czech Rep.	Type B	1965-83	Passenger Coach			2'2'	140	39t	24.5					920
Czech Rep.	Type Bt	1986-92	Passenger Coach			2'2'	120	38t	24.5					920
Czech Rep.	Eas		Freight Wagon			2'2'	120 tare 100 laden	23t tare	14.04					920
Czech Rep.	Falls		Freight Wagon 4-axle coal hopper			2'2'	100 tare 90 laden	26.8t tare	13.5		2000			920
Czech Rep.	Class 680	2003-5	High Speed Train Tilting Pendolino; 7-car	25kV/15kV/3kV DC	3920kW	(1A)(A1)+2´2´+ (1A)(A1)+2´2´+ (1A)(A1)+2´2´+ (1A)(A1)	230	13.5t max/axle	185.3m total 26.5/car	159kN	7			920

Country	Class	Date	Type	Power Type	Output Power Continuous kW	Wheelsets Arrangement	Speed km/h	Axleload tonne	Length m	Max Tractive Effort (kN)	Number of Type	Total No. of Similar	Suspension	Wheel Diameter mm
Denmark	MG/FG/FH/MG	2003-	DMU 4-car	Diesel 2 motor cars	four 560kW engines /unit	2 motored axles/car	180				83		Articulated	
Denmark	ET/FT/ET	2000-2003	EMU 3-car	25kV 2 motor cars/unit	290kW/motor	4 motored axles/car	180				24	49 (25 in Sweden)		
Denmark	SA/SB/SC/SD	1995-2004	EMU 8-car	1.5kV 6 motor cars/unit	180kW/motor	4 motored axles/car	120				92	+31 4-cars		
Germany	ICE1	1990	High Speed Train	15kV	4,800		280	?			50	216		
Germany	ICE3	2000	High Speed Train	15kV	8,000		330	< 17			50	216		
Germany	152	1997	Electric Loco	15kV	6,400	Bo-Bo	140			300	170			
Germany	185	2001	Electric Loco	15kV/25kV	4,200	Bo-Bo	140			300	400	+ 80x145s		
Germany	423	1999	EMU 4-car	15kV	2,350		140				190	440		
Germany	232*	1973	Diesel Loco	Diesel	2,235kW new engine (2,200 old)	Co-Co	120	108?			140	482 +64 @ 140km/h		
Germany	611/612	1997-2004	DMU 2-car	Diesel	1,118		160	116			250			
Germany	143	1984-	Electric Loco	15kV	3,720	Bo-Bo	120	82.8			634			
Germany	DBpza753	1996	Passenger Coach Double Decker				160				250	+option for 350		
Spain	269	1973	Electric Loco	3kV DC	3,100	B-B	140/80 160/90	88			262			1250
Spain	252	1991	Electric Loco	3kV DC/25 kV AC	5,600	Bo-Bo	220/100	90			74			1250
Spain	311	1990-91	Diesel Loco	Diesel	504	Bo-Bo	90	80			60			1100
Spain	333	1974	Diesel Loco	Diesel	1,875	Co-Co	146	140 120-rebuilt		311 363-rebuilt	93	includes 34 locos rebuilt in 2002		
Spain	S102, 102-2	2003	EMU 8-car	25kV 4 motor cars	four 550kW motors/ motor car	4 motored axles/car	330	heaviest 17t laden			46	26 S-103 18 S-100		
Spain	440/440R	1974	EMU 2/3 car	3kV DC	300 Kw per motor	4 motored axles/car	140	133.3 (4 cars)	80.164 (4 cars)		199			
Spain	446	1989	EMU 3-car	3kV DC	300 KW per motor	4 motored axles/car	100	166 (3 cars)	75.993 (3 cars)		167			890
Spain	447	1993	EMU 3-car	3kV DC	300 KW per motor	4 motored axles/car	120	157 (3 cars)	75.993 (3 cars)		183			890
Spain	464	2004	EMU 2/3/4/5-car	3kV DC	2,200		120				248			
Spain	S120	2003	EMU 4 car	3kV DC/25 kV AC	500 KW per motor	4 motored axles/car	250	256 (4cars)	107.26 (4 cars)		57		Variable gauge (1435/1668 mm)	
Spain	592 200	96-97 updated from 1981	DMU 2/3-car	Diesel	213kW per motor	2 motored axles/car 2-motor cars/unit	140	9.7/12.1t			24	21 unmodified at 120km/h		910
Spain	130	2007	High Speed Train	25kV	4,800kW		250/220						Pendular Variable gauge (1435/1668 mm)	

Country	Class	Date	Type	Power	Output Power	Wheelset	Speed	Axleload	Length	Max Tractive	Number	Total No. of	Suspension	Wheel
				Type	Continuous kW	Arrangement	km/h	tonne	m	Effort kN	of Type	Similar		Diameter
Sweden	RC,1,2 & 4	1967-75	Electric Loco Freight	15kV	3600kW total	Bo'Bo'	135	76-80	15.5		225	~50% of freight locos	High Yaw Stiffness-40MNm/rad Damaging High unsprung mass 3200kg/axle GENSYS model	1300
Sweden	RC 3,6 & 7	1970-82	Electric Loco Passenger	15kV	3600kW total	Bo'Bo'	160	77,78	15.5		132		High Yaw Stiffness-40MNm/rad Damaging High unsprung mass 3200kg/axle GENSYS model	1300
Sweden	MTAB IORE	2000-04	Electric Loco Freight 2 in tandem	15kV	10800kW total	Co'Co' x2	80/ 60 laden	300 / 360t	45.8	1200kN total	4 @300t/ 5@360t		High Yaw stiffness High RCF damage GENSYS/MEDYNA Models	1250
Sweden	T44	1968-77	Diesel loco Freight	Diesel	1235kW total	Bo'Bo'	100 laden	76t	15.4	220kN	117			1015
Sweden	X1 A+B	1967-95	EMU	15kV	four 320kW motors on the motor car	Bo'Bo+ 2'2'	120	78-82t /2-car	49.5 /2-car		91		GENSYS Model	920
Sweden	X2 Coach	1990-97	Passenger coache Tilting			2'2'	210	47-55t	25		225		tilting GENSYS model	880
Sweden	X2 loco	1990-97	Electric loco Tilting	15kV	815kW/motor	Bo'Bo'	210	73.2	17.4		45		tilting GENSYS model	1100
Sweden	X50/54	2001-04	EMU 2/3-car	15kV	265kW	Bo'Bo'+Bo'2'	180/200	60t/car	27		81 vehicles		soft steering bogie: GENSYS Simpack models	840
Sweden	X10/X11	1982-95	EMU	15kV	four 320kW motors on the motor car	Bo'Bo'+ 2'2'	140/160	103t /2-car	49.9m /2-car		101		Low Yaw stiffness GENSYS model	
Sweden	X40	2005	EMU Double Decker	15kV	400kW	Bo'2'+2'Bo' or Bo'2'+2'Bo' +2'Bo'	200	70t /vehicle	27.5		55		High Taw Stiffness Conventional rigid bogie. Somewhat heavy bogie. Vocodyn model owned by supplier	920
Sweden	X60	2005	MU Articulated 6-car	15kV	250kW/motor	Bo'(Bo')(Bo') (Bo')(2')(Bo')Bo'	160	206t/6-car	107m /6-car		65	+option 50	Articulated Jacobs bogie (conventional bogies rigid!)	850
Sweden	Y31-32	2002-04	DMU Articulated 2/3-car	Diesel	480kW/engine	(1A)'+2'+(A1)' or (1A)'+2'+2'+(A1)'	140	69/87t /unit	38.4/54.8		12+		Articulated Jacobs bogie	850

Country	Class	Date	Type	Power	Output Power	Wheelset	Speed	Axleload	Length	Max Tractive	Number	Total No. of	Suspension	Wheel
				Type	Continuous kW	Arrangement	km/h	tonne	m	Effort kN	of Type	Similar		Diameter
Sweden	4-axle freight wagon Y25 bogie	1960-	Freight wagon 4-axle			2'2'	120 tare 100 laden	3.5t tare 22.5t laden	14-23m		150		Y25 Bogie Low-Medium Yaw stiffness GENSYS Model	920
Sweden	4-axle freight wagons; several		Freight Wagon 4-axle			2'2'	120 tare 100 laden	4.55-5.75t tare; 25t laden	14-23		5000	50% of freight wagons	Bogie running gear; Y25, Y25 TTV, Link bogie (G-type), TF25, Axle Motion II, Amsted Motion Controll (Three piece bogie), SCTE BER; GENSYS Model	920
	Iron Ore Freight Wagon 4-axle	2005	Freight wagon 4-axle			2'2'	70 tare 60 laden	5.5t tare 30t laden	10.3		600	10% of fleet	Medium yaw astiffness, AMSTED Motion Control "three piece"	915
Sweden	2-axle freight wagons; several		Freight Wagon 2-axle				120 tare 100 laden	5-8t tare; 20-25t laden	10-17m		4000	40% of freight wagons	Medium Yaw stiffness Single axle running gear; UIC double-link suspension, TF25 SA, Unitruck; GENSYS Model	920
Netherlands	cl 1600	1981	Electric Loco		4,540	B-B	160	20.75			58			
Netherands	cl 1700	1991	Electric Loco		4,540	B-B	160	21.5			81			
Netherands	6400	1988	Diesel Loco		1,180	Bo-Bo	120				120			
Netherands	64-2	1964	EMU 2 car unit		984	4/unit	140				242			
Netherands	SGM-3	1975	EMU 3 car unit		2,640	8/unit	125				60			
Netherands	ICM-3	1977	EMU 3 car unit		1,248	4/unit	160				94			
Netherands	ICM-4	1991	EMU 4 car unit		2,496	8/unit	160				50			
Netherands	DM90	1995	DMU 2 car unit		1,280	4/unit	140				53			

Country	Class	Date	Type	Power Type	Output Power Continuous kW	Wheelsets Arrangement	Speed km/h	Axleload tonne	Length m	Max Tractive Effort (kN)	Number of Type	Total No. of Similar	Suspension	Wheel Diameter mm
Poland	SU45	1967	Diesel Loco		1,287	Co-Co	100				161			
Poland	EU07/EP07	1963	Electric Loco		2,000	Bo-Bo	125				240			
Poland	ST44	1966	Electric Loco		1,471	Co-Co	100	19.3			50			
Poland	EN67	1962	EMU 3 car unit		608	4/unit	110				75			
France														
France	BB27000	2001-2006	Electric Loco	25kV/1.5kV	4,200	Bo-Bo	140	22.5 (90t total)	19.52	320 (max) 250 (60kmh) 110 (max speed)	180 (built)	210	Coil spring (primary + secondary)	
France	BB7200	1976-85	Electric Loco	1.5kV	4,420	Bo-Bo	160	21.25 (85t total)	17.48	295 88 (max speed)	240 (built) 237 (in service)		Coil spring (primary) - rubber bush sandwich (secondary)	
France	BB26000	1988-98	Electric Loco	25kV/1.5kV	5,600	Bo-Bo	200	88.825 (total)	17.71	320 220 (80kmh) 100 (max speed)	234 (built)		Coil spring (primary) - rubber bush sandwich (secondary)	
France	Z 20500	1988-2000	EMU Double Decker	25kV/1.5kV	2,800	2 motor cars per set 4 powered axles / motor cars	140	70t (tare)	25.1 (motor unit)	310	194 (in service)			
France	TGVs		Electric MU	25kV/1.5kV DC	6,450 SE 8,800 A + R + Thal 12,200 Euro*	2 motor cars per set 4 powered axles / motor cars	270-300 320 (Réseau + Duplex)	418t SE 416t R 420t Thal 424t Dupl 386 490t A 816t Euro*	200 SE + R +Thal +Dupl 237 A 394 Euro*		107 SE 105 A 90 R 38 Euro* 27 Thalys 87 Duplex	454 total		
France	X72500	1997-2003	DMU 2-car 44 units are 3-car with unpowered mid car	Diesel Turbocompressor both cars motored	1,200kW/unit	2 motored axles/car	160	56.708t (tare)	26.45 (motor unit)		73 (bi-caisse) 44 (tri-caisse)			

Country	Class	Date	Type	Power Type	Output Power Continuous kW	Wheelset Arrangement	Speed km/h	Axleload tonne	Length m	Max Tractive Effort kN	Number of Type	Total No. of Similar	Suspension	Wheel Diameter
France	X76500	2004-…	DMU		1324kW per set	2 motored axles/car	160	123t (per set)	57.4 (3 cars)	?	Being delivered			
France	BB7500	2006-2015	Electric Loco	25kV/1.5kV	2,000	Bo-Bo	140?				400			
France	BB60000	2008	Diesel Loco	Diesel	1,400kW??	Bo-Bo	120?	20?			160			
France	Z12500	2008 -	EMU 7 0r 8 car?	25kV/1.5kV DC	2,620kW		140				330			
Italy	D145	1982	Diesel Loco	Diesel	850	B-B	100	18			100	?		
Italy	D146	2003	Diesel Loco	Diesel	900	B-B	100	?			33			
Italy	ALn668	1956	Diesel Railcar	Diesel	110-170	2-axle	110-130				693			
Italy	ETR460	1988	High Speed Electric Trainset	3kV DC	500	4 motored axle per car on 6/9 vehicles	250	?			29 x 9 car sets	15 x 9 car sets	Tilting	
Italy	ETR500	1992	High Speed Electric Trainset	3kV DC	11000	2 x Bo-Bo motor vehicles per 13 car unit	300	?			60 x 13 car sets			
Italy	E402B	1996	Electric Loco	3kV DC / 25kV AC	5600	Bo-Bo	250	21			80			
Italy	E464	1999	Electric Loco	3kV DC	3000	Bo-Bo	160	18			288			
Italy	E636	1941	Electric Loco	3kV DC	1890	Bo-Bo	110	25.25			242			
Italy	E656	1975	Electric Loco	3kV DC	4200	Bo-Bo	150	30			451			
Italy	ALe7244	1982	EMU	3kV DC	305	2 x Bo-Bo motor vehicles per unit	140	?			89			
Italy	ALe426/4	1997	EMU	3kV DC	318	4 motored axles per unit	140	?			188			
Italy	Ale/Aln 501 & 502	2004	EMU	3kv & 1.5Kv DC	2 x 625kW	Bo-2-2-Bo 3-car articulated	160	92t total	14.8-13.8-14.8		110 sets	90 sets equivalent DMU @ 130km/h	Articulated	

Country	Class	Date	Type	Power	Output Power	Wheelset	Speed	Axleload	Length	Max Tractive	Number	Total No. of	Suspension	Wheel
				Type	Continuous kW	Arrangement	km/h	tonne	m	Effort kN	of Type	Similar		Diameter
UK	Mk4	1989	Passenger Coach	n/a	n/a	n/a	200	10			353			
UK	Class 43	1976	Diesel Loco	Diesel	3.4MW per 2 power cars; 1,320kW continuous / power car	Bo-Bo	200	17.5	17.8		198			
UK	Class 66	1998	Diesel Loco	Diesel	2385	Co-Co	120	15	21.35		394	Same design used other countries	Steering bogie	
UK	Class 220	2000	DEMU	Diesel	1 x 560kW engine per vehicle (1,880kW continuous)	2 motors per vehicle	200	12t 44.5t - 48.1t	22.8 23.9m		34 x 4 car and 44 x 5 car sets			
UK	Class 221	2000	DEMU	Diesel	1 x 560kW engine per vehicle (2,350kW continuous)	2 motors per vehicle	200	14t 54.9t 58.3t	22.8 23.9m		44 x 5 car sets			
UK	Class 390	2001	High Speed Electric Trainset	25kV AC	5,100	12 traction motors per 9 car set	200 (225 max)	?	23.9	204	53 x 9 car sets		Tilting	
UK	Class 373	1992	High Speed Electric Trainset	25kV AC + 3000V and 750V DC	12,200	Bo-Bo / 2-2	300	varies (15.7t ave)	18.7-22.1		62 x 10 car + 14 x 8 car sets		Articulated	
UK	Class 375	2001	EMU	25kV AC + 750V DC	1,500kW	6 motor axles/unit	160	36.7-40.7t tare	20.4m 20.0m		1318 vehicles (mix 3/4/5 car sets)			
UK	Class 185	2006	DMU	Diesel	1 x 560kW engine per vehicle	?	160	13.75	23		51 x 3 cars sets			
UK	Class 156	1987	DMU	Diesel	1 x 213kW engine per vehicle	?	120	9.5	20		662 vehicles (mix 1/2/3 car sets)	662 includes C150 - 156		
UK	Mk3	1976 - 1984	Passenger Coach	n/a	n/a	n/a	200	9 (33.6t tare)	23		1124		BT13 bogie	

Annex 4: Potential European Representative Vehicles

Electric Loco Bo-Bo	**High Speed**	**Standard Speed**		
	Austria 1016/1116 230km/h Sweden X2 loco tilting 200km/h	Germany 152 140km/h Germany 185 140km/h Spain 1973 269 80/160km/h Sweden RC 1-7 135-160km/h France 2001 BB27000 140km/h		
Diesel Loco	**Bo-Bo**	**Co-Co**		
	Austria 2016 140km/h medium yaw stiffness Sweden T44 100km/h laden UK Class 43 HST 200km/h	Germany 1973 232 120km/h Poland SU45 120km/h UK Class 66 120km/h		
EMU	**160km/h**	**120km/h**	**Novel**	**Double Decker**
	Italy Ale/Aln 501 502 Articulated UK Class 375	Austria 1978-87 4020/7020/6020 Spain 2003 464 120km/h	Austria 4023/4024/4124 Articulated 140km/h	Sweden X40 200km/h 70t/vehicle France 20500 140km/h 70t/vehicle
DMU	**200km/h**	**160km/h**	**120km/h**	
	UK Class 220 DEMU Denmark MG/FG/FH 180km/h	France X72500 UK Class 185	Austria 5022 articulated	
High Speed Train	**Non-tilting**	**Tilting**		
	France TGV 270-320km/h Germany ICE3 330km/h Italy ETR 500 300km/h	Czech Rep Class 680 230km/h UK Class 390 225km/h		
Freight Wagon	**4-axle**	**2-axle**		
	Austria Habbinss 28-70 Sweden 100km/h laden	Austria Hbbins 24-70 Sweden 100km/h laden		
Passenger Coach	**High Speed**	**Standard Speed**	**Double Decker**	
	Austria Bmpz 29-91	Austria Bmz 21 71 Czech Rep. Type Bt 120km/h	Germany DBpza753 160km/h	

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