BS EN 15528:2015

BSI Standards Publication

Railway applications — Line categories for managing the interface between load limits of vehicles and infrastructure

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National foreword

This British Standard is the UK implementation of EN 15528:2015. It supersedes BS EN 15528:2008+A1:2012 which is withdrawn.

The UK committee draws users' attention to the distinction between normative and informative elements, as defined in Clause 3 of the CEN/CENELEC Internal Regulations, Part 3.

Normative: Requirements conveying criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted.

Informative: Information intended to assist the understanding or use of the document. Informative annexes do not contain requirements, except as optional requirements, and are not mandatory. For example, a test method may contain requirements, but there is no need to comply with these requirements to claim compliance with the standard.

When speeds in km/h require unit conversion for use in the UK, users are advised to use equivalent values rounded to the nearest whole number. The use of absolute values for converted units should be avoided in these cases. Please refer to the table below for agreed conversion figures:

INS, RST and ENE speed conversions	
km/h	**mph**
2	1
3	1
5	3
10	5
15	10
20	10
30	20
40	25
50	30
60	40
80	50
100	60
120	75
140	90
150	95
160	100
170	105
180	110
190	120
200	125
220	135
225	140
230	145
250	155
280	175
300	190
320	200
350	220
360	225

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A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Railway applications - Line categories for managing the interface between load limits of vehicles and infrastructure

Applications ferroviaires - Catégories de ligne pour la gestion des interfaces entre limites de charges des véhicules et de l'infrastructure

Bahnanwendungen - Streckenklassen zur Behandlung der Schnittstelle zwischen Lastgrenzen der Fahrzeuge und Infrastruktur

This European Standard was approved by CEN on 22 August 2015.

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European foreword

This document (EN 15528:2015) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2016, and conflicting national standards shall be withdrawn at the latest by April 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 15528:2008+A1:2012.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part of this document.

Significant technical changes between this European Standard and the previous edition are:

— Extension of the range of Line Categories

  — new Line Categories a10, a12 and a14 to cover light passenger vehicles (Urban Rail);

  — new Line Categories D5 and E6 to optimize the payload for freight wagons.

— Providing information and guidance for additional dynamic checks, for higher speeds and certain vehicle types.

— Implementation of MU-classes alternative to individual train checks.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The existing European railway infrastructure consists of elements designed for varying historical requirements. Most civil engineering railway infrastructure was built before the introduction of the Technical Specifications for Interoperability (TSIs) and the Eurocodes for the design of structures.

This European Standard defines a line classification system for infrastructure managers and railway undertakings to manage the interface between the load limits for railway vehicles and the payload limits for freight wagons and the vertical load carrying capacity of a line.

The line classification system takes into account parameters such as:

— axle load (P);

— geometrical aspects relating to the spacing of axles;

— mass per unit length (p);

— speed;

and provides a transparent method for determining whether the vertical loading characteristics of vehicles are compatible with the load carrying capacity of lines on the network.

The line classification system utilizes a suite of line categories with each line category defined in this standard by a load model.

1 Scope

This European Standard describes methods of classification of existing and new railway lines and the categorization of vehicles. The standard specifies the technical requirements for ensuring the compatibility of the interface between a vehicle and infrastructure with respect to the vertical load carrying capacity of a line. The standard is suitable for use on freight, passenger and mixed traffic lines with standard track gauge and wider than standard track gauge. It contains requirements relevant to:

— classification of the vertical load carrying capacity of railway infrastructure;

— design of railway vehicles;

— determination of payload limits of freight wagons.

A summary of the classification of infrastructure and the categorization of vehicles is given in Annex B.

The assessment of the vertical load carrying capacity of civil engineering structures, track, sub-grade and earthworks by the use of the load models defined in Annex A permits the classification of infrastructure into line categories.

This European Standard identifies on which lines vehicles are compatible to the infrastructure for regular traffic regarding vertical load effects.

Line categories are provided for:

— all traffic types;

— heavy freight traffic;

— locomotives;

— multiple units;

— lightweight passenger traffic.

Portable trolleys as defined by EN 13977 are outside the scope of this European Standard as well as the working mode of maintenance vehicles (e.g. rail mounted plant, cranes).

This European Standard does not cover the system used in Great Britain, where all lines and vehicles are classified in accordance with the RA (Route Availability) System. A guide to the equivalent categories in accordance with this European Standard is given in Annex Q.

This European Standard does not cover requirements relating to the maximum total mass or maximum length of a train.

The requirements of this European Standard do not replace any regulations related to running behaviour of vehicles described by the assessment quantities for running safety, track loading and ride characteristics (see EN 14363).

This Standard does not impose any requirements to vehicles or infrastructure, but gives guidance to a simplified management of the interface between vehicles and infrastructure.

Publication of line categories is outside the scope of this European Standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1991-2:2003, *Eurocode 1: Actions on structures — Part 2: Traffic loads on bridges*

EN 15663:2009[1)], *Railway applications — Definition of vehicle reference masses*

EN 15877-1, *Railway applications — Marking on railway vehicles — Part 1: Freight wagons*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
associated maximum speed
local maximum speed for which the line category is valid

3.1.2
axle load
P
sum of the static vertical wheel forces exerted on the track through a wheelset or a pair of independent wheels divided by *g*

Note 1 to entry: In this standard "load" and "force" are described with units of "mass" (kg or t).

3.1.3
axle load
P_i
axle load *P* of the axle *i*

3.1.4
axle spacing
design values of the distances between the centres of adjacent axles

3.1.5
bending moment
designation of an internal force of a beam as used in structural design

3.1.6
categorization of vehicles
statement of the vertical loading characteristics of a railway vehicle, according to the combination of axle loads and axle spacing, by allocation of a line category

1) This document is currently impacted by the corrigendum EN 15663:2009/AC:2010.

3.1.7
classification of infrastructure
statement of the load carrying capacity of infrastructure on a line by allocation of a line category and related speed information

3.1.8
compatibility
demonstration of the satisfactory interface between the load effects of the vehicles and the load capacity of the infrastructure

3.1.9
design mass under normal payload
mass of vehicle equipped with all the consumables and occupied by all staff, which it requires in order to fulfil its function plus the normal payload defined in EN 15663 as implemented by Annex D

3.1.10
design mass under exceptional payload
mass of vehicle equipped with all the consumables and occupied by all staff, which it requires in order to fulfil its function plus the exceptional payload defined in EN 15663 as implemented by Annex D

3.1.11
length over buffers
L
length over buffers or between coupling planes in case of no buffers

3.1.12
line category
designation of the specific load model based on reference wagons

3.1.13
line speed
general maximum speed of traffic on a route

3.1.14
load limit
maximum allowable payload for a wagon related to each line category

3.1.15
load model
defined by a specific formation of reference wagons

3.1.16
locomotive
traction vehicle that is not intended to carry a payload

Note 1 to entry: In this standard, power heads are considered as locomotives.

3.1.17
locomotive class
reference vehicle with representative locomotive parameters

3.1.18
mass per unit length
p
mass of a vehicle or unit divided by length over buffers

3.1.19
maximum passenger traffic speed/maximum freight traffic speed
additional information provided by the infrastructure manager giving the general limit to the maximum traffic speed on a line according to the type of traffic

3.1.20
reference wagon
virtual vehicle used as a module of loading for a load model defined by axle load, axle spacing and mass per unit length

3.1.21
multiple unit
MU
fixed formation or railcar that can operate as a train not intended to be reconfigured, except within a workshop environment

3.1.22
MU-group
group of MU-trains determined according to the predominant running gear within the unit (conventional bogie, articulated bogie, single axle)

3.1.23
MU-class
defined by the train parameters, axle spacing pattern and axle load within a MU-group

3.1.24
passenger carriages
vehicles without traction: coaches, restaurant cars, sleeping cars, couchettes cars, vans, driving trailers, car carriers and similar vehicles, intended to be integrated in a variable formation as passenger train

3.1.25
series of locomotives
locomotives designed to be equal (the same axle spacing and the same nominal values for mass m_{nom} and, axle loads $P_{i,\text{nom}}$)

3.1.26
shear force
designation of an internal force of a beam as used in structural design

3.1.27
special vehicles
vehicles which are designed for maintenance, inspection or renewal of infrastructure elements or for special transport purposes where the fleet is operated with a low mileage compared to normal railway vehicles including:

a) maintenance vehicles including:

   1) cranes and matching wagons;

2) on-Track Machines (see EN 14033 (all parts));

3) road rail machines (see EN 15746 (all parts));

4) demountable machines (see EN 15955 (all parts));

5) trailers (see EN 15954 (all parts));

b) monitoring and inspection vehicles, including:

1) track inspection vehicles;

2) catenary inspection vehicles;

c) special transport vehicles, including:

1) transformer transporter;

2) crucible transporters;

3) loaded wagons with more than 8 axles (UIC 502-1)

3.1.28
wheel load
Q
static vertical wheel/rail contact forces divided by g

Note 1 to entry: The terminology in this standard for “load” and “force” is used with the meaning and units of “mass” (kg or t).

3.1.29
wheel load
Q_i
wheel load Q of the axle i

3.2 Symbols and abbreviated terms

$1 + \varphi'$	Dynamic factor	—
$1 + \varphi'_{UIC}$	Limit value of the dynamic factor as defined in UIC 776–1	—
$2a^*$	Bogie spacing between pivot centres within a vehicle	m
$2a^*_{adopted}$	Adopted value of 2a* used in Annex U	m
$2a^*_{table}$	$2a^*$ value in tables of Annex U	m
$2a^*_{unit}$	$2a^*$ value of a MU unit used in Annex U	m
$2a^+$	Axle spacing in a bogie	m
$2a^+_{table}$	$2a^+$ value in tables of Annex U	m
$2a^+_{unit}$	$2a^+$ value of a MU unit used in Annex U	m
AB	Articulated bogie	Unit
a	Distance between axles	m

b	Distance from end axle to the end of the nearest coupling plane	m
c	Distance between two inside axles	m
CB	Conventional bogie	—
ETCS	Electronic Train Control System	—
HSLM	High Speed Load Model	—
d_n	Distance between axle *n* and axle (n-1)	m
g	acceleration due to gravity	9,81 m/s^2
L	Length over buffers	mm
L_Coa	Coach length	m
m	Mass	t
m_{nom}	Nominal values for mass	t
$m_{\text{nom,excess}}$	Modified nominal value for mass due to excess of tolerances	t
MU	Multiple unit	—
No_Coa	Number of coaches within a unit	—
No_Units	Number of units within a train	—
n	Axle number	—
n_0	Natural frequency	Hz
p	Mass per unit length	t/m
P	Axle load	t
P_i	Axle load of axle *i*	t
$P_{i,\text{nom}}$	Nominal value for axle load of axle *i*	t
$P_{\text{LineCategory}}$	Maximum axle load for a Line Category	t
P_{MUclass}	Maximum axle load for a MU-class	t
$P_{\text{nom,excess}}$	Modified nominal value for axle load due to excess of tolerances	t
P_{red}	Reduced value of axle load	t
P_{unit}	Maximum axle load within the unit	t
Q	Wheel load	t
Q_i	Wheel load of axle *i*	t
$Q_{i\text{r}}/Q_{i\text{l}}$	Wheel load of axle *i* right or left	t
RA	Route Availability	—
SA	Single axle	—
s_n	Distance between axle *n* and axle 1	m
$u1+u2$	Bogie spacing between pivot centres of adjacent vehicles	m
$u3$	Overhang of end coaches	m
u_{unit}	Overhang value of a MU unit used in Annex U	m
u_{table}	Overhang value in tables of Annex U	m

UIC	International Union of Railways	—
V	Speed	km/h

4 Classification system

4.1 Definition of line categories

The use of a classification system using line categories permits easy understanding of the load-related compatibility of vehicles and infrastructure.

The line category resulting from the classification process for infrastructure represents the ability of the infrastructure (track, track substructures, earthworks, civil engineering structures) to withstand the vertical loads imposed by vehicles on the line or section of line for regular service.

Each line category (a10, a12, a14, A, B1, B2, C2, C3, C4, D2, D3, D4, D5, D4xL and also E4 and E5, E6) is defined by a load model based on reference wagons defined by the characteristics given in Annex A:

— axle load;

— geometrical characteristics of the spacing of axles;

— length of the vehicle.

The value “mass per unit length” of the reference wagon is determined from the above parameters.

4.2 Correlation to types of vehicles

The load effects of different vehicle types are compared to the load models defining the different line categories.

All types of vehicles and freight wagons with their corresponding payload are covered by the line categories A, B1, B2, C2, C3, C4, D2, D3, D4.

Line categories D5, E4, E5 and E6 are defined exclusively for heavy freight wagons.

Locomotives can be covered by:

— line categories B1, B2, C2, C3, C4, D2, D3, D4 and D4xL (plus optional detailed specification for axle spacing ranges);

— locomotive classes L4 and L6.

Passenger carriages and Multiple Units can be covered by:

— line categories a10, a12, a14, B1, C2, D2 (plus optional detailed specification for axle spacing and vehicle lengths). Line categories a10, a12 and a14 have been specially developed for light rail vehicles with up to 14 t axle loads.

— MU-groups and MU-classes, which are provided to assist additional compatibility checks between infrastructure and vehicles where there is a risk of excessive dynamic effects in bridges.

For rail vehicles or wagons with payload limits categorized above D4 or D4xL it is recommended that the infrastructure manager and railway undertaking consider the use of static and dynamic wheel load measuring devices attached to the track and/or fitted to vehicles to assist with ensuring compliance with the requirements of this European Standard.

4.3 Correlation between line category and speed

4.3.1 Introduction

The classification of infrastructure applies to all types of railway vehicles, which can have different maximum speeds (e.g. freight and passenger traffic). Additional information defining the maximum speed corresponding to the line category shall be stated.

As a result of the classification of infrastructure, additional information specifying the line classification can be given to cover two or more combinations (e.g. different maximum speeds and associated line categories for passenger and freight trains).

NOTE Examples illustrating information about line classification and relationship with speed are given in Annex H.

The combinations used for publication should be in accordance with legal, technical and operational requirements (e.g. ETCS [2]) speed levels).

The local line speed shall be taken into account for the classification of engineering structures (see 5.1) and other relevant infrastructure elements (see 5.2).

The line category and associated maximum speed shall be considered as a single combined quantity.

4.3.2 Freight traffic

When classifying infrastructure lines into line categories, the line category at maximum freight traffic speed (maximum 120 km/h) shall be determined.

120 km/h corresponds to the maximum speed for conventional freight traffic and is the limit of validity for freight traffic using line categories. In excess of 120 km/h individual checks shall be carried out.

Optionally, an additional higher line category at an associated lower speed (less than the maximum freight traffic speed) may be determined.

NOTE In some situations it may be desirable to determine the line category at a lower speed to maximize the line category.

In addition, for D5, E4, E5 or E6 lines, an associated maximum speed for such traffic shall be stated together with the associated maximum speed for conventional line traffic of line category D4.

4.3.3 Mixed traffic and passenger traffic

On mixed traffic lines with passenger traffic, the line category at maximum freight traffic speed in 4.3.2 is generally sufficient and appropriate for the optimization of freight traffic.

For vehicles and locomotives, categorized into the same or lesser line category as the line, and which run faster than the maximum freight traffic speed, additional checks starting on the basis of the maximum freight traffic speed shall be taken into account for the classification of engineering structures (see 5.1) and other relevant infrastructure elements (see 5.2).

For speeds over 120 km/h and up to the maximum line speed, the different combinations of line categories-with speed shall be in accordance with general technical and operational requirements or restrictions.

NOTE Line Categories as classification information for speeds over 120 km/h may be related to vehicle types or types of traffic. Additional compatibility checks at different speed levels for different vehicle types may be required to demonstrate compatibility (see 5.1.2 and Annex F).

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2) European Train Control System.

5 Classification of infrastructure

5.1 Civil engineering structures

5.1.1 Classification

When classifying a railway line into line categories, the load carrying capacity of structures supporting the track on the line shall be determined and expressed using the load models of Annex A taking speed into account. The speed(s) and where relevant traffic types shall be in accordance with 4.2 and 4.3.

The method used to determine the load carrying capacity of structures (bridges and other structures supporting the track) shall take account of the condition of the existing structures and be in accordance with national requirements.

NOTE Examples of typical methods used to determine the load carrying capacity of structures are given in Annex G.

The assessment of the load capacity of structures shall take the following into account:

— load models and combination of vehicles shall be applied to produce the most onerous load effects (e.g. on continuous beams parts of the load model which produce a relieving effect shall be neglected);

— dynamic load effects (e.g. using the dynamic factor for real trains in EN 1991-2:2003, Annex C);

— partial safety factors for railway loading due to mass tolerances and potential overloading (see 6.2);

— existing operating and other restrictions relating e.g. to different types of traffic.

When determining the line classification and maximum operating speed for locomotives, account may be taken of the reduced likelihood of overloading and cargo displacements (in comparison with other traffic types). Any reduction in partial safety factors for railway loads should be in accordance with national requirements.

The load models defined in Annex A are for the classification of lines and are not to be used for the design of new structures. For the design of new structures the rail traffic loading given in EN 1991-2 shall be used.

The resulting output of the classification process of each structure on a line shall satisfy the requirements of Clause 4.

5.1.2 Dynamic checks

To address the potential risk of adverse bridge dynamic effects, resulting from resonance and other excessive dynamic effects in the structure, the need to carry out additional dynamic checks shall be considered according to the risk arising from the combination of vehicle type and speed.

NOTE 1 Annex F provides guidance on combinations of vehicle type and speed which do not require dynamic compatibility checks on existing bridges.

Where it is identified that dynamic checks are required:

— the maximum bridge deck accelerations under the track shall be assessed;

— allowances for the dynamic increase in load effects in the structure shall be checked (e.g. the adequacy of the dynamic factor for real trains in EN 1991-2:2003, Annex C applied to the static loading).

When investigating the dynamic response of bridges, the following parameters shall be taken into account:

— bridge parameters such as structural type, span, mass, natural frequencies, damping and stiffness, for example;

— train data such as formation of vehicles, coach lengths, axle load as specified in Annex D, and axle spacing, for example;

— speed range.

Guidance on carrying out dynamic calculations on a range of bridges is given in Annex P.

To reduce the effort of carrying out dynamic checks, a proposed train can be compared to trains or load models (MU-classes or HSLM [3)]) for which compatibility with bridges on the line has been previously demonstrated using methods which allow for dynamic effects.

Load models of MU-classes covering the dynamic excitation of different families of real individual MU's are defined in Annex E. Dynamic calculations made with these load models cover the evaluation of the effects of these families.

The results of the dynamic analysis can be used to assist the decision on the compatibility of either individual trains or MU-classes with the infrastructure.

If a proposed train is within the scope of a MU-class that has previously been demonstrated to be compatible with the infrastructure, then no further checks are needed to demonstrate compatibility (see 6.5 and Annex C). Otherwise, the normal procedure for an individual train check is required.

If infrastructure compatibility for an MU-class is not demonstrated or achieved, individual train checks can be performed to check compatibility.

NOTE 2 Annex S provides information on typical loco hauled passenger trains that may be used for dynamic checks.

5.2 Track construction, track substructure and earthworks

The load carrying capacity of the track, track substructure and earthworks shall be determined in accordance with national requirements. Typically such methods take account of the type of rail and track components, sleeper spacing, track geometry, track quality, annual tonnage of traffic, inspection and maintenance regimes and other national requirements, etc.

The limit values for cant deficiency for lines with track gauges wider than nominal track gauge may be modified according to EN 13803–1.

For E4 and E5 traffic, a maximum service speed of 100 km/h and a maximum cant deficiency of 100 mm are recommended. For E6 traffic a maximum speed of 80 km/h is recommended.

In order to establish an appropriate maximum speed for wagons with axle loads greater than 22,5 t for proposed speeds > 100 km/h, special studies should be undertaken to check the dynamic effects on the track.

The infrastructure manager shall determine the correspondence between the local track classification system and the line classification system defined in this European Standard. Annex O shows an example of the correspondence.

The results shall be used to determine the line classification in accordance with this European Standard with respect to the load carrying capacity of the track, track substructure and earthworks.

3) High speed load model defined in EN 1991-2.

5.3 Infrastructures classification results

The classification of a line or a section shall be taken as the lesser of:

— the line classification of civil engineering structures determined in accordance with 5.1;

— the line classification of track, track substructures and earthworks determined in accordance with 5.2;

— relevant associated requirements relating to speed in accordance with 5.1.2;

— other general requirements including requirements relating to maximum permitted speeds for different types of traffic and operating restrictions;

— additional qualifications relating to the validity of the line classification.

The result of infrastructure classification shall include the permissible line category(ies) and their associated maximum speed(s) of each line or section of line. If necessary, additional speed regulations and operating requirements relating to locomotives (e.g. locomotive classes and associated maximum speed) or traffic types (e.g. maximum speed of freight traffic or passenger traffic) shall be considered.

For publication and implementation, the result of the infrastructure classification due to this standard should be adjusted according to international and national requirements including legal, technical and operational requirements.

Where the line classification related to associated speed is D4xL, D5, E4, E5 or E6, the maximum speed for line category D4 shall also be stated.

NOTE Examples of line classification result are given in Annex H.

6 Categorization of railway vehicles

6.1 General rules

The categorization of a vehicle by line category or the determination of payload limits for a freight wagon defined by line category represents the static vertical load effects produced by the vehicle or freight wagon.

A vehicle is appropriate to a line category, when the static vertical load effects produced by the vehicle to be investigated are equal to or do not exceed the static load effects produced by the reference wagon (see Annex A) of this line category. The axle loads, the number of axles, the axle spacing and the length of the vehicle are required for comparison with the static load effects produced by the reference wagons.

The line category of a vehicle or the permissible payload of vehicles shall be determined such that the maximum bending moments and maximum shear forces on a single beam of any span length, and throughout the span, for any position of load across the span due to the vehicle being categorized, do not exceed the values calculated for the load models defined in Annex A. In the calculations, the vehicle being categorized shall be represented by an unlimited number of the vehicles formed into a train, unless specified differently (e.g. see 6.6).

For non-symmetric vehicles (e.g. where the end overhang at each end of the vehicle is different or the axle loads vary along the length of the vehicle) the most onerous orientation of the vehicle (or fixed formation) shall be used.

Where the vehicle(s) operate in a predefined or fixed formation, the formation (single or required number of coupled formations) shall be compared with the load models of line categories defined in Annex A (e.g. for multiple units or cranes). Two cases shall be considered: a train comprising the most onerous arrangement of the fixed formations and the fixed formation incorporated into a train of the reference wagons.

Simply supported spans from 1,0 m to 100,0 m shall be checked. The maximum span increments shall not exceed the values in Table 1.

Table 1 — Maximum span increments depending on span length

span range [m]	**maximum span increment** [m]
1,0 to 10,0	0,2
10,0 to 20,0	1,0
20,0 to 60,0	2,0
60,0 to 100,0	5,0

NOTE 1 An example of the application of the method is given in Annex I.

NOTE 2 The determination of maximum bending moments and maximum shear forces can be undertaken using influence lines or multilevel approximation methods.

Annexes J, K, L, T and U provide tables to determine the corresponding line category without any calculation, if the specified conditions are fulfilled.

The axle load distribution of each vehicle shall be determined by measurement for the load condition design mass in working order according to EN 15663 (for freight wagons, this load condition is equal to tare condition). For locomotives and passenger carrying vehicles single wheel loads shall be measured.

If any of the items (e.g. staff masses, parts of the fuel and consumables, wear of wheels) are not included in the measured weights, adjustments shall be made by calculation.

Based on the measured weight results, any missing payload components (e.g. passenger mass) up to the relevant mass condition (see Table 2 and Annex D) shall be completed by calculation.

Within a series of vehicles of the same type, the nominal values of mass m_{nom} and axle loads $P_{i,\text{nom}}$ shall be considered the same.

To determine the line category (or the locomotive class) of a vehicle type, the nominal axle loads in the load cases specified in column B of Table 2 shall be used. If all individual vehicles within the same type are within the tolerances given in columns C to D of Table 2 their compliance with the vehicle type is demonstrated.

If the tolerances used for a vehicle type exceed these acceptable tolerances, the excess load shall be added to the nominal axle load and nominal masses used for the determination of the line category for the vehicle type.

If some values of a single vehicle are outside this acceptable tolerance, the excess load shall be added to the nominal axle load and nominal masses. These new values shall be used for the determination of the line category for this single vehicle.

If a single vehicle or vehicle type is modified leading to loads outside the acceptable tolerance field, the excess load shall be added to the nominal axle load and nominal masses. These new values shall be used for the determination of the line category for the single vehicle or the vehicle type.

NOTE 3 In some of these cases an adjustment of the nominal values m_{nom} and $P_{i,\text{nom}}$ may be adequate to allow all values to satisfy the tolerances in Table 2.

NOTE 4 For freight wagons a change of tare or change of axle distribution requires a check of the payload values in the wagon load table.

Table 2 — Tolerances specified for categorization of vehicles into line categories

A	B	C	D	E
Vehicle Type	**Load case for determination of nominal values used for categorization of vehicles**	**Acceptable tolerances and deviations for the use of nominal values for categorization of vehicles**		
		Mass m	**Axle load** P_i	**Wheel load** Q_{ir} **or** Q_{il}
Wagons	Design mass under normal payload (max payloads specified in the load table of the vehicle) according to EN 15663	a	≤ 100 kg on each individual axle load a	b
Locomotives [c]	Design mass in working order according to EN 15663	≤ 3 %	≤ 3 %	≤ 5 % of the mean wheel load of each individual axle
Passenger Carriages **Multiple Units**	Design mass with payload according to Annex D	≤ 3 %	≤ 3 %	≤ 5 % [d]
Special vehicles	Self-propelled special vehicles shall be treated as locomotives, the others as a wagon. For predefined or fixed formations made up of various types of vehicles, the approach used for each vehicle in the formation shall correspond to the type of vehicle.			

[a] The tare weight of the wagon (corresponding to design mass in working order) plus the payload of the relevant line category (marked on the wagon load table), taking into account the UIC Loading Guidelines [9], generate the maximum mass and maximum axle load. The payloads of the load table shall be revised, if changes in axle load of more than 100 kg, whether as a result of technical alterations or as a change of the axle load distribution, occur.

[b] The ratio of the two wheel loads on each axle shall not exceed 10/8 = 1,25 in any loaded condition. Additionally, the sum of both wheel loads shall not exceed the axle load relevant for line category (UIC Loading Guidelines [9]).

[c] See Annex R for an example of a weight note used to assist with determining the axle loads used for categorizing locomotives.

[d] Each individual wheel load according to load condition design mass with payload according to Annex D shall not exceed 5 % of half of the maximum axle load corresponding to the relevant line category. This shall be checked taking into account the measured wheel load distribution in tare condition with a calculated allowance for payload including any eccentricity of the centre of gravity of the payload.

If the nominal values of mass or axle load or the axle arrangement of a vehicle type are changed (e.g. due to any modification in design or later), a re-categorization (or re-calculation of payload limits in the case of freight wagons) shall be undertaken. In that case compliance with tolerances for the new nominal weight and axle load shall be demonstrated by new measurements of wheel and/or axle load.

6.2 Freight wagons

6.2.1 Specific rules for freight wagons

The compatibility of freight wagons and their loads with the load capacity of lines is determined by their geometrical and load characteristics, i.e. axle spacing, axle loads and the resulting mass per unit length.

The payload limit according to line category shall be determined according to 6.1.

The maximum permissible payload and axle load for each type of wagon corresponding to each line category can be calculated as shown in Annex I. Alternatively, permissible axle loads for 4- and 6-axle wagons are given in Annex J and Annex K, which can be used to determine the maximum permitted payloads.

The above payload limits are only valid if the permissible payload is evenly distributed over the length of the wagon. In the case of longitudinally displaced or unevenly distributed loading, the payload shall be reduced, so that the value of the permissible axle load is not exceeded.

As an exception 20 t axle loads may be exceeded by up to 0,5 t on category C lines for:

— 2-axle wagons with 20 t axle loads and 14,10 m < length over buffers < 15,50 m to bring their payload up to 25 t;

— wagons designed for 22,5 t axle loads to offset the extra tare incurred in making them suitable for such axle loads;

— the maximum permissible wheel load shall be 11,1 t.

6.2.2 Resulting load limits for freight wagons

The results of the calculation of the maximum payload of a wagon for each line category determined according to 6.1 and 6.2.1 is shown in Annex I and shall be marked in the wagon load table according to EN 15877-1.

Where lower load limits are required by specific regulations (e.g. speed restrictions, braking) these lower values shall be used.

The tare of a wagon shall be rounded up to the nearest tenth of a tonne.

Groups of wagons with the same equipment shall be identified within each major manufacturing series (e.g. wagons with air brakes, wagons with air brakes and gangway fitted with a screw brake). For each group of wagons, a nominal tare value shall be determined and used in the calculations, if the tare of each wagon of this group is within the tolerances for wagons given in columns C to D of Table 2. Alternatively, the measured weight of an individual wagon can be used to determine the payload limit for the corresponding wagon.

The corresponding payload marked on the wagon load table shall be rounded down to the nearest tenth of a tonne.

6.3 Locomotives

6.3.1 General

Locomotives shall be categorized into line categories.

6.3.2 4-axle locomotives

Generally, the relevant parameters for categorization of 4-axle locomotives are axle load P (18 t to 22,5 t) and the bogie axle spacing (2,2 m to 3,4 m).

Typically the mass per unit length is less than 6,4 t/m and the distance from the end axle to the end of the nearest coupling plane is greater than 1,9 m.

Subject to satisfying the above criteria the maximum axle load determines the line category:

— line category D2: 20 *t* < maximum axle load *P* ≤ 22,5 t;

— line category C2: 18 *t* < maximum axle load *P* ≤ 20 t;

— line category B2: 16 *t* < maximum axle load *P* ≤ 18 t.

NOTE Additional L4 locomotive classes are defined in Annex M to provide greater graduation (e.g. to facilitate providing additional information indicating that a 21,0 t 4-axle locomotive is compatible with a C2 line).

6.3.3 6-axle locomotives

Generally, the relevant parameters for categorization of 6-axle locomotives are:

— the maximum axle load *P* (18 t to 22 t) in combination with;

— the distance between axles within a bogie (1,80 m to 2,25 m).

Typically, the mass per unit length (p) is less than 6,4 t/m and the distance from end axle to the end of the nearest coupling plane (a) is greater than 2,1 m.

Line categories of 6-axle locomotives according to *P* and *a* are given in Annex L.

NOTE To assist with optimizing line categories for most 6-axle locomotives, locomotive classes $L6_{19}$, $L6_{20}$, $L6_{21}$ and $L6_{22}$ are defined in Annex N.

6.4 Passenger carriages

Passenger carriages shall be categorized into line categories. Alternatively, if the vehicle parameters of the carriage satisfy the requirements given in Table 3, Table 4 can be used to identify the line category.

Table 3 — Requirements for the application of Table 4

Parameter	Parameter range
Axle spacing in bogie	1,8 m ≤ $2a^+$ ≤ 3,0 m
Bogie spacing between pivot centres	$2a^*$ ≥ 15,6 m
Overhang (distance pivot centre to coupling plane)	*u* ≥ 3,0 m

Table 4 — Corresponding line category (in combination with Table 3)

Max axle load	Line category
≤ 10,0 t	a10
≤ 12,0 t	a12
≤ 14,0 t	a14
≤ 16,0 t	A
≤ 18,0 t	B1
≤ 20,0 t	C2
≤ 22,5 t	D2

Mass condition and passenger payload for determining the line category and for checking dynamic compatibility are given in Annex D.

6.5 Multiple units

Multiple units shall be categorized into line categories. The procedure described in 6.1 can be replaced by the simple parameter check given in Annex T (especially see T.5). Typical formations of light rail MUs and the minimum values of axle geometrics are given in Annex U to provide guidance for categorization.

Mass condition and passenger payload for determining the line category and for checking dynamic compatibility are given in Annex D.

Multiple units with a maximum design speed in excess of the values in Annex F shall be checked against the train parameters covered by each MU-class in accordance with Annex C. When the multiple unit satisfies the parameters it shall be allocated to the relevant MU-class.

6.6 Special vehicles

Special vehicles shall be categorized into line categories. When determining the line category, two different cases shall be taken into account:

Case 1: a train of an unlimited number of fixed formation vehicles (or single vehicles) as appropriate;

Case 2: one single fixed formation or single vehicle as appropriate conveyed in a train of reference wagons (except reference wagons xL-a and xL-b) defined in Annex A corresponding to the line category determined from Case 1.

The categorization shall be taken as the most onerous of Case 1 and Case 2.

The line category for road-rail machines, demountable machines and trailers shall be documented in the technical documentation.

6.7 Vehicle categorization results

The result of the categorization process is shown in Table 5.

Table 5 — Categorization results

Type of vehicles	Result
Freight wagons	Payload limits
Locomotives	Line category and, where available, locomotive class
Passenger carriages	Line category
Multiple units	Line category and, if applicable MU-class (max P_{MUclass} and max v)
Special vehicles	Line category or payload limits

If vehicles or wagons and payloads cannot be categorized, being outside of the scope of the line categories defined in 6.1 in this standard, these vehicles shall be treated as individual vehicles.

The following information, being part of the technical documents of the vehicle, should be made available as it is necessary for carrying out individual checks for demonstrating the compatibility between a vehicle and infrastructure and should be recorded in the demonstration of compatibility:

— total vehicle mass (for each vehicle) and mass per axle (for each axle) for the load conditions design mass in working order and according to Annex D;

— the position of the axles along the vehicle (or fixed formation of vehicles) – axle spacing and the distance from the coupling planes to the adjacent axles;

— the length of the vehicle (or fixed formation of vehicles);

— maximum design speed of the vehicle (or fixed formation of vehicles).

7 Compatibility of the interface between vehicle and infrastructure

If the category of a vehicle (or the payload limit of a wagon) is less than or equal to the classification of the line, compatibility has been demonstrated. Requirements related to speed also form part of this validation.

The line categories of Table A.2, representing the basic line categories for all vehicles, are defined by capital letter A < B < C < D and number 1 < 2 < 3 < 4 (Exception: Line Category A has no number and is covered by all other Line Categories of Table A.2). A ranking is only possible, if both letter and number shall be less than or equal (e.g. D4 > C3, C2 > B2, C4 > B2; a ranking is not possible between some combinations for example C3 ≠ D2 or D3 ≠ C4), because the relativity of load effect varies according to span length. Rankings of other Line Categories are shown within the notes of the Tables A.3 and A.4 of Annex A.

When considering a train, the ruling case for the train shall be the vehicle with the most onerous categorization with the maximum speed of the train limited to the most restrictive speed requirement.

Freight traffic is compatible with the line if the line category corresponding to the payload of all wagons and line categories of the locomotive(s) do not exceed the line category of the line taking into account the maximum freight speed (see 4.3.2).

Passenger traffic is compatible with the line if the line categories of locomotives and coaches do not exceed the line category of the line taking into account the associated maximum speed. If necessary, additional requirements (e.g. locomotive classes, conditions for compatibility for single approvals from individual line checks) shall be taken into account.

Where compatibility using line categories cannot be demonstrated, an individual line check, taking local procedures into account, shall be performed to demonstrate compatibility.

An individual line check is necessary:

— for individual vehicles (see 5.1 and 6.7);

— if the line category of a vehicle or payload limit of a wagon exceeds the line category of the line;

— if the operating speed exceeds the associated maximum speed of the line category;

— for exceptional consignments [4)] (e.g. loaded wagons with more than 8 axles);

— for freight traffic not complying with the requirements of this European Standard.

In most cases, individual line checks require additional specific evaluations or calculations.

Where a new or different vehicle or payload is proposed that will require an individual line check, early consultation should be carried out with the infrastructure manager during the first stages of design of the vehicle and or the planning of operation to facilitate optimization of the compatibility process.

Possible results of individual line checks are:

— compatibility demonstrated;

— compatibility demonstrated subject to additional restrictions on operating speeds or loading, limitations on train formation, the use of e.g. protection wagons;

— compatibility not demonstrated, vehicle or train operation refused.

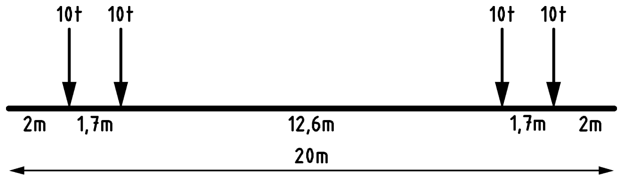
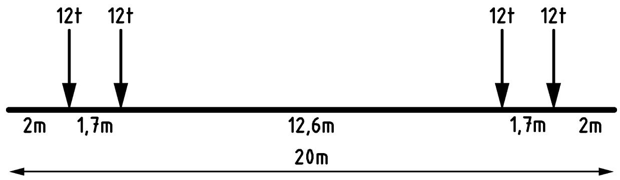
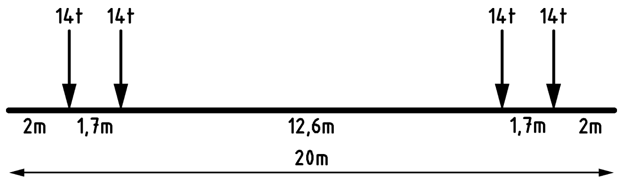
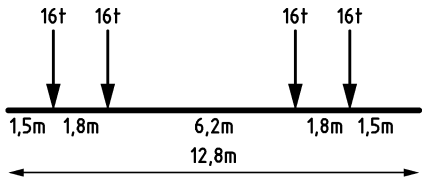
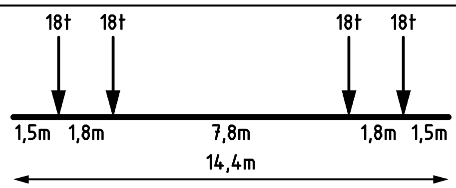
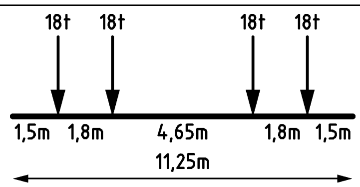
If the static approach on which the line categories are based for characterizing the interaction between vehicle formation and infrastructure is not sufficient, depending on speed, the need to carry out additional dynamic checks shall be considered to demonstrate compatibility (see 5.1.2).

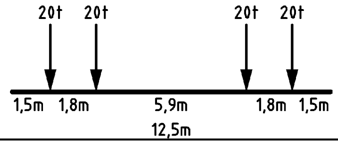
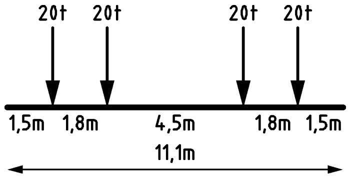
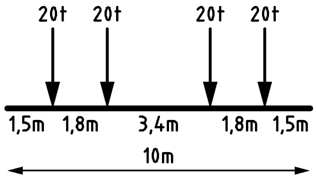
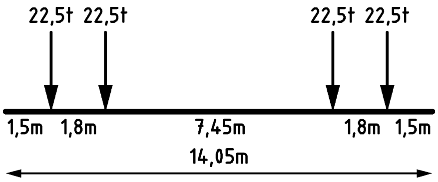
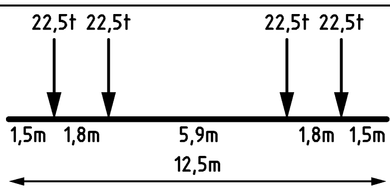
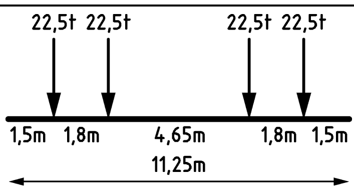
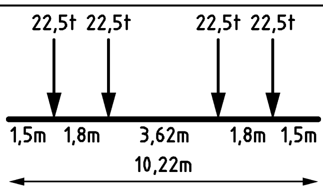
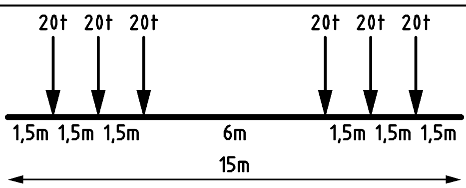
4) Exceptional consignments are defined in UIC 502-1.

Annex A
(normative)

Reference wagons and load models representing the line categories

Table A.1 — Reference wagons

Reference wagon	Axle load P (t)	Geometrical characteristics	Mass per unit length p (t/m) [a]
a10	10,0		2,0
a12	12,0		2,4
a14	14,0		2,8
A	16,0		5,0
B1	18,0		5,0
B2	18,0		6,4

Reference wagon	Axle load *P* (t)	Geometrical characteristics	Mass per unit length *p* (t/m) [a]
C2	20,0		6,4
C3	20,0		7,2
C4	20,0		8,0
D2	22,5		6,4
D3	22,5		7,2
D4	22,5		8,0
D5	22,5		8,8
xL-a	20,0		8,0

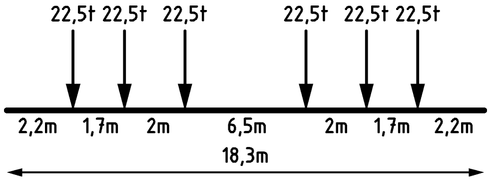
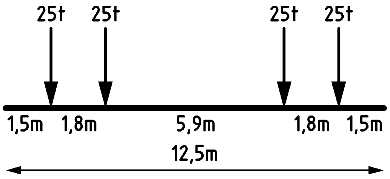
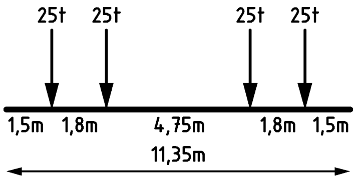
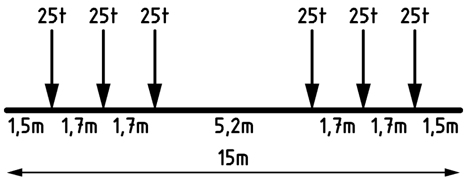
Reference wagon	**Axle load** *P* **(t)**	**Geometrical characteristics**	**Mass per unit length** *p* **(t/m)** [a]
xL-b	22,5		7,4
E4	25,0		8,0
E5	25,0		8,8
E6	25,0		10,0
Additional reference wagons may be used to manage special traffic on specific lines (e.g. reference wagon F with axle load *P* equal to 27,5 t or G with axle load *P* equal to 30,0 t).			
[a] The value for "*p*" results from the relationship: (number of axles) x *P*/(length of reference wagon). The reference wagon is defined by "*P*" and the geometrical characteristics.			

Table A.2 — Load models representing the line categories for all vehicles

Line category	**Arrangement of reference wagons** *n* **....unlimited number**
A	*n* × A 
B1	*n* × B1 
B2	*n* × B2 
C2	*n* × C2 
C3	*n* × C3 
C4	*n* × C4 
D2	*n* × D2 
D3	*n* × D3 
D4	*n* × D4 
NOTE 1 The first character, a letter, characterizes the limits for axle load and the second character, a number, characterizes the limits for mass per unit length of the corresponding reference wagon of the load model. The line categories are ranked by letter A < B < C < D and number 1 < 2 < 3 < 4. NOTE 2 D2 < D3 and C2 < D3, but D2 ≠ C3.	

Table A.3 — Load models representing the line categories for light rail vehicles

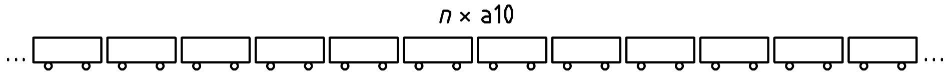
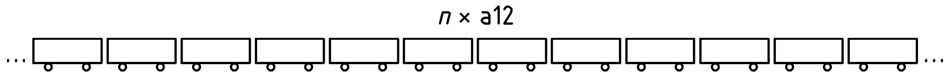
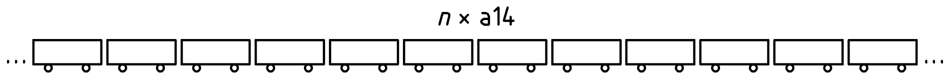
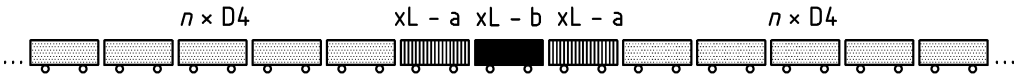
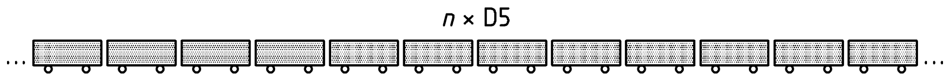
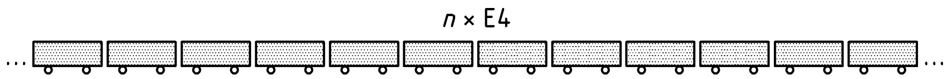
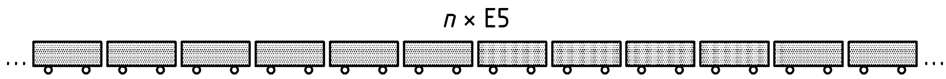
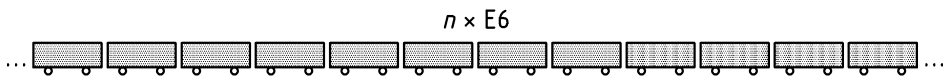
Line category	**Arrangement of reference wagons** *n* **....unlimited number**
a10	
a12	
a14	
NOTE Ranking: a10 < a12 < a14; A of Table A.2 > a10, 12, and a14.	

Table A.4 — Load models representing the line categories for specific types of vehicles

Line category	**Arrangement of reference wagons** *n* **....unlimited number**
D4xL [a]	
D5 [b]	
E4 [b]	
E5 [b]	
E6 [b]	
D4xL may be used for other types of vehicles. Special traffic may be categorized according to deviating regulations or to different line categories (e.g. line category F – 27,5 t or G – 30,0 t).	
[a] D4xL was developed for locomotives. [b] D5, E4, E5 and E6 only valid for freight wagons.	
NOTE Ranking: E4 < E5 < E6; D5 < E5 < E6; but not comparable E4 ≠ D5; D4xL is not comparable to all others; all members of Table A.4 > D4 of Table A.2.	

Annex B
(informative)

Flow chart: Classification of infrastructure and categorization of vehicles

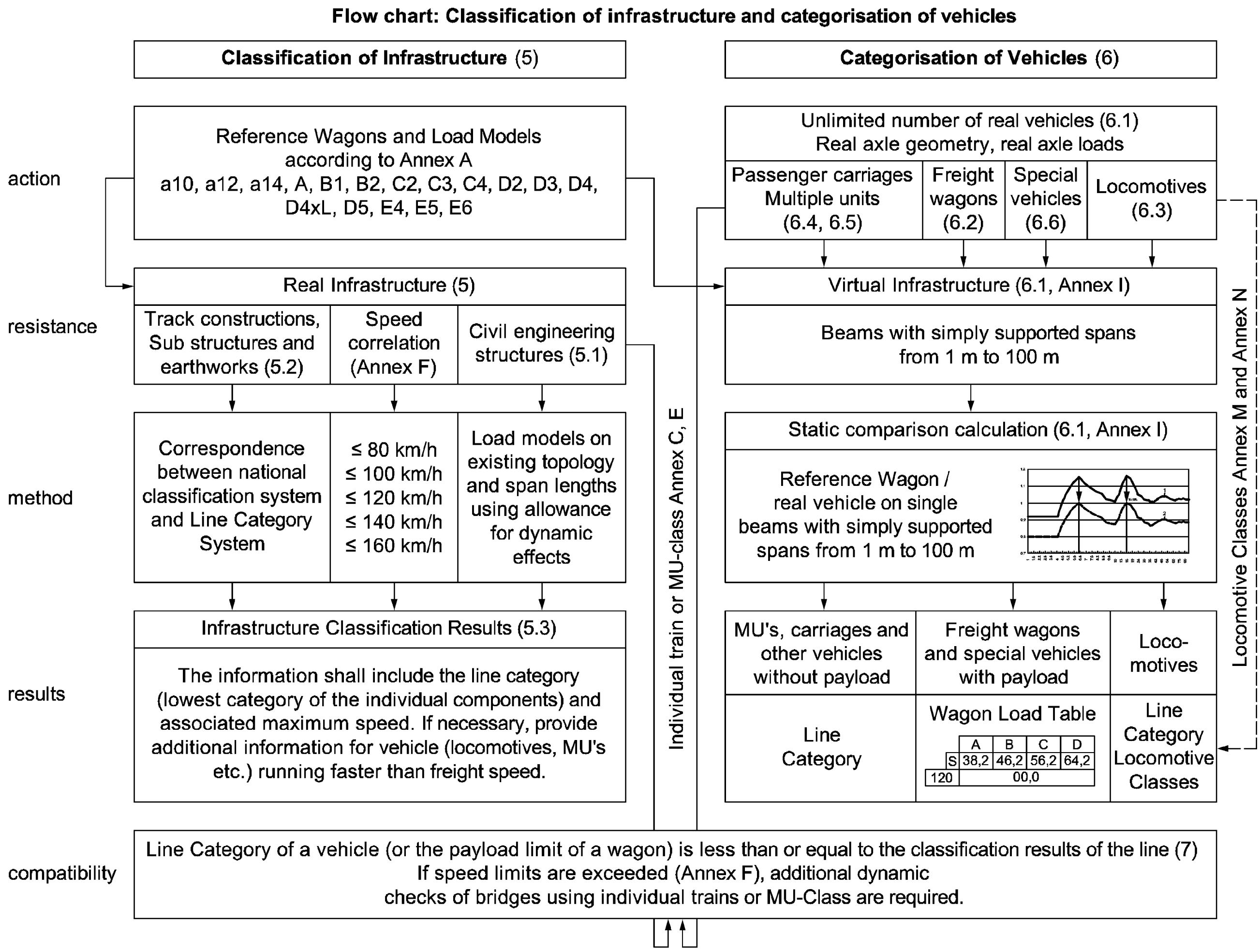


Figure B.1 — Flow chart for the classification of infrastructure and categorization of vehicles

Annex C
(informative)

MU-Groups and MU-Classes

C.1 Definition

Multiple units can be grouped according to type of traffic service (high speed – long distance, intercity – regional and commuter/suburban) or to the kind of running gear (conventional bogies, articulated bogies and single axles).

In some cases, due to potentially excessive dynamic load effects on a bridge (see 5.1 and Annex F), line category checks alone are not sufficient to demonstrate compatibility. To minimize the need for undertaking a dynamic check of individual trains, several typical and wide spread MU-designs have been grouped in MU-classes. For these groups of vehicles, load models covering the specified design parameter ranges have been developed to allow the efficient dynamic analysis of bridges. For practical reasons, the number of MU classes was limited and for trains outside the range of parameters covered, the process of checking an individual train existing at the time of publication of this standard as state of the art shall be used.

Each MU-class is defined by:

— ranges of train parameters covered and;

— a corresponding load model (see Annex E) for carrying out dynamic checks on bridges.

In this standard MUs are classified into the MU-Groups: conventional bogies (CB), articulated bogies (AB) and single axles (SA). To identify the relevant group, the end bogies of a unit shall be disregarded and the type of the majority of the remaining bogies considered. If there are the same numbers of conventional bogies and articulated bogies within the unit, correspondence to both MU-groups CB and AB shall be checked.

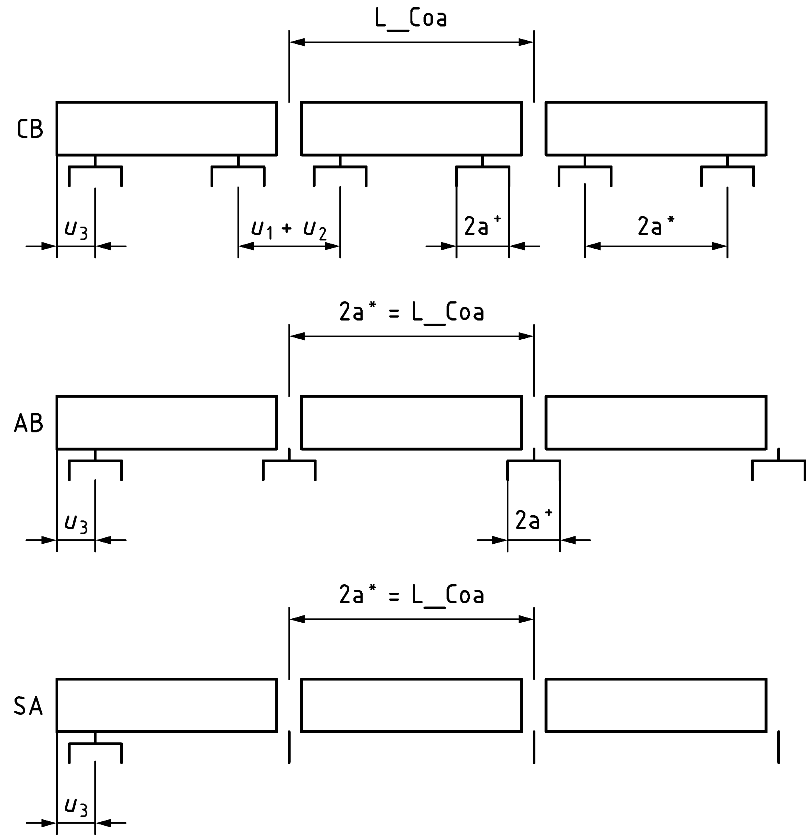
Each MU-Group comprises of several MU-Classes. Table C.1 shows the MU-Classes of each MU-Group.

Table C.1 — Relationship MU-groups – MU-classes

MU-Group	MU-Class
conventional bogie (CB)	CB_1 CB_2
articulated bogie (AB)	AB_1 AB_2 AB_3 AB_4
single axle (SA)	SA_1 SA_2
Individual trains: see Note.	

NOTE The development of the MU-classes covered most, but not all, of the known existing trains. Trains falling outside the classes are treated on an individual basis.

Figure C.1 and Table C.2 provide the definition of the relevant train parameters that determine the MU-class.



Key

CB conventional bogie

AB articulated bogie

SA single axle

Figure C.1 — Train parameters related to MU-Groups

Table C.2 — Explanation of train parameters

Name	Parameter	Unit
$2a^*$	Bogie spacing between pivot centres within a vehicle	m
$2a^+$	Axle spacing in bogie	m
$u1+u2$	Bogie spacing between pivot centres of adjacent vehicles	m
$u3$	Overhang of end coaches	m
L_Coa	Coach length	m
No_Coa	Number of coaches within a unit	-
No_Units	Number of units within a train	-

If a real MU-train fulfils the parameters of one of the following parameter sets, the allocation to this MU-class has been proved.

An example of a train check against the parameters of the MU-classes is given in C.5.

C.2 MU-Group CB

C.2.1 General

Multiple units predominantly equipped with conventional bogies are covered by the two MU-Classes CB_1 and CB_2 in MU-Group CB.

C.2.2 Train parameters of MU-Class CB_1

Table C.3 — Train parameters for conformity with MU-Class CB_1

max No_Units	2
max No_Coa	8
L_Coa	23,8 m ≤ L_Coa ≤ 25,3 m
$2a^*$	16,8 m ≤ $2a^*$ ≤ 18,0 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m
$(u1+u2)$	7,0 m ≤ $(u1+u2)$ ≤ 7,6 m
$u3$	4 m ≤ $u3$ ≤ 6 m
max axle load P	see E.3

The corresponding load model for MU-Class CB_1 is described in E.2.2.

C.2.3 Train parameters of MU-Class CB_2

Table C.4 — Train parameters for conformity with MU-Class CB_2

max No_Units	2
max No_Coa	7
L_Coa	25,3 m ≤ L_Coa ≤ 27,5 m
$2a^*$	18,0 m ≤ $2a^*$ ≤ 19,5 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m
$(u1+u2)$	7,2 m ≤ $(u1+u2)$ ≤ 8,0 m
$u3$	4 m ≤ $u3$ ≤ 6 m
max axle load P	see E.3

The corresponding load model of MU-Class CB_2 is described in E.2.3.

C.3 MU-Group AB

C.3.1 General

Multiple units predominantly equipped with articulated bogies are covered by the 4 MU-Classes AB_1, AB_2, AB_3 and AB_4 in MU-Group AB.

C.3.2 Train parameters of MU-Class AB_1

Table C.5 — Train parameters for conformity with MU-Class AB_1

max No_Units	4
max No_Coa	5
$2a^*$	14,9 m ≤ $2a^*$ ≤ 16,0 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m
$u3$	3,0 m ≤ $u3$ ≤ 5,5 m
max axle load P	see E.3

The corresponding load model of MU-Class AB_1 is described in E.2.4.

C.3.3 Train parameters of MU-Class AB_2

Table C.6 — Train parameters for conformity with MU-Class AB_2

max No_Units	4
max No_Coa	5
$2a^*$	18,8 m ≤ $2a^*$ ≤ 19,5 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m
$u3$	3,0 m ≤ $u3$ ≤ 5,5 m
max axle load P	see E.3

The corresponding load model of MU-Class AB_2 is described in E.2.5.

C.3.4 Train parameters of MU-Class AB_3

Table C.7 — Train parameters for conformity with MU-Class AB_3

max No_Units	2
max No_Coa	11
$2a^*$	17,0 m ≤ $2a^*$ ≤ 17,5 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m
$u3$	4,5 m ≤ $u3$ ≤ 5,7 m
max axle load P	see E.3

NOTE The value for 2a* of end coaches can be outside the range of Table C.7, if the number of end coaches is less than the number of mid coaches.

The corresponding load model of MU-Class AB_3 is described in E.2.6.

C.3.5 Train parameters of MU-Class AB_4

Table C.8 — Train parameters for conformity with MU-Class AB_4

max No_Units	2
max No_Coa	10
2a*	18,7 m ≤ 2a* ≤ 19,2 m
2a^+	2 m ≤ 2a^+ ≤ 3 m
u**3**	4,3 m ≤ u3 ≤ 5,3 m
max axle load P	see E.3

NOTE The value for 2a* of end coaches can be outside the range of Table C.7, if the number of end coaches is less than the number of mid coaches.

The corresponding load model of MU-Class AB_4 is described in E.2.7.

C.4 MU-Group SA

C.4.1 General

Multiple units predominantly equipped with single axles are covered by the 2 MU-Classes SA_1 and SA_2 in MU-Group SA.

C.4.2 Train parameters of MU-Class SA_1

Table C.9 — Train parameters for conformity with MU-Class SA_1

max No_Units	3
max No_Coa	10
2a*	9,2 m ≤ 2a* ≤ 9,8 m
u**3**	4,25 m ≤ u3 ≤ 6,25 m
max axle load P	see E.3

The corresponding load model of MU-Class SA_1 is described in E.2.8.

C.4.3 Train parameters of MU-Class SA_2

Table C.10 — Train parameters for conformity with MU-Class SA_2

max No_Units	2
max No_Coa	14
2a*	12,8 m ≤ 2a* ≤ 13,5 m
u**3**	4,25 m ≤ u3 ≤ 6,25 m
max axle load P	see E.3

The corresponding load model of MU-Class SA_2 is described in E.2.9.

C.5 Example: Correspondence check of a real MU-train to MU-classes

C.5.1 General

The following procedure sets out how a real MU-train can be correlated with one of the MU-groups and MU-classes defined in this Annex.

C.5.2 General description of the real MU-train to be checked

The train formation and the relevant parameters are described in Figure C.2 and Table C.11.

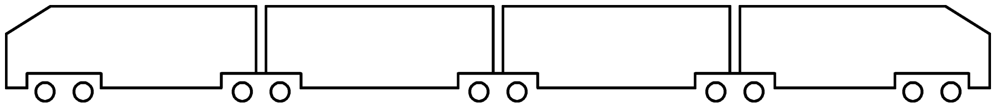


Figure C.2 — Train parameters related to MU-Groups

Table C.11 — Unit parameters

Length of the unit	85,8 m
Number of coaches	4
Max. number of coupled units	4
Length of mid coach	19,0 m
Length of end coach	23,9 m
$2a^{+}$	2,8 m
$2a^{*}$	19,0 m
$u3$	4,9 m
Maximum speed	200 km/h
maximum $P_{LineCategory}$ [a]	21,0 t
maximum $P_{MUclass}$ [a]	19,4 t

[a] $P_{LineCategory}$ and $P_{MUclass}$ according to the mass definitions of Annex D.

C.5.3 MU-group identification

The example MU-train has 2 conventional bogies and 3 articulated bogies. After disregarding the end bogies the majority (in this case all) of the bogies are articulated. This train falls into MU-Group AB (see Table C.1).

C.5.4 MU-class identification

The example MU-train corresponds to MU-Class AB_2 as shown in Table C.12.

Table C.12 — Checking correspondence to MU-Class AB_2

Train parameters	Limits for MU-class AB_2 [a]	Values of the real MU-train
No_Units	max 4	4
No_Coa	max 5	4
$2a^*$	18,8 m ≤ $2a^*$ ≤ 19,5 m	19,0 m
$2a^+$	2 m ≤ $2a^+$ ≤ 3 m	2,8 m
$u3$	3,0 m ≤ $u3$ ≤ 5,5 m	4,9 m

[a] According to Table C.6.

C.5.5 Results

The example MU-train described in C.5.2, that is categorized in line category D2 also corresponds to MU-class AB_2 (P_{MUclass} 19,4 t and 200 km/h).

C.5.6 Example of infrastructure compatibility check

In the following Table C.13 some examples of possible line information and investigation of the compatibility of the example real MU-train with infrastructure are described.

Table C.13 — Examples of compatibility of the real MU-train with line information

Example	Line information	compatibility of the real MU-train
1	**AB_2-**$P_{19,0}$ −250	not demonstrated [a]
2	**AB_2-**$P_{21,5}$ −160	demonstrated up to max 160 km/h [b]
3	**AB_2-**$P_{21,5}$ −200	demonstrated
4	**AB_2-**$P_{20,0}$ −200	demonstrated

[a] Individual train check required to demonstrate compatibility.

[b] Individual train check required to demonstrate compatibility for speeds above 160 km/h.

Annex D
(normative)

Mass definitions for line category and dynamic compatibility check for passenger carriages and multiple units

For the compatibility check between infrastructure and rolling stock the following mass definitions for the relevant axle loads shall be used:

— design mass under exceptional payload according to EN 15663 for the categorization into Line Category (see 6.1);

— design mass under normal payload according to EN 15663 where dynamic checks are required for checking vehicle/bridge compatibility (see 5.1 and Annex E),

taking the values for passenger payload in standing areas as shown in Table D.1 into account.

Table D.1 — Passenger payload in standing areas in kg/m²

Type of trains	**Normal payload** to determine Dynamic Compatibility	**Exceptional Payload** to determine Line Category
High speed and long distance trains EN 15663:2009, Table 3	160 [a]	320
High speed and long distance trains Reservation Obligatory EN 15663:2009, Table 3	0	320
Others (regional, commuter, suburban trains) EN 15663:2009, Table 4	280	500 [b]

[a] Normal payload of EN 15663:2009, Table 3 and additional 160 kg/m² for standing areas.

[b] In extreme circumstances higher values for passenger payload in standing areas shall be taken into account.

Annex E
(informative)

Load models corresponding to MU-classes

E.1 General

Load models corresponding to each of the MU-classes have been developed for carrying out dynamic checks on bridges.

If compatibility can be demonstrated on all bridges along a line or line section according to the load model of a specific MU-class, all MU trains satisfying the parameters of this MU-class (see Annex C) are compatible.

Each load model of a MU-class is defined by the axle spacing pattern (see E.2) and the axle load P_{MUclass} (see E.3). Where MU-classes are used to describe infrastructure capability, additional information shall be given concerning the associated maximum speed.

E.2 Geometric axle configuration

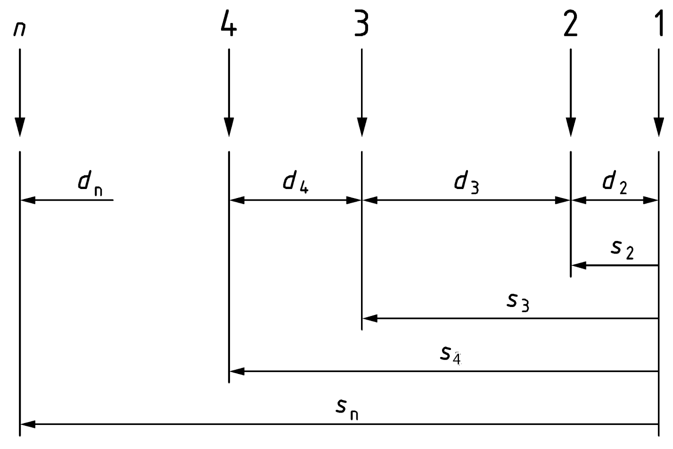
E.2.1 General

The axle spacing pattern of each MU-class is defined by:

— number of axles; and

— axle distances.

Figure E.1 gives an explanation about the following tables.



Key

n axle number *n* (axle No)

d_n distance (m) between axle number n and axle number (*n*-1)

s_n sum (m) – distance between axle number *n* and axle number 1

Figure E.1 — Axle spacing pattern

E.2.2 Axle spacing pattern of MU-Class CB_1

Table E.1 — Axle spacing pattern of MU-class CB_1 (64 axles)

CB_1			CB_1		
Axle No	**distance** [m]	**sum** [m]	**Axle No**	**distance** [m]	**sum** [m]
1	0,0	0,0	**33**	5,0	196,7
2	3,0	3,0	**34**	3,0	199,7
3	14,2	17,2	**35**	14,2	213,9
4	3,0	20,2	**36**	3,0	216,9
5	4,3	24,5	**37**	4,3	221,2
6	3,0	27,5	**38**	3,0	224,2
7	14,2	41,7	**39**	14,2	238,4
8	3,0	44,7	**40**	3,0	241,4
9	4,3	49,0	**41**	4,3	245,7
10	3,0	52,0	**42**	3,0	248,7
11	14,2	66,2	**43**	14,2	262,9
12	3,0	69,2	**44**	3,0	265,9
13	4,3	73,5	**45**	4,3	270,2
14	3,0	76,5	**46**	3,0	273,2
15	14,2	90,7	**47**	14,2	287,4
16	3,0	93,7	**48**	3,0	290,4
17	4,3	98,0	**49**	4,3	294,7
18	3,0	101,0	**50**	3,0	297,7
19	14,2	115,2	**51**	14,2	311,9
20	3,0	118,2	**52**	3,0	314,9
21	4,3	122,5	**53**	4,3	319,2
22	3,0	125,5	**54**	3,0	322,2
23	14,2	139,7	**55**	14,2	336,4
24	3,0	142,7	**56**	3,0	339,4
25	4,3	147,0	**57**	4,3	343,7
26	3,0	150,0	**58**	3,0	346,7
27	14,2	164,2	**59**	14,2	360,9
28	3,0	167,2	**60**	3,0	363,9
29	4,3	171,5	**61**	4,3	368,2
30	3,0	174,5	**62**	3,0	371,2
31	14,2	188,7	**63**	14,2	385,4
32	3,0	191,7	**64**	3,0	388,4

E.2.3 Axle spacing pattern of MU-Class CB_2

Table E.2 — Axle spacing pattern of MU-class CB_2 (56 axles)

CB_2			CB_2		
Axle No	**distance** [m]	**sum** [m]	**Axle No**	**distance** [m]	**sum** [m]
1	0,0	0,0	**29**	5,0	189,0
2	3,0	3,0	**30**	3,0	192,0
3	16,0	19,0	**31**	16,0	208,0
4	3,0	22,0	**32**	3,0	211,0
5	5,0	27,0	**33**	5,0	216,0
6	3,0	30,0	**34**	3,0	219,0
7	16,0	46,0	**35**	16,0	235,0
8	3,0	49,0	**36**	3,0	238,0
9	5,0	54,0	**37**	5,0	243,0
10	3,0	57,0	**38**	3,0	246,0
11	16,0	73,0	**39**	16,0	262,0
12	3,0	76,0	**40**	3,0	265,0
13	5,0	81,0	**41**	5,0	270,0
14	3,0	84,0	**42**	3,0	273,0
15	16,0	100,0	**43**	16,0	289,0
16	3,0	103,0	**44**	3,0	292,0
17	5,0	108,0	**45**	5,0	297,0
18	3,0	111,0	**46**	3,0	300,0
19	16,0	127,0	**47**	16,0	316,0
20	3,0	130,0	**48**	3,0	319,0
21	5,0	135,0	**49**	5,0	324,0
22	3,0	138,0	**50**	3,0	327,0
23	16,0	154,0	**51**	16,0	343,0
24	3,0	157,0	**52**	3,0	346,0
25	5,0	162,0	**53**	5,0	351,0
26	3,0	165,0	**54**	3,0	354,0
27	16,0	181,0	**55**	16,0	370,0
28	3,0	184,0	**56**	3,0	373,0

E.2.4 Axle spacing pattern of MU-Class AB_1

Table E.3 — Axle spacing pattern of MU-class AB_1 (60 axles)

AB_1		
Axle No	distance [m]	sum [m]
1	0,0	0,0
2	2,0	2,0
3	14,0	16,0
4	2,0	18,0
5	14,0	32,0
6	2,0	34,0
7	14,0	48,0
8	2,0	50,0
9	14,0	64,0
10	2,0	66,0
11	14,0	80,0
12	2,0	82,0
13	6,0	88,0
14	2,0	90,0
15	14,0	104,0
16	2,0	106,0
17	14,0	120,0
18	2,0	122,0
19	14,0	136,0
20	2,0	138,0
21	14,0	152,0
22	2,0	154,0
23	14,0	168,0
24	2,0	170,0
25	6,0	176,0
26	2,0	178,0
27	14,0	192,0
28	2,0	194,0
29	14,0	208,0
30	2,0	210,0

AB_1		
Axle No	distance [m]	sum [m]
31	14,0	224,0
32	2,0	226,0
33	14,0	240,0
34	2,0	242,0
35	14,0	256,0
36	2,0	258,0
37	6,0	264,0
38	2,0	266,0
39	14,0	280,0
40	2,0	282,0
41	14,0	296,0
42	2,0	298,0
43	14,0	312,0
44	2,0	314,0
45	14,0	328,0
46	2,0	330,0
47	14,0	344,0
48	2,0	346,0
49	6,0	352,0
50	2,0	354,0
51	14,0	368,0
52	2,0	370,0
53	14,0	384,0
54	2,0	386,0
55	14,0	400,0
56	2,0	402,0
57	14,0	416,0
58	2,0	418,0
59	14,0	432,0
60	2,0	434,0

E.2.5 Axle spacing pattern of MU-Class AB_2

Table E.4 — Axle spacing pattern of MU-class AB_2 (48 axles)

AB_2		
Axle No	**distance** [m]	**sum** [m]
1	0,0	0,0
2	2,0	2,0
3	17,5	19,5
4	2,0	21,5
5	17,5	39,0
6	2,0	41,0
7	17,5	58,5
8	2,0	60,5
9	17,5	78,0
10	2,0	80,0
11	17,5	97,5
12	2,0	99,5
13	6,0	105,5
14	2,0	107,5
15	17,5	125,0
16	2,0	127,0
17	17,5	144,5
18	2,0	146,5
19	17,5	164,0
20	2,0	166,0
21	17,5	183,5
22	2,0	185,5
23	17,5	203,0
24	2,0	205,0

AB_2		
Axle No	**distance** [m]	**sum** [m]
25	6,0	211,0
26	2,0	213,0
27	17,5	230,5
28	2,0	232,5
29	17,5	250,0
30	2,0	252,0
31	17,5	269,5
32	2,0	271,5
33	17,5	289,0
34	2,0	291,0
35	17,5	308,5
36	2,0	310,5
37	6,0	316,5
38	2,0	318,5
39	17,5	336,0
40	2,0	338,0
41	17,5	355,5
42	2,0	357,5
43	17,5	375,0
44	2,0	377,0
45	17,5	394,5
46	2,0	396,5
47	17,5	414,0
48	2,0	416,0

E.2.6 Axle spacing pattern of MU-Class AB_3

Table E.5 — Axle spacing pattern of MU-class AB_3 (56 axles)

AB_3		
Axle No	**distance** [m]	**sum** [m]
1	0,0	0,0
2	3,0	3,0
3	11,0	14,0
4	3,0	17,0
5	3,0	20,0
6	3,0	23,0
7	15,5	38,5
8	2,0	40,5
9	15,5	56,0
10	2,0	58,0
11	15,5	73,5
12	2,0	75,5
13	15,5	91,0
14	2,0	93,0
15	15,5	108,5
16	2,0	110,5
17	15,5	126,0
18	2,0	128,0
19	15,5	143,5
20	2,0	145,5
21	15,5	161,0
22	2,0	163,0
23	15,5	178,5
24	3,0	181,5
25	3,0	184,5
26	3,0	187,5
27	11,0	198,5
28	3,0	201,5

AB_3		
Axle No	**distance** [m]	**sum** [m]
29	7,0	208,5
30	3,0	211,5
31	11,0	222,5
32	3,0	225,5
33	3,0	228,5
34	3,0	231,5
35	15,5	247,0
36	2,0	249,0
37	15,5	264,5
38	2,0	266,5
39	15,5	282,0
40	2,0	284,0
41	15,5	299,5
42	2,0	301,5
43	15,5	317,0
44	2,0	319,0
45	15,5	334,5
46	2,0	336,5
47	15,5	352,0
48	2,0	354,0
49	15,5	369,5
50	2,0	371,5
51	15,5	387,0
52	3,0	390,0
53	3,0	393,0
54	3,0	396,0
55	11,0	407,0
56	3,0	410,0

E.2.7 Axle spacing pattern of MU-Class AB_4

Table E.6 — Axle spacing pattern of MU-class AB_4 (56 axles)

AB_4			AB_4		
Axle No	**distance** [m]	**sum** [m]	**Axle No**	**distance** [m]	**sum** [m]
1	0,0	0,0	**29**	7,0	222,0
2	3,0	3,0	**30**	3,0	225,0
3	11,0	14,0	**31**	11,0	236,0
4	3,0	17,0	**32**	3,0	239,0
5	3,0	20,0	**33**	3,0	242,0
6	3,0	23,0	**34**	3,0	245,0
7	17,0	40,0	**35**	17,0	262,0
8	2,0	42,0	**36**	2,0	264,0
9	17,0	59,0	**37**	17,0	281,0
10	2,0	61,0	**38**	2,0	283,0
11	17,0	78,0	**39**	17,0	300,0
12	2,0	80,0	**40**	2,0	302,0
13	17,0	97,0	**41**	17,0	319,0
14	2,0	99,0	**42**	2,0	321,0
15	17,0	116,0	**43**	17,0	338,0
16	2,0	118,0	**44**	2,0	340,0
17	17,0	135,0	**45**	17,0	357,0
18	2,0	137,0	**46**	2,0	359,0
19	17,0	154,0	**47**	17,0	376,0
20	2,0	156,0	**48**	2,0	378,0
21	17,0	173,0	**49**	17,0	395,0
22	2,0	175,0	**50**	2,0	397,0
23	17,0	192,0	**51**	17,0	414,0
24	3,0	195,0	**52**	3,0	417,0
25	3,0	198,0	**53**	3,0	420,0
26	3,0	201,0	**54**	3,0	423,0
27	11,0	212,0	**55**	11,0	434,0
28	3,0	215,0	**56**	3,0	437,0

E.2.8 Axle spacing pattern of MU-Class SA_1

Table E.7 — Axle spacing pattern of MU-class SA_1 (39 axles)

SA_1		
Axle No	**distance** [m]	**sum** [m]
1	0,0	0,0
2	2,5	2,5
3	9,5	12,0
4	9,5	21,5
5	9,5	31,0
6	9,5	40,5
7	4,5	45,0
8	9,5	54,5
9	9,5	64,0
10	9,5	73,5
11	9,5	83,0
12	9,5	92,5
13	2,5	95,0
14	10,0	105,0
15	2,5	107,5
16	9,5	117,0
17	9,5	126,5
18	9,5	136,0
19	9,5	145,5
20	4,5	150,0

SA_1		
Axle No	**distance** [m]	**sum** [m]
21	9,5	159,5
22	9,5	169,0
23	9,5	178,5
24	9,5	188,0
25	9,5	197,5
26	2,5	200,0
27	10,0	210,0
28	2,5	212,5
29	9,5	222,0
30	9,5	231,5
31	9,5	241,0
32	9,5	250,5
33	4,5	255,0
34	9,5	264,5
35	9,5	274,0
36	9,5	283,5
37	9,5	293,0
38	9,5	302,5
39	2,5	305,0

E.2.9 Axle spacing pattern of MU-Class SA_2

Table E.8 — Axle spacing pattern of MU-class SA_2 (46 axles)

SA_2		
Axle No	**distance** [m]	**sum** [m]
1	0,0	0,0
2	2,0	2,0
3	11,0	13,0
4	2,0	15,0
5	3,0	18,0
6	2,0	20,0
7	11,0	31,0
8	13,0	44,0
9	13,0	57,0
10	13,0	70,0
11	13,0	83,0
12	13,0	96,0
13	13,0	109,0
14	13,0	122,0
15	13,0	135,0
16	13,0	148,0
17	13,0	161,0
18	11,0	172,0
19	2,0	174,0
20	3,0	177,0
21	2,0	179,0
22	11,0	190,0
23	2,0	192,0

SA_2		
Axle No	**distance** [m]	**sum** [m]
24	7,0	199,0
25	2,0	201,0
26	11,0	212,0
27	2,0	214,0
28	3,0	217,0
29	2,0	219,0
30	11,0	230,0
31	13,0	243,0
32	13,0	256,0
33	13,0	269,0
34	13,0	282,0
35	13,0	295,0
36	13,0	308,0
37	13,0	321,0
38	13,0	334,0
39	13,0	347,0
40	13,0	360,0
41	11,0	371,0
42	2,0	373,0
43	3,0	376,0
44	2,0	378,0
45	11,0	389,0
46	2,0	391,0

E.3 Axle load $P_{MUclass}$

In addition to the load pattern (see E.2) axle loads $P_{MUclass}$ shall be defined.

The axle load value shall be taken as the maximum for the design mass under normal payload in accordance with Annex D. All axle loads within the MU-load model shall be taken as equal.

Four levels of values for $P_{MUclass}$ are recommended in Table E.9.

Table E.9 — Levels of axle load $P_{MUclass}$

Level	$P_{MUclass}$ [t]
$P_{21,5}$	21,5
$P_{19,0}$	19,0
$P_{17,0}$	17,0
$P_{15,0}$	15,0

The infrastructure manager may define alternative values for $P_{MUclass}$, (e.g. to assist with optimization and avoidance of individual train checks).

Table E.10 provides information about the relationship between the maximum values of $P_{LineCategory}$ and $P_{MUclass}$.

Table E.10 — Relationship max $P_{LineCategory}$ – max $P_{MUclass}$

Line Category	max $P_{LineCategory}$ [t]	max $P_{MUclass}$ [t]
D2	22,5	21,5
C2	20,0	19,0
B1	18,0	17,0
A	16,0	15,0

NOTE The values in Table E.10 represent maximum values. It is possible that a D2-MU-train having $P_{LineCategory}$ 20,8 t may have 19,0 t $P_{MUclass}$.

E.4 Results and basic information

If all bridges on a line or a section of a line are demonstrated being dynamically compatible using the MU-load models the following information shall be stated:

— MU class;

— level of $P_{MUclass}$; and

— maximum line speed.

This information complements the line category classification results.

Table E.11 shows an example.

Table E.11 — Examples of basic information

Example	Line category speed [km/h]	MU-class – speed [km/h]
1	D2 – 120	**CB_1-**$P_{21,5}$ – 160, **AB_3-**$P_{19,0}$ – 250
2	C2 – 120	**SA_1-**$P_{19,0}$ – 160, **AB_2-**$P_{17,0}$ – 200

Annex F
(informative)

Speeds which do not require dynamic compatibility checks

Table F.1 gives guidance on the relationship between Line Category/Locomotive Class, vehicle type and maximum speed, where the verification of compatibility does not require additional dynamic checks.

Table F.1 — Speed limit (in km/h) in relationship Line Category/Locomotive Class and vehicle type

Line category Locomotive class	Freight wagon	Locomotive	Passenger carriage	Multiple unit	Special vehicle
a10 [a]	-	-	-	-	-
a12 [a]	-	-	-	-	-
a14 [a]	-	-	-	-	-
A	120	120 [b] / 160	160 [c]	160 [c]	120
B1	120	120 [b] / 160	160 [c]	160 [c]	120
B2	120	120 [b] / 160	-	-	120
C2	120	120 [b] / 160	140 [c]	140 [c]	120
C3	120	120	-	-	120
C4	120	120	-	-	120
D2	120	120 [b] / 160	120 [c]	120 [c]	120
D3	120	120	-	-	120
D4	120	120	-	-	120
D4xL	120 [d]	120	-	-	120 [d]
D5	100	-	-	-	100
E4	100	-	-	-	100
E5	100	-	-	-	100
E6	80	-	-	-	80
L4	-	120 [b] / 160	-	-	-
L6	-	120	-	-	-

[a] Light railways – normal operating speeds are generally significantly less than the speed at which additional dynamic checks would need to be considered.

[b] Three or more adjacent coupled locomotives.

[c] Additional limits for max "*p*" see Table F.2.

[d] Option.

Table F.2 — Max values for *p* (t/m) for passenger carriages and MUs

Line category	A	B1	C2	D2
max *p*	2,45	2,75	3,10	3,50

Annex G
(informative)

Methods used to determine the load carrying capacity of existing structures

Methods typically used to determine the load carrying capacity of structures include:

— recalculation of structural capacity taking into account structural configuration and details, the condition of the structure, the distribution of load effects, material properties, the load capacity of structural elements, other safety related criteria and structural performance criteria;

— comparison of the original design loading specification with the load effects generated by the load models taking into account dynamic effects, together with allowances as necessary for the condition of structures and advances in predicting the load carrying capacity of structures;

— in the absence of data from bridge recalculations or information on the original design loading specification, engineering judgement may be used to assign the structure a line category on the basis of its current condition and behaviour under the line category of vehicles regularly using the structure for a significant period at up to the same speed.

The methodology used should be in accordance with national requirements.

Annex H
(informative)

Line classification result

H.1 General

Depending on the option used for taking speed into account, the results may not be sufficient for the intended operations. When this occurs, consideration may be given to determining a higher line category at a reduced speed to reduce the need for individual line checks. Similarly, where the maximum speed of operation is not sufficient, consideration may be given to determining a reduced line category at higher speeds to reduce the need for individual line checks.

Line classifications relating to locomotives may be expressed in accordance with the load models defined in Annex A or the locomotive classes defined in Annex M and Annex N.

The following examples illustrate some of the options for providing information on infrastructure capability to assist the checking of compatibility between rolling stock and the infrastructure of a route:

H.2 Example 1

Traffic type:	Mixed traffic
Line speed:	90 km/h
Max freight traffic speed:	90 km/h
Published information	D4 (map)
Additional:	-
Optional:	E4–60
	D4xL-90

H.3 Example 2

Traffic type:	Mixed traffic
Line speed:	120 km/h
Max freight traffic speed:	100 km/h
	(Published and documented in the network statement, infrastructure register or other industry document)
Published information	C4 (map)
Additional:	information for locomotives, coaches and MU for speeds greater than 100 km/h
	e.g. D2 or $L4_{22,5}$ (derived from national regulations)
Optional:	D4–80
	D4xL-60

H.4 Example 3

Traffic type:	Mixed traffic
Local line speed:	160 km/h
Max freight traffic speed:	120 km/h
	(Published and documented in the network statement, infrastructure register or other industry document)
Published information	D4 (map)
Additional:	information for locomotives, coaches and MU for speeds greater than 120 km/h
	e.g. Loco: D2 or $L4_{22,5}$
	MU: CB_1-$P_{21.5}$ – 160, CB_2-$P_{21.5}$ – 160
Optional:	E4–100
	D4xL-120

The speed associated with a line classification may be lower than the maximum line speed as published by the infrastructure manager.

The implementation should be in accordance with operational and technical requirements. Typical associated requirements relating to speed, may include consideration of the maximum permitted speed of the various vehicles in the train, limits on the speed of a train from operating requirements, and published requirements correlating line category with associated maximum speed for the infrastructure.

To satisfy legal, technical and operational requirements relating to speed (e.g. ETCS and permitted speed levels), the result and possible combinations due to this standard may be adapted or reduced for implementation.

Annex I
(informative)

Example of calculation methodology

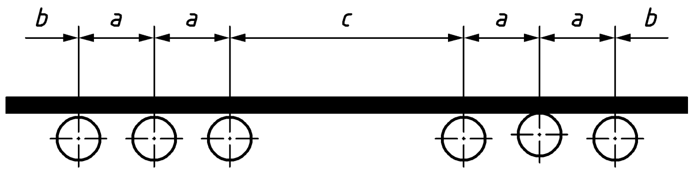
I.1 General

This annex shows how to categorize vehicles into line categories and how to calculate the load limit table of a freight wagon.

Step 1: Wagon data

The vehicle manufacturer shall provide the relevant information for the vehicle or wagon to be categorized (geometrical characteristics, tare weight, individual axle loads in tare condition, individual maximum axle loads for the vehicle in accordance with this standard, in this example when the wagon is fully laden).

The example in this annex considers a wagon with two 3-axled bogies.



Key

a distance between axles (1,8 m)

b distance from end axle to the end of the nearest coupling plane (1,5 m)

c distance between the two inside axles (6,7 m)

Tare weight	39 t (all axle loads 6,5 t for empty wagon)
Load limit of wagon	99 t
Fully laden weight	(in this example 99 t + 39 t = 138 t, all axle loads 23 t)

Figure I.1 — Wagon with two 3-axled bogies

Step 2: Calculation

Assemble a train with an unlimited number of six axle wagons as illustrated in Figure I.2.

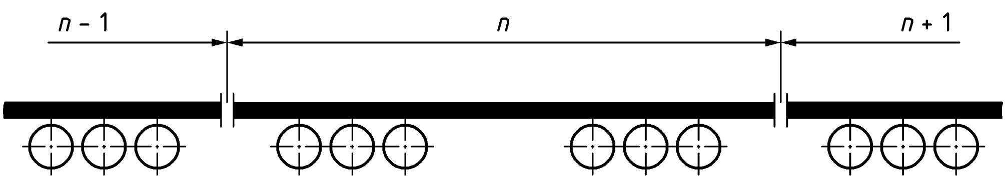


Figure I.2 — Typical train assembly with an unlimited number of wagons (full loaded – 23,0 t axle loads)

The maximum bending moments and maximum shear forces in simply supported beams with spans in the range from 1 m to 100 m due to this assembled train of wagons are calculated and compared to the values of maximum bending moment and maximum shear forces respectively due to the load models of each line category according to 6.1.

Table I.2 and Table I.3 show the calculated values of the maximum bending moments and maximum shear forces for each span compared to the corresponding values due to load model E4. In column “full/E4” the resulting values, named “E4 factor”, are stated and the maximum value is identified: Table I.2 “E4-factor” 1,159 at 16,0 m span and Table I.3 1.111 at 14,0 m span.

For the laden vehicle to be compatible with line category E4, for example, the load effects from the train of wagons for each span shall be less than or equal to the values produced by load model E4.

Figure I.3 and Figure I.5 show graphically the data comparing the train of wagons with the load model E4.

Step 3: Load limit table

In this example the train of wagons values exceed the E4 values with a maximum “E4 factor” of 1,159 at a span of 16,0m.

To be compatible with line category E4, the maximum total weight of the wagon is therefore reduced (by 1/1,159) from 138 t to 119 t. The payload limit for E4 is 80,0 t (119 t minus 39 t tare weight).

Table I.1 — Load limit table

	A	B1	B2	C2	C3	C4	D2	D3	D4	D4xL	E4	E5
											80,0 t	

The values in Table J.1 and Table K.1 may be used as an auxiliary tool producing approximate results. More precise values may be determined using the method defined in Clause 6 and illustrated in this annex.

NOTE The resulting payload value for E4 using Table K.1 is 78 t (19,5 t multiplied by 6, minus 39 t tare weight).

The values for the other line categories are obtained using the same method.

Other existing wagon restrictions, relating to the maximum speed of the wagon and UIC Loading Guidelines (concentrated loading, eccentric loading), may result in further reductions to the maximum permitted payloads.

I.2 Tables of calculation results for example in Annex I

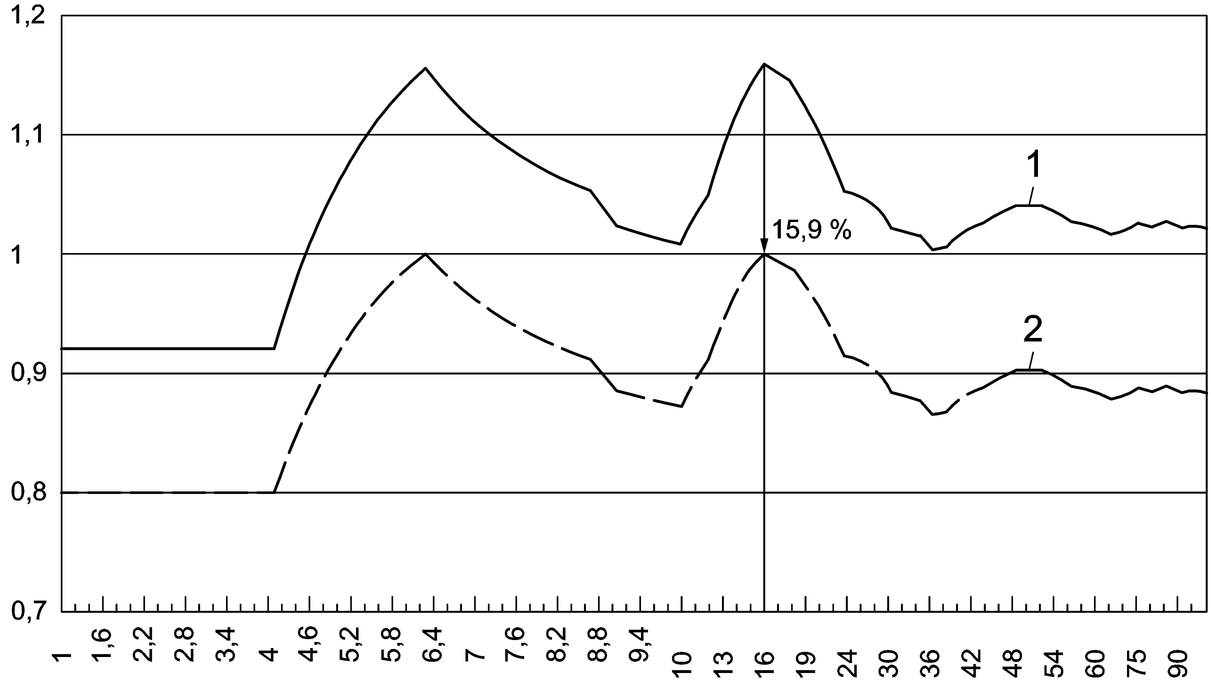
Table I.2 — Maximum bending moments

Span [m]	**E4** [tm × 10]	**empty** [tm × 10]	**full** [tm × 10]	**full/E4**
5,6	493	156	552	1,119
5,8	517	166	586	1,133
6,0	542	176	621	1,146
6,2	567	185	655	1,155
6,4	605	195	690	1,141
6,6	642	205	724	1,128
6,8	679	214	759	1,117
13,0	2 093	641	2 267	1,083
14,0	2 340	737	2 608	1,115
15,0	2 588	834	2 950	1,140
16,0	2 840	930	3 291	**1,159**
17,0	3 152	1 027	3 634	1,153
18,0	3 472	1 124	3 976	1,145
19,0	3 844	1 220	4 318	1,123

Table I.3 — Maximum shear forces

Span [m]	E4 [t × 10]	empty [t × 10]	full [t × 10]	full/E4
4,2	392	111	394	1,005
4,4	397	115	408	1,026
4,6	402	119	420	1,044
4,8	406	122	431	1,062
5,0	420	125	442	1,051
5,2	430	128	451	1,050
5,4	439	130	460	1,047
11,0	694	209	740	1,067
12,0	725	224	794	1,094
13,0	754	235	833	1,105
14,0	789	248	877	**1,111**
15,0	833	257	911	1,093
16,0	866	264	933	1,078
17,0	906	273	965	1,065

I.3 Diagram of calculation results for example in Annex I

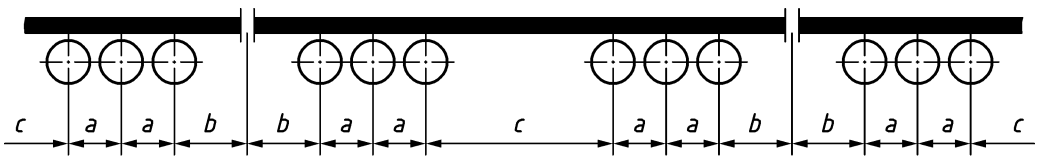


Key

1 full/E4

2 wagons loaded with payload corresponding to E4

Figure I.3 — Ratio of bending moments in simply supported beams with spans from 1 m to 100 m; maximum bending moment of loaded wagons/maximum bending moment for E4



NOTE Wagon with two 3-axle bogies where, a = 1,8 m / b = 1,5 m / c = 6,7 m, tare weight = 39 t, maximum load limit of wagon = 99 t, wagon fully laden = 138 t, and axle load = 23 t.

Key

a distance between axles

b distance from end axle to the end of the nearest coupling plane

c distance between the two inside axles

Figure I.4 — Wagon with two 3-axled bogies

Key

1 full/E4

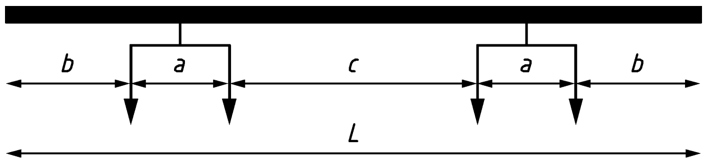
2 wagons loaded with payload corresponding to E4

Figure I.5 — Ratio of shear forces in simply supported beams with spans from 1 m to 100 m; maximum shear force of loaded wagons/maximum shear force for E4

Annex J
(informative)

Maximum permissible axle load *P* – Wagons with two 2-axles bogies

Maximum permissible axle load *P* for the various line categories in relation to the dimensions *a* and *b*.



Key

a distance between axles

b distance from end axle to the end of the nearest coupling plane

c distance between the two inside axles

L wagon length over buffers

Figure J.1 — Wagon with two 2-axled bogies

Table J.1 — Maximum permissible axle load *P* for the various line categories in relation to the dimensions *a* and *b*

Values of dimensions		Line categories						
a [m]	b [m]	A [t]	B2 B1 [t]	C4 C3 C2 [t]	D5 D4 D3 D2 [t]	D4xL [t]	E4 E5 [t]	E6 [t]
1,80	1,50	16,0	18,0	20,0	22,5	22,5	25,0	25,0
	1,40	15,0	17,0	19,0	21,5	22,5	24,0	25,0
	1,30	14,5	16,5	18,5	20,5	22,0	23,0	25,0
	1,20	14,0	16,0	17,5	20,0	21,5	22,0	25,0
1,70	1,50	15,0	17,0	19,0	21,5	22,5	23,5	25,0
	1,40	15,0	17,0	19,0	21,0	22,0	23,5	25,0
	1,30	14,0	16,0	18,0	20,0	21,5	22,5	25,0
	1,20	14,0	15,5	17,5	19,5	21,0	21,5	24,0
1,60	1,50	14,5	16,0	18,0	20,5	21,0	22,5	23,5
	1,40	14,5	16,0	18,0	20,0	21,0	22,5	23,5
	1,30	14,0	15,5	17,5	20,0	21,0	22,0	23,5
	1,20	13,5	15,0	17,0	18,5	20,5	21,0	23,0
1,50	1,50	13,5	15,5	17,0	19,5	20,0	21,0	22,5
	1,40	13,5	15,5	17,0	19,5	20,0	21,0	22,5
	1,30	13,5	15,5	17,0	19,0	20,0	21,0	22,5
	1,20	13,0	14,5	17,0	18,0	20,0	20,5	22,5
1,40	1,50	13,0	14,5	16,5	18,5	19,0	20,0	21,5
	1,40	13,0	14,5	16,5	18,5	19,0	20,0	21,5
	1,30	13,0	14,5	16,5	18,5	19,0	20,0	21,5
	1,20	13,0	14,5	16,5	18,5	19,0	20,0	21,5
1,30	1,50	12,5	14,0	15,5	17,5	18,5	18,5	20,0
	1,40	12,5	14,0	15,5	17,5	18,5	18,5	20,0
	1,30	12,5	14,0	15,5	17,5	18,5	18,5	20,0
	1,20	12,5	14,0	15,5	17,5	18,5	18,5	20,0

The axle loads shown in the above table are only valid, if:

— the distance between the two inside axles is greater than double the distance from the end axle to the end of the nearest buffer ($c > 2 \cdot b$). If this is not the case, the dimension b is instead taken as the value $c/2$ or the nearest value below according to Table J.1. If $c/2 < 1{,}20$ m, a calculation is required (see 6.1) and

— the wagon length over buffers L is such that the mass per unit length p falls within the line category under consideration. Otherwise the permissible axle load is lower and is equal to $p \cdot L/4$.

EXAMPLE 1

Wagon with two 2-axled bogies (a = 1,62 m, b = 1,43 m, c = 7,30 m, Tare weight 28,22 t)

Load limit is determined according to line category C3:

1) Check if $c > 2 \cdot b$ (7,3 > 2·1,43) and if $c/2 > 1,2$ (7,3/2 > 1,2);

2) a and b values are rounded down to the first decimal place (1,62 to 1,60; 1,43 to 1,40);

3) The value of P from the table for a = 1,60 and b = 1,40 and C3 is 18,0 t;

4) Check mass per unit length $4 \cdot P/(2\cdot(a + b) + c) \leq 7,2$ t/m, (4 · 18,0/(2·(1,62 + 1,43) + 7,3) = 5,37 < 7,20 t/m;

5) The payload limit according to C3 is 4 · P-Tare (rounded up to the tenth of a tonne), 4 · 18 - 28,3 = 43,7 t.

Due to the fact that the table is an auxiliary tool, the result of 43,7 t is an approximation. The calculated result according to 6.1 is 44,4 t.

EXAMPLE 2

Wagon with two 2-axled bogies (a = 1,45 m, b = 1,23 m, c = 2,93 m, Tare weight 20,30 t)

Load limit is determined according to line category D5:

1) Check if $c > 2 \cdot$ b (2,93 > 2·1,45) and if $c/2 > 1,2$ (2,93/2 > 1,2); **OK**

2) a and b values are rounded down to the first decimal place (1,45 to 1,40; 1,23 to 1,20);

3) The value of P from the table for a = 1,40 and b = 1,20 and D5 is 18,5 t;

4) Check mass per unit length $4 \cdot P/ (2\cdot(a + b) + c) \leq 8,8$ t/m (4 · 18,5/(2·(1,45 + 1,23) + 2,93) = 8,93 **>** 8,80 t/m) **not OK**; → table value P needs to be reduced:

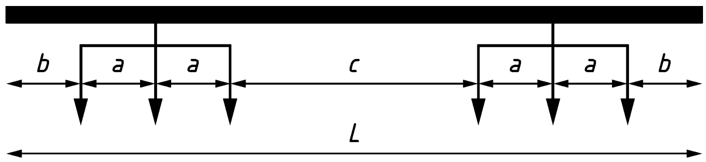
5) P_{red} = 8,8/8,93 · 18,5 = 18,2 (rounded down to the first decimal place)

6) The payload limit according to D5 is 4 · P_{red} - Tare (rounded up to the tenth of a tonne) 4 · 18,2 - 20,3 = 52,5 t.

Annex K
(informative)

Maximum permissible axle load *P* – Wagons with two 3-axles bogies

Maximum permissible axle load *P* for the various line categories in relation to the dimensions *a* and *b*.



Key

a distance between axles

b distance from end axle to the end of the nearest coupling plane

c distance between the two inside axles

L wagon length over buffers

Figure K.1 — Wagons with two 3-axled bogies

Table K.1 — Maximum permissible axle load *P* for the various line categories in relation to the dimensions *a* and *b*

Values of dimensions		Line categories													
a [m]	*b* [m]	**A** [t]	**B1** [t]	**B2** [t]	**C2** [t]	**C3** [t]	**C4** [t]	**D2** [t]	**D3** [t]	**D4** [t]	**D4xL** [t]	**D5** [t]	**E4** [t]	**E5** [t]	**E6** [t]
1,80	1,50	12,5	13,5	14,0	16,0	16,0	16,0	17,0	18,0	18,0	21,0	18,0	19,5	20,0	25,0
	1,40	12,5	13,5	14,0	15,5	16,0	16,0	17,0	17,5	18,0	20,5	18,0	19,0	20,0	25,0
	1,30	12,0	13,0	14,0	15,0	16,0	16,0	16,5	17,0	18,0	20,0	18,0	19,0	19,5	24,0
	1,20	12,0	13,0	14,0	15,0	15,5	16,0	16,5	17,0	17,5	20,0	17,5	18,5	19,0	23,5
1,70	1,50	12,5	13,5	13,5	15,5	15,5	15,5	17,0	17,5	17,5	20,5	17,5	19,0	19,5	25,0
	1,40	12,0	13,0	13,5	15,0	15,5	15,5	16,5	17,0	17,5	20,0	17,5	19,0	19,5	24,0
	1,30	12,0	13,0	13,5	15,0	15,5	15,5	16,0	17,0	17,5	20,0	17,5	18,5	19,0	23,5
	1,20	12,0	13,0	13,5	14,5	15,5	15,5	16,0	16,5	17,0	19,5	17,0	18,0	18,5	22,5
1,60	1,50	12,0	13,5	13,5	15,0	15,0	15,0	16,5	16,5	16,5	20,0	17,0	19,0	19,0	23,0
	1,40	12,0	13,0	13,5	15,0	15,0	15,0	16,0	16,5	16,5	20,0	17,0	18,5	19,0	22,5
	1,30	11,5	13,0	13,5	14,5	15,0	15,0	16,0	16,5	16,5	19,5	16,5	18,0	18,5	22,5
	1,20	11,5	12,5	13,5	14,0	15,0	15,0	15,5	16,0	16,5	18,5	16,5	18,0	18,0	21,5
1,50	1,50	11,5	13,0	13,0	14,5	14,5	14,5	16,0	16,0	16,0	20,0	16,5	18,0	18,0	21,0
	1,40	11,5	13,0	13,0	14,5	14,5	14,5	16,0	16,0	16,0	19,0	16,5	18,0	18,0	21,0
	1,30	11,5	12,5	13,0	14,5	14,5	14,5	15,5	16,0	16,0	18,5	16,0	17,5	18,0	21,0
	1,20	11,5	12,5	13,0	14,0	14,5	14,5	15,5	16,0	16,0	18,0	16,0	17,5	18,0	20,5
1,40	1,50	11,0	12,5	12,5	14,0	14,0	14,0	15,5	15,5	15,5	18,0	16,0	17,5	17,5	20,0
	1,40	11,0	12,5	12,5	14,0	14,0	14,0	15,5	15,5	15,5	18,0	16,0	17,5	17,5	20,0
	1,30	11,0	12,5	12,5	14,0	14,0	14,0	15,5	15,5	15,5	18,0	15,5	17,5	17,5	20,0
	1,20	11,0	12,5	12,5	14,0	14,0	14,0	15,5	15,5	15,5	17,5	15,5	17,0	17,5	19,5
1,30	1,50	10,5	12,0	12,0	13,5	13,5	13,5	15,0	15,0	15,0	17,0	15,5	17,0	17,0	18,5
	1,40	10,5	12,0	12,0	13,5	13,5	13,5	15,0	15,0	15,0	17,0	15,5	17,0	17,0	18,5
	1,30	10,5	12,0	12,0	13,5	13,5	13,5	15,0	15,0	15,0	17,0	15,5	17,0	17,0	18,5
	1,20	10,5	12,0	12,0	13,5	13,5	13,5	15,0	15,0	15,0	17,0	15,5	17,0	17,0	18,5

The axle loads shown in the above table are only valid, if:

— the distance between the two inside axles is greater than double the distance from the end axle to the end of the nearest buffer ($c > 2 \cdot b$). If this is not the case, the dimension b is taken instead as the value $c/2$ or the nearest value below shown in the table. If $c/2 < 1{,}20$ m, a calculation is required (see 6.1); and

— the wagon length L between buffers is such that the mass per unit length p falls within the line category under consideration. Otherwise the permissible axle load is lower and is equal to $p \cdot L/6$.

EXAMPLE

Wagon with two 3-axled bogies (a = 1,80 m, b = 1,50 m, c = 6,70 m, Tare weight 39,00 t)

Load limit is determined according to Line Category E4

1) Check if $c > 2 \cdot b$ (6,70 > 2·1,50) and if $c/2 > 1,2$ (6,70/2 > 1,2);

2) a and b values are rounded down to the first decimal place (1,80 to 1,80; 1,50 to 1,50);

3) The value of P from the table for a = 1,80 and b = 1,50 and E4 is 19,5 t;

4) Check mass per unit length $6 \cdot P/(2 \cdot (b + \mathbf{2}a) + c) \leq 8,0$ t/m;
(6·19,5/(2·(1,50 + 2·1,80)) + 6,70) = 6,90 < 8,00 t/m);

5) The payload limit according to E4 is 6·P-Tare (rounded up to the tenth of a tonne) 6·19,5 - 39,0 = 78,0 t.

Due to the fact that the table is an auxiliary tool, the result of 78,0 t is an approximation. The calculated result according to 6.1 is 80,0 t.

Annex L
(informative)

Line categories of 6-axle locomotives

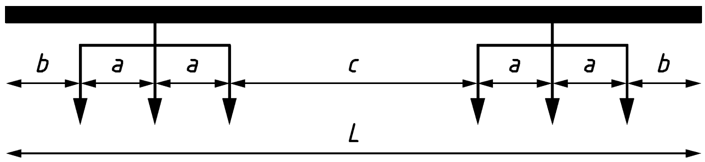
To avoid the calculation according to 6.1, Table L.1 provides the appropriate Line Categories for 6-axle locomotives.

Table L.1 is only valid, if the parameters of the locomotive to be checked are within the following limits:

— $b \geq 2{,}1$ m; and

— $c \geq 2 \cdot b$; and

— $c \geq 6 \cdot P$ / 6,4 t/m − $(4 \cdot a + 2 \cdot b)$.



Key

a distance between axles

b distance from end axle to the end of the nearest coupling plane

c distance between the two inside axles

L length over coupling planes

Figure L.1 — 6-axle locomotive

For intermediate or different values, the higher value for "*P*" and the lower value for "*a*" shall be used with Table L.1.

Table L.1 — Line Category of 6-axle locomotives

Axle load *P* / Distance *a*	18 t	19 t	20 t	21 t	22 t	22,5 t
1,50 m	D4xL	D4xL	D4xL	--	--	--
1,60 m	D4xL	D4xL	D4xL	--	--	--
1,70 m	D4xL	D4xL	D4xL	D4xL	--	--
1,80 m	D4xL	D4xL	D4xL	D4xL	D4xL	--
1,90 m	D3	D4xL	D4xL	D4xL	D4xL	D4xL
2,00 m	D3	D3	D4xL	D4xL	D4xL	D4xL
2,10 m	D2	D3	D3	D4xL	D4xL	D4xL
2,20 m	C2	D3	D3	D4xL	D4xL	D4xL

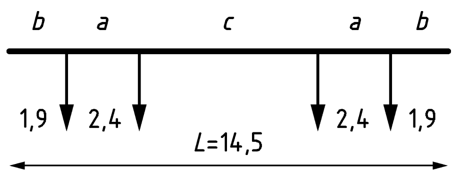
Annex M
(informative)

L4 locomotive classes (4-axle locomotives)

4-axle locomotives with intended equal axle loads can be categorized into L4-locomotive classes without calculation methodology providing the values *L*, *a* and *b* of the real locomotive are greater than or equal to the values shown in Table M.1. If the value $c < 2 \cdot b$, the dimension *b* shall instead be taken as the value $c/2$. In this case *c* shall be greater than or equal to 3,8 m.

The axle load *P*, relevant for categorization rounded up to half a tonne (xx,x), completes the exact notation of the L4-class.

Table M.1 — L4 locomotive classes

Locomotive class	**Axle load** *P*	**Geometrical characteristics**
L4xx,x [a]	≤ 22,5 t	

[a] **Xx,x** = axle load *P* (t) relevant for categorization rounded up to half a tonne.
a = distance between axles (m)
b = distance from end axle to the end of the nearest coupling plane (m)
c = distance between the two inside axles (m)
L = length over buffers (m)

L4-classes are useful for optimizing passenger train speed. The infrastructure manager may provide additional line information (see example in Annex F) including L4-locomotive classes.

The correspondence between L4-locomotive classes and line categories is:

— $L4_{22,5}$ to $L4_{20,5}$ fit within line categories D2, D3, D4, D4xL;

— $L4_{20,0}$ to $L4_{18,5}$ fit within line categories C2, C3, C4;

— $L4_{18,0}$ and below 18 t fit within line categories B1 and B2.

EXAMPLE Locomotive: P = 21,3 t, L = 16,06 m, a = 2,90 m, b = 2,58 m, c = 5,10 m

Check: L > 14,5 m, a > 2,4 m, b > 1,9 m, $c < 2b$, c > 3,8 m ⇨ $L4_{21,5}$

This locomotive is categorized in D2 and can also be $L4_{21,5}$. If the published line information is given as “D2 – 120 km/h” and “$L4_{21,5}$ – 140 km/h” the locomotive class may optimize the passenger train speed in this case.

Annex N
(informative)

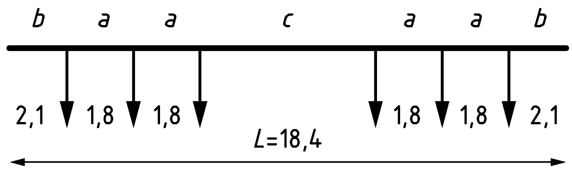
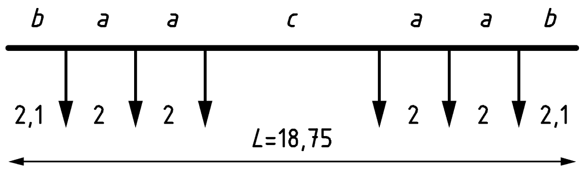
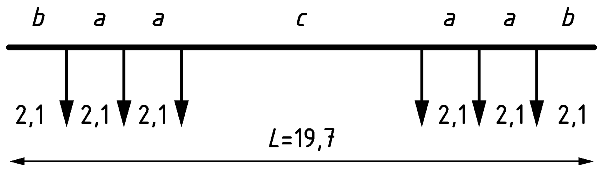
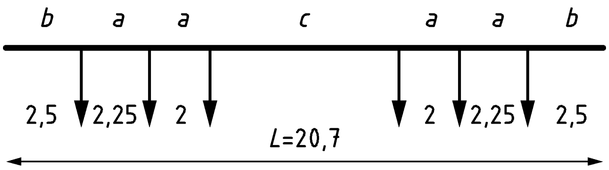
L6 locomotive classes (6-axle locomotives)

6-axle locomotives with Intended equal axle loads can be categorized into L6-locomotive classes without calculation process providing the values *L*, *a* and *b* of the real locomotive shall be greater than or equal to the values of relevant locomotive class shown in Table N.1. If the value $c < 2 \cdot b$, the dimension *b* shall instead be taken as the value $c/2$. In this case **c** shall be greater than or equal to $2 \cdot b$.

The axle load *P*, relevant for categorization rounded up to a tonne (xx), fixes and determines the L6-class.

Compared to L4-classes there is a given number of L6-classes as shown in Table N.1.

Table N.1 — L6 locomotive classes

Locomotive class	Axle load *P*	Mass per unit length *p*	Geometrical characteristics
L6$_{19}$	19,0 t	6,2 t/m	
L6$_{20}$	20,0 t	6,4 t/m	
L6$_{21}$	21,0 t	6,4 t/m	
L6$_{22}$	22,0 t	6,4 t/m	

a distance between axles (m)
b distance from end axle to the end of the nearest coupling plane (m)
c distance between the two inside axles (m)
L length over buffers (m)

L6-classes are useful for optimizing locomotive speeds. The infrastructure manager may provide additional line information including L6-classes.

EXAMPLE Locomotive: P = 19,8 t, L = 18,8 m, a = 2,45 m, b = 2,15 m, c = 4,7 m

Check: L > 18,75 m, a > 2,0 m, b > 2,1, c > 2 b ⇨ $L6_{20}$

This locomotive is categorized in D2 and can also be $L6_{20}$. If the published line information for passenger service is given like "C2 – 120 km/h" and "$L4_{20}$ – 120 km/h" the locomotive class optimizes the line acceptance of 6-axle locos.

Annex O
(informative)

Example of correspondence between a national track classification system and line categories

Table O.1 — National track classification

Track classification	Minimum track equipment	
	Rail profile "Vignole" [kg/m]	Sleeper spacing [mm]
3	36	750
	40	750
4 a	41	710
	41	650
	46	750
	46	700
	46	670
	46	620
4 b	46	600
5	≥ 50	600

Table O.2 — Correspondence between national track classification system and line categories depending on speed

Line category	Track classification	Axle load	Mass per unit length
C4	3, 4a, 4b, 5	20 t	8,0 t/m
D4	3, 4a, 4b, 5	22,5 t	8,0 t/m

Table O.3 — Operating conditions and different units consisting of line category and associated maximum speed

Track classification	Maximum permitted speed		Maximum axle load		Additional conditions (Minimum track equipment for the maximum permitted speed)		Line category
	Passenger train [km/h]	Freight train [km/h]	Passenger train (locomotive) [t]	Freight train (freight car) [t]	Rail profile "Vignole" [kg/m]	Sleeper spacing [mm]	
3	95		20		41	720	**C4/D4**
		50 [b]		20	36	750	
		50		20	40	750	
		60		20	41	750	
		30/40 [a]		22,5	36	750	
		30/40 [b]		22,5	40	750	
		50		22,5	41	720	
4a	115		21,6		46	670	**C4/D4**
		60		20	41	710	
		70 [b]		20	46	750	
		80		20	46	670	
		90 [a]		20	46	620	
		60		22,5	41	650	
		60		22,5	46	700	
		70		22,5	46	670	
		80 [b]		22,5	46	620	
4b	160		20		46	580/600	**C4/D4**
	135		21		46	600	
		90		20	46	600	
		100		20	50	670	
		80		22,5	46	600	
5	200		22,5		50	600	**D4**
		160 [c]		16	50	600	
		140 [c]		18	50	600	
		120		20	50	600	

Track classification	Maximum permitted speed		Maximum axle load		Additional conditions (Minimum track equipment for the maximum permitted speed)		Line category
	Passenger train [km/h]	Freight train [km/h]	Passenger train (locomotive) [t]	Freight train (freight car) [t]	Rail profile "Vignole" [kg/m]	Sleeper spacing [mm]	
		120		22,5	50	600	
		100		22,5	50	620	
		100		22,5	55	670	

[a] If monthly average freight tonnage ≤ 20 000 t.

[b] If monthly average freight tonnage ≤ 120 000 t.

[c] Light freight service > 120 km/h due to individual checks (see 4.3.2).

Annex P
(informative)

Parametric studies for dynamic analysis

P.1 Nature and objective

Dynamic analysis of traffic actions on railway bridges may be necessary, especially at higher speeds, in order to check that the response does not exceed allowable design values, in terms of deflections, accelerations or other mechanical performance limits. This may require individual computations with different degrees of detail, as well as experimental measures and calibration of the models.

A first step towards the dynamic analysis of bridges on a given railway line may be performed by parametric analyses. The aim of these studies shall identify the characteristics of bridges with a potential risk of excessive dynamic response by means of simplified dynamic models covering the range of bridge parameters on a given network/line. These bridges may then be checked further in a second stage using more detailed individual analysis methods to establish which bridges are compatible with the proposed operation and those which would need upgrading. This Annex provides some guidance and a representative example..

P.2 Parameters to consider

Two basic classes of parameters should be considered:

1) *Range of bridges:* e.g. bridge typology (e.g. whether simply supported or not, including torsion), bridge span (L), fundamental frequency (n_0), mass per unit length ($\overline{m}$), stiffness (whether bending, shear or torsional), damping etc.

2) *Range of trains and associated speeds:* collection of individual real trains, train classes (MU classes, see Annex C and Annex E), High speed load model (HSLM-A, HSLM-B, as defined in EN 1991-2).

P.3 Methods and assumptions

As the number of cases to study may be large, the analysis methods for the first stages of the studies should be simple in order to allow a quick evaluation in order to establish an appraisal in a reasonable time. The assumptions should also be clearly stated in order to permit a judgement regarding the validity of the approximation and conservatism of the evaluation for each case. As an example some options may include the following. General guidance for dynamic analysis is provided in EN 1991-2:2003, 6.4.

1) *Solution method*. The dynamic analysis should be carried out performing a time history solution of the equations. This may be performed on discretized structural models of bridges using Finite Element software, either by direct integration of the full equations or by modal analysis of a reduced set of significant modes of vibration. Alternatively modal analysis may also be performed directly on the structural dynamics equations for simple bridges (e.g. simply supported or homogeneous continuous beams). Adequate consideration should be given to the refinement of the spatial discretization, to the number of vibration modes included in the model, and to the time-step employed in the time marching solution.

2) *Traffic loads.* Models with moving loads for each axle are generally a conservative and sufficiently approximate option, neglecting the vibration of vehicle masses on primary or secondary

suspension, as well as the inertial effect of non-suspended mass (e.g. wheelsets). For short spans the effect of load distribution by the track supports on the deck can be significant and may be incorporated into the moving load model by representing each axle by three point loads split 1:2:1. Finally, depending on the relative dynamic characteristics of the bridge and the vehicle dynamic interaction effects may be included. These may incorporate non-suspended masses as well as masses attached to primary or secondary suspension, with appropriate dynamic models.

3) *Structural model*. The most basic models include only bending response on straight line beams with simple supports. More detailed models may additionally include axial and shear deformation, and torsional and three-dimensional effects.

4) *Damping*. The values, defined in EN 1991-2:2003, 6.4.6.3 (3) are recommended. Where available, site-specific data on damping for the bridge structural type and construction details should be used.

5) *Frequency components*. The frequency range to include in the structural response will define the number of vibration modes to consider in modal analyses, as well as the time-step employed for the time discretization. This may be particularly critical for output results of acceleration time histories.

P.4 Results

The primary results required from dynamic analyses are time histories of selected dynamic load effects (e.g. accelerations). Each time history will correspond to an individual load case for, each train, each bridge, and each variable (e.g. displacement), at a particular point in the span (e.g. mid span section). In order to facilitate engineering judgement, time histories may be processed as envelopes of maximum or minimum values.

1) *Variables to monitor*. These should include bridge deck accelerations and deflections (see EN 1990-2:2002, A.2 and EN 1991). Section force resultants such as bending moments, shear or axial forces, and torsional moments, may be required. Acceleration time histories are more sensitive to time discretization than time-integrated values such as deflections. The number of points to be monitored should therefore be representative of the maximum or minimum structural response to be considered.

2) *Envelopes*. Primary envelopes include the maxima for each time history with respect to speed, up to the required maximum train speed for each case. Higher order envelopes are often also useful, for example a second order envelope, which would represent the maximum accelerations up to a certain speed (obtained from the primary envelopes) in terms of bridge span.

P.5 Example

A representative example is summarized below for the evaluation of dynamic effects in simply supported bridges for multiple unit trains in Europe [11]. The characteristics of this parametric study are as follows.

a) simply supported bridges with line beam behaviour subject to bending;

b) bridge spans: 5 m, 6 m, 7 m, 8 m, 9 m, 10 m, 12 m, 14 m, 16 m, 18 m, 20 m, 25 m and 30 m;

c) mass: including structural and non structural mass, four categories have been considered:

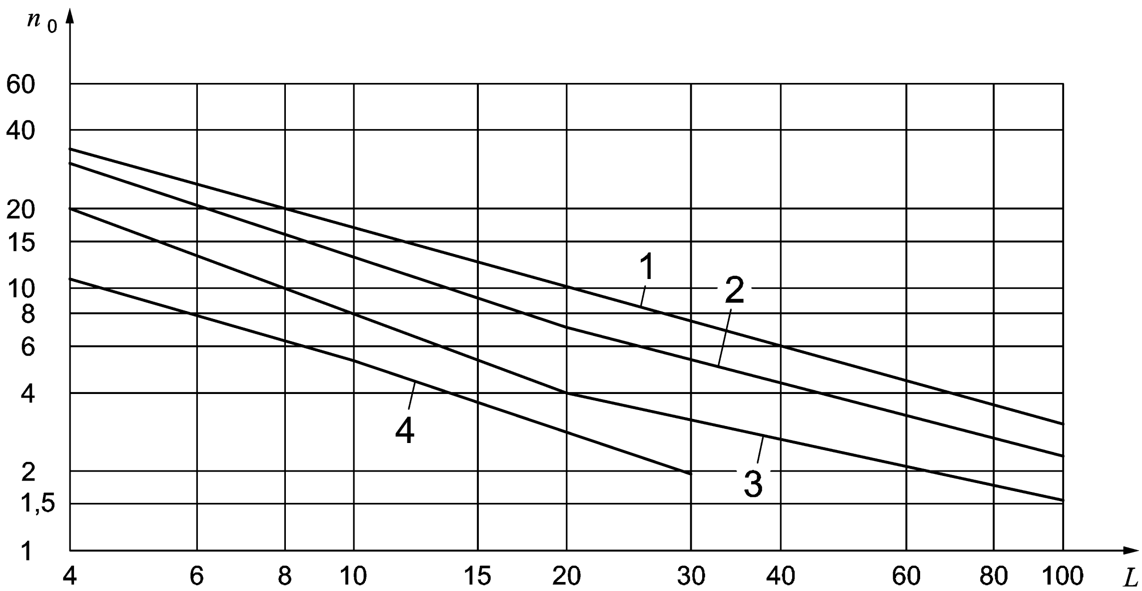
    1) very low: 3 t/m;

    2) low: 8 t/m;

3) medium: 12 t/m;

4) high: 20 t/m;

d) frequency (or equivalently, stiffness) (units in Hz and kNm²) (see Figure P.1):



Key

1 high

2 medium

3 low

4 very low

Figure P.1 — Limits of bridge natural frequency n_0 [Hz] as function of the span L [m]

1) very low:

i) $4 < L < 10$ m → $n_0 = 14{,}5 - 0{,}925 \cdot L$;

ii) $10 < L < 16$ m → $n_0 = 8{,}4 - 0{,}315 \cdot L$;

iii) $16 < L < 30$ m → $n_0 = 4{,}98 - 0{,}101 \cdot L$;

2) low: (lower bound of EN 1991-2:2003, Figure 6.10);

i) $4 \leq L \leq 20$ m → $n_0 = 80/L$;

ii) $L > 20$ m → $n_0 = 23{,}8 \cdot L^{-0{,}592}$

3) high: (upper bound of EN 1991-2:2003, Figure 6.10);

i) $n_0 = 94{,}76 \cdot L^{-0{,}748}$;

4) medium: average between the low and high values defined above;

e) damping: as defined in EN 1991-2:2003 for reinforced concrete bridges;

f) calculations are performed with moving loads, considering the load distribution through the track on the bridge deck. The vertical load acting on the rail from an individual axle, is distributed over three consecutive sleepers in the following proportions, 1/4, 1/2 and 1/4 (Figure P.2):

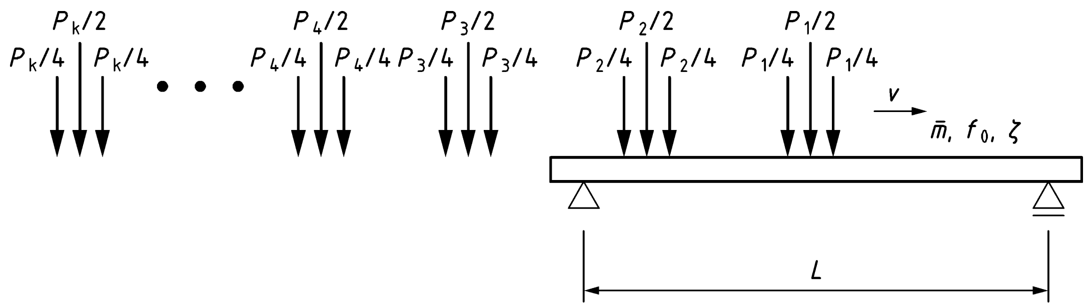


Figure P.2 — Moving loads model schema

g) the trains considered included the MU-classes (see Annex C and Annex E), and the following real trains: TGV, CAF, HS7, IC1, IC10 and the maximum running speed as shown in Table P.1.

Table P.1 — Trains considered and maximum running speeds

MU-class	Max. speed	Real train	Max. speed
AB_1D [a]	250 km/h		
AB_2D [a]	250 km/h	IC-1	250 km/h
AB_3D [a]	420 km/h		
AB_4D [a]	420 km/h	TGV	420 km/h
CB_1D [a]	420 km/h		
CB_2D [a]	420 km/h	IC-10	250 km/h
SA_1D [a]	220 km/h		
SA_2D [a]	420 km/h	HS-7	420 km/h
		CAF	250 km/h

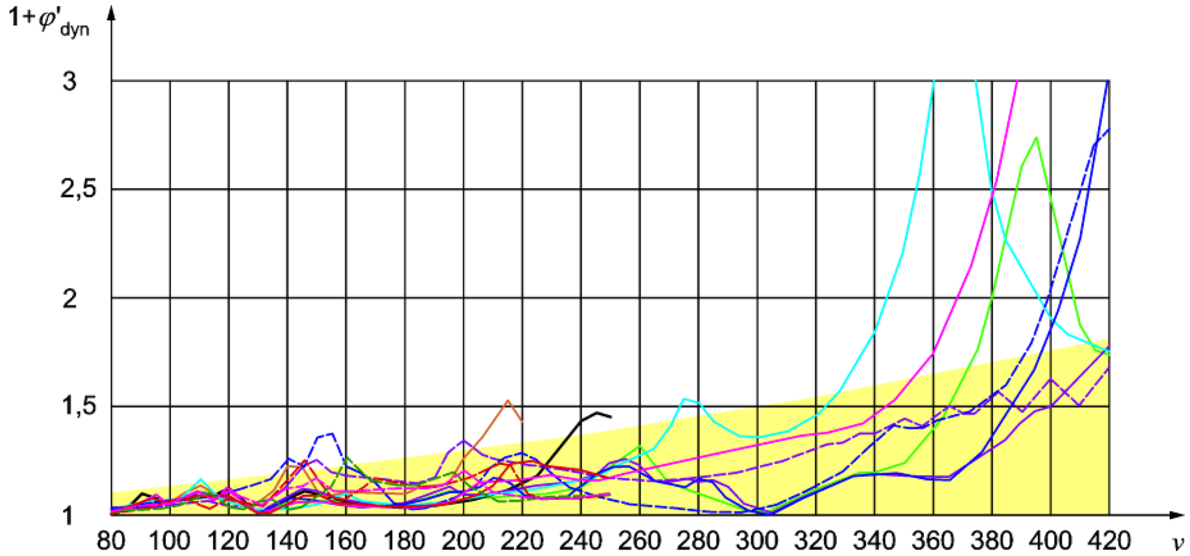
a "D" means $P_{MUclass}$ = 21,5 t (e.g. **AB_1D = AB_3**-$P_{21.5}$) according to E.4.

h) number of modes of vibration: modes with frequency below 100 Hz have been considered.

i) computational model: Modal superposition determined from dynamic analysis with a step by step solution of the dynamic equations for the normal modes of the bridge subject to moving trains, with or without vehicle interaction. For simply supported bridges with beam-type behaviour and assuming no shear deformation the normal modes are simple harmonic functions (i.e. sine functions) and are determined analytically. A time-marching algorithm with an exact solution for stepwise linear histories was used [11].

j) the results have been processed by running speed: up to 120 km/h, 160 km/h, 200 km/h, 220 km/h, 250 km/h, 300 km/h, 350 km/h and 420 km/h. This permits assessment of when a bridge can accept trains up to a certain speed. The *dynamic factor* for displacements ($1 + \varphi'$) for a given bridge fundamental natural frequency n_0 does not depend on the mass of the bridge. Therefore, results are provided for only one mass case, say medium mass. The accelerations or displacements are dependent on the mass value.

Some representative results from the parametric analyses undertaken are given below as an example. Figures P.3 and P.4 represent primary envelopes, with respect to train speed, for a 10 m span bridge for the case of medium frequency and medium mass, as stated above. Figure P.3 contains the envelope of dynamic displacements as a relative ratio between the maximum dynamic displacement and the static displacement, for each train considered. This ratio is equal to the *dynamic factor* $(1 + \varphi')$. The limit $(1 + \varphi'_{UIC})$, as defined in UIC 776-1, is also included to facilitate assessment of the point at which excessive dynamic effects are evident. It can be seen from Figure P.3 that, for speeds above 320 km/h, the dynamic effects due to most trains increase significantly.



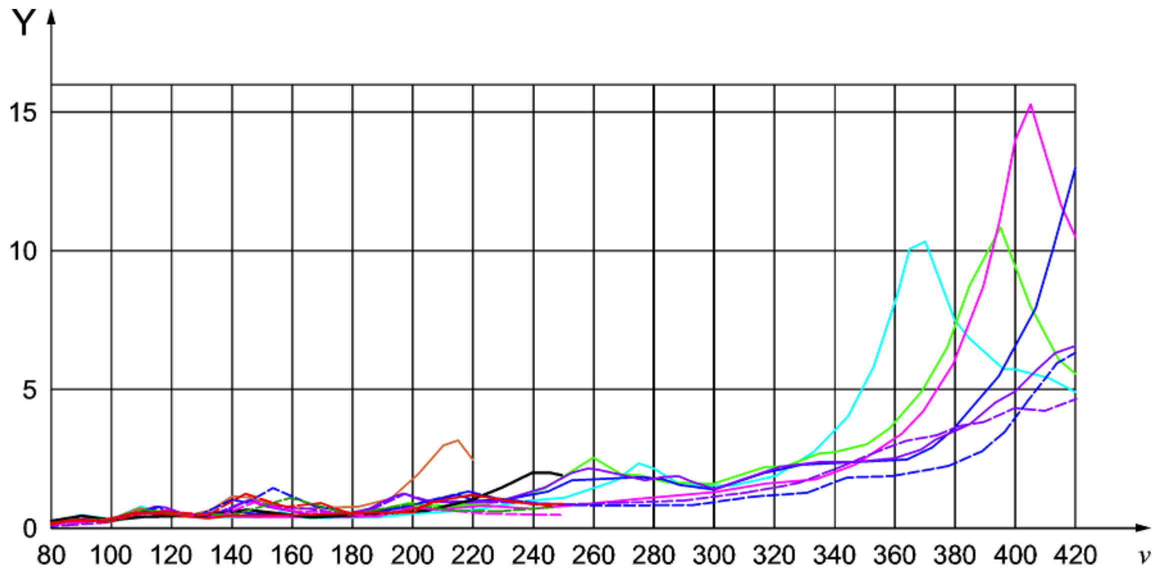
Key

(solid black)	AB 1D	(solid violet)	SA 2D
(solid red)	AB 2D	(dashed green)	CAF
(solid green)	AB 3D	(dashed red)	IC1
(solid blue)	AB 4D	(dashed blue)	TGV
(solid cyan)	CB 1D	(dashed magenta)	IC10
(solid magenta)	CB 2D	(dashed violet)	HS7
(solid orange)	SA 1D	(yellow box)	$1 + \varphi'_{UIC}$

V speed in km/h

Figure P.3 — Deflection impact factor at the centre of span versus train speed for a 10 m span bridge with medium frequency – subject to a moving load model

Figure P.4 shows the envelope of maximum accelerations for the trains considered. It demonstrates that for speeds above 340 km/h, the accelerations are generally above the acceptable limit.

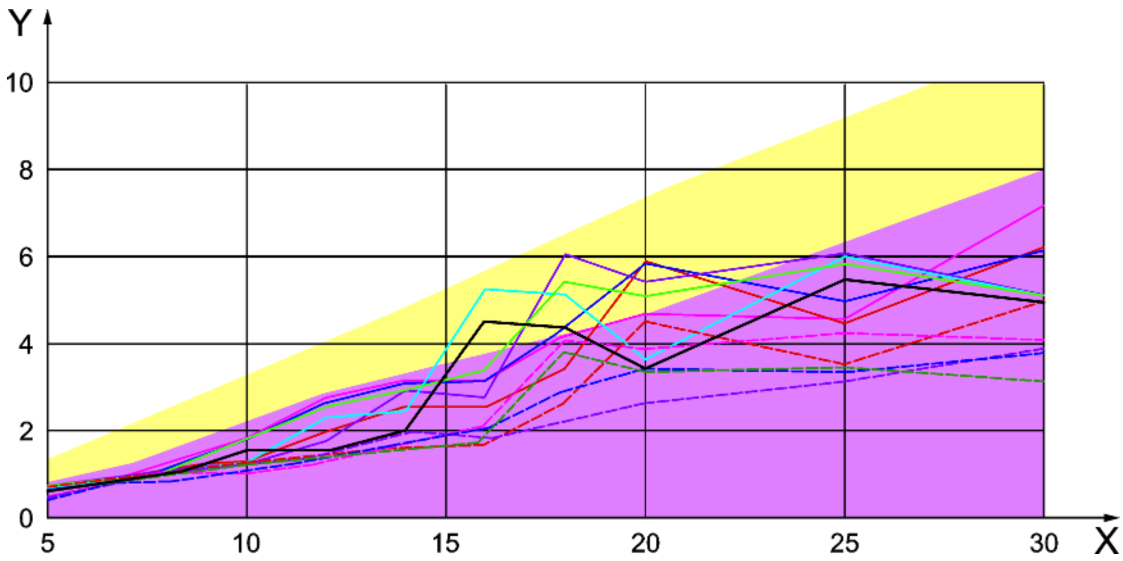


Key

——	AB 1D	——	SA 2D
——	AB 2D	----	CAF
——	AB 3D	----	IC1
——	AB 4D	----	TGV
——	CB 1D	----	IC10
——	CB 2D	----	HS7
——	SA 1D		
V	speed in km/h	Y	maximum acceleration [m/s^2]

Figure P.4 — Acceleration at the centre of span versus train speed for a 10 m span bridge with medium frequency – subject to a moving load model

Figure P.5 and Figure P.6 show second order envelopes, with respect to bridge span. Figure P.5 includes the dynamic deflections, here presented as absolute deflections in mm. For assessing the significance of these deflections two comparative limits are used: one representing the design envelope in the EN 1991-1 series for LM71·Φ_2, and a second limit which represents the maximum dynamic effect for train D2 with the impact factor for real trains. Figure P.6 contains the acceleration envelope with respect to bridge span, showing larger dynamic response in bridges between 15 m and 20 m span.

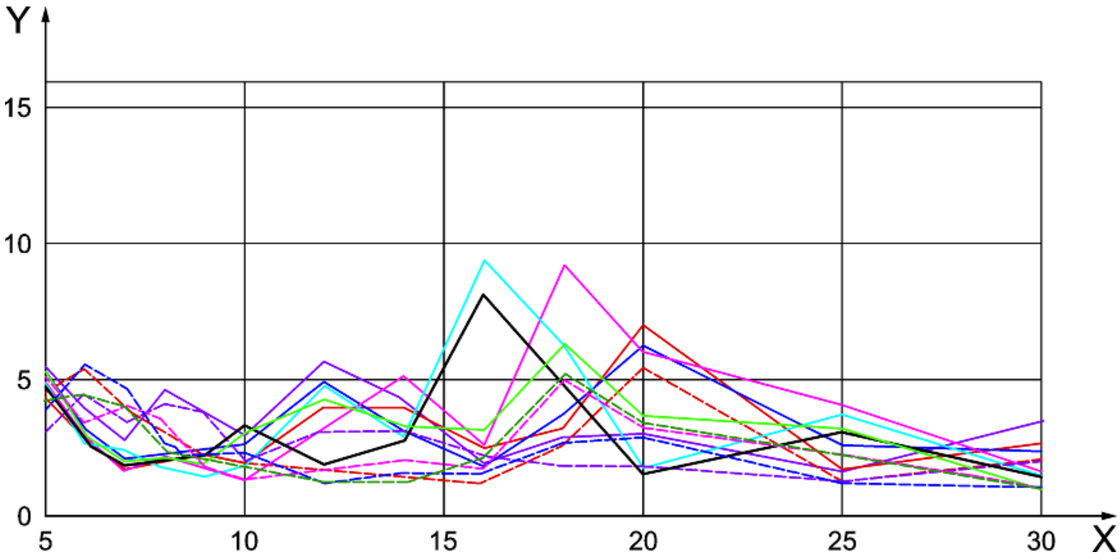


NOTE Other mass cases may be obtained by simple scaling.

Key

(black solid line)	AB 1D	(red dashed line)	IC1
(red solid line)	AB 2D	(blue dashed line)	TGV
(green solid line)	AB 3D	(magenta dashed line)	IC10
(blue solid line)	AB 4D	(purple dashed line)	HS7
(cyan solid line)	CB 1D	(yellow area)	LM71·Φ_2
(magenta solid line)	CB 2D	(violet area)	1 + φ'_{UIC} D2
(purple solid line)	SA 2D	X	span [m]
(green dashed line)	CAF	Y	maximum mid span deflection [mm]

Figure P.5 — Maximum deflection of the bridges with medium mass and medium frequency – speeds up to 250 km/h



Key

——— (black)	AB 1D	——— (violet)	SA 2D
——— (red)	AB 2D	- - - - (green)	CAF
——— (green)	AB 3D	- - - - (red)	IC1
——— (blue)	AB 4D	- - - - (blue)	TGV
——— (cyan)	CB 1D	- - - - (magenta)	IC10
——— (magenta)	CB 2D	- - - - (violet)	HS7
X	span [m]	Y	maximum acceleration [m/s^2]

Figure P.6 — Maximum acceleration of bridges with medium mass and medium frequency – speeds up to 250 km/h

Finally summary tables may also be produced for each train up to a certain speed. For a given type of bridge, taking account of properties such as mass, frequency level, and span length, accelerations can easily be obtained (Table P.4). A colour code in Table P.4 helps to visualize whether the mass and acceleration values provide acceptable combinations or not.

Table P.2 — Bridge natural frequency and damping

	Span (m)												
Frequency	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**	**25**	**30**
High	28,4	24,8	22,1	22,0	18,3	16,9	14,8	13,2	11,9	10,9	10,1	8,5	7,4
Medium	22,2	19,1	16,8	15,0	13,6	12,5	10,7	9,4	8,5	7,7	7,0	6,0	5,3
Low	16,0	13,3	11,4	11,0	8,9	8,0	6,7	5,7	5,0	4,4	4,0	3,5	3,1
Very low	9,9	9,0	8,0	7,1	6,2	5,3	4,6	4,0	3,4	3,2	3,0	2,5	2,0
Damping (%)	2,6	2,5	2,4	2,3	2,3	2,2	2,1	1,9	1,8	1,6	1,5	1,5	1,5

Table P.3 — Bridge mass classes

Bridge mass	
High	20 000 kg/m
Medium	12 000 kg/m
Low	8 000 kg/m
Very low	3 000 kg/m

Table P.4 — Summary table of the parametric studies for AB-1D up to 250 km/h – maximum acceleration values at centre of span are shown for different bridge classes

Train: AB-1D		Speed up to 250 km/h												
		Span (m)												
Frequency	**Mass**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**	**25**	**30**
High	high	1,8	1,6	1,1	1,2	0,7	0,6	0,3	0,6	0,9	0,6	0,4	2,1	1,1
	medium	3,0	2,7	1,8	2,0	1,2	1,0	0,6	1,0	1,5	1,0	0,7	3,4	1,8
	low	4,5	4,0	2,7	3,0	1,8	1,6	0,9	1,6	2,2	1,5	1,1	5,1	2,7
	very low	12,0	10,7	7,2	8,1	4,8	4,2	2,3	4,2	5,9	3,9	2,8	13,7	7,3
Medium	high	2,9	1,6	1,1	1,3	1,3	2,0	1,1	1,7	4,9	2,9	0,9	1,8	0,9
	medium	4,9	2,7	1,8	2,1	2,2	3,3	1,9	2,8	8,1	4,9	1,5	3,1	1,4
	low	7,3	4,1	2,7	3,2	3,4	5,0	2,8	4,1	12,2	7,3	2,3	4,6	2,2
	very low	19,5	10,9	7,3	8,4	8,9	13,2	7,5	11,0	32,6	19,5	6,1	12,3	5,8
low	high	2,9	5,1	3,6	3,9	9,7	8,3	2,6	4,4	5,9	9,8	11,9	3,8	3,8
	medium	4,8	8,4	6,0	6,5	16,2	13,8	4,3	7,4	9,8	16,4	19,8	6,3	6,4
	low	7,3	12,6	9,0	9,8	24,4	20,7	6,4	11,1	14,7	24,6	29,7	9,5	9,6
	very low	19,4	33,7	24,1	26,2	65,0	55,3	17,2	29,6	39,1	65,6	79,2	25,2	25,6
Very low	high	9,8	20,8	24,5	18,9	12,3	12,0	24,8	26,0	21,4	17,8	12,0	4,5	4,0
	medium	16,3	34,7	40,9	31,6	20,5	20,0	41,4	43,4	35,7	29,6	20,0	7,6	6,7
	low	24,4	52,0	61,3	47,4	30,7	30,0	62,1	65,1	53,5	44,4	29,9	11,3	10,0
	very low	65,0	138,7	163,5	126,3	81,9	79,9	165,6	173,5	142,8	118,5	79,9	30,2	26,6

Acceleration < 3,5 m/s^2.
3,5 m/s^2 < acceleration < 5 m/s^2.
5 m/s^2 < acceleration < 7 m/s^2.
Acceleration > 7 m/s^2.

Annex Q
(informative)

Comparison of RA-classification with line categories

In Great Britain all lines and vehicles are categorized by a Route Availability (RA) number in accordance with a classification system called the RA (Route Availability) system. As part of placing a vehicle into service, each vehicle is required to be categorized under the RA system. The RA system (including the methodology for calculating the RA number of a vehicle) is defined in Railway Group Standard GE/RT8006 Interface between vehicle weights and underline bridges.

Table Q.1 — Line categories corresponding to RA system

Line category	Direction [c]	RA – number [a]
a10, a12	⇨	RA 1
a14	⇨	RA 2
A	⇨	RA 3
B1	⇨	RA 5
B2	⇨	RA 6
C2	⇨	RA 7 [b]
C3	⇨	RA 8 [b]
C4	⇨	RA 10 [b]
D2	⇨	RA 8
D3	⇨	RA 8
D4	⇨	RA 10

NOTE D5, E4, E5 and E6 exceed RA10.

[a] The correspondence is valid for span lengths up to 50 m. Additional requirements apply for spans over 50 m – see GE/RT8006. Additionally, the line category (e.g. D3, D4) of a vehicle with a particular RA number varies according to span length and this table should not be used to determine the line category (D3, D4 etc.) on the basis of RA number.

[b] For line category C the RA number takes account of the NOTE in 6.2.1 regarding the exception for 20 t axle loads to be exceeded by up to 0,5 t.

[c] Table Q.1 provides only the correspondence of the line categories to a RA-number and not the other way round. The relationship between RA numbers and EN 15528 line category, speed and different business types of traffic is complex and it is not appropriate to compare this table against the Appendix F covering GB Route Availability in the TSI.

Annex R
(informative)

Weight note for locomotives

R.1 General

Table R.1 — Measurement data sheet of a 4-axle locomotive

axles		1	2	3	4	tolerance deviation

nominal axle load	P_i, nominal	kg				

nominal mass due to mass in working order according to EN 15663	kg	
max mass within tolerances due to design mass in working order according to EN 15663	kg	
max axle load within tolerances due to design mass in working order according to EN 15663	kg	
max wheel load within tolerances due to design mass in working order according to EN 15663	kg	

weighed or calculated wheel loads of the individual vehicle due to design mass in working order according to EN 15663

Wheel load on the right	$Q_{i\mathrm{r}}$	kg					
Wheel load on the left	$Q_{i\mathrm{l}}$	kg					
Axle load	$P_i = Q_{i\mathrm{l}} + Q_{i\mathrm{r}}$	kg					
Axle load tolerance	$\Delta P_i = (P_i / P_{i,\mathrm{nominal}} - 1) \times 100$	%					≤ 3 %
Wheel load deviation	$(Q_i / P_i / 2 - 1) \times 100$	%					≤ 5 %

Mass of the individual vehicle	kg	

Mass tolerance	$(\Sigma P_i / \Sigma P_{i,\mathrm{nominal}} - 1) \times 100$	%		≤ 3 %

Axle load for categorization due to design mass in working order according to EN 15663	kg	
Design mass in working order according to EN 15663	kg	
Vehicle mass marking on the vehicle according to EN 15877–2 (operational mass in working order according to EN 15663)	kg	
Difference between design mass and operational mass	kg	

mass deviation	
axle load deviation	
wheel load deviation	

R.2 Example of a weight note for a series A locomotive

Table R.2 — Example of a weight note for a series A locomotive

axles			1	2	3	4	tolerance deviation
nominal axle load	P_i, nominal	kg	22 500	22 500	22 500	22 500	

nominal mass due to mass in working order according to EN 15663	kg	90 000
max mass within tolerances due to design mass in working order according to EN 15663	kg	92 700
max axle load within tolerances due to design mass in working order according to EN 15663	kg	23 175
max wheel load within tolerances due to design mass in working order according to EN 15663	kg	12 167

weighed or calculated wheel loads of the individual vehicle due to design mass in working order according to EN 15663

			1	2	3	4	tolerance deviation
Wheel load on the right	$Q_{i\mathrm{r}}$	kg	11 850	11 450	11 950	11 550	
Wheel load on the left	$Q_{i\mathrm{l}}$	kg	11 150	10 950	11 150	11 150	
Axle load	$P_i = Q_{i\mathrm{l}} + Q_{i\mathrm{r}}$	kg	23 000	22 400	23 100	22 700	
Axle load tolerance	$\Delta P_i = (P_i / P_{i,\mathrm{nominal}} - 1) \times 100$	%	2,2	−0,4	2,7	0,9	≤ 3 %
Wheel load deviation	$(Q_i / P_i / 2 - 1) \times 100$	%	3,0	2,2	3,5	1,8	≤ 5 %

Mass of the individual vehicle	kg	91 200

Mass tolerance	$(\Sigma P_i / \Sigma P_{i,\mathrm{nominal}} - 1) \times 100$	%	1,3	≤ 3 %

Axle load for categorization due to design mass in working order according to EN 15663	kg	22 500
Design mass in working order according to EN 15663	kg	90 000
Vehicle mass marking on the vehicle according to EN 15877–2 (operational mass in working order according to EN 15663)	kg	88 000
Difference between design mass and operational mass	kg	2 000

mass deviation	OK
axle load deviation	OK
wheel load deviation	OK

If the results of the weight notes of all locomotives of series A are within the tolerances defined in 6.1 (Table 2), max $P_{i,\mathrm{nom}}$ (the maximum value for “intended axle load”) is used for categorization of all locomotives of series A according to 6.1.

R.3 Example of a weight note for a series B locomotive

Table R.3 — Example of a weight note for a series B locomotive

axles			1	2	3	4	tolerance deviation
nominal axle load	P_i, nominal	kg	22 500	22 500	22 500	22 500	

nominal mass due to mass in working order according to EN 15663	kg	90 000
max mass within tolerances due to design mass in working order according to EN 15663	kg	92 700
max axle load within tolerances due to design mass in working order according to EN 15663	kg	23 175
max wheel load within tolerances due to design mass in working order according to EN 15663	kg	12 167

weighed or calculated wheel loads of the individual vehicle due to design mass in working order according to EN 15663

			1	2	3	4	tolerance deviation
Wheel load on the right	$Q_{i\text{r}}$	kg	11 600	11 200	11 700	11 300	
Wheel load on the left	$Q_{i\text{l}}$	kg	11 900	11 700	11 900	11 900	
Axle load	$P_i = Q_{i\text{l}} + Q_{i\text{r}}$	kg	23 500	22 900	23 600	23 200	
Axle load tolerance	$\Delta P_i = (P_i / P_{i,\text{nominal}} - 1) \times 100$	%	4,4	1,8	4,9	3,1	≤ 3 %
Wheel load deviation	$(Q_i / P_i / 2 - 1) \times 100$	%	1,3	2,2	0,8	2,6	≤ 5 %

Mass of the individual vehicle	kg	93 200

Mass tolerance	$(\Sigma P_i / \Sigma P_{i,\text{nominal}} - 1) \times 100$	%	3,6	≤ 3 %

Axle load for categorization due to design mass in working order according to EN 15663	kg	extra considerati on
Design mass in working order according to EN 15663	kg	93 200
Vehicle mass marking on the vehicle according to EN 15877–2 (operational mass in working order according to EN 15663)	kg	91 200
Difference between design mass and operational mass	kg	2 000

mass deviation	not OK
axle load deviation	not OK
wheel load deviation	OK

The axle loads P_1 and P_3 and mass m of this locomotive of series B exceed the tolerances defined in 6.1 (Table 2). To determine the line category, the excess (see 6.1) is added to the nominal values m_{nom} and $P_{i,\text{nom}}$.

The excess for mass is 0,5 t (93,2 – 92,7), and for axle load 0,425 t (23,600 – 23,175). $P_{\text{nom,excess}}$ = 22,925 t (22,5 + 0,425) and $m_{\text{nom,excess}}$ = 90,5 t is used for the categorization of this single locomotive of series B.

In this example, this single locomotive is treated as individual vehicle (see 6.7 and Clause 7).

Annex S
(informative)

Examples of axle spacings for locomotives and for a standard passenger carriage

S.1 Introduction

If the speed associated with line categories or the values for mass per unit length is not compatible (see Annex F), additional dynamic checks can be undertaken, taking into account (see 5.1.2):

— a load model with 15 adjacent coupled coaches;

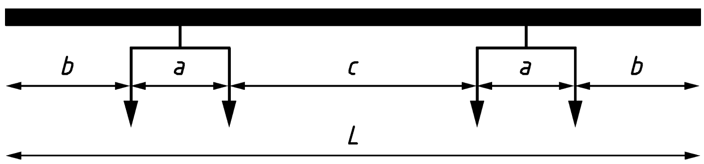
— the mass condition according to Annex D; and

— the effect of locomotives.

NOTE Passenger carriages, like restaurant cars, integrated into a train as a single coach, are not relevant for dynamic checks.

S.2 Typical axle spacing patterns of locomotives with 22,5 t axle load

Table S.2 provides a list of some locomotive parameters that may be used to create a locomotive hauled load model for dynamic checks. Where available, train specific data describing the proposed or envisaged trains should be used.



Key

a = distance between axles

b = distance from end axle to the end of the nearest coupling plane

c = distance between the two inside axles

L = wagon length over buffers

Figure S.1 — 4-axle locomotive

Table S.1 — Minimum values of vehicle parameters

Locomotive parameter	*b* [m]	*a* [m]	*c* [m]	*L* [m]
Loco 1	2,80	2,6	8,3	19,1
Loco 2	3,20	3,0	6,9	19,3
Loco 3	3,32	3,0	6,9	19,6
Loco 4	2,60	2,8	6,9	17,7

S.3 Axle spacing pattern and axle load of a 26,4 m carriage

To form a load model of a locomotive hauled train, Table S.2 can be used in combination with the locomotives shown in S.2.

All possible combinations of the number and position of locomotives within the train according to the operating requirements should be considered.

Alternatively typical carriage parameter ranges listed in Table S.3 may be used to create different load models.

NOTE Passenger carriages, like restaurant cars, integrated into a train as a single coach, are not relevant for dynamic checks.

Table S.2 — Load model of 15 standard carriages of 26,4 m length

SC			SC		
Axle No	**distance** [m]	**sum** [m]	**Axle No**	**distance** [m]	**sum** [m]
1	0,0	0,0	**31**	16,5	203,8
2	2,5	2,5	**32**	2,5	206,3
3	16,5	19,0	**33**	4,9	211,2
4	2,5	21,5	**34**	2,5	213,7
5	4,9	26,4	**35**	16,5	230,2
6	2,5	28,9	**36**	2,5	232,7
7	16,5	45,4	**37**	4,9	237,6
8	2,5	47,9	**38**	2,5	240,1
9	4,9	52,8	**39**	16,5	256,6
10	2,5	55,3	**40**	2,5	259,1
11	16,5	71,8	**41**	4,9	264,0
12	2,5	74,3	**42**	2,5	266,5
13	4,9	79,2	**43**	16,5	283,0
14	2,5	81,7	**44**	2,5	285,5
15	16,5	98,2	**45**	4,9	290,4
16	2,5	100,7	**46**	2,5	292,9
17	4,9	105,6	**47**	16,5	309,4
18	2,5	108,1	**48**	2,5	311,9
19	16,5	124,6	**49**	4,9	316,8
20	2,5	127,1	**50**	2,5	319,3
21	4,9	132,0	**51**	16,5	335,8
22	2,5	134,5	**52**	2,5	338,3
23	16,5	151,0	**53**	4,9	343,2
24	2,5	153,5	**54**	2,5	345,7
25	4,9	158,4	**55**	16,5	362,2
26	2,5	160,9	**56**	2,5	364,7
27	16,5	177,4	**57**	4,9	369,6
28	2,5	179,9	**58**	2,5	372,1
29	4,9	184,8	**59**	16,5	388,6
30	2,5	187,3	**60**	2,5	391,1

Table S.3 shows typical coach parameters values.

Table S.3 — Typical coach parameter ranges

Coach parameter ranges	**Typical coach** [m]
Coach length	24,5 – 27,5
$2a^+$	2,4 – 2,6
$2a^*$	17,2 – 19,5
u	3,65 – 4,00

The specification of the axle load values P of the passenger carriages according to Annex D completes the definition of the load model of a locomotive hauled train.

Annex T
(informative)

Categorization of MUs by parameter check

T.1 General

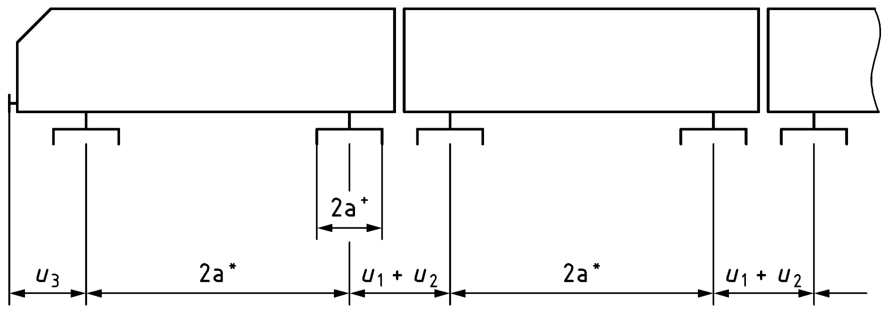
The categorization procedure described in 6.1 can be replaced by a simple parameter check. If the MU parameters of the unit to be categorized satisfy the requirements given in this Annex, Table T.5 can be used to identify the appropriate line category.

The relevant tables for each MU-group are listed in Table T.1.

Table T.1 — Relevant table for each MU-Group

MU-group	Table
CB	T.2
AB	T.3 and if relevant T.2
SA	T.4 and if relevant T.2 and T.3

T.2 MU-Group CB



Key

$u3$	overhang (distance pivot centre to coupling plane) of end coaches (in m)
$u1+u2$	bogie spacing between pivot centres of adjacent vehicles (in m)
$2a*$	bogie spacing between pivot centres (in m)
$2a^{+}$	axle spacing in bogie (in m)

Figure T.1 — Parameters of MU with conventional bogies

Table T.2 — Requirements for the application of Table T.5 for MU-coaches with conventional bogies (CB)

1,8 m ≤ $2a^+$ ≤ 3,0 m
$2a^*$ ≥ 15,6 m
u3 ≥ 3,0 m
u1 + u2 ≥ 6 m

T.3 MU-Group AB

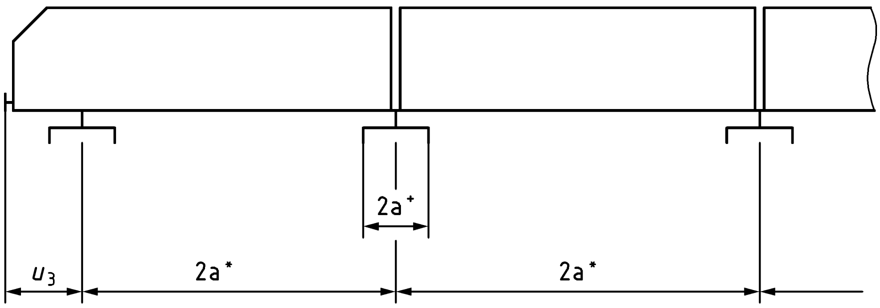


Figure T.2 — Parameters of MU with articulated bogies

Table T.3 — Requirements for the application of Table T.5 for MU-coaches with articulated bogies (AB)

1,8 m ≤ $2a^+$ ≤ 3,0 m
$2a^*$ ≥ 14,0 m
u3 ≥ 3,0 m

If the first vehicle of the AB-unit is a power car or power head with 2 conventional bogies, the check for the “$2a^*$” value of the end vehicles and the “($u1$+$u2$)” value between conventional bogies shall be checked against Table T.2 values.

T.4 MU-group SA

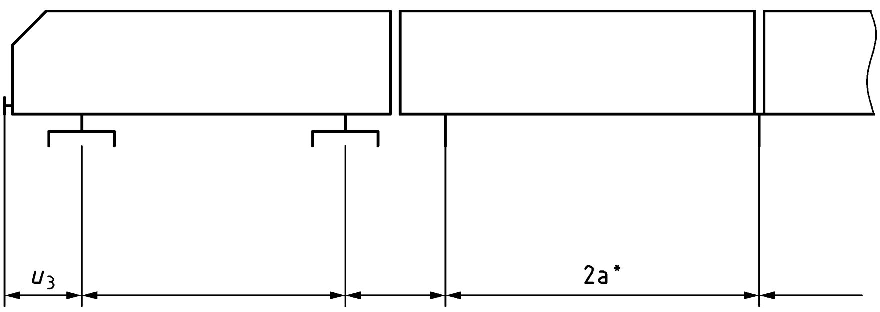


Figure T.3 — Parameters of MU with single axles

Table T.4 — Requirements for the application of Table T.5 for MU-coaches with singles axles (SA)

2a* ≥ 5,0 m
u3 ≥ 3,0 m

When required, min ($u1$+$u2$) values between conventional bogies (end coaches) or conventional bogie and single axle and minimum 2a* value between bogies can be taken from Table T.2 and Table T.3.

T.5 Identification of line category by axle load

If all parameters of a real MU to be categorized exceed the values of the relevant tables above, Table T.5 can be used to identify the line category.

Table T.5 — Appropriate line category

Max axle load	Line category
≤ 16,0 t	A
≤ 18,0 t	B1
≤ 20,0 t	C2
≤ 22,5 t	D2

Annex U
(informative)

Guidance for categorizing light rail MUs into line category a10, a12 or a14

U.1 General

The following figures give an overview of the most common types of light rail MU's and the typical axle spacing arrangements.

As an alternative to the calculation methodology according to 6.1 the following method may be used to determine the line category a10, a12 or a14 by axle load, providing the axle spacing and configuration satisfy the requirements specified in this annex.

If the axle distance parameters of the real MU unit are greater than those in the relevant tables, the corresponding line category a10, a12 or a14 can be determined using Table U.1, Table U.4 or Table U.8.

Table U.1 — Appropriate line category

Line category	Max axle load
a10	≤ 10,0 t
a12	≤ 12,0 t
a14	≤ 14,0 t

The maximum axle load of the unit shall be determined according to the mass definition of Annex D. For the use of this annex the maximum axle load of the unit is relevant.

U.2 4 axle light rail MU with 2 bogies

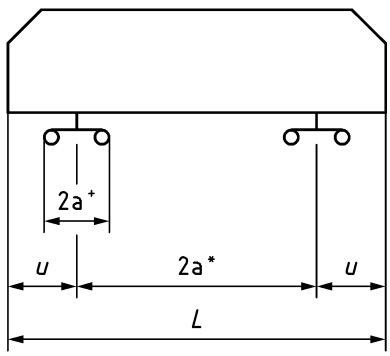


Figure U.1 — Axle spacing of MU with 2 bogies

Use of Table U.2:

Step 1: Identify the maximum axle load P_{unit} within the unit (according to Annex D).

Step 2: Identify the $2a^{+}_{unit}$ value of the real MU to be categorized.

Step 3: Look at Table U.2 and round down $2a^{+}_{unit}$ to the next matching value for $2a^{+}_{table}$.

Step 4: Check the other values, u and $2a^*$, of the real MU using the row of Table U.2 with the closest fitting $2a^+_{table}$ value. If none of the values of the specific row determined from the $2a^+_{table}$ value exceed the values of the real MU-unit to be checked, max P_{unit} can be used in Table U.1 for determining the line category.

Table U.2 — Minimum values of vehicle parameters u and 2*a depending from 2*a*⁺**

$2a^+$ [m]	u [m]	$2a^*$ [m]
1,7	2,85	14,3
1,8	2,90	14,4
1,9	2,95	14,5
2,0	3,00	14,6
2,1	3,05	14,7
2,2	3,10	14,8

If the $2a^*$ values of the unit are smaller than those in Table U.2, use Table U.4. The value u of the unit shall be always greater than or equal to Table U.2 ($u_{unit} \geq u_{table}$).

Use of Table U.3:

Step 1: In order to use Table U.4 adopt the $2a^*$ value of the unit (take the minimum one, if different):

$2a^*_{adopted} = 2a^*_{unit} - (\max 2a^+_{unit} - 1{,}8)$ for $2a^+_{unit} > 1{,}8$ m.

Identify the maximum axle load P within the unit (according to Annex D).

Step 2: Use the values max P_{unit} and $2a^*_{adopted}$ to enter in Table U.4 to identify the relevant line category; interim values can be interpolated linearly.

NOTE An example how to use Table U.2 and Table U.4 is given in U.4.

U.3 4 axle light rail MU with 4 single axles

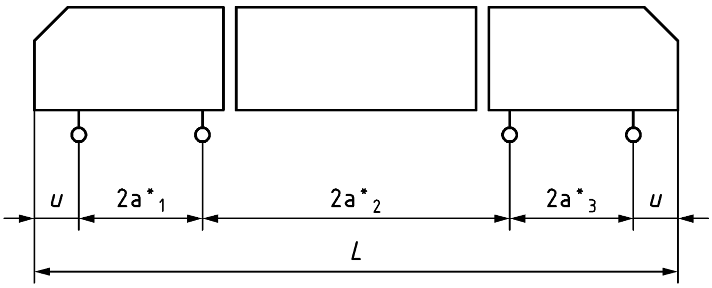


Figure U.2 — Axle spacing of MU with 4 single axles

Use of Table U.3:

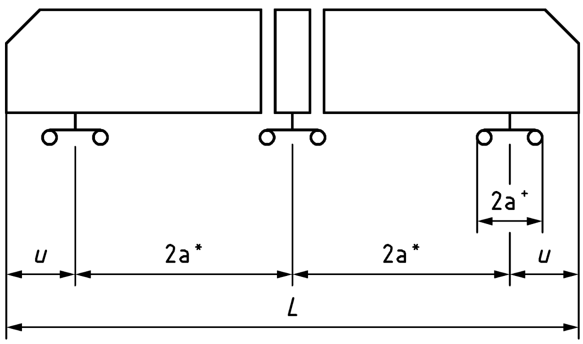
Step 1: Identify the maximum axle load P within the unit (according to Annex D).

Step 2: Check the values of the real MU-unit against the 6 cases. If one case can be found, where all table values of the specific row do not exceed the values of the real MU-unit to be checked, max P_{unit} can be used in Table U.1 for determining the line category.

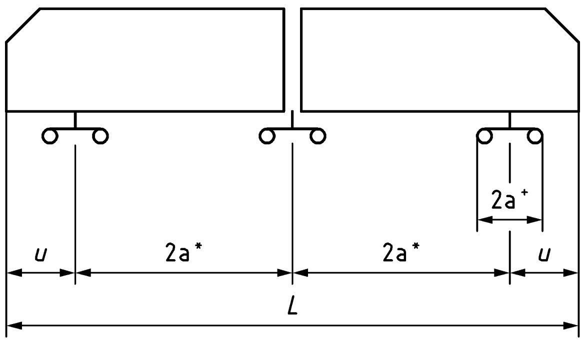
Table U.3 — Minimum values of vehicle parameters of 4 axle light rail MUs with 4 single axles

Case	**u** [m]	**$2a^*_1 = 2a^*_3$** [m]	**$2a^*_2$** [m]
1	2,0	1,8	12,6
2	2,0	3,0	10,0
3	2,0	4,5	7,0
4	2,0	5,5	5,5
5	2,0	6,0	4,0
6	2,0	7,5	1,8

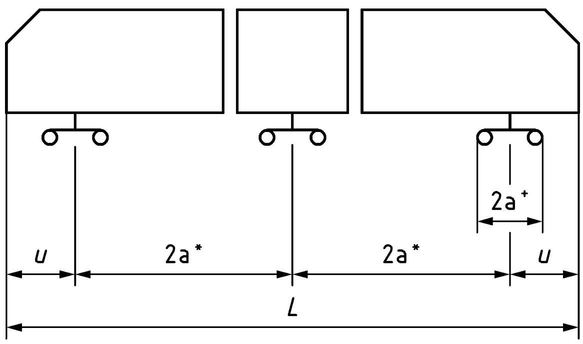
U.4 6 axle light rail MU with 3 bogies



a) Example 1



b) Example 2



c) Example 3

Figure U.3 — Axle spacing of MUs with 3 bogies

Use of Table U.2:

Step 1: Identify the maximum axle load P within the unit (according to Annex D).

Step 2: Identify the $2a^+$ value of the real MU to be categorized.

Step 3: Round it down to the next matching table value for $2a^+$ in Table U.2.

Step 4: Check now the values u and $2a^*$ in Table U.2 of the real MU using the row with the closest fitting $2a^+$ value.

If the values of the specific row determined by the $2a^+$ value do not exceed the values of the real MU-unit to be checked, max P_{unit} can be used in Table U.1 for determining the line category.

If the $2a^*$ values of the unit are smaller than those in Table U.2, use Table U.4. The value u of the unit shall always be greater than or equal to Table U.2 ($u_{unit} \geq u_{table}$).

For values $2a^+ > 1,8$ m, the $2a^*$ values of the unit to check shall be adopted ($2a^*_{adopted} = 2a^*_{unit} - (2a^+ - 1,8)$) before using Table U.4.

Use of Table U.4:

Step 1: In order to use Table U.4 adopt the $2a^*$ value of the unit (take the minimum, if different):

$2a^*_{adopted} = 2a^*_{unit} - (\max 2a^+_{unit} - 1,8)$ for $2a^+_{unit} > 1,8$ m.

Identify the maximum axle load P within the unit (according to Annex D).

Step 2: Use the values max P_{unit} and $2a^*$adopted to enter in Table U.4 to identify the relevant line category; interim values can be interpolated linearly.

EXAMPLE real MU-unit: max $P_{unit} = 11,2$ t, max $2a^+_{unit} = 1,9$ m, $u_{unit} = 3,05$ m, min $2a^*_{unit} = 8,6$ m

Table U.2: see row "($2a^+$ 1,9)":

check: 1. $u_{unit} \geq u_{table}$ $(3,05 \geq 2,95) \rightarrow$ O.K.

2. $2a^*_{unit} \geq 2a^*_{table}$ $(8,6 < 14,5) \rightarrow$ not O.K.

Table U.2 cannot be used → go to Table U.4.

Table U.4: $2a^*_{adopted} = 2a^*_{unit} - (\max 2a^+_{unit} - 1,8) = 8,6 - (1,9 - 1,8) = 8,5$ m.

$2a^*_{adopted} = 8,5$ m, max $P_{unit} = 11,2$ t → Line Category a14.

Table U.4 — Maximum axle load *P* in t for smaller values of 2*a valid for 1,7 ≤ 2*a*+ ≤ 1,8 m**

2*a** [m]	max *P* a10 [t]	max *P* a12 [t]	max *P* a14 [t]
14,4	≤ 10,0	≤ 12,0	≤ 14,0
14,0	≤ 10,0	≤ 12,0	≤ 14,0
13,0	≤ 10,0	≤ 12,0	≤ 14,0
12,0	≤ 9,8	≤ 11,7	≤ 13,7
11,0	≤ 9,4	≤ 11,3	≤ 13,2
10,0	≤ 9,1	≤ 11,0	≤ 12,8
9,0	≤ 8,6	≤ 10,4	≤ 12,1
8,0	≤ 8,1	≤ 9,8	≤ 11,4
7,0	≤ 7,6	≤ 9,2	≤ 10,7
6,0	≤ 7,0	≤ 8,5	≤ 9,9

U.5 6 axles light rail MUs with 6 single axles

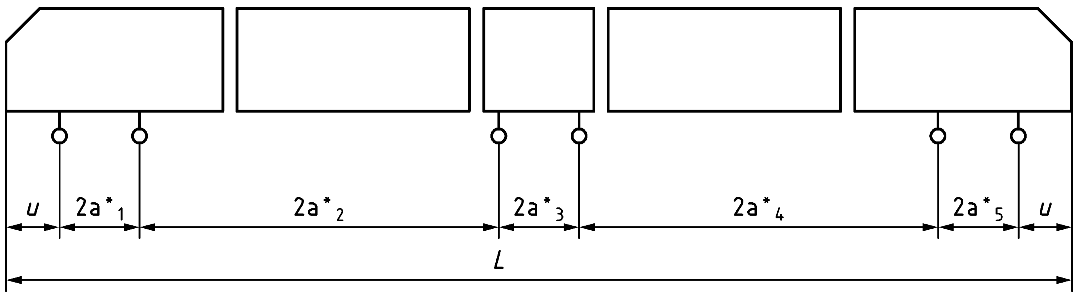


Figure U.4 — Axle spacing of MU with 6 single axles

Use of Table U.5:

Step 1: Identify the maximum axle load *P* within the unit (according to Annex D).

Step 2: Check the values of the real MU-unit against the 7 cases. If one case can be found, where all table values of the specific row do not exceed the values of the real MU-unit to be checked, max P_{unit} can be used in Table U.1 for determining the line category.

Table U.5 — Minimum values of vehicle parameters of 6 axles light rail MUs with 6 single axles

Case	u [m]	$2a^*_1 = 2a^*_3 = 2a^*_5$ [m]	$2a^*_2 = 2a^*_4$ [m]
1	2,0	3,0	9,5
2	2,0	4,0	7,5
3	2,0	5,0	5,5
4	2,0	5,3	5,3
5	2,0	5,5	5,0
6	2,0	6,0	4,0
7	2,0	7,0	3,0

U.6 6 axles light rail MUs with 2 bogies and 2 single axles

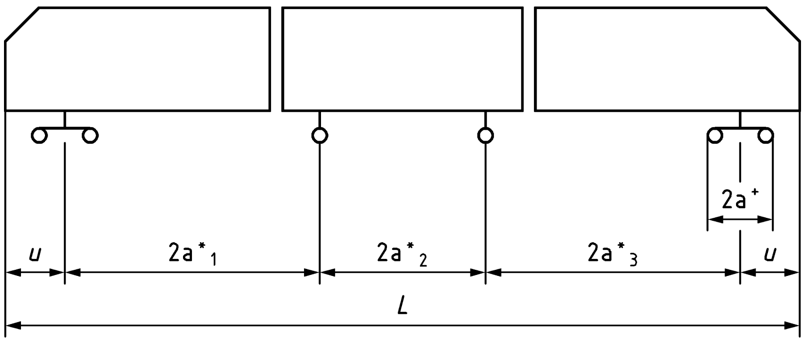


Figure U.5 — Axle spacing of MU with 2 bogies and 2 single axles

Use of Table U.6:

Step 1: Identify the maximum axle load P within the unit (according to Annex D);

Step 2: Check the value u using $2a^+_{unit}$ in Table U.2 ($u_{unit} \geq u_{Table\ U.2}$);

Step 3: Check the values $2a^*_1 = 2a^*_3$ and $2a^*_2$:

($2a$*1 unit ≥ $2a$*1 Table U.6; $2a$*2 unit ≥ $2a$*2 Table U.6; $2a$*3 unit ≥ $2a$*3 Table U.6);

If $2a^+_{unit} > 1{,}8$ m, the values $2a^*_{1\ Table\ U.6}$ and $2a^*_{3\ Table\ U.6}$ shall be enlarged (see Table U.7).

If all $2a^*$ values of the unit exceed the Table U.6 values, max P_{unit} and Table U.1 can be used for determining the line category.

If one of the $2a^*$ values are smaller than in Table U.6, use Table U.8.

Table U.6 — Minimum values of vehicle parameters of 6 axle light rail MUs with 2 bogies and 2 single axles (valid for 1,70 m ≤ $2a^+$ ≤ 1,80 m)

$2a^*_1 = 2a^*_3$	$2a^*_2$
12,6 m	1,8 m

Table U.7 — Δ2a* values dependent on 2a^+ values

2a^+ [m]	**Δ2a*** [m]
1,7	0,00
1,8	0,00
1,9	0,05
2,0	0,10
2,1	0,15
2,2	0,20

Use of Table U.8:

Step 1: Adopt the $2a^*$unit value (take the minimum, if different):

$2a^*_{1,3\ \text{adopted}} = 2a^*_{1,3\ \text{unit}} - \Delta 2a^*$ (according to Table U.7) for $2a^+_{\text{unit}} > 1{,}8$ m.

Identify the maximum axle load P within the unit (according to Annex D).

Step 2: Use the values max P_{unit} and $2a^*_{1,3\ \text{adopted}}$ to enter in Table U.8 to identify the relevant line category; interim values can be interpolated linearly.

Table U.8 — Maximum axle load P in t for smaller values of $2a^*_1$ and $2a^*_3$ for $2a^*_2 \geq 1{,}8$ m and for 1,70 m ≤ $2a^+$ ≤ 1,80 m

$2a^*_1 = 2a^*_3$ [m]	**max P a10** [t]	**max P a12** [t]	**max P a14** [t]
12,6	10,0	12,0	14,0
12,0	9,8	11,7	13,7
11,0	9,4	11,3	13,2
10,0	9,1	11,0	12,8
9,0	8,7	10,4	12,1
8,0	8,2	9,8	11,5
7,0	7,7	9,2	10,8

EXAMPLE real MU-unit: max $P_{\text{unit}} = 10{,}4$ t, max $2a+_{\text{unit}} = 2{,}0$ m, $u_{\text{unit}} = 3{,}10$ m,

$2a^*_{1\ \text{unit}} = 2a^*_{3\ \text{unit}} = 10{,}0$ m, $2a^*_{2\ \text{unit}} = 4{,}0$ m,

Table U.2: see row “(2a+ = 2,0”):

check: $u_{\text{unit}} \geq u_{\text{table}}$ (3,10 ≥ 3,00) → O.K.

Table U.7: see row “(2a+ = 2,0”): Δ 2a* = 0,10 m

Table U.6: check:

1) $2a^*_{1,3\ \text{unit}} \geq 2a^*_{1,3\ \text{Table U.6}} + \Delta 2a^*_{\text{Table U.7}}$; 10,0 ≥ 12,6 + 0,10 → not O.K.

2) $2a^*_{2\ unit} \geq 2a^*2_{\ Table\ U.6}$; 4,0 ≥ 1,8 → O.K.

Table U.6 cannot be used → go to Table U.8

Table U.8 $2a^*_{1,3\ adopted}$ = 10,0 – 0,10 = 9,90 m, max P_{unit} = 10,4 t → Line Category a12

U.7 8 axles light rail MUs or more axles

Relevant minimum vehicle parameter values for MUs with 8 axles or more can be related and used from the tables before.

For MUs with carriages with conventional or articulated bogies, Table U.2, Table U.1 or Table U.4 shall be used. The ($u1+u2$) values (bogie spacing between pivot centres of adjacent carriages with conventional bogies) shall be checked using $2 \cdot u$ of Table U.2. ($(u1+u2)_{unit} \geq 2 \cdot u_{Table\ U.2}$).

Annex ZA
(informative)

Relationship between this European standard and the Essential Requirements of EU Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community (Recast)

This European Standard has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the Directive 2008/57/EC [5)].

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 for RST Loc and Pass, Table ZA.2 for RST Freight Wagons and in Table ZA.3 for Infrastructure confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

5) This Directive 2008/57/EC adopted on 17th June 2008 is a recast of the previous Directives 96/48/EC 'Interoperability of the trans-European high-speed rail system' and 2001/16/EC 'Interoperability of the trans-European conventional rail system' and revisions thereof by 2004/50/EC 'Corrigendum to Directive 2004/50/EC of the European Parliament and of the Council of 29 April 2004 amending Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC of the European Parliament and of the Council on the interoperability of the trans-European conventional rail system'.

Table ZA.1 — Correspondence between this European Standard, the Commission Regulation concerning a technical specification for interoperability relating to the 'rolling stock — locomotives and passenger rolling stock' subsystem of the rail system in the European Union published in the Official Journal L356/228 on 12/12/2014, and Directive 2008/57/EC

Clause(s)/ sub clause(s) of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
Clause 6 Categorization of railway vehicles 6.1 General rules 6.3 Locomotives 6.4 Passenger carriages 6.5 Multiple units 6.6 Special vehicles Clause 7 Compatibility of the interface between vehicle and infrastructure Annex A Annex D	4.Characterization of the rolling stock subsystem 4.2. Functional and technical specifications of the subsystem 4.2.2.Structure and mechanical parts §4.2.2.10. Load conditions and weighed mass 4.2.3 Track interaction and gauging 4.2.3.2. Axle load and wheel load, 6.Assessment of conformity or suitability for use and EC verification 6.2.Rolling stock subsystem 6.2.3. Particular assessment procedures for subsystems §.6.2.3.2.Wheel load (Clause 4.2.3.2.2) 7.Implementation 7.5.Aspects that have to be considered in the revision process or in other activities of the Agency 7.5.1. Aspects related to a basic parameter in this TSI §7.5.1.1.Axle load parameter (Clause 4.2.3.2.1)	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2. 1.5.Technical compatibility 2 Requirements specific to each subsystem 2.4 Rolling stock 2.4.3 Technical compatibility §3	Clause 7.5.1.1. of the TSI mandates EN 15528:2015 The Clause 1.4 5 - Environmental protection – of the essential requirements of the Directive 2008/57/EC is covered by the TSI INF and not by this TSI.

Table ZA.2 — Correspondence between this European Standard, the Commission Regulation concerning the technical specification of interoperability relating to the subsystem "rolling stock - freight wagons" of the rail system in the European Union published in the Official Journal L104/1 on 12/4/2013, and Directive 2008/57/EC

Clause(s)/ sub clause(s) of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
Clause 6 Categorization of railway vehicles 6.1 General rules 6.2 Freight wagons Clause 7 Compatibility of the interface between vehicle and infrastructure Annex A	4.Characteristics of the subsystem 4.2 Functional and technical specification of the subsystem 4.2.3 Gauging and track interaction §.4.2.3.2 Compatibility with load carrying capacity of lines	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2 1.5.Technical compatibility 2 Requirements specific to each subsystem 2.4 Rolling stock 2.4.3 Technical compatibility §3	Clause 4.2.3.2 of the TSI mandates 6.1 and 6.2 of EN 15528:2015. The Clause 1.4 5 - Environmental protection – of the essential requirements of the Directive 2008/57/EC is covered by the TSI INF and not by this TSI.

Table ZA.3 — Correspondence between this European Standard, the Commission Regulation on the technical specifications for interoperability relating to the “Infrastructure” subsystem of the rail system in the European Union published in the Official Journal L356/1 on 12/12/214, and Directive 2008/57/EC

Clause(s)/ sub clause(s) of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
Clause 5. Classification of infrastructure Clause 7 Compatibility of the interface between vehicle and infrastructure Annex A Annex D	4. Description of the Infrastructure subsystem 4.2 Functional and technical specifications of subsystem 4.2.1 TSI Categories of Line 4.2.6.Track resistance to applied loads §4.2.6.1.Track resistance to vertical loads 4.2.7.Structures resistance to traffic loads §4.2.7.1.Resistance of new bridges to traffic loads §4.2.7.1.1 Vertical loads §.4.2.7.4. Resistance of existing bridges and earthworks to traffic loads 6.Assessment of conformity of interoperability constituents and EC verification of the subsystems 6.2 Infrastructure sub system 6.2.4.Particular assessment procedures for infrastructure subsystem~~s~~ § 6.2.4.9 Assessment of new structures, earthworks and earth pressure effects 6.2.4.10.Assessment of existing structures 7.Implementation of the Infrastructure TSI 7.6.Ascertain compatibility of infrastructure and rolling stock after authorization of rolling stock Appendix E – Capability requirements for structures according to traffic code Appendix K – Basis for minimum requirements for structures for passenger coaches and multiple units Appendix L – Definition of EN line category a12 for traffic code P6	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.4 Environmental protection Clause 1.4.5 1.5 Technical compatibility	Clause 7.6 and Annexes E and L of the TSI mandate EN 15528:2015 EN 15528:2015 does not cover the RA classification system for lines and vehicles according the RA system used in the UK (see Annex F of the INF TSI)

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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