BS EN 12299:2009

Railway applications — Ride comfort for passengers — Measurement and evaluation

ICS 13.160; 45.060.20

British Standards

National foreword

This British Standard is the UK implementation of EN 12299:2009. It supersedes DD ENV 12299:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/1/-/5, Ride comfort.

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

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Foreword

This document (EN 12299:2009) 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of an identical text or by endorsement, at the latest by October 2009, and conflicting national standards shall be withdrawn at the latest by October 2009.

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1 Scope

This standard specifies methods for quantifying the effects of vehicle body motions on ride comfort for passengers and vehicle assessment with respect to ride comfort. The effect considered is:

— discomfort, associated with relatively low levels of acceleration and roll velocity.

Other effects, not included in the standard, are associated with higher acceleration levels:

— health risk effect: physical damage and psychological deterioration.

The standard applies to passengers travelling in railway vehicles on railway lines, including main, secondary and suburban lines. This standard could be used as a guide for other railway vehicles, for example locomotives, metros, trams, etc.

The standard applies to passengers in good health.

This standard applies to measurements of motions. It also applies to simulated motions.

2 Normative references

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

EN 14363, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

EN ISO 5353, *Earth-moving machinery, and tractors and machinery for agriculture and forestry - Seat index point (ISO 5353:1995)*

EN ISO 8041, *Human response to vibration - Measuring instrumentation (ISO 8041:2005)*

ISO 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

3 Terms and definitions

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

3.1
passengers
people travelling in a railway vehicle, without specific activities related to the transport

3.2
ride comfort
complex sensation produced during the application of oscillations and/or inertia forces, via whole-body transmission caused by the railway vehicle body motions

3.3
interfaces
contact parts between the vehicle body or seat and the passenger with the function of sustaining and guiding the passenger and of transmitting the weight of the same to the vehicle body itself, e.g. floor-feet

3.4
Mean Comfort
perceived comfort level, continuously adjusted, as evaluated through measurement on a long-time basis (at least some minutes)

3.5
Continuous Comfort
level of accelerations, ISO frequency weighted continuously evaluated as a set of rms (root mean square) values in vertical, lateral and longitudinal direction over a short time period (typical 5 s)

3.6
Comfort on Curve Transition
discomfort, due to a perceived curve transition

3.7
Comfort on Discrete Event
discomfort, due to a perceived transient oscillation

3.8
whole-body transmission
motion transmitted to the whole body through the interfaces between vehicle body and passenger

3.9
indirect measurement
measurement of motion environment by different motion quantities, such as acceleration or roll velocity

3.10
direct measurement
measurement of actual passenger reactions, for example by asking passengers to fill in a questionnaire

3.11
vehicle assessment with respect to ride comfort
identifying the vehicle's contribution to the ride comfort by relating the measured ride comfort to the condition of the track (geometry, irregularities, turnout, bridges, etc.) and operation condition (speed, cant deficiency, etc.)

3.12
test section
part of a line used for the comfort test

3.13
test zone
continuous five-minute period, which is used for Mean Comfort evaluation

3.14
five-second time period
sampling period, of which 60 forms the test zone

3.15
reference system
local reference system for a vehicle body is defined through:

Origin: on the floor of the vehicle body, in the central position between the two body-bogie centre pivots (existing or ideally defined)

Axis:

— x-axis: longitudinal

— y-axis: lateral

— z-axis: vertical

Roll motions (φ) are defined as rotation around the x-axis.

For human body reference system, right hand system is used with vertical direction defined upwards.

A more detailed definition of the reference system is given in Annex A.

4 Symbols, units and abbreviations

Table 1 defines the symbols, units and abbreviations used in this standard.

Table 1 — Symbols, units and abbreviation

General parameters			
Parameter	**Symbol**	**Unit**	
Time	t	[s]	
Time period	T	[s]	
Integration variable	τ	[s]	
Vehicle speed	V	[km/h]	
Frequency	f	[Hz]	
Interface, the floor (Plancher in French)	P	[-]	
Interface, the seat pan (Assise in French)	A	[-]	
Interface, the seat back (Dossier in French)	D	[-]	
Frequency weighting curve for vertical direction	W_b	[-]	
Frequency weighting curve for longitudinal direction (backrest),	W_c	[-]	
Frequency weighting curve for lateral/longitudinal direction,	W_d	[-]	
Low-pass filter	W_p	[-]	
n-tile	k	[-]	
Percentile	n	[%]	
Number of samples	N	[-]	
Imaginary unit	i	[-]	
Root mean square	rms	[-]	
Parameter	**Longitudinal axis**	**Lateral Axis**	**Vertical Axis**
Translational Accelerations on running gear [m/s^2]			
Wheel set *i*	–	$\ddot{y}_i$	–
Translational Accelerations in vehicle body [m/s2]			
Leading end of passenger compartment	–	$\ddot{y}^*_{EI}$	$\ddot{z}^*_{EI}$
Over leading bogie	–	$\ddot{y}^*_{I}$	$\ddot{z}^*_{I}$
Body centre	$\ddot{x}^*_{M}$	$\ddot{y}^*_{M}$	$\ddot{z}^*_{M}$

Table 1 *(continued)*

Parameter	**Longitudinal axis**	**Lateral Axis**	**Vertical Axis**
Over trailing bogie	–	$\ddot{y}^*_{\mathbf{II}}$	$\ddot{z}^*_{\mathbf{II}}$
Trailing end of passenger compartment	–	$\ddot{y}^*_{EII}$	$\ddot{z}^*_{\mathbf{EII}}$
Floor, rms	$a_{\mathbf{XP}}$	$a_{\mathbf{YP}}$	$a_{\mathbf{ZP}}$
Translational Weighted accelerations [m/s2]			
Seat, weighted $W_{\mathbf{c}}$, $W_{\mathbf{b}}$	$\ddot{x}^*_{\mathbf{D,Wc}}$	–	$\ddot{z}^*_{\mathbf{A,Wb}}$
Vehicle body, weighted $W_{\mathbf{d}}$, $W_{\mathbf{b}}$	$\ddot{x}^*_{\mathbf{P,Wd}}$	$\ddot{y}^*_{\mathbf{P,Wd}}$	$\ddot{z}^*_{\mathbf{P,Wb}}$
Vehicle body, weighted $W_{\mathbf{p}}$	–	$\ddot{y}^*_{\mathbf{P,Wp}}$	–
Seat, weighted $W_{\mathbf{c}}$, $W_{\mathbf{d}}$, $W_{\mathbf{b}}$, rms	$a^{\mathbf{W_c}}_{\mathbf{XD}}$	$a^{\mathbf{W_d}}_{\mathbf{YA}}$	$a^{\mathbf{W_b}}_{\mathbf{ZA}}$
Floor, weighted $W_{\mathbf{d}}$, $W_{\mathbf{b}}$, rms	$a^{\mathbf{W_d}}_{\mathbf{XP}}$	$a^{\mathbf{W_d}}_{\mathbf{YP}}$	$a^{\mathbf{W_b}}_{\mathbf{ZP}}$
Floor, Weighted $W_{\mathbf{d}}$, $W_{\mathbf{b}}$, rms, 50th percentile	$a^{\mathbf{W_d}}_{\mathbf{XP50}}$	$a^{\mathbf{W_d}}_{\mathbf{YP50}}$	$a^{\mathbf{W_b}}_{\mathbf{ZP50}}$
Seat, weighted $W_{\mathbf{c}}$, $W_{\mathbf{d}}$, $W_{\mathbf{b}}$, rms, 95th percentile	$a^{\mathbf{W_c}}_{\mathbf{XD95}}$	$a^{\mathbf{W_d}}_{\mathbf{YA95}}$	$a^{\mathbf{W_b}}_{\mathbf{ZA95}}$
Floor, weighted $W_{\mathbf{d}}$, $W_{\mathbf{b}}$, rms, 95th percentile	$a^{\mathbf{W_d}}_{\mathbf{XP95}}$	$a^{\mathbf{W_d}}_{\mathbf{YP95}}$	$a^{\mathbf{W_b}}_{\mathbf{ZP95}}$
One-second average	–	$\ddot{y}_{\mathbf{1s}}(t)$	–
Two-second average	–	$\ddot{y}_{\mathbf{2s}}(t)$	–
Peak to peak	–	$\ddot{y}_{\mathbf{pp}}(t)$	–
One-second average, maximum absolute value	–	$\lvert\ddot{y}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	–
Two-second average, absolute value	–	$\lvert\ddot{y}_{\mathbf{2s}}(t)\rvert$	–
Translational jerk in vehicle body [m/s^3]			
One-second average	–	$\dddot{y}_{\mathbf{1s}}(t)$	–
One-second average, maximum absolute value	–	$\lvert\dddot{y}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	–
Angular velocity in vehicle body [rad/s]			
Body	$\dot{\varphi}^*(t)$	–	–
Weighted $W_{\mathbf{p}}$	$\dot{\varphi}^*_{\mathbf{Wp}}(t)$	–	–
One-second average	$\dot{\varphi}_{\mathbf{1s}}(t)$	–	–
One-second average, maximum absolute value	$\lvert\dot{\varphi}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	–	–

Table 1 *(continued)*

Parameter	Longitudinal axis	Lateral Axis	Vertical Axis
Comfort indexes [-]			
Mean Comfort Standard Method	N_{MV}		
Mean Comfort Standard Method, partial index	N_{MVx}	N_{MVy}	N_{MVz}
Mean Comfort Complete Method, seated passenger (in French: VA=voyageur assis)	N_{VA}		
Mean Comfort Complete Method, standing passenger (in French: VD=voyageur debout)	N_{VD}		
Continuous Comfort	C_{Cx}	C_{Cy}	C_{Cz}
Comfort on Curve Transitions	P_{CT}		–
Comfort on Discrete Events	–	P_{DE}	–
Constants for Passenger Comfort on curve transitions and discrete events			
Parameter	**Symbol**		**Unit**
Constant in acceleration component in Curve Transitions	A		[s^2/m]
Constant in acceleration component in Curve Transitions	B		[s^3/m]
Constant in acceleration component in Curve Transitions	C		[-]
Constant in roll velocity component in Curve Transitions	D		[s/rad]
Constant in roll velocity component in Curve Transitions	E		[-]
Constant in acceleration component in Discrete Events	a		[s^2/m]
Constant in acceleration component in Discrete Events	b		[s^2/m]
Constant in acceleration component in Discrete Events	e		[-]
Transfer functions			
Parameter	**Symbol**		**Unit**
Corner frequencies, n=1,2,3,4,5,6	f_n		[Hz]
Resonant quality factors, n=1,2,3,4	Q_n		[-]
Gain	K		[-]
High pass transfer function	$H_h(f)$		[-]
Low pass transfer function	$H_l(f)$		[-]
Acceleration to velocity transfer function	$H_t(f)$		[-]
Upward gradient transfer function	$H_s(f)$		[-]

5 General description

5.1 General

The comfort of passengers in a railway vehicle is influenced by a number of different factors (temperature, noise, vibration, etc.). This standard considers only that part of the comfort influenced by the vibrations and motions of the vehicle. This is described as ride comfort or as passenger comfort. The standard can also be used for vehicle assessment with respect to ride comfort.

This standard defines as the Standard Method:

a) The Standard Method for Mean Comfort evaluation, taking into account the effects of vibration exposure measured on the floor of the vehicle body.

This standard also defines several methods for special applications:

b) taking into account the short time effects of vibration exposure measured on the floor of the vehicle body as Continuous Comfort for the longitudinal, lateral, and vertical direction;

c) taking into account the vibration exposure measured on the seat or other interfaces on ride comfort as the Complete Method for Mean Comfort evaluation;

d) taking into account the effects of:

   1) discrete events (Comfort on Discrete Events) and

   2) running on curve transitions (Comfort on Curve Transitions) on ride comfort.

e) taking into account the vibration exposure measured on the floor of the vehicle body for the purpose of vehicle assessment with respect to ride comfort.

5.2 Passenger exposure to vibrations

Railway transport exposes passengers to vibrations related to the dynamic motions of the vehicle body.

The motions of the vehicle body transmit their effects to the human body through the following interfaces:

a) in the standing position:

   1) floor – feet

b) in the seated position:

   1) headrest – neck

   2) arm rest – arms

   3) seat – hip

   4) backrest – back

   5) floor – feet

The type of transmission is whole-body transmission which acts on the whole body through the interfaces.

5.3 Application

Table 2 lists the items included or excluded from this standard:

Table 2 — Items considered by this standard

Item	Included	Excluded
Effects of vibration exposure	— on ride comfort — on vehicle assessment with respect to ride comfort	— on health — on activities — on motion sickness
Vibration transfer	— on whole body through interfaces — through floor interface	— on single body part — on whole surface
Test procedure	— definitions — reference system — requirements — measurement and evaluation rules — report guidance	— notes or attributes related to service quality and/or passenger expectation — limiting values
Posture and activities of passenger	— standing — seated	— lying — performing specific actions (reading, writing etc.)
Type of measurement	— indirect measurement, i.e. measurement of motion environment by different motion quantities	— direct measurements (by asking test subjects) — combined measurements

5.4 Characteristics of railway vehicle motions

The basic typical motion characteristics, referred to the type of measurement and evaluation, are:

a) Different properties, depending on the type of evaluation:

   1) quasi-stationary (Mean Comfort)

   2) non-stationary (Comfort on Curve Transitions and Comfort on Discrete Events).

b) The frequency range of motions expected in rail vehicles includes, in the lateral direction:

   1) up to 15 Hz: due to track characteristics, vehicle body swing-roll and yaw modes at lower frequencies, and suspensions characteristics and vehicle body modes at higher frequencies;

c) The frequency range of motions expected in rail vehicles includes, in the vertical direction:

   1) up to 40 Hz: due to track characteristics, suspensions characteristics, wheel defects, vehicle body modes;

d) Range of frequencies from 0 Hz (quasi-static) to 2 Hz for Comfort on Curve Transitions and for Discrete Events.

5.5 Ride comfort

The ride comfort for passengers is the complex sensation, produced on the passenger by the vehicle body motions of the railway vehicle, transmitted to the whole body through the interfaces.

This sensation is classified as:

a) average sensation, based on the vibration applied on a long-time basis (several minutes);

b) quasi-static lateral acceleration due to curving.

c) instantaneous sensation: a sudden change of the average sensation, due to a short-basis event (change of mean lateral acceleration level with possible oscillation, roll motion at significant velocity and lateral jerk);

The first type of sensation is taken into account in the Mean Comfort evaluation.

The second and the third type of sensation are taken into account in the Comfort on Curve Transitions and in Comfort on Discrete Events.

5.6 Direct and indirect measurements

The quantification of ride comfort for passengers is performed through indirect measurements, i.e. measuring and post-processing the relevant motion quantities. Other types of tests and evaluation, such as direct tests based on the assessment of the perceptions of tested passengers, and combined tests, including both direct and indirect tests, are not defined in this standard. However, some guidance for direct tests is given in Annex F.

5.7 Summary table of procedures

The evaluation of ride comfort for passengers is taken into account in this standard by:

a) procedure for the quantification of comfort index “Mean Comfort” by the Standard Method ($N_{\mathbf{MV}}$), see Clause 6 and Annex H;

b) procedure for the quantification of comfort index “Mean Comfort” by the Complete Method ($N_{\mathbf{VA}}$, $N_{\mathbf{VD}}$), see Clause 6 and Annex H;

c) procedure for the quantification of comfort index “Comfort on Curve Transitions” ($P_{\mathbf{CT}}$), see Clause 7 and Annex H;

d) procedure for the quantification of comfort index “Comfort on Discrete Events” ($P_{\mathbf{DE}}$), see Clause 8 and Annex H;

e) procedure for the quantification of Continuous Comfort *(* $C_{\mathbf{Cx}}$, $C_{\mathbf{Cy}}$, $C_{\mathbf{Cz}}$ *)*, see Clause 6 and Annex H.

This standard also provides requirements for assessment of vehicles with respect to ride comfort by Continuous Comfort and the Standard Method ($N_{\mathbf{MV}}$) with acceptable deviations; see Annex E.

Motion quantities and position of measurement for the different comfort indices are listed in Table 3.

Table 3 — Motion quantities and measurement position for estimation of ride comfort

	Mean Comfort Standard Method	**Mean Comfort Complete Method**		**Continuous Comfort**	**Comfort on Curve Transitions**	**Comfort on Discrete Events**
Comfort index	$N_{\mathbf{MV}}$	$N_{\mathbf{VD}}$	$N_{\mathbf{VA}}$	$C_{\mathbf{Cx}}$, $C_{\mathbf{Cy}}$, $C_{\mathbf{Cz}}$	$P_{\mathbf{CT}}$	$P_{\mathbf{DE}}$
Motion quantities	Accelerations in three directions	Accelerations in three directions		Accelerations in three directions	Lateral acceleration, Lateral jerk, Roll velocity	Lateral acceleration
Measuring position	Floor	Floor	Floor and interfaces	Floor	Floor	Floor

5.8 Application of comfort indices

The different procedures for ride comfort estimation and their applications are summarised in Table 4.

Table 4 — Specification of different comfort indices for estimations of ride comfort and Vehicle assessment with respect to ride comfort

	Mean Comfort Standard Method	Mean Comfort Complete Method	Continuous Comfort	Comfort on Curve Transitions	Comfort on Discrete Events
Comfort Index	N_{MV}	N_{VA}, N_{VD}	C_{Cx}, C_{Cy}, C_{Cz}	P_{CT}	P_{DE}
Passenger comfort	✓	✓	✓	✓	✓
Vehicle assessment	✓		✓	✓ (tilting vehicles)	

All procedures are normative. The Mean Comfort Standard Method is normative for Mean Comfort applications. If used, the Mean Comfort Complete Method shall be used together with the Mean Comfort Standard Method.

Certain other applications where it is possible to use the different comfort indices are shown in Table 5.

Table 5 — Guidance to use the different comfort indices for other applications

	Mean Comfort Standard Method	Mean Comfort Complete Method	Continuous Comfort	Comfort on Curve Transitions	Comfort on Discrete Events
Comfort Index	N_{MV}	N_{VA}, N_{VD}	C_{Cx}, C_{Cy}, C_{Cz}	P_{CT}	P_{DE}
Track geometry				✓	
Maintenance - track	✓		✓		✓
Maintenance - vehicle	✓		✓		

6 Mean Comfort and Continuous Comfort

6.1 General

Mean ride comfort is divided in two methods; the Standard Method taking into account the vibration on the floor interface and the Complete Method (seated and standing) taking into account vibrations in seat and/or floor interfaces.

The formula of the Standard Method is a simplification of the more general but more complicated Complete Method. The Complete Method is better correlated with the passenger's perception of comfort than the Standard Method.

The Continuous Comfort is a quadratic average (rms) of the frequency weighted accelerations measured to evaluate the Mean Comfort.

These methods can be applied on straight and curved lines.

NOTE 1 Caution should be taken when applying these methods on curved track, as the effects of quasi-static lateral accelerations in curves are excluded by the frequency weighting filters. The methods are validated on fairly straight lines.

NOTE 2 The application of the Standard Method is constrained by the condition that the longitudinal vibration should not be excessive.

NOTE 3 When the Complete Method is used, the Standard Method should also be applied, for reference purposes.

The object is to define:

a) the conditions for carrying out running tests to assess Mean Comfort (Standard and Complete Method) and Continuous Comfort;

b) the parameters to be measured and the methods to be used to obtain the assessment values.

This clause constitutes an application document for the railway field covering the measurement, analysis and evaluation of vibration, taking into account that mechanical vibration in a railway vehicle presents certain specific characteristics.

Application of this clause, on the basis of the measurement of certain accelerations, will permit an evaluation to be made of Mean Comfort and Continuous Comfort in a defined vehicle under defined service conditions.

Application of these methods will give comfort indexes or rms-values for the vehicle-track system. The separate influence of the vehicle and track cannot be assessed without further information on vehicle and seat characteristics, track layout and track geometry quality.

Application of these methods under the prescribed conditions may assist in the identification of causes of discomfort.

6.2 Base of the method

Comfort is perceived in different ways by different people. It is therefore impossible to specify a unique assessment system which is valid for everybody.

As a result of this, the evaluation of Mean Comfort, made in this standard, is based on the relationship between the accelerations measured in a vehicle and the Mean Comfort ratings given by a representative group of passengers for periods of 5 min.

NOTE The Standard and Complete Methods are demonstrated and validated in the reports of the ERRI B153 Committee, particularly in Rp10, Rp12, Rp13, Rp17 and DT219 (B153) (exists only in French).

6.3 Methodology

Evaluation of Mean Comfort and Continuous Comfort consists of:

a) measuring the accelerations on the floor of the vehicle and for the Complete Method also on seat interfaces;

b) digitisation together with appropriate anti-aliasing filter.

The computation is carried out through:

c) frequency weighting of signals;

d) calculation of rms-values over 5 s time periods, resulting in Continuous Comfort;

e) calculation of the 95^{th} percentile and for the Complete Method also 50^{th} percentile over a time period of 5 min;

f) calculation of Mean Comfort index for each measuring point.

6.4 Test conditions

6.4.1 General

The general test conditions are described in this clause. The detailed conditions may vary depending on the application and should be considered in the specification of the test. The test conditions used shall be given in the test report, see 6.8. For the purpose of vehicle assessment with respect to ride comfort the test conditions are further elaborated in Annex E.

6.4.2 Selection of test sections

The choice of the test sections should be done in such a way that operating conditions representative for the tested vehicle are taken into account, for instance, track geometry and track quality.

The duration of the measurements for evaluation of Mean Comfort shall be a multiple of 5 min. The minimum required is four test zones of 5 min. These test zones may be separate, but each of them shall be issued from a continuous record.

It is recommended to record the vehicle's position along the track during the test run.

6.4.3 Test speed

The comfort of the passenger should be evaluated at the various operating speeds of the vehicle, which really occur, or are foreseen, in service, and especially at the maximum operating speed.

For Mean Comfort evaluation, the test speed should be kept constant during the test zones of 5 min.

6.4.4 Wheel-rail contact geometry

The comfort may be influenced by the wheel-rail contact geometry. This is especially important for the purpose of vehicle assessment, see Annex E.

6.4.5 Vehicle condition

The comfort is influenced by the vehicle characteristics (mass, centre of gravity, inertia, stiffness, damping etc.) and position in the train of the vehicle(s) tested. The mass, centre of gravity etc. depend on type of vehicle, vehicle-mounted equipment, passenger loads, etc.

The comfort is also influenced by characteristics of the tilting system (if any).

The coupling should be tightened as for normal service.

6.5 Parameters to be measured

6.5.1 General

Mean Comfort and Continuous Comfort are calculated on the basis of accelerometer measurements. These measurements are carried out at different points on the floor and/or seat interfaces.

Annex B describes the measuring techniques.

6.5.2 Location of measuring points

The accelerations at a given point in a vehicle are closely dependent upon the location of that point. For this reason, the measurements shall be carried out at the centre of the body and at both ends of the passenger compartment, at the seats most closely located to these positions. Figure 1 shows an example of the locations of these measuring points on the floor of a conventional vehicle; Figure 2 shows the same on a double-deck vehicle.

Depending on the method used and the type of vehicle, the following measuring points are to be taken into account:

a) single-deck vehicles:

1) one point at the centre and one point at each end of the passenger compartment.

b) double-deck vehicles:

1) one point at the centre and one point at each end of the lower deck of the passenger compartment;

2) one point at the centre of the upper deck of the passenger compartment.

Floor accelerometers shall be fixed to the floor as closely as possible to the vertical projection at the centre of the seat pan (preferably less than 100 mm from this point). In the case of standing position studies on urban transit stock, an accelerometer shall also be placed on the vestibule floor.

Additional measuring points may be used depending on the purpose of the test, for example measurement above the pivot of the bogie.

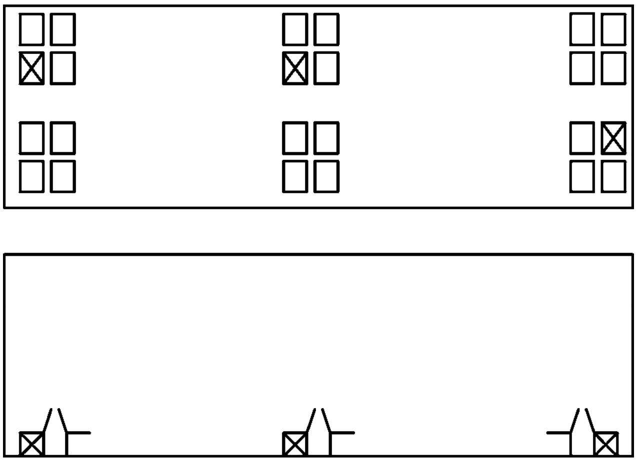


Figure 1 — Locations of measuring points
Passenger coach (Conventional or articulated)

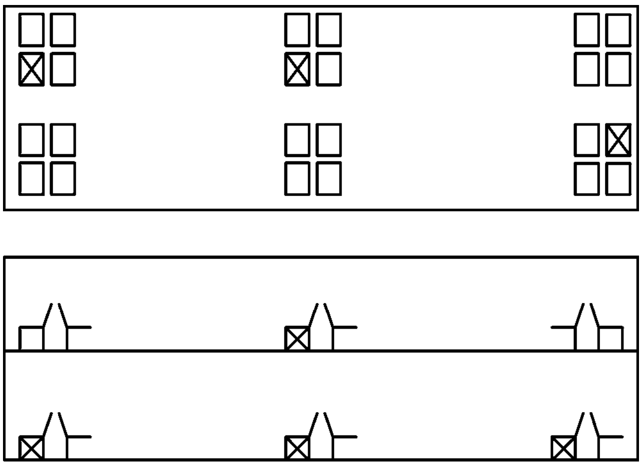


Figure 2 — Location of measuring points
Double-Deck vehicle (Conventional or articulated)

6.5.3 Filtering

The measured signals shall be filtered using the weighting curves with tolerance bands defined in Annex C.

6.6 Definition of intermediate quantities

6.6.1 Symbols and indices

Symbols

N = Comfort index

General expressions of frequency weighted rms-accelerations:

$a_{Xj}^{W_i}(t)$ (Longitudinal)

$a_{Yj}^{W_i}(t)$ (Lateral)

$a_{Zj}^{W_i}(t)$ (Vertical)

where

a rms acceleration values, in m/s^2, taken over 5 s

W_i superscript index relates to the weighted frequency values in accordance with the weighting curve ***i*** (***i*** = b, c, d):

b: vertical direction W_b

c: longitudinal direction (backrest), W_c

d: lateral/longitudinal direction, W_d

j subscript indices related to:
j : measuring position
P: the floor interface
A: the seat pan interface
D: the seat back interface

NOTE The weighting curve W_b deviates from W_k defined in ISO 2631-1.

General expressions of a percentile taken from a frequency weighted rms-acceleration distribution:

$a_{Xjk}^{W_i}$ (Longitudinal)

$a_{Yjk}^{W_i}$ (Lateral)

$a_{Zjk}^{W_i}$ (Vertical)

where

a Distribution of rms acceleration values, in m/s^2

W_i superscript index relates to the weighted frequency values in accordance with the weighting curve ***i*** (***i*** = b, c, d):

b: vertical direction, W_b

c: longitudinal direction (backrest), W_c

d: lateral/longitudinal direction , W_d

j subscript indices related to:
j : measuring position
P: the floor interface

A: the seat pan interface
D: the seat back interface

k: subscript index indicating the percentile used
(*k*=95 for the 95th percentile)

6.6.2 Rms-values of weighted accelerations

The five-second rms-values of the frequency weighted accelerations are calculated as:

$$a_{\mathbf{Xj}}^{\mathbf{W_i}}(t) = \left[\frac{1}{T} \cdot \int_{t-T}^{t} (\ddot{x}_{\mathbf{W_i}}^{*}(\tau))^2 \, d\tau \right]^{0.5} \quad (1)$$

$$a_{\mathbf{Yj}}^{\mathbf{W_i}}(t) = \left[\frac{1}{T} \cdot \int_{t-T}^{t} (\ddot{y}_{\mathbf{W_i}}^{*}(\tau))^2 \, d\tau \right]^{0.5} \quad (2)$$

$$a_{\mathbf{Zj}}^{\mathbf{W_i}}(t) = \left[\frac{1}{T} \cdot \int_{t-T}^{t} (\ddot{z}_{\mathbf{W_i}}^{*}(\tau))^2 \, d\tau \right]^{0.5} \quad (3)$$

where

T = 5 s and t is a multiple of 5 s.

Work flows for numerical integration are shown in Annex G.

6.6.3 95th and 50th percentiles

The 95th percentiles of the distributions of five-second weighted rms-values calculated over a time period of 5 min are denoted as below:

$a_{\mathbf{XP95}}^{\mathbf{W_d}}$

$a_{\mathbf{YP95}}^{\mathbf{W_d}}$

$a_{\mathbf{ZP95}}^{\mathbf{W_b}}$

The 50th percentiles (median) of the distributions of five-second weighted rms-values calculated over a time period of 5 min are denoted as below:

$a_{\mathbf{XP50}}^{\mathbf{W_d}}$

$a_{\mathbf{YP50}}^{\mathbf{W_d}}$

$a_{\mathbf{ZP50}}^{\mathbf{W_b}}$

NOTE The kth n-tile of N samples is the value that corresponds to a cumulative frequency of $N \cdot k / n$, and if n = 100 it is called percentiles. Therefore, for a collection of 60 samples (5 min of five-second rms-values) the 95th percentile is the 57th value and the 50th percentile is the 30th value.

6.7 Definition of comfort indexes

6.7.1 Continuous Comfort

On floor level, the rms-values of the frequency weighted accelerations are defined as:

$$C_{\mathbf{Cx}}(t) = a_{\mathbf{XP}}^{\mathbf{W_d}}(t) \quad (4)$$

$$C_{\mathrm{Cy}}(t) = a_{\mathrm{YP}}^{\mathrm{W_d}}(t) \tag{5}$$

$$C_{\mathrm{Cz}}(t) = a_{\mathrm{ZP}}^{\mathrm{W_b}}(t) \tag{6}$$

The measures for the Continuous Comfort are functions of time.

6.7.2 Mean Comfort Standard Method

Comfort formula:

$$N_{\mathrm{MV}} = 6 \cdot \sqrt{\left(a_{\mathrm{XP95}}^{\mathrm{W_d}}\right)^2 + \left(a_{\mathrm{YP95}}^{\mathrm{W_d}}\right)^2 + \left(a_{\mathrm{ZP95}}^{\mathrm{W_b}}\right)^2} \tag{7}$$

If this formula is to be used for measurements carried out at more than one point of the vehicle, the value $a_{\mathrm{XP95}}^{\mathrm{W_d}}$ may be obtained from the centre of the vehicle.

Depending on the application, it can be useful to calculate the following partial Comfort Indexes:

$$N_{\mathrm{MVx}} = 6 \cdot a_{\mathrm{XP95}}^{\mathrm{W_d}} \tag{8}$$

$$N_{\mathrm{MVy}} = 6 \cdot a_{\mathrm{YP95}}^{\mathrm{W_d}} \tag{9}$$

$$N_{\mathrm{MVz}} = 6 \cdot a_{\mathrm{ZP95}}^{\mathrm{W_b}} \tag{10}$$

6.7.3 Mean Comfort Complete Method

Comfort formula for seated:

$$N_{\mathrm{VA}} = 4 \cdot \left(a_{\mathrm{ZP95}}^{\mathrm{W_b}}\right) + 2 \cdot \sqrt{\left(a_{\mathrm{YA95}}^{\mathrm{W_d}}\right)^2 + \left(a_{\mathrm{ZA95}}^{\mathrm{W_b}}\right)^2} + 4 \cdot \left(a_{\mathrm{XD95}}^{\mathrm{W_c}}\right) \tag{11}$$

Comfort formula for standing:

$$N_{\mathrm{VD}} = 3 \cdot \sqrt{16 \cdot \left(a_{\mathrm{XP50}}^{\mathrm{W_d}}\right)^2 + 4 \cdot \left(a_{\mathrm{YP50}}^{\mathrm{W_d}}\right)^2 + \left(a_{\mathrm{ZP50}}^{\mathrm{W_b}}\right)^2} + 5 \cdot \left(a_{\mathrm{YP95}}^{\mathrm{W_d}}\right) \tag{12}$$

6.8 Test report

The test report shall be sufficiently detailed so that the execution of the comfort test is comprehensible and that special occurrences can be identified. The level of details depends on the purpose of the test. Annex D gives guidelines for the test report.

7 Comfort on Curve Transitions

7.1 General

The assessment of passenger comfort according to P_{CT} is useful in situations where curve transitions make a significant contribution to the passenger's perception of comfort. It gives a measure of the passenger comfort for an individual transition curve without evaluation of cumulative effects. It is applicable to all vehicles and at any speed.

The object is to define:

a) the conditions for carrying out running tests to assess Comfort on Curve Transitions;

b) the parameters to be measured and the methods to be used to obtain the assessment values.

7.2 Base of the method

The method is based on the technical report BRR TR DOS 017, also assumed as a calculation and experimental guideline by ERRI B176 Committee and applied, with some clarifications, in Italy and Switzerland for tilting system tests in 1991.

The method concerns measurements and evaluation of the Comfort on Curve Transitions instantaneously perceived by the passengers as a sudden modification of the average feeling of ride comfort, due to low-frequency behaviour on entry, reverse transitions and transitions with increasing lateral acceleration within compound curves. This type of feeling is perceived in different ways by different people. It is therefore impossible to specify a unique assessment, valid for everybody, based on direct tests. Transition curves with strictly decreasing magnitude of lateral acceleration do not cause passenger discomfort.

As a result, the evaluation of Comfort on Curve Transitions is based on the relationship between the average percentage of dissatisfied passengers and the most relevant magnitudes of lateral acceleration, lateral jerk, and roll velocity of the vehicle body.

The formula has been validated for transitions with increasing magnitude of lateral acceleration, where curvature and cant change linearly with respect to distance along the track, having duration of at least 2 s. However, there are no alternative formulas for transition curves and cant transitions with other shapes of curvature and cant, and/or transition curves with a shorter duration than 2 s.

7.3 Methodology

Evaluating the Comfort on Curve Transitions consists of:

a) measuring the lateral acceleration (on the floor, in the middle of the passenger compartment and at the leading end of the passenger compartment) and roll velocity of the vehicle body, from beginning to end of the relevant time period, see Note below;

b) identification of each relevant time period; and for each period digitising together with appropriate anti-aliasing filter;

c) low-pass filtering of signals;

d) sliding window analysis and subsequent computation of:

   1) variation of lateral acceleration of the vehicle body from beginning to end of this time period;

   2) maximum values (not necessarily occurring simultaneously) for roll velocity and lateral jerk of the vehicle body;

   3) P_{CT} Comfort index calculation, at each measuring point indicated above.

NOTE If a bogie is placed under the passenger compartment, the measurement at the end of the passenger compartment may be replaced by the measurement at position above that bogie.

7.4 Test conditions

7.4.1 General

The general test conditions are described in this clause. The detailed conditions may vary depending on the application and should be considered in the specification of the test. The test conditions used shall be given in the test report, see 7.8.

7.4.2 Selection of test sections

The choice of the test sections depends on the purpose of the investigation. It may be a selection of representative service conditions, or a selection of worst cases, with respect to the track geometry.

7.4.3 Test speed

The choice of the test speed depends on the purpose of the investigation; this may be the service speed or a different speed.

7.4.4 Wheel-rail contact geometry

Wheel-rail contact geometry normally has little influence on Comfort on Curve Transitions evaluated as $P_{\mathbf{CT}}$. No specific recommendations are needed.

7.4.5 Vehicle condition

The comfort is influenced by characteristics of the tilting system (if any). However, the comfort is also influenced by the vehicle characteristics (mass, centre of gravity, inertia, stiffness, damping etc.) and position in the train of the vehicle(s) tested. The mass, centre of gravity etc. depend on type of vehicle, vehicle-mounted equipment, passenger loads, etc.

The coupling should be tightened as for normal service.

7.5 Parameters to be measured

7.5.1 General

Comfort on Curve Transitions is calculated on the basis of accelerometer and gyroscope measurements. These are carried out at different points on the floor.

Annex B describes the measuring techniques.

7.5.2 Location of measuring points

The following measurements shall be taken:

a) lateral acceleration $\ddot{y}^*_{\mathbf{M}}(t)$ in the middle of the vehicle body floor and the leading end of the passenger compartment $\ddot{y}^*_{\mathbf{EI}}(t)$;

b) roll velocity of the vehicle body $\dot{\varphi}^*(t)$, at a suitable position of the vehicle body.

7.5.3 Filtering

The measured signals shall be filtered using the low-pass filter $W_{\mathbf{p}}$ with tolerance bands defined in Annex C. This leads to the filtered lateral acceleration $\ddot{y}^*_{\mathbf{P,Wp}}(t)$, and filtered roll velocity $\dot{\varphi}^*_{\mathbf{Wp}}(t)$.

7.6 Definition of intermediate quantities

7.6.1 Symbols and indices

$\lvert\ddot{y}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	The maximum absolute value of lateral acceleration in the vehicle body, in the time period between the beginning of transition curve and the end plus 1,6 s, expressed in m/s^2 (see Note).
$\lvert\dddot{y}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	The maximum absolute value of lateral jerk in the transition curve, in the time period between 1 s before the beginning of the transition curve, and the end of the transition, expressed in m/s^3.
$\lvert\dot{\varphi}_{\mathbf{1s}}\rvert_{\mathbf{max}}$	The maximum absolute value of roll velocity, in the time period between the beginning and the end of the transition curve, expressed in radians per second.

$P_{\mathbf{CT}}$ Comfort index on Curve Transitions, calculated following Equation (16), indicating the percentage of dissatisfied passengers.

For reverse transitions, maximum value $\left|\ddot{y}_{\mathbf{1s}}\right|_{\mathbf{max}}$ shall be taken in the time period from the inflexion point where lateral acceleration is zero to the end plus 1,6 s (see Note).

NOTE The time period may be extended if it is evident that the peak acceleration is reached after the end plus 1,6 s

7.6.2 Averaging procedure

The signals shall be treated as follows:

a) the filtered lateral acceleration of the vehicle body $\ddot{y}^{*}_{\mathbf{Wp}}(t)$ treated by a one-second averaging window, leads to one-second averaged lateral acceleration $\ddot{y}_{\mathbf{1s}}(t)$ maximal stepping time period of 0,1 s (see Figure 3 —);

b) the filtered roll velocity $\dot{\varphi}^{*}_{\mathbf{Wp}}(t)$, treated by a one-second averaging window, leads to one-second averaged roll velocity $\dot{\varphi}_{\mathbf{1s}}(t)$ (see Figure 4);

c) the filtered lateral jerk $\dddot{y}_{\mathbf{1s}}(t)$ is derived from the one-second averaged lateral acceleration $\ddot{y}_{\mathbf{1s}}(t)$.

The averaging during the period T of 1 s, shall be performed according to Equation (13), Equation (14) and Equation (15), note that the new signal shall refer to the centre position of the averaging window.

$$\ddot{y}_{1s}(t)=\frac{1}{T}\cdot\int_{t-\frac{T}{2}}^{t+\frac{T}{2}}\ddot{y}^{*}_{\mathrm{Wp}}(\tau)d\tau \qquad (13)$$

where

T = 1 s

$$\dot{\varphi}_{1s}(t)=\frac{1}{T}\cdot\int_{t-\frac{T}{2}}^{t+\frac{T}{2}}\dot{\varphi}^{*}_{Wp}(\tau)d\tau \qquad (14)$$

where

T = 1 s

$$\dddot{y}_{\mathbf{1s}}(t)=\frac{1}{T}\cdot\left(\ddot{y}_{\mathbf{1s}}(t+\frac{T}{2})-\ddot{y}_{\mathbf{1s}}(t-\frac{T}{2})\right) \qquad (15)$$

where

T = 1 s

7.6.3 Identification of transition periods

For entry, reverse transitions and transitions with increasing lateral acceleration within compound curves, the points of beginning and end are selected on the basis of the nominal track geometry. See Figure 5.

7.6.4 Intermediate quantities

a) In the time period from beginning to end plus 1,6 s (see Note) of the transition curve, the maximum absolute value of lateral acceleration $|\ddot{y}_{1s}|_{max}$, shall be taken as the maximum absolute value of $\ddot{y}_{1s}(t)$;

b) in the time period from 1 s before the beginning to the end of the transition curve, the maximum absolute value of lateral jerk, $|\dddot{y}_{1s}|_{max}$, shall be taken as the maximum absolute value of $\dddot{y}_{1s}(t)$;

c) in the time period from the beginning to the end of the transition curve, the maximum absolute value of body roll velocity $|\dot{\varphi}_{1s}|_{max}$, shall be taken as the maximum absolute value of $\dot{\varphi}_{1s}(t)$.

For reverse transitions, maximum value $|\ddot{y}_{1s}|_{max}$ shall be taken in the time period from the inflexion point where lateral acceleration is zero to the end plus 1,6 s (see Note).

NOTE The time period may be extended if it is evident that the peak acceleration is reached after the end plus 1,6 s.

7.7 Definition of comfort index P_{CT}

The P_{CT} Comfort index is calculated on the basis of the Equation (16) with constants according to Table 6.

$$P_{CT} = 100 \cdot \left\{ \max\left[(A \cdot |\ddot{y}_{1s}|_{max} + B \cdot |\dddot{y}_{1s}|_{max} - C); 0 \right] + (D \cdot |\dot{\varphi}_{1s}|_{max})^{E} \right\} \quad (16)$$

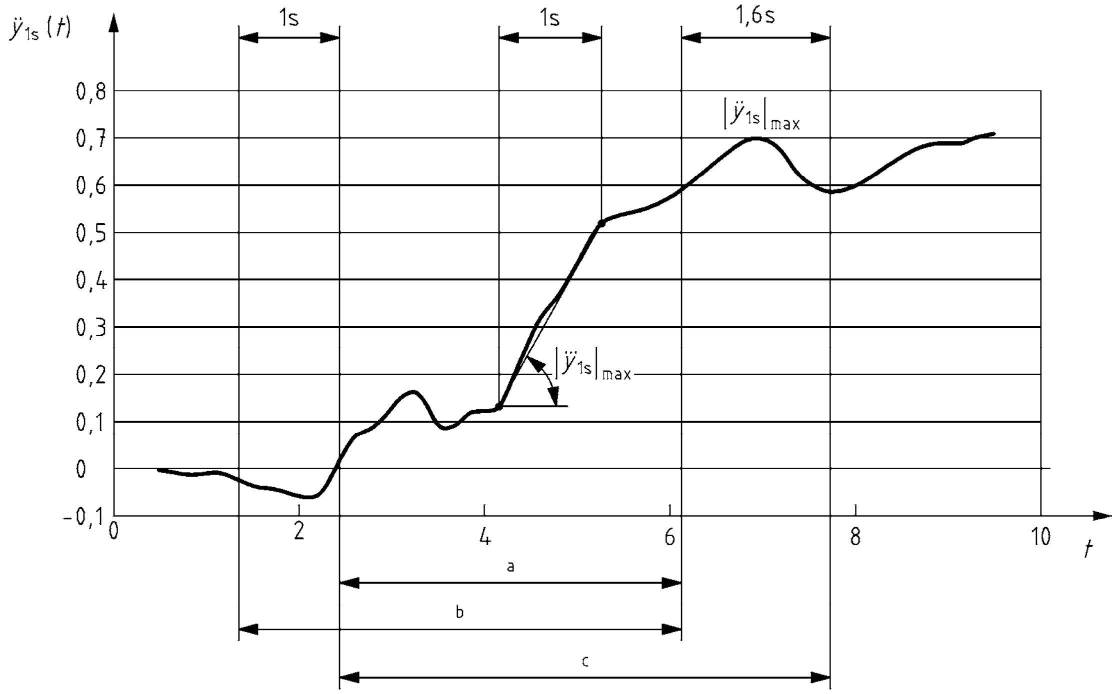
Table 6 — Constants for P_{CT} comfort index

Condition	A [s²/m]	B [s³/m]	C [-]	D [s/rad]	E [-]
In rest – standing	0,2854	0,2069	0,111	3,64	2,283
In rest – seated	0,0897	0,0968	0,059	0,916	1,626

7.8 Test report

The test report shall be sufficiently detailed so that the execution of the comfort test is comprehensible and that special occurrences can be identified. The level of details depends on the purpose of the test. Annex D gives guidelines for the test report.

7.9 Example diagrams



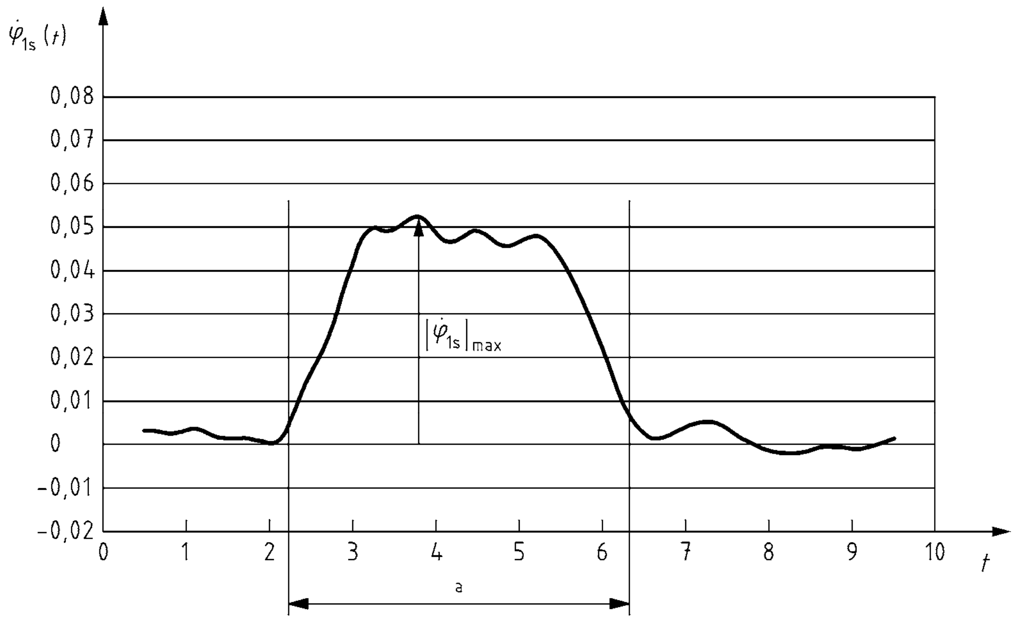
Key

a entry transition

b period for $\left|\dddot{y}_{1s}\right|_{max}$ evaluation

c period for $\left|\ddot{y}_{1s}\right|_{max}$ evaluation

Figure 3 — Interpretation of the terms, $\left|\ddot{y}_{1s}\right|_{max}$ and $\left|\dddot{y}_{1s}\right|_{max}$ in the P_{CT} formula



Key

a entry transition and period for $\left|\dot{\varphi}_{1s}\right|_{max}$ evaluation

Figure 4 — Interpretation of the term $\left|\dot{\varphi}_{1s}\right|_{max}$ in the P_{CT} formula

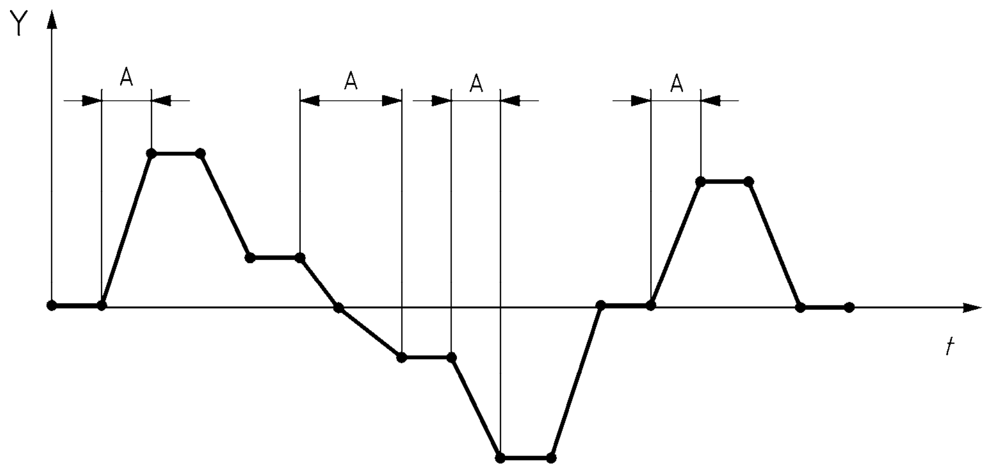


Figure 5 — Relevant time periods A_i on curve transition

NOTE 1 The method is validated for curve transitions annotated A_i if longer than 2 s. The test report should clarify whether transitions shorter than 2 s are excluded or included in the analysis.

NOTE 2 For cases where a straight track between two curves in opposite directions is very short, the original research report from British Rail Research (TR DOS 017) gives no guidance whether the transition curves should be treated as two separate transitions or as a continuous transition. Therefore, P_{CT} may be evaluated using the maximum lateral jerk and maximum roll velocity from both transition curves surrounding this short straight. The test report should clarify how the time period is defined. (The same applies to a very short circular curve between two transition curves where the lateral jerk has the same direction.)

8 Comfort on Discrete Events

8.1 General

The assessment of passenger comfort according to $P_{\mathbf{DE}}$ is useful in situations where the passenger's overall perception of comfort is influenced significantly by the presence of discrete events with respect to lateral acceleration. It gives a measure of the passenger comfort for an individual discrete event, without evaluation of cumulative effects. It is applicable to all vehicles, at any speed and on any track layout.

The object is to define:

a) the conditions for carrying out running tests to assess Comfort on Discrete Events;

b) the parameters to be measured and the methods to be used to obtain the assessment values.

8.2 Base of the method

The method is based on the technical report BRR TR DOS 017, using both conventional and tilting vehicles for a wide range of speeds and levels of uncompensated lateral acceleration covering both conventional and high speed operation.

The method concerns measurements and evaluation of Comfort on Discrete Events, instantaneously perceived by the passengers as a sudden change of the feeling of ride comfort, due to the dynamic behaviour of the vehicle on local track irregularities. This type of feeling is perceived in different ways by different people. It is therefore impossible to specify a unique assessment, valid for everybody, based on direct tests.

As a result, the evaluation of Comfort on Discrete Events is based on the relationship between the average percentage of dissatisfied passengers and the most relevant magnitudes of peak-to-peak lateral acceleration and mean lateral acceleration level.

8.3 Methodology

Evaluation of the Comfort on Discrete Events consists of:

a) measuring the lateral acceleration (on the floor, in the middle of the passenger compartment and at the leading end of the passenger compartment), see Note 1;

b) identification of relevant sections for evaluation; the whole test run or a part of it, see Note 2;

c) carry out digitisation together with appropriate anti-aliasing filter;

d) low-pass filtering of signals;

e) on a time window of 2 s: assessment of the maximum peak-to-peak lateral acceleration and of the mean lateral acceleration value;

f) in the case of separate evaluation of an individual event, the local maximum of $P_{\mathbf{DE}}(t)$ shall be considered as representative.

NOTE 1 If a bogie is placed under the passenger compartment, the measurement at the end of the passenger compartment may be replaced by the position above that bogie.

NOTE 2 The computation shall normally be applied to the whole test run. It can be applied to parts of it, such as bridges, junctions, single curves. In this case, the method needs the identification of the relevant parts.

8.4 Test conditions

8.4.1 General

The general test conditions are described in this clause. The detailed conditions may vary depending on the application and should be considered in the specification of the test. The test conditions used shall be given in the test report, see 8.8.

8.4.2 Selection of test sections

The choice of the test sections depends on the purpose of the investigation. It may be a selection of representative service conditions, or a selection of worst cases, with respect to the track geometry.

8.4.3 Test speed

The choice of the test speed depends on the purpose of the investigation; this may be the service speed or a different speed.

8.4.4 Wheel-rail contact geometry

The Comfort on Discrete Events may be influenced by the wheel-rail contact geometry.

8.4.5 Vehicle condition

The comfort is influenced by the vehicle characteristics (mass, centre of gravity, inertia, stiffness, damping etc.) and position in the train of the vehicle(s) tested. The mass, centre of gravity etc. depend on type of vehicle, vehicle-mounted equipment, passenger loads, etc.

The comfort is also influenced by characteristics of the tilting system (if any).

The coupling should be tightened as for normal service.

8.5 Parameters to be measured

8.5.1 General

Comfort on Discrete Events is determined on the basis of accelerometer measurements. These measurements are carried out at different points on the floor.

Annex B describes the measuring techniques.

8.5.2 Location of measuring points

The following measurements shall be taken:

— lateral acceleration $\ddot{y}^*_{\mathbf{M}}(t)$ in the middle of the vehicle body floor and the leading end of the passenger compartment $\ddot{y}^*_{\mathbf{El}}(t)$.

8.5.3 Filtering

The measured signals shall be filtered using the low-pass filter $W_{\mathbf{p}}$ with tolerance bands defined in Annex C. This leads to the filtered lateral accelerations $\ddot{y}^*_{\mathbf{P,Wp}}(t)$.

8.6 Definition of intermediate quantities

8.6.1 Symbols and indices

$|\ddot{y}_{\mathbf{2s}}(t)|$ Absolute value of mean value of lateral acceleration of the vehicle body, expressed in m/s^2.

$\ddot{y}_{\mathbf{pp}}(t)$ Maximum corresponding peak-to-peak lateral acceleration expressed in m/s^2.

$P_{\mathbf{DE}}$ Index for Comfort on Discrete Events, calculated following Equation (19), indicating the percentage of dissatisfied passengers.

a, b, c Constants defined in Table 7.

For each calculated value, the abscissa, in space or time, is given by the centre of calculation period.

The formula can be used for all types of horizontal alignments, straight track included, with the aim of an easier application.

8.6.2 Averaging procedure

The signals shall be treated as follows:

— the filtered lateral acceleration of the vehicle body $\ddot{y}^*_{\mathbf{P,Wp}}(t)$ treated by a two-second averaging window and taking the absolute values, leads to the corresponding acceleration $|\ddot{y}_{\mathbf{2s}}(t)|$ (Figure 6); maximal stepping time period of 0,1 s.

The averaging of the signals during the period T of 2 s shall be performed according to Equation (17), note that the new signal shall refer to the centre position of the averaging window.

$$|\ddot{y}_{\mathbf{2s}}(t)| = \frac{1}{T}\left|\int_{t-\frac{T}{2}}^{t+\frac{T}{2}} \ddot{y}^*_{\mathbf{P,Wp}}(\tau)d\tau\right| \tag{17}$$

where

T = 2 s

8.6.3 Intermediate quantities

Generally the complete test section is used in a continuous record.

The peak-to-peak calculation during the period T of 2 s, shall be performed according to Equation (18), i.e. the new signal shall refer to the centre position of the window.

$$\ddot{y}_{pp}(t) = \max\left(\ddot{y}^*_{P,Wp}(\tau), \tau \in \left[t-\frac{T}{2}, t+\frac{T}{2}\right]\right) - \min\left(\ddot{y}^*_{P,Wp}(\tau), \tau \in \left[t-\frac{T}{2}, t+\frac{T}{2}\right]\right) \tag{18}$$

where

T = 2 s

8.7 Definition of comfort index P_{DE}

The P_{DE} Comfort index is calculated on the basis of Equation (19) with constants according to Table 7.

$$P_{DE}(t) = 100 \cdot \max\left[a \cdot \ddot{y}_{pp}(t) + b \cdot \left|\ddot{y}_{2s}(t)\right| - c;0\right] \quad (19)$$

Table 7 — Constants for P_{DE} comfort index

Condition	a [s²/m]	b [s²/m]	c [-]
In rest – standing	0,1662	0,2701	0,37
In rest – seated	0,0846	0,1305	0,217

The Comfort Index $P_{DE}(t)$ is a continuous signal as a function of time and can be reported as such. For the assessment of a particular local event the local maximum of $P_{DE}(t)$ shall be used.

8.8 Test report

The test report shall be sufficiently detailed so that the execution of the comfort test is comprehensible and that special occurrences can be identified. The level of details depends on the purpose of the test. Annex D gives guidelines for the test report.

8.9 Example diagrams

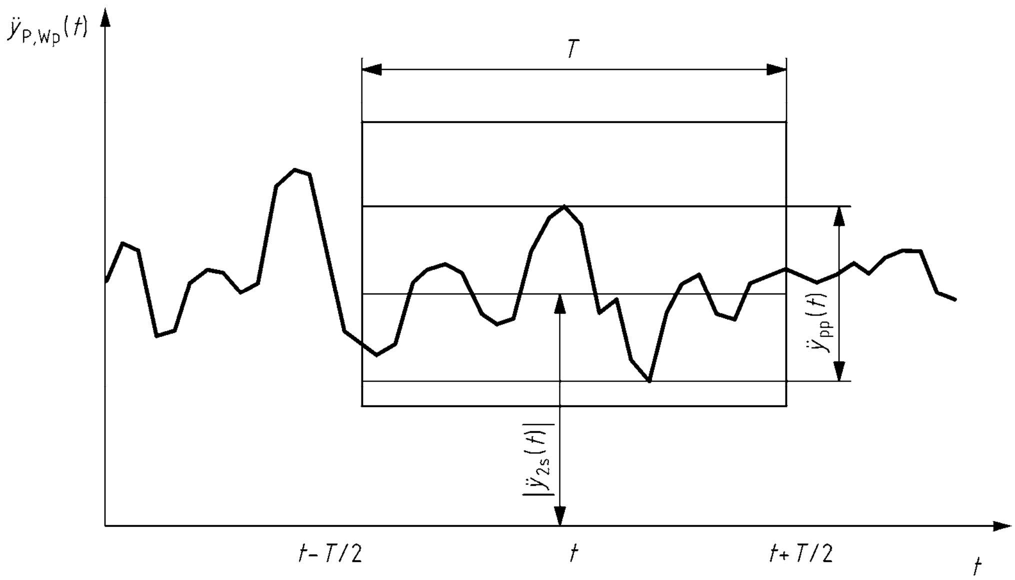


Figure 6 — Interpretation of $\left|\ddot{y}_{2s}(t)\right|$ and $\ddot{y}_{pp}(t)$ for calculation of P_{DE}

9 Guide for the interpretation of the results (Informative)

9.1 General

The following indexes indicate different aspects of comfort. The perceived comfort will depend on the expectations of the passenger for a particular type of service (long distance, commuter, high speed etc).

9.2 Mean Comfort

A scale for the comfort index N_{MV} is given in Table 8.

Table 8 — Scale for the N_{MV} comfort index

N_{MV} < 1,5	Very comfortable
1,5 ≤ N_{MV} < 2,5	Comfortable
2,5 ≤ N_{MV} < 3,5	Medium
3,5 ≤ N_{MV} < 4,5	Uncomfortable
N_{MV} ≥ 4,5	Very uncomfortable

The index should be reported for each individual test zone with one decimal (threshold of the passenger sensitivity). No guidance is given by ERRI B153 for a combination of the comfort indexes values of the individual test zones.

9.3 Continuous Comfort

There is a need for a scale to evaluate the comfort in the individual y and z directions.

A preliminary scale, based on certain experiences, is indicated in Table 9. The scale approximately matches N_{MV} values for possible combinations of accelerations in x, y and z directions. It should be noted that a scale for the one-dimensional indexes $C_{Cy}(t)$ and $C_{Cz}(t)$ cannot perfectly match the scale for the N_{MV} index for all relations between accelerations in the different directions that can occur, as N_{MV} is based on measurements in three directions.

The relevance of the preliminary scale can be assessed through field tests and future experiences.

Table 9 — Preliminary scale for the $C_{Cy}(t)$ and $C_{Cz}(t)$ comfort indexes

$C_{Cy}(t)$, $C_{Cz}(t)$ < 0,20 m/s²	Very comfortable
0,20 m/s² ≤ $C_{Cy}(t)$, $C_{Cz}(t)$ < 0,30 m/s²	Comfortable
0,30 m/s² ≤ $C_{Cy}(t)$, $C_{Cz}(t)$ < 0,40 m/s²	Medium
0,40 m/s² ≤ $C_{Cy}(t)$, $C_{Cz}(t)$	Less comfortable

The index should be reported with two decimals.

9.4 Comfort on Curve Transitions

P_{CT} values indicate the percentage of the passengers that are dissatisfied with the comfort. However, the magnitudes of dissatisfaction will depend on the expectations of the passenger for particular type of service (long distance, commuter, high speed etc). However, for a particular type of service, a higher P_{CT} will always indicate poorer passenger comfort. Theoretically, the P_{CT} formula can take values above 100, but such high values are above the interesting range of application.

9.5 Comfort on Discrete Events

P_{DE} values indicate the percentage of the passengers that are dissatisfied with the comfort. However, the magnitudes of dissatisfaction will depend on the expectations of the passenger for particular type of service (long distance, commuter, high speed etc). However, for a particular type of service, a higher P_{DE} will always indicate poorer passenger comfort. Theoretically, the P_{DE} formula can take values above 100, but such high values are above the interesting range of application.

On a transition curve with high lateral acceleration, the mean value of lateral acceleration $\left|\ddot{y}_{2s}(t)\right|$ may lead to a P_{DE} value above 0, even when the lateral oscillations are small. The lateral jerk will also generate a peak-to-peak lateral acceleration within the two-second window, $\ddot{y}_{pp}(t)$, which will contribute to a P_{DE} value above 0. In such a case, the corresponding P_{CT} value will be higher and should be considered the best quantification of the comfort disturbance.

Annex A
(normative)

Reference system

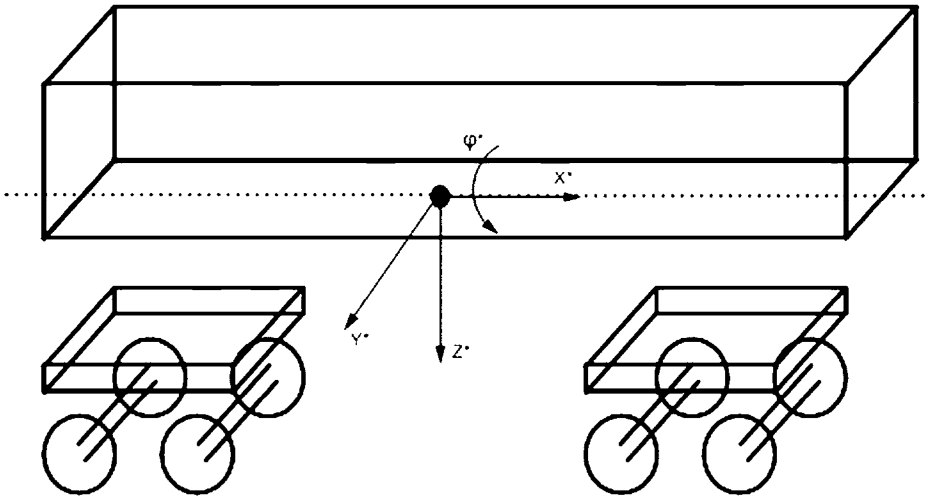


Figure A.1 — Local reference system for a vehicle body

The local reference system (see Figure A.1) for a vehicle body is defined through:

a) origin: on vehicle body floor, in the central position between the two body-bogie centre pivots (existing or ideally defined);

b) axis:

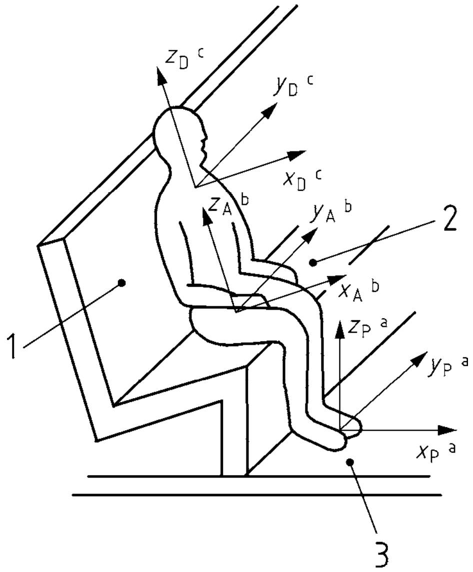
1) x-axis: longitudinal, in travelling sense, on floor plan;

2) y-axis: lateral, right-oriented in travelling sense, on floor plan;

3) z-axis: vertical downwards perpendicular to floor plan;

c) roll motions (φ) are defined as rotation around the x-axis.

The local reference systems for a human body are defined in Figure A.2 and Figure A.3:



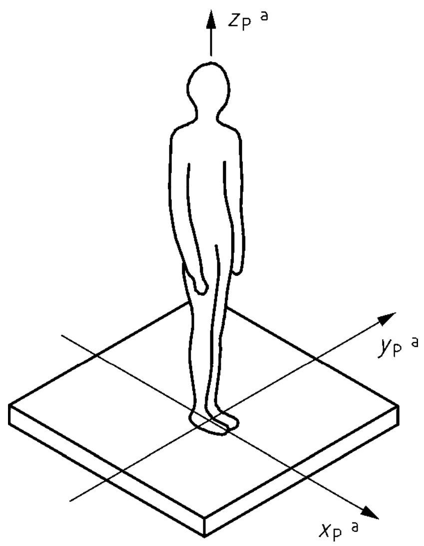
Key

1 seat back interface, D (Dossier in French)

2 seat pan interface, A (Assise in French)

3 floor interface, P (Plancher in French)

Figure A.2 — Local reference systems for a person in a seated position



Key

1 floor interface, P (Plancher in French)

Figure A.3 — Local reference system for a person in standing position

Annex B
(normative)

Measurement techniques

B.1 General

The physical quantities to be measured are the translational accelerations and rotational velocities.

The term ‘measuring equipment’ used below covers all the equipment which permits the measurement and recording of the signals.

B.2 Measuring equipment

B.2.1 General

The measuring equipment includes the following:

a) transducers (accelerometers, gyroscopes);

b) amplifiers and processing filters;

c) recording equipment;

d) computer for data recording including software.

All this equipment together constitutes a measurement system. The characteristics of the equipment shall be consistent. The precision of the measuring equipment shall be defined both in terms of the characteristics of each component and in terms of certain characteristics of the system as a whole. The calibration of the equipment shall be verified at regular periods in accordance with applicable standards.

B.2.2 Accelerometers and processing amplifiers

It is generally not possible to separate the transducer from its processing amplifier; these elements will be dealt with together; they shall meet the following requirements:

a) the global transfer function shall be flat to within ± 0,5 dB in the frequency range given by Table B.1.

Table B.1 — Frequency range for the global transfer function

Mean Comfort	Comfort on Curve Transitions and Comfort on Discrete Events
0,4 Hz to 100 Hz	0 Hz to 10 Hz

b) non-linearity plus hysteresis: ≤ 0,3 % of full scale;

c) cross sensitivity: ≤ 0,05 m/s^2;

d) effect of temperature:

1) on zero: ≤ 3 % of full scale;

2) on sensitivity: ≤ $5 \cdot 10^{-4}$ of full scale/°C.

B.2.3 Recording equipment

Recording equipment shall meet the following requirements:

a) flat pass band between 0 Hz and 100 Hz;

b) at 100 Hz, the loss shall be less than 1 dB.

The recorded signal level shall be sufficient to allow the analysis to be carried out properly and automatically.

B.2.4 Fixing transducers to the floor

When fixing a transducer to the floor, the following precautions shall be taken:

a) the transducer shall perform the same motions as that part of the structure to which the seat is fixed;

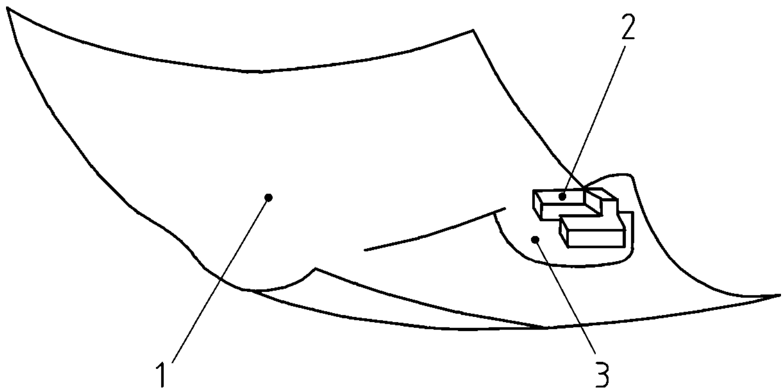
b) the signal from the transducer shall not be modified either by operating too close to the first resonant frequency of its mounting, or as a result of the local modes of the fixing surfaces. It is therefore necessary to ensure that the mounting used for the accelerometer is as rigid as possible.

Detailed requirements are contained in ISO 5348.

B.3 Seat measuring devices and their applications

Examples of seat measuring devises are given in Figure B.1 to Figure B.3.

NOTE Standard ISO seat pans for these measurements are acceptable.



Key

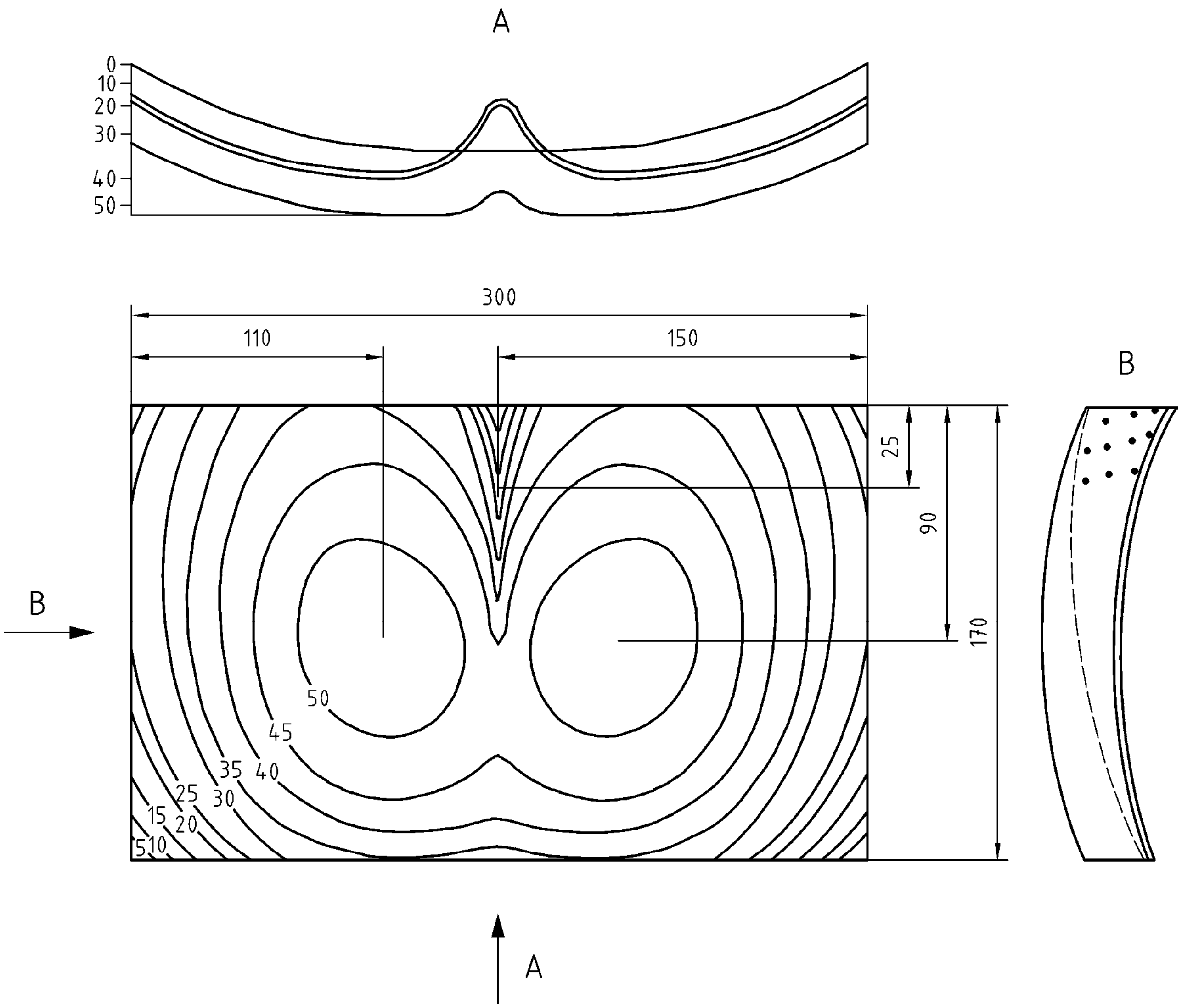
1 plate

2 device for angling the transducer

3 transducer

Figure B.1 — Seat pan measuring device (for y- and z-direction)

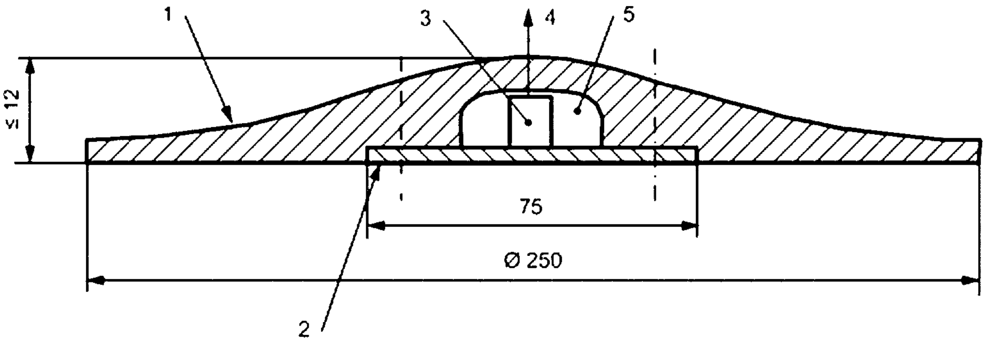
Dimension in millimetres



approximately one perforation of one mm per cm^2

Figure B.2 — Seat pan measuring device

Dimensions in millimetres



Key

1 flexible material

2 thin metal disk

3 unidirectional acceleration transducer

4 axis of measurement

5 cavity

Figure B.3 — Seat back measurement device

Before commencing the tests, but after any movement of the materials of the seat has taken place, the orientation of the axes to match the y and z axes of the individual shall be adjusted. This adjustment shall be verified at the end of the test.

The seat pan shall be placed on the seat surface such that the transducer is located midway between the ischial tuberosities of the seated person. For comfort reasons, it is acceptable if the centre of the disc is located slightly in front (up to 5 cm) of the ischial tuberosities.

A unidirectional accelerometer in the x-direction shall be installed on the seat back, at the interface to the subject, at the point of maximum pressure between the subject's back and the seat back. The position shall be reported. For practical reasons, it is usually not possible to perfectly align the accelerometers in the disc with the directions of the basicentric coordinate system. In a tolerance range within ±15° of the appropriate directions the accelerometers can be considered as aligned parallel to these directions.

It is necessary to ensure that the subject still remain in an identical position (described in the report) during all the measurement time (foot on the ground, hands on the thigh and back correctly applied on seat back rest.

For some subjects, this condition is difficult to respect. For example, drivers do not maintain their back on the backrest all the time to operate, the consequence being that the measurements contain the slamming effect of the free backrest. In that case, the position of the seat back measurement device shall be the lowest position on the back that remains continuously in contact with the backrest. The recommended position of the accelerometer is at approximately 150 mm above the Seat Index Point (SIP) as defined in EN ISO 5353.

Annex C
(normative)

Weighting curves

C.1 General

In order to take account of the different degrees of sensitivity displayed by different individuals as a function of frequency, weighting curves have been established for vertical and horizontal acceleration signals. The curves for W_c and W_d are the same as in ISO 2631-1 and EN ISO 8041. However, it should be noted that the curve for W_b is not the same as in ISO 2631-4.

The curves are determined for sinusoidal vibrations, and are considered valid for broad-band stationary vibrations.

Although each individual has his own weighting curves, the curves selected are the optimum curves for assessing comfort.

The weighting curves are summarised in Table C.1 below.

Table C.1 — Weighting curves

Weighting curves	Application
W_b	Z floor, Z seat pan
W_c	X seat back
W_d	X floor, Y floor, Y seat pan
W_p	Y floor, φ floor

C.2 Filter functions

C.2.1 General

The frequency weightings are defined by the parameters listed in Table C.2, including the appropriate band-limiting weightings, and by the Equation (C.1) to Equation (C.4).

Table C.2 — Parameters and transfer functions of the frequency weightings

Weighting	Band-limiting			a-v transition [a]			Upward step				Gain
	f_1 [Hz]	f_2 [Hz]	Q_1 [-]	f_3 [Hz]	f_4 [Hz]	Q_2 [-]	f_5 [Hz]	f_6 [Hz]	Q_3 [-]	Q_4 [-]	K [-]
W_b	0,4	100	$1/\sqrt{2}$	16	16	0,63	2,5	4	0,8	0,8	0,4
W_c	0,4	100	$1/\sqrt{2}$	8	8	0,63	-	-	-	-	1
W_d	0,4	100	$1/\sqrt{2}$	2	2	0,63	-	-	-	-	1
W_p	-	100	$1/\sqrt{2}$	2	2	0,63	-	-	-	-	1

[a] a-v transition means acceleration to velocity transition

The frequencies f_1, ..., f_6 and the resonant quality factors Q_1, ..., Q_4 are parameters of the transfer functions which determine the overall acceleration frequency weightings. The overall frequency weighting function is a product of band-limiting, a-v transition and for W_b the upward step filters.

C.2.2 Band-limiting filter

The band-limiting element is a combination of high and low-pass second order Butterworth filter characteristics. These components are defined by:

High pass:

$$H_h(f) = \frac{1}{1 - \left(\frac{f_1}{f}\right)^2 - i \cdot \frac{f_1}{Q_1 f}} \quad \text{(C.1)}$$

Low pass:

$$H_l(f) = \frac{1}{1 - \left(\frac{f}{f_2}\right)^2 + i \cdot \frac{f}{Q_1 f_2}} \quad \text{(C.2)}$$

The product $H_h(f) \cdot H_l(f)$ represents the band limiting transfer function.

C.2.3 Acceleration to velocity transition

The weighting is proportional to acceleration at lower frequencies and to velocity at higher frequencies. The a-v transition is defined by:

$$H_t(f) = \frac{\left(1 + i \cdot \frac{f}{f_3}\right)}{1 - \left(\frac{f}{f_4}\right)^2 + i \cdot \frac{f}{Q_2 f_4}} \quad \text{(C.3)}$$

C.2.4 Upward gradient

The upward gradient is approximately 6 dB per octave and is proportional to the jerk:

$$H_s(f) = K \cdot \frac{1 - \left(\frac{f}{f_5}\right)^2 + i \cdot \frac{f}{Q_3 f_5}}{1 - \left(\frac{f}{f_6}\right)^2 + i \cdot \frac{f}{Q_4 f_6}} \quad \text{(C.4)}$$

C.2.5 Overall frequency weighting

The overall frequency weighting function is a product of band-limiting, a-v transition and for W_b the upward step filters.

For $W_{\mathbf{c}}$, $W_{\mathbf{d}}$ and $W_{\mathbf{p}}$:

$$H(f) = H_{\mathbf{h}}(f) \cdot H_{\mathbf{l}}(f) \cdot H_{\mathbf{t}}(f) \qquad \text{(C.5)}$$

For $W_{\mathbf{b}}$:

$$H(f) = H_{\mathbf{h}}(f) \cdot H_{\mathbf{l}}(f) \cdot H_{\mathbf{t}}(f) \cdot H_{\mathbf{s}}(f) \qquad \text{(C.6)}$$

The magnitudes of the weighting functions $W_{\mathbf{b}}$, $W_{\mathbf{c}}$, $W_{\mathbf{d}}$ and $W_{\mathbf{p}}$ are shown in Figure C.5 to Figure C.8.

C.2.6 Reduction of the upper limit of the frequency range in vertical direction

The upper limit of the frequency range in the vertical direction may be reduced to 40 Hz if this has been justified by a prior test, by means of a two-pole low-pass filter with Butterworth characteristics having an asymptotic gradient of -12 dB per octave. This reduction in frequency limit can compensate for the filtering effect that a soft cushion has when the vertical acceleration is measured on the floor.

C.3 Tolerances

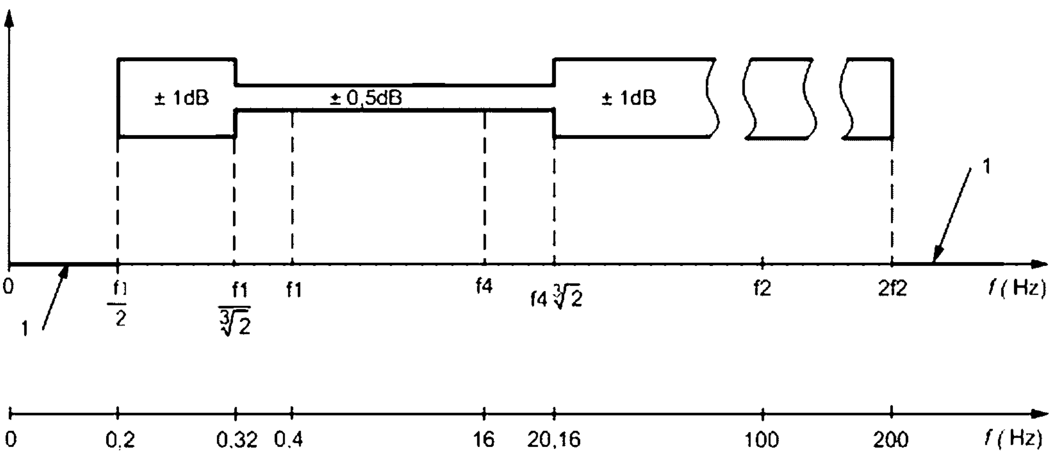
The tolerances of the weighting curves are given in Table C.3, they are also shown in Figure C.1 to Figure C.4.

Table C.3 — Tolerances on weighting curves

1	Within the nominal frequency band, the overall tolerance of the filters used to pre-process the signals and of the filters used for weighting the signal shall be better than ± 0,5 dB.
2	Outside this band, the tolerance shall be better than + 1/-∞ dB. Attenuation shall not be less than 12 dB/octave one octave away from the nominal frequency band.

The tolerance of ± 0,5 dB corresponds to the result of the imperfection of the filter (frequency weighting) and the band limits (attenuation at cut-off frequencies). For each frequency, this tolerance represents the maximum difference between the theoretical value and the value actually obtained.

Vertical weighting Mean Comfort (floor and seat pan)

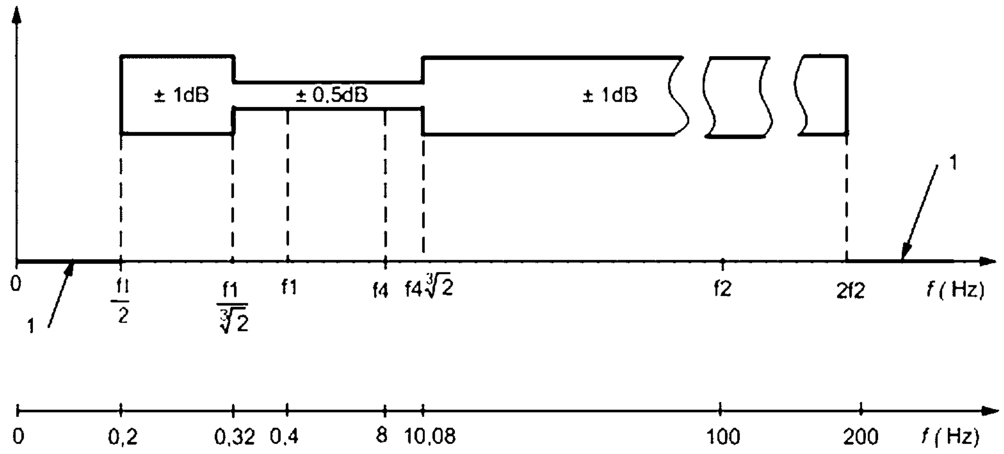


Key

1 attenuation may rise to infinity

Figure C.1 — Tolerances for $W_{\mathbf{b}}$

Longitudinal weighting Mean Comfort (seat back)

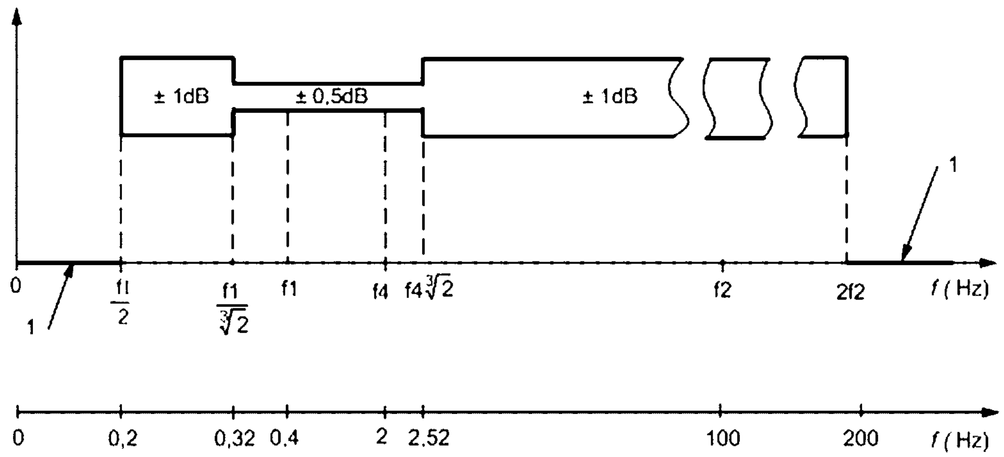


Key

1 attenuation may rise to infinity

Figure C.2 — Tolerances for W_c

Transverse weighting Mean Comfort (floor and seat pan)

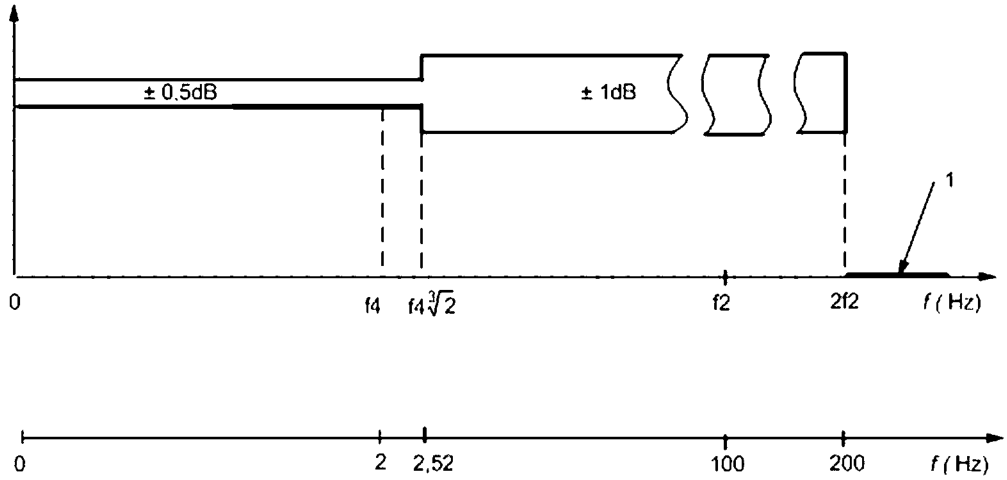


Key

1 attenuation may rise to infinity

Figure C.3 — Tolerances W_d

Transverse weighting for Comfort in Curve Transitions and Discrete Events (floor)



Key

1 attenuation may rise to infinity

Figure C.4 — Tolerances for W_p

C.4 Diagrams

The magnitudes of the weighting functions W_b, W_c, W_d and W_p, and their tolerances, are shown in Figure C.5 to Figure C.8.

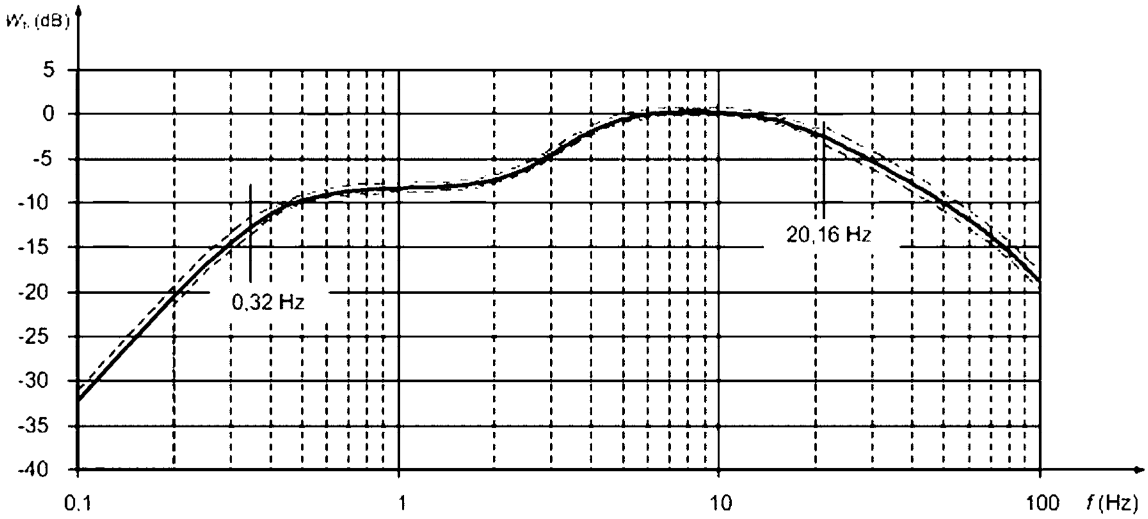


Figure C.5 — Magnitude of the alternative frequency weighting W_b for vertical vibration along the z-axis on the floor and seat pan

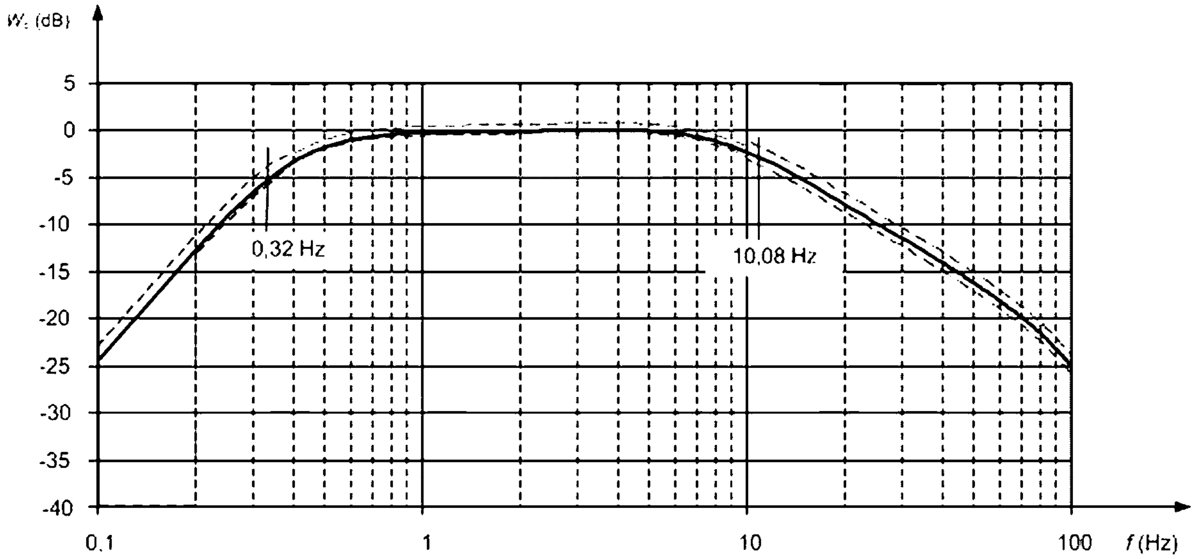


Figure C.6 — Magnitude of the frequency weighting W_c for horizontal vibration along the x-axis, for the seat back

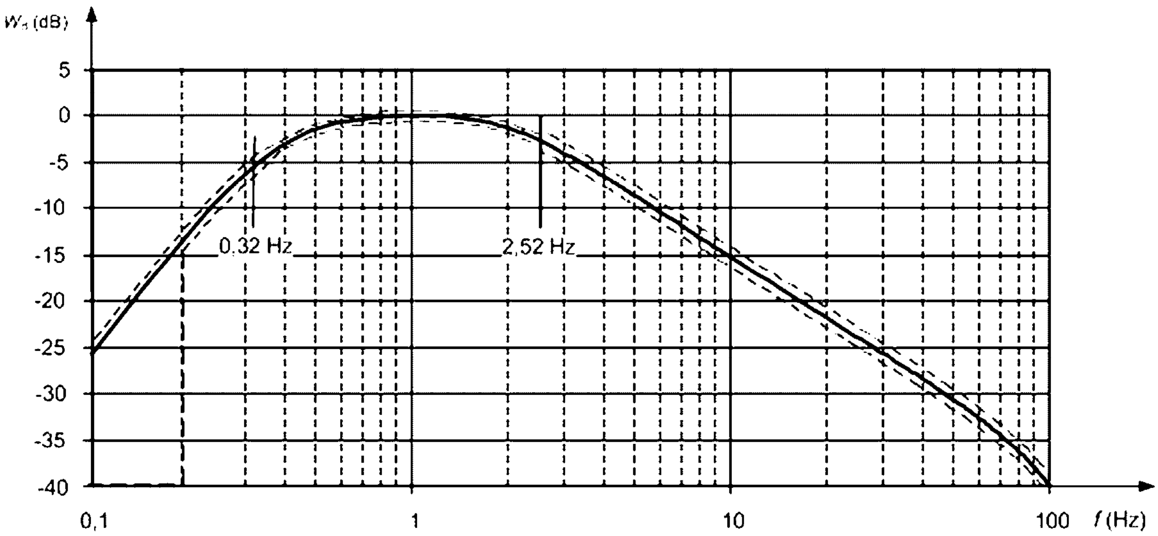


Figure C.7 — Magnitude of the frequency weighting W_d for horizontal vibration along the x- or y-axis on the floor, or along the y-axis on the seat pan

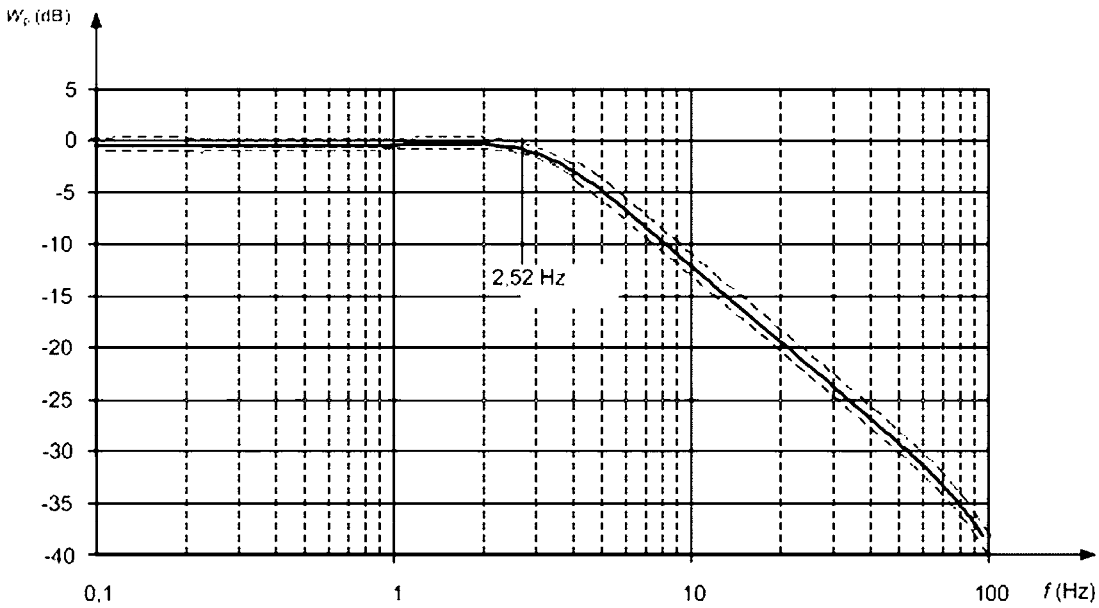


Figure C.8 —Magnitude of the frequency weighting W_{p} for lateral acceleration for P_{CT} and P_{DE}, and for roll velocity for P_{CT} evaluation

Annex D
(informative)

Presentation of test report

D.1 General

The test report should include the test specification, the characteristics of the tested vehicle, the track characteristics and a precise description of the actual test conditions, including all necessary measurements. More details are given in the following clauses. The measuring system should be reported according to the requirements of ISO 8002.

D.2 Aim of test

The aim of the test should be reported.

D.3 Test performer

The test performer should be reported; company and test leader.

D.4 References

References should be given to:

a) test specification;

b) documentation of measuring system;

c) applied standards.

D.5 Test conditions

D.5.1 General information

The following general information should be given in the test report.

a) date and time;

b) location (test line);

c) local weather conditions (wet/dry rails).

D.5.2 Vehicle

The following vehicle characteristics should be described in the test report.

a) vehicle (multiple unit, coach, locomotive, etc.);

b) identification (manufacturer, model, serial number of all vehicles);

c) loading conditions (empty, normal load, etc.);

d) type (saloon, compartment, etc.);

e) structural details (steel, aluminium, type of suspension, type of bogie, etc.);

f) wheel profiles and equivalent conicity or, if not available, mileage run by the wheelsets since last reprofiling;

g) other relevant factors (bogie type, suspension and damper measurements, etc.);

h) operational number of the vehicle.

D.5.3 Seat (for Mean Comfort Complete Method)

a) identification (manufacturer, model, etc);

b) type (class, saloon, compartment, etc.);

c) settings (inclination, stiffness, damping, etc).

D.5.4 Seat occupant (for Mean Comfort Complete Method)

— size, weight, posture.

D.5.5 Track

The following track characteristics should be described in the test report.

a) length and location of the test zones;

b) designed geometry through table or schematic drawing;

c) type of track and identification of track category: nominal gauge, sleeper type, rail type, rail inclination;

d) track irregularities or track quality;

e) location and identification of track features (including switches, crossings, etc.).

It is recommended to report the longitudinal position of the vehicle for each five-second period.

For Comfort on Curve Transitions see also D.8.

D.5.6 Speed profile

The planned test speed profile and the realised speed profile should be reported for each test.

D.5.7 Test configurations

The various configurations during the tests (combinations of test conditions) should be defined and reported.

D.6 Measurements and processing

D.6.1 Measurements

The measurement techniques should be reported.

a) the measuring points (name, symbol, units, position, schemes, pictures);

b) the transducers (type, location, axes, pictures);

c) the acquisition chain (type, filters).

The identification number of used equipment with integrity check and calibration should be archived.

D.6.2 Processing

The processing techniques should be reported:

a) processing applied (comfort indexes and others);

b) processing software used (name, version, …).

D.7 Report on Mean Comfort and Continuous Comfort

D.7.1 General

It is recommended to characterise vibrations by spectral analyses and statistical results. Spectral analysis can help to explain the influence of the vehicle and the track on the comfort.

D.7.2 Time series

The following information should be given:

a) time series of rms-values $C_{\mathbf{Cx}}$, $C_{\mathbf{Cy}}$ and $C_{\mathbf{Cz}}$;

b) other relevant information, such as realised speed profile, non-compensated lateral acceleration, etc.

Examples are given in Figure D.1.

D.7.3 Statistical results

The following statistical information should be given, calculated on the basis of the rms-values:

a) distribution function;

b) cumulative frequency function;

c) the statistical parameters evaluated can also be indicated (mean, standard deviation, maximum, etc.).

Number and width of classes for the histogram of distribution should be reported.

Different types of histogram of the weighted rms-values calculated every period may be created and the 95th percentiles may be determined; these values are needed for the calculation of the comfort index $N_{\mathbf{MV}}$. Examples are shown in Figure D.2, where the 50th and 95th percentiles are calculated. Figure D.2 also contains the time series for the actual five-minute unit.

D.7.4 Comfort evaluation

The comfort indexes which have been obtained should be reported. It is recommended to include any other parameter which may give useful information.

D.7.5 Spectral analyses

Representative mean spectra of the vibrations on the floor during five-minute units should be reported. An example of the spectrum of vibration is presented in Figure D.3 referring to the Mean Comfort measurements, where the longitudinal, lateral and vertical accelerations at floor level are given as power spectral densities, un-weighted and weighted in accordance with the weighting curves of Annex C.

D.7.6 Examples of diagrams

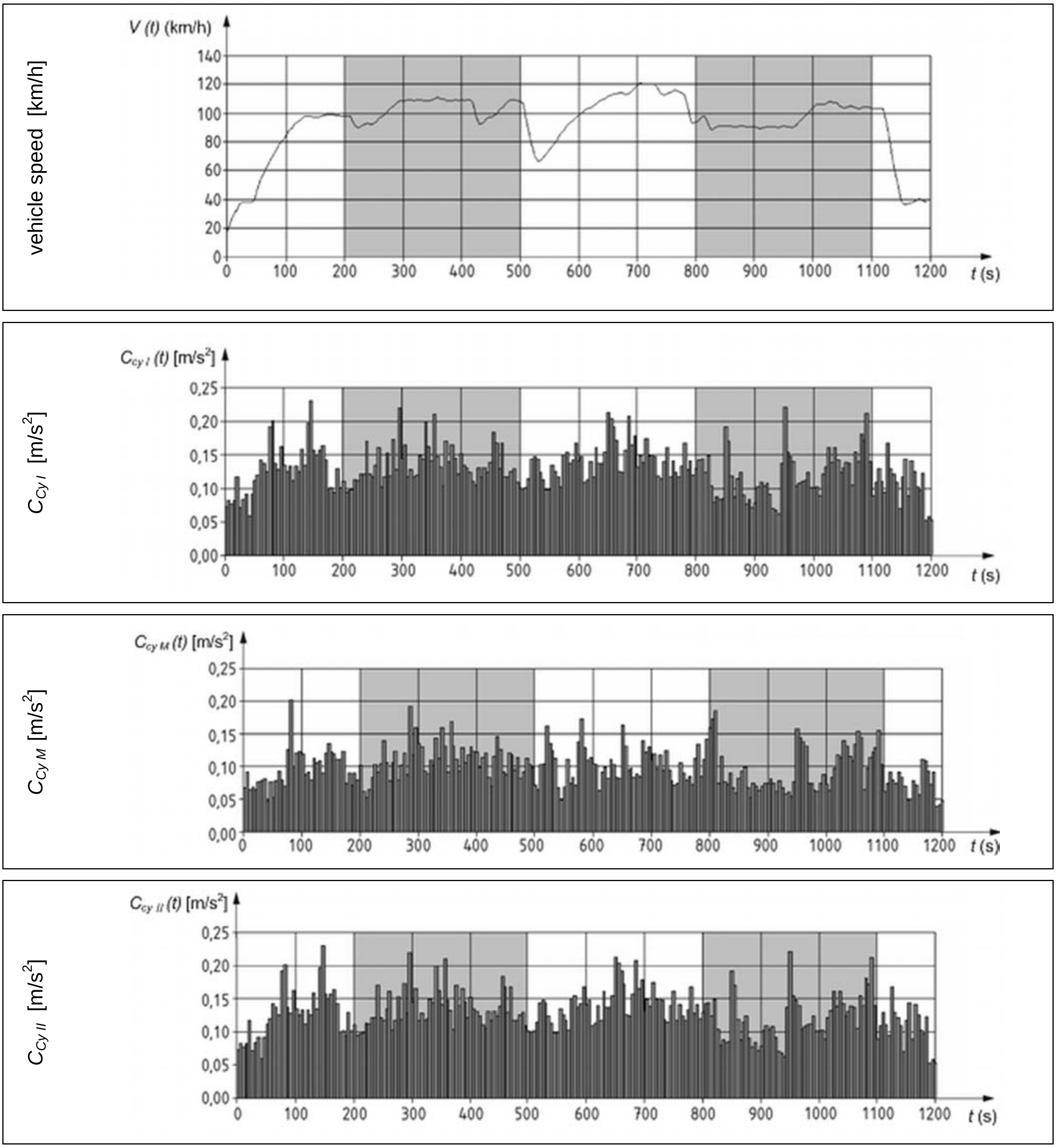
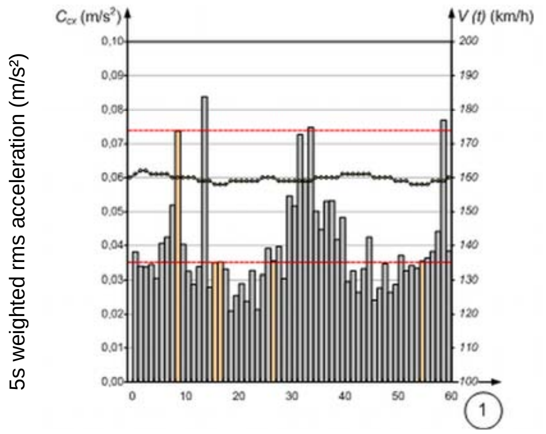
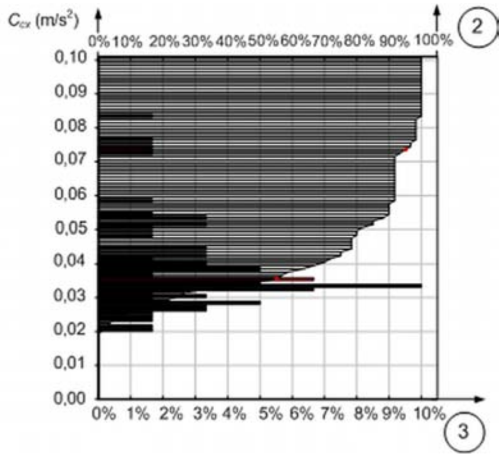


Figure D.1 — Continuous Comfort - Collection of five-minute periods (selected periods marked grey)

Continuous Comfort | **Distribution and cumulative frequency** | **Data**

X





Number of samples: 60

Min. value: 0,021 m/s²

Max. value: 0,084 m/s²

Std. deviation: 0,014 m/s²

Class width: 0,001 m/s²

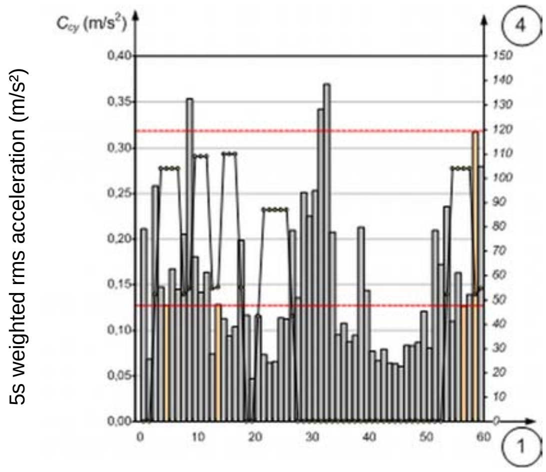
50th percentile: 0,035 m/s²

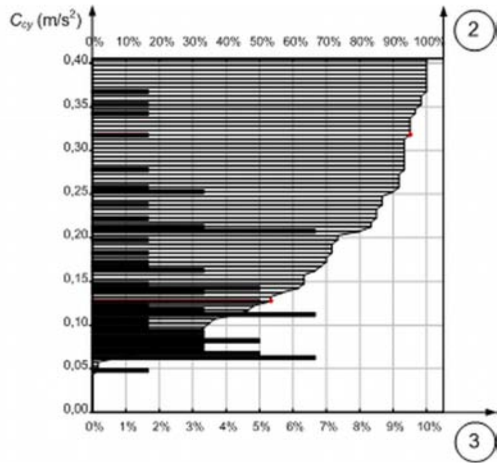
95th percentile: 0,074 m/s²

N_{MVx} = 0,4

N_{MV} = 3,8

Y





Number of samples: 60

Min. value: 0,047 m/s²

Max. value: 0,369 m/s²

Std. deviation: 0,079 m/s²

Class width: 0,005 m/s²

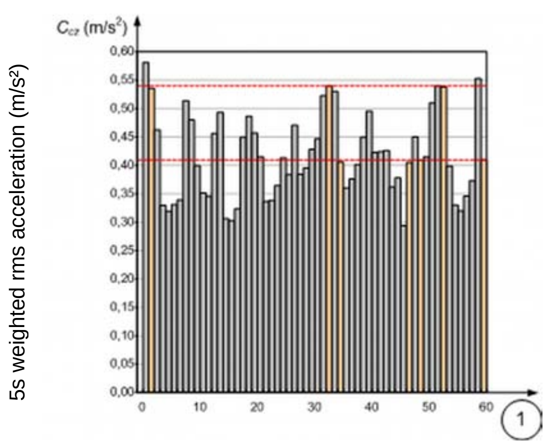
50th percentile: 0,127 m/s²

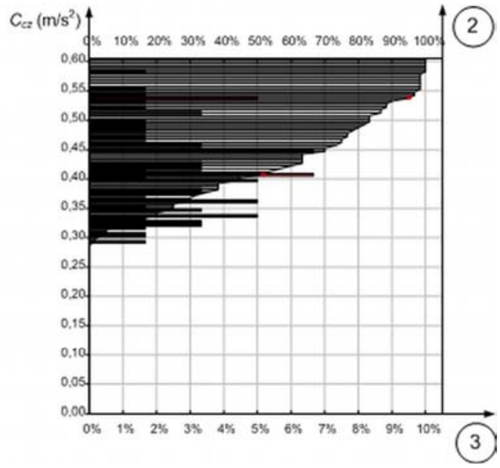
95th percentile: 0,319 m/s²

N_{MVy} = 1,9

N_{MV} = 3,8

Z





Number of samples: 60

Min. value: 0,294 m/s²

Max. value: 0,581 m/s²

Std. deviation: 0,073 m/s²

Class width: 0,005 m/s²

50th percentile: 0,410 m/s²

95th percentile: 0,540 m/s²

N_{MVz} = 3,2

N_{MV} = 3,8

Key

1 sample number

2 cumulative frequency function

3 histogram of distribution (% of events)

4 cant deficiency

Figure D.2 — Example of Continuous Comfort and statistical distribution for a five-minute period

X direction

$a_{XP} = 0{,}112$ m/s²

$a_{XP}^{W_d} = 0{,}042$ m/s²

Y direction

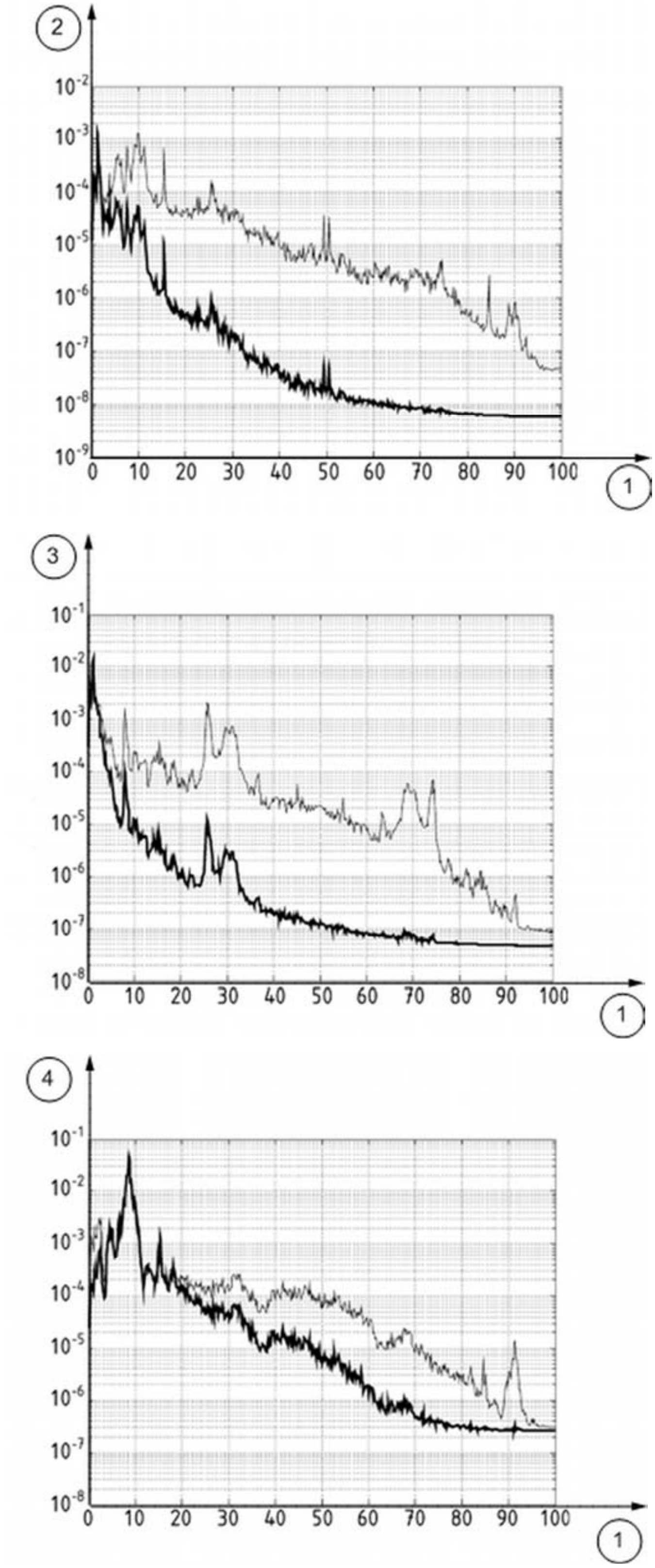
$a_{YP} = 0{,}213$ m/s²

$a_{YP}^{W_d} = 0{,}172$ m/s²

Z direction

$a_{ZP} = 0{,}712$ m/s²

$a_{ZP}^{W_b} = 0{,}423$ m/s²



Key

1 frequency f (Hz)

2 power spectral density of longitudinal acceleration ($(m/s^2)^2$/Hz)

3 power spectral density of lateral acceleration ($(m/s^2)^2$/Hz)

4 power spectral density of vertical acceleration ($(m/s^2)^2$/Hz)

Figure D.3 — Example of weighted (bold line) and un-weighted (thin line) power spectral density of floor level acceleration in x, y and z directions (Duration: 307,2 s / Sampling rate: 400 Hz / FFT : 2048 points)

D.8 Report on comfort in curve transitions

The following information is to be given for each analysed transition:

a) $\left|\ddot{y}_{\mathbf{1s}}\right|_{\mathbf{max}}$;

b) $\left|\dddot{y}_{\mathbf{1s}}\right|_{\mathbf{max}}$;

c) $\left|\dot{\varphi}_{\mathbf{1s}}\right|_{\mathbf{max}}$;

d) for seated passengers $P_{\mathbf{CT}}$;

e) for standing passengers $P_{\mathbf{CT}}$;

f) detailed geometrical characteristics: radius and cant (on circular curves), length and type of transition curve and/or cant transition;

g) the planned test speed and the realised speed.

The method to identify the tangent points and the relevant transition curves according to 7.6.3 should be reported.

It should be reported whether or not transition curves with increasing magnitude of lateral acceleration and with durations shorter than 2 s are included in the analysis. It should be reported whether the evaluation of lateral acceleration is based on an extension beyond 1,6 s after the entry of the circular curve (see 7.6.4).

D.9 Reporting on Comfort on Discrete Events

It is recommended to characterise the motions on discrete events by time histories. Time histories of two-second averaged lateral acceleration and the $P_{\mathbf{DE}}$ comfort index should be reported. An example of the time history is presented in Figure D.4.

If local maxima of $P_{\mathbf{DE}}$ are presented in a table, it is recommended to report for each event:

a) $\left|\ddot{y}_{\mathbf{2s}}(t)\right|$;

b) $\ddot{y}_{\mathbf{pp}}(t)$;

c) for seated passengers $P_{\mathbf{DE}}$;

d) for standing passengers $P_{\mathbf{DE}}$;

e) location of the discrete event;

f) the planned test speed and the realised speed.

NOTE On a transition curve with high lateral acceleration, the mean lateral acceleration $\left|\ddot{y}_{\mathbf{2s}}(t)\right|$ may lead to a $P_{\mathbf{DE}}$ value above 0, even when the lateral oscillations are small. The lateral jerk will also generate a peak-to-peak lateral acceleration within the two-second window, $\ddot{y}_{\mathbf{pp}}(t)$, which will contribute to a $P_{\mathbf{DE}}$ value above 0. In such a case, the corresponding $P_{\mathbf{CT}}$ value will be higher and should be considered the best quantification of the comfort disturbance. Such occurrences should be noted in the test report.

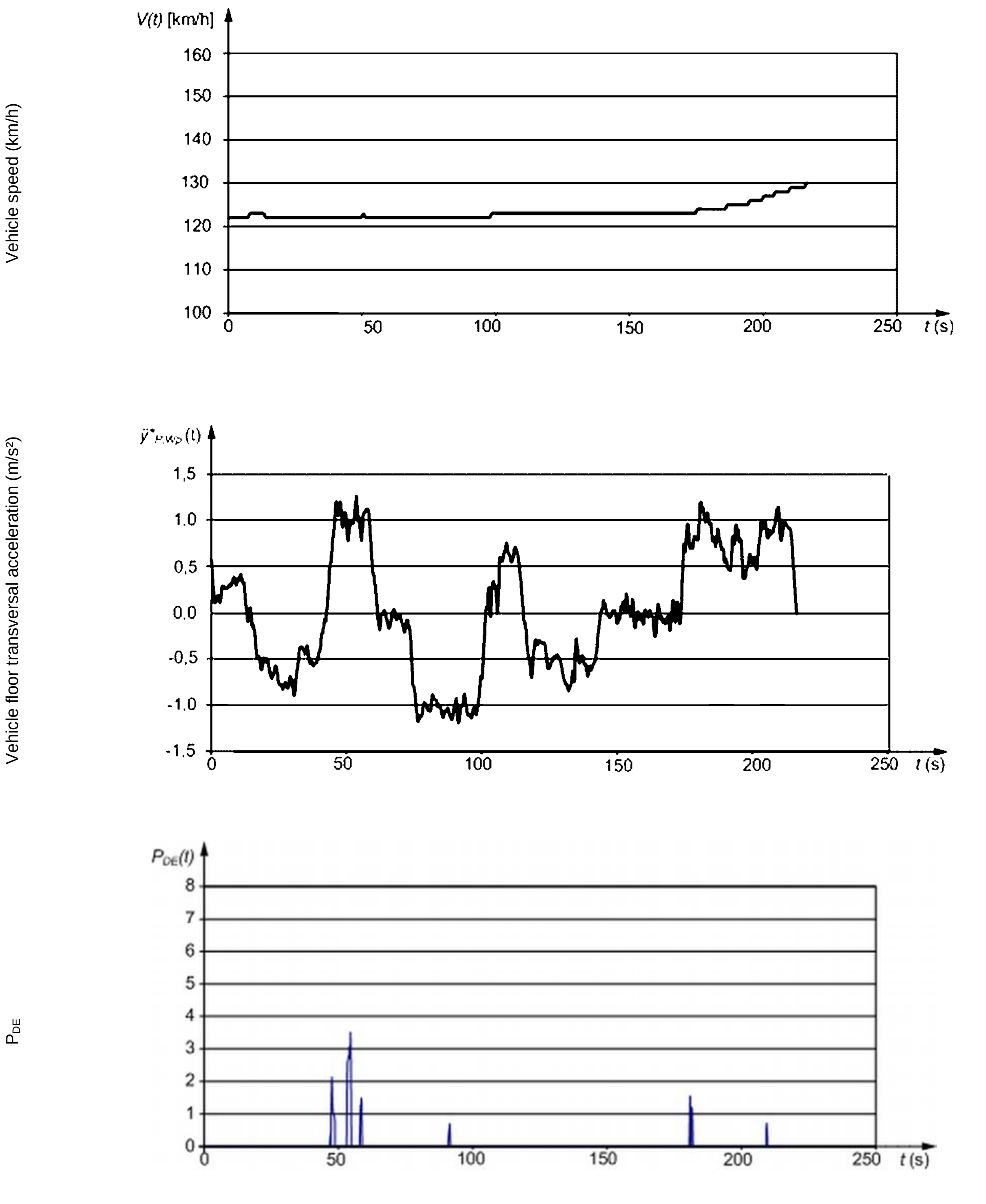


Figure D.4 —Example of time series for P_{DE} evaluation

Annex E
(normative)

Vehicle assessment with respect to Mean Comfort Standard Method

E.1 General

For vehicle assessment with respect to ride comfort, this annex defines requirements and acceptable modifications to the Mean Comfort Standard Method.

Vehicle assessment with respect of ride comfort means the process of identifying the contribution of the vehicle to the experienced level of comfort due to the vibration level. The methods for Mean Comfort evaluation defined in this standard focus on the highest levels of acceleration, since direct tests have shown that these contribute to the experienced level of comfort. The acceleration levels are highly correlated to the track features and track quality, which means that a few local disturbances, such as passing a switch or a crossing, may result in a higher comfort index.

E.2 Track geometric quality

In order to better identify the contribution of the vehicle to the Mean Comfort, the most detailed available description of the track geometric quality shall be reported.

There exists no uniformly adapted procedure for quantifying the track quality, since different railways have different procedures and track-measuring vehicles.

One method is given in EN 14363. However, for comfort evaluation, this method has a few weaknesses that shall be kept in mind:

a) longer wavelengths are not considered. The standard prescribes that longer wavelengths should be taken into account at line speeds exceeding 200 km/h, but no wavelengths or limit values are yet defined. Note that the longer wavelengths may have an influence on the riding comfort also at speed lower than 200 km/h;

b) track twist, gauge and cyclic irregularities are not part of the definition of track geometry quality;

c) inhomogeneous track design (like bridges, switches, crossings) is not considered.

E.3 Test conditions

E.3.1 Selection of test sections and test zones

The test sections shall be selected in such a way that operating conditions representative of the tested vehicle are taken into account, for instance, high speed line, normal speed line, sharply curved track. Test sections shall also be selected in such a way that the track quality corresponds to the one specified for the running speed required.

Within the test sections, test zones of 5 min may be defined so that they do not contain any unrepresentative events (measurement disturbances, passing certain crossings, bridges, etc).

Other track characteristics to be considered are the type of track and identification of track category; nominal gauge, sleeper type, rail type and rail inclination.

The track characteristics of the test zones shall be specified in the test report for the purpose of vehicle assessment with respect to ride comfort.

E.3.2 Test speed

The comfort shall be evaluated at the various operating speeds of the vehicle, which really occur or are foreseen in service and especially at the maximum permissible speed of the vehicle.

The test speed shall be kept constant during the test zones of 5 min.

E.3.3 Wheel-rail contact geometry

The behaviour of the vehicle is influenced by the wheel-rail contact geometry. For applications needing the assessment of separate influence of the vehicle, the wheel-rail contact parameters shall be quantified.

To determine the numerical value of the equivalent conicity, the actual wheel profiles of the test vehicle are combined with theoretical rail profile normally used in the test zones (including inclination and gauge).

For a better interpretation of the results, it can be useful to determine the equivalent conicity taking into account actual rail profiles of the test zone giving low and high conicity values.

Ranges of equivalent conicity for both straight track and curves are proposed in EN 14363.

E.3.4 Vehicle condition

The vehicle condition shall be specified before the test, taking into account particularly the factors which may affect the passenger comfort, such as vehicle-mounted equipment, wheel irregularities, etc. This includes also the main data referred to the mechanical, hydraulic, electrical and electronic features of the tilting system (if any).

The list of the characteristics which are planned to be verified shall be specified before each test is carried out.

The test vehicle shall be in its normal operating condition. With respect to loading, the vehicle shall be tested in the empty condition. It may also be tested with other load conditions.

In the case of a multiple unit, be it articulated or not, the test specification shall stipulate which types of vehicles, and at what positions in the vehicle, are to be used for measuring comfort (for instance the first and last vehicle carrying passengers, the potentially most critical vehicle, a representative vehicle, …).

E.4 Acceptable modifications of the methods for Mean Comfort evaluation

For the purpose of vehicle assessment with respect to comfort **only**, the following modifications of the Mean Comfort Standard Method may be done:

a) the position of the accelerometer may be above the bogie pivot instead of the end of the passenger compartment.

If the vehicle is to be assessed with respect to the Continuous Comfort Indexes only, then also the following modifications may be done:

b) the rms acceleration values may be calculated over track sections as described in EN 14363 (designated track layout and length), instead of five-second periods;

c) the samples may be taken from a non-continuous measurement, for example grouping the samples according to test zones as described in EN 14363 (straight track, large radius curves, small radius curves, very small radius curves).

E.5 Test report

The test report shall be sufficiently detailed so that the execution of the comfort test is comprehensible and that special occurrences can be identified. Since the purpose of the test is to assess a vehicle with respect to ride comfort, it is important to separate (as far as possible) the vehicle's contribution to ride comfort from other contributions (such as track and operational conditions). Therefore, it is recommended that the test report follows the guidelines in Annex D.

Note that characteristics of the track and the wheel-rail contact geometry are especially important for the purpose of vehicle assessment with respect to ride comfort.

Any modification according to E.4 shall be reported and motivated.

Annex F
(informative)

Guideline for the application of direct tests

Direct tests of actual passenger reaction are of value in particular circumstances but the variability of results from one set of tests to another necessitates clear understanding of what can and cannot be achieved by this method.

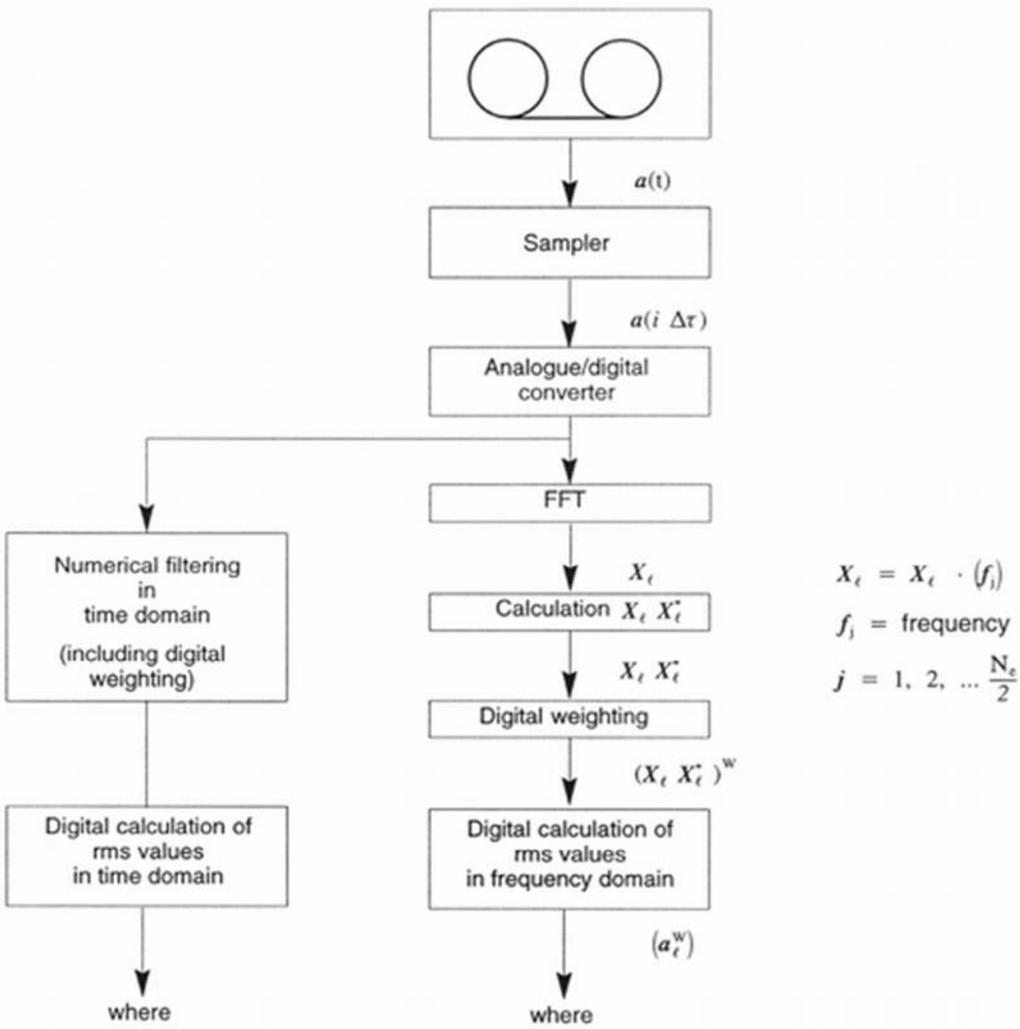
The main difficulties associated with direct testing are that different individuals have different expectations of what a satisfactory ride shall be, that individuals are inevitably affected by other aspects of their environment (temperature, humidity, external scenery, internal decorations etc.) as well as by the vehicle ride and that even the same individual may not be consistent from day to day and from vehicle to vehicle.

Bearing in mind the above comments, direct tests can be used, with care, to compare two different vehicles in the same train provided that an adequate sample of individuals is used (at least ten in each vehicle) and that an adequate number of test zones are used (at least four test zones of 5 min each). The groups of passengers shall then be swapped between vehicles and the test repeated over a similar number and range of test zones. This attempts to ensure that the two samples of individuals have a similar range of reactions. If the two vehicles being compared have different internal fittings or equipment, this is bound to affect the passenger response. Sometimes, this can be used to advantage in testing passenger reaction to the total environment but this is outside the scope of pure ”ride comfort”.

Direct tests can be useful in assessing the expectations of passengers in different types of environment. For example the ride expected of an Intercity vehicle will be different from that expected of a suburban vehicle and a measure of the difference could be obtained from direct tests.

Annex G
(informative)

Workflow for numerical integration



$$(a_\ell^w) = \sqrt{\frac{1}{N_e} \cdot \sum_{i=(\ell-1)\cdot N_e+1}^{\ell \cdot N_e} [a^w(i \cdot \Delta\tau)]^2}$$

$i = 1, 2, \ldots N_e$

$\ell = 1, 2, \ldots N_b$

$\tau = 5$ s

$$(a_\ell^w) = \sqrt{\sum_{i=i_1}^{i_2} [X_\ell(f_i) \, X_\ell^*(f_i)]^w}$$

$i = 1, 2, \ldots N_e$

$f_{i_1} = 0,4$ Hz

$f_{i_2} = 80$ Hz

Annex H
(informative)

Determining quantities

Table H.1 — Determining quantities for Mean Comfort

Sensor	Position	Assessment quantities [a]	Filtering Weighting curves [b]	Statistical processing by test section			Statistical processing by test zone		Mean Comfort			
				Sampling period	Statistical value	Intermediate quantities for Continuous Comfort	Grouping of data		Standard Method	Complete Method		
							Number of sampling periods	Percentile to be used	N_{MV} [c]	N_{VA} [d]	N_{VD} [e]	
Acceleration [m/s²]	Floor longitudinal	$\ddot{x}$	W_d	5 s	rms-values	$C_{Cx}(t) = a_{XP}^{W_d}(t)$	60 (blocks of 5 min)	F_0=50% F_1=95%	$a_{XP95}^{W_d}$	–	$a_{XP50}^{W_d}$	–
	Seat backrest		W_c			–			–	$a_{XD95}^{W_c}$	–	–
	Floor horizontal	$\ddot{y}$	W_d			$C_{Cy}(t) = a_{YP}^{W_d}(t)$			$a_{YP95}^{W_d}$	–	$a_{YP50}^{W_d}$	$a_{YP95}^{W_d}$
	Seat horizontal		W_d			–			–	$a_{YA95}^{W_d}$	–	–
	Floor vertical	$\ddot{z}$	W_b			$C_{Cz}(t) = a_{ZP}^{W_b}(t)$			$a_{ZP95}^{W_b}$	$a_{ZP95}^{W_b}$	$a_{ZP50}^{W_b}$	–
	Seat vertical		W_b			–			–	$a_{ZA95}^{W_b}$	–	–

[a] Measuring points in the middle of the vehicle body and at the two ends of the passenger compartment.

[b] Weighting curves according to Annex C.

[c] $N_{MV} = 6 \cdot \sqrt{\left(a_{XP95}^{W_d}\right)^2 + \left(a_{YP95}^{W_d}\right)^2 + \left(a_{ZP95}^{W_b}\right)^2}$,and in single direction evaluation: $N_{MVx} = 6 \cdot a_{XP95}^{W_d}$, $N_{MVy} = 6 \cdot a_{YP95}^{W_d}$ and $N_{MVz} = 6 \cdot a_{ZP95}^{W_b}$

[d] $N_{VA} = 4 \cdot \left(a_{ZP95}^{W_b}\right) + 2 \cdot \sqrt{\left(a_{YA95}^{W_d}\right)^2 + \left(a_{ZA95}^{W_b}\right)^2} + 4 \cdot \left(a_{XD95}^{W_c}\right)$

[e] $N_{VD} = 3 \cdot \sqrt{16 \cdot \left(a_{XP50}^{W_d}\right)^2 + 4 \cdot \left(a_{YP50}^{W_d}\right)^2 + \left(a_{ZP50}^{W_b}\right)^2} + 5 \cdot \left(a_{YP95}^{W_d}\right)$

Table H.2 — Determining quantities for Comfort in Curve Transitions and Discrete Events

Sensor	Position	Assessment quantities [a]	Filtering Weighting curve [b]	Statistical processing by test section			Statistical processing by time period	Passenger comfort on	
				Averaging [c]	Absolute values	Statistical value	Grouping of data [e]	Curve Transitions P_{CT} [f]	Discrete Events P_{DE} [g]
Roll velocity	Floor	$\dot{\varphi}$	W_{p}	1 s	Yes	Maximum	Begin to end of transition	$\lvert\dot{\varphi}_{1s}\rvert_{max}$	–
Acceleration	Floor horizontal	$\ddot{y}$		1 s	Yes	Maximum	Begin to end of transition plus 1,6s	$\lvert\ddot{y}_{1s}\rvert_{max}$	–
				2 s	Yes	Mean Value	Running	–	$\lvert\ddot{y}_{2s}(t)\rvert$
					No	Peak-to-Peak	Running	–	$\ddot{y}_{pp}(t)$
Jerk	Floor horizontal	$\dddot{y}$		[d]	Yes	Maximum	1 s before begin to end of transition	$\lvert\dddot{y}_{1s}\rvert_{max}$	–

[a] Measuring points in the middle of the vehicle body and at the two ends of the passenger compartment.

[b] Weighting curve according to Annex C.

[c] Sliding averaging windows with a maximum stepping period of 0,1 s.

[d] The lateral jerk is calculated as the difference over 1 s of the one-second averaged lateral acceleration.

[e] See Figure 3 — to Figure 5 for P_{CT} evaluation and Figure 6 for P_{DE} evaluation.

[f] $P_{CT} = 100 \cdot \{\max[(A \cdot \lvert\ddot{y}_{1s}\rvert_{max} + B \cdot \lvert\dddot{y}_{1s}\rvert_{max} - C);0] + (D \cdot \lvert\dot{\varphi}_{1s}\rvert_{max})^{E}\}$ constants for standing and seating people according to Table 6.

[g] $P_{DE}(t) = 100 \cdot \max[a \cdot \ddot{y}_{pp}(t) + b \cdot \lvert\ddot{y}_{2s}(t)\rvert - c;0]$ Constants for standing and seating people according to Table 7.

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[1)] May be purchased from:

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