

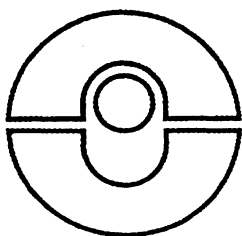
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Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles



International Union of Railways

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R**Leaflet to be classified in Volume:**

V - Rolling Stock

Amendments

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Preliminary remark:

The double vertical line (||) in the margin indicates modifications introduced on the date shown at the foot of the page.

Enforcement of this leaflet is subject to the conditions stipulated under the heading "application" at the end of the document.

Note

This leaflet is one of a series which also includes:

- Leaflet 515 : Coaches - Running gear
- Leaflet 518 : Testing and approval of railway vehicles from the point of view of their dynamic behaviour Safety - Track fatigue - Ride quality.
- Leaflet 565-1 : Special comfort and constructional characteristics for sleeping-cars accepted in international traffic.
- Leaflet 565-2 : Special comfort and constructional characteristics and rules of hygiene for restaurant-cars accepted in international traffic.
- Leaflet 566 : Loadings of coach bodies and their components.
- Leaflet 567-1 : Standard and X and Y coaches accepted for running on international services - Characteristics.
- Leaflet 567-2 : Standard Z-type coaches accepted for running in international traffic - Characteristics.

Reference may also be made to the following ISO standards:

- ISO 2631 : Vibrations and impacts - Guidelines for evaluating the effects of whole body vibrations on the human body
- ISO 2041 : Vibrations and impacts - vocabulary
- ISO 4865 : Vibrations and impacts - method of analysis and presentation of data
- ISO 5805 : Mechanical vibrations and impacts which have adverse effects on the human body - vocabulary
- ISO 8002 : Mechanical vibrations of land vehicles - methods of presenting the measured results
- ISO 8041 : Measuring instruments for vibrations perceived by persons
- ISO 5347 : Methods of calibrating impact and vibration pick-ups
- ISO 5348 : Mechanical fastening of accelerometers

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ISO DP 9629 : Characterisation of track irregularities¹

ISO DIS 10326-1: Mechanical vibrations: laboratory method for evaluating vehicle vibrations
Part 1: Basic requirements

ISO CD 10326-2 : Mechanical vibrations: laboratory method for evaluating vehicle vibrations
Part 2: Application to rail vehicles

1) Currently in draft form only.

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1 - Purpose

The purpose of this leaflet is to define the following:

- the conditions for performing tests designed to evaluate passenger ride comfort (passengers are all those on trains, including train crews),
- the parameters which should be measured, together with the means of determining the evaluation factors,
- a passenger comfort evaluation scale.

Since this leaflet specifies only how tests should be conducted and measurements processed, it is necessary to supplement it by a test specification suitable for the test vehicle and taking specific account of the conditions under which the vehicle operates.

This test specification should give the running conditions (track and vehicle characteristics, running speeds etc.) which, in combination with the conditions set out in section 5 below, make it possible to define the test programme in full, including in particular the test sections, speeds and areas where the parameters are recorded.

2 - Scope of application

ISO standard 2631 "Effects of whole body vibrations on the human body" is a document of general character capable of application to any situation which may be encountered by human beings in the course of normal activities (work, travel, etc.).

It describes the measurement of whole body vibrations and their effects.

This UIC leaflet is an application-specific document for the railway environment covering measurement, analysis and evaluation of vibrations, to allow for the fact that mechanical vibrations in railway vehicles have specific characteristics.

Based on the measurement of certain accelerations, the use of this leaflet should make it possible to evaluate passenger comfort in a specific vehicle and under given operating conditions (speed, type of track, etc.).

Evaluation of the ride of a specific vehicle under specified operating conditions (speed, type of track, etc.) is dealt with in UIC Leaflet 518.

The use of this leaflet may be useful in identifying the causes of discomfort (excessive vibration at floor level; exaggerated amplification through the seat, etc.).

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This leaflet may be applied to the vibrations normally encountered on railways. A correct evaluation of comfort based on this leaflet will only be possible if there is strict observance of its specifications. It proposes a method which takes into account the non-stationary character of these vibrations.

In order to characterise behaviour in the range of very low frequencies on curved track in connection with certain vehicles (tilting body trains, active suspensions, etc.), additional measurements may be necessary.

This leaflet also suggests a way of presenting data to evaluate vibration comfort.

It is not concerned with any appreciation of working conditions in railway vehicles.

It is also not concerned with any effects of vibrations on the health of people on board railway vehicles.

This leaflet applies only to people in good health.

3 - Average vibration comfort - Definition

Vibration comfort is perceived differently by each individual. It is therefore impossible to find an evaluation scale which can be applied to each individual.

Consequently the evaluation of vibration comfort used in this leaflet is based on the relationship, obtained over 5-minute periods, between the accelerations measured in the vehicle and the average of the vibration comfort ratings given by a representative group of passengers.

4 - Methods of evaluation

4.1 - Principles

The principles underlying the tests of passenger comfort in order to propose evaluation methods are based on:

- the vibration environment of the railways, which has the following characteristics:
- low level of vibration
- a large part of the energy contained below 3 Hz

- physiological weightings have been made, in particular in the 0.5 to 5 Hz frequency range, to take account of this environment.
- measurements of translation acceleration at standard points on the vehicle and the seat, with no allowance for rotary accelerations on account of their minimal contribution
- a statistical evaluation method obtained with the aid of correlations between objective measurements and subjective impressions of passengers in railway vehicles.

Since the vibrations of railway vehicles are not stationary but instead tend to fluctuate, the chosen statistical analysis is made with the aid of the weighted RMS values, calculated for a period of 5 seconds. Based on this statistical analysis, the value which contains the fluctuation, i.e. the 95% percentile, is calculated.

Currently, two methods of evaluation are possible:

- a simplified method, based solely on accelerations measured at floor level
- a fuller method, based on accelerations measured at floor level and at the seat (seat pan and seat back).

In the statistical method of characterising comfort, use is made of the weighted RMS values of these accelerations.

4.2 - Procedure

The evaluation of the average vibration comfort of a passenger in a railway vehicle comprises:

- acceleration measurements at the interfaces between the vehicle and the passenger.

The main axes of the human body in seated and standing position are shown in Appendix 1.

The principles for acceleration measurement are set out in Appendix 2.

- processing of the signals thus measured as described in Appendix 3, including:
 - a frequency weighting
 - a calculation of the RMS values evaluated every 5 seconds and a statistical analysis of these RMS values for a period of 5 minutes
 - a calculation of mean comfort indices.

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The measurements are conducted with two test persons respectively weighing 52 kg (+/- 5%) - representative of the 5th percentile of women - and 90 kg (+/- 5%) - representative of the 95th percentile of men - or with two test persons with the same weight of 70 kg (+/- 5%), representative of the 50th percentile of the population in general.

The duration of the measuring period depends on the objective of the tests. It will in any event be a multiple of 5 minutes, the basic sequence which makes use of the method possible. A period of 4 sequences of 5 minutes which are representative of the operating conditions is the minimum.

4.3 - Simplified method

The comfort of a seated passenger may be determined approximately from measurements at floor level alone.

The position of the measuring points is shown in Figures 4 and 5 of Appendix 2.

4.4 - Full method

The evaluation is made at the interfaces with the test person (Appendix 1), i.e.:

- in standing position, based on acceleration measurements at floor level
- in seated position based on acceleration measurements at the seat pan, seat back and floor.

These measurements are made with the aid of sensors, the characteristics of which are described in Appendix 2.

5 - Test conditions

5.1 - Running conditions

The comfort of the passenger is evaluated at the various operating speeds of the vehicle which actually occur in service, and in particular at the maximum operating speed.

5.2 - Selection of test lines

The test lines should be selected so that provision is made for the operating conditions representative of the use of the test vehicle (e.g. deployment on high-speed lines, on lines with normal speeds, on lines with small-radius curves).

For each type of line thus defined, at least 4 blocks each of 5 minutes shall be defined as test zones. These zones may be separate, but each zone shall be of 5 minutes' continuous duration.

5.2.1 - Track geometry

(Open)

A test zone should be chosen in which the geometrical characteristics of the track correspond to those defined for the desired running speed.

N.B:

Since there is at present no international criterion for defining a track, it is not possible to give a standard definition of track quality. However, since each railway has its own definition criteria, it is possible to specify routes which produce equivalent effects as regards vehicles.

The track characteristics of the zones used shall be set out in the test report.

Appendix 4 provides a specimen of the presentation of the geometrical characteristics of the track.

5.2.2 - Wheel-rail contact geometry

On straight track and on curves with radius $R > 2500$ m, the equivalent conicity should not normally exceed the following maximum values:

- 0.40 at $v < 200$ km/h
- 0.30 at $v > 200$ km/h.

The determination of comfort will inevitably be made with wheel profiles with an equivalent conicity of at least 0.10 with rail cant of 1:20, and of at least 0.15 with rail cant of 1:40. This so-called "wear profile" may be obtained naturally or by machining.

A test shall be made on characteristic rails, the profiles of which have been recorded over the test zones.

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The equivalent conicity for which allowance is to be made is that obtained with actual wheel profiles and rail profiles of the test zone, taking into consideration the lateral movement of the wheelset in the 0 +/- 3 mm range.

The definition and the various methods of measuring and calculating equivalent conicity are contained in RP 3 of ERRI Committee C 116.

The characteristics of the wheel-rail contact geometry are to be set out in the test report.

5.3 - Condition of the vehicle

The vehicle tested should conform in every respect to the definition specification. Checking of those characteristics of the vehicle in its normal state of maintenance which are of importance for its dynamic behaviour, such as the characteristics of the shock absorbers, vertical and lateral elasticities, should take place before the ride test on the line.

In view of the wide range of different bogie types and of linkage between coach body and bogie, it is not possible to give a list of characteristics to be checked in this document. Such a list should be drawn up in each case prior to the ride test, and as part of the detailed specification for test implementation.

The vehicle will inevitably be tested empty in ready-for-service condition; it may also be tested with the normal payload.

5.4 - Other conditions

The position of the vehicle in the train has no effect on the application of the method.

However, it can be stated that, in the case of a specific vehicle, comfort in vehicles at the end of the train may be different. The tightening of the couplings should be regular.

In the case of a motor trainset, whether articulated or not, the designation of the vehicles for which comfort is determined, needs to be set out precisely in the test specification. The choice depends on the design of the train; measurements should therefore be made in a vehicle of each possible type, depending on the bogies on which they are mounted and on the coach body - bogie linkages.

6 - Measured variables

The comfort of passengers is determined on the basis of acceleration measurements. These are taken at various points on the floor and on the seat (seat and back).

The conditions of measurement are set out in Appendix 2.

7 - Calculated variables

7.1 - Symbols and indices

7.1.1 - Symbols

a = effective value of the acceleration

N = comfort index

7.1.2 - Indices

- w_i This upper index relates to frequency-weighted values according to the weighting curve i ($i = b, c, d$):
 b : vertical
 c : seat back
 d : horizontal
- σ_j These lower indices relate to the interfaces:
 (σ : direction of the sensitive axis of the sensor)
 (j : A for seating surface, P for floor, D for seat back)
- k This lower index relates to the percentile used.
 ($k = 50$ for the 50th percentile and $k = 95$ for the 95th percentile)
- ℓ : This lower index relates to the type of comfort):
 $\ell = MV$ (simplified method)
 $\ell = VA$ (passenger in seated position)
 $\ell = VA$ (passenger in standing position)

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7.2 - Average passenger comfort

The filtering and processing conditions are described in Appendix 3.

7.2.1 - Simplified formula in seated or standing position

a) Variables used

At floor level a_{XP} , a_{YP} , a_{ZP}

b) Simplified formula

$$N_{MV} = 6 \sqrt{(a_{XP95}^{w_d})^2 + (a_{YP95}^{w_d})^2 + (a_{ZP95}^{w_d})^2}$$

In order to be able to use this formula at the vehicle end, allowance should be made for the value, $a_{XP95}^{w_d}$ which is obtained in the vehicle centre.

7.2.2 - Full method in seated position

a) Variables used

At floor level : a_{ZP}

At seat pan level : a_{YA} , a_{ZA}

At seat back level : a_{XD}

b) Comfort formula

$$N_{VA} = 4 \cdot (a_{ZP95}^{w_b}) + 2 \cdot \sqrt{(a_{YA95}^{w_d})^2 + (a_{ZA95}^{w_b})^2} + 4 \cdot (a_{XD95}^{w_c})$$

7.2.3 - Full method in standing position

a) Variables used

At floor level a_{XP} , a_{YP} , a_{ZP}

b) Comfort formula

$$N_{VD} = 3 \cdot \sqrt{16 \cdot (a_{XP50}^{w_d})^2 + 4 \cdot (a_{YP50}^{w_d})^2 + (a_{ZP50}^{w_b})^2 + 5 \cdot (a_{YP95}^{w_d})^2}$$

In order to be able to use this formula at the vehicle end, allowance should be made for the value $a_{XP50}^{w_d}$, which is obtained in the vehicle centre.

8 - Evaluation scale

The proposed scale, in comfort units with a maximum class interval of the comfort unit of 0.10, is as follows:

$N < 1$	very good comfort
$1 < N < 2$	good comfort
$2 < N < 4$	moderate comfort
$4 < N < 5$	poor comfort
$N > 5$	very poor comfort

9 - Recommended limiting values

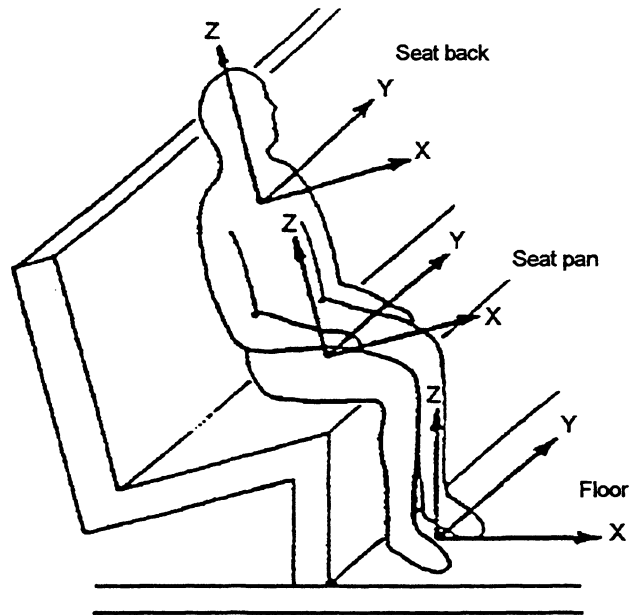
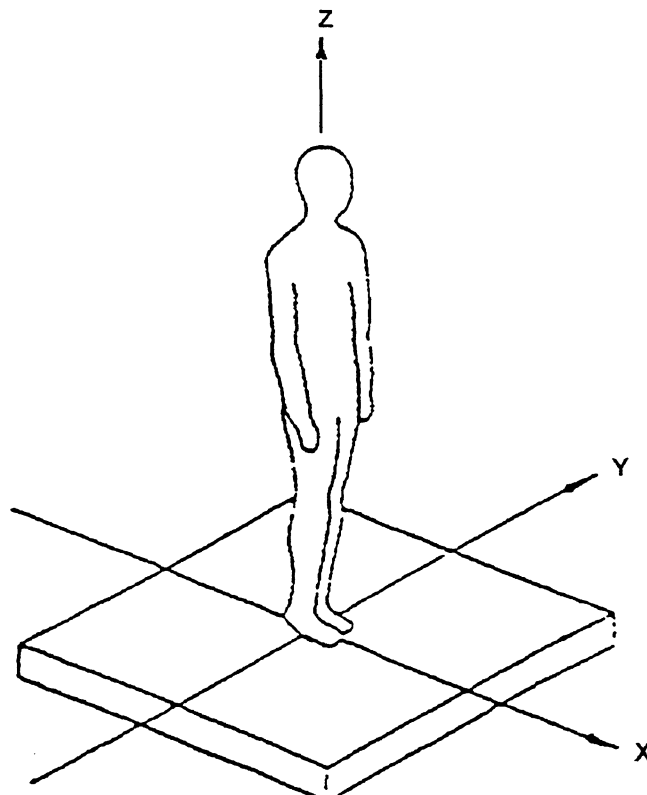
In seated and standing position and when the simplified method is used, the following provisional limit values are recommended:

Suburban	4
Conventional rolling stock	3
De-luxe rolling stock	2

10 - Test report

The test report should refer to the test specification, set out the characteristics of the vehicle and seat tested and the track used, and precisely describe the test conditions with all measurements in proof.

A specimen presentation is shown in Appendix 5.

Principle axes of the human body**Seated position****Standing position**

Measurement of the vibrations

1 - Variables to be measured

In accordance with the chosen evaluation method, the physical variables to be measured are the translation accelerations at floor level or (and) at the seat/person interfaces.

The term "measuring equipment" used below relates to all the instruments which make it possible to measure and record the signals.

"Measuring method" describes the mode of use of the measuring equipment in order to bring together the data which constitute the subject of the test.

2 - Measuring equipment

The measuring equipment comprises the following:

- sensors (accelerometers)
- conditioning amplifiers and filters
- recorders (if required)

This equipment taken together represents a measuring chain. The characteristics of this equipment should be consistent. The accuracy of the measuring chain should be defined not only by the characteristics of each component but also by specific characteristics of the measuring chain as a whole.

The calibration of the equipment is to be checked regularly in accordance with the relevant standards.

2.1 - Accelerometers and conditioning amplifiers

In general it is not possible to separate the sensor from its conditioning amplifier, and therefore these components are dealt with together; they should satisfy the following conditions:

- the global transfer function should be flat between 0.4 and 00 Hz at +/- 0.5 Db,
- non-linearity + hysteresis: $\leq 0.3\%$ of the measuring range,
- cross-axis sensitivity: $\leq 0.05 \text{ (m/s}^2\text{)(m/s}^2\text{)}$,