UIC CODE

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Translation

OR

Testing and approval of railway vehicles from the point of view of their dynamic behaviour - Safety - Track fatigue - Ride quality

Essais et homologation de véhicules ferroviaires du point de vue du comportement dynamique - Sécurité - Fatigue de la voie - Qualité de marche

Fahrtechnische Prüfung und Zulassung von Eisenbahnfahrzeugen - Fahrsicherheit, Fahrwegbeanspruchung und Fahrverhalten

Leaflet to be classified in Volumes:

V - Rolling stock

VII - Way and works

Application:

With effect from 1 August 2005
All members of the International Union of Railways

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1st edition, July 1995   First issue

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3rd edition, October 2005   Addition of amendments approved by group of expert in January 2005: point 5 and Appendix A

The person responsible for this leaflet is named in the UIC Code

Contents

Summary

UIC Leaflet 518 covers all the provisions dealing with on-line running tests and the analysis of the results in terms of rolling stock approval (conventional vehicles, new-technology vehicles and special vehicles) from the point of view of dynamic behaviour in connection with safety, track fatigue and running behaviour for international traffic acceptance purposes.

Concerning vehicles equipped with cant-deficiency compensating systems, the provisions of the leaflet may be provisionally implemented for exclusively national operating purposes.

Vehicles are approved on the basis of a code of practice defining:

-   the implementation conditions of the line tests (track alignment design, track geometric quality, speed and cant deficiency),

-   the geometry of the wheel-rail contact,

-   the state of the vehicle,

-   the measured quantities related to vehicle dynamic behaviour,

-   the conditions for the automatic and statistical processing of data,

-   the assessment quantities,

-   the related limit values.

The attention of the reader shall be drawn to the fact that the code of practice used for international acceptance does not necessarily address the most severe operating conditions likely to be met locally by any vehicle (for example mountain lines, sharply curved lines, etc.). On the other hand, the testing procedure does consider the extreme operating conditions concerning speed and cant deficiency.

This UIC leaflet also defines the implementation conditions of:

-   the full procedure (test zones with tangent track, large-radius curves, small-radius curves, empty or loaded vehicles),

-   the partial procedure (for some combinations of the cases mentioned above),

-   the measuring methods:

    •   the normal method (measurement of wheel-rail interaction forces Y and Q and measurement of accelerations in the vehicle body),
    •   the simplified methods (measurement of lateral forces H on wheelset and/or measurement of accelerations on wheelset, bogie-frame and vehicle body).

In order to facilitate the interpretation of test results, the UIC Leaflet also proposes an example of graphical presentation of the development of typical statistical quantities as well as track geometric characteristics, by sections of line.

1 - Purpose of leaflet

The purpose of this leaflet is to set out the rules to be met when conducting dynamic behaviour tests in connection with safety, track fatigue and running behaviour - and when analysing the results for railway rolling stock approval purposes.

The purpose of this leaflet is not to require vehicle approval tests to be based on track alignment designs, track geometries and/or operating conditions that would be more severe than those likely to be met by any vehicle in revenue-service.

The current leaflet contains a <u>code of practice</u> with respect to track alignment design, track geometry and related operating conditions (cant deficiency and speed) to be complied with for the vehicle approval tests. Vehicle performance results shall serve as comparative indicators for the operation of international services.

For networks or specified routes where track conditions (track alignment design, track geometric quality) and/or operating conditions are poorer than those used as a reference in this leaflet, additional verifications should be carried out where required to ensure safety for the particular operation.

On the contrary, if actual track alignment design and track geometry happen to be better than those prescribed for the conduct of approval tests, enhanced operating conditions could be a reasonable prospect.

This leaflet is based upon existing rules, procedures and practices. The following principles have been followed:

1. It is essential to harmonise existing rules or even to introduce new rules in order to cater for international traffic growth, notably that of high-speed traffic. It is also vital to review existing rules given the significant progress made in terms of measuring methods, railway engineering data analysis and processing.

2. The current safety and reliability performance levels should at least be maintained when vehicle design or operating conditions are to be altered, because of speed-enhancements and/or increased axle-loads in particular.

This leaflet reflects the current state-of-the-art to be considered when line-tests are conducted and their outcome is to be evaluated.

The procedures set out in this leaflet are meant to be used for approval testing of vehicle dynamic behaviour but may also be helpful when addressing similar issues in vehicle-track interaction.

This document describes:

- the implementation conditions of line tests,

- the measured quantities related to vehicle dynamic behaviour,

- the conditions for the automatic and statistical processing of data,

- the assessment quantities,

- the limit values,

as required for the completion of dynamic behaviour tests and for the approval of railway vehicles from the points of view of:

- safety,

- track fatigue,

- running behaviour.

o **2 - Field of application**

An approval test shall be carried out:

- for new vehicle or new running-gear designs,

- in the event of redesigning constituent parts which affect the dynamic behaviour of already approved stock,

- in the event of revised operating conditions.

In the event of an extension to the operating conditions, the approval test shall apply to the revised conditions only.

Approval tests shall be detailed in a report establishing the ability of the vehicle to operate in the most severe conditions for which it is designed or modified.

Additional requirements are due to be specified for vehicles fitted with cant-deficiency compensation (tilting) systems, but in the meantime, the arrangements contained in the normal procedure may be adopted on a provisional basis for any approval procedure with a purely domestic scope. Any vehicle shall be approved for the cant-deficiency values that have been used at its design and development stages.

o 3 - Definitions

3.1 - Operating parameters

Operating parameters:

- V_{lim} : vehicle operating speed limit.

- I_{adm} : permissible cant deficiency for the train-category in which the vehicle is to be operated.

3.2 - Track parameters

Vertical alignment (N_L)

Geometrical error, in the vertical plane, represented by the difference (in millimetres) between a point of the top of the rail in the running plane and the ideal mean line of the longitudinal profile.

Lateral alignment (D)

Geometrical error, in the transverse direction of the horizontal plane, represented by the difference (in millimetres) between a point of the side of the rail, at a height of approximately 15 mm below the running plane and the ideal mean line of the alignment.

Gauge (E)

Distance (in millimetres) between the inner faces of the rails, at a height of approximately 15 mm below the running plane.

Twist (g_b)

Twist g_b is the difference of cant (in millimetres) between two sections of track, at a distance b (in meters) apart, divided by the measurement base b. Twist is expressed in mm/m.

3.3 - Vehicle parameters

- The wheel-rail interaction forces in the lateral Y and vertical Q directions, measured at each wheel.

- The lateral forces measured at the level of the axle-boxes H ; in this case, the forces resulting from the dynamic movements of the wheelset are ignored.

- The linear accelerations measured at the level of the bogie frame, in the lateral direction $\ddot{y}^{+}$, and at the level of the body, above the axles or bogies, in the lateral $\ddot{y}^{*}$ and vertical $\ddot{z}^{*}$ directions.

- The lateral acceleration measured at the level of the wheelset $\ddot{y}$.

3.4 - Load conditions

Unloaded in running order: the state of a vehicle, free of all payload to convey, but equipped with all the elements and manned by staff required to ensure service.

Loaded in running order: the state of a loaded vehicle where all places are occupied for normal operating conditions, that is, in the case of passenger traffic, a vehicle with a comfort level corresponding to the type of train to be operated (commuter train, stopping train, long-distance train).

Extraordinary load: the state of a vehicle at maximum load .For vehicles fitted for passenger traffic, this occurs when unexpected and temporary events generate uncommon transport conditions The exceptional load depends upon the number of passenger seats and upon the number of passengers per m^2 in standing areas. These prescriptions are set by the operator on the basis of existing regulations and will give the corresponding exceptional load and the number of passengers allowed to be carried in these vehicles.

3.5 - Wheel-rail interaction

The parameter best characterising the interaction of the wheel-rail contact is the equivalent conicity ($\tan\gamma e$) which, for a given wheelset running on a given track, equals the tangent of the cone angle $\tan\gamma e$ of a conical profile wheelset whose transverse movement has the same wavelength of kinematic movement as the wheelset under consideration.

The equivalent conicity is a function of the maximum amplitude $\hat{y}$ of transverse movement of the wheelset:

$$\tan\gamma e = f(\hat{y})$$

Generally speaking, the equivalent conicity is calculated for:

$$\hat{y} = \pm 3mm$$

4 - Symbols and abbreviations

The symbols and abbreviations used in this document are tabled below:

Table 1 : Symbols and abbreviations

Parameter	Direction for measurements	Symbol	Unit
VEHICLE			
Guiding force Y			
Wheelset i, wheel j	lateral	Y_{ij}	kN
Force ΣY or H			
Wheelset i	lateral	ΣY_i or H_i	kN
Wheel force Q			
Wheelset i, wheel j	vertical	Q_{ij}	kN
Static axle-load	vertical	P_0	kN
Accelerations on running gear $\ddot{y}$, $\ddot{y}^+$			
Assessment quantities for running safety			
Wheelset i (on wheelset I, II...)	lateral	$\ddot{y}_{s1}$, $\ddot{y}_{s2}$	m/s^2
Bogie frame, above wheelset i, wheel j	lateral	$\ddot{y}_{sij}^+$	m/s^2
Accelerations in vehicle body $\ddot{y}^*$, $\ddot{z}^*$			
Assessment quantities for running safety			
Vehicle body, above running gear I, II...	lateral	$\ddot{y}^*_{sI}$, $\ddot{y}^*_{sII}$	m/s^2
Vehicle body, above running gear I, II...	vertical	$\ddot{z}^*_{sI}$, $\ddot{z}^*_{sII}$	m/s^2
Assessment quantities for running behaviour			
Vehicle body, above running gear I, II...	lateral	$\ddot{y}^*_{qI}$, $\ddot{y}^*_{qII}$	m/s^2
Vehicle body, above running gear I, II...	vertical	$\ddot{z}^*_{qI}$, $\ddot{z}^*_{qII}$	m/s^2
Influencing quantities			
Speed	-	V	km/h
Cant deficiency	-	I	mm
TRACK			
Vertical alignment	vertical	N_L	mm
Lateral alignment	lateral	D	mm
Gauge	lateral	E	mm
Twist	vertical/ longitudinal	g_b	mm/m

Table 1 : Symbols and abbreviations

Parameter	Direction for measurements	Symbol	Unit
Statistical parameters for track geometric quality	-	QNi	mm
OTHER SYMBOLS			
Equivalent conicity	-	$\tan \gamma e$	-
Quotient of the simplified methods	-	λ	-
Centile corresponding to 50% of the distribution function of a parameter on a given track-section	-	F_0	%
Centile corresponding to 0,15% of the distribution function of a parameter on a given track-section	-	F_1	%
Centile corresponding to 99,85 % of the distribution function of a parameter on a given track-section	-	F_2	%
Statistical value of parameter x corresponding to centile Fn	-	$x\,(F_n)$	-
Mean value of parameter x	-	$\bar{X}$	-
Standard deviation for a parameter	-	s	-
Estimated maximum value of parameter x	-	$\hat{X}_{max}$	-
Quasi-static value of parameter x	-	x_{qst}	-
Limit-value of parameter x	-	x_{lim}	-
Index s: filtering of assessment quantities for running safety			
Index q: filtering of assessment quantities for running behaviour			
Index 2m: sliding mean over 2 meters of track			

5 - General principles

5.1 - Preamble

Any approval of a railway vehicle from a dynamic behaviour point of view shall be based on a line-test (rather than on a simulation) using a test procedure defining:

- the track geometric-quality characteristics,

- the vehicle characteristics,

- the operating conditions and the characteristics of test zones:

  • on tangent track,
  • in large-radius curves,
  • in small-radius curves,

- the condition of the vehicle to be considered (empty, loaded...).

The railway vehicle shall be approved for each operating category in which it shall be used, e.g. high-speed line at 300 km/h, conventional line at 200 km/h ...

According to the nature of the approval procedure which may be an extension to the approval, the procedure to be applied will be termed as:

- full, taking into account all running conditions and all vehicle conditions,

- partial, if only part of these conditions are taken into consideration.

In order to carry out this test, there is a need to apply a measuring method which is known as:

- "normal" if the individual wheel/rail interaction forces Y and Q are measured and the Y/Q ratio is calculated,

- "simplified" if only H forces and/or accelerations on the wheelsets, bogie-frame and body are to be measured.

5.2 - Choice of the method to be applied

The approval of a vehicle will be in one of the two situations:

- the vehicle concerned is new, in which case this is the first approval process,

- the vehicle has been altered or is to be operated differently, in which case it becomes an extension to the approval.

Vehicles may fall in one of these three categories:

- "conventional" vehicles if they are of conventional design and subject to usual operating arrangements,

- new-technology vehicles,

- "special" vehicles which are either unique or found in low numbers, belong to either of the following classes:

  a. track-maintenance vehicles, including rerailing vehicles,
  b. special transport stock.

The selection of the method to be applied, i.e. normal or simplified, is illustrated by the flow-chart in Appendix A - page 44.

5.2.1 - Approval of a new vehicle

In this case, the full procedure as well as the normal measuring method shall be applied.

However, if the vehicle complies with the requirements set out in point 5.3, a simplified measuring method may be applied except for new-technology vehicles which shall be subject to the full procedure and the normal measuring method.

For standardised freight wagons special cases are given in point 5.4.

5.2.2 - Extension to an approval

When an already approved vehicle:

- is to be operated differently,

- includes revised design features,

an extension to the approval may be agreed by applying the normal method, or one of the simplified methods, solely to the test cases on which the modification has an impact. Instructions on how to proceed are given in point 10.2 - page 40.

If the vehicle was initially approved by the normal method, the extension is approved on the basis of the instructions given in point 10.2.

If the vehicle has already been approved internationally, the criteria given in point 10.2 may be applied, by special dispensation.

For standardised freight wagons special cases are given in point 5.4.

5.3 - Conditions for application of the simplified method

Simplified measuring methods have been developed, based on the experience gained by railways with conventional vehicles. They are based on:

- the measurement of H forces at the wheelsets with accelerations being measured on the vehicle body ($\ddot{y}*$ and $\ddot{z}*$),

- the acceleration measurements on the bogie-frame ($\ddot{y}^{+}$) and on the body ($\ddot{y}*$ and $\ddot{z}*$) for bogie vehicles,

- the acceleration measurements on the wheelsets $(\ddot{y})$ and on the body ($\ddot{y}*$ and $\ddot{z}*$) for non-bogie vehicles.

Whenever H forces are measured on a vehicle of whichever type, lateral accelerations ($\ddot{y}^+$) are to be measured on the bogies, especially on the non-instrumented bogies so as to check their dynamic behaviour.

Accelerations are measured on the wheelsets $(\ddot{y})$ and on the body ($\ddot{y}*$ and $\ddot{z}*$) of non-bogie vehicles. On bogie vehicles, accelerations are measured on the bogie frame ($\ddot{y}^+$), at the outer axle and on the vehicle body ($\ddot{y}*$ and $\ddot{z}*$).

On the vehicle body, accelerations are usually measured at the wheelsets or bogie pivots.

If the vehicle's geometrical design is strongly dissymmetrical or if masses are not well distributed, accelerations should then be measured at the end of the vehicle body.

Note: The measurement of $\ddot{y}*$ and $\ddot{z}*$ with filtering defined in Appendix F - page 57 will make it possible to give assessment quantities for running safety ($\ddot{y}_s^*$ and $\ddot{z}_s^*$) replacing the measurement of lateral forces, as well as assessment quantities for running behaviour $\ddot{y}_q^*$ and $\ddot{z}_q^*$.

5.3.1 - General conditions

- Speed :

  • locomotives: $V \leq 160$ km/h
  • EMUs / DMUs: $V \leq 200$ km/h
  • passenger vehicles: $V \leq 200$ km/h
  • freight wagons and special vehicles: $V \leq 120$ km/h

- Cant deficiency: apply Appendix C - page 50.

- Axle load:

  • conventional vehicles: $2 Q_0 \leq 200$ kN
  • special vehicles: $2 Q_0 \leq 225$ kN

5.3.2 - Specific conditions

Over and above the general conditions to be met, the following provisions shall apply:

5.3.2.1 - Conventional vehicles

Locomotives:

- locomotives with 2-axle bogies as a maximum:

  • $V \leq 120$ km/h: measurement of accelerations on the body and bogies
  • 120 km/h < $V \leq 160$ km/h: measurement of H forces and of accelerations on the body

- locomotives with 3-axle bogies: measurement of H forces and of accelerations on the body.

- electric/diesel multiple units including railcars:

  - bogies $\leq$ 10 t: V $\leq$ 200 km/h: measurement of accelerations on the body and bogies
  - bogies > 10 t: V $\leq$ 120 km/h: measurement of accelerations on the body and bogies

    120 < V $\leq$ 160 km/h: measurement of H forces and of accelerations on the vehicle body

- shunting engines (shunting engines with axles):
  V $\leq$ 100 km/h: measurement of accelerations on the vehicle body

Passenger vehicles:

- vehicles fitted with 2 two-axle bogies: V $\leq$ 200 km/h: measurement of accelerations on the vehicle body and bogies

- non-bogie vehicles: V $\leq$ 120 km/h: measurement of accelerations on the vehicle body

Freight wagons:

- non-bogie wagons,

- wagons with 2-axle bogies,

- articulated vehicles comprising several units, with axles or 2-axle bogies:

  - measurement of accelerations on wheelsets and body for non-bogie wagons
  - measurement of accelerations on body and bogies for bogie wagons

- wagons with 3-axle bogies,

- articulated vehicles comprising several units, with 3-axle bogies:

  - measurement of H forces and accelerations on the vehicle body.

5.3.2.2 -   Special vehicles

Non-bogie vehicles or vehicles with 3-axle bogies as a maximum:

- measurement of accelerations on bodies and bogies for bogie vehicles,

- measurement of accelerations on wheelset and bodies for non-bogie vehicles.

Vehicles with more than 3-axle bogies:

- measurement of H forces on the wheelsets in the most unfavourable position and of accelerations on the vehicle body.

5.4 - Special cases for freight wagons

Freight wagons have a lot of standardised components (described in different UIC-leaflets). *UIC Leaflet 432* describes conditions under which freight wagons fitted with standard running gears can be accepted without further running tests.

o 6 - Test conditions

The running conditions during tests shall include all combinations in terms of:

- speed,

- cant deficiency,

- curve radius.

In addition, vehicles meant for international traffic shall be tested as follow:

- one test and its evaluation made on rails laid at 1/20,

- one test and its evaluation made on rails laid at 1/40.

In the case of exclusively domestic operation, the test shall be made applying only the rail inclination used on the relevant network.

With regard to special vehicles, the test may be carried out with a single rail inclination if the estimated maximal safety values are below 85% of the limit value.

With regard to the three test-track configurations set out hereunder, the test zone should be made of a given number of different track sections, which may or may not be juxtaposed but shall exclude any overlap.

The partitioning of test tracks into sections is required for the statistical analysis set out in point 8 - page 24.

6.1 - Test zones

The permissible cant-deficiency value (I_{adm}) to be reflected in the selection of test sections is given in Appendix C - page 50 table, in accordance with train categories.

Test conditions to be applied are defined below:

6.1.1 -   Zones on tangent track and in large-radius curves

- Test speed:
  $V = 1,1 \, V_{lim}$ with a minimum of $V_{lim} + 10$ km/h
  tolerance: ± 5 km/h

- Cant deficiency:
  $I \leq 40$ mm

- Number of sections:
  $N \geq 25$

- Length of each section:
  ℓ = 250 m if $V_{lim} \leq 220$ km/h
  ℓ = 500 m if $V_{lim} > 220$ km/h

- 10% tolerance on length of each section

- Minimum length of the zone encompassing all the sections
  $L = N.\ell \geq 10$ km

- Statistical processing .

6.1.2 - Zone in large-radius curves

Full curves and transition curves are processed separately.

- Test speed:
  $V_{lim} \leq V \leq 1,1 \, V_{lim}$
  tolerance : ± 5 km/h

- Cant deficiency:
  $0,75 \, I_{adm} \leq I \leq 1,10 \, I_{adm}$
  tolerance : $\pm 0,05 \, I_{adm}$

NB : If it is not possible to find a European railway network in which the contents of Appendix C can be applied (cant-deficiency values to be taken into account), the approval test may be carried out with a lower cant-deficiency value, which is to be stated in the test report.

Full-curve sections:

- Number of sections:

  • one-dimensional statistical processing method

    $N_1 \geq 25$ with $0,75 \, I_{adm} \leq I \leq 1,10 \, I_{adm}$
    including $N_2 \geq 0,2 \, N_1$ with $I = 1,10 \, I_{adm}$
    tolerance : $\pm 0,05 \, I_{adm}$

  • two-dimensional statistical processing method (see Point 9.2)

    $N_1 \geq 25$ with $0,75 \, I_{adm} \leq I \leq 1,10 \, I_{adm}$ distributed as best as possible over the interval
    including $N_2 = (0,20 \pm 0,05) \, N_1$ with $I = 1,10 \, I_{adm}$
    tolerance : $\pm 0,05 \, I_{adm}$

- Length of each section:
  ℓ = 100 m if $V_{lim} \leq 140$ km/h
  ℓ = 250 m if 140 km/h $< V_{lim} \leq 220$ km/h
  ℓ = 500 m if $V_{lim} > 220$ km/h

NB : For V ≤ 160 km/h it is possible to use 100-metre long sections if the railway's topography so demands.

- 10% tolerance on length of each section

- Minimum length of the zone encompassing all the sections: L = N.ℓ ≥ 10 km

- Several sections possible per curve

- Statistical processing (see point 9 - page 25).

Transition curve sections:

- Include all the relevant transition curves for the selected curves

- Single section per transition

- Statistical processing (see point 9).

6.1.3 - Zone in small-radius curves

The curves are placed into two categories, depending on the radius. These have to be processed separately.

Transition curves are also processed separately, which results in a total of four processing operations.

The track geometric quality to be taken into consideration is that corresponding to a speed of 80 km/h < V ≤ 120 km/h, as stipulated in Appendix D - page 51.

Full curve sections

1. 400 m ≤ R ≤ 600 m

   Optimised distribution of curves with radii between 400 and 600 m, with a mean value of 500 ± 50 m.

   • Cant deficiency:
   $0{,}75\ I_{adm} \le I \le 1{,}10\ I_{adm}$
   tolerance : $\pm 0{,}05\ I_{adm}$

   • Number of sections:

   one-dimensional statistical processing method (see point 9.2 - page 26):
   $N_1 \ge 50$ with $0{,}75\ I_{adm} \le I \le 1{,}10\ I_{adm}$
   including $N_2 \ge 0{,}2\ N_1$ with $I = 1{,}10\ I_{adm}$
   tolerance : $\pm 0{,}05\ I_{adm}$

   two-dimensional statistical processing method (see point 9.2):
   $N_1 \ge 50$ with $0{,}75\ I_{adm} \le I \le 1{,}10\ I_{adm}$ distributed as best as possible over the interval
   including $N_2 = (0{,}20 \pm 0{,}05)\ N_1$ with $I = 1{,}10\ I_{adm}$
   tolerance : $\pm 0{,}05\ I_{adm}$

- Length of each section: ℓ = 100 m

- 10% tolerance on length of each section

- Statistical processing (see point 9 - page 25).

2. 250 m $\leq$ R < 400 m

    Optimised distribution of curves with radii between 250 and 400 m, with a mean value of 300^{+50}_{-20} m.

    - Cant deficiency:
      $0,75\ I_{adm} \leq I \leq 1,10\ I_{adm}$
      tolerance : $\pm 0,05\ I_{adm}$

    - Number of sections:

      one-dimensional statistical processing method (see point 9.2 - page 26):
      $N_1 \geq 25$ with $0,75\ I_{adm} \leq I \leq 1,10\ I_{adm}$
      including $N_2 \geq 0,2\ N_1$ with $I = 1,10\ I_{adm}$
      tolerance : $\pm 0,05\ I_{adm}$

      two-dimensional statistical processing method (see point 9.2):
      $N_1 \geq 25$ with $0,75\ I_{adm} \leq I \leq 1,10\ I_{adm}$ distributed as best as possible over the interval
      including $N_2 = (0,20 \pm 0,05)\ N_1$ with $I = 1,10\ I_{adm}$
      tolerance : $\pm 0,05\ I_{adm}$

    - Length of each section: ℓ = 70 m

    - 10% tolerance on length of each section

    - Statistical processing (see point 9).

Transition curve sections

Separate processing of the relevant transitions for the selected curves is required for each category of curves.

Statistical processing (see point 9).

6.1.4 -   Special conditions (recommended)

 Running on track turnouts (turnout route) at the maximum speed authorised by each railway.

6.2 -   Selecting the test route

Test routes shall be selected among routes normally used in revenue service. The curves shall be chosen so as to meet the requirements set for the operating speeds and cant deficiency. The requirements in terms of rail inclination shall be met as well as those concerning the wheelset-track clearances.

6.2.1 - Selection of test-zones according to vehicle-type

The following principles are applied according to vehicle-type:

- Conventional vehicles:

  - tangent track
  - large-radius curves   } Point 6.1 - page 14 to be applied
  - small-radius curves

- New-technology vehicles:

  - tangent track
  - large-radius curves   } Point 6.1 to be applied
  - small-radius curves

- Special vehicles:

  infrastructure-maintenance vehicles, including rerailing vehicles:

  • tangent track: point 6.1.1 - page 14 to be applied

  • curves:

    $N \geq 25$ sections

    $V = V_{lim}$
    tolerance : ± 10 km/h

    $0,75\ I_{adm} \leq I \leq 1,10\ I_{adm}$, with some values greater than I_{adm}
    tolerance : $\pm 0,05\ I_{adm}$

    Length of each section:
    $\ell = 100$ m for $R \geq 400$ m
    $\ell = 70$ m for $R < 400$ m

    10% tolerance on length of each section.

    special transport stock, with more than 3-axle bogies:

  - tangent track
  - large-radius curves   } Point 6.1 to be applied
  - small-radius curves

6.2.2 - Track geometric quality

The following track geometric quality parameters should be taken into account because they have an impact on vehicle dynamic behaviour:

- vertical alignment,

- lateral alignment,

- twist,

- track gauge.

The test zone should be selected in such a way that the above-mentioned parameters shall reflect the vehicle operating speed limit.

The method to be applied in order to describe the test-track geometry and the relevant parameter values are given in Appendix D - page 51.

According to vehicle-type, the following criteria shall be applied :

- Conventional vehicles : Appendix D to be applied.

- New-technology vehicles : Appendix D to be applied.

- Special vehicles:

  • infrastructure-maintenance vehicles, including rerailing vehicles: compliance with the QN2 criterion for standard deviation (Appendix D),

  • special transport vehicles, with more than 3-axle bogies: Appendix D to be applied.

6.2.3 - Geometry of the wheel-rail contact

If, in tangent track and large-radius curves R ≥ 2500 m, the vehicle's dynamic behaviour is found to be unstable in some locations, the corresponding sections may be disregarded if the equivalent conicity exceeds the maximum value given below:

- 0,50 for V ≤ 140 km/h

- 0,40 for 140 km/h < V ≤ 200 km/h

- 0,35 for 200 km/h < V ≤ 230 km/h

- 0,30 for 230 km/h < V ≤ 250 km/h

- 0,25 for 250 km/h < V ≤ 280 km/h

- 0,15 for 280 km/h < V ≤ 350 km/h

The equivalent conicity should be calculated with the actual wheel profile of the test vehicle and the actual rail profile of the test track, the lateral wheelset movement being at $\hat{y} = \pm 3$ mm .

The values obtained for those sections that have been disregarded shall be identified in the test report.

6.3 - Test vehicle condition

6.3.1 - Mechanical characteristics (statically and dynamically)

The approval test must be conducted with a vehicle whose characteristics have been checked and recognised as complying with those specified for the series. If necessary, preliminary test rig measurements are to be carried out in order to verify the main parameters (stiffness, friction torque, damping...) and to check that maintenance tolerances are respected.

The results of these measurements are to be given in the test report.

For safety reasons, vehicles equipped with air suspension will also be subject to a test-run with deflated air springs under the same conditions as those indicated in point .

6.3.2 - Load condition

The vehicle has to be tested:

- in running order for locomotives and power cars,

- unloaded, in running order and with normal load for passenger stock (except for suburban stock),

- unloaded, in running order and with extraordinary loads for suburban stock,

- unloaded and loaded for wagons, with the maximum loading compatible with the operating conditions for which approval is being sought.

If the wagon is suitable for highly asymmetrical load configurations (for example some container carriers), the test shall be conducted under such conditions.

6.3.3 - Wheel profiles

The approval test has to be conducted with:

- either a wheel profile naturally worn in service, or copied on the lathe to represent such wear,

- or a theoretical wheel profile which is new or otherwise, which will lead to a provisional approval. If the equivalent conicity in service does not increase by more than 50% or more than 0,05 when compared with the value obtained with the tested wheel profile, then the provisional approval becomes final.

The equivalent conicity in service should be calculated with the actual wheel profiles of the test vehicle and the theoretical rail profile with a 1435 mm track gauge, the lateral wheelset movement being at $\hat{y} = \pm 3$ mm.

6.4 - Other conditions to be met

6.4.1 - Position of the vehicle in the trainset

If the vehicle is hauled, it is placed towards the rear of the trainset, with loose coupling.

If the test is carried out with a traction unit, it will be performed with the unit pulling, possibly supplemented by a test in pushing mode.

If the test is carried out with an EMU or DMU or a fixed formation trainset, the specifications shall indicate the vehicles which are to be measured and their position in the trainset.

6.4.2 - Direction of travel

Where possible, the test shall be conducted in both directions of travel. If not, for bogie stock, the bogie fitted with measurement equipment is placed in the position which was established to be the most unfavourable one during a preliminary test or a preliminary simulation calculation.

6.4.3 - Rail condition

The rail must be dry. In all events, the rail condition, atmospheric conditions and the time of the test shall all be logged in the test report.

7 - Quantities to be measured

o 7.1 - Normal method

The quantities which have to be measured (see list of measured quantities, whether mandatory or not, in Appendix E - page 56) are the following:

- Forces at wheel-rail contact in lateral Y and vertical Q directions at least for each outer axle on instrumented bogies or each wheelset for non-bogie wagons.

- Lateral and vertical accelerations at the ends of the body, above the bogies, or above the wheelsets in the case of non-bogie vehicles in lateral $\ddot{y}^*$ and vertical $\ddot{z}^*$ directions. The measurements must be taken on the floor or, if the vehicle does not have a floor, on the underframe at a point defined in the test report.

- Lateral accelerations on the bogie-frame $\ddot{y}^+$, at the position of each wheelset.

o 7.2 - Simplified methods

Depending on the simplified method applied (H forces and accelerations or accelerations only), the quantities to be measured (see Appendix E) are as follows:

- **For bogie vehicles:**

  - Lateral forces H for each outer axle on instrumented bogies.
  - Lateral and vertical accelerations at body end $\ddot{y}^*$ and $\ddot{z}^*$, above the bogies, at floor level for tractive stock and passenger vehicles; in addition, lateral accelerations will be measured on freight wagons at the vehicle body end, in the horizontal plane containing the centre-of-gravity.
  - Lateral accelerations on each bogie frame $\ddot{y}^+$, at the position of each outer wheelset.

- **For non-bogie vehicles:**

  - Lateral forces H for each wheelset.
  - Lateral and vertical accelerations at body end $\ddot{y}^*$ and $\ddot{z}^*$, above the wheelset, at floor level for tractive stock and passenger vehicles; in addition, lateral accelerations will be measured on freight wagons at the vehicle body end, in the horizontal plane containing the centre-of-gravity.
  - Lateral accelerations on wheelset $\ddot{y}$.

7.3 - Additional measurements

Further measurements may be taken to contribute to the evaluation of running safety and vehicle dynamic behaviour, and possibly account for specific behaviour. The additional quantities and measurement points are to be specified in each case.

o 7.4 - Recording of measured signals

All quantities due to be subsequently processed are to be recorded (magnetic tape, computer, etc.).

In addition, quantities used for immediate analysis (especially for safe testing conditions) are to be recorded on graphs.

The minimum filtering bandwidths to be observed for such recordings are given in Appendix E - page 56.

o 8 - Assessment quantities

Assessment of the dynamic behaviour of the vehicle (safety, track fatigue and running behaviour) shall be based on the determination of assessment quantities obtained from the measured quantities.

8.1 -   Normal method

The assessment quantities involved are as follows:

-   Sum of guiding forces per axle $(\Sigma Y)_{2m}$

-   Ratio of the lateral to the vertical force per wheel for the guiding wheelset $(Y/Q)_{2m}$

-   Vertical force between wheel and rail Q

-   Quasi-static force between wheel and rail Y_{qst} and Q_{qst}

-   Lateral acceleration values measured at the body $\ddot{y}_s^*$ and the bogie frame $\ddot{y}_s^+$, with a view to extend the approval subsequently

-   Lateral and vertical acceleration in the vehicle body $\ddot{y}_q^*$ and $\ddot{z}_q^*$

-   Quasi-static acceleration in the vehicle body $\ddot{y}_{qst}^*$

The processing rules for measured signals are shown in Appendix .

8.2 -   Simplified methods

According to the simplified method applied (H forces and accelerations or accelerations only), the assessment quantities to be obtained are as follows:

-   **For bogie vehicles:**

    •   H forces and $\ddot{z}_s^*$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour, **or,**

    • $\ddot{y}_s^+$, $\ddot{y}_s^*$ and $\ddot{z}_s^*$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour.

-   **For non-bogie vehicles:**

    •   H forces and $\ddot{z}_s^*$ and $\ddot{y}_s$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour, **or**
    • $\ddot{y}_s^*$, $\ddot{z}_s^*$ and $\ddot{y}_s$ accelerations for safety and $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour.

The processing rules for measured signals are shown in Appendices .

9 - Processing of assessment quantities

The processing of assessment quantities mentioned in point 8 - page 24 is an automated process based on recordings. The sampling frequency should be at least 200 Hz. Processing is carried out for each of the three test zones mentioned in point 6.1 - page 14. Its objective is to estimate the maximum value of assessment quantities, and processing is subdivided into the two phases described below.

9.1 - Statistical processing per section

The statistical processing shall be carried out for each defined section. Transition and full curve sections should make up separate sections in curved zones. The input data xi are derived from the statistical processing of the test sections. For each section, each quantity and each measuring point, the following shall be calculated:

- Normal method:

  • the distribution functions $F(x)$ for quantities $(\Sigma Y)_{2m}$, Q, $(Y/Q)_{2m}$, $\ddot{y}_q^*$ and $\ddot{z}_q^*$, from which are derived the statistical quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles corresponding to the statistical quantities for frequencies $F_1 = 0,15\%$ and $F_2 = 99,85\%$ of these distribution functions,

  • the distribution functions $F(x)$ to determine the central values for $xi(F_0)$ in the assessment of the quasi-static components of assessment quantities Y_{qst}, Q_{qst} and $\ddot{y}_{qst}^*$ during curve negotiation (full-curve sections only), F_0 being the centile corresponding to frequency $F_0 = 50\%$ of the distribution functions,

  • the weighted r.m.s. values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$ for running behaviour.

  If an approval extension is to be considered in the future, quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles $F_1 = 0,15\%$ and $F_2 = 99,85\%$, have to be calculated for bogie lateral accelerations bogie $\ddot{y}_s^+$.

  Appendix F.1 - page 57 specifies for each quantity, the filtering to be used, the classification methods and the statistical parameters for the processing, with groupings of input data to be achieved in connection with the various operating conditions.

  Appendix G - page 62 provides information on the generation of samples from the range of signal measured.

- Simplified methods:

  The distribution functions $F(x)$ for the following quantities:

  • for bogie vehicles:
  H forces and $\ddot{z}_s^*$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour, from which are derived the statistical quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles corresponding to the statistical quantities for frequencies $F_1 = 0,15\%$ and $F_2 = 99,85\%$ of these

distribution functions,

or

$\ddot{y}_s^+$, $\ddot{y}_s^*$ and $\ddot{z}_s^*$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ for running behaviour, from which are derived the statistical quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles corresponding to the statistical quantities for frequencies $F_1 = 0,15\%$ and $F_2 = 99,85\%$ of these distribution functions.

- • for non-bogie vehicles:
  H forces and $\ddot{z}_s^*$ and $\ddot{y}_s$ accelerations for safety, $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour, from which are derived the statistical quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles corresponding to the statistical quantities for frequencies $F_1 = 0,15\%$ and $F_2 = 99,85\%$ of these distribution functions,

  or

  $\ddot{y}_s^*$, $\ddot{z}_s^*$ and $\ddot{y}_s$ accelerations for safety and $\ddot{y}_q^*$ and $\ddot{z}_q^*$ accelerations for running behaviour, from which are derived the statistical quantities $xi(F_1)$ and $xi(F_2)$, F_1 and F_2 being the centiles corresponding to the statistical quantities for frequencies $F_1 = 0,15\%$ and $F_2 = 99,85\%$ of these distribution functions.

- the distribution functions $F(x)$ to determine the central values $xi(F_0)$ in the evaluation of the quasi-static components of quantities $\ddot{y}_{qst}^*$ during curves negotiations (full-curve sections only), F_0 being the centile corresponding to frequency $F_0 = 50\%$ of the distribution functions,

  the r.m.s. values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$ for running behaviour assessment.

Appendices F.2 - page 59, F.3 - page 60, F.4 - page 61 specify for each quantity, the filtering to be used, the classification methods and the statistical parameters for the processing, with groupings of input data to be achieved in connection with the various operating conditions.

Appendix G - page 62 provides information on the generation of samples from the range of signal measured.

9.2 - Statistical processing per test zone

For the approval of a vehicle from the dynamic behaviour point of view, a one-dimensional or two-dimensional statistical method shall be used for each test zone as per point 6.1 - page 14.

The statistical quantities selected or the r.m.s. values of a measured quantity represent the sample. The N, 2N or 4N statistical quantities or the N r.m.s values of all the sections for a test zone are put together in the form of input data x_i.

The quantities relating to the instability criterion are processed separately (see point 9.3 - page 27).

Statistical methods are defined in Appendix H - page 66.

9.2.1 - Tangent track and full curves

The statistical methods to be used are the following :

- tangent track:

  one-dimensional processing method,

- full curve:

  one or two-dimensional method.

The estimated maximum value shall be compared with the limit value given in point 10 - page 29.

When the one-dimensional statistical method is not fully conclusive for approval purposes (limit value exceeded, unacceptable variation in track geometric quality...), the statistical processing shall be supplemented with a two-dimensional regression. The results thus presented enable permissible values to be derived for significant quantities affecting dynamic behaviour such as: operating speed, curve radius, lateral acceleration, load, ...

When it is clear that the statistical population does not follow a normal statistical distribution, the use of a suitable statistical analysis method is recommended and should be set out in the test report.

9.2.2 - Transition curves

For each parameter, one shall calculate the maximum value of quantities xi ordered according to requirements applicable to Appendix F - page 57 curves, for all transition curves.

The maximum value shall be compared with the limit value given in point 10.

9.3 - Instability criterion

The instability of a railway vehicle is assessed, only on tangent or large-radius curve track, on the basis of the following parameters:

- normal method:

  • ΣY forces,

- simplified methods:

  • All vehicles except freight wagons and special vehicles (non-bogie):

    H forces **or**

    lateral accelerations in the bogie frame $\ddot{y}_s^+$ (when using the measuring method based on accelerations),

  • Freight wagons and special vehicles (non-bogie):

    lateral accelerations in the wheelset $\ddot{y}_s$.

The following procedure must be applied for each parameter:

- pass-band filtering around the instability frequency $f_0 \pm 2$ Hz, with an attenuation rate greater than or equal to 24 dB/octave,

- calculation throughout the test zone of the moving r.m.s value over a 100 m length in 10 m increments. This root means square value shall be noted $s\Sigma Y$, sH, $s\ddot{y}_s^+$ or $s\ddot{y}_s$, depending on the measuring method used.

The r.m.s. values thus calculated for each test zone must all fall below the limit value given in point 10 - page 29.

10 - Limit values for assessment quantities

The provisional limit values for track fatigue mentioned below may be exceeded by agreement between infrastructure manager and railway operator.

10.1 - Approval of a new vehicle

10.1.1 - Normal method

10.1.1.1 - Safety

1. Sum of guiding forces $(\Sigma Y_{2m})_{lim}$ (sliding mean over 2m of track)

   Lateral force (sliding mean over 2m of track):

   $$(\Sigma Y_{2m})_{lim} = \alpha \left(10 + \frac{P_0}{3} \right)$$

   where P_0 (axle-load) and $(\Sigma Y_{2m})_{lim}$ are expressed in kN.

   - traction units, passenger vehicles (tractive and trailer stock): $\alpha = 1$
   - wagons: $\alpha = 0,85$.

   NB : The values of coefficient α define the minimum characteristics required for track stability under the lateral forces exerted by vehicles. They correspond to a track laid with timber sleepers set at maximum 65 cm intervals, crushed stone ballast, rails with a linear mass of ≥ 46 kg/m, the geometry of which is maintained by tamping (see DT 66 and the RP1 from ORE Committee C 138.)
   The coefficient α is 0,85 for wagons, on account of the greater manufacturing tolerances and of their maintenance condition.

2. $[(Y/Q)_{2m}]_{lim}$ ratio per wheel (sliding mean over 2m track)

   $[(Y/Q)_{2m}]_{lim} = 0,8$ for $R \geq 250$ m

   NB : The recommended limit value was given by ORE Committee C 138 in RP9.

   For track-twist, the conditions quoted in ORE B55 RP8 have to be met.

3. Instability

   $$(s\Sigma Y)_{lim} = \frac{(\Sigma Y)_{lim}}{2}$$

10.1.1.2 - Track fatigue

The limiting values for track loading are consistent with the measurement and analysis methods presented in this leaflet.

1. Vertical force Q_{lim}

    *   Area of application:
        maximum static load per wheel: 112,5 kN

    *   Law of variation:
        $Q_{lim} = 90 + Q_0$
        Q_{lim} and Q_0 expressed in kN, Q_0 being the static load on each wheel

    *   Limits:

for	$V_{lim} \leq 160$ km/h	$Q_{lim} \leq 200$ kN
for 160 km/h <	$V_{lim} \leq 200$ km/h	$Q_{lim} \leq 190$ kN
for 200 km/h <	$V_{lim} \leq 250$ km/h	$Q_{lim} \leq 180$ kN
for 250 km/h <	$V_{lim} \leq 300$ km/h	$Q_{lim} \leq 170$ kN
for	$V_{lim} > 300$ km/h	$Q_{lim} \leq 160$ kN

        where V_{lim} is the vehicle operating speed limit.

        The limiting value to be selected is the smallest of the values obtained by applying the law of variation and the limitation due to speed.

    *   Filtering for the measurements: cut-off frequency 20 Hz.

2. Quasi-static lateral force in curves $(Y_{qst})_{lim}$

    $(Y_{qst})_{lim} = 60$ kN

    only in small radius curves defined in point , excluding transition curves.

3. Quasi-static vertical force in curves $(Q_{qst})_{lim}$

    $(Q_{qst})_{lim} = 145$ kN

    only in small radius curves defined in point , excluding transition curves.

10.1.1.3 - Running behaviour

1. Maximum value of accelerations $\left(\ddot{y}_q^*\right)_{lim}$ and $\left(\ddot{z}_q^*\right)_{lim}$

    *   traction units:
        $\left(\ddot{y}_q^*\right)_{lim} = 2,5$ m/s^2

$$\left(\ddot{z}_q^*\right)_{lim} = 2{,}5 \text{ m/s}^2$$

- passenger vehicles (tractive and trailer stock):

$$\left(\ddot{y}_q^*\right)_{lim} = 2{,}5 \text{ m/s}^2$$

$$\left(\ddot{z}_q^*\right)_{lim} = 2{,}5 \text{ m/s}^2$$

- bogie wagons:

$$\left(\ddot{y}_q^*\right)_{lim} = 3 \text{ m/s}^2$$

$$\left(\ddot{z}_q^*\right)_{lim} = 5 \text{ m/s}^2$$

- non-bogie wagons:

$$\left(\ddot{y}_q^*\right)_{lim} = 4 \text{ m/s}^2$$

$$\left(\ddot{z}_q^*\right)_{lim} = 5 \text{ m/s}^2$$

2. r.m.s. value for the accelerations $\left(s\ddot{y}_q^*\right)_{lim}$ and $\left(s\ddot{z}_q^*\right)_{lim}$

- traction units:

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- passenger vehicles (tractive and trailer stock):

  suspension in normal condition:

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

  suspension in degraded mode (deflated air bags):

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- bogie wagons:

$$\left(s\ddot{y}_q^*\right)_{lim} = 1{,}3 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 2 \text{ m/s}^2$$

- non-bogie wagons:

$$\left(s\ddot{y}_q^*\right)_{lim} = 1{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 2 \text{ m/s}^2$$

3. Quasi-static lateral acceleration $\left(\ddot{y}_{qst}^*\right)_{lim}$

traction units: 1,5 m/s^2

passenger vehicles (tractive and trailer stock):   1,5 m/s^2

freight wagons: 1,3 m/s^2

only in the curves mentioned in points 6.1.2 - page 15 and 6.1.3 - page 16, excluding transition curves.

10.1.2 - Simplified method: measurement of H forces and body-accelerations

The limit values to be adopted are as follows:

10.1.2.1 - Safety

1. Lateral forces $(H_{2m})_{lim}$

$$(H_{2m})_{lim} = \beta\left(10 + \frac{P_0}{3}\right)$$

P_0 is the static axle-load, expressed in kN.

- tractive stock:
  $\beta = 0{,}9$

- passenger vehicles (tractive and trailer stock):
  $\beta = 0{,}9$

- freight wagons:

  empty freight stock: $\beta = 0{,}75$
  loaded freight stock: $\beta = 0{,}8$

- special vehicles:
  $\beta = 0{,}9$

NB : Coefficient β allows for the dynamic behaviour of the wheelset in the lateral direction.

For freight stock, β also allows for the greater manufacturing tolerances and their maintenance condition.

2. Vertical accelerations in body $(\ddot{z}_s^*)_{lim}$:

- for tractive stock:

  single stage suspension:

  $(\ddot{z}_s^*)_{lim}= 4$ m/s^2

  two stage suspension:

  $(\ddot{z}_s^*)_{lim}= 3$ m/s^2

- passenger vehicles (tractive and trailer stock):

  single stage suspension:

  $(\ddot{z}_s^*)_{lim}= 4$ m/s^2

  two stage suspension:

  $(\ddot{z}_s^*)_{lim}= 3$ m/s^2

- for freight wagons and special vehicles:

  $(\ddot{z}_s^*)_{lim}= 5$ m/s^2

3. Instability:

- all vehicles except freight wagons and special vehicles (non-bogie):

  $(sH)_{lim} \; = \; \dfrac{H_{lim}}{2}$

- freight wagons and special vehicles (non-bogie):

  $\left(s\ddot{y}_s^*\right)_{lim} = 5$ m/s^2 (provisional limit value)

10.1.2.2 -   Running behaviour

1. Maximum value of accelerations $\left(\ddot{y}_q^*\right)_{lim}$ and $\left(\ddot{z}_q^*\right)_{lim}$

- for tractive stock:

  $\left(\ddot{y}_q^*\right)_{lim} = 2{,}5$ m/s^2

  $\left(\ddot{z}_q^*\right)_{lim} = 2{,}5$ m/s^2

- for passenger vehicles (tractive and trailer stock):

  $\left(\ddot{y}_q^*\right)_{lim} = 2{,}5$ m/s^2

$\left(\ddot{z}_q^*\right)_{lim}$ = 2,5 m/s^2

- for bogie wagons and special bogie vehicles:

  $\left(\ddot{y}_q^*\right)_{lim}$ = 3 m/s^2

  $\left(\ddot{z}_q^*\right)_{lim}$ = 5 m/s^2

- for non-bogie wagons and special vehicles (non-bogie):

  $\left(\ddot{y}_q^*\right)_{lim}$ = 4 m/s^2

  $\left(\ddot{z}_q^*\right)_{lim}$ = 5 m/s^2

2. r.m.s. values for the accelerations $\left(s\ddot{y}_q^*\right)_{lim}$ and $\left(s\ddot{z}_q^*\right)_{lim}$

- for tractive stock:

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 0,5 m/s^2

  $\left(s\ddot{z}_q^*\right)_{lim}$ = 1 m/s^2

- for passenger vehicles (tractive and trailer stock):

  suspension in normal condition:

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 0,5 m/s^2

  $\left(s\ddot{z}_q^*\right)_{lim}$ = 0,75 m/s^2

  suspension in degraded mode (deflated air bags):

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 0,75 m/s^2

  $\left(s\ddot{z}_q^*\right)_{lim}$ = 1 m/s^2

- for bogie wagons and special bogie vehicles:

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 1,3 m/s^2

  $\left(s\ddot{z}_q^*\right)_{lim}$ = 2 m/s^2

- for non-bogie wagons and special vehicles (non-bogie):

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 1,5 m/s^2

  $\left(s\ddot{z}_q^*\right)_{lim}$ = 2 m/s^2

3. Quasi-static lateral acceleration $\left(\ddot{y}^*_{qst}\right)_{lim}$

> traction units: $1,5 \text{ m/s}^2$
>
> passenger vehicles (tractive and trailer stock): $1,5 \text{ m/s}^2$
>
> freight wagons and special transport vehicles: $1,3 \text{ m/s}^2$

only in the curves mentioned in points 6.1.2 - page 15 and 6.1.3 - page 16, excluding transition curves.

10.1.3 - Simplified method: acceleration measurements, bogie vehicles

10.1.3.1 - Safety

1. Lateral accelerations on bogie frame $\left(\ddot{y}^+_s\right)_{lim}$

$$\left(\ddot{y}^+_s\right)_{lim} = 12 - \frac{M_b}{5}$$

where M_b is the mass of the bogie expressed in tonnes.

This mass is that of the bogie including all its constituent parts, including the wheelsets.

2. Lateral accelerations on vehicle body $\left(\ddot{y}^*_s\right)_{lim}$

- for tractive stock:

    on straight track and in large-radius curves:

    $$\left(\ddot{y}^*_s\right)_{lim} = 3 \text{ m/s}^2$$

    in small-radius curves:

    $$400 \text{ m} \le R \le 600 \text{ m} : \left(\ddot{y}^*_s\right)_{lim} = 2,8 \text{ m/s}^2$$

    $$250 \text{ m} \le R < 400 \text{ m} : \left(\ddot{y}^*_s\right)_{lim} = 2,6 \text{ m/s}^2$$

- for passenger vehicles (tractive and trailer stock):

    on straight track and in large-radius curves:

    $$\left(\ddot{y}^*_s\right)_{lim} = 3 \text{ m/s}^2$$

    in small-radius curves:

    $$400 \text{ m} \le R \le 600 \text{ m} : \left(\ddot{y}^*_s\right)_{lim} = 2,8 \text{ m/s}^2$$

$$250 \text{ m} \leq R < 400 \text{ m} : \left(\ddot{y}_s^*\right)_{lim} = 2,6 \text{ m/s}^2$$

- for freight wagons and special transport vehicles:

$$\left(\ddot{y}_s^*\right)_{lim} = 3 \text{ m/s}^2$$

3. Vertical accelerations in body $\left(\ddot{z}_s^*\right)_{lim}$

- for tractive stock:
  single stage suspension: $(\ddot{z}_s^*)_{lim} = 4 \text{ m/s}^2$

  two stage suspension: $(\ddot{z}_s^*)_{lim} = 3 \text{ m/s}^2$

- for passenger vehicles (tractive and trailer stock):
  single stage suspension: $(\ddot{z}_s^*)_{lim} = 4 \text{ m/s}^2$

  two stage suspension: $(\ddot{z}_s^*)_{lim} = 3 \text{ m/s}^2 =$

- for freight wagons and special transport vehicles:
  $(\ddot{z}_s^*)_{lim} = 5 \text{ m/s}^2$

4. Instability:
$$(s\ddot{y}_s^+)_{lim} = \frac{(\ddot{y}_s^+)_{lim}}{2}$$

10.1.3.2 -   Running behaviour

1. Maximum value for accelerations $\left(\ddot{y}_q^*\right)_{lim}$ and $\left(\ddot{z}_q^*\right)_{lim}$

- for tractive stock:
  $\left(\ddot{y}_q^*\right)_{lim} = 2,5 \text{ m/s}^2$
  $\left(\ddot{z}_q^*\right)_{lim} = 2,5 \text{ m/s}^2$

- for passenger vehicles (tractive and trailer stock):
  $\left(\ddot{y}_q^*\right)_{lim} = 2,5 \text{ m/s}^2$
  $\left(\ddot{z}_q^*\right)_{lim} = 2,5 \text{ m/s}^2$

- for freight wagons and special transport vehicles:

$$\left(\ddot{y}_q^*\right)_{lim} = 3 \text{ m/s}^2$$

$$\left(\ddot{z}_q^*\right)_{lim} = 5 \text{ m/s}^2$$

2. r.m.s. value for the accelerations $\left(s\ddot{y}_q^*\right)_{lim}$ and $\left(s\ddot{z}_q^*\right)_{lim}$

- for tractive stock:

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- for passenger vehicles (tractive and trailer stock):

suspension in normal condition:

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

suspension in degraded mode (deflated air bags):

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- for freight wagons and special transport vehicles:

$$\left(s\ddot{y}_q^*\right)_{lim} = 1{,}3 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 2 \text{ m/s}^2$$

3. Quasi-static lateral acceleration $\left(\ddot{y}_{qst}^*\right)_{lim}$

-	traction units	1,5 m/s^2
-	passenger vehicles (tractive and trailer stock):	1,5 m/s^2
-	freight wagons and special transport vehicles:	1,3 m/s^2

only in the curves mentioned in points 6.1.2 - page 15 and 6.1.3 - page 16, excluding transition curves.

10.1.4 - Simplified method : acceleration measurements, non-bogie vehicles

10.1.4.1 - Safety

1. Maximum values of lateral accelerations on vehicle body $\left(\ddot{y}_s^*\right)_{lim}$

   • for tractive stock:

   on straight track and in large-radius curves:

   $$\left(\ddot{y}_s^*\right)_{lim} = 3 \text{ m/s}^2$$

   in small-radius curves:

   $$400 \text{ m} \le R \le 600 \text{ m}: \left(\ddot{y}_s^*\right)_{lim} = 2,8 \text{ m/s}^2$$

   $$250 \text{ m} \le R < 400 \text{ m}: \left(\ddot{y}_s^*\right)_{lim} = 2,6 \text{ m/s}^2$$

   • for passenger vehicles (tractive and trailer stock):

   on straight track and in large-radius curves:

   $$\left(\ddot{y}_s^*\right)_{lim} = 3 \text{ m/s}^2$$

   in small-radius curves:

   $$400 \text{ m} \le R \le 600 \text{ m}: \left(\ddot{y}_s^*\right)_{lim} = 2,8 \text{ m/s}^2$$

   $$250 \text{ m} \le R < 400 \text{ m}: \left(\ddot{y}_s^*\right)_{lim} = 2,6 \text{ m/s}^2$$

   • for freight wagons and special transport vehicles:

   $P_0 < 60 \text{ kN}$ $\left(\ddot{y}_s^*\right)_{lim} = 4 \text{ m/s}^2$ (provisional limit value)

   $60 \text{ kN} \le P_0 \le 200 \text{ kN}$ $\left(\ddot{y}_s^*\right)_{lim} = 4,43 - \dfrac{P_0}{140}$ (provisional limit value)

   $P_0 > 200 \text{ kN}$ $\left(\ddot{y}_s^*\right)_{lim} = 3 \text{ m/s}^2$ (provisional limit value)

   P_0 being the static load per axle, expressed in kN.

2. Maximum values of vertical accelerations in body $\left(\ddot{z}_s^*\right)_{lim}$

- for tractive stock:

  single stage suspension: $\left(\ddot{z}_s^*\right)_{lim}$ = 4 m/s^2

  two stage suspension: $\left(\ddot{z}_s^*\right)_{lim}$ = 3 m/s^2

- for passenger vehicles (tractive and trailer stock):

  single stage suspension: $\left(\ddot{z}_s^*\right)_{lim}$ = 4 m/s^2

  two stage suspension: $\left(\ddot{z}_s^*\right)_{lim}$ = 3 m/s^2

- for freight wagons and special transport vehicles:

  $\left(\ddot{z}_s^*\right)_{lim}$ = 5 m/s^2

3. Instability

$\left(s\ddot{y}_s^*\right)_{lim}$ = 5 m/s^2 (provisional limit value).

10.1.4.2 -   Running behaviour

1. Maximum value of accelerations $\left(\ddot{y}_q^*\right)_{lim}$ and $\left(\ddot{z}_q^*\right)_{lim}$

- for tractive stock

  $\left(\ddot{y}_q^*\right)_{lim}$ = 2,5 m/s^2

  $\left(\ddot{z}_q^*\right)_{lim}$ = 2,5 m/s^2

- for passenger vehicles (tractive and trailer stock):

  $\left(\ddot{y}_q^*\right)_{lim}$ = 2,5 m/s^2

  $\left(\ddot{z}_q^*\right)_{lim}$ = 2,5 m/s^2

- for freight wagons and special transport vehicles:

  $\left(\ddot{y}_q^*\right)_{lim}$ = 4 m/s^2

  $\left(\ddot{z}_q^*\right)_{lim}$ = 5 m/s^2

2. r.m.s. value for the accelerations $\left(s\ddot{y}_q^*\right)_{lim}$ and $\left(s\ddot{z}_q^*\right)_{lim}$

- for tractive stock:

  $\left(s\ddot{y}_q^*\right)_{lim}$ = 0,5 m/s^2

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- for passenger vehicles (tractive and trailer stock):

  suspension in normal condition:

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

  suspension in degraded mode (deflated air bags):

$$\left(s\ddot{y}_q^*\right)_{lim} = 0{,}75 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 1 \text{ m/s}^2$$

- for freight wagons and special transport vehicles:

$$\left(s\ddot{y}_q^*\right)_{lim} = 1{,}5 \text{ m/s}^2$$

$$\left(s\ddot{z}_q^*\right)_{lim} = 2 \text{ m/s}^2$$

3. Quasi-static lateral acceleration $\left(\ddot{y}_{qst}^*\right)_{lim}$

traction units:	1,5 m/s^2
passenger vehicles (tractive and trailer stock):	1,5 m/s^2
freight wagons and special transport vehicles:	1,3 m/s^2

only in the curves mentioned in points , excluding transition curves.

10.2 - Extension of approval

Once a railway vehicle has been approved, an extension of approval may be granted if the vehicle's operating conditions or construction are changed.

The initial approval was made using either the normal measuring method or one of the simplified methods.

10.2.1 - Application conditions

Let λ be the minimum value of the "limit value/estimated maximum value" ratios of the following safety parameters:

- normal method:

  - ΣY and Y/Q

- simplified methods:

  • for bogie vehicles:

    H and $\ddot{z}_s^*$ **or**

    $\ddot{y}_s^+$, $\ddot{y}_s^*$ and $\ddot{z}_s^*$,

  • for non-bogie vehicles:

    H, $\ddot{z}_s^*$ and $\ddot{y}_s$ **or**

    $\ddot{y}_s^*$, $\ddot{z}_s^*$ and $\ddot{y}_s$

The tables of Appendix B concerning:

- locomotives and shunters (see B.1 - page 45),

- EMUs/DMUs and railcars (see B.2 - page 46),

- passenger coaches (see B.3 - page 47),

- bogie wagons (see B.5 - page 49),

- non-bogie wagons not fitted with a UIC double link suspension (see B.5),

must be applied if $\lambda \geq 1{,}1$ for each test zone.

10.2.2 - Definition of procedures and testing conditions

Each table consists of three parts:

- the left-hand part gives the modified parameters (modified since the initial approval),

- the centre part gives the conditions for waiving the test and applying a simplified method, only when $\lambda \geq 1{,}1$ according to the rate of variation of $\dfrac{x_{final} - x_{initial}}{x_{initial}}$ expressed in % of the parameter(s) under consideration,

- the right-hand part gives the procedure to be applied, which may be:

  • full:

    vehicle empty and laden,
    test zones on tangent track and on both large- and small-radius curves;

  • partial:

    one or more of the above-stated test cases.

10.2.2.1 - Initial approval was based on the normal method

Value λ shall be examined:

- if $\lambda \geq 1,1$: the instructions of the centre part of the table must be applied to the test cases given in the right-hand part of the same table; outside the indicated tolerance intervals, the normal method must be applied, for the test cases given in the right-hand part of the table.

   For a simplified method using only acceleration measurements to be applied, a new limit value is worked out only for the following safety parameters: $\ddot{y}_s^*$ and $\ddot{y}_s^+$ (for bogie vehicles) or $\ddot{y}_s^*$ (for non-bogie vehicles). For the parameter under consideration, the limit value should be found at a third of the remaining margin between the estimated maximum value and the initial limit value
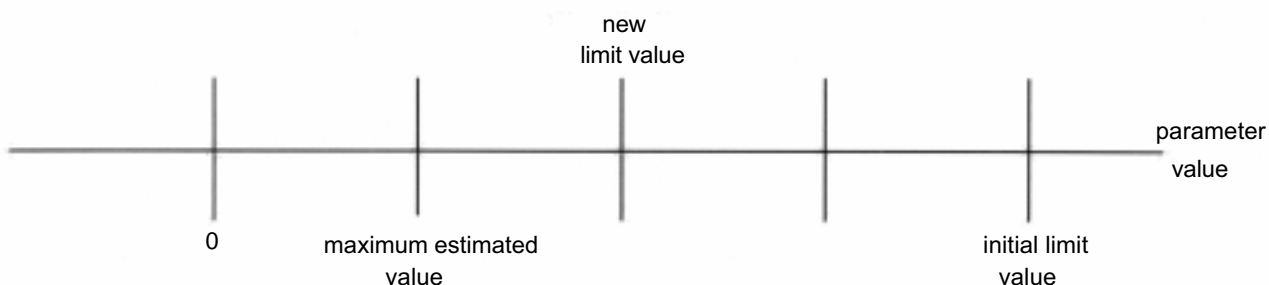
- if $\lambda < 1,1$: the normal method should be applied, for the test cases given in the right-hand part of the table.

10.2.2.2 - Initial approval by one of the simplified methods

If initial approval was by one of the simplified methods, it is first necessary to examine whether, for an extension of approval, the general conditions for applying a simplified method (see point 5.3 - page 10) still hold.

- if so, the value of λ must be examined:

   • if $\lambda \geq 1,1$: it must be checked whether the modifications can be approved **either** on the basis of a waiver of testing (1st column of centre part of table), **or** on the basis of limited testing (other columns of table),

   • if $\lambda < 1,1$: one can proceed with a simplified method (as per point 5.3) for the test cases given in the right-hand part of the corresponding table,

- if not, the normal method must be applied, for the test cases given in the right-hand part of the corresponding table.

o 11 - Presentation of test results

The test report shall indicate the test specifications, give the characteristics of the test vehicle and those of the track used and it shall accurately describe the actual test conditions, with all the supporting evidence.

Results shall be presented as follows:

- a list of caslculated values for safety parameters (ΣY, Y/Q, $\ddot{y}_s^+$, $\ddot{y}_s^*$ and $\ddot{z}_s^*$ in accordance with the method used) on all sections for which limit values are exceeded, with the possible reason for it (conicity, track gauge, rail profile...),

- a table of the estimated maximum values for the assessment quantities expressed in absolute value and as a percentage of the limit, for the test zones specified in point 6.1 - page 14,

- an example of the typical graphic recording for each quantity measured (see Appendix F - page 57 for the filtering to be used).

It is recommended to draw up, for each test section, a graph showing the typical statistical quantities (as per Appendix F) and the geometrical characteristics of the track, section by section (see example of presentation in Appendix I - page 69.).

The test report shall also include the statistical analysis method if it is specific.

Appendix A - Approval of a railway vehicle

Fig. 1 - General flowchart
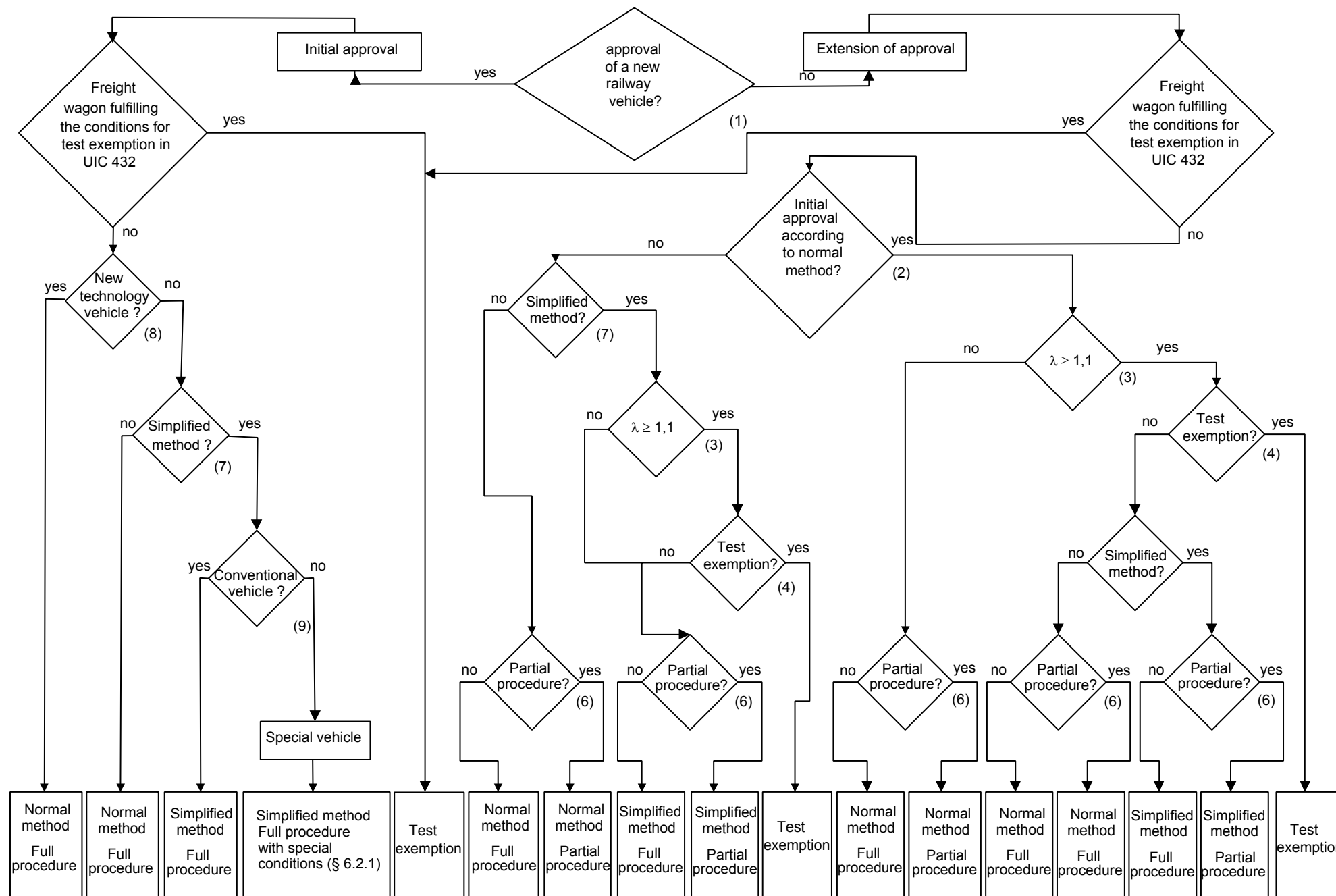
Explanatory notes to the flowchart

(1) Does the matter concern approval of a new railway vehicle ?

(2) (Was the initial acceptance made using the normal measurement method (forces Y, Q...) ?

(3) Was the λ factor calculated during the initial approval greater than or equal to 1,1 ?

(4) Are the conditions for waiving the tests (first column of the centre part of the table corresponding to the type of vehicle) met ?

(5) Are the specific conditions for applying a simplified method (2nd and 3rd columns of the centre part of the table corresponding to the type of tractive vehicle) met ?

(6) The test cases marked in the right-hand part of the corresponding table must be carried out.

(7) Are the conditions for applying a simplified method (see point 5.3 - page 10) met ?

(8) Is the vehicle a new-technology design (see point 5.2 - page 9) ?

(9) Is the vehicle a conventional one (see point 5.2)?

Appendix B - Application conditions for the partial procedure and the simplified methods

B.1 - Locomotives and shunting engines

Table 1 : Locomotives and shunting engines

Parameters modified		Conditions for waiving the test and applying a simplified method, when $\lambda \geq 1{,}1$ [1]			Procedure to be applied (full, partial)				
		Variation range compared to already-approved vehicle [2]			Load conditions		Test sections [3]		
		For dispensation from test	For simplified method		Empty	Loaded	Straight track	Curves	
			Measurement $\ddot{y}^+, \ddot{y}^*, \ddot{z}^*$	Measurement $H, \ddot{y}^*, \ddot{z}^*$				Large-radius curves	Small-radius curves
Vehicle		**Vehicle**			**Vehicle**				
Vehicle wheel-base		-5%, +20%	-10%, -5% +20%, +∞ [5]		YES	NO	YES	NO	NO
Height of centre of gravity		-20%, +10%	-40%, -20% +10%, +40%		YES	NO	YES	YES	NO
Mass	unsprung	±5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with a single suspension-level (total mass if the vehicle has **no** secondary suspension)	±5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with two suspension levels	±10%			YES	NO	YES	YES	YES
Moment of inertia of body relative to the vertical central axis		±10%			YES	NO	YES	YES	YES
Increase in tractive effort		0, +10%			YES	NO	YES	YES	YES
Increase in operating speed			0, +10 km/h	+10 km/h, +20 km/h	YES	NO	YES	YES	NO
Bogie		**Bogie**			**Bogie**				
Bogie wheelbase		0, +5%		+5%, +20%	YES	NO	NO	NO	YES
			-5%, 0		YES	NO	YES	YES	NO
Nominal wheel diameter		-10%, +15%			YES	NO	YES	YES	YES
Stiffness of vertical primary suspension [4] (for vehicles **with** secondary suspension only)		±20%			YES	NO	YES	YES	YES
Stiffness of vertical secondary suspension [4] (or stiffness of primary vertical suspension for vehicle **without** secondary suspension)		±10%	-40%, -10% +10%, +40%		YES	NO	YES	YES	NO
Axle guiding	stiffnesses	0, +10%	-10%, 0		YES	NO	YES	YES	NO
	damping, clearances, ...	±10%			YES	NO	YES	YES	YES
Rotational torque		±10%	-20%, -10% +10%, +20%		YES	NO	YES	YES	NO
Moment of inertia of bogie relative to the vertical central axis		-100%, +5%	+5%, +10%		YES	NO	YES	NO	NO
Secondary lateral suspension (stiffnesses, damping, clearances...)		±10%			YES	NO	YES	YES	YES

Explanatory notes to sheets 1 to 5

(1) By definition,

$$\lambda = \min\left(\frac{\text{Limit value}}{\text{maximum estimated value}}\right)$$

taking into consideration the following safety parameters:
- standard method:

ΣY and Y/Q

- simplified method:

$H, \ddot{y}_S^+, \ddot{y}_S^*, \ddot{z}_S^*$ and $\ddot{y}_S$

according to the method used.

(2) Beyond the variation ranges or when the latter are not mentioned, the full procedure should be applied, solely for the test cases shown in the right-hand part of the table.

(3) The test should be carried with one rail inclination only.

(4) Checking the non-bottoming of springs is part of the design and shall be set out in a forthcoming document.

(5) ∞ : maximum limiting value authorised.

B.2 - Multiple units and railcars

Table 2 : Multiple units and railcars

Parameters modified		Conditions for waiving the test and applying a simplified method, when $\lambda \geq 1,1$ [1]			Procedure to be applied (full, partial)				
		Variation range compared to already-approved vehicle [2]			Load conditions		Test sections [3]		
		For dispensation from test	For simplified method				Straight track	Curves	
			Measurement $\ddot{y}^+, \ddot{y}^*, \ddot{z}^*$	Measurement $H, \ddot{y}^*, \ddot{z}^*$	Empty	Loaded		Large-radius curves	Small-radius curves
Vehicle		**Vehicle**			**Vehicle**				
Vehicle wheelbase		-5%, +20%	-10%, -5% +20%, +∞ [5]		YES	NO	YES	NO	NO
Height of centre of gravity		-20%, +10%	-40%, -20% +10%, +40%		YES	NO	YES	YES	NO
Mass	unsprung	± 5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with a single suspension-level (total mass if the vehicle has **no** secondary suspension)	± 5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with two suspension-levels	±10%			YES	YES	YES	YES	YES
Moment of inertia of body relative to the vertical central axis		±10%			YES	YES	YES	YES	YES
Increase in tractive effort		0, +10%			YES	YES	YES	YES	YES
Increase in operating speed			0, +10 km/h	+10 km/h, +20 km/h	YES	NO	YES	YES	NO
Bogie		**Bogie**			**Bogie**				
Bogie wheelbase		0, +5%		+5%, +20%	NO	YES	NO	NO	YES
			-5%, 0		YES	NO	YES	YES	NO
Nominal wheel diameter		-10%, +15%			YES	YES	YES	YES	YES
Stiffness of vertical primary suspension [4] (for vehicles **with** secondary suspension only)		±20%			YES	YES	YES	YES	YES
Stiffness of vertical secondary suspension [4] (or stiffness of primary vertical suspension for vehicle **without** secondary suspension)		±10%	-40%, -10% +10%, +40%		YES	NO	YES	YES	NO
Axle-guiding	stiffnesses	0, +10%	-10%, 0		YES	NO	YES	YES	NO
	damping, clearances, ...	±10%			YES	YES	YES	YES	YES
Rotational torque		±10%	-20%, -10% +10%, +20%		YES	NO	YES	YES	NO
Moment of inertia of bogie relative to the vertical central axis		-100%, +5%	+5%, +10%		YES	NO	YES	NO	NO
Secondary lateral suspension (stiffnesses, damping, clearances...)		±10%			YES	YES	YES	YES	YES

Explanatory notes to sheets 1 to 5

(1) By definition,

$$\lambda = \min\left(\frac{\text{Limit value}}{\text{maximum estimated value}}\right)$$

taking into consideration the following safety parameters:
- standard method:

ΣY and Y/Q

- simplified method:

$H, \ddot{y}_s^+, \ddot{y}_s^*, \ddot{z}_s^*$ and $\ddot{y}_s$

according to the method used.

(2) Beyond the variation ranges or when the latter are not mentioned, the full procedure should be applied, solely for the test cases shown in the right-hand part of the table.

(3) The test should be carried with one rail inclination only.

(4) Checking the non-bottoming of springs is part of the design and shall be set out in a forthcoming document.

(5) ∞ : maximum limiting value authorised.

B.3 - Passenger vehicles

Table 3 : Passenger vehicles

Parameters modified		Conditions for waiving the test and applying a simplified method, when $\lambda \geq 1,1$[1]			Procedure to be applied (full, partial)				
		Variation range compared to already-approved vehicle[2]			Load conditions		Test sections[3]		
		For dispensation from test	For simplified method				Straight track	Curves	
			Measurement $\ddot{y}^+, \ddot{y}^*, \ddot{z}^*$	Measurement $H, \ddot{y}^*, \ddot{z}^*$	Empty	Loaded		Large-radius curves	Small-radius curves
Vehicle		**Vehicle**			**Vehicle**				
Vehicle wheelbase		-5%, +20%	-10%, -5% +20%, +∞ [5]		YES	NO	YES	NO	NO
Height of centre of gravity		-20%, +10%	-40%, -20% +10%, +40%		YES	NO	YES	YES	NO
Mass	unsprung	±5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with a single suspension-level (total mass if the vehicle has **no** secondary suspension)	±5%	-10%, -5% +5%, +10%		YES	NO	YES	YES	NO
	with two suspension-levels	±10%			YES	YES	YES	YES	YES
Moment of inertia of body relative to the vertical central axis		±10%			YES	YES	YES	YES	YES
Increase in operating speed			0, +10 km/h		YES	NO	YES	YES	NO
				+10 km/h, +20 km/h	YES	YES	YES	YES	NO
Bogie		**Bogie**			**Bogie**				
Bogie wheelbase		0, +5%		+5%, +20%	NO	YES	NO	NO	YES
			-5%, 0		YES	NO	YES	YES	NO
Nominal wheel diameter		-10%, +15%			YES	YES	YES	YES	YES
Stiffness of vertical primary suspension [4] (for vehicles **with** secondary suspension only)		±20%	-40%, -20% +20%, +40%		YES	NO	YES	YES	NO
Stiffness of vertical secondary suspension [4] (or stiffness of primary vertical suspension for vehicle **without** secondary suspension)		±10%	-40%, -10% +10%, +40%		YES	NO	YES	YES	NO
Axle-guiding	stiffnesses	0, +10%	-10%, 0		YES	NO	YES	YES	NO
	damping, clearances, ...	±10%			YES	YES	YES	YES	YES
Rotational torque		±10%	-20%, -10%		YES	NO	YES	YES	NO
				+10%, +20%	YES	NO	NO	NO	YES
Moment of inertia of bogie relative to the vertical central axis		-100%, +5%	+5%, +10%		YES	NO	YES	YES	NO
Secondary lateral suspension (stiffnesses, damping, clearances...)		±10%			YES	YES	YES	YES	YES

Explanatory notes to sheets 1 to 5

(1) By definition,

$$\lambda = \min\left(\frac{\text{Limit value}}{\text{maximum estimated value}}\right)$$

taking into consideration the following safety parameters:
- standard method:

ΣY and Y/Q

- simplified method:

$H, \ddot{y}_s^+, \ddot{y}_s^*, \ddot{z}_s^*$ and $\ddot{y}_s$

according to the method used.

(2) Beyond the variation ranges or when the latter are not mentioned, the full procedure should be applied, solely for the test cases shown in the right-hand part of the table.

(3) The test should be carried with one rail inclination only.

(4) Checking the non-bottoming of springs is part of the design and shall be set out in a forthcoming document.

(5) ∞ : maximum limiting value authorised.

B.4 - Bogie wagons

Table 4 : Bogie wagons

Parameters modified		Conditions for waiving the test and applying a simplified method, when $\lambda \geq 1,1$ [1]			Procedure to be applied (full, partial)				
		Variation range compared to already-approved vehicle [2]			Load conditions		Test sections [3]		
		For dispensation from test	For simplified method	For simplified method	Empty	Loaded	Straight track	Curves	
			Measurement $\ddot{y}^+$, $\ddot{y}^*$, $\ddot{z}^*$	Measurement H, $\ddot{y}^*$, $\ddot{z}^*$				Large-radius curves	Small-radius curves
Vehicle		**Vehicle**			**Vehicle**				
Wagon wheelbase	$2a^* \geq 9$ m	-15 %, +∞ [5]	-30 %, -15 %		YES	NO	YES	NO	NO
Wagon wheelbase	$2a^* < 9$ m	-5%, +∞ [5]	-10%, -5%		YES	NO	YES	NO	NO
Height of centre of gravity	empty wagon	-100%, +20%	+20%,+∞ [5]		YES	NO	YES	YES	NO
Height of centre of gravity	loaded wagon	-100%, +50%	+50%,+∞ [5]		NO	YES	YES	YES	NO
Torsional stiffness C^*_t (10^{10} kN/mm²/rad)	$C^*_t \leq 3$	-66%, +200%			YES	YES	YES	YES	YES
Torsional stiffness C^*_t (10^{10} kN/mm²/rad)	$C^*_t > 3$	-50%, +∞ [5]			YES	YES	YES	YES	YES
Tare	≥ 16 t	-15%, +∞ [5]	-30%, -15%		YES	NO	YES	NO	NO
Increase in maximum axle-load ($2Qo_{max} \leq 22{,}5$ t/axle)		0, +5%		+5%, +10%	NO	YES	NO	YES	YES
Increase in operating speed			0, +10 km/h	+10 km/h, +20 km/h	YES	YES	YES	YES	NO
Bogie		**Bogie**			**Bogie**				
Bogie wheelbase		0, +10%		+10%, +20%	YES	YES	NO	NO	YES
			-10%, 0		YES	NO	YES	YES	NO
Nominal wheel diameter		-10%, +15%			YES	YES	YES	YES	YES
Vertical suspension [4] primary or secondary	Increased stiffness(es)	0, +25%			YES	YES	YES	YES	YES
Vertical suspension [4] primary or secondary	Lower transitional load	-5%, 0			YES	YES	YES	YES	YES
Axle guiding (stiffnesses, damping, clearances...)					YES	YES	YES	YES	YES
Rotational torque		±20%			YES	YES	YES	YES	YES
Moment of inertia of bogie relative to the vertical central axis		-100%, +10%	+10%, +20%		YES	NO	YES	NO	NO
Secondary lateral suspension (stiffnesses, damping, clearances...)					YES	YES	YES	YES	YES

Explanatory notes to sheets 1 to 5

(1) By definition,

$$\lambda = min\left(\frac{\text{Limit value}}{\text{maximum estimated value}}\right)$$

taking into consideration the following safety parameters:
- standard method:

$$\Sigma Y \text{ and } Y/Q$$

- simplified method:

$$H, \ddot{y}^+_s, \ddot{y}^*_s, \ddot{z}^*_s \text{ and } \ddot{y}_s$$

according to the method used.

(2) Beyond the variation ranges or when the latter are not mentioned, the full procedure should be applied, solely for the test cases shown in the right-hand part of the table.

(3) The test should be carried with one rail inclination only.

(4) Checking the non-bottoming of springs is part of the design and shall be set out in a forthcoming document.

(5) ∞ : maximum limiting value authorised.

B.5 - Non-bogie wagons without UIC double link suspensions

Table 5 : Non-bogie wagons without UIC double link suspensions

Parameters modified		Conditions for waiving the test and applying a simplified method, when $\lambda \geq 1,1$ [1]			Procedure to be applied (full, partial)				
		Variation range compared to already-approved vehicle [2]			Load conditions		Test sections [3]		
		For dispensation from test	For simplified method				Straight track	Curves	
			Measurement $\ddot{y}^+, \ddot{y}^*, \ddot{z}^*$	Measurement $H, \ddot{y}^*, \ddot{z}^*$	Empty	Loaded		Large-radius curves	Small-radius curves
Vehicle		**Vehicle**			**Vehicle**				
Wagon wheelbase	$2a^* \geq 8m$	-15%, +∞ [5]	-30%, -15%		YES	NO	YES	NO	NO
	$2a^* < 8m$	-5%, +∞ [5]	-10%, -5%		YES	NO	YES	NO	NO
Nominal wheel diameter		-10%, +15%			YES	YES	YES	YES	YES
Height of centre of gravity	empty wagon	-100%, +20%	+20%,+∞ [5]		YES	NO	YES	YES	NO
	loaded wagon	-100%, +50%	+50%, +∞ [5]		NO	YES	YES	YES	NO
Torsional stiffness C^*_t (10^{10} kN/mm^2/rad)	$C^*_t \leq 3$	-66%, +200%			YES	YES	YES	YES	YES
	$C^*_t > 3$	-50%, +∞ [5]			YES	YES	YES	YES	YES
Moment of inertia of body relative to the vertical central axis		-100%, +10%			YES	NO	YES	NO	NO
Tare	≥ 12 t	-15%, +∞ [5]	-30%, -15%		YES	NO	YES	NO	NO
Increase in maximum axle load ($2Qo_{max} \leq 22,5$ t/axle)		0, +5%		+5%, +10%	NO	YES	NO	YES	YES
Increase in operating speed			0, +10 km/h	+10 km/h, +20 km/h	YES	YES	YES	YES	NO
Vertical suspension [4] primary or secondary	Increased stiffness(es)	0, +25%			YES	YES	YES	YES	YES
	Lower transitional load	-5%, 0			YES	YES	YES	YES	YES
Axle guiding (k_x, k_y, damping, clearances)					YES	YES	YES	YES	YES

Explanatory notes to sheets 1 to 5

(1) By definition,

$$\lambda = \min\left(\frac{\text{Limit value}}{\text{maximum estimated value}}\right)$$

taking into consideration the following safety parameters:
- standard method:

ΣY and Y/Q

- simplified method:

$H, \ddot{y}^+_s, \ddot{y}^*_s, \ddot{z}^*_s$ and $\ddot{y}_s$

according to the method used.

(2) Beyond the variation ranges or when the latter are not mentioned, the full procedure should be applied, solely for the test cases shown in the right-hand part of the table.

(3) The test should be carried with one rail inclination only.

(4) Checking the non-bottoming of springs is part of the design and shall be set out in a forthcoming document.

(5) ∞ : maximum limiting value authorised.

Appendix C - Cant-deficiency value to be taken into account

Train category		Speed (km/h)	I_{adm} (mm)
Ia - Freight trains (conventional design)		$V \leq 120$	130
Ib - Freight trains (appropriate design)		$120 < V \leq 140$	130
Ic - Freight trains (appropriate design), also enabling passenger train paths to be used		$140 < V \leq 160$	150
II - Passenger trains (conventional design)		$V \leq 230$[a]	150
III - Non-tilting multiple units and railcars with special features (eg low center of gravity, lower axle-loads)	conventional lines	$0 < V \leq 160$	165
		$160 < V \leq 230$	150
	High-speed lines	$200 < V \leq 250$	150
		$250 < V \leq 300$	130[b]
IV - Tilting train / vehicle		$0 < V \leq 300$	[c]

a. For V > 200 km/h and for trains hauled by locomotives, the latter should exhibit the same characteristics as the power-cars in category III multiple units.

b. For trains using high-speed lines equipped with concrete slab track, the reference value for cant deficiency is I_{adm} = 150 mm.

c. Additional requirements are due to be specified for vehicles fitted with cant-deficiency compensation (tilting) systems, but in the meantime, the arrangements contained in the standard procedure shall be adopted on a provisional basis for any approval procedure with a purely domestic scope. Any vehicle shall be approved with the cant-deficiency values for which it has been designed and developed.

Appendix D - Track geometric quality

D.1 - Basic principles

For formal vehicle-approval purposes, track geometric quality is based upon track maintenance criteria, represented by three levels of quality defined as follows:

QN 1   refers to the value which necessitates observing the condition of the track or taking maintenance measures as part of regularly-planned maintenance operations.

QN 2   refers to the value which requires short term maintenance action.

QN 3   refers to the value which, if exceeded, leads to the track section being excluded from the analysis because the track geometric quality encountered is not representative of usual quality standards. At this stage, this value is not as poor as the value reflecting the most unfavourable maintenance condition but remains acceptable.

For the choice of test sections within each test zone (tangent track, large radius curves, small radius curves), the following distribution is recommended:

50% of the sections to yield a value equal to or better than QN1,
40% of the sections to yield a value between QN1 and QN2,
10% of the sections to yield a value between QN2 and QN3.

A graphic representation of the frequency distribution is recommended, but not obligatory.

Furthermore, since no measuring coach is currently capable of producing a continuous record of the equivalent conicity of the wheel-rail contact, no recommendation can be given in respect of this parameter.

The final report for UIC 7G20 work states : "despite the differences in the measurement and analysis methods used by different railways, the general evaluation principles are in broad agreement and the measurement results from several railways can be converted into a different measuring system".

D.2 - Description of track geometric quality by standard deviation and peak value

According to the UIC 7G20's final report, the description of track geometry according to quality levels QN1, QN2 and QN3 is a possible method. "However, the task of reviewing the measuring results to make them comparable would have been much more challenging, time consuming and costly. Harmonisation of measuring results would, in many instances, have required a modification to the measuring principle, for which most track-measuring cars owned by the railways are not suitable".

It is currently easier to obtain better agreement and an improved comparison between measurement results for the following reasons:

-   the distortion of measured values can be corrected more easily in certain conditions,

-   new track-measuring vehicles, the measuring results of which can be processed more easily, are now being used or being developed.

This appendix therefore only deals with corrected geometrical values, either using a correction factor (see the table of coefficients given in point D.2.3 - page 54) or using the transfer function of the measuring vehicle.

To allow a comparison to be made between analysed results obtained from different railways, the following conditions shall be applied:

1. Definition of the band-width of the track geometrical error

2. Definition of the evaluation method for test sections

Concerning point 1.

-   In order to describe a geometric error by its frequency response, a band pass filter with the following characteristics shall be used:

    -   4-pole Butterworth filters,
    -   low-frequency cut-off L_b = 3,00 m
    -   high-frequency cut-off L_h = 25 m.

-   Within the transmission area the filter shall have a precision of ± 1 dB.

-   Outside the transmission area, a gradient of 24 dB/octave is required with a maximum attenuation of 60 dB.

These cut-off wavelengths shall apply up to a maximum line speed of 200 km/h.

For speeds greater than 200 km/h, the work should not be restricted to the short wavelength geometrical errors, but geometrical errors with a wavelength of more than 25 m should be accounted for. The corresponding values (for wavelength and quality) remain to be defined.

Concerning point 2.

-   The track geometric quality is only governed by the standard deviation for vertical and lateral alignment of the track.

-   The peak values of isolated errors for vertical and lateral alignment are provided for guidance only. When the isolated errors reach the QN3 values, the test section involved is excluded from the analysis.

-   The geometric quality shall be determined for vertical and lateral alignment, separately. As a rule, an evaluated section will consist of two different quality categories, i.e. for vertical and lateral alignment.

-   The decisive criterion for track classification is the maximum absolute value measured on both rails, with the exception of lateral alignment in curves where the peak value on the outside rail is decisive, particularly for curves where R is less than 600 m.

-   The reference speed to be used when applying the contents of the following tables shall be determined in the following way:

    -   V_{lim} + 10 km/h for straight track and large-radius curve sections,

- 80 km/h < V ≤ 120 km/h for sections with small-radius curves.

- Two analysis methods may be used:

  - 1st method:

    The track sections used for the analysis shall be exactly the same as those selected for the statistical evaluation of the vehicle behaviour. In this case, it is essential to identify distances very carefully.

    With this method, the values at 50% and 90% of peak values for isolated track errors depend upon the length used for the calculation of the maximum peak value.

  - 2nd method:

    The track sections used for the analysis are derived from data recorded by track-measuring vehicles.

    In this case, it is not possible for track-related and vehicle-related sections to strictly coincide.

    However, for every straight-track or large-radius curve section, it is necessary to ensure that the track-related sections coincide in the best possible way with the vehicle-related sections so that the lengths over which they do not coincide shall not exceed 50% of the vehicle-related section lengths.

    In order to improve upon this, the use of standard-deviation sliding values is recommended, with a rather low sliding interval such as 10 m for example.

If these arrangements are complied with, standard-deviation values can be compared. Railways are free to elicit the appropriate method so as to process measuring values. The method to be applied depends upon the characteristics of measuring systems.

o   D.2.1 -   Standard deviation

The tables below set out the values of standard deviation for vertical and lateral alignment for track quality levels QN1 and QN2 which are to be taken into account in the choice of test sections used for vehicle acceptance:

Standard deviation: vertical alignment		QN 1 (mm)	QN 2 (mm)
	V ≤ 80 km/h	2,3	2,6
80 <	V ≤ 120 km/h	1,8	2,1
120 <	V ≤ 160 km/h	1,4	1,7
160 <	V ≤ 200 km/h	1,2	1,5
200 <	V ≤ 300 km/h	1,0	1,3

Standard deviation: lateral alignment		QN 1 (mm)	QN 2 (mm)
	V ≤ 80 km/h	1,5	1,8
80 <	V ≤ 120 km/h	1,2	1,5
120 <	V ≤ 160 km/h	1,0	1,3
160 <	V ≤ 200 km/h	0,8	1,1
200 <	V ≤ 300 km/h	0,7	1,0

o D.2.2 - Peak values of isolated track errors

Isolated track errors mean maximum values obtained by calculation for a given section.

Peak values of isolated track errors for QN1 and QN2 track qualities are given for guidance only.

QN3 is defined as : QN3 = 1,3 * QN2.

When the value of an isolated track error reaches QN3, the section involved may be excluded from the analysis.

The peak values for vertical and lateral alignment are given in the following tables :

Maximum isolated error: vertical alignment		QN 1 (mm)	QN 2 (mm)
	V ≤ 80 km/h	12,0	16,0
80 <	V ≤ 120 km/h	8,0	12,0
120 <	V ≤ 160 km/h	6,0	10,0
160 <	V ≤ 200 km/h	5,0	9,0
200 <	V ≤ 300 km/h	4,0	8,0

Maximum isolated error: lateral alignment		QN 1 (mm)	QN 2 (mm)
	V ≤ 80 km/h	12,0	14,0
80 <	V ≤ 120 km/h	8,0	10,0
120 <	V ≤ 160 km/h	6,0	8,0
160 <	V ≤ 200 km/h	5,0	7,0
200 <	V ≤ 300 km/h	4,0	6,0

D.2.3 - Corrections

The values QN1 and QN2 relating to standard deviations and peak values for isolated track errors have been obtained from measurements taken with the NS measuring vehicle; on this vehicle, the transfer function of the measuring system equals 1 for all wave-lengths.

If the measuring vehicle of another railway is used for measurements, the values of QN1 and QN2 shall be corrected and the coefficients to be applied can be found in the following table:

Coefficient K		
Measuring vehicle	**Vertical alignment**	**Lateral alignment**
BR	1,14	1,20
CFF	0,91	1,47
CFF/long	1,25	-
CFR	1,40	1,95
CD	1,00	1,00
DB	1,24	1,47
FS	1,33	1,72
NS	1,00	1,00
ÖBB	1,00	1,00
PKP	0,73	0,71
RENFE	0,91	1,47
SNCF	0,91	1,47

$$s_{(other)} = K.s_{(NS\ vehicle)}$$

$$\text{Peak value}_{(other)} = K.\text{Peak value}_{(NS\ vehicle)}$$

QN1 and QN2 values can also be derived from measuring values recorded by a track-measuring vehicle and subsequently corrected by means of the transfer function of the measuring system.

D.3 - Twist and gauge

Twist and track gauge are not reflected in the definition of track quality standards. However, some requirements should be met for both quantities during test runs.

Twist: The requirements of ERRI B55 shall be complied with. The test route should preferably include sections with limiting values for twist.

Track gauge: On the straight track section of the test route, the runs at maximum speed must include some runs on sections featuring a mean track gauge value, measured over 100 m, which is less than:

1432 mm for		$V \leq 140$ km/h
1433 mm for	140 km/h <	$V \leq 200$ km/h
1434 mm for	200 km/h <	$V \leq 300$ km/h
1435 mm for		$V > 300$ km/h

Curves shall include sections with track gauge up to at least 1455 mm. The maximum values of track gauge are to be logged in the test report.

Appendix E - List of measured quantities and measurement points

Description	Symbols	Units	Filtering on recording : cut-off frequency	
			magnetic [3] [4]	graphical [3]
Lateral wheel-rail forces on two wheelsets [1]	Y_{11}, Y_{12} Y_{21}, Y_{22}	kN	$\geq$40 Hz	$\geq$10 Hz
Lateral axle-track forces on two wheelsets [1]	H_1, H_2	kN	$\geq$40 Hz	$\geq$10 Hz
Vertical wheel-rail forces on two wheelsets [1]	Q_{11}, Q_{12} Q_{21}, Q_{22}	kN	$\geq$40 Hz	$\geq$20 Hz
Lateral accelerations at body ends [2]	$\ddot{y}_I^*, \ddot{y}_{II}^*$	m/s^2	$\geq$40 Hz	$\geq$10 Hz
Vertical accelerations at body ends [2]	$\ddot{z}_I^*, \ddot{z}_{II}^*$	m/s^2	$\geq$40 Hz	$\geq$20 Hz
Lateral accelerations at bogie ends [2]	$\ddot{y}_1^+, \ddot{y}_2^+$	m/s^2	$\geq$40 Hz	$\geq$10 Hz
Lateral accelerations on wheelsets [1]	$\ddot{y}_1, \ddot{y}_2$	m/s^2	$\geq$40 Hz	$\geq$10 Hz

(1)   On the two outer wheelsets of the vehicle/bogie, as a minimum.

(2)   On the body floor, along the longitudinal axis:

- in the case of a non-bogie vehicle : above the wheelsets,

- in the case of a bogie vehicle : above the bogies,

- in the case of freight wagons : in the lateral direction, at vehicle body-end, in the horizontal plane containing the centre-of-gravity.

(3)   Cut-off frequency of low-pass filter at -3 dB, gradient $\geq$24 dB/octave, tolerance of $\pm$0,5 dB until the cut-off frequency, $\pm$1 dB beyond that value.

(4)   Where data acquisition is fed directly to the computer, the band width must be greater than or equal to 20 Hz.

Appendix F - Determining statistical quantities

F.1 - Normal method

N°	Assessment quantities	Filtering (prior to processing): cut-off frequencies	Statistical processing by section		Statistical processing by test zone			Coef. k
			Method of calculation	Percentile to be used	Grouping of data			
					Tangent track	Large-radius curves	Small-radius curves	
1	$(\Sigma Y)_{2m}$ wheelsets 1 and 2	≥20 Hz [1]	Sliding mean: - over 2 m,	$F_1 = 0,15\%$ $F_2 = 99,85\%$	For each wheelset, total of: $\left|xi(F_1)\right|$ and $Xi(F_2)$	For each wheelset, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
2	$\left(\dfrac{Y}{Q}\right)_{2m}$ leading wheelset	≥20 Hz [1]	- sampling interval 0,5 m	$F_1 = 0,15\%$ $F_2 = 99,85\%$	-	For the external wheel in the curve, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
3	$\ddot{y}_s^{+}$ [4] [5] wheelsets 1 and 2	10 Hz [1]	-	$F_1 = 0,15\%$ $F_2 = 99,85\%$	For each wheelset, total of: $\left|xi(F_1)\right|$ and $xi(F_2)$	For each wheelset, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
4	$\ddot{y}_s^{*}$ [4] ends I and II	6 Hz [1]	-	$F_1 = 0,15\%$ $F_2 = 99,85\%$	For each end, total of: $\left|xi(F_1)\right|$ and $xi(F_2)$	For each end total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
5	Q wheels 1, 2, 3, 4	20 Hz [1]	-	$F_2 = 99,85\%$	$xi(F2)$ total of wheels 1 to 4	$xi(F2)$ total of external wheels in curve		2,2
6	Y_{qst} wheels 1, 2, 3, 4	≥20 Hz [1]	-	$F_0 = 50\%$	-	-	For each wheelset, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$ for the external wheel in the curve	0
7	Q_{qst} wheels 1, 2, 3, 4	≥20 Hz [1]	-	$F_0 = 50\%$	-	-	$xi(F_0)$, total for the external wheel in the curve	0

N°	Assessment quantities	Filtering (prior to processing): cut-off frequencies	Statistical processing by section		Statistical processing by test zone				Coef. k
			Method of calculation	Percentile to be used	Grouping of data				
					Tangent track	Large-radius curves	Small-radius curves		
8	$\ddot{y}_q^*$ and $\ddot{z}_q^*$ ends I and II	0,4 - 10 Hz [2]	-	$F_1 = 0,15\%$ $F_2 = 99,85\%$	For each quantity and each end, total of $\|xi(F_1)\|$ and $xi(F)_2$				2,2
				r.m.s. values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$	For each quantity and each end, r.m.s. values				2,2
9	$\ddot{y}_{qst}^*$ ends I and II	≥ 20 Hz [1]	-	$F_0 = 50\%$	-	For each end, total of: - on right $xi(F_0)$ - on left $\|xiF_{(0)}\|$			0
10	ΣY wheelsets 1 and 2	$f_0 \pm 2$ Hz [2][3]	-	-	Sliding r.m.s value calculated over a length of 100 m at 10 m increments.		-		-

(1) Low-pass filter at -3 dB, gradient $\geq$24 dB/octave, tolerance of $\pm$0,5 dB up to the cut-off frequency, $\pm$1 dB beyond that value.

(2) Band-pass filter at -3 dB, gradient $\geq$24 dB/octave, tolerance of $\pm$0,5 dB within the band, $\pm$1 dB outside the band.

(3) f_0 is the instability frequency.

(4) This statistical processing is applied for a future extension of approval when using a simplified measuring method.

(5) Only for bogie vehicles.

F.2 - Simplified method: measurement of H forces and accelerations on vehicle body

N°	Assessment quantities	Filtering (prior to processing): cut-off frequencies	Statistical processing by section — Method of calculation	Percentile to be used	Statistical processing by test zone — Grouping of data — Tangent track	Large-radius curves	Small-radius curves	Coef. k
1	$(H)_{2m}$ wheelsets 1 and 2	20 Hz [1]	Sliding mean: - over 2 m - sampling interval 0,5 m	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each wheelset, total of: $\left\lvert xi(F_1)\right\rvert$ and $Xi(F_2)$	For each wheelset, total of: - on right $xi(F_2)$ - on left $\left\lvert xi(F_1)\right\rvert$		3
2	$\ddot{z}_s^*$ ends I and II	0,4 - 4 Hz [2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	-	For each end, total of: $\left\lvert xi(F_1)\right\rvert$ and $xi(F_2)$		3
3	$\ddot{y}_q^*$ and $\ddot{z}_q^*$ ends I and II	0,4 - 10 Hz [2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each quantity and each end, total of $\left\lvert xi(F_1)\right\rvert$ and $xi(F_2)$			2,2
			r.m.s values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$		For each quantity and each end, r.m.s. values			2,2
4	$\ddot{y}_{qst}^*$ ends I and II	≥20 Hz [1]	-	$F_0 = 50\%$	-	For each end, total of: - on right $xi(F_0)$ - on left $\left\lvert xi(F_0)\right\rvert$		0
5	H [4] wheelsets 1 and 2	$f_0 \pm 2$ Hz [2][3]	-	-	Sliding r.m.s. value calculated over a length of 100 m at 10 m increments.	-		-
6	$\ddot{y}_s^*$ [5] wheelsets 1 et 2	$f_0 \pm 2$ Hz [2][3]	-	-	Sliding r.m.s. value calculated over a length of 100 m at 10 m increments.	-		-

(1)   Low-pass filter at -3 dB, gradient ≥24 dB/octave, tolerance of ±0,5 dB up to the cut-off frequency, ±1 dB beyond that value.

(2)   Band-pass filter at -3 dB, gradient ≥24 dB/octave, tolerance of ±0,5 dB within the band, ±1 dB outside the band.

(3) f_0 is the instability frequency.

(4)   For all vehicles except freight wagons and special vehicles (non-bogie).

(5)   For freight wagons and special vehicles (non-bogie).

F.3 -   Simplified method: acceleration measurements - Bogie vehicles

N°	Assessment quantities	Filtering (prior to processing): cut-off frequencies	Method of calculation	Percentile to be used	Tangent track	Large-radius curves	Small-radius curves	Coef. k
1	$\ddot{y}_s^+$ wheelsets 1 and 2	10 Hz [1]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each wheelset, total of: $\left|xi(F_1)\right|$ and $Xi(F_2)$	For each wheelset, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
2	$\ddot{y}_s^*$ ends I and II	6 Hz [1]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each end, total of: $\left|xi(F_1)\right|$ and $Xi(F_2)$	For each end, total of: - on right $xi(F_2)$ - on left $\left|xi(F_1)\right|$		3
3	$\ddot{z}_s^*$ ends I and II	0,4 - 4 Hz [2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	-	For each end, total of $\left|xi(F_1)\right|$ and $xi(F_2)$		3
4	$\ddot{y}_q^*$ et $\ddot{z}_q^*$ ends I and II	0,4 - 10 Hz [2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each quantity and each end, total of $\left|xi(F_1)\right|$ and $xi(F_2)$			2,2
4			-	r.m.s. values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$	For each quantity and each end, r.m.s. values			2,2
5	$\ddot{y}_{qst}^*$ ends I and II	$\geq$20 Hz [1]	-	$F_0 = 50\%$	-	For each end, total of: - on right $xi(F_0)$ - on left $\left|xi(F_0)\right|$		0
6	$\ddot{y}_s^+$ ends I and II	$f_0\pm$ 2 Hz [2][3]	-	-	Sliding r.m.s. value calculated over a length of 100 m at 10 m increments.	-		-

(1)   Low-pass filter at -3 dB, gradient $\geq$24 dB/octave, tolerance of $\pm$0,5 dB up to the cut-off frequency, $\pm$1 dB beyond that value.

(2)   Band-pass filter at -3 dB, gradient $\geq$24 dB/octave, tolerance of $\pm$0,5 dB within the band, $\pm$1 dB outside the band.

(3) f_0 is the instability frequency.

F.4 - Simplified method : measurements of accelerations - non-bogie vehicles

N°	Assessment quantities	Filtering (prior to processing): cut-off frequencies	Statistical processing by section		Statistical processing by test zone			Coef. k
			Method of calculation	Percentile to be used	Grouping of data			
					Tangent track	Large-radius curves	Small-radius curves	
1	$\ddot{y}_s^*$ ends I and II	6 Hz[1]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each end, total of: $\left\|xi(F_1)\right\|$ and $Xi(F_2)$	For each end, total of: - on right $xi(F_2)$ - on left $\left\|xi(F_1)\right\|$		3
2	$\ddot{z}_s^*$ ends I and II	0,4 - 4 Hz[2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	-	For each end, total of $\left\|xi(F_1)\right\|$ and $xi(F_2)$		3
3	$\ddot{y}_q^*$ and $\ddot{z}_q^*$ ends I and II	0,4 - 10 Hz[2]	-	$F_1 = 0{,}15\%$ $F_2 = 99{,}85\%$	For each quantity and each end, total of $\left\|xi(F_1)\right\|$ and $xi(F_2)$			2,2
			-	r.m.s values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$	For each quantity and each end, r.m.s. values			2,2
4	$\ddot{y}_{qst}^*$ ends I and II	≥20 Hz[1]	-	$F_0 = 50\%$	-	For each end, total of: - on right $xi(F_0)$ - on left $\left\|xi(F_0)\right\|$		0
5	$\ddot{y}_s^*$ wheelsets 1 and 2	$f_0 \pm 2$ Hz[2][3]	-	-	Sliding r.m.s. value calculated over a length of 100 m at 10 m increments.		-	-

(1)   Low-pass filter at -3 dB, gradient ≥24 dB/octave, tolerance of ±0,5 dB up to the cut-off frequency, ±1 dB beyond that value.

(2)   Band-pass filter at -3 dB, gradient ≥24 dB/octave, tolerance of ±0,5 dB within the band, ±1 dB outside the band.

(3) f_0 is the instability frequency.

Appendix G - Generation of data samples

G.1 - Selecting the test zones

The approval test shall normally be conducted over three zones:

- a tangent track zone,

- a large-radius curve zone,

- a small-radius curve zone.

If the vehicle is subject to an extension of approval, the test may be restricted to one or two test-zones. This applies in particular to a speed enhancement for which runs on small radius curves are not needed since this configuration has already been accepted.

Each test zone is partitioned into a number of track sections which may or may not be juxtaposed but shall exclude any overlap so as to comply with the requirements for the geometrical characteristics of the track.

Each segment shall be a continuous length.

In curved track, transition and full curve segments shall make up separate sections.
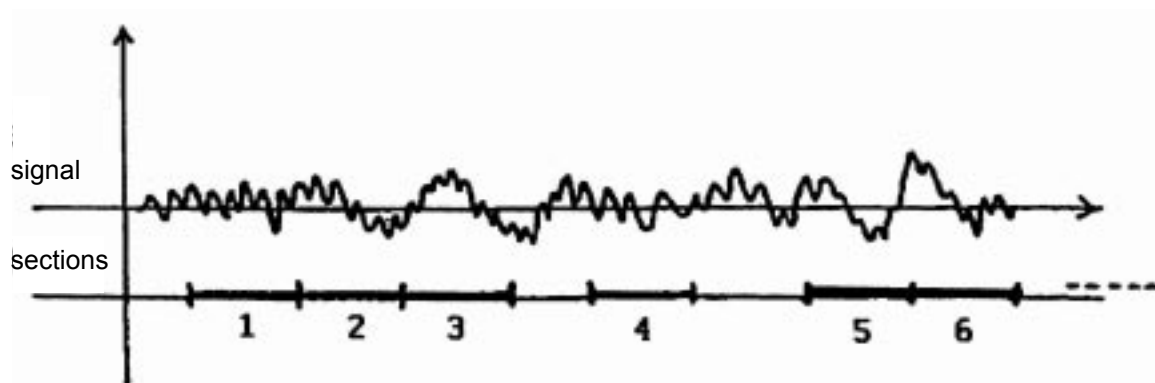

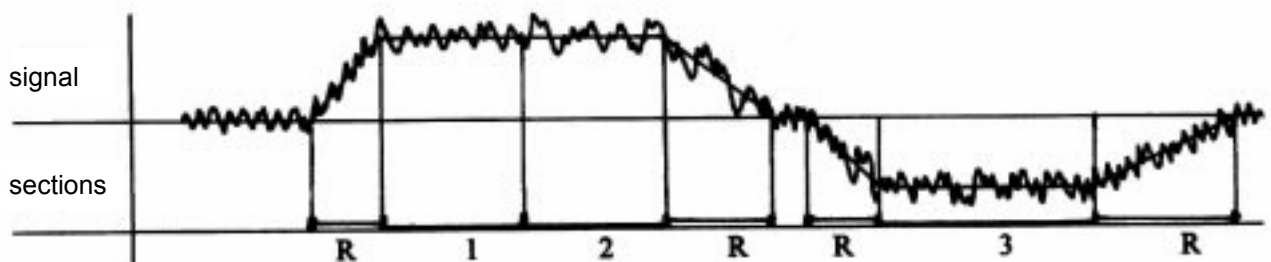*Fig. 2 - Example of test zone partitioning on tangent track*

Fig. 3 - Example of test zone partitioning in curved track

G.2 - Statistical processing

Example based on the normal method

The statistical processing comprises two stages:

G.2.1 - Processing per section

This enables the determination of the input data xi to be used for the statistical analysis which is made for each measured quantity, measuring point and relevant test section:

- the statistical distribution function values for 0,15% and 99,85%, based either on the sampled values (for Q, $\ddot{y}_s^+$, $\ddot{y}_s^*$, $\ddot{y}_q^*$, $\ddot{z}_q^*$) or on the sliding means over 2 m $(\Sigma Y)_{2m}$ and $(Y/Q)_{2m}$,

- the r.m.s. values $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$ for the quantities $\ddot{y}_q^*$ and $\ddot{z}_q^*$, for the evaluation of running behaviour,

- the statistical distribution function value for 50% in order to evaluate the quasi-static component in curved track (Y_{qst}, Q_{qst} and $\ddot{y}_{qst}^*$).

In order to calculate the 0,15% and 99,85% values, the number of samples to be disregarded will be rounded up.

G.2.2 - Processing per zone

The statistical analysis is based upon the population of xi values derived from the previous phase.

For illustration purposes and with N sections for example, populations to be taken into account are as follows:

- on tangent track:

  - ΣY: a set of 2N values per wheelset (those values at 99.85% frequency and the absolute values of those at 0.15%)
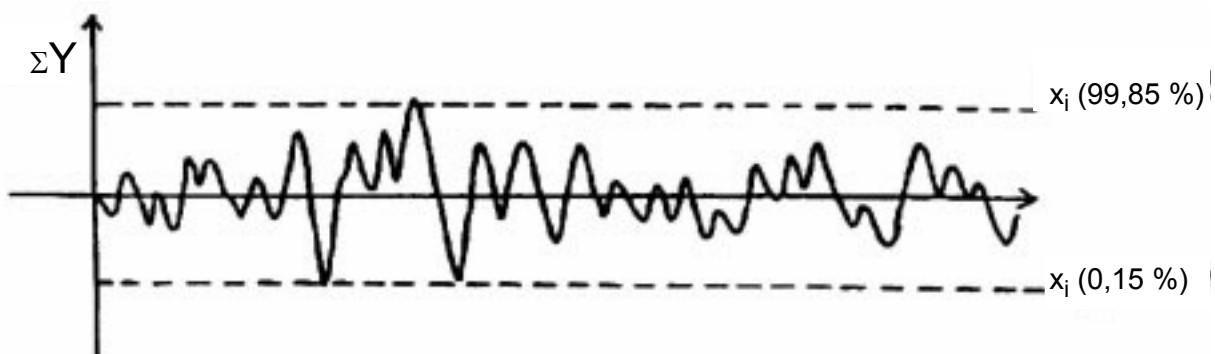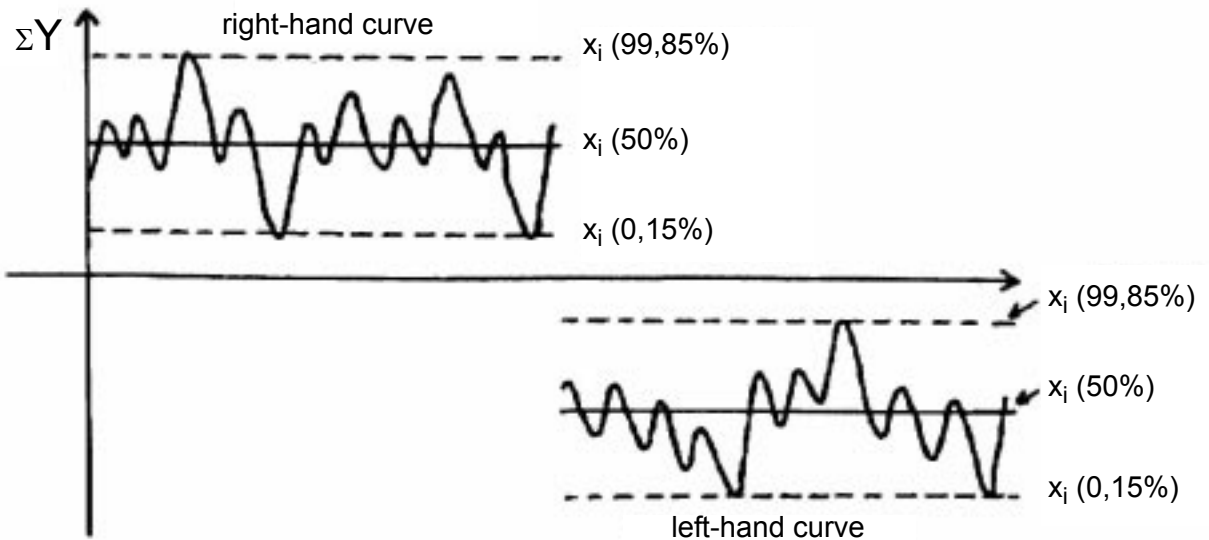
- Q: a set of 4N values for the four bogie wheels (at 99,85%)
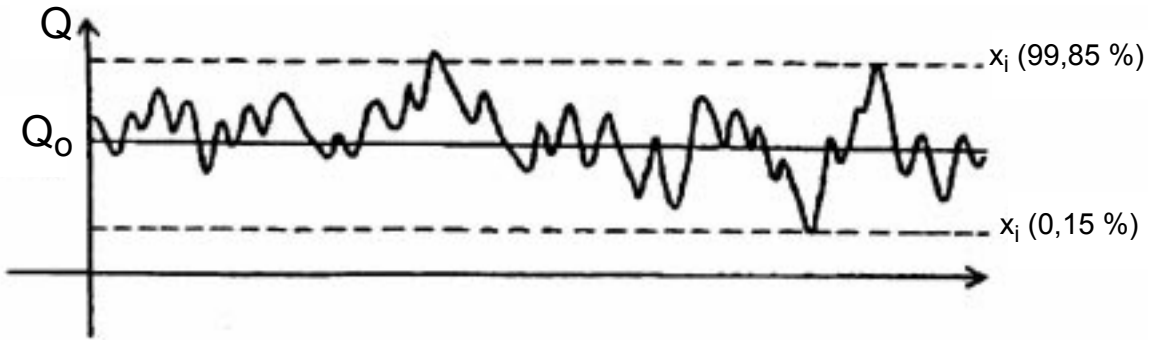
- $\ddot{y}_s^*$: 2N values per end (those values at 99,85% and the absolute values of those at 0,15%)

- $\ddot{y}_s^+$: 2N values for each outer wheelset of the bogie (those values at 99,85% and the absolute values of those at 0,15%)

- $\ddot{y}_q^*$ and $\ddot{z}_q^*$: 2N values per quantity and per body-end (those values at 99,85% and the absolute values of those at 0,15%)

- $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$: N values per quantity and per body-end

- in curved track:

- ΣY: N values per wheelset (those values at 99,85% for right-hand curves and the absolute values of those at 0,15% for left-hand curves)

- $\ddot{y}_s^*$: N values per end (those values at 99,85% for right-hand curves and the absolute values of those at 0,15% for left-hand curves)

- $\ddot{y}_s^+$: 2N values for each outer wheelset of the bogie (those values at 99,85% for right-hand curves and the absolute values of those at 0,15% for left-hand curves)

- Y/Q: N values for the leading wheelset (those values at 99,85% for the outer wheel in right-hand curves and the absolute values of those at 0,15% for the outer wheel in left-hand curves)

- Q: 2N values per bogie (those values at 99,85% for the two outer wheels in both right-hand and left-hand curves)

- Y_{qst}: 2N values per bogie (those values at 50% for the outer wheel for right hand curves and the absolute values of those at 50% for the outer wheel in left hand curves) excluding transition curves

- Q_{qst}: 2N values per bogie (those values at 50% for the 2 outer wheels in both right hand and left hand curves) excluding transition curves

- $\ddot{y}_q^*$ and $\ddot{z}_q^*$: 2N values per quantity and per body-end (those values at 99,85% and the absolute values for those at 0,15%)

- $\ddot{y}_{qst}^*$: N values per body-end (those at 50% in both right-hand and left-hand curves) excluding transition curves

- $s\ddot{y}_q^*$ and $s\ddot{z}_q^*$: N values per quantity and per body-end.

Appendix H - One and two-dimensional statistical processing methods

The estimated maximum value of an assessment quantity is calculated using either a one-dimensional or a two-dimensional statistical processing method.

H.1 - One-dimensional statistical processing method

Under this method it is necessary first to calculate the considered parameters:

- arithmetic mean $\bar{x}$,

- and standard deviation s,

for the quantities x_i grouped as prescribed in Appendix .

These statistical values serve to determine the maximum estimated value, using the equation:

$$\hat{x}_{max} = \bar{x} + k \cdot s$$

where k is a factor that depends, among other things, on the level of confidence selected.

In general:

- k = 3 for assessment quantities relating to safety,

- k = 2,2 for assessment quantities relating to track fatigue and running behaviour,

- k = 0 for quasi-static assessment quantities.

The value of k to be used as a function of the method used and of the assessment quantity is given in the right-hand column of the table in Appendix F.

H.2 - Two-dimensional statistical processing method

In large and small radius curves, a two-dimensional statistical processing method can be used to calculate the maximum estimated value of the parameter under consideration by varying the cant deficiency in the interval:

$0,75\ I_{adm} \leq I \leq 1,10\ I_{adm}$
tolerance: $\pm 0,05\ I_{adm}$

This method can also be used to determine the influence of a given parameter, such as speed or the track gauge.

Use of the two-dimensional method implies that the variation of the quantity Y according to X follows a linear regression, in the form of:

$Y_c = a + bX$

When $X = X_0$, the mean value of Y equals the value given by the linear regression, i.e. $Y_c(X_0) = a + bX_0$.

Also when $X = X_0$, the bounds within which Y will fall with a certain probability can be found by using a Student bilateral distribution t, in which Y_p is the predicted value of Y:

$$t = \frac{y_c(X_0) \pm Y_p}{S_{Y(X_0)}}$$

with N-2 degrees of freedom, where N stands for the number of (X,Y) pairs for which:

$$S_{Y(X_0)} = S_e \sqrt{1 + \frac{1}{N} + \frac{N(Xo - \overline{X})^2}{N\Sigma X^2 - (\Sigma X)^2}}$$

S_e representing the scatter of the Y values about the regression line for all values of X,

$$S_e = \sqrt{\frac{\Sigma(Y - Y_c)^2}{N - 2}}$$

Depending on the confidence interval selected (99% for the safety parameters and 95% for the track fatigue and running behaviour parameters), the value of the t coefficient of Student to be applied is given in the table below:

Degrees of freedom		25	30	40	50	60	80	100	∞
Confidence interval	95%	2,060	2,042	2,021	2,009	2,000	1,999	1,984	1,960
	99%	2,787	2,750	2,704	2,678	2,660	2,639	2,626	2,576

The maximum estimated value equals the highest value of the interval, in other words:

$$\hat{Y}(X_0) = Y_p = Y_c(X_0) + t \cdot S_{Y(X_0)}$$

When the variable is the cant deficiency, X_0 is the value corresponding to $I = 1,10 \, I_{adm}$.

For the quasi-static parameters, the maximum estimated value equals the mean value of the linear regression for $X = X_0$, i.e. $\hat{Y}(X_0) = a + bX_0$.
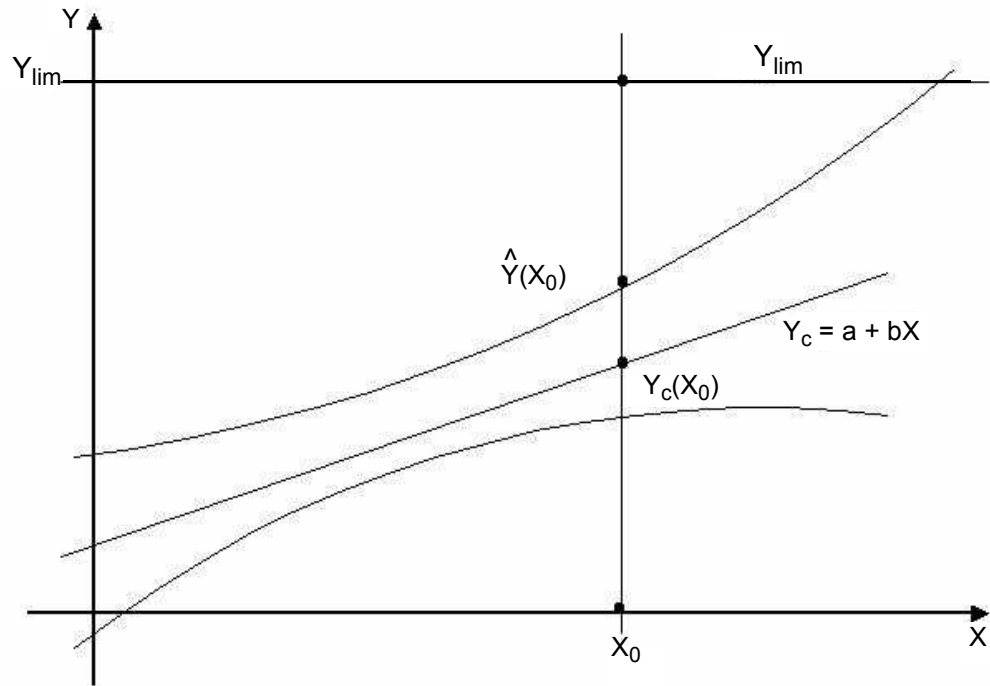
If the value $\hat{Y}(X_0)$ is higher than the limiting value Y_{lim}, the two-dimensional method can be used to find the value X'_0 of the parameter for which the limiting value is reached $(\hat{Y}(X'_0) = Y_{lim})$.

Appendix I - Example of graphical presentation for the development of estimated quantities

I.1 - Test zones

Track sections used for the statistical processing

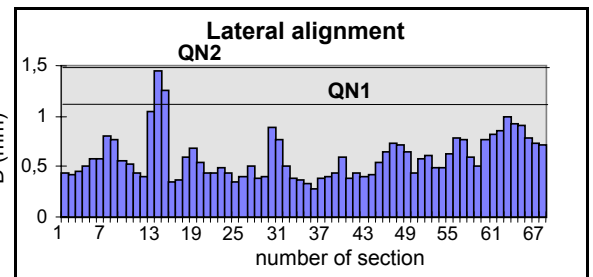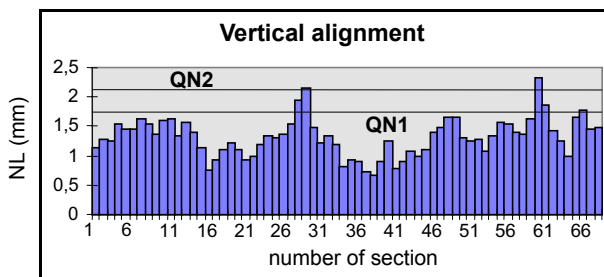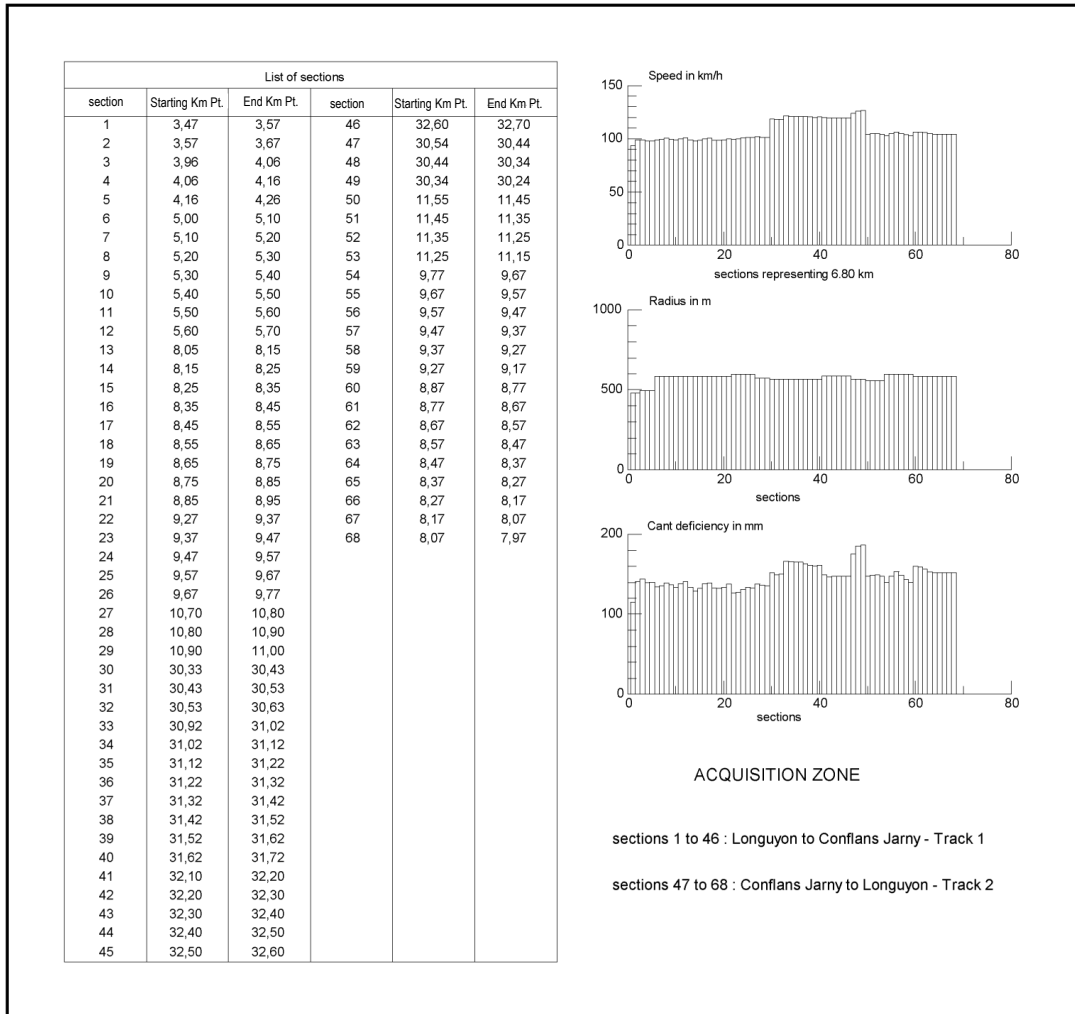| List of sections					
section	Starting Km Pt.	End Km Pt.	section	Starting Km Pt.	End Km Pt.
1	3,47	3,57	46	32,60	32,70
2	3,57	3,67	47	30,54	30,44
3	3,96	4,06	48	30,44	30,34
4	4,06	4,16	49	30,34	30,24
5	4,16	4,26	50	11,55	11,45
6	5,00	5,10	51	11,45	11,35
7	5,10	5,20	52	11,35	11,25
8	5,20	5,30	53	11,25	11,15
9	5,30	5,40	54	9,77	9,67
10	5,40	5,50	55	9,67	9,57
11	5,50	5,60	56	9,57	9,47
12	5,60	5,70	57	9,47	9,37
13	8,05	8,15	58	9,37	9,27
14	8,15	8,25	59	9,27	9,17
15	8,25	8,35	60	8,87	8,77
16	8,35	8,45	61	8,77	8,67
17	8,45	8,55	62	8,67	8,57
18	8,55	8,65	63	8,57	8,47
19	8,65	8,75	64	8,47	8,37
20	8,75	8,85	65	8,37	8,27
21	8,85	8,95	66	8,27	8,17
22	9,27	9,37	67	8,17	8,07
23	9,37	9,47	68	8,07	7,97
24	9,47	9,57			
25	9,57	9,67			
26	9,67	9,77			
27	10,70	10,80			
28	10,80	10,90			
29	10,90	11,00			
30	30,33	30,43			
31	30,43	30,53			
32	30,53	30,63			
33	30,92	31,02			
34	31,02	31,12			
35	31,12	31,22			
36	31,22	31,32			
37	31,32	31,42			
38	31,42	31,52			
39	31,52	31,62			
40	31,62	31,72			
41	32,10	32,20			
42	32,20	32,30			
43	32,30	32,40			
44	32,40	32,50			
45	32,50	32,60			

ACQUISITION ZONE

sections 1 to 46 : Longuyon to Conflans Jarny - Track 1

sections 47 to 68 : Conflans Jarny to Longuyon - Track 2

Fig. 4 - Small-radius curves

I.2 - Configuration 1: measuring bogie leading

Graphs of development by section
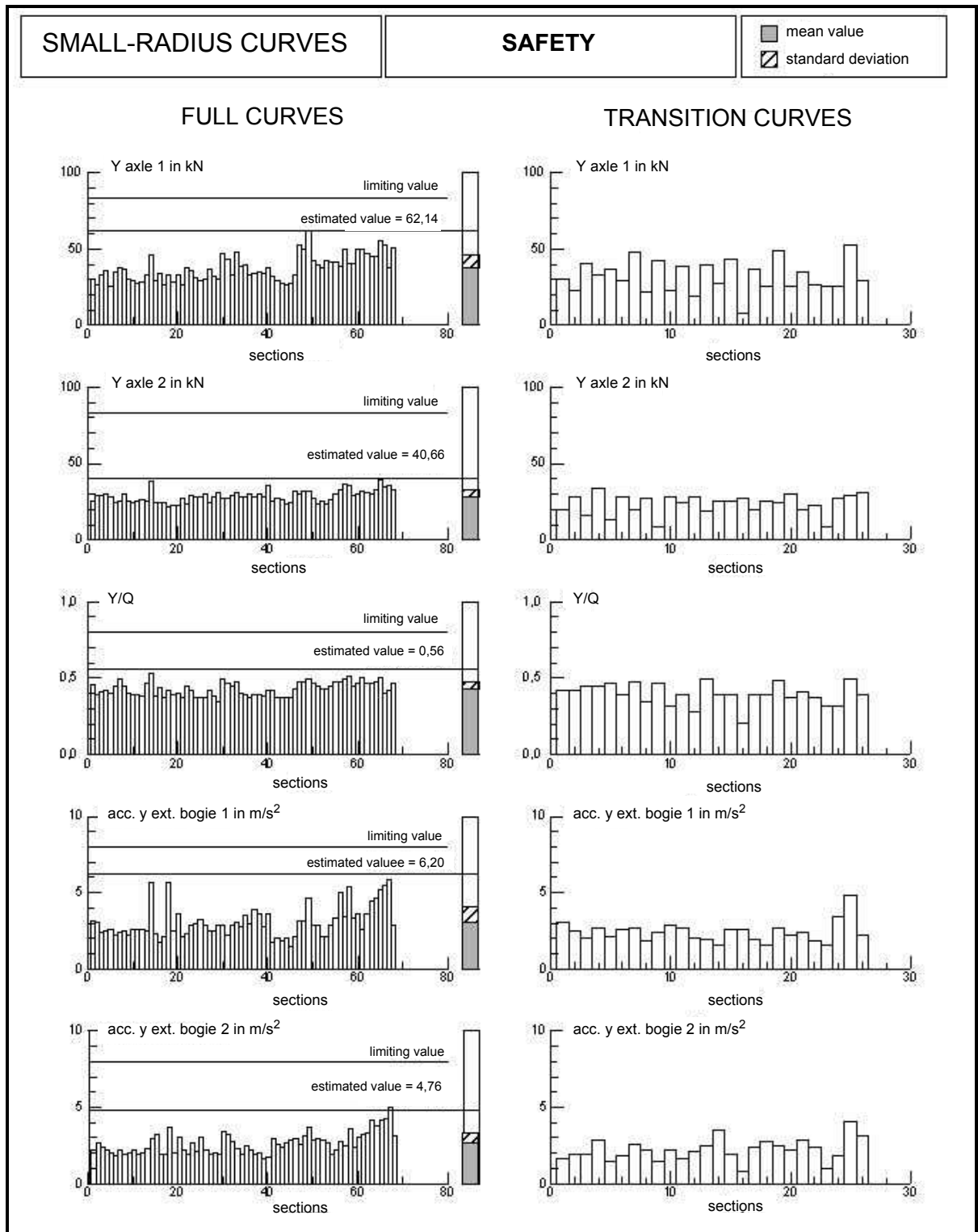
Fig. 5 - Orientation of vehicle: Leading axle 1 - Trailing axle 2 - Axle load: 220,0 kN
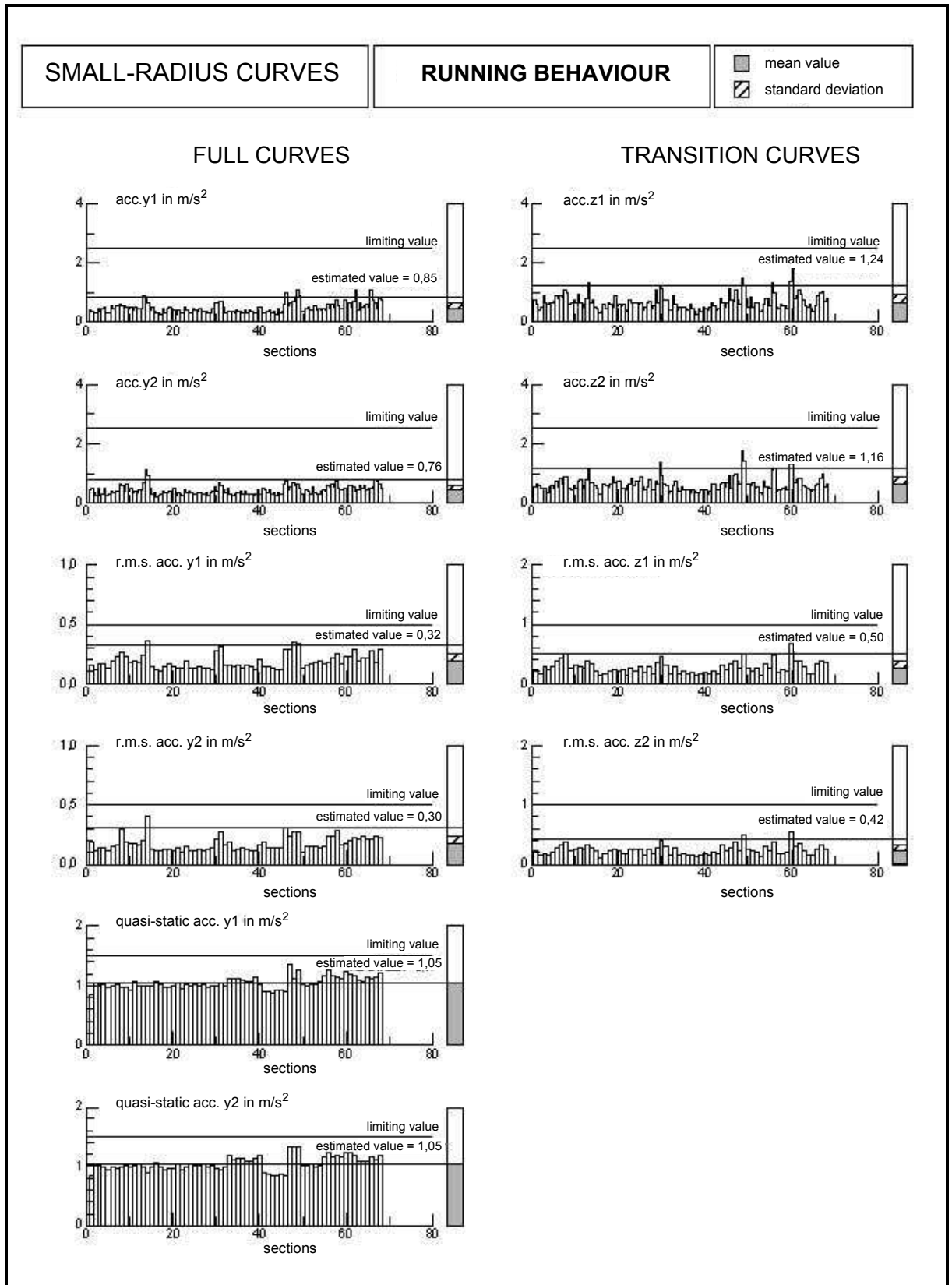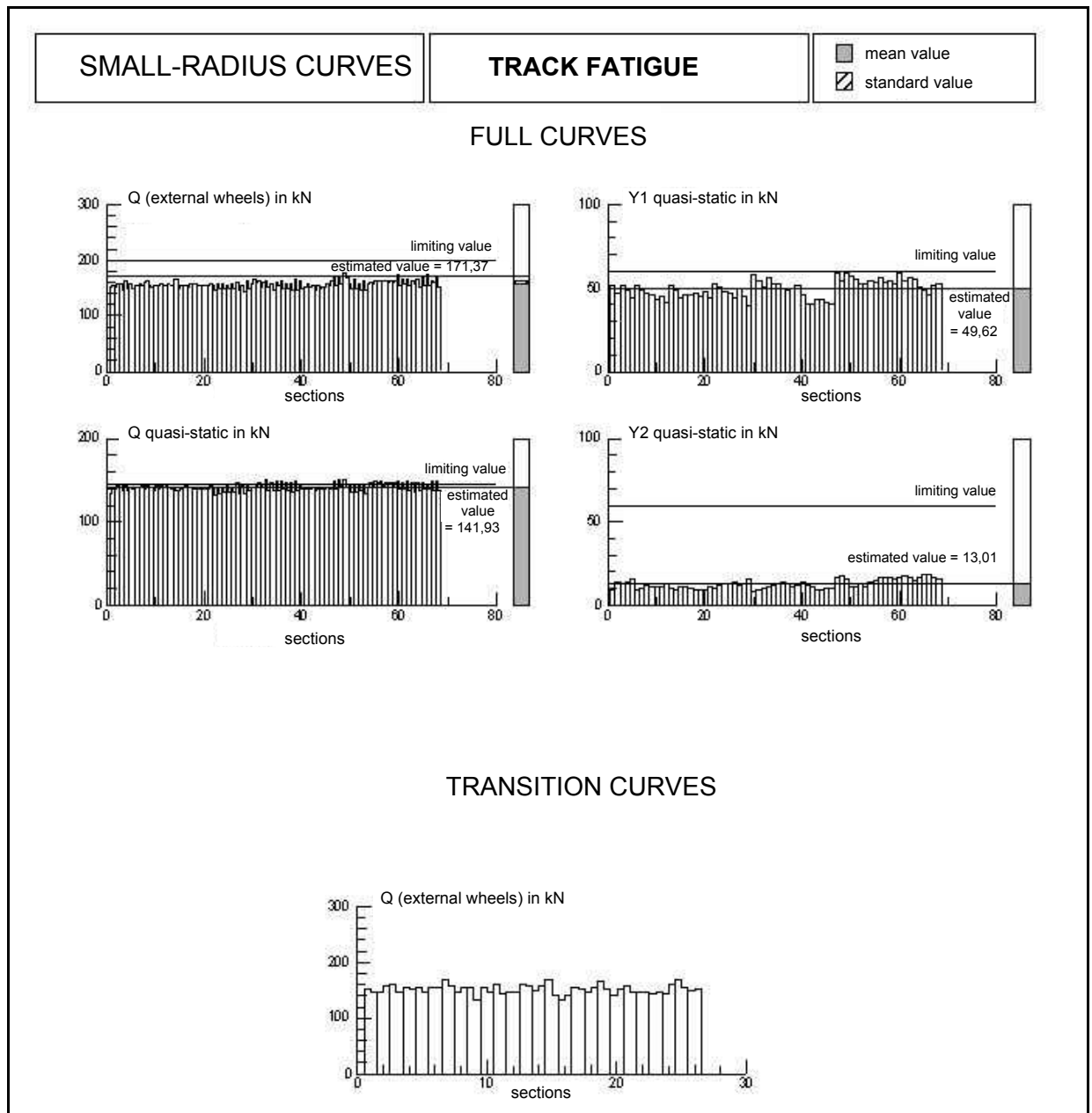
SMALL-RADIUS CURVES	**RUNNING BEHAVIOUR**	▦ mean value ▨ standard deviation

FULL CURVES

acc.y1 in m/s²
limiting value
estimated value = 0,85
sections

acc.y2 in m/s²
limiting value
estimated value = 0,76
sections

r.m.s. acc. y1 in m/s²
limiting value
estimated value = 0,32
sections

r.m.s. acc. y2 in m/s²
limiting value
estimated value = 0,30
sections

quasi-static acc. y1 in m/s²
limiting value
estimated value = 1,05
sections

quasi-static acc. y2 in m/s²
limiting value
estimated value = 1,05
sections

TRANSITION CURVES

acc.z1 in m/s²
limiting value
estimated value = 1,24
sections

acc.z2 in m/s²
limiting value
estimated value = 1,16
sections

r.m.s. acc. z1 in m/s²
limiting value
estimated value = 0,50
sections

r.m.s. acc. z2 in m/s²
limiting value
estimated value = 0,42
sections

Fig. 6 -

SMALL-RADIUS CURVES	TRACK FATIGUE	▦ mean value ▨ standard value

FULL CURVES

Q (external wheels) in kN — limiting value — estimated value = 171,37

Y1 quasi-static in kN — limiting value — estimated value = 49,62

Q quasi-static in kN — limiting value — estimated value = 141,93

Y2 quasi-static in kN — limiting value — estimated value = 13,01

TRANSITION CURVES

Q (external wheels) in kN

Fig. 7 -

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Warning