1 Norwegian dynamic gauge NO1 and NO2: general

Norwegian dynamic gauge NO1 and NO2: general Vehicles used on the Norwegian networks should be gauged according to the rules in this section. General conditions are summarized in the table below:

<table>
<tr><th>Gauging property</th><th colspan="3">Values</th></tr>
<tr><td>Dynamic referance contour</td><td colspan="3">Gauges NO1 and NO2 See §1.3</td></tr>
<tr><td>Projections in curves (space widening) for NO1</td><td>Inside of curve
$S_i = \frac{81}{2R} + 0.015\ m$</td><td>Outside of curve
$S_i = \frac{63}{2R} + 0.015\ m$</td><td>Pantograph
$S_w = 0.015\ m$</td></tr>
<tr><td>Projections in curves (space widening) for NO2</td><td>Inside of curve
$S_i = \frac{100}{2R} + 0.015\ m$</td><td>Outside of curve
$S_i = \frac{87}{2R} + 0.015\ m$</td><td>Pantograph
$S_w = 0.015\ m$</td></tr>
<tr><td>Projections on straight track (space widening)</td><td colspan="3">$S = 0.015\ m$</td></tr>
<tr><td>Track cant D maximum allowed</td><td colspan="2">R < 275 m:
$D_{max} = \frac{0.15}{225} \cdot (R - 50)\ m$</td><td>R ≥ 275 m:
$D_{max} = 0.150\ m$</td></tr>
<tr><td>Cant deficiency I maximum allowed</td><td>R < 200 m:
$I_{max} = 0.100\ m$</td><td>200 ≤ R < 275 m:
$I_{max} = \frac{0.15}{225} \cdot (R - 50)\ m$
ev.
I_{max} = Maximum permissible for the vehicle, if this is smaller</td><td>R ≥ 275 m:
I_{max} = Maximum permissible for vehicle.</td></tr>
</table>

2 Reference profiles

Gauges listed in this chapter refer to same gauges included in the Part 1 and Part 3 of this Norm. They are denoted as below:

- Gabarit NO1 og NO2

3 Reference profile of gauge NO1 and NO2. NB: The projections need to be added to the reference profile NO1 and NO2.

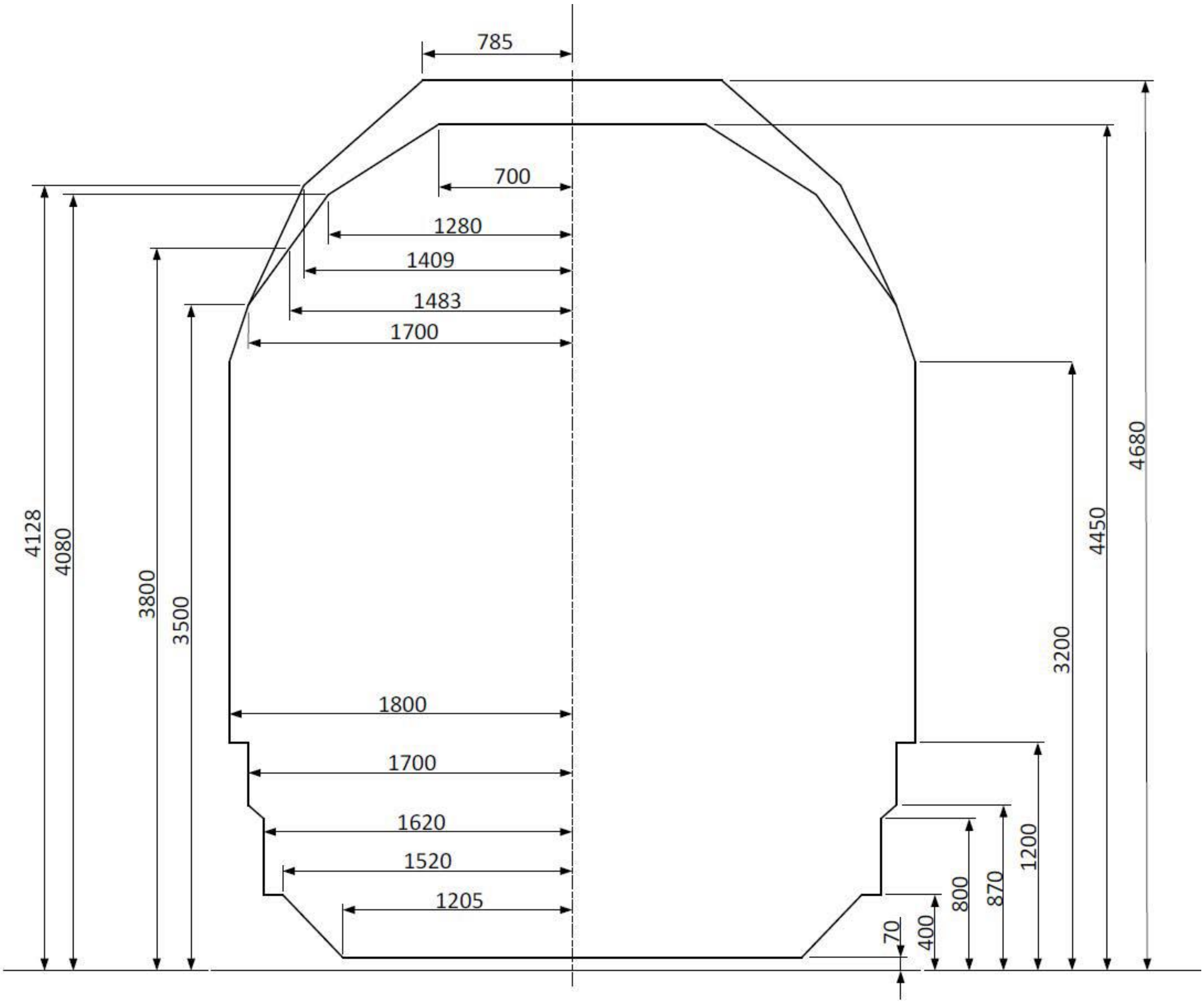


Figure 1: Reference profile of dynamic gauge NO1 (lower) and NO2 (higher)

4 Reference profile for lower parts of gauge NO1 and NO2:

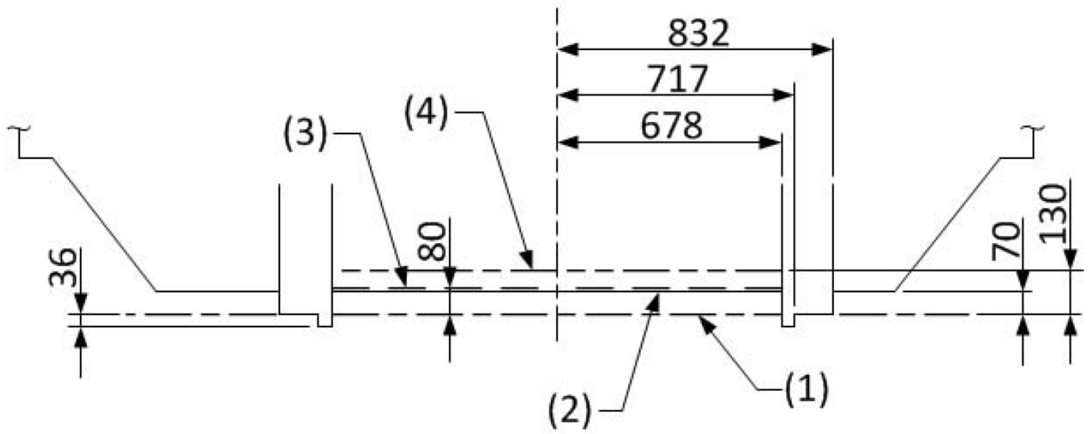


Figure 2: NO1 and NO2 profile for lower parts

Key
(1) Running surface
(2) Reference profile for Vehicles which cannot pass shunting brakes
(3) Reference profile for Vehicles which may pass shunting brakes in lowered position
(4) Reference profile for Vehicles which may pass shunting brakes in raised position

5 NO1 and NO2 profile for pantograph

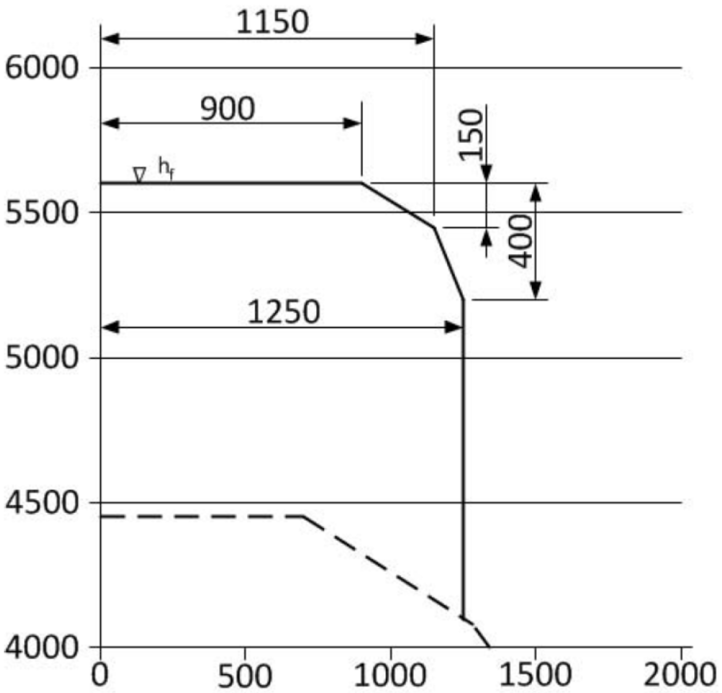


Figure 3: NO1 and NO2 reference profile for pantograph

6 Methodology for movement calculation by geometric formulas

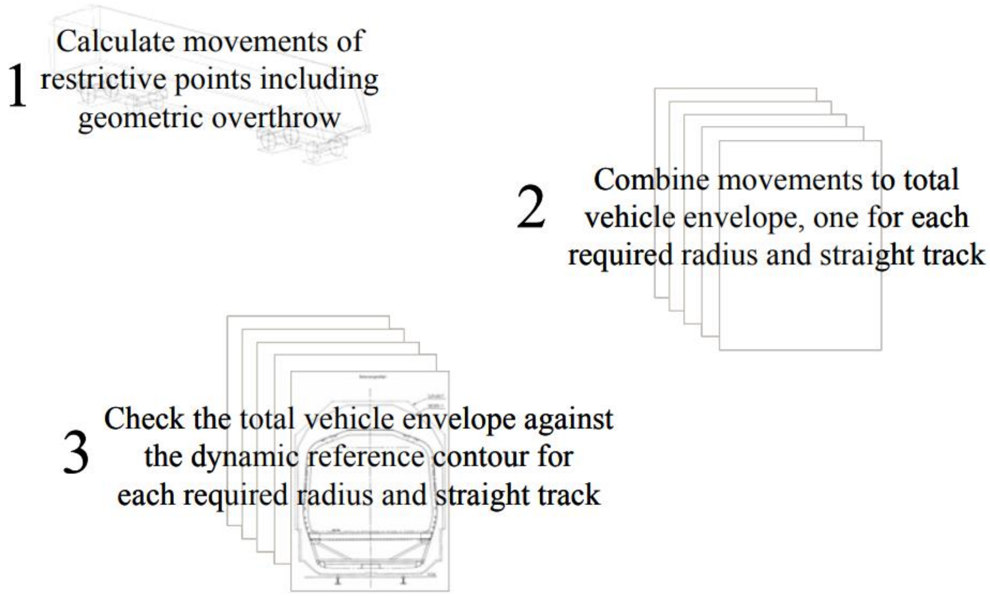
Movement calculation by geometric formulas is allowed for conventional vehicle arrangements like:

- Vehicles fitted with axles
- Vehicles fitted with bogies
- Symmetrical articulated vehicles

It is not allowed for:

- Asymmetrical articulated vehicles
- Vehicles with active devices on which the gauging depends, for example vehicles with carbody tilt.

A flow chart of the methodology is shown in the figure below.



Vehicle movements have to be calculated for each vehicle of the train for each load/suspension condition at selected cross sections. At least the following cross sections shall be calculated:

- Carbody ends
- Start of tapering
- Carbody centre
- Other protruding pads, such as steps, damper brackets etc.
- Pantograph top at 5.6 m

Points on cross sections shall be selected to represent the most restrictive points, normally at vehicle corners or inside corners of the dynamic reference contour.

6.1 Horizontal curves

Curve radii of 150 m, 275 m, 900 m and 3000 m (for curve radii = 3000 m, only for h above 800 mm) shall be considered. Freight wagons shall also consider curve radius 60 m.

Full load and inflated air springs shall be considered if applicable.

Between bogie pivots or axles

For 2-axle standardized UIC freight wagons as well as motor bogies the movement σ track - wheel shall be considered, to 27.5 mm $\left(\frac{1435+30-1410}{2} = 27.5\right)$ ((definition of trailer and motor bogies is given under Definitions).

Suspension lateral movement q + w carbody to wheelsets is assumed to be fully displayed to mechanical stop or, if less, displacement corresponding to a track cant maximum allowed + a supplementary cant D_{sup} of 40 mm. Note that the maximum track cant is dependent on curve radius.

For standardized UIC freight wagons the suspension lateral movement carbody to wheelsets is assumed to be fully displayed to mechanical stop, i.e. 23 mm for a standard 2-axle freight wagon and 11.5 mm for a standard bogie freight wagon, including tolerances.

Curve radius depending lateral stop may be considered, if applicable.

Suspension roll, carbody to wheelsets shall be calculated at a track cant maximum allowed + a supplementary cant D_{sup} of 40 mm. Note that the maximum track cant is dependent on curve radius.

This means that the vehicle movement towards the internal side of the curve is:

$$Dpl_i = A_\sigma \cdot \sigma + A_q \cdot q + A_w \cdot w + s \cdot \frac{D_{max} + D_{sup}}{1.500} \cdot |h - h_c|_{>0} + \frac{1}{2R} \cdot \left[an - n^2 + \frac{p^2}{4}\right]$$

where following movement factors A shall be considered.

Displacement coefficients between bogie pivots or axles			
Type of vehicle	Terms, the coefficient is applicable to		
With two trailer bogies (Definition of motor and trailer bogies are given at "Definitions")	Rail – wheel A_σ	Wheel – bogie A_q	Bogie – carbody A_w
	0	1	1
At least one motor bogie	1	1	1
2-axle vehicles	1	1	Not applicable

Outside bogie pivots or axles

The rail/wheel movement σ shall be considered equal to 27.5 mm $\left(\frac{1435+30-1410}{2} = 27.5\right)$.

Suspension lateral movement q + w carbody to wheelsets are assumed to 95% of maximum to mechanical stop or, if less, at a cant deficiency maximum allowed + a supplementary cant deficiency I_{sup} of 60 mm. Note that the maximum cant deficiency is dependent on curve radius and vehicle design.

For standardized UIC freight wagons the suspension lateral movement carbody to wheelsets is assumed to be fully displayed to mechanical stop, i.e. 23 mm for a standard 2-axle freight wagon and 11.5 mm for a standard bogie freight wagon, including tolerances.

Curve radius depending lateral stop may be considered, if applicable.

Suspension roll, carbody to wheelsets shall be calculated at a cant deficiency maximum allowed + a supplementary cant deficiency I_{sup} of 60 mm. Note that the maximum cant deficiency is dependent on curve radius and vehicle design.

This means that the vehicle movement towards the external of the curve is:

Displacement coefficients beyond bogie pivots or axles			
Type of vehicle	Terms, the coefficient is applicable to		
With two trailer bogies (Definition of motor and trailer bogies are given at "Definitions")	Rail – wheel A_σ	Wheel – bogie A_q	Bogie – carbody A_w
	$\frac{a+n}{a}$	$\frac{a+n}{a}$	$\frac{a+n}{a}$
At least one motor bogie	$\frac{a+n}{a}$	$\frac{a+n}{a}$	$\frac{a+n}{a}$
2-axle vehicles	$\frac{a+2n}{a}$	$\frac{a+2n}{a}$	Not applicable

6.2 Straight line

The track/wheel movement shall be considered equal to 27.5 mm $\left(\frac{1435+30-1410}{2} = 27.5\right)$.

Suspension lateral movement q + w carbody to wheelsets is assumed to be fully displayed to mechanical stop or, if less, to 35 mm.

For standardized UIC freight wagons the suspension lateral movement carbody to wheelsets is assumed to be fully displayed to mechanical stop, i.e. 23 mm for a standard 2-axle freight wagon and 11.5 mm for a standard bogie freight wagon, including tolerances.

Suspension roll, carbody to wheelsets shall be calculated at a supplementary cant deficiency I_{sup} of 60 mm

Between bogie pivots or axles

This means that the vehicle movement on straight track is:

$$Dpl_i = A_\sigma \cdot \sigma + A_q \cdot q + A_w \cdot w + s \cdot \frac{I_{sup}}{1.500} \cdot |h - h_c|_{>0}$$

where following movement factors A shall be considered:

Displacement coefficients between bogie pivots or axles			
Type of vehicle	Terms, the coefficient is applicable to		
	Rail – wheel A_σ	Wheel – bogie A_q	Bogie – body A_w
Any type of vehicle	1	1	1

Outside bogie pivots or axles

This means that the vehicle movement on straight track is:

$$Dpl_i = A_\sigma \cdot \sigma + A_q \cdot q + A_w \cdot w + s \cdot \frac{I_{sup}}{1.500} \cdot |h - h_c|_{>0}$$

where following movement factors A shall be considered

Displacement coefficients beyond bogie pivots or axles			
Type of vehicle	Terms, the coefficient is applicable to		
	Rail – wheel A_σ	Wheel – bogie A_q	Bogie – body A_w
Any type of vehicle	$\frac{a+2n}{a}$	$\frac{a+2n}{a}$	$\frac{a+2n}{a}$

6.3 Vertical curves, calculation of upper parts

The geometric curving overthrow for the vertical curve Rv = 1500 m shall be considered.

Unloaded condition shall be considered.

Concave vertical curve between bogie pivots or axles:

Maximum wheel radius shall be considered.

Upward suspension movement ξ shall be considered to a value of 0.015 m per suspension stage.

Suspension roll, carbody to wheelsets shall be calculated at a cant deficiency that is allowed. Note that the maximum cant deficiency is dependent on curve radius and vehicle design.

This means that the vehicle movement upwards is:

$$u_i = \xi \pm s \cdot \frac{I_{max}}{1.500} \cdot b + \frac{1}{2R_V} \cdot \left[an - n^2 + \frac{p^2}{4}\right]$$

Note: When the vehicle is subject to roll motions a point in the upper carbody corner receives a combined lateral and vertical movement. A point opposite to the inclination side rises but at the same time moves away from the dynamic reference contours. A point on the same side as the inclination lowers. In the formula this involves ±.

Convex vertical curve outside bogie pivots or axles

Maximum wheel radius on one bogie or axle, on the other maximum allowed wheel radius difference between bogies or axles Δr_{wb} shall be considered.

Upward suspension movement ξ shall be considered to a value of 0.015 m per suspension stage at the same end as where maximum wheel radius is applied.

Suspension roll, carbody to wheelsets shall be calculated at a cant deficiency maximum allowed. Note that the maximum cant deficiency is dependent on curve radius and vehicle design.

This means that the vehicle movement upwards is:

$$u_a = \frac{n}{a} \cdot \Delta r_{wb} + \frac{n+a}{a} \cdot \xi \pm s \cdot \frac{I_{max}}{1.500} \cdot b + \frac{1}{2R_V} \cdot \left[an + n^2 - \frac{p^2}{4}\right]$$

6.4 Vertical curves, calculation of lower parts

The geometric curving overthrow for the vertical curve Rv = 1500 m shall be considered.

Suspension roll, carbody to wheelsets shall be calculated at a cant deficiency maximum allowed. Note that the maximum cant deficiency is dependent on curve radius and vehicle design.

Wear in carbody support (part of Δh1) shall be considered.

If only one suspension, step b2 shall be considered as the transvers distance to the suspension.

To be considered for steel and rubber springs (part of Δh1 and Δh2):

- deflection under maximum static load.
- additional deflection under 30% overload on the maximum static load to take account for dynamic stress or until hard stops.
- deflection due to flexibility tolerances (most unfavourable values due to maintenance limits have to be considered).
- deflection due to suspension creep.

To be considered for air springs (part of Δh2):

- Total deflection with deflated air springs (including emergency suspension if applicable)

Adjustment devices to compensate for varying wheel radius as well as suspension creep and wear may be considered.

Convex vertical curve between bogie pivots or axles:

Minimum wheel radius Δr_w on all axles shall be considered.

Sag f due to load shall be considered.

This means that the vehicle movement downwards is:

$$e_i = \Delta r_w + \Delta h_1 + \Delta h_2 + f + s \cdot \frac{I_{max}}{1.500} \cdot (b - b_2)_{>0} + \frac{1}{2R_V} \cdot \left[an - n^2 + \frac{p^2}{4} \right]$$

Concave vertical curve outside bogie pivots or axles

Minimum wheel radius on one bogie or axle Δr_w, on the other maximum allowed wheel radius difference between bogies or axles Δr_{wb} shall be considered.

Deflection of springs shall be considered at the same end as where minimum wheel radius is applied, normally inflated air springs on the other end.

This means that the vehicle movement downwards is:

$$e_a = \Delta r_w + \frac{n}{a} \cdot \Delta\, r_{wb} + \Delta h_1 + \Delta h_2 + \sqrt{\left[\frac{n}{a} \cdot (\Delta h_1 + \Delta h_2)\right]^2 + \left[s \cdot \frac{I_{max}}{1.500} \cdot (b - b_2)_{>0}\right]^2} + \frac{1}{2R_V} \cdot \left[an + n^2 - \frac{p^2}{4}\right]$$

6.5 Shunting hills

This section only applies to vehicles which may pass shunting hills and sags and only to surfaces that including vehicle movement downwards can be below 0.15 m.

The geometric curving overthrow for the vertical curve Rv = 500 m shall be considered.

Passenger load may not be considered.

Calculation methodology according to vertical curves, lower surfaces shall be applied.

6.6 Pantograph verification

The verification must be done with collecting height of 5.60 m and with a horizontal curve of radius 275 m.

Inner side of curve:

$$Dpl_{i\,dyn} = \frac{an_i - n_i^2 + \frac{p^2}{4}(A)}{2R} + \frac{l_{max} - d}{2}(A) + q(A) + wi_{(R)}(A) + z_{dyn} + (t - 0.030) + (\tau - 0.010)$$

External side of curve:

$$Dpl_{a\,dyn} = \frac{an_a + n_a^2 + \frac{p^2}{4}(A)}{2R} + \frac{l_{max} - d}{2}(A) + q(A) + wa_{(R)}(A) + z_{dyn} + (t - 0.030) + (\tau - 0.010)$$

Values for (A) are identical as for the carbody calculation.

Those displacements must be considered also when calculating the collecting position of pantograph during simulation process.

7 Total vehicle envelope

The movements from each calculation, also considering the different load and suspension states are combined to a total vehicle envelope for each curve radius and straight track. The worst case of any combination of conditions shall be considered.

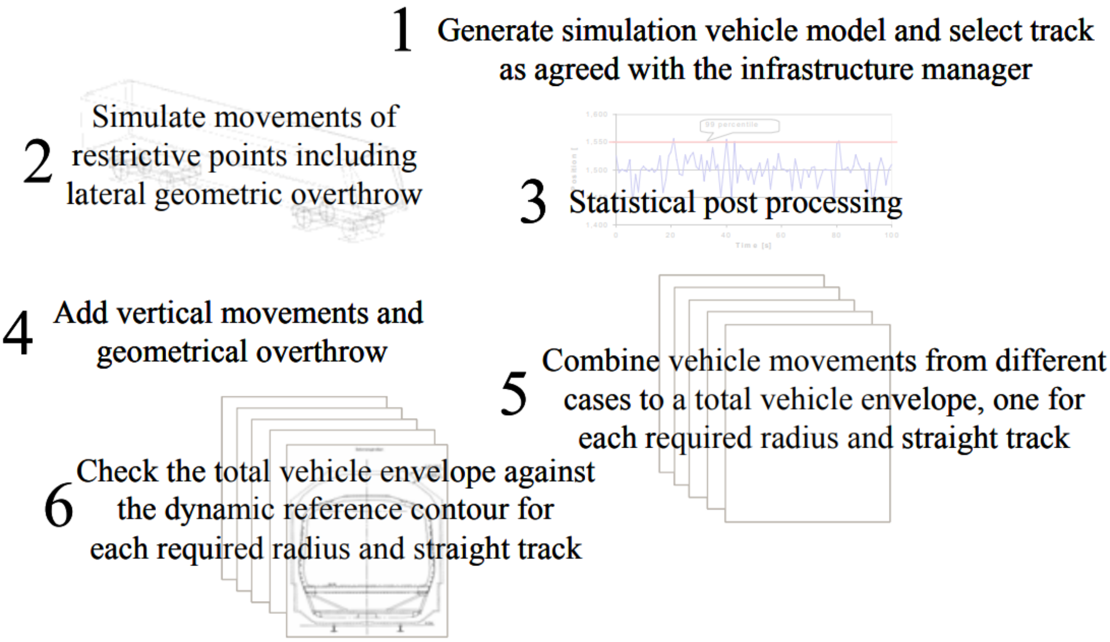
8 Methodology for movement calculation by simulation

Movement calculation by simulation is allowed for all vehicles including:

- Asymmetrcal articulated vehicles
- Vehicles with active devices on which the gauging depends, for example vehicles with carbody tilt

Movement calculation by simulation is also allowed to maximize the vehicle dimensions of conventional vehicles where movement calculation by geometric formulas is allowed.

A flow chart of the methodology is shown in the figure below.



All movement calculations shall refer to the real track as the dynamic reference contour does.

Vehicle movements have to be calculated for each vehicle of the train consist for each load/suspension condition at selected cross sections. At least the following cross sections shall be calculated:

- Carbody ends
- Start of tapering
- Carbody centre
- Other protruding parts, such as steps, damper brackets etc.

8.1 Total vehicle envelope

The movements from each simulation are combined to a total vehicle envelope for each curve radius and straight track. The worst case of any combination of cant excess / deficiency, speed and load/suspension conditions shall be considered.

8.2 Proof against the permitted reference contour

The total vehicle envelope for each curve radius and straight track is finally checked against the dynamic reference contour plus the corresponding projection. In the horizontal direction the comparison could generally be expressed as:

Dynamic reference contour + Projections ≥ [Vehicle Width + Vehicle Tolerances + Vehicle Movements + Curving Overthrow]$_{max}$

This could also, as an alternative, be expressed as maximum vehicle width:

Vehicle Width ≤ Dynamic reference contour + Projections – [Vehicle Tolerances + Vehicle Movements + Curving Overthrow]$_{max}$

9 Dynamic gauging method: Verification

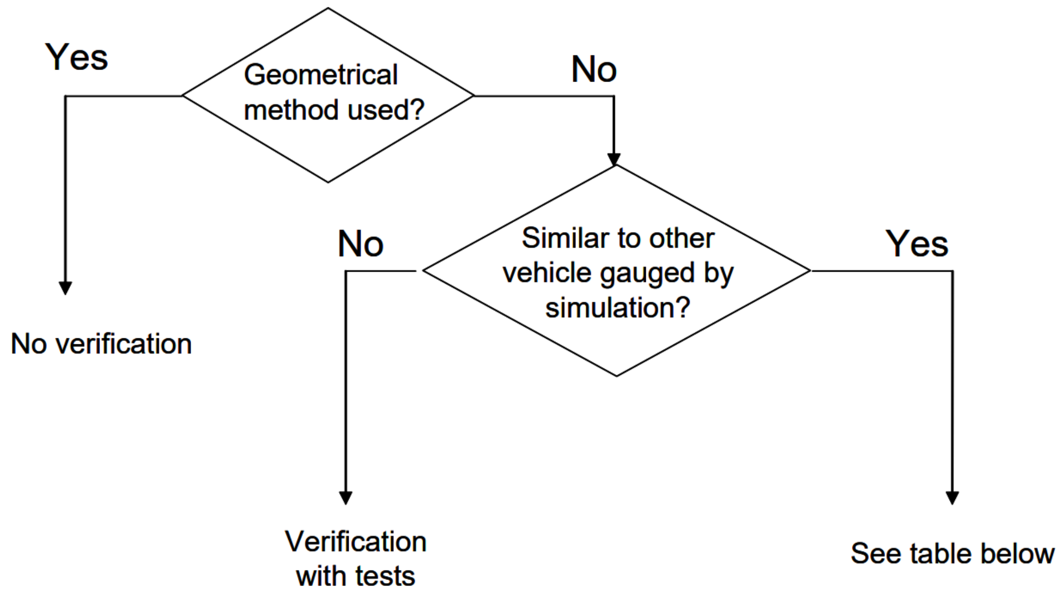
Verification of simulated movements by means of testing is in some cases necessary. For calculations by geometric formulas no verification is necessary.

In principal, movement data which are critical for the sizing of the vehicle shall be verified in such cases.

In particular, a new simulation model shall be verified with testing. In the choice between stationary tests and 'ontrack' test, the level of risk, innovation and complexity in the vehicle design shall be considered. Also, the novelty of the simulation model shall be considered. In some cases verification with simulations are sufficient.

Verification testing shall preferably be performed in conjunction with other type testing.

As a guideline, although not mandatory, the verification need is given in the flow chart below.



Parameter	Verification not required if parameter has turned:	Verification required	
		Verification by simulation allowed if parameter changed by:	Verification by tests required if parameter changed by more than
Wheel diameters	-	Less than described in "Verification tests required"	+ 0.1 m; -0.1 m
Wheelbase	-		+ 0.1 m; -0.1 m
Bogie distance	Smaller		+ 0.5 m
Bogie dimensions	Smaller		+ 0.1 m
Bogie mass	Smaller		+ 10 %
Bogie inertia	Smaller		+ 10 %
Carbody length	Smaller		+ 0.5 m
Carbody mass	Smaller		+ 10 %
Carbody c. of gr.	Lower		+ 10 %
Suspension stiffness in relation to carbody mass and inertia	Greater		- 10 %
Suspension damping in relation to carbody mass and inertia	Greater		- 20 %

9.1 Verification by simulation

Verification with comparative simulations is allowed for minor modification on an already approved and verified vehicle. Simulations shall be made for critical cases and the most restrictive points found in simulations or tests on the comparator vehicle.

9.2 Verification with stationary tests

The vehicle is placed at maximum track cant with air suspension leveling valves disabled if existing.

Following measurement variables are needed to verify lateral and roll displacements.

- Wheelset to bogie frame, lateral
- Bogie frame to carbody, lateral
- Wheelset to bogie frame, vertical, both sides
- Bogie frame to carbody, vertical, both sides

Displacements on critical/significant points of the vehicle are to be calculated from the measurement variables and to be compared with simulations. The results shall be assessed by the local authority (notified body, infrastructure manager).

9.3 Verification with 'on-track' tests

Verification with running measurements may be part of the homologation process according to prEN 14363 or UIC 518 etc.

Verification shall be made at least for critical cases and the most restrictive points of the vehicle, as found in simulations or tests. This includes a proper choice of vehicle loads, track quality, speed and curve data.

A nearby case may be selected if a particular case cannot be realised. Proper account must be taken to the different case in the test evaluations and comparisons.

Example:

Straight track, V = 30, 80 and 160 km/h

Curved track, R = 150, 275 and 3000 m at maximum cant excess, balanced speed and at maximum cant deficiency.

Turnout combination, R = 190 m, intermediate straight 10 m and R=190 m.

The track quality shall be between QN2 and QN3 quality limits according to ENV 12299 (same as specified in UIC 518).

Following measurement variables are needed to verify lateral, vertical and inclination displacements.

- Track to bogie frame, lateral
- Bogie to carbody, lateral
- Wheelset to bogie frame, vertical
- Bogie to carbody, vertical

To be calculated from the measurements:

- Displacements in simulated points, statistically evaluated

Test results shall be compared with simulations. The vehicle builder shall propose to the notified body whether the results are in satisfactory agreement.