EN standard 12299 for evaluation of ride comfort for rail passengers

Dr Björn Kufver (Ferroplan)

Contents

Introduction - 1

- The European Committee for Standardization (CEN) - Technical Committee TC256 - European standards for the railway sector
- 1999 - a European prestandard for comfort evaluation ENV 12299
- The research was conducted by UIC (ORE) and BRR
- Revision – performed by experts from France, Germany, Italy, Sweden
- A new standard EN 12299 was published in 2009

Basic principles - 1

- Indirect measurements
- Accelerometers and gyros – vehicle body
- Vehicle conditions – accelerometer positions – test speed – test sections – time intervals
- Full scale tests (and computer simulations)
- Low-pass or band-pass filtering
- Statistical post-processing
- Scales / interpretation of results
- Ride comfort as such / vehicle assessment

The mean comfort standard method - 1

- Validated for seated passengers (UIC / ORE)
- Calculated for a 5-minute run
- Measurements in the floor
- Accelerations in *x*-, *y*-, and *z*-directions
- Band-passed filtered signals 0.4-100 Hz
- … validated for fairly straight tracks
- 3 * 60 5-second rms-values
- 95 percentile (4th highest value) from each direction

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

The mean comfort standard method - 2

Evaluation scale for N_{MV}:

$N_{MV} < 1.5$	Very comfortable
$1.5 \leq N_{MV} < 2.5$	Comfortable
$2.5 \leq N_{MV} < 3.5$	Medium
$3.5 \leq N_{MV} < 4.5$	Uncomfortable
$N_{MV} \geq 4.5$	Very uncomfortable

The mean comfort standard method - 3

- Certain similarities with ISO 2631 evaluation
- The controversial point is the 95 percentiles
- In each direction only 1 (of 60) 5-second rms-values is used

Table 1: Three hypothetical five-minute vibration patterns for one direction (each of sixty five-second rms values, m/s^2).

	First highest rms value	2nd	3rd	4th	5th	*i*th	60th
Series A	0.3	0.3	0.3	0.3	0.1	0.1	0.1
Series B	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Series C	0.9	0.9	0.9	0.3	0.3	0.3	0.3

The mean comfort standard method - 4

- The 95 percentiles in x-, y-, and z-directions, respectively, may occur during three different 5-second intervals.
- The final N_{MV}-value cannot be well correlated to local track condition (since the critical lateral y-value and the critical vertical z-value may be located several kilometres apart.

Continuous comfort C_{Cx}, C_{Cy} and C_{Cz}

- Since N_{MV} is based on only 3 of 180 rms-vales, there is a substantial loss of information.
- The CEN working group recommends that all 180 values are presented in the test report, as three time series: Continuous Comfort.
- A preliminary scale is suggested for evaluation of individual rms-values

Table 1: Preliminary scale for the $C_{Cy}(t)$ and $C_{Cz}(t)$ comfort indexes.

$C_{Cy}(t)$, $C_{Cz}(t) < 0.20$ m/s^2	Very comfortable
0.20 m/s$^2 \leq C_{Cy}(t)$, $C_{Cz}(t) < 0.30$ m/s^2	Comfortable
0.30 m/s$^2 \leq C_{Cy}(t)$, $C_{Cz}(t) < 0.40$ m/s^2	Medium
$C_{Cy}(t)$, $C_{Cz}(t) \geq 0.40$ m/s^2	Less comfortable

The mean comfort complete methods - 1

The N_{VA} method takes vibrations both at the floor and at the seat into account.

- Floor: vertical direction
- Seat pan: lateral and vertical directions
- Seat back: longitudinal direction
- Based on 95 percentiles
- More cumbersome to use, both in real tests and computer experiments

The mean comfort complete methods - 2

The N_{VD} method is validated for standing passengers.

- Floor: x-, y-, z-directions, median values
- Floor: lateral y-direction, maximum value
- Too sensitive to outliers ? (ORE)
- Maximum value replaced with 95 percentile (ORE)

Both "complete methods" N_{VA} and N_{VD} have the same disadvantages as the "standard method" N_{MV}

Comfort on Discrete Events P_{DE} - 1

Validated for seated and standing passengers (BRR, additional tests conducted by UIC/ERRI)

Voting by test subjects on a scale

- Very comfortable
- Comfortable
- Acceptable
- Uncomfortable
- Very uncomfortable

Quantifies the percentage who voted "Uncomfortable" or "Very uncomfortable"

Comfort on Discrete Events P_{DE} - 2

Discomfort was found on large track irregularities (Discrete Events; P_{DE}) and on short transition curves (Curve Transitions; P_{CT})

P_{DE} is derived from conditions on straight track and circular curves (based on a manual selection of peak-to-peak patterns of the lateral acceleration)

- Mean lateral acceleration (due to curvature and cant)
- Peak-to-peak lateral acceleration

$$P_{\mathrm{DE}} = \max\left[16.62 \cdot \ddot{y}_{\mathrm{pp}} + 27.01 \cdot \left|\ddot{y}_{\mathrm{mean}}\right| - 37.0;0\right]$$

Comfort on Discrete Events P_{DE} - 3

ERRI suggested a more automatic evaluation of Discrete Events (P_{DE}) based on continuous evaluation of several signals

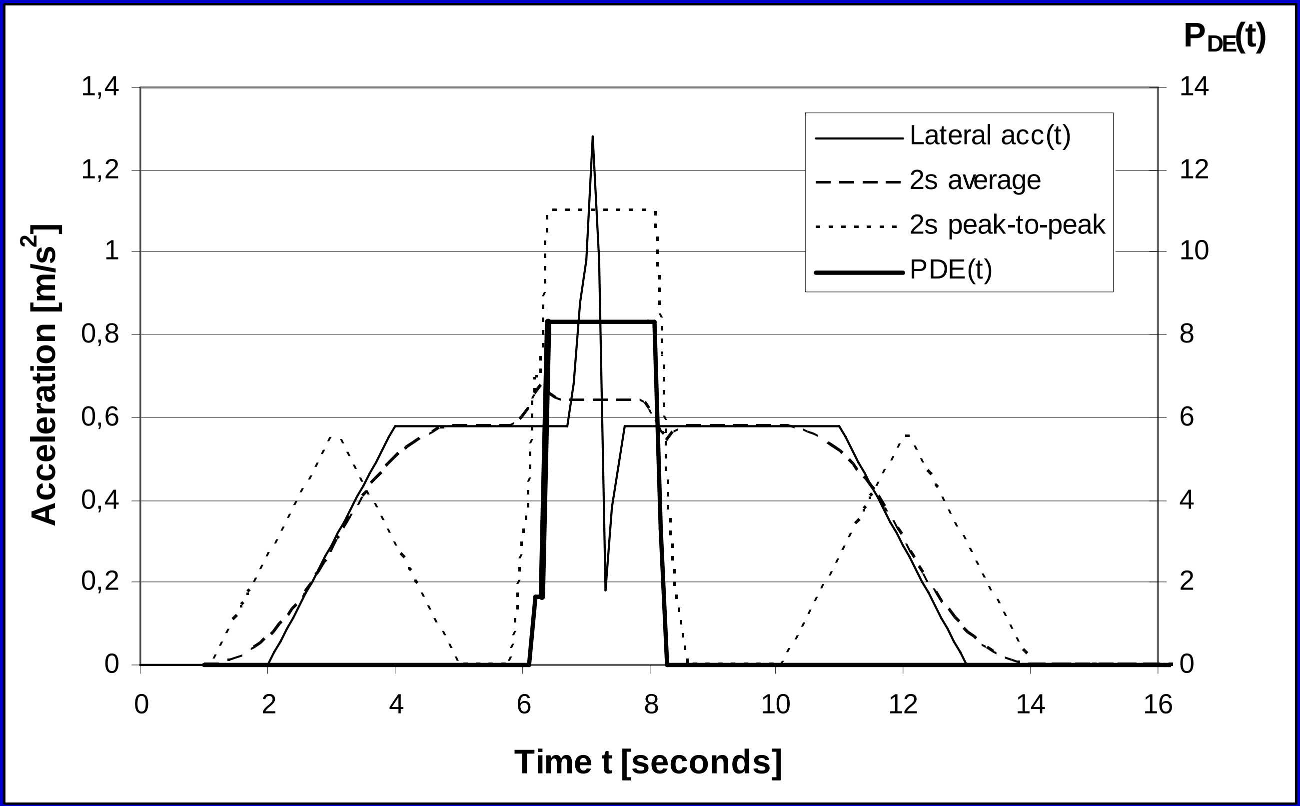
$$\left|\ddot{y}_{2\mathrm{s}}(t)\right| = \frac{1}{T}\left|\int_{t-\frac{T}{2}}^{t+\frac{T}{2}} \ddot{y}^{*}_{\mathrm{P,Wp}}(\tau)\,d\tau\right|$$

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

$$P_{\mathrm{DE}}(t) = \max\left[16.62 \cdot \ddot{y}_{\mathrm{pp}}(t) + 27.01 \cdot \left|\ddot{y}_{2\mathrm{s}}(t)\right| - 37.0; 0\right]$$

Comfort on Discrete Events P_{DE} - 4

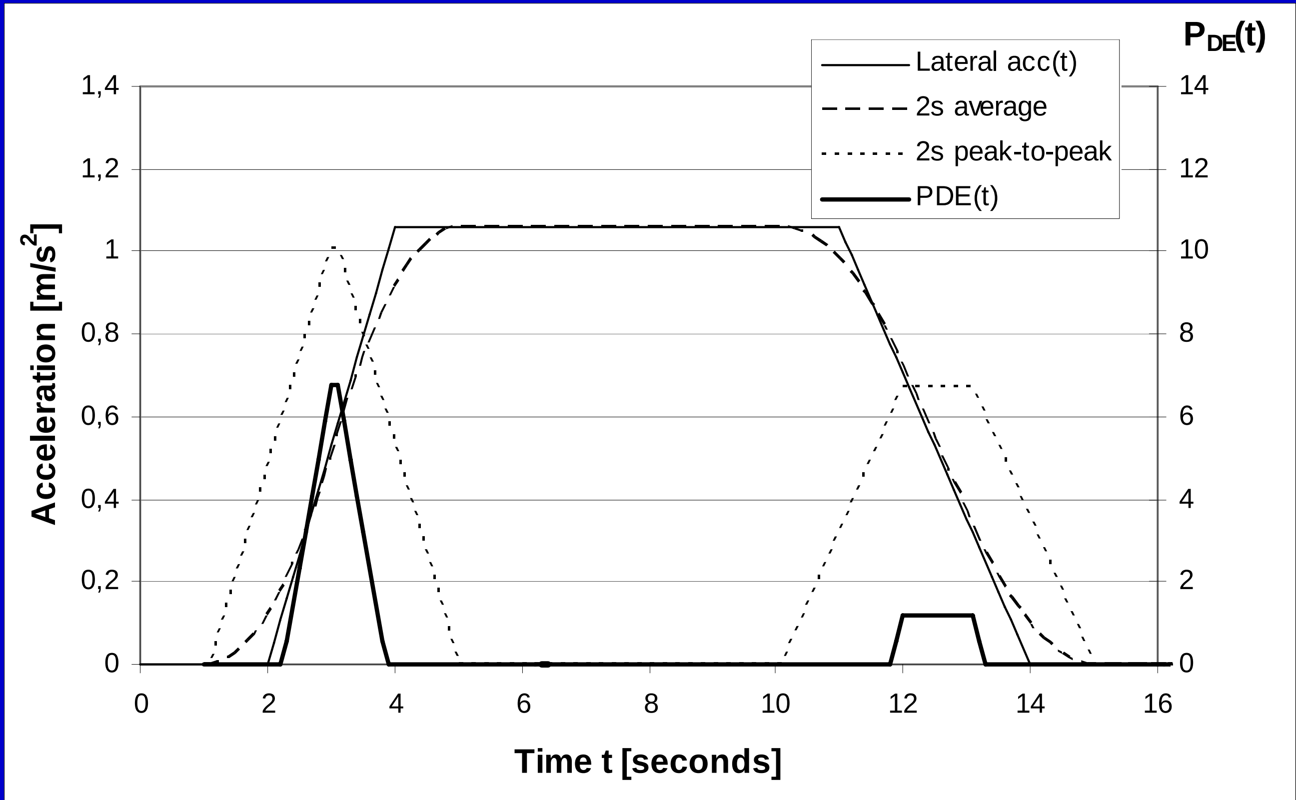
For the assessment of a particular local event (which will affect the two-second sliding window during more than 2 seconds), the local maximum of $P_{\mathrm{DE}}(t)$ shall be used)



B Kufver - Ferroplan

Comfort on Discrete Events P_{DE} - 5

Originally, the P_{DE} functions were derived and validated for circular curves and straight track only. $P_{\mathrm{DE}} > 0$ may be found in short transition curves without large track irregularities.



B Kufver - Ferroplan

Comfort on Curve Transitions P_{CT} - 1

P_{CT} is derived from conditions on transitions curves of the clothoid type, evaluation starting 1 seconds before the transition curve to 1.6 seconds after the transition curve

- Maximum lateral acceleration (averaged 1 second)
- Maximum lateral jerk (averaged 1 second)
- Maximum roll velocity (averaged 1 second)

$$P_{\mathrm{CT}} = \max\left[28.54 \cdot \left|\ddot{y}_{1\mathrm{s}}\right|_{\max} + 20.69 \cdot \left|\dddot{y}_{1\mathrm{s}}\right| - 11.1);0\right],$$

$$+ (27.36 \cdot \left|\dot{\varphi}_{1\mathrm{s}}\right|_{\max})^{2.283}$$

Comfort on Curve Transitions P_{CT} - 2

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

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

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

Comfort on Curve Transitions P_{CT} - 3

$$P_{\mathrm{CT}}(t) = \max\Big\{0; (28.54 \cdot \left|\ddot{y}_{1\mathrm{s}}(t)\right|, + 20.69 \cdot \max\big(\mathrm{sign}(\ddot{y}_{1\mathrm{s}}(t)) \cdot \dddot{y}_{1\mathrm{s}}(\tau), \tau \in \left]t - T_A - 2.6\mathrm{s}, t\right]\big)\Big\}, + (27.36 \cdot \max\big(\left|\dot{\varphi}_{1\mathrm{s}}(\tau)\right|, \tau \in \left]t - T_A - 1.6\mathrm{s}, t\right]\big))^{2.283}$$

The parameter T_A (seconds) should be chosen large enough to allow high lateral jerk and high roll velocity to affect the evaluation even if they occur in the beginning of a long transition curve,

but small enough in order to exclude these values when they do not belong to the same transition as the lateral acceleration at the time t.

Discussion - 1

The new EN 12299 (as well as the old ENV 12299) is based on research from UIC/ORE/ERRI and BRR.

- Missing knowledge #1: Monetary assessment
- Missing knowledge #2: Motion sickness

Discussion - 2

The N_{MV}, N_{VA} and N_{VD} methods:

- Believed to be valid on fairly straight lines (but not on curves)
- neglect up to 98.3% (59 of 60) of the measured rms-values
- (may) combine longitudinal (x), lateral (y) and vertical (z) vibration values from three different 5-second intervals.

Discussion - 3

P_{CT} and P_{DE} methods:

- P_{CT} - clothoids and linear cant transitions only
- P_{CT} - very short straight lines or circular curves ?
- Derived from the same tests and the using almost – but not exactly - the same post-processing (see next slide)

Discussion - 4

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

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

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

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

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

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

Discussion - 5

Even if a new European standard has been published, …

… there is still room for further research in the area of ride comfort evaluation