EN standard 12299 for evaluation of ride comfort for rail passengers

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Contents

• Introduction / Background (1)
• Basic principles in the CEN comfort standard (1)
• Mean comfort standard method $N_{MV}$ (4)
• Continuous comfort $C_{Cx}, C_{Cy}$ and $C_{Cz}$ (1)
• Mean comfort complete methods $N_{VA}$ and $N_{VD}$ (2)
• Comfort on discrete events $P_{DE}$ (5)
• Comfort on curve transitions $P_{CT}$ (3)
• Discussion and conclusions (5)
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

\[ N_{MV} = 6 \cdot \sqrt{(a_{XP95}^{Wd})^2 + (a_{YP95}^{Wd})^2 + (a_{ZP95}^{Wb})^2} \]
The mean comfort standard method - 2

Evaluation scale for $N_{MV}$:

<table>
<thead>
<tr>
<th>$N_{MV}$</th>
<th>Comfort level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{MV} &lt; 1.5$</td>
<td>Very comfortable</td>
</tr>
<tr>
<td>$1.5 \leq N_{MV} &lt; 2.5$</td>
<td>Comfortable</td>
</tr>
<tr>
<td>$2.5 \leq N_{MV} &lt; 3.5$</td>
<td>Medium</td>
</tr>
<tr>
<td>$3.5 \leq N_{MV} &lt; 4.5$</td>
<td>Uncomfortable</td>
</tr>
<tr>
<td>$N_{MV} \geq 4.5$</td>
<td>Very uncomfortable</td>
</tr>
</tbody>
</table>
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).

<table>
<thead>
<tr>
<th></th>
<th>First highest rms value</th>
<th>2^{rd}</th>
<th>3^{rd}</th>
<th>4^{th}</th>
<th>5^{th}</th>
<th>6^{th}</th>
<th>60^{th}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series A</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Series B</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Series C</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>
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.

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

- Since $N_{MV}$ is based on only 3 of 180 rms-values, 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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Comfort Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{Cy}(t), C_{Cz}(t) &lt; 0.20 \text{ m/s}^2$</td>
<td>Very comfortable</td>
</tr>
<tr>
<td>$0.20 \text{ m/s}^2 \leq C_{Cy}(t), C_{Cz}(t) &lt; 0.30 \text{ m/s}^2$</td>
<td>Comfortable</td>
</tr>
<tr>
<td>$0.30 \text{ m/s}^2 \leq C_{Cy}(t), C_{Cz}(t) &lt; 0.40 \text{ m/s}^2$</td>
<td>Medium</td>
</tr>
<tr>
<td>$C_{Cy}(t), C_{Cz}(t) \geq 0.40 \text{ m/s}^2$</td>
<td>Less comfortable</td>
</tr>
</tbody>
</table>
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

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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

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

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

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

$$\dot{j}_{pp}(t) = \max \left( \dot{j}_{p,wp}^*(\tau), \tau \in \left[ t - \frac{T}{2}, t + \frac{T}{2} \right] \right), - \min \left( \dot{j}_{p,wp}^*(\tau), \tau \in \left[ t - \frac{T}{2}, t + \frac{T}{2} \right] \right)$$

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

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Comfort on Discrete Events $P_{DE}$

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 $P_{DE}(t)$ shall be used.

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Comfort on Discrete Events $P_{DE}$ - 5

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

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

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

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Comfort on Curve Transitions $P_{CT}$ - 2

\[
\ddot{y}_{1s}(t) = \frac{1}{T} \left( \int_{t-T/2}^{t+T/2} \ddot{y}_{wp}(\tau) d\tau \right)
\]

\[
\ddot{y}_{1s}(t) = \frac{1}{T} \left( \ddot{y}_{1s}(t + \frac{T}{2}) - \ddot{y}_{1s}(t - \frac{T}{2}) \right)
\]

\[
\dot{\phi}_{1s}(t) = \frac{1}{T} \left( \int_{t-T/2}^{t+T/2} \dot{\phi}_{wp}(\tau) d\tau \right)
\]

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$P_{CT}(t) = \max \left\{ 0; (28.54 \cdot |\ddot{y}_{1s}(t)|, \right. $

$\left. + 20.69 \cdot \max (\text{sign}(\ddot{y}_{1s}(t)) \cdot \dddot{y}_{1s}(\tau), \tau \in [t - T_A - 2.6s, t]) \right\},$

$+ (27.36 \cdot \max (|\phi_{1s}(\tau)|, \tau \in [t - T_A - 1.6s, t])^{2.283}$

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 $t$.

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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
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.
$P_{\text{CT}}$ and $P_{\text{DE}}$ methods:

- $P_{\text{CT}}$ - clothoids and linear cant transitions only
- $P_{\text{CT}}$ - 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

\[ \ddot{y}_{1s}(t) = \frac{1}{T} \cdot \int_{t-T/2}^{t+T/2} \dddot{y}_{wp}(\tau) d\tau \]

\[ \dddot{y}_{1s}(t) = \frac{1}{T} \left( \dddot{y}_{1s}(t + \frac{T}{2}) - \dddot{y}_{1s}(t - \frac{T}{2}) \right) \]

\[ \dot{\phi}_{1s}(t) = \frac{1}{T} \cdot \int_{t-T/2}^{t+T/2} \dot{\phi}_{wp}(\tau) d\tau \]

\[ |\dddot{y}_{2s}(t)| = \frac{1}{T} \left| \int_{t-T/2}^{t+T/2} \dddot{y}_{p,wp}(\tau) d\tau \right| \]

\[ \dddot{y}_{pp}(t) = \max \left( \dddot{y}_{p,wp}(\tau), \tau \in \left[ t - \frac{T}{2}, t + \frac{T}{2} \right] \right) \]

\[ - \min \left( \dddot{y}_{p,wp}(\tau), \tau \in \left[ t - \frac{T}{2}, t + \frac{T}{2} \right] \right) \]

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Even if a new European standard has been published, …

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