Ride quality objective evaluation of heavy commercial vehicles

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Main goals

- Definition of a Ride Perceived Quality Index
- Definition of Vehicle Technical Specifications for Target Setting

and then ...

- Objective Ride Methodology definition
- Subjective Ride Methodology tuning (Customer Perceived)
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Ride Objective Evaluation in Fiat Group

From the beginning of the ’90s a Vibration Perceived Quality Index has been established in Fiat Group Automobiles.

Now the same approach has been transferred towards Heavy Trucks.

IQV distribution

Measured vehicles

IQV value

Class B
Class C
Class D
Class E

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Ride Quality Index HCV
Background and Project Plan

QUALITY INDEX – APPLIED PROCEDURE

SUBJECTIVE ANALYSIS

- Questionnaire definition
- Statistical spread analysis (outlier judges, not significant aspects)
- Partial rating determination
- Correlation analysis (partial rating influence on the global one)

Test Mission Definition

OBJECTIVE ANALYSIS

- Sensor setup and measures
- Objective parameters computation

Objective Parameters selection on basis of correlation analysis (statistical + technical analysis)
- Partial Index definition (multi-linear regression models)
- Partial quantities weight fine tuning on Global

OVERALL RIDE QUALITY INDEX
Background and Project Plan

REFERENCE VEHICLES

- 5 vehicles (balance between significant statistic sample and test timing/resources)
- Test Configuration: Full Load since these vehicles are mainly used in this way
- Test vehicles remarkably different to assure best subjective perception distinction (among Worst and Best in Class). Therefore, test vehicles NOT defined with performance benchmarking criteria BUT to assure the best evaluation of Ride differences to define the quality index.

TEST TRACK:

<table>
<thead>
<tr>
<th>Subjective</th>
<th>Objective</th>
</tr>
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<tbody>
<tr>
<td>La Mandria/Balocco</td>
<td>La Mandria/Balocco</td>
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Questionnaire definition and Jury Selection

**Jury Selection**
- 15 Drivers
- Professional drivers
- Selected from IVECO and external companies

**Subjective evaluation**

**Vibration Quality**

- **Vibration at Idle**
  - Floor
  - Seat Cushion
  - Seat back
  - Steering Wheel

- **Vibration on Highway**
  - Floor
  - Seat Cushion
  - Seat back
  - Steering Wheel

- **Vibration on Rough Roads**
  - Floor
  - Seat Cushion
  - Seat back
  - Steering Wheel
  - Cab motions

- **Vibration on obstacle**
  - Floor
  - Seat Cushion
  - Seat back
  - Steering Wheel
  - Cab motions
Subjective evaluation

Statistical spread analysis

Search of outlier judges

Driver with different average votes
Drivers who do not use the full scale range

More meaningful aspects

Judges could not evaluate only 1 aspect: steering wheel vibration on pavè
Evaluation of vibration perceived at the seat cushion on a rough road. A certain overlapping between statistical groups is observed.
A principal component analysis has been applied for the identification of the main clusters in subjective perception.
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Objective evaluation

- Vehicle setup
- Test procedure
- Post-processing and Example of some results

Measured variables for quality index are:
- TRIAXIAL ACCELERATION AT THE SEAT CUSHION
- TRIAXIAL ACCELERATION UNDER THE SEAT (CAB SIDE)
- VERTICAL ACCELERATION AT THE SEAT GUIDE
- VERTICAL ACCELERATION AT THE FLOOR
- TRIAXIAL ACCELERATION AT THE STEERING WHEEL

TOTAL: 11 channels + vehicle speed
Objective evaluation

- Vehicle setup
- **Test procedure**
- Post-processing and Example of some results

Ride road tests:
- Highway
- Rough Roads (both asphalt and paved)
- Rectangular obstacle
- Idle

**Seat Guide vertical Acceleration**

- Vehicle A
- Vehicle B
Objective evaluation

- Vehicle setup
- Test procedure
- Post-processing and synthesis

Main calculated parameters

Random Roads & Idle
- RMS in time domain
- RMS in a frequency band
- RMS from spectra filtered ISO 2631

Obstacle:
- Range
- RMS
- RMS difference (between impact and stationary)
- Dissipation Time
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Ride Quality Index

The process for Index identification

1: Partial index
Subjective evaluations are correlated with measured parameters.

2: Global quality index
Starting from the weights of partial aspects on global determined from subjective evaluation, a refinement is done in order to compensate the aspect not yet covered by partial objective indexes.
Ride Quality Index

Partial ratings: Correlation with Subjective Evaluations

Seat vibration on rough road

Index = A + B * Param1 + C * Param2

Parameters:
- **Param1**: RMS of vertical vibration at seat guide ISO 2631 filtered
- **Param2**: RMS of longitudinal vibration at cushion

\[ R^2 = 0.78 \]
\[ \text{RMSE} = 0.43 \]
Ride Quality Index

Global Ride rating: Correlation & Composition

Subjective global Ride evaluation vs. Predicted global Ride Perceived Quality

- Vehicle A
- Vehicle B
- Vehicle C
- Vehicle D
- Vehicle E

R² = 0.80
RMSE = 0.67
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Conclusions and Next steps

**A methodology for objective Ride assessment of HCV was developed**

- TECHNICAL TARGET SETTING USING PERCEIVED QUALITY INDEX
- OBJECTIVE EVALUATION OF PROJECT SOLUTIONS/PROTOTYPES
- TARGET DEPLOYMENT REVIEW/IMPROVEMENT

**Next steps: further methodology development**

- DEPLOYMENT TO SUBSYSTEMS AND COMPONENTS - PROCEDURES & STANDARDS
- TARGET VIRTUAL VERIFICATION USING SIMULATION MODELS
- EXTENSION TO OTHER VEHICLE PERFORMANCES