HANDLING QUALITY OBJECTIVE EVALUATION OF LIGHT COMMERCIAL VEHICLES

PRESENTING AUTHOR
M. Pesce
CRF, VEHICLE DYNAMICS

CO-AUTHORS
D. Gostoli, A. Fagiano - IVECO, QUALITY EVALUATION, CS & QUALITY
M. Mazzarino - IVECO, TECHNICAL INNOVATION
S. Data, M. Grillo - CRF, VEHICLE DYNAMICS
C. Randazzo - CRF, PRODUCT QUALITY

Stuttgart, May 6, 2008
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Main goals

- **Objective Handling Methodology definition**;
- **Subjective Handling Methodology tuning (Customer Perceived)**;
- **Subjective-Objective Handling Correlation – Handling Quality Index (IQH or other)**;
- **Know How / Know Why competences for Objective and Subjective Handling Assessment**;

- **New internal Handling Norm definition (Subjective/Objective/IQH)**;
Main goals

APPLICATION: NEW DAILY PLATFORM:

Target Setting: technical measurable Target Definition

Target Deployment: Break Down on Technical Functions Review
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Quality Indexes approach

CUSTOMER ORIENTATION IN VEHICLE DESIGN:
Methods/Tools Development and Application for target setting, deployment and achieving

Fuel consumption
Handling & Steering
Driveability Vibration
Braking

Purchase Criteria & Perceived Quality
Perceived Quality measurements (Q.I.)
Deployment procedure & simulation tools

Voice of Customer
Vehicle Target Setting
Sub-systems Target Deployment
Components Target Achieving

Design Specifications

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Handling Quality Index LCV
Quality Indexes approach

QUALITY INDEXES (Q.I.)

SUBJECTIVE Characterisation

- Panel Test: professional and non-professional drivers in free driving conditions
- Questionnaire: subjective assessments expressed on different levels coherent with the performance tree
- Evaluation on a panel of different vehicles

OBJECTIVE Characterisation

- Instrumented Vehicle
- Test Procedure: standard maneuvers carried out on the basis of specific requirements
- Objective Parameters: acquisition and analysis of road data for the identification of performance indicators

STATISTICAL Analysis

Objective vs Subjective

• Partial Quality Index IQ<sub>1</sub>: R² = 0.54
• Subjective Judgment vs IQ<sub>1</sub>: R² = 0.51
• IQ vs Customer Perception: R² = 0.35

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Quality Indexes approach

Handling Objective Evaluation in Fiat Group

Continuous development according to Fiat Group experience & ISO TC22/SC9 New Work items:
- limit handling
- rollover, NHTSA
- uneven roads
- power on / power off
- braking

Extension vs. Light & Heavy Commercial Vehicles
Extension vs. Agricultural Tractors

References about objective handling assessment in Fiat Group

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Conference / Journal</th>
<th>Seat</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective evaluation of steering system quality</td>
<td>Data, Ugo (CRF)</td>
<td>Fisita 96</td>
<td>Praga</td>
<td>Jun-96</td>
</tr>
</tbody>
</table>
| Vehicle lateral dynamics analysis in frequency domain: the car as a linear system | Camuffo, Data (CRF)  
Krief (Fiat Auto) | ATA 1999                      | Firenze | Nov-99 |
| Brake system quality evaluation                 | Ricci, Ugo (CRF)             | Testing Expo                                  | Stuttgart | Jun-01 |
| Objective evaluation of handling quality         | Data, Frigerio (CRF)         | Journal of automobile engineering - Special issue on Vehicle Dynamics | -     | Mar-02 |
| Evaluation Criteria for AWD vehicles system analysis | Borio, Delcaro, Frediani, Ricci (CRF)  
Caviasso (Fiat Auto) | SAE - Automotive Dynamics & Stability Conference | Detroit | Mar-04 |
| Handling on uneven roads: testing and simulation | Camuffo, Frigerio, Santi (CRF) | Vehicle Dynamics Expo 2005                     | Stuttgart | Jun-05 |
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QUALITY INDEX – APPLIED PROCEDURE

- EXPERIMENTAL MEASUREMENTS IN STANDARD MANOEUVRES
- VEHICLE HANDLING EVALUATION QUESTIONARY
- OBJECTIVE PARAMETERS IDENTIFICATION
- STATISTICAL ANALYSIS ON SUBJECTIVE EVALUATION
- OBJECTIVE PARAMETERS CORRELATION vs. SUBJECTIVE EVALUATIONS
**Project plan**

**REFERENCE VEHICLES**

- **5 vehicles** (balance between significant statistic sample and test timing/resources)
- Test Configuration: **No Load / Full Load**
- Test vehicles remarkably different to assure best subjective perception distinction (among Worst and Best in Class). Therefore, test vehicle **NOT** defined with performance benchmarking criteria **BUT** to assure the best evaluation of Handling differences in the frame of IQH construction.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle A</strong></td>
<td>wheelbase 3.3, H2, Tyres 225/70 R15, no ESP</td>
</tr>
<tr>
<td><strong>Vehicle B</strong></td>
<td>wheelbase 3.0, H2, Tyres 225/65 R16, with ESP</td>
</tr>
<tr>
<td><strong>Vehicle C</strong></td>
<td>wheelbase 3.75, Twin Tyres 195/65 R16, with ESP</td>
</tr>
<tr>
<td><strong>Vehicle D</strong></td>
<td>wheelbase 3.66, 315F37/35, Tyres 235/65 R16, with ESP</td>
</tr>
<tr>
<td><strong>Vehicle E</strong></td>
<td>wheelbase 3.5, Tyres 225/70 R15, no ESP</td>
</tr>
</tbody>
</table>

**TEST TRACK:**

- **Subjective**: *La Mandria/Scarmagno*
- **Objective**: *La Mandria/Balocco*
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Subjective evaluation

Goals:

- Definition of a questionnaire to be used for Subjective Handling tests.
- Building of the Db of the average subjective ratings, that will be correlated with objective measurements.
- Estimation of the weights of the partial aspects on the global handling evaluation.

1. Questionnaire definition and Jury Selection
2. Statistical spread analysis to search outlier judge or not significant aspects
3. Partial rating determination
4. Correlation analysis to evaluate the influence that every partial rating has on the global one.
Subjective evaluation

Questionnaire definition and Jury Selection

<table>
<thead>
<tr>
<th>Questionnaire subjective Handling LCV (11 partial ratings + 1 global)</th>
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<tbody>
<tr>
<td>Feeling I/QS + IQH</td>
</tr>
<tr>
<td>Steering wheel Torque feedback</td>
</tr>
<tr>
<td>Steering wheel torque in parking                            U</td>
</tr>
<tr>
<td>Steering wheel torque in normal driving                     B</td>
</tr>
<tr>
<td>On center quality                                            U</td>
</tr>
<tr>
<td>Steering wheel re-alignment velocity and free steer stability B</td>
</tr>
<tr>
<td>Lateral Dynamics Response</td>
</tr>
<tr>
<td>Steering wheel activity in cornering                        B</td>
</tr>
<tr>
<td>Quickness of vehicle response in cornering                  B</td>
</tr>
<tr>
<td>Vehicle feedback progressiveness                             U</td>
</tr>
<tr>
<td>Aerodynamics interactions sensitivity                       U</td>
</tr>
<tr>
<td>Traction capability in a curve                               U</td>
</tr>
<tr>
<td>Roll Response</td>
</tr>
<tr>
<td>Roll motion in cornering                                     B</td>
</tr>
<tr>
<td>Roll velocity in cornering                                   B</td>
</tr>
</tbody>
</table>

U = Unipolar
B = Bipolar

Jury Selection
- About 15 Drivers
- Professional and non professional drivers
- Selected from IVECO, FGA, CRF

Subjective evaluation

Unipolar aspect
Example: On center quality

Bipolar aspect
Example: Steering wheel torque in normal driving

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Handling Quality Index LCV
Subjective evaluation

Statistical spread analysis

Search of outlier judge

Search of more meaningful aspects

Driver more aligned at the average evaluation

Driver more different from average evaluation

More meaningful aspects
Subjective evaluation

Partial ratings
Average evaluations of partial aspects by the whole jury for each vehicle
Subjective evaluation

Partial rating example: Roll Motion

Evaluation of global roll angle during turning in a normal driving without rapid transient maneuvers (“quasi steady” conditions).

Evaluation diagrams for empty and full load vehicles showing subjective evaluation of roll motion for different vehicles.

Subjective evaluation

Handling Global Evaluation in Normal Driving

Global Rating

Weights of the partial aspects

A principal component analysis approach has been applied for the identification of the main clusters in subjective perception.

Some aspects are not relevant from a statistical point of view.
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Objective evaluation

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

Measured signals and measurements/filtering procedures comply to ISO 15037-1

Measured variables for quality indexes are:
- STEERING WHEEL ANGLE
- LATERAL ACCELERATION
- YAW RATE
- SIDE SLIP ANGLE
- STEERING WHEEL TORQUE
- ROLL RATE
- THROTTLE POSITION
- VEHICLE SPEED

Additional signals are acquired for a more complete analysis:
longitudinal acceleration, pitch rate, suspension travel, height sensors
Objective evaluation

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

Handling road tests (Balocco & La Mandria tracks):

- Steady state circular test 40 m (ISO 4138)
- Constant speed test 80 km/h (ISO 4138)
- Step steer input 100 km/h (ISO 7401)
- Free steer control test 100 km/h (ISO 17288)
- Sweep input 60-100 km/h – 0.25, 0.4, 0.55 g (ISO 7401)
- Sinusoidal input 60-120 km/h – 0.2 Hz – 0.25 g (13674-1)
- Complete steer cycles with vehicle in standstill and at low speed
Objective evaluation

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

Main calculated parameters:
- Steady state behaviour,
- Transient gains,
- Time delay,
- Hysteretic cycles.

Regarding:
- Lateral dynamics,
- Roll response,
- Steering wheel torque.

In different conditions of:
- Vehicle speed,
- Steering wheel amplitude,
- Steering wheel frequency.
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The process for Index identification

1: Partial index
Subjective evaluations are correlated with measured parameters starting from the IQH car experience.
Weights are modified and additional parameters are included in the model when necessary to improve the correlation level.
A final rating in 0-10 scale is obtained.

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.
Quality Index (IQH)

Partial ratings: Correlation with Subjective Evaluations

**LCV feedback progressiveness**

\[ I_{pi} = A + B \times (C_0 + C_1\times\text{Param1} + C_2\times\text{Param2} + C_3\times\text{Param3}) \]

**Parameters:**

- **Param1:** time delay between yaw rate and lateral acceleration calculated in manoeuver frequency sweep, at speed 60 kph, linear range.
- **Param2:** …
- **Param3:** …

Subjective Rating vs. Objective Index

- Full load
- Empty

R\(^2\) = 0.91
Quality Index (IQH)

Partial ratings: Correlation with Subjective Evaluations

Objective Index

- Full load
- Empty

Subjective Rating

IAV: Steering wheel activity
R² = 0.73

IRV: Quickness in LCV response
R² = 0.79

IPI: LCV response progressiveness
R² = 0.91

ICOVC: Roll motion
R² = 0.90

ISP: Steering Wheel Torque in Parking
R² = 0.95

ISM: Steering Wheel Torque in Normal Driving
R² = 0.72

IDIR: On-centre quality
R² = 0.89

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Handling Quality Index LCV
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Conclusions and Next steps

A methodology for objective handling assessment of LCV was developed, starting from past experience on passenger cars, ready for application

- TECHNICAL TARGET SETTING USING IQH
- TARGET DEPLOYMENT REVIEW/IMPROVEMENT
- TARGET VIRTUAL VERIFICATION USING SIMULATION MODELS
- OBJECTIVE EVALUATION OF PROJECT SOLUTIONS/PROTOTYPES

Next steps: further methodology development

- EXTENSION TO M-HCV
- EXTENSION TO HANDLING PARAMETERS NOT YET COVERED BY OBJECTIVE TESTING PROCEDURES (e.g. Aerodynamics Interaction sensitivity)
- DEPLOYMENT TO SUBSYSTEMS AND COMPONENTS - PROCEDURES & NORMS
- EXTENSION TO OTHER VEHICLE PERFORMANCES (e.g. Driveability, Ride comfort, ...)