FIAT GROUP

Trucks and Commercial Vehicles

CRF CENTRO RICERCHE FIAT

IVECO

HANDLING QUALITY OBJECTIVE EVALUATION OF LIGHT COMMERCIAL VEHICLES

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Main goals

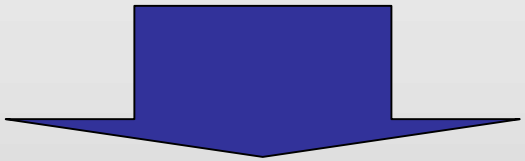
- *Objective Handling Methodology definition;*
- *Subjective Handling Methodology tuning (Customer Perceived);*
- *Subjective-Objective Handling Correlation – Handling Quality Index (IQH or other);*
- *Know How / Know Why competences for Objective and Subjective Handling Assessment;*

- *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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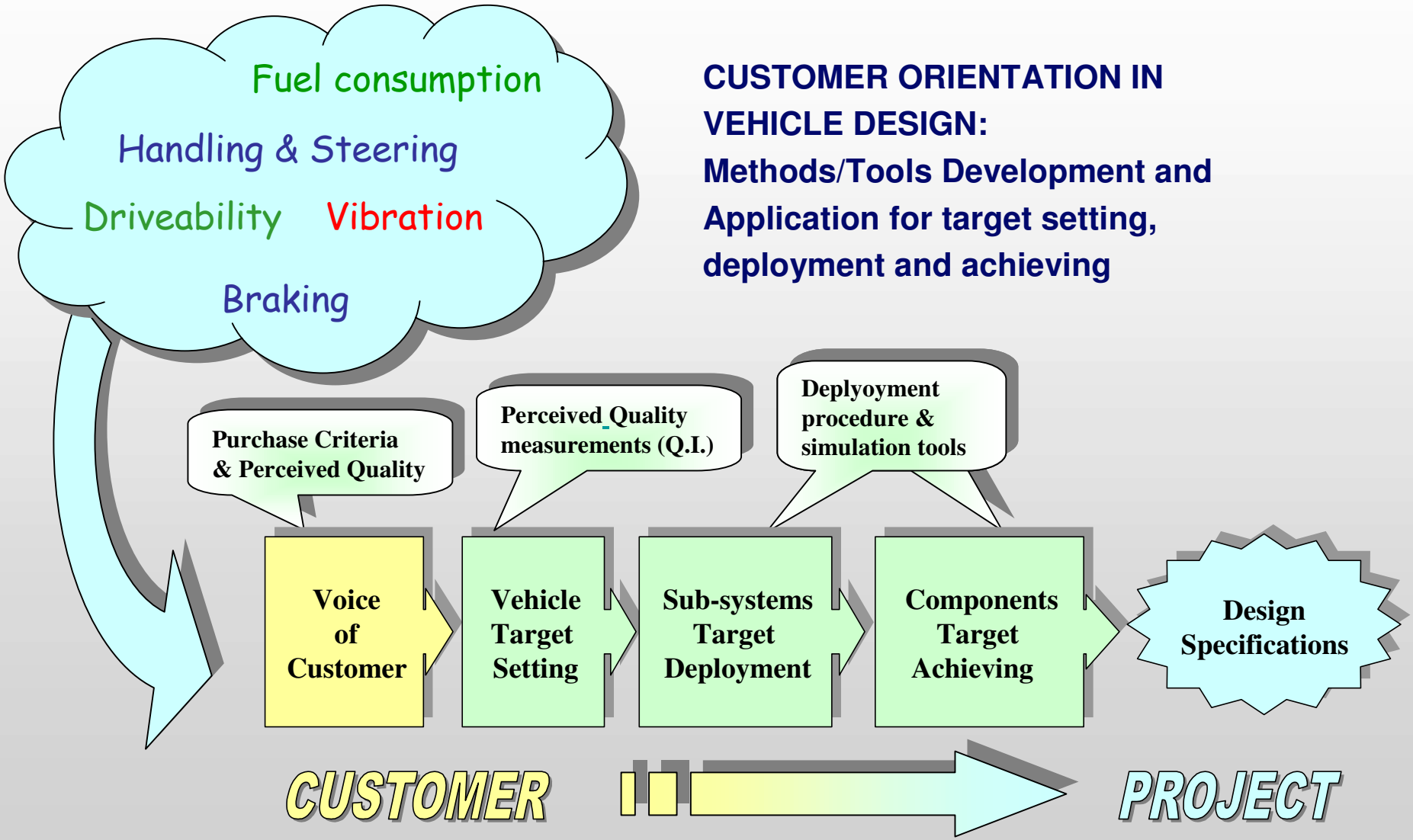
Quality Indexes approach



Quality Indexes approach

QUALITY INDEXES (Q.I.)

SUBJECTIVE Characterisation

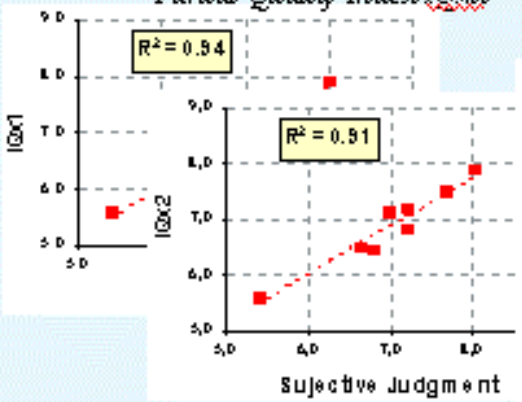
- **Panel Test:** professional and non professional drivers in free driving conditions
- **Questionnaire:** subjective assessments expressed on different levels coherent with the performance tree
- **Evaluation on a panel of different vehicles**

OBJECTIVE Characterisation

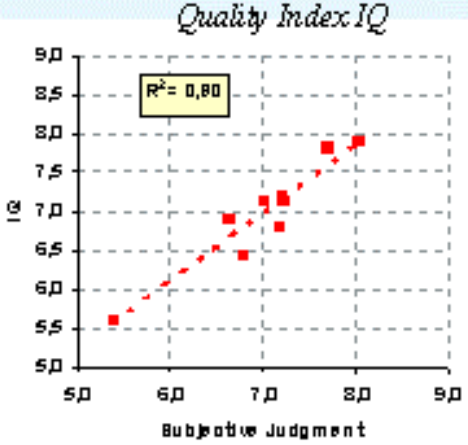
- **Instrumented Vehicle**
- **Test Procedure:** standard maneuvers carried out on the basis of specific requirements
- **Objective Parameters**: acquisition and analysis of road data for the identification of performance indicators

STATISTICAL Analysis
Objective vs Subjective

Partial Quality Index IQxx

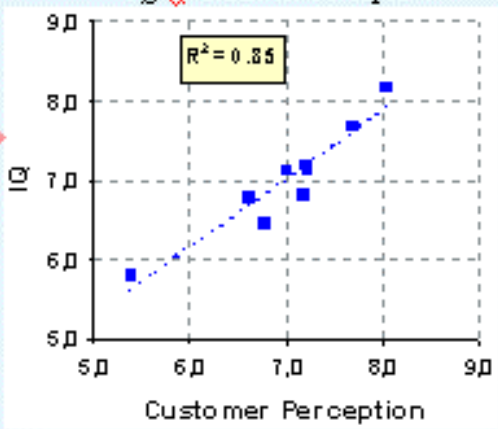


Quality Index IQ



VOC

IQ vs Customer Perception



Quality Indexes approach

Handling Objective Evaluation in Fiat Group

1994: first handling (IQH) and steering feel (IQS) metric for Fiat cars

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

Title	Authors	Conference / Journal	Seat	Date
Objective evaluation of steering system quality	Data, Ugo (CRF)	Fisita 96	Praga	Jun-96
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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Project plan

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.

• **Vehicle A**	wheelbase 3.3, H2, Tyres 225/70 R15 , no ESP
• **Vehicle B**	wheelbase 3.0, H2, Tyres 225/65 R16 , with ESP
• **Vehicle C**	wheelbase 3.75, Twin Tyres 195/65 R16 , with ESP
• **Vehicle D**	wheelbase 3.66, 315F37/35, Tyres 235/65 R16, with ESP
• **Vehicle E**	wheelbase 3.5, Tyres 225/70 R15, no ESP

TEST TRACK:

Subjective	***La Mandria/Scarmagno***
Objective	***La Mandria/Balocco***

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Subjective evaluation

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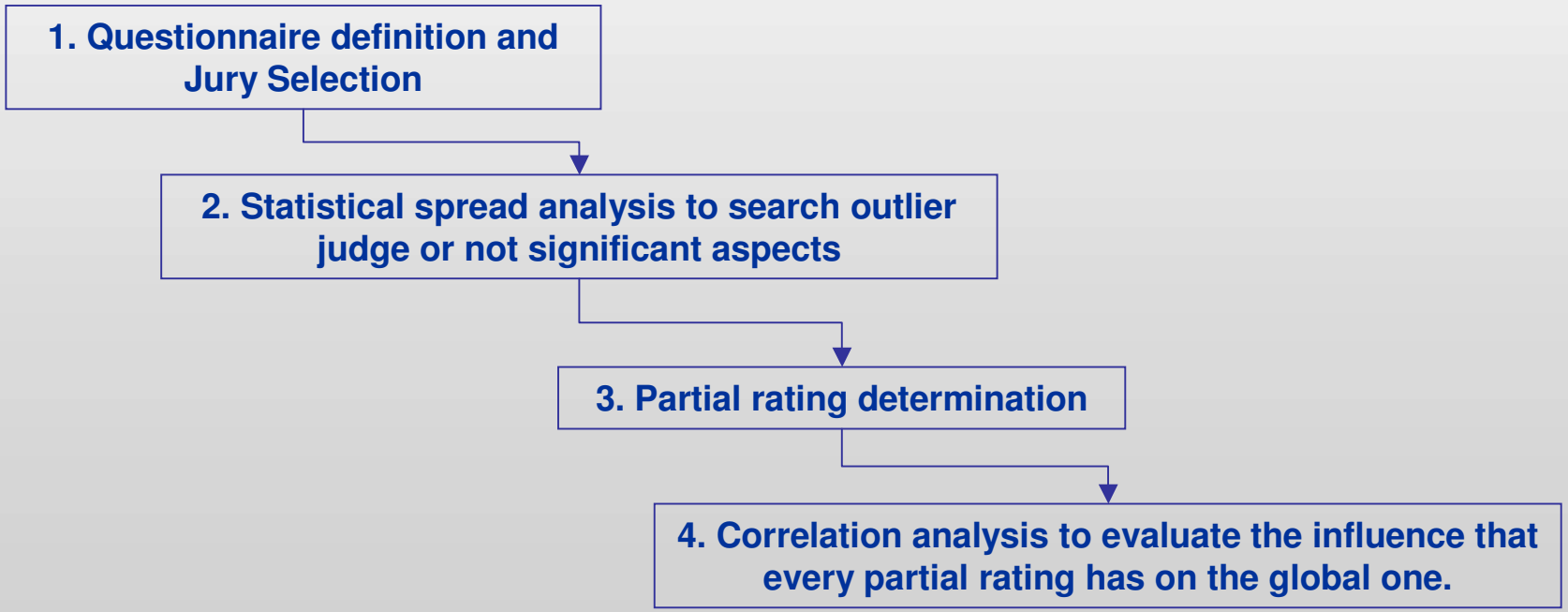
Goals:

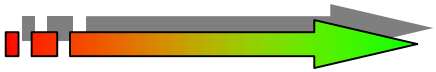
- **Definition of a questionnaire to be used for Subjective Handling tests.**
- **Building of the Db of the average subjective ratings, that will be correlated with objective measurements.**
- **Estimation of the weights of the partial aspects on the global handling evaluation.**



Subjective evaluation

Questionnaire definition and Jury Selection

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

Unipolar aspect Bad  Good

Example: On center quality

Bipolar aspect Too high  Optimum Too small

Example: Steering wheel torque in normal driving

Jury Selection

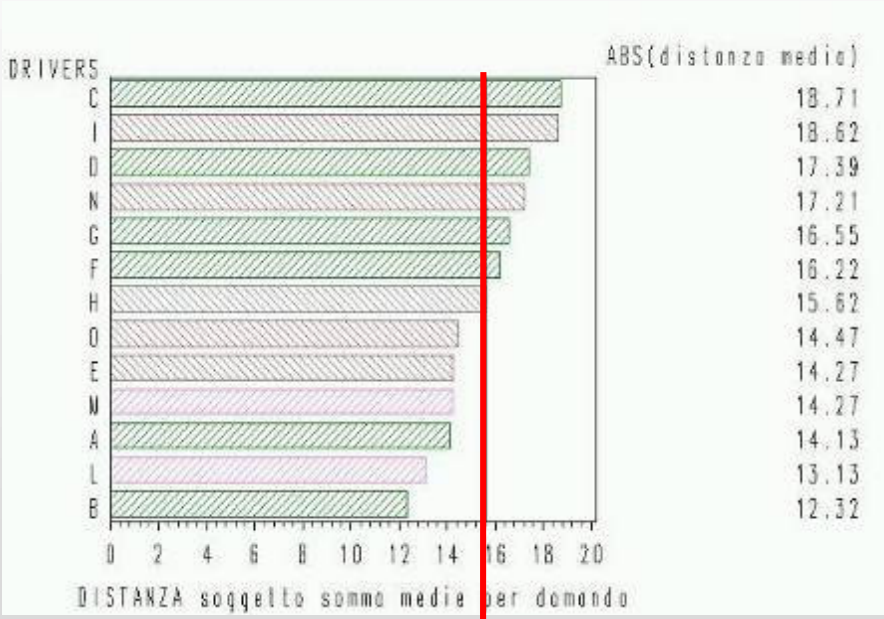
- *About 15 Drivers*
- *Professional and non professional drivers*
- *Selected from IVECO, FGA, CRF*

U =	Unipolar
B =	Bipolar

Subjective evaluation

Statistical spread analysis

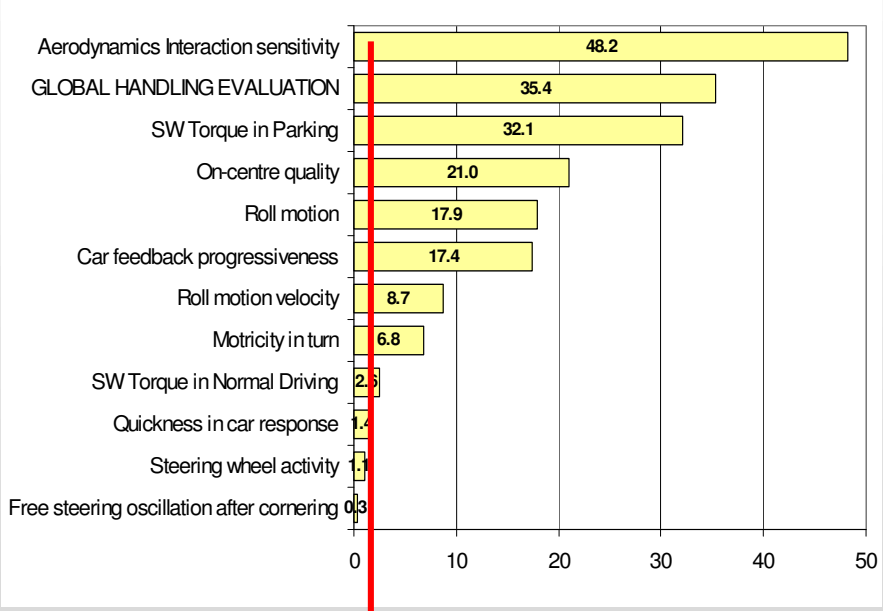
Search of outlier judge



Driver more aligned at the average evaluation

Driver more different from average evaluation

Search of more meaningful aspects

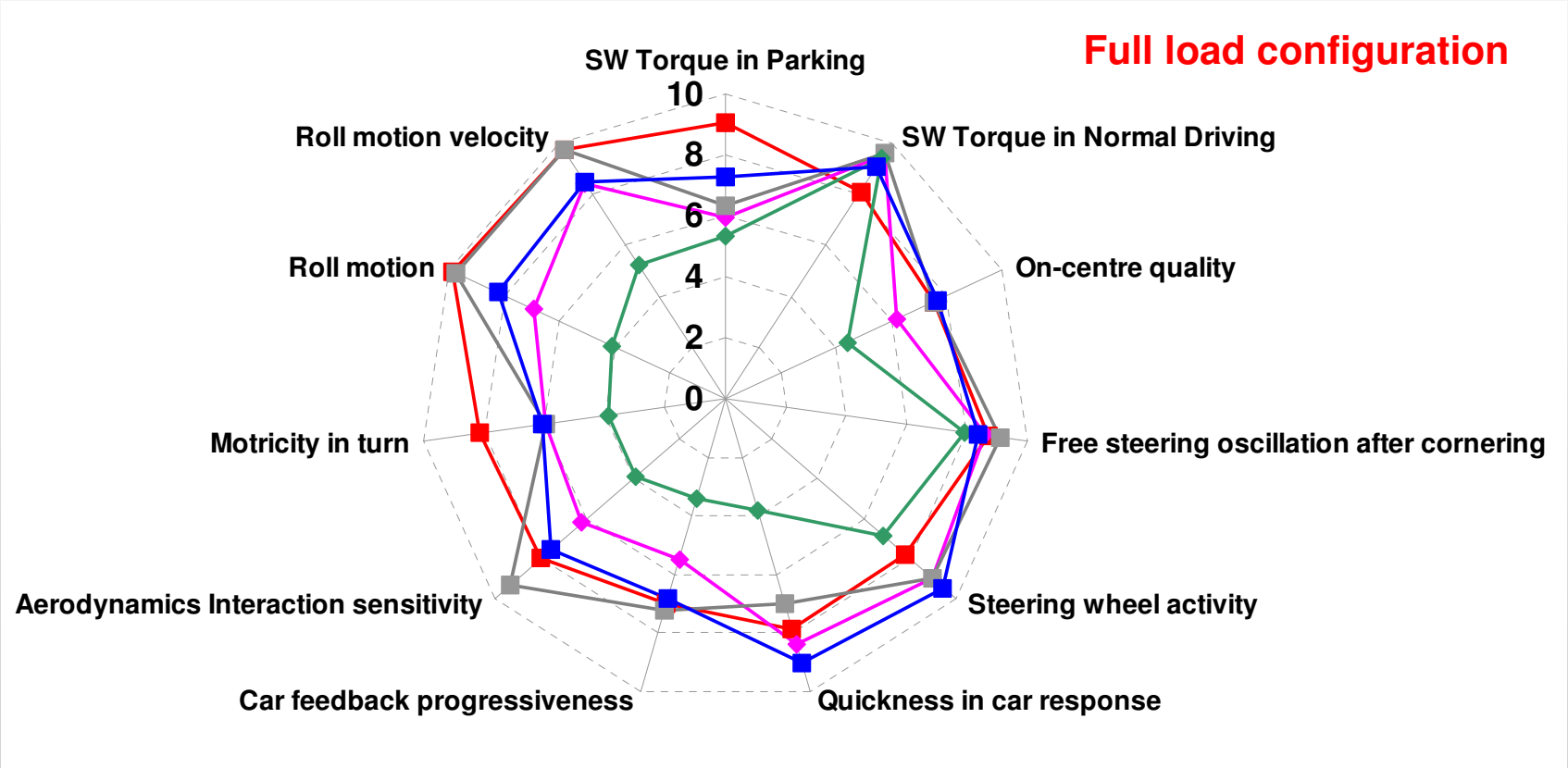


More meaningful aspects

Subjective evaluation

Partial ratings

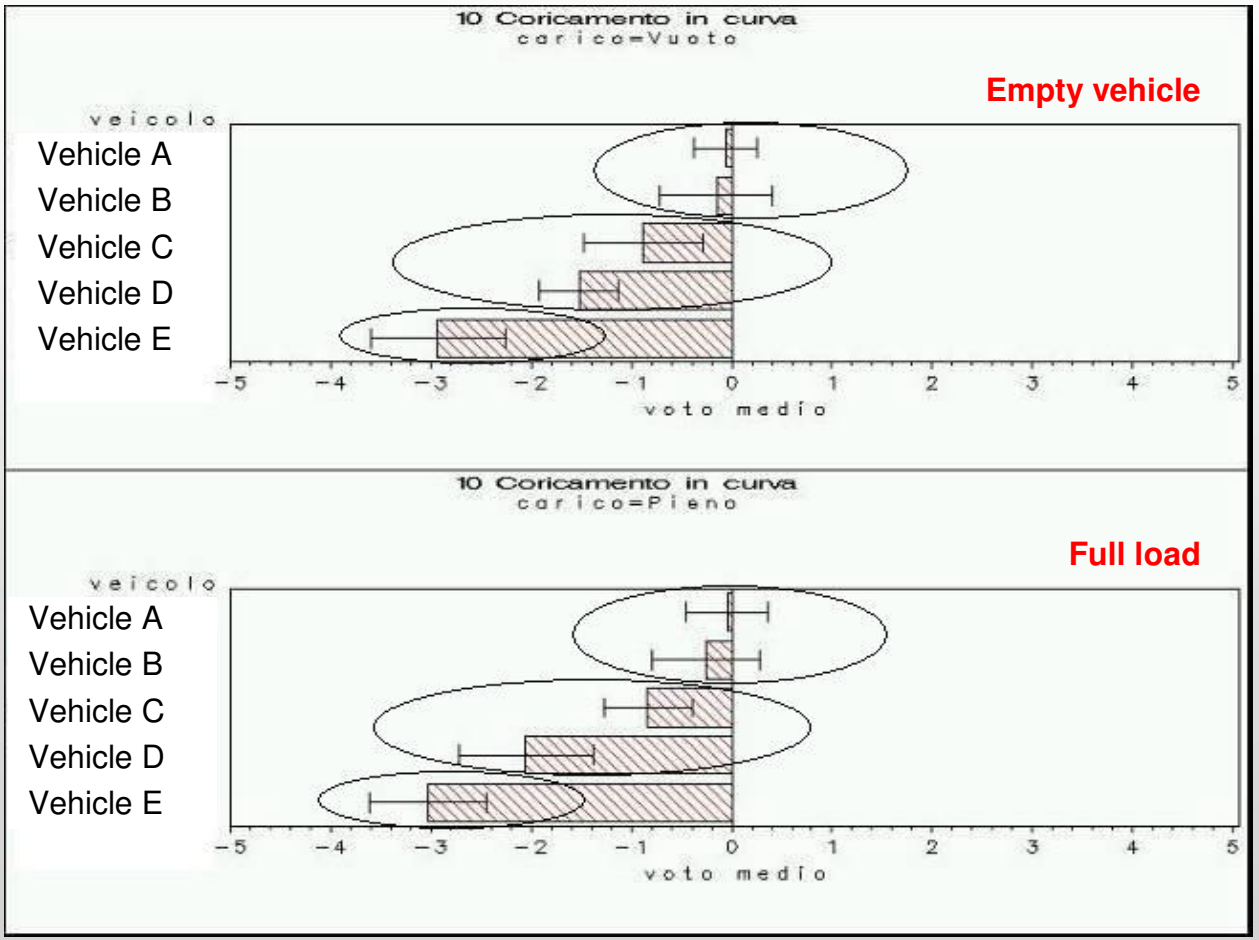
Average evaluations of partial aspects by the whole jury for each vehicle



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).

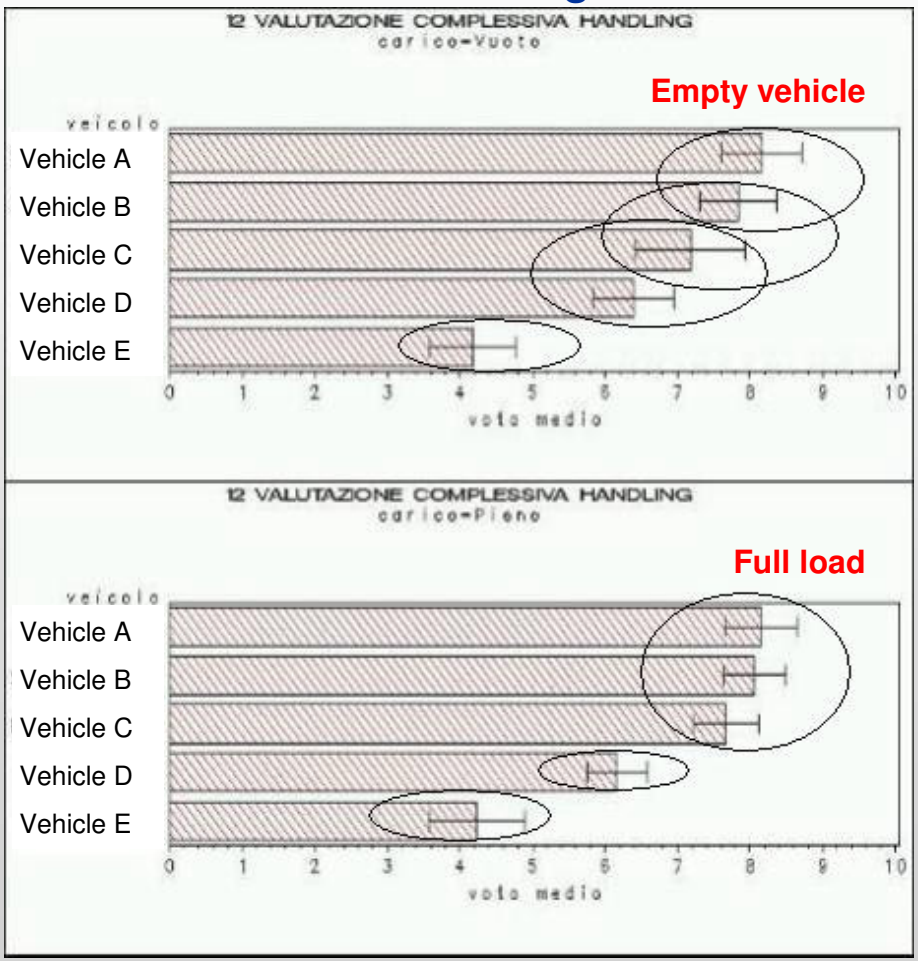


Too high [=-5] → Optimal [=0] → Too small [=5]

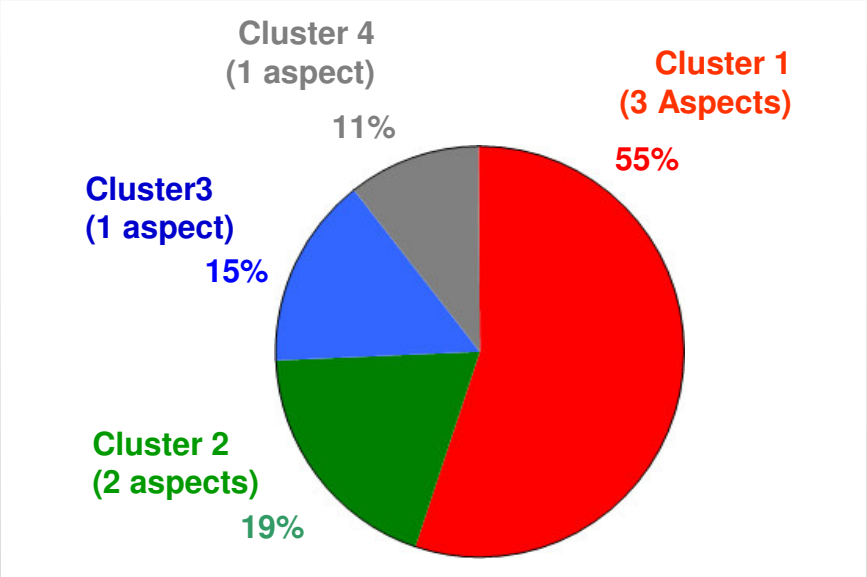
Subjective evaluation

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**

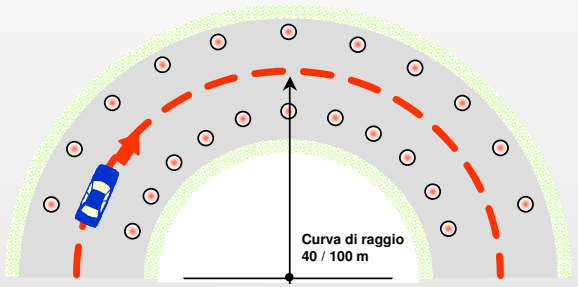
Additional signals are acquired for a more complete analysis: longitudinal acceleration, pitch rate, suspension travel, height sensors

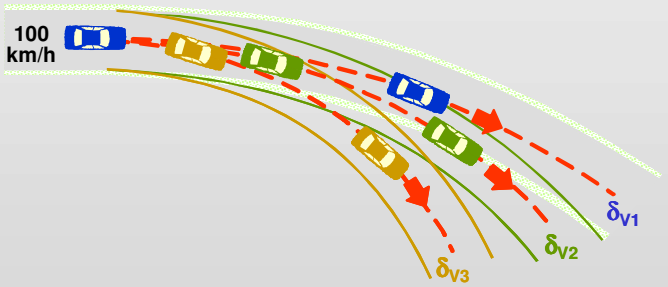
Objective evaluation

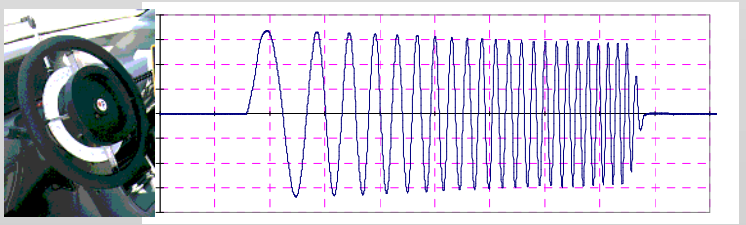
- Vehicle setup
- **Test procedure**
- Post-processing and Example of some results

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:

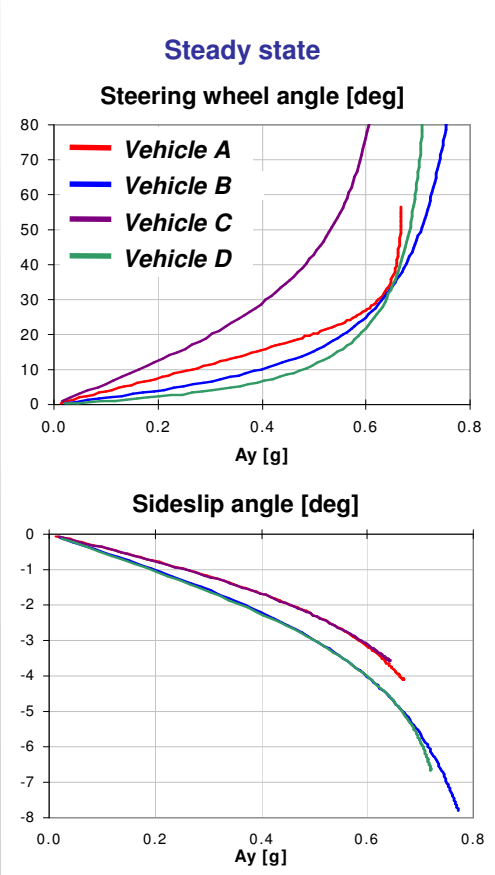
- **Steady state behaviour,**
- **Transient gains,**
- **Time delay,**
- **Hysteretic cycles.**

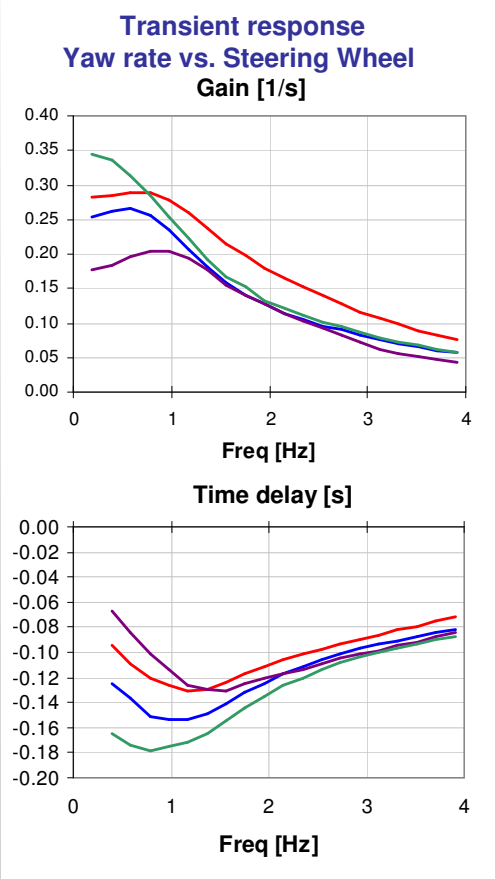
Regarding:

- **Lateral dynamics,**
- **Roll response,**
- **Steering wheel torque.**

In different conditions of:

- **Vehicle speed,**
- **Steering wheel amplitude,**
- **Steering wheel frequency.**





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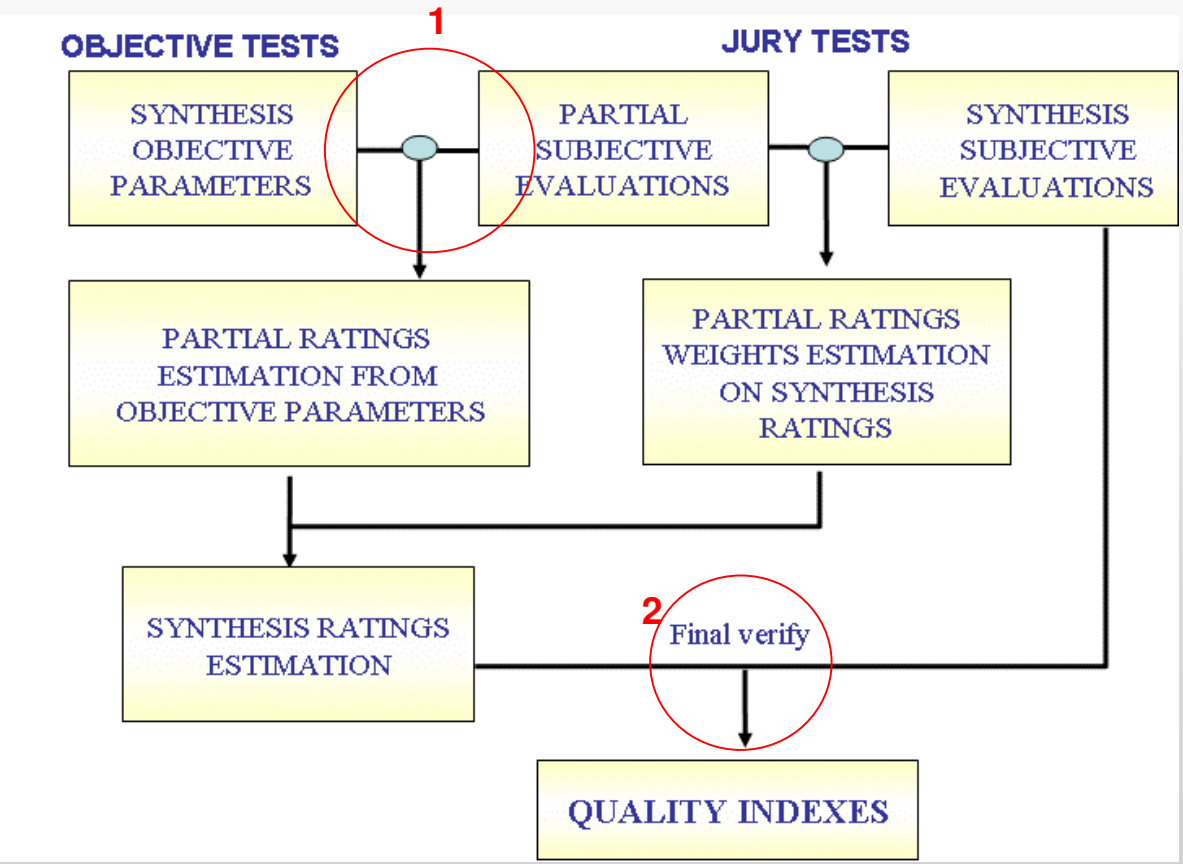
Quality Index (IQH)

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.

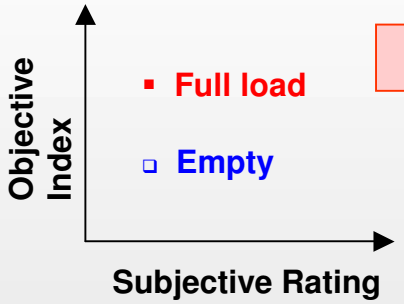
A final rating in 0-10 scale is obtained.

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

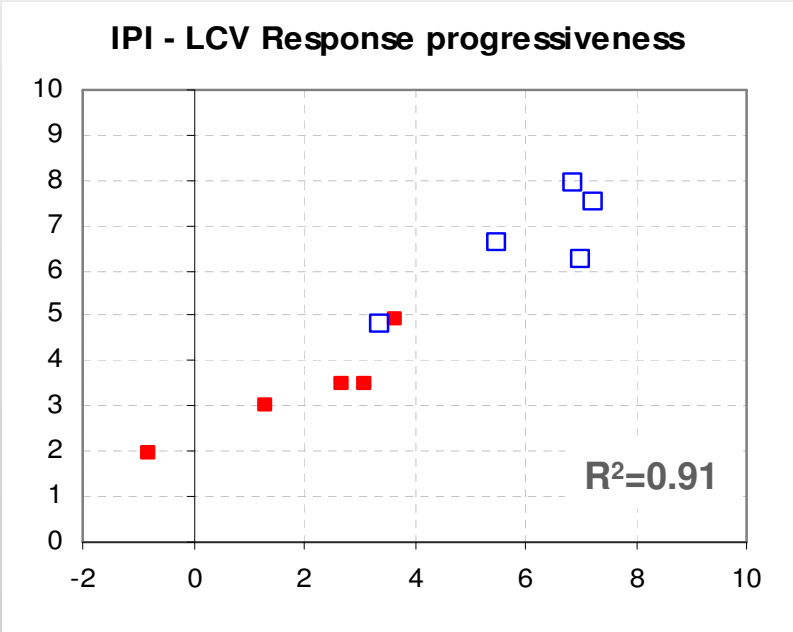
```
Ipi = A + B * [C0 + C1*Param1 + C2*Param2 + C3*Param3]
```

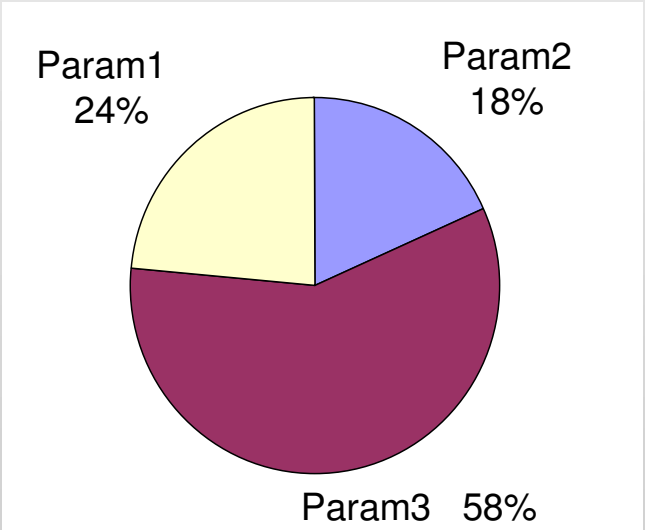
Parameters:

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

Param2: *…*

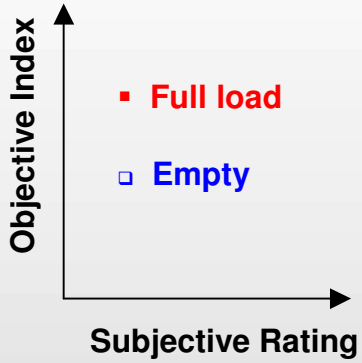
Param3: *…*



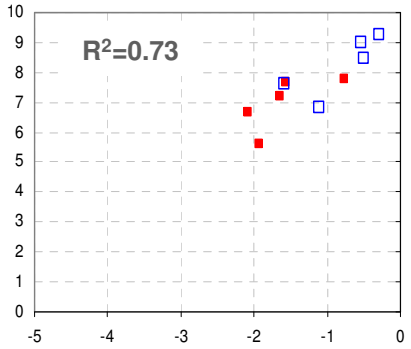


Quality Index (IQH)

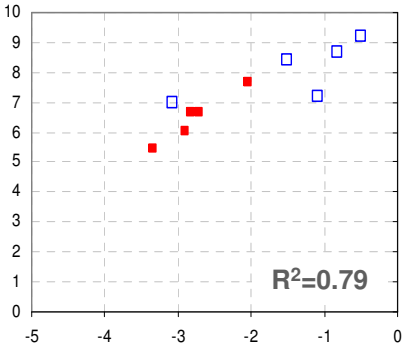
Partial ratings: Correlation with Subjective Evaluations



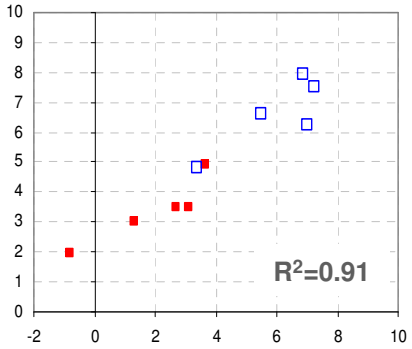
IAV: Steering wheel activity



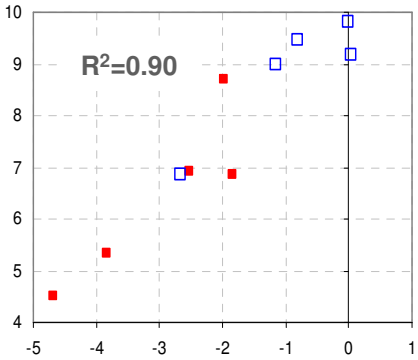
IRV: Quickness in LCV response



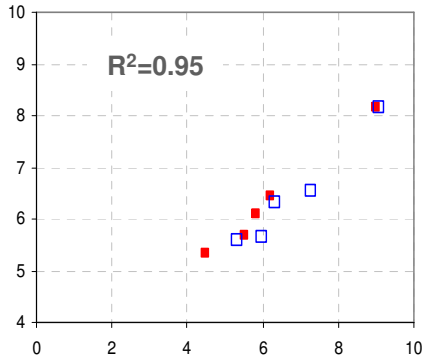
IPI: LCV response progressiveness



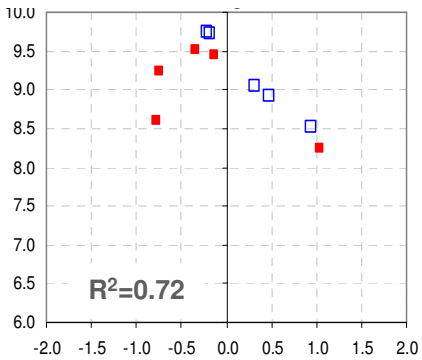
ICOVC: Roll motion



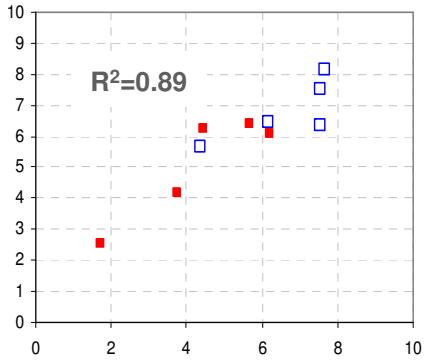
ISP: Steering Wheel Torque in Parking



ISM: Steering Wheel Torque in Normal Driving

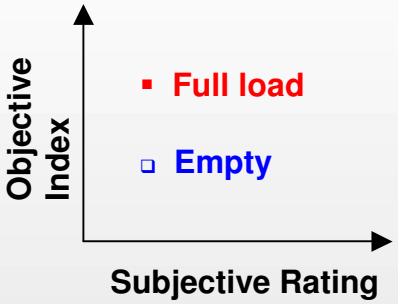


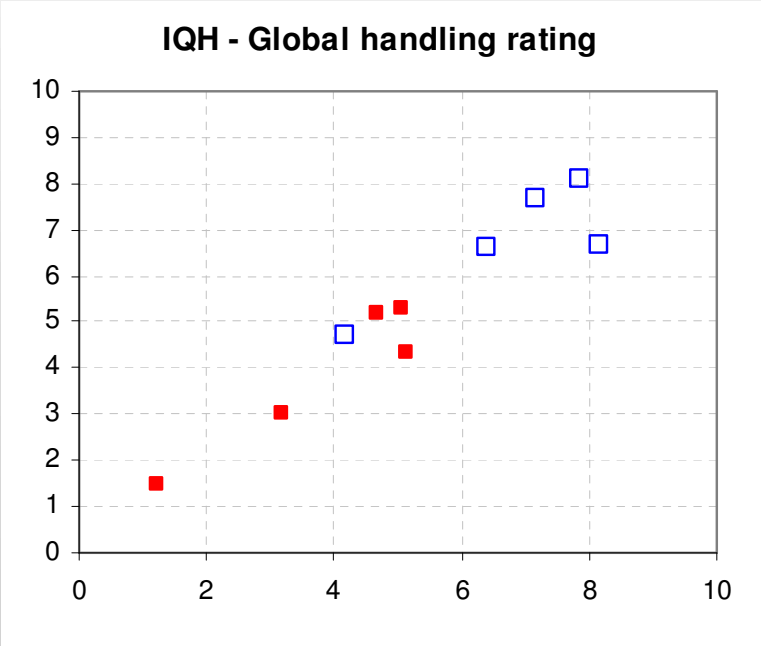
IDIR: On-centre quality



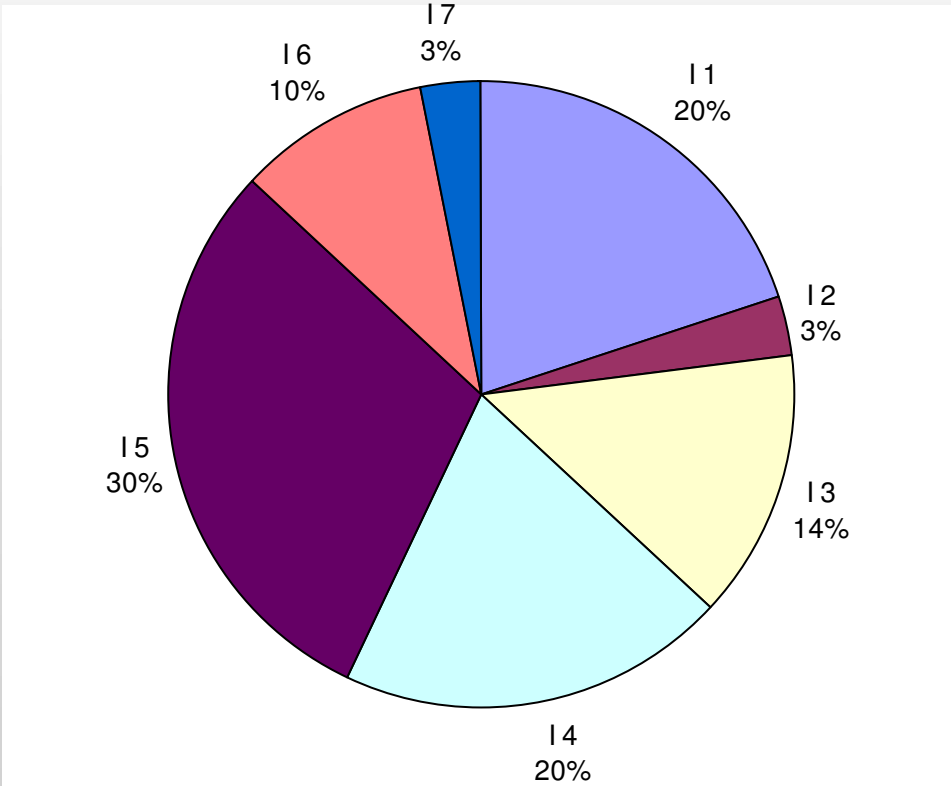
Quality Index (IQH)

Global handling rating: Correlation & Composition





Weight of Partial ratings vs. Global Index



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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, …)