Submitted by the experts of OICA

UTAC CERAM

Informal Document **GRBP-75-19 Rev.1**
75th GRBP, February 8-11, 2022
Agenda item 2

ACEA - Tyre Performance Study
Noise VS other performances

10/02/2022 – GRBP, 75th

Update of the previous study GRBP-70-25 (presentation) / GRBP-74-09 (report)

Content

1 - Literature Study

Reason for why the literature study was conducted

- **Is it possible to optimize Rolling Sound performance without compromising other parameters essential for vehicle safety and CO2 emission reduction ?**

- **Do performance parameters, i.e., like**
  - Rolling Sound (coast-by) ➔ Health Protection
  - Rolling Resistance ➔ Environmental Protection (CO_2 emission reduction)
  - Wet Grip ➔ Safety (braking distance, handling)

- **…affect other performance parameters like**
  - Longitudinal and Lateral Aquaplaning
  - Rolling Sound during Acceleration
  - Dry Grip
  - Dry Handling
  - Wet Performance
  - Wear Life

Significant studies which have been analysed

- **Journalistic Studies**
  - EVO103_LD (2015)
  - Auto Express Studies (2018)
  - Whichcar Wheels (2017)
- **European Research Organization Studies**
  - GRB-61-03 Study based on TNO 2014 R10735 report (12 June 2014)
  - FEHRL – Study SI2,408210 Tyre/Road Noise (2007)
- **Internal Manufacturer Studies**
  - Noise Technology (Continental - 2011)
  - Noise Trade-offs (Michelin - 2007)
  - Tire-Road Noise (Goodyear - 2018)
  - Noise (Michelin – 2015)
- **Technical University Studies**
  - Inter.noise_HAMBURG 2016
  - Tyre modelling for rolling resistance (MASTER'S THESIS IN AUTOMOTIVE ENGINEERING) 2014

Analysis template

- **Framework**
  - Framework and goal of the studies
- **Content**
  - Description of the content and the parameters of the studies
- **Vehicle type**
  - Information about vehicles used for each tests
- **Tyre types, sizes and dimensions**
  - Description of the sample used for each tests
- **Tracks**
  - Description of the tracks used for each tests
- **Test methods**
  - Description of the tests methods used
  - Description of the tests conditions
  - Description of the tests equipment

Summary of all important information regarding measured parameters and test method used

Study	Wet-Grip	Longitudinal aquaplaning	Aquaplaning in curve	Dry-Grip	Handling	Snow Performance	Rolling Resistance	Rolling Sound	RS during acceleration	Wear
TNO R10735 report (2014)	EU Regulation EC1222/2009	No Information	No Information	No Information	No Information	No Information	EU Regulation EC1222/2009	- EU Regulation EC1222/2009 - VENOLIVA	- EU Regulation EC1222/2009 - VENOLIVA	No Information
FEHRL – Study (2007)	- ECE R117 - 80 to 10km/h ; water depth 1,5mm	- ECE R117 - Water depth 8 mm ; slip of 15% was reach	No Information	No Information	No Information	No Information	- ISO 8767:1992 or 9948:1992 - ISO 18 164 : 2005	ECE R117	No Information	No Information
Continental (2011)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	ECE R117	No Information	No Information
Michelin (2007 & 2015)	- 80 to 10 km/h - on macro rough surface	- Water depth 8mm - 82 to 66km/h	- Water depth 7mm - acceleration 55 to 85km/h	No Information	No Information	No Information	No Information	ISO 10 844	No Information	No Information
GoodYear (2018)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	- ISO 10 844 At 50km/h - ISO 3745	No Information	No Information
Inter-noise HAMBURG (2016)	No Information	No Information	No Information	No Information	No Information	No Information	Trailer method	CPX method nowadays specified ISO/FDIS 11 819-2	No Information	No Information
Tyre modelling for RR (2014)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information
EVO103_LD (2015)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information
Auto Express Studies (2018)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information
Whichcar Wheels (2017)	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information	No Information

➔ No study has information in each cell

Conclusions

- **3 Tyre Manufacturers studies show antagonistic relationship between Noise and Safety (Aquaplaning, Wet Grip and Handling)**
- **2 Tyre Manufacturers studies show relationship between Noise and Rolling Resistance**
- **Test procedures or testing methods are disparate from one study to another**
- **General agreement on the major role of road surface on the noise emission**
- **Due to the purpose of the journalistic studies and the lack of technical information it is difficult to make a statement about the results**
  - The main goal of the journalistic studies is to rank a sample of tyres
  - Test methods are not described precisely and are different from one study to another
  - In some studies, repeatability conditions are questionable
  - Test data are not provided
- **ACEA Tyre Performance Study aims at determining the inter-dependency between rolling sound, rolling resistance and the main safety performances by carrying out tests according to regulatory or standard procedures**

2 - Test Program

Test Program 2019

Test sample

- 16 different tyre references
  - OEM x4
  - After Market x12
- 2 snow tyres (3PMSF) among the 16
- 205 55 R16 91H, T, V or W
  - Most common size on European after market

Tests Content

- Rolling Resistance
  - Bench test
  - RR Index
- Rolling Sound
  - Vehicle test / VW GOLF 5 & NISSAN LEAF
  - Noise level in different conditions
- Wet Grip
  - Trailer method test on wet surface
  - Wet Grip index
- Dry Grip
  - Vehicle test / PEUGEOT 308
  - Braking performance on dry surface
- Dry handling (Flat) Track
  - Bench test
  - Cornering stiffness
- Aquaplaning
  - Vehicle test / PEUGEOT 308
  - Aquaplaning speed and acceleration under aquaplaning condition

Test Program – Tyre Wear

Test sample

- **6 tyres selected out of 16 tyres from original program**
  - After Market x 6
  - B, C, I, L, O, P
- 205 55 R16 91H, T, V or W
  - Most common size on European after market

Tests Content

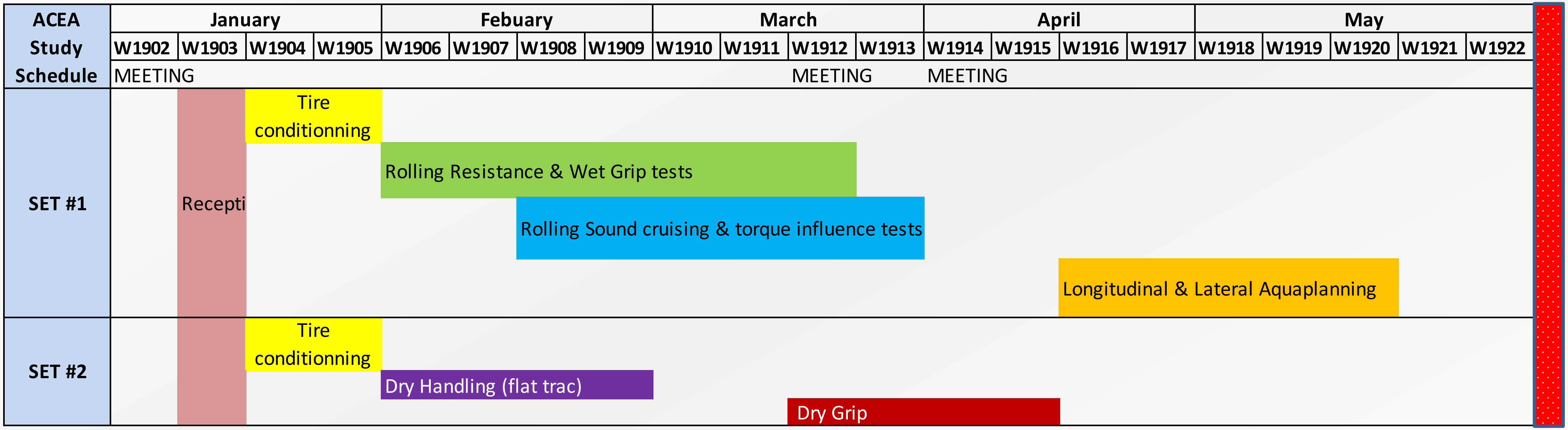
- Wear
  - 6 Vehicles for testing- PEUGEOT 308
  - Circuit on open roads 15 000 Km
  - The tyres were switched between all cars for each 500 km intervals
  - The drivers switched 3 times between cars for each 500 km intervals
  - Measurements every 3 000 km

Test Programs

Test Methods

- Rolling Resistance : UN Regulation No.117 procedure
- Rolling Sound : UN Regulation No.117 procedure & UN Regulation No.R51.03
- Wet Grip : UN Regulation No.117 procedure
- Dry Grip : UN Regulation No.R13H procedure Type 0
- Dry handling (Flat Track): Procedure proposed by ETRTO
- Aquaplaning : VDA E08 Longitudinal Aquaplaning & VDA E05 Lateral Aquaplaning
- Wear : specific test on open roads, validated by ACEA

Tests Schedule



The wear study was carried out from 25/05/21 to 27/07/21

3 - Statistical Analysis

Interdependence analysis

Results, Explanations & Interpretation

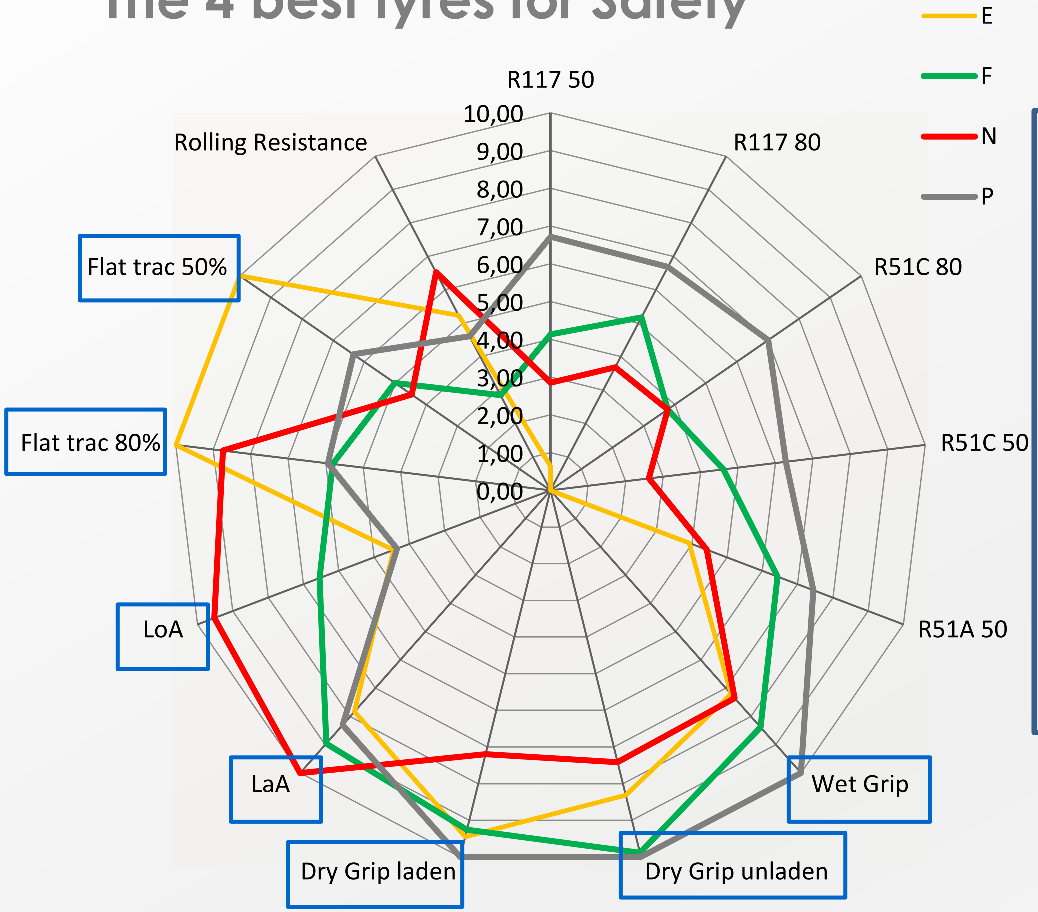
Results Table

	TEST															
	Rolling Resistance	Rolling Sound					Flat Trac		Wet Grip	Dry Grip		Longi. Aqua.	Lateral Aqua.	Weight	Void ratio	Tread Depth
List	RR (index)	R117 50 kph AVG (dB(A))	R117 80 kph Arr LR-1dB (dB(A))	R51A 50 kph (dB(A))	R51C 80 kph T° corr (dB(A))	R51C 50 kph T° corr (dB(A))	80% LI (N/°)	50% LI (N/°)	WG (index)	Ratio unladen (%)	Ratio laden (%)	Ratio LoA (%)	LaA (Integer m/s)	(Kg)	% Void	Mean (mm)
A	8,985	64,8	70,7	66,4	72,4	65,5	1417	1288	1,57	95,52	93,7	103,22	63,96	8,18	36,8	6,87
B	9,949	64,9	70,3	66,3	72,2	65,7	1387	1080	1,46	94,06	94,31	108,76	70,52	9,55	42	7,82
C	8,142	65	70,8	67,1	72,8	66,1	1265	1099	1,51	96,37	97,76	103,67	61,43	7,84	46,2	7,44
D	8,444	65,1	71,1	67,5	73	66,4	1462	1144	1,56	96,58	96,71	103,2	63,29	8,27	24,7	7,13
E	8,117	65,8	72,4	67,4	73,8	66,8	1669	1507	1,55	96,04	98,66	100,18	66,15	8,13	34,3	6,53
F	8,953	64,7	70,3	66,3	72,5	65,4	1500	1294	1,63	99,74	98,18	103,99	69,75	8,86	43,4	7,3
G	9,002	63,6	69,6	65,5	71,7	64,9	1641	1337	1,38	91,89	94,03	102,05	57,49	9,62	23,1	7,83
H	8,454	63,2	68,5	66,6	71,1	64,6	1420	1130	1,43	92,59	90,06	94,96	49,11	9,19	29,9	7,46
I	7,865	62,9	68,4	65	70,4	64,3	1550	1278	1,69	97,14	95,57	94,76	54,18	9,55	31,9	7,01
J	9,760	63	70,1	67,4	71,8	63,8	1479	1090	1,06	76,48	75,54	93,03	41,28	11,8	33	8,18
K	7,075	65,1	71,0	67,5	73	66,6	1351	1232	1,50	97,85	99,02	100,8	59,74	8,14	40,9	6,39
L	6,449	63,9	69,7	65,8	71,5	65	1326	1126	1,64	94,14	96,9	97,92	55,48	8,23	41,8	6,89
M	8,389	66	70,6	69,2	72,6	66,8	1294	1126	1,67	86,53	84,63	110,29	63,39	8,43	39,7	7,92
N	7,666	65,1	70,9	67,3	72,5	66	1618	1271	1,56	93,92	93,14	109,43	73,05	8,83	37,4	7,4
O	7,175	63,6	69,2	66,5	71,2	64,7	1382	1168	1,27	89,69	90,99	92,08	47,52	8,27	40,8	6,87
P	8,336	63,9	69,7	65,9	71,4	64,9	1505	1351	1,74	100	100	100	67,65	8,77	32,3	6,97

*Tyre P is the reference tyre for dry Grip & Longitudinal Aquaplaning.

Spider Diagrams

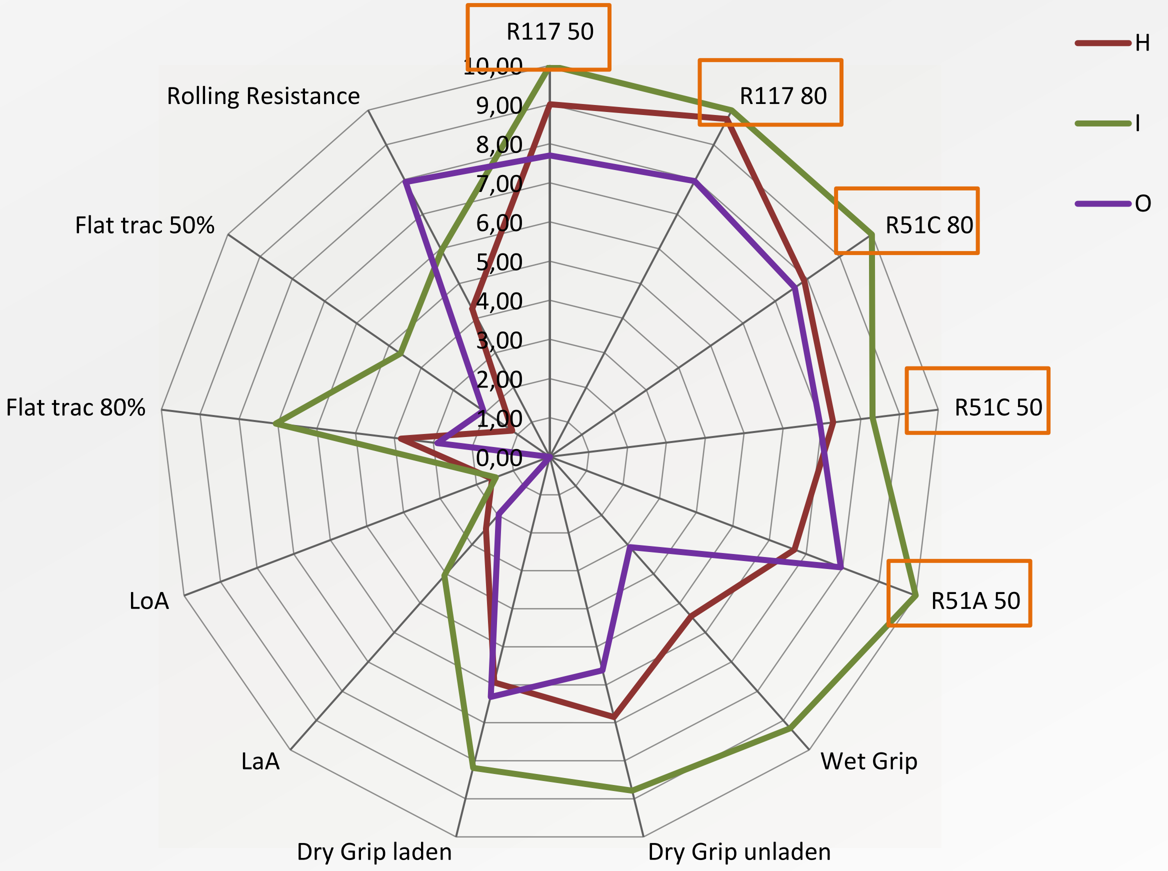
The 4 best tyres for Safety



10 : Defined by the best tyre of the sample

0 : Defined by the worst tyre of the sample

The 3 best tyres for Noise

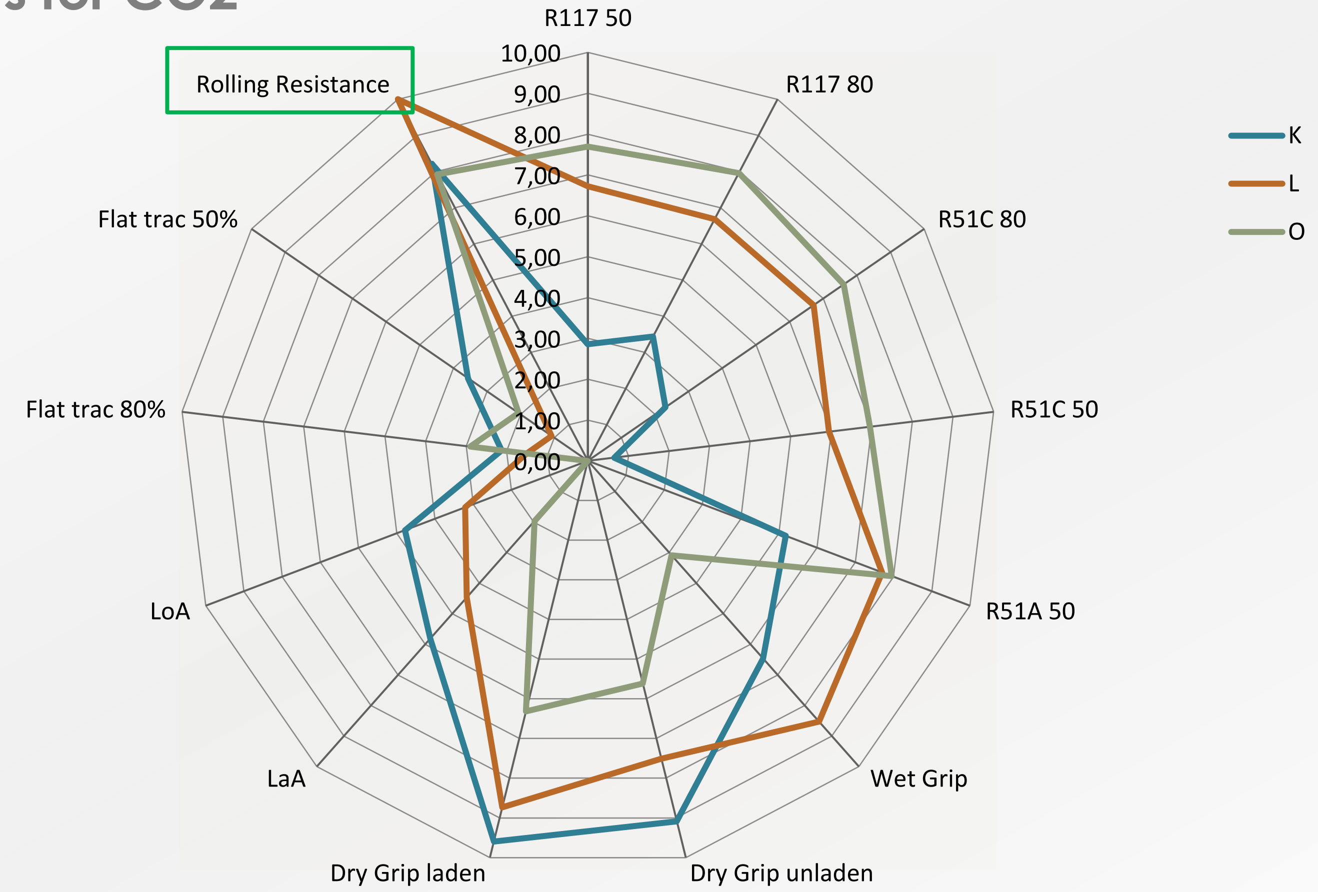


Good in Safety ➔ Less in Noise

Good in Rolling Sound ➔ Less in Aquaplaning

Spider Diagrams

The 3 best tyres for CO_2



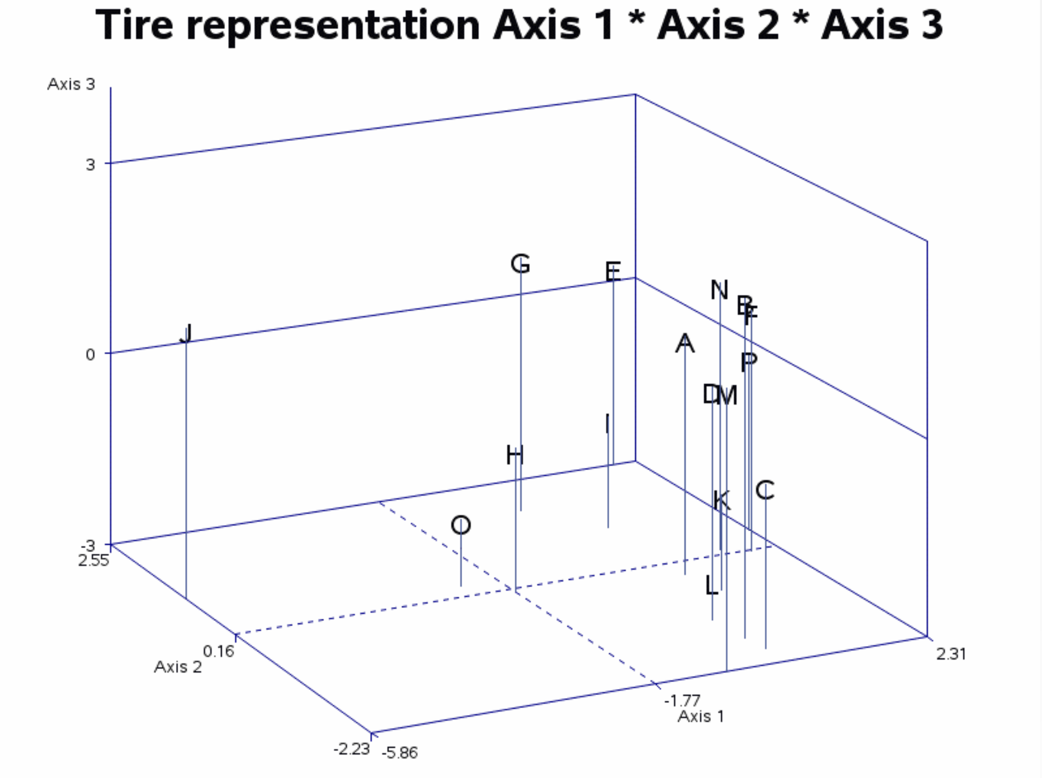
Good in Rolling Resistance ➔ Less in Handling and Aquaplaning

Toolbox

Principal Component Analysis (PCA)

- "**Principal component analysis** (**PCA**) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables (entities each of which takes on various numerical values) into a set of values of linearly uncorrelated variables called **principal components**". *Wikipedia*

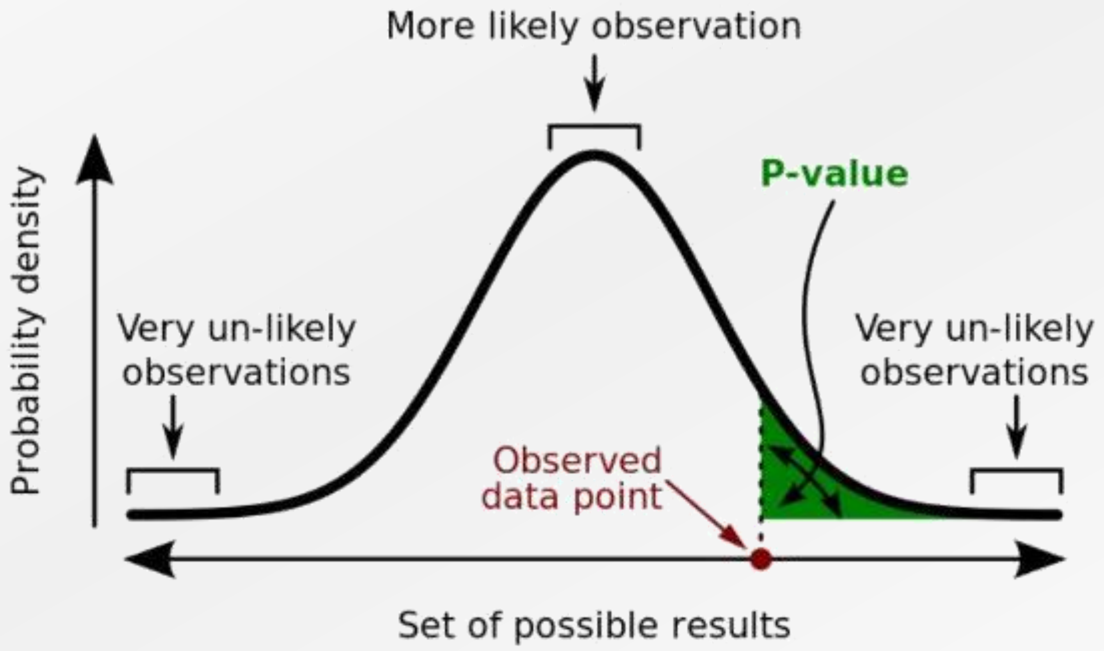
- In our case it is used to **reduce the number of input characteristics** (rolling resistance, dry grip, wet grip and aquaplaning) **from 8 to 3** to allow a 2D or 3D visualization



3D representation
Letters A to P correspond to the 16 tyres tested

Toolbox

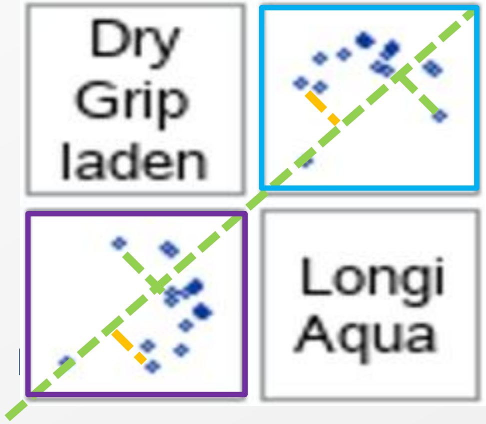
- **The P-value or probability value is, for a given statistical model, the probability that, when the null hypothesis is true, the statistical summary would be greater than or equal to the actual observed results**. In our case the hypothesis is "there is no correlation between characteristics". In other words, if p-value is low then our hypothesis is false and we can conclude that there is a correlation. The admitted threshold value is 5%.



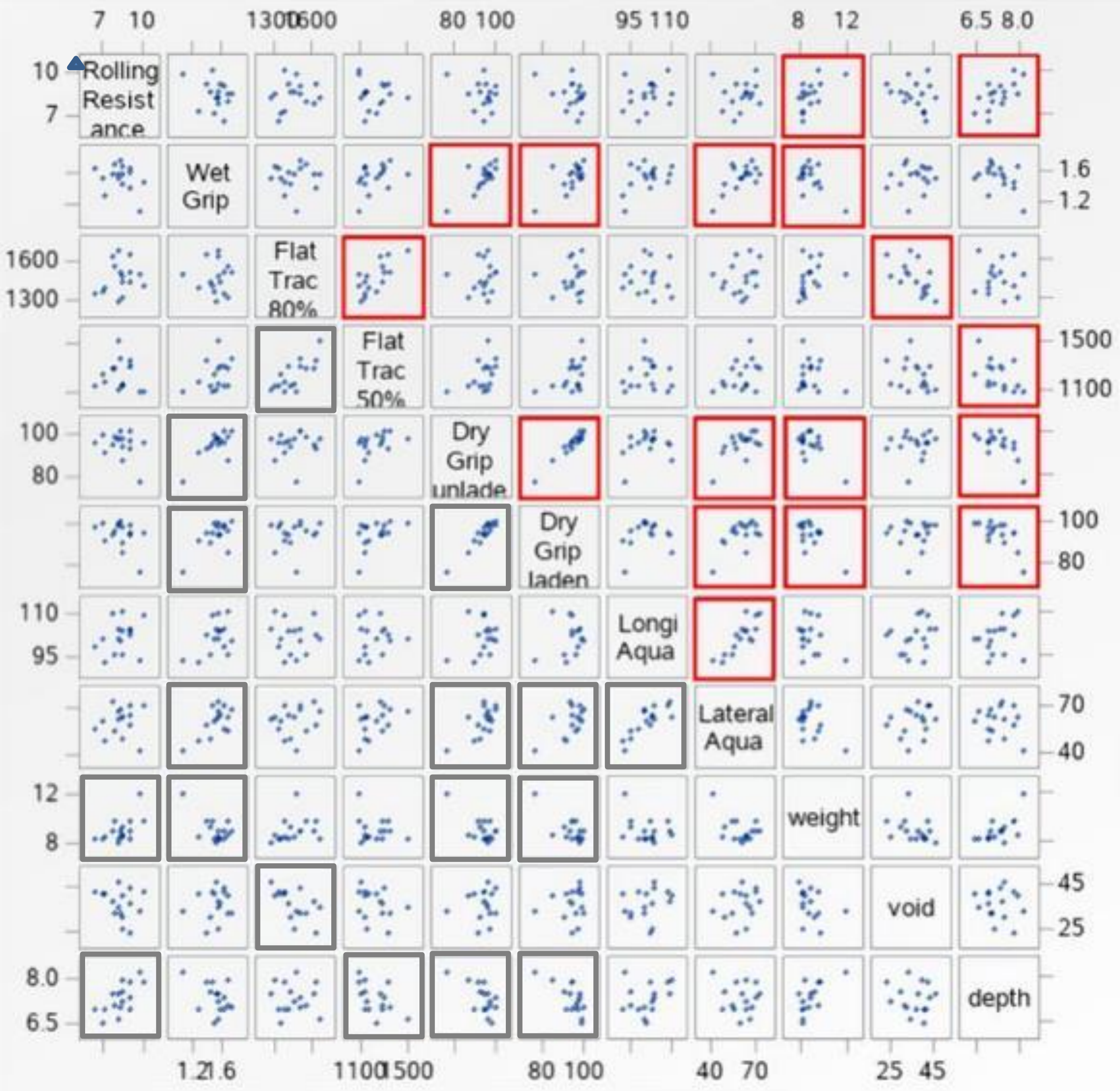
A **p-value** (shaded green area) is the probability of an observed (or more extreme) result assuming that the null hypothesis is true.

Toolbox

- In **the chart of scatterplots**, Red boxes show strong probability of correlation (**P-value <5%)**
- As the chart is symmetric, we just focus on the right part of it.



Test	Units
Rolling Resistance	RR Index
Wet Grip	WG Index
Flat Track	N/°
Dry Grip	%
Longitudinal Aquaplaning	%
Lateral Aquaplaning	m/s (integer)
Weight	Kg
Void Ratio	%
Tread Depth	mm



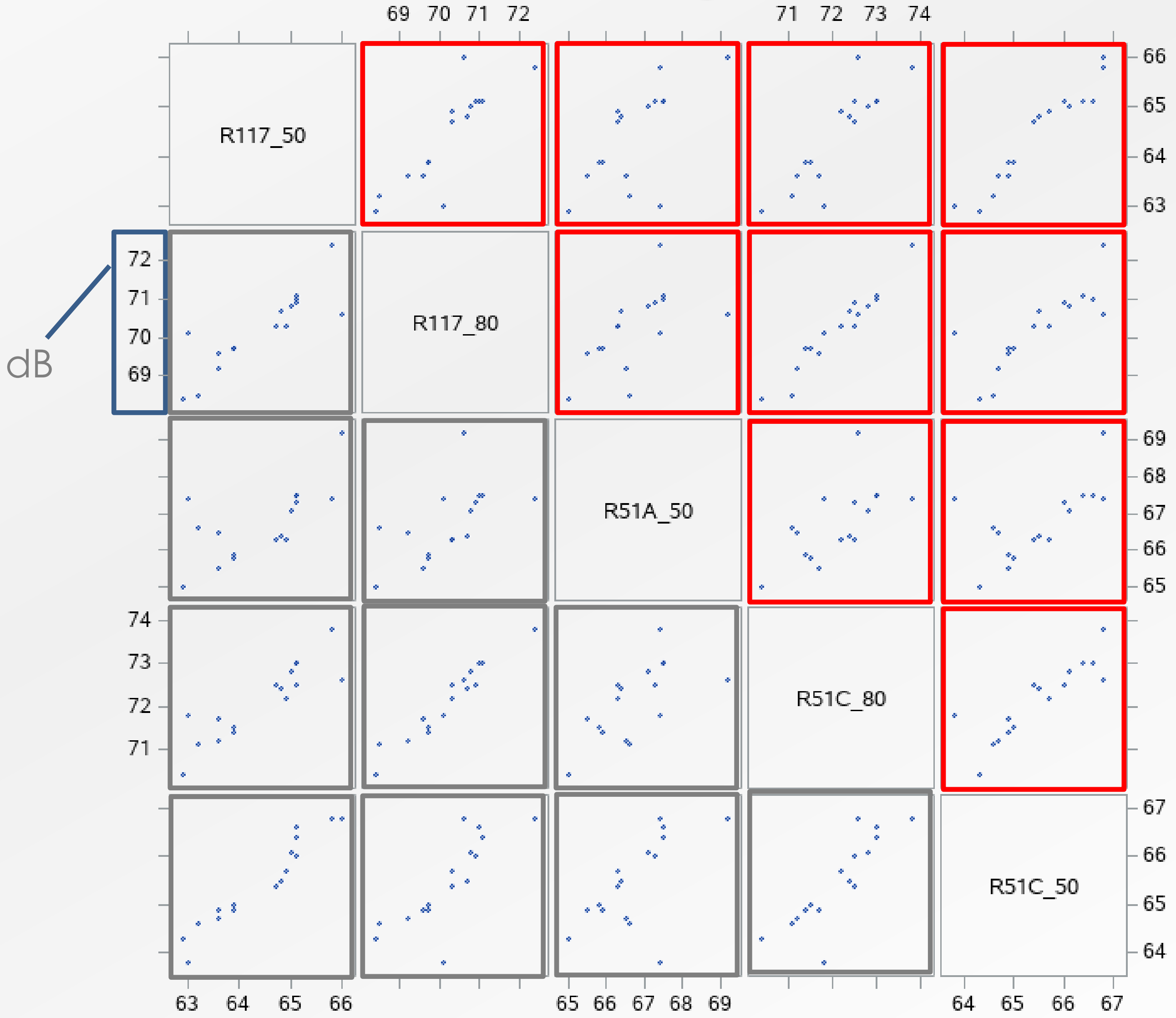
Without Rolling Sound

→ This tool allows us to show direct relationship between the parameters

2D charts and Scatterplots for rolling sounds

- Comparison between each Rolling Sound tests with **P-value <1%**
- As the P-value is less than 1% we have a top level of probability of correlation

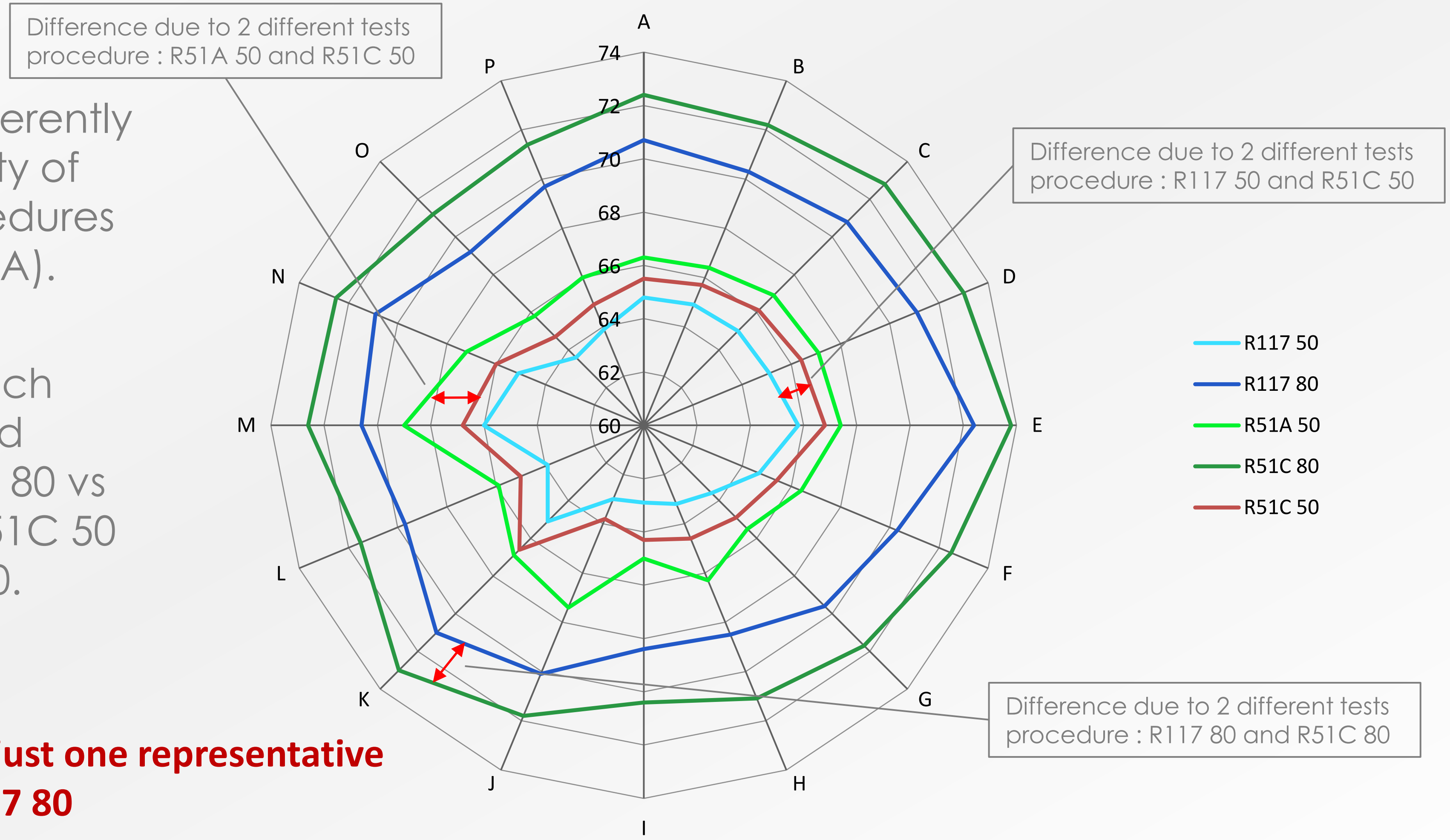
➔ We have the opportunity to state on the Rolling Sound performance only through one noise characteristics e. g. R117



Rolling Sound tests correlation

- The tyres are behaving differently depending on the sensitivity of each tyre to the test procedures used (R117, R51C and R51 A).

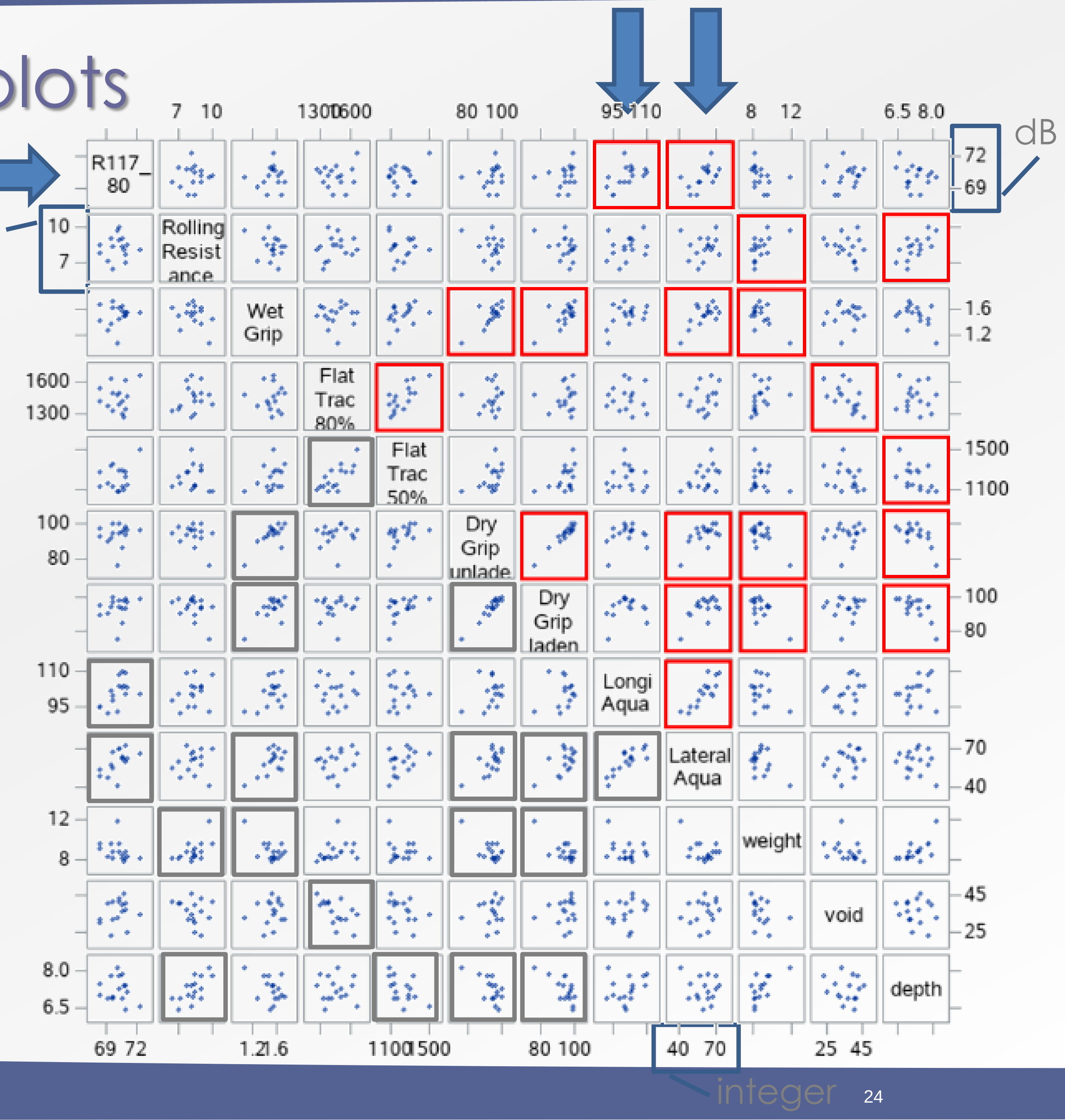
- In general the shape of each "circle" shows a quite good correlation, better for R117 80 vs R51C 80 and R51A 50 vs R51C 50 than for R117 50 vs R51C 50.



This confirms that we can keep just one representative characteristic among the 5 : R117 80

2D charts and Scatterplots

See next slide for visualization : R117_80 vs Aquaplaning



- Same as before but **with R117 80**
- Red boxes show very strong probability of correlation (**P-value <5%)**

Tests results - Visualization

- Strong correlation between R117 80 and Aquaplaning visually noticeable (sorted on R117 80)

	TEST															
	Rolling Resistance	Rolling Sound					Flat Trac		Wet Grip	Dry Grip		Longi. Aqua.	Lateral Aqua.	Weight	Void ratio	Tread Depth
List	RR (index)	R117 50 kph AVG (dB(A))	R117 80 kph Arr LR-1dB (dB(A))	R51A 50 kph (dB(A))	R51C 80 kph T° corr (dB(A))	R51C 50 kph T° corr (dB(A))	80% LI (N/°)	50% LI (N/°)	WG (index)	Ratio unladen (%)	Ratio laden (%)	Ratio LoA (%)	LaA (Integer)	(Kg)	% Void	Mean (mm)
I	7,865	62,9	68,4	65	70,4	64,3	1550	1278	1,69	97,14	95,57	94,76	54,18	9,55	31,9	7,01
H	8,454	63,2	68,5	66,6	71,1	64,6	1420	1130	1,43	92,59	90,06	94,96	49,11	9,19	29,9	7,46
O	7,175	63,6	69,2	66,5	71,2	64,7	1382	1168	1,27	89,69	90,99	92,08	47,52	8,27	40,8	6,87
G	9,002	63,6	69,6	65,5	71,7	64,9	1641	1337	1,38	91,89	94,03	102,05	57,49	9,62	23,1	7,83
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C	8,142	65	70,8	67,1	72,8	66,1	1265	1099	1,51	96,37	97,76	103,67	61,43	7,84	46,2	7,44
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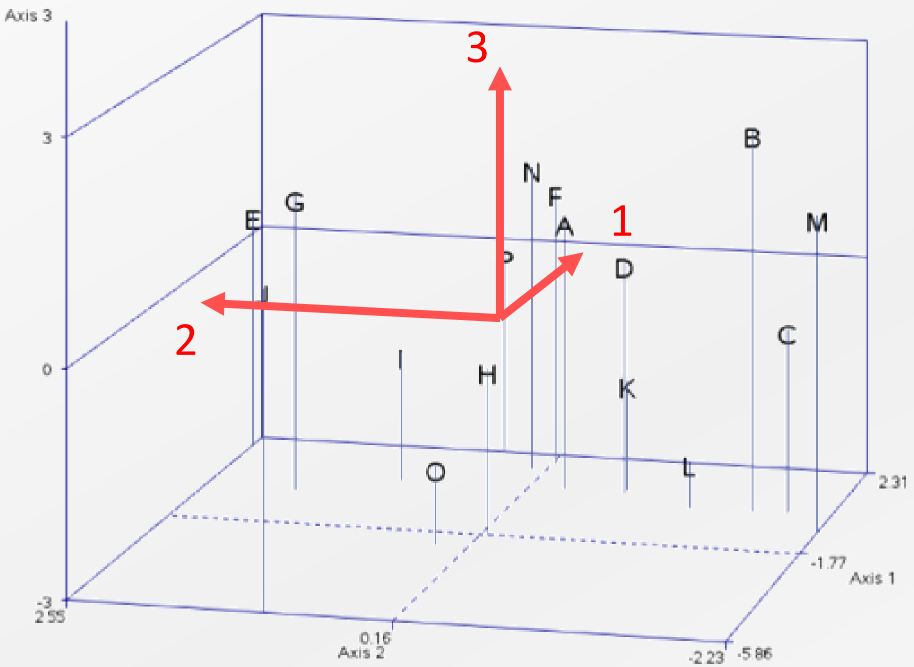
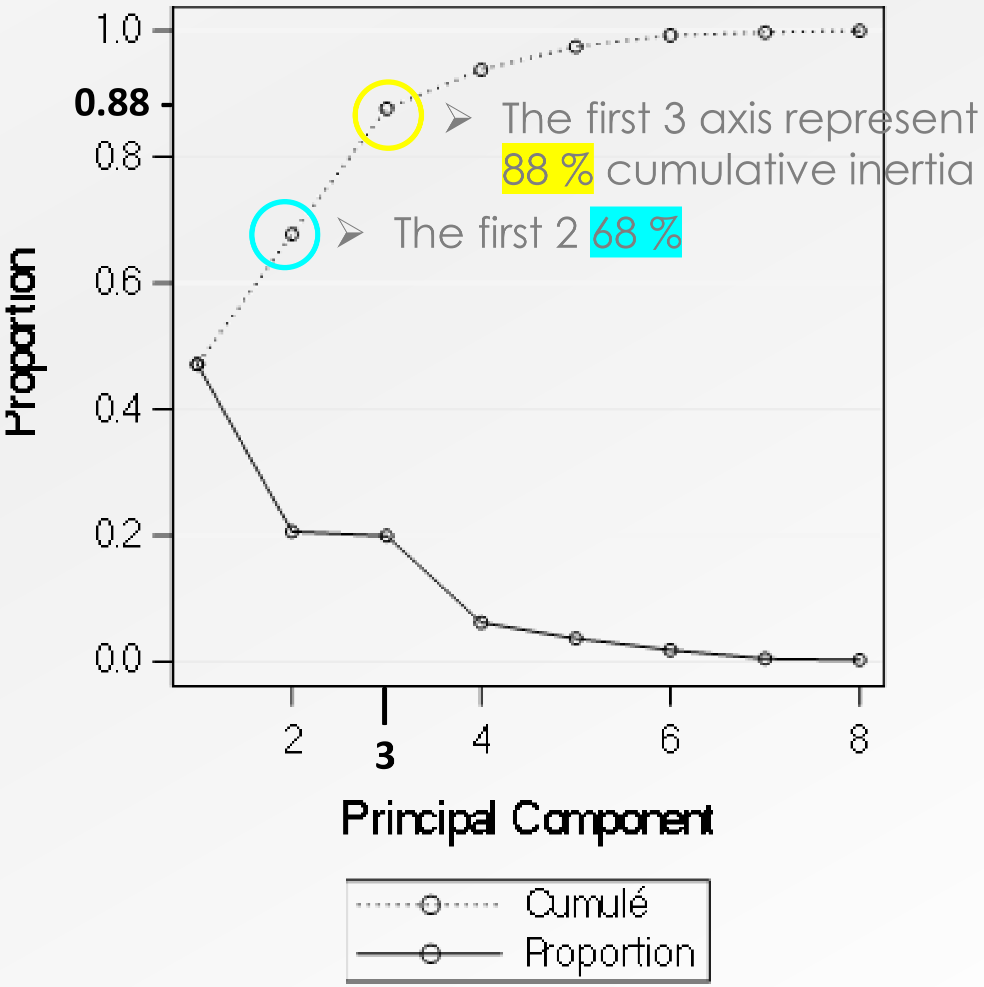
D	8,444	65,1	71,1	67,5	73	66,4	1462	1144	1,56	96,58	96,71	103,2	63,29	8,27	24,7	7,13
E	8,117	65,8	72,4	67,4	73,8	66,8	1669	1507	1,55	96,04	98,66	100,18	66,15	8,13	34,3	6,53

Multidimensional Analysis - Axis

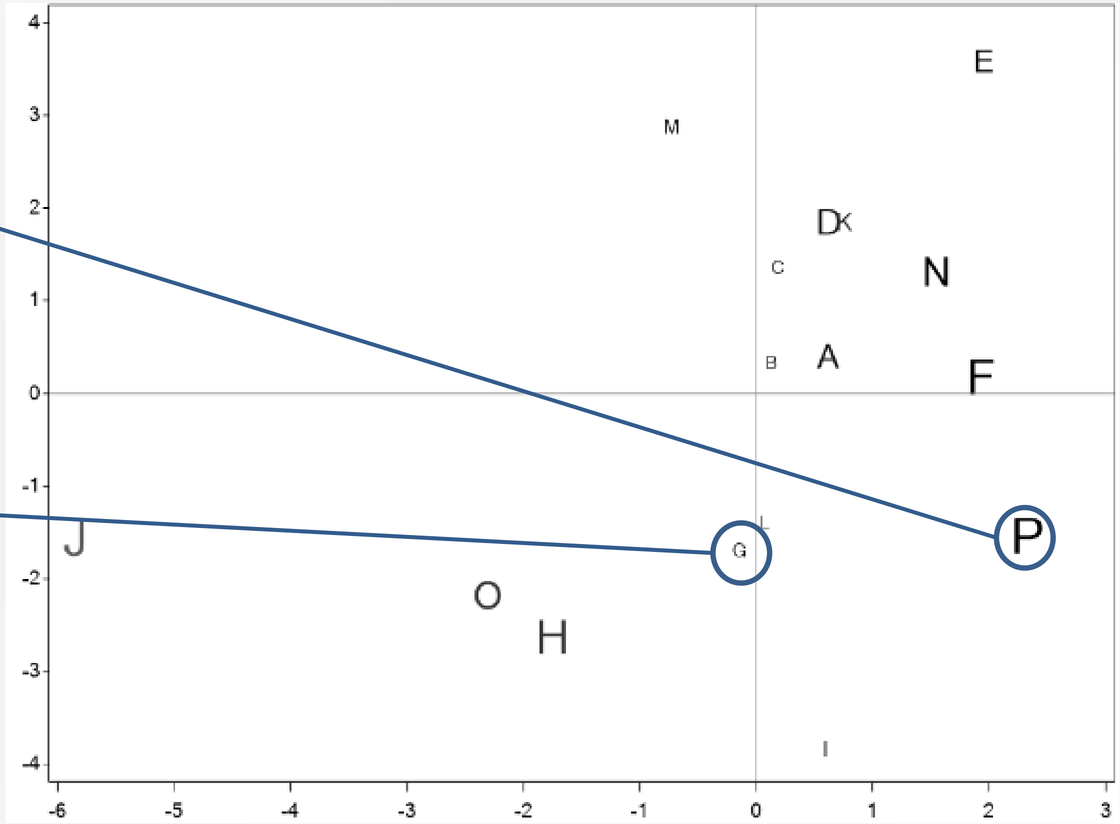
- **Principal Component Analysis (PCA)**
  - **Reduce the 8 studied characteristics** (Rolling Resistance, Wet Grip, Flat Track 80%, Flat Track 50%, Dry Grip unladen, Dry Grip laden, Longitudinal & Lateral Aquaplaning) **to 3 variables**





2D representation

- **In the 2D representation :**
  - The **bigger the letters**, the **more** the **axis** is **driven** by the **tyre** in comparison to the others for this 16 tyres sample
  - The **smaller the letters**, the **less** the **axis** is **driven** by this **tyre** in comparison to the others for this 16 tyres sample



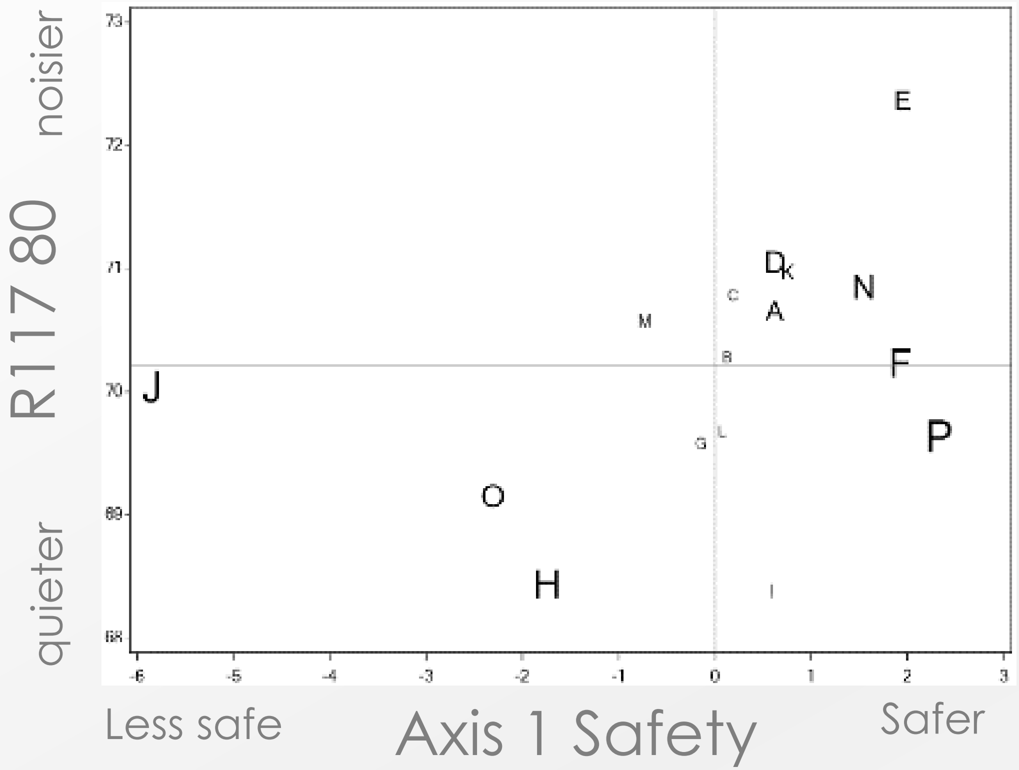
Principal Component Analysis (PCA)

- **Axis 1** mainly represents **Wet Grip, Dry Grip, Lateral aquaplaning**
  To be noted that in axis 1 direction all tests performance improve
  - It is representative for **Safety**
- **Axis 2** mainly represents **Flat Track**
  - It is representative for **Handling**
- **Axis 3** mainly represents **Rolling Resistance** and **Longitudinal Aquaplaning**
  - It is representative for **CO2 Emissions** because Rolling Resistance factor is the most important

Part of inertia	47%	21%	20%
	Axis 1	**Axis 2**	**Axis 3**
Rolling resistance	-0.24951	0.08299	0.83255
Wet Grip	0.84198	-0.24064	-0.11640
Flat Trac 80%	0.26003	0.87159	0.30945
Flat Trac 50%	0.60116	0.73587	0.05038
Dry grip unladen	0.90781	-0.03298	-0.25292
Dry grip laden	0.88151	0.01045	-0.32418
Longi aquaplaning	0.50930	-0.48779	0.64278
Lateral aquaplaning	0.84231	-0.20959	0.45471

PCA Results (1st axis)

R117_80 vs Axis 1 Safety



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Axis 1 mainly controlled by Wet Grip, Dry Grip, Lateral aquaplaning

Among the **6 references** tested for **wear**, 2 of them were well represented on **axis 1**, **P** which is the safest and **O** the 2nd less safe among the 16 references, **P** presents less good performances on wear and **O** the best performances.

Interpretations (1st axis)

- **Axis 1** mainly represents Safety through **Wet Grip**, **Dry Grip**, **Lateral Aquaplaning**

- The statistic concerning our sample of 16 tyres shows a **conflict between Rolling Sound and Safety performances.**

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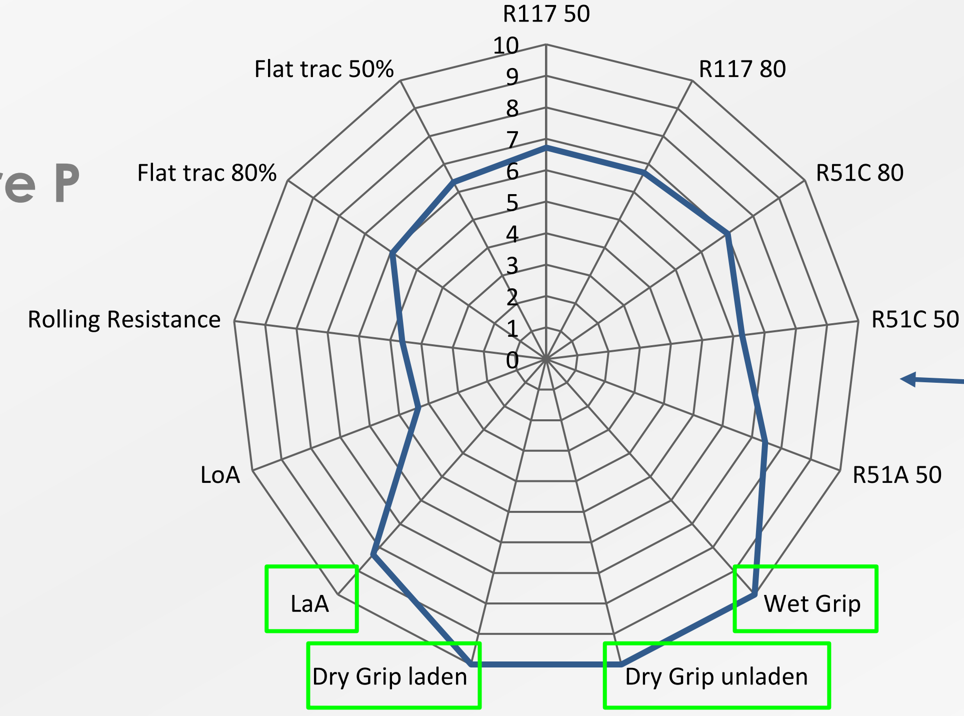
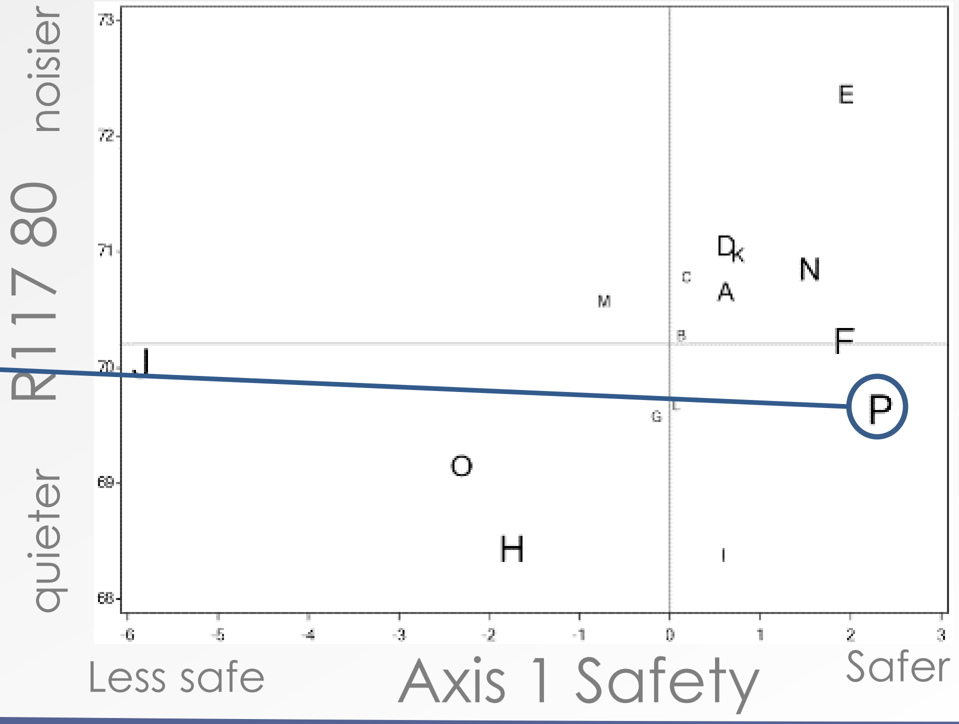
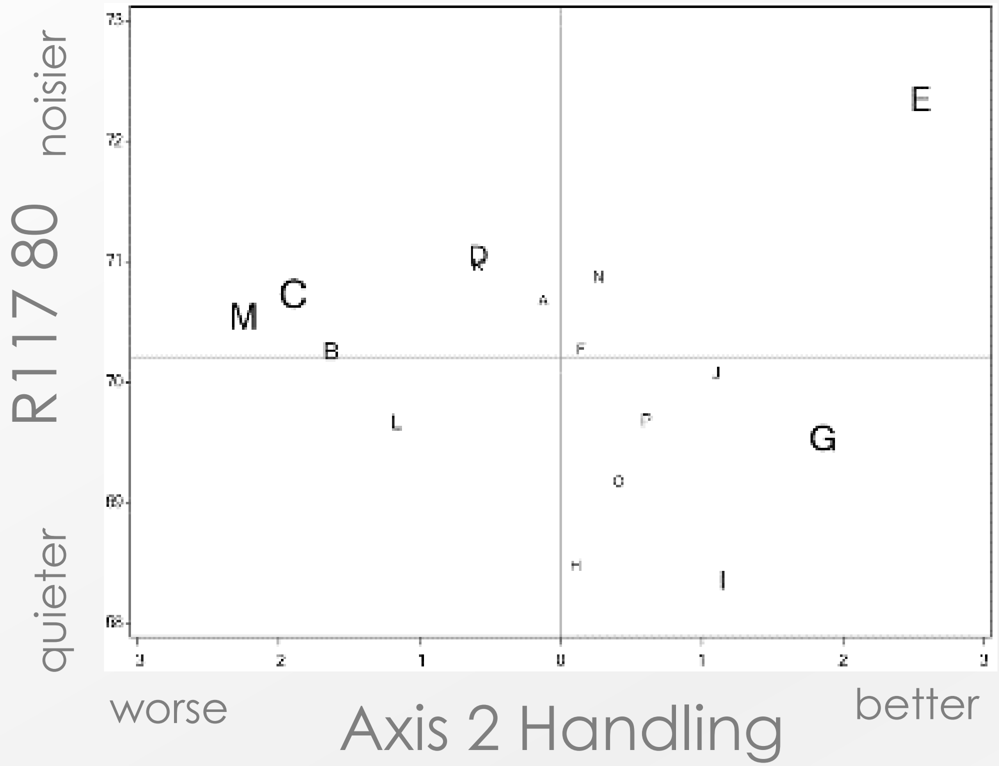
Focus on Tyre P





PCA Results (2nd axis)

- R117_80 vs Axis 2 Handling



	Axis 1	Axis 2	Axis 3
Rolling resistance	-0.24951	0.08299	0.83255
Wet Grip	0.84198	-0.24064	-0.11640
Flat Trac 80%	0.26003	0.87159	0.30945
Flat Trac 50%	0.60116	0.73587	0.05038
Dry grip unladen	0.90781	-0.03298	-0.25292
Dry grip laden	0.88151	0.01045	-0.32418
Longi aquaplaning	0.50930	-0.48779	0.64278
Lateral aquaplaning	0.84231	-0.20959	0.45471

Axis 2 mainly controlled by Flat Track 50 % and Flat Track 80 %

Tyres B, C and I are quite well represented on axis 2 (handling axis), B and C are worse on handling and on wear performances too, tyre I is quite better on handling and has 2nd rank performances for wear.

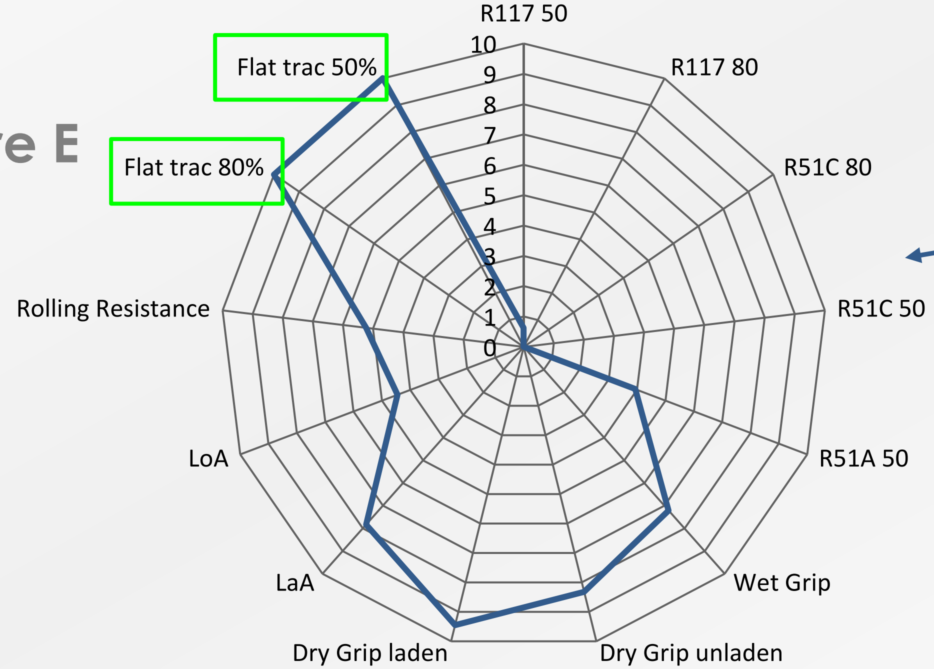
Interpretations (2nd axis)

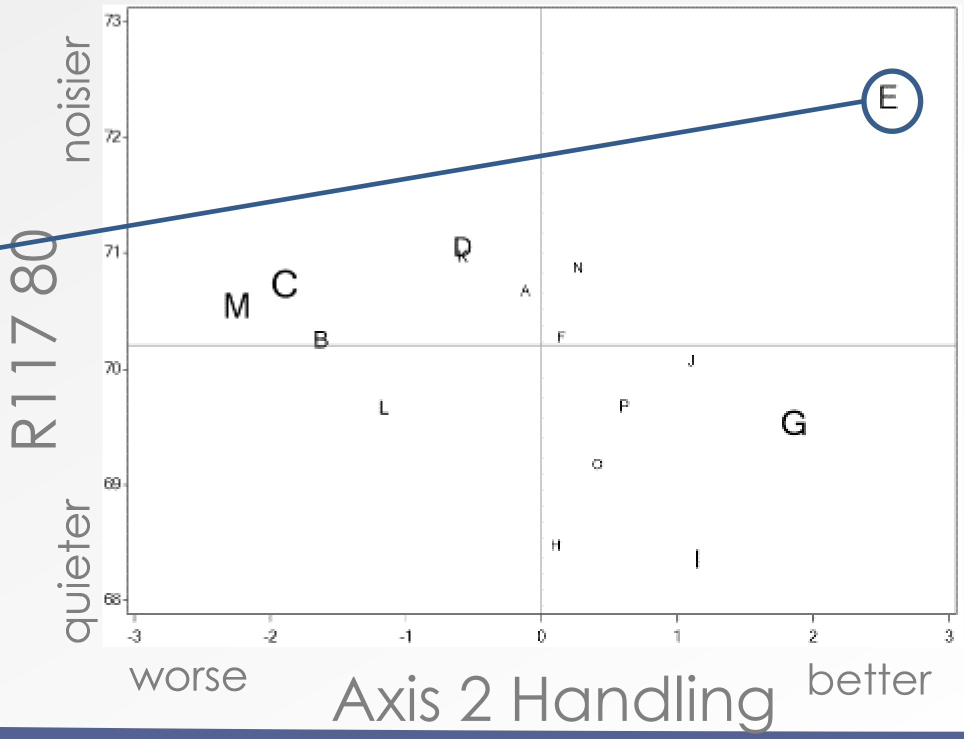
- **Axis 2** mainly represents handling through **Flat Track**

- **Noise and Handling performances improve together along Axis 2 (E does not follow the trend)**

	Axis 1	Axis 2	Axis 3
Rolling resistance	-0.24951	0.08299	0.83255
Wet Grip	0.84198	-0.24064	-0.11640
Flat Trac 80%	0.26003	0.87159	0.30945
Flat Trac 50%	0.60116	0.73587	0.05038
Dry grip unladen	0.90781	-0.03298	-0.25292
Dry grip laden	0.88151	0.01045	-0.32418
Longi aquaplaning	0.50930	-0.48779	0.64278
Lateral aquaplaning	0.84231	-0.20959	0.45471

Focus on Tyre E

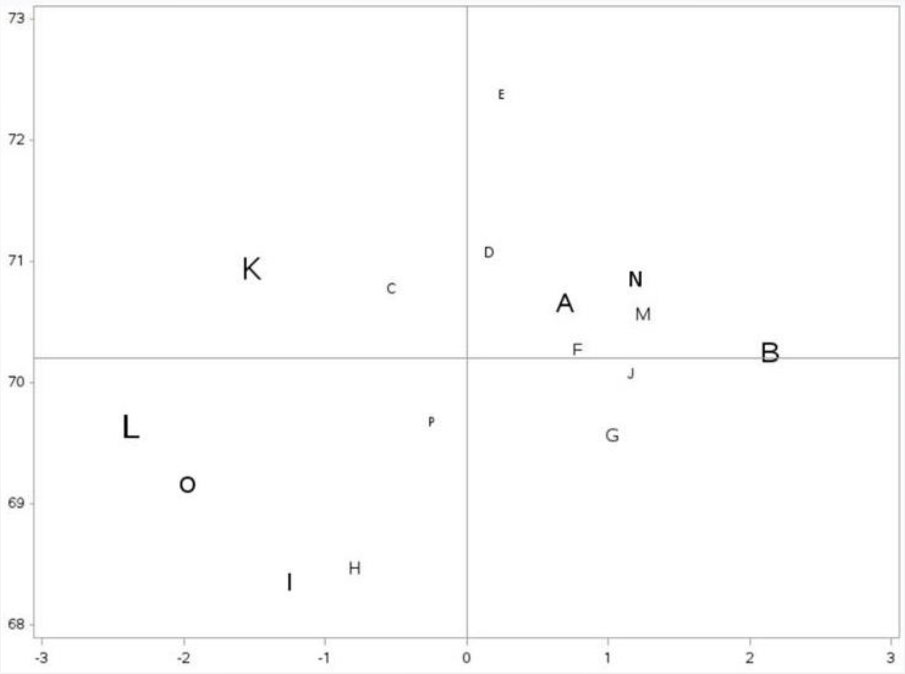




PCA Results (3rd axis)

R117_80 vs Axis 3 CO2

R117 80 noisier / quieter



worse — Axis 3 CO2 — better **Longitudinal Aquaplaning**

better — worse **Rolling Resistance**

	Axis 1	Axis 2	Axis 3
Rolling resistance	-0.24951	0.08299	0.83255
Wet Grip	0.84198	-0.24064	-0.11640
Flat Trac 80%	0.26003	0.87159	0.30945
Flat Trac 50%	0.60116	0.73587	0.05038
Dry grip unladen	0.90781	-0.03298	-0.25292
Dry grip laden	0.88151	0.01045	-0.32418
Longi aquaplaning	0.50930	-0.48779	0.64278
Lateral aquaplaning	0.84231	-0.20959	0.45471

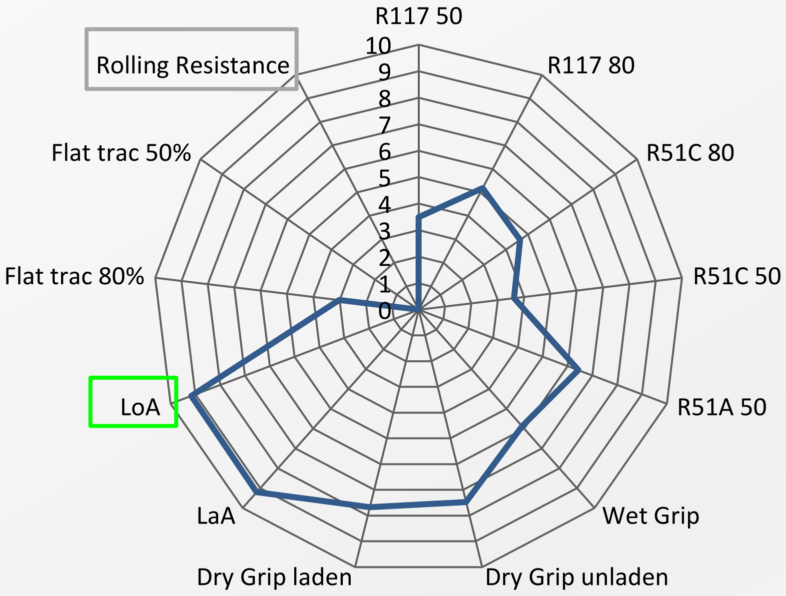
Axis 3 mainly controlled by
Rolling Resistance & Longitudinal Aquaplaning

Interpretations (3rd axis)

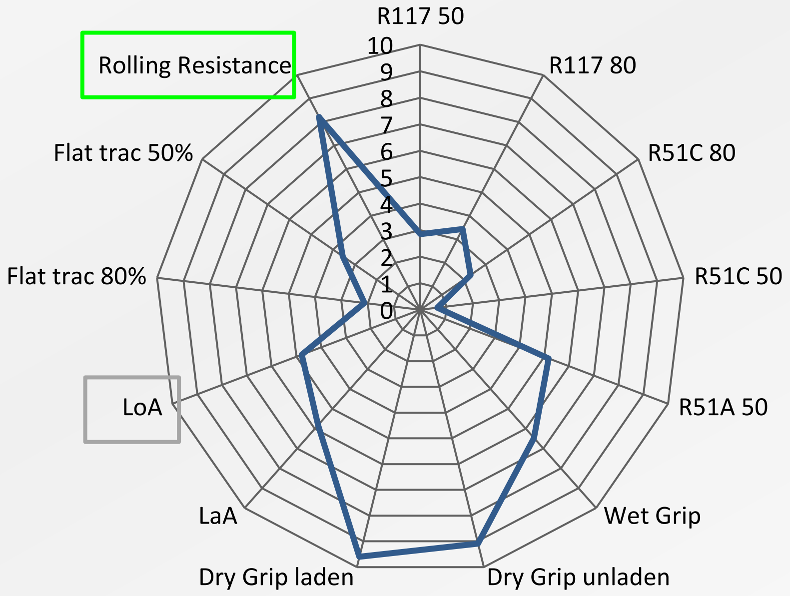
- **Axis 3** mainly represents CO2 Emissions (through **Rolling Resistance) and Longitudinal Aquaplaning.**
- **(!)** In this axis, performance in **Rolling Resistance decreases while increasing in Longitudinal Aquaplaning**

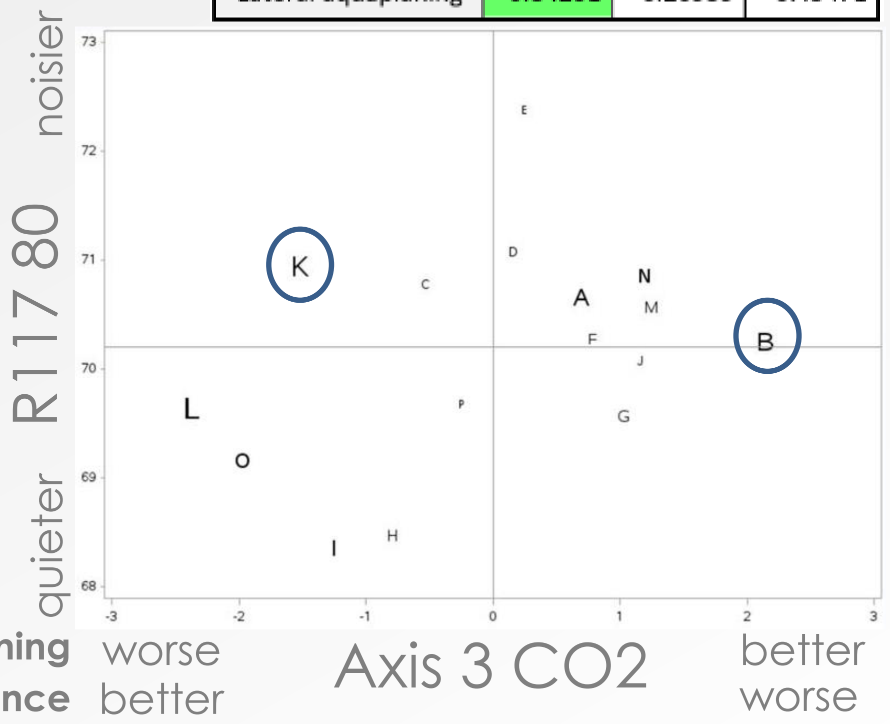
	Axis 1	Axis 2	Axis 3
Rolling resistance	-0.24951	0.08299	0.83255
Wet Grip	0.84198	-0.24064	-0.11640
Flat Trac 80%	0.26003	0.87159	0.30945
Flat Trac 50%	0.60116	0.73587	0.05038
Dry grip unladen	0.90781	-0.03298	-0.25292
Dry grip laden	0.88151	0.01045	-0.32418
Longi aquaplaning	0.50930	-0.48779	0.64278
Lateral aquaplaning	0.84231	-0.20959	0.45471

Focus on Tyre B



Focus on Tyre K





Simple conclusion can not be drawn on Axis 3

WEAR STUDY – ADDITIONAL RESULTS

The table summarizing the tests described in UTAC CERAM test report AFFSAS1801813 is updated after integration of the results of wear study

	TESTS																	
	Rolling Resistance	Rolling Sound					Flat Trac		Wet Grip	Dry Grip		Longi. Aqua.	Lateral Aqua.	Void Ratio	Wear Study			
List	RR (index)	R117 50 kph AVG (dB(A))	R117 80 kph Arr LR-1dB (dB(A))	R51A 50 kph (dB(A))	R51C 80 kph T° corr (dB(A))	R51C 50 kph T° corr (dB(A))	80% LI (N/°)	50% LI (N/°)	WG (index)	Ratio unladen (%)	Ratio laden (%)	Ratio LoA (%)	LaA (Integer m/s)	% Void	Front tyres wear (Δmm @15Kkm)	Front tyres wear (%mm @15Kkm)	Front tyres wear (Δkg @15Kkm)	Front tyres wear (%kg @15Kkm)
A	8.985	64.8	70.7	66.4	72.4	65.5	1417	1288	1.57	95.52	93.7	103.22	63.96	36.8	Not studied			
B	9.949	64.9	70.3	66.3	72.2	65.7	1387	1080	1.46	94.06	94.31	108.76	70.52	42	1.37	19.06	0.32	3.4
C	8.142	65	70.8	67.1	72.8	66.1	1265	1099	1.51	96.37	97.76	103.67	61.43	46.2	1.21	17.43	0.28	3.5
D	8.444	65.1	71.1	67.5	73	66.4	1462	1144	1.56	96.58	96.71	103.2	63.29	24.7	Not studied			
E	8.117	65.8	72.4	67.4	73.8	66.8	1669	1507	1.55	96.04	98.66	100.18	66.15	34.3	Not studied			
F	8.953	64.7	70.3	66.3	72.5	65.4	1500	1294	1.63	99.74	98.18	103.99	69.75	43.4	Not studied			
G	9.002	63.6	69.6	65.5	71.7	64.9	1641	1337	1.38	91.89	94.03	102.05	57.49	23.1	Not studied			
H	8.454	63.2	68.5	66.6	71.1	64.6	1420	1130	1.43	92.59	90.06	94.96	49.11	29.9	Not studied			
I	7.865	62.9	68.4	65	70.4	64.3	1550	1278	1.69	97.14	95.57	94.76	54.18	31.9	0.97	14.4	0.3	3.2
J	9.760	63	70.1	67.4	71.8	63.8	1479	1090	1.06	76.48	75.54	93.03	41.28	33	Not studied			
K	7.075	65.1	71.0	67.5	73	66.6	1351	1232	1.50	97.85	99.02	100.8	59.74	40.9	Not studied			
L	6.449	63.9	69.7	65.8	71.5	65	1326	1126	1.64	94.14	96.9	97.92	55.48	41.8	0.99	14.7	0.28	3.3
M	8.389	66	70.6	69.2	72.6	66.8	1294	1126	1.67	86.53	84.63	110.29	63.39	39.7	Not studied			
N	7.666	65.1	70.9	67.3	72.5	66	1618	1271	1.56	93.92	93.14	109.43	73.05	37.4	Not studied			
O	7.175	63.6	69.2	66.5	71.2	64.7	1382	1168	1.27	89.69	90.99	92.08	47.52	40.8	0.85	12.31	0.2	2.4
P	8.336	63.9	69.7	65.9	71.4	64.9	1505	1351	1.74	100	100	100	67.65	32.3	1.14	16.2	0.28	3.2

Selection of 6 tyres references of the 16 initial ones
Selected 6 tyres represent a good mix of rolling sound, wet grip and handling.

WEAR STUDY – ADDITIONAL RESULTS

Weight and groove evolution of tyres

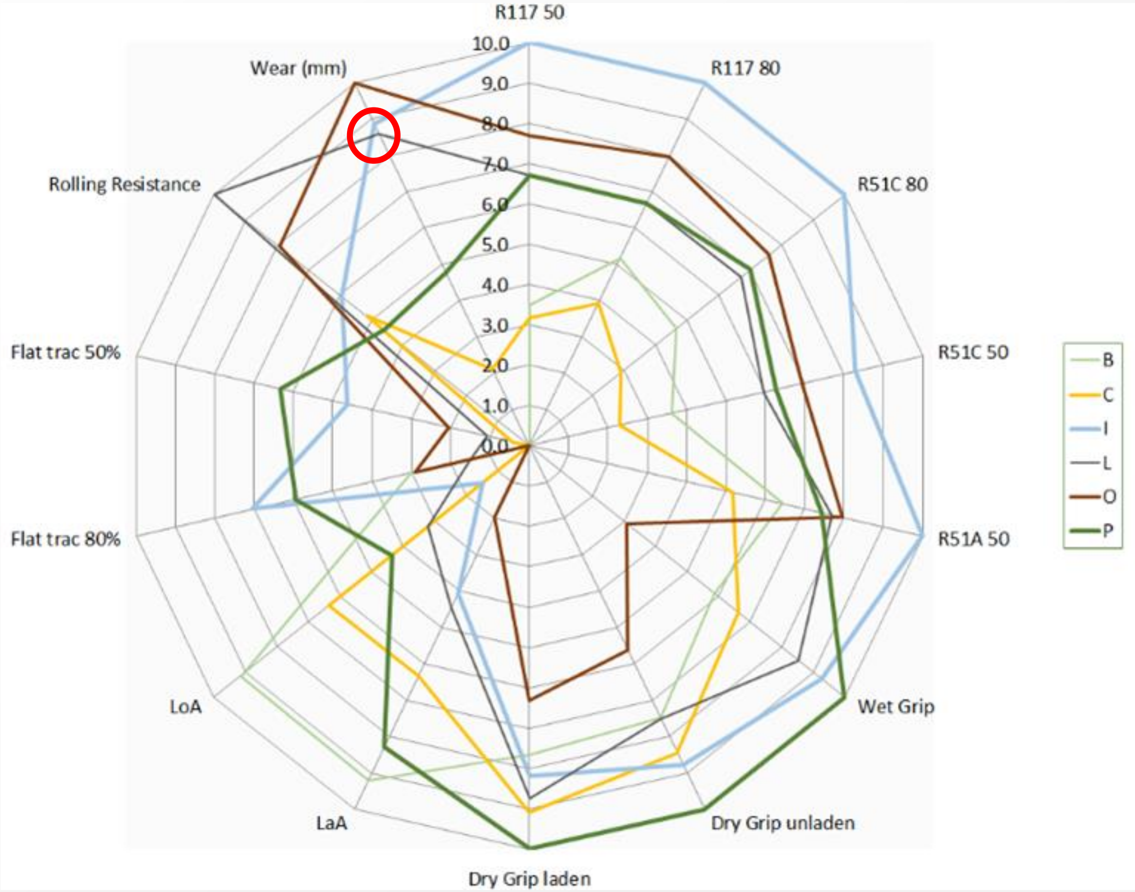
Tyres identification	Tyres position	Mean initial weight (kg)	Mean final weight (kg)	Mean loss (kg)	Mean loss (%)	Mean initial depth (mm)	Mean final depth (mm)	Mean loss (mm)	Mean loss (%)
B	Front axle	9.43	9.10	0.32	3.4	7.16	5.80	1.37	19.06
	Rear axle	9.48	9.33	0.15	1.6	7.29	6.39	0.90	12.35
C	Front axle	7.85	7.58	0.28	3.5	6.94	5.73	1.21	17.43
	Rear axle	7.88	7.70	0.18	2.2	6.89	5.99	0.90	13.06
I	Front axle	9.48	9.18	0.30	3.2	6.74	5.77	0.97	14.40
	Rear axle	9.48	9.35	0.12	1.3	6.75	6.09	0.66	9.78
L	Front axle	8.25	7.98	0.28	3.3	6.74	5.75	0.99	14.70
	Rear axle	8.18	8.08	0.10	1.2	6.72	6.06	0.66	9.75
O	Front axle	8.40	8.20	0.20	2.4	6.91	6.06	0.85	12.31
	Rear axle	8.28	8.20	0.08	0.9	6.99	6.30	0.69	9.86
P	Front axle	8.73	8.45	0.28	3.2	7.01	5.87	1.14	16.20
	Rear axle	8.73	8.60	0.13	1.4	7.00	6.21	0.79	11.22

Mean values for each axle, with absolute and relative values of weight loss and groove depth loss, at the final state at 15,000 kms

Axle composed of tyres A and B ➔ *Mean_Weight_Axle* = *(Weight_A+Weight_B)/2*

Weight loss = *Mean_Weight_Axle (t2)* – *Mean_Weight_Axle (t1).*

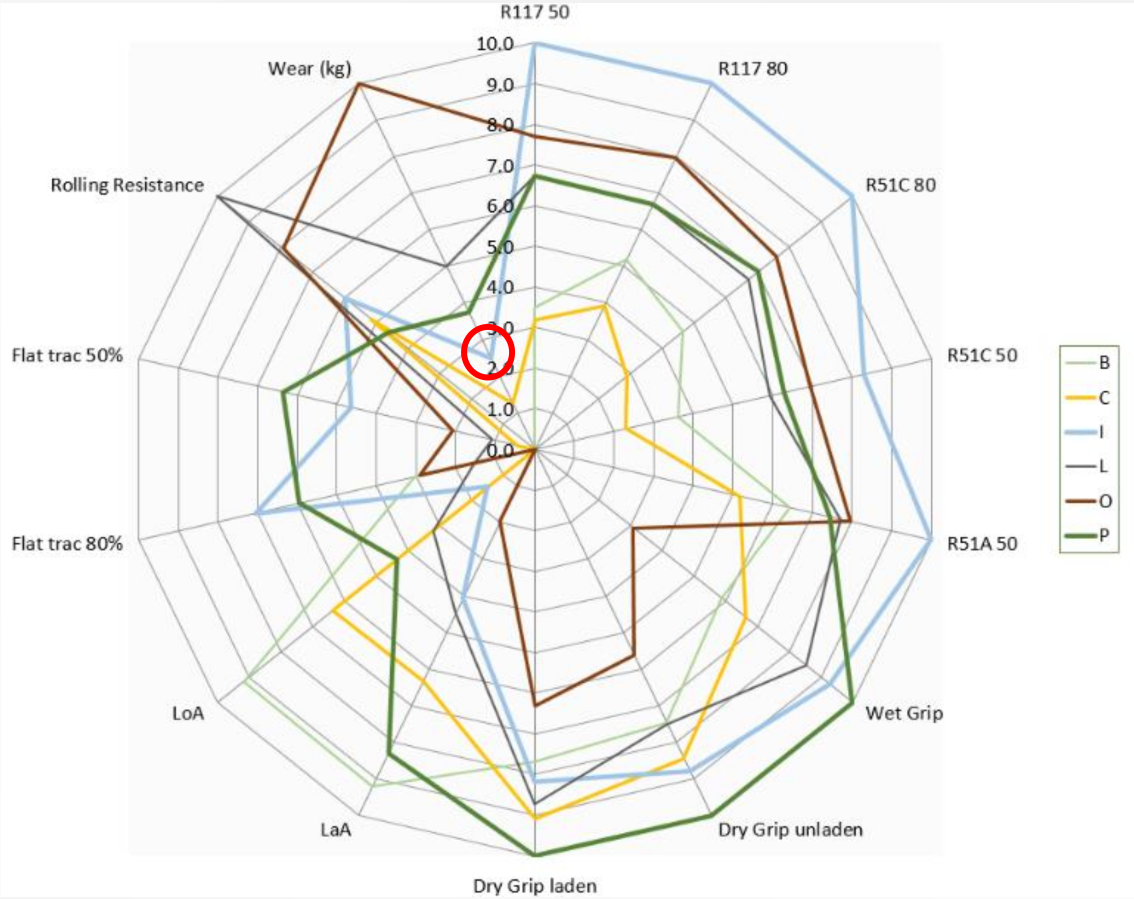
Spider Diagrams – Wear study



Spider diagram with absolute measurement of groove depth evolution

10 : Defined by the best tyre of the sample

0 : Defined by the worst tyre of the sample



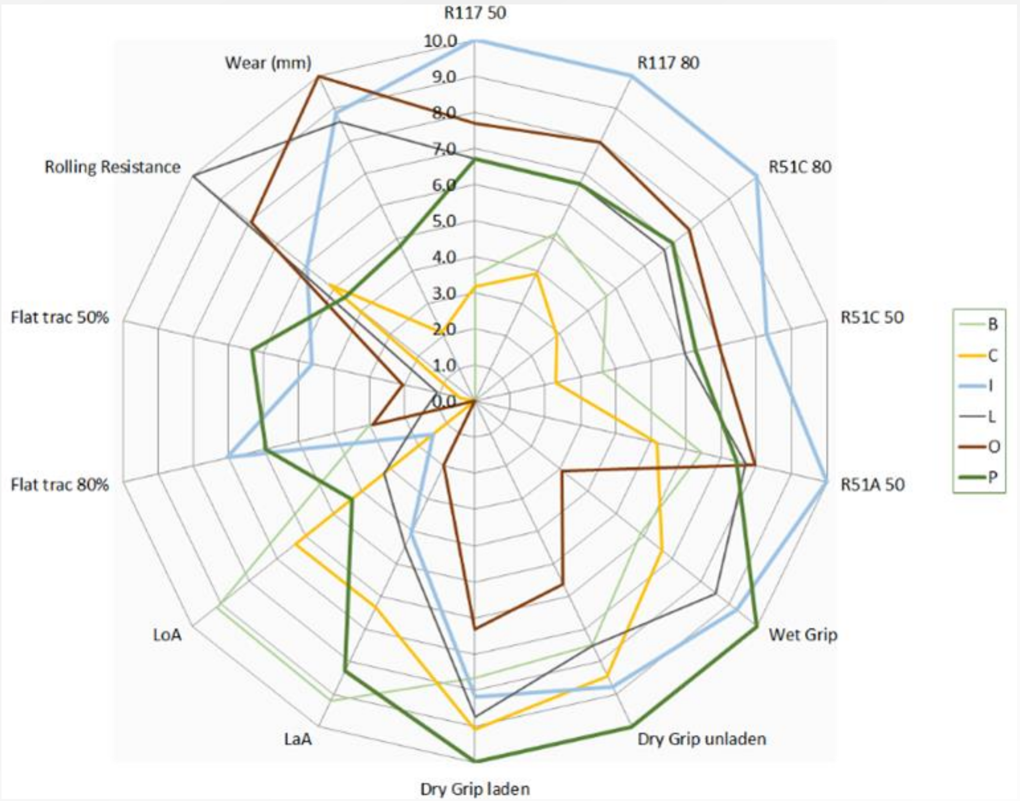
Spider diagram with absolute measurement of weight evolution

-> Wear in terms of tread depth is not necessarily correlated with the tyre wear in terms of loss of material

Analysis & Conclusions – Wear study

- **Difficult to draw conclusions on interactions between wear, noise and grip ability**
  - Tendency is quite clear for 3 of 6 tyres references (B, C, P), with a combined evolution between the three features
  - A better grip tends to result in a higher rolling sound emission and increased tyre wear
  - This tendency is not that clear for other tested tyres

- **To confirm the tendency**, the study should be extended based on more mileage and for a larger number & variety of tyres. This will strengthen the results of the Principal Component Analysis.
  - Study findings are drawn from restricted mileage of 15,000 km & small numbers of tyres selected

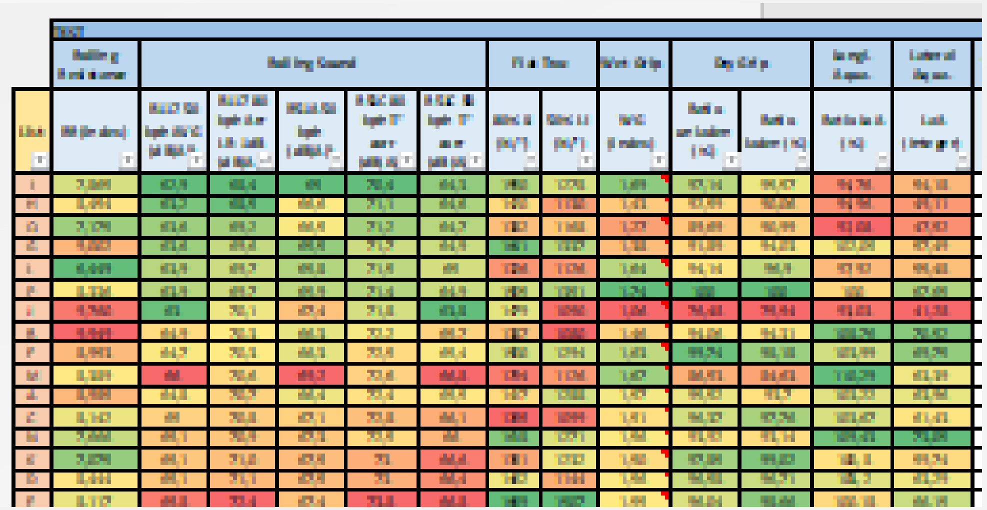


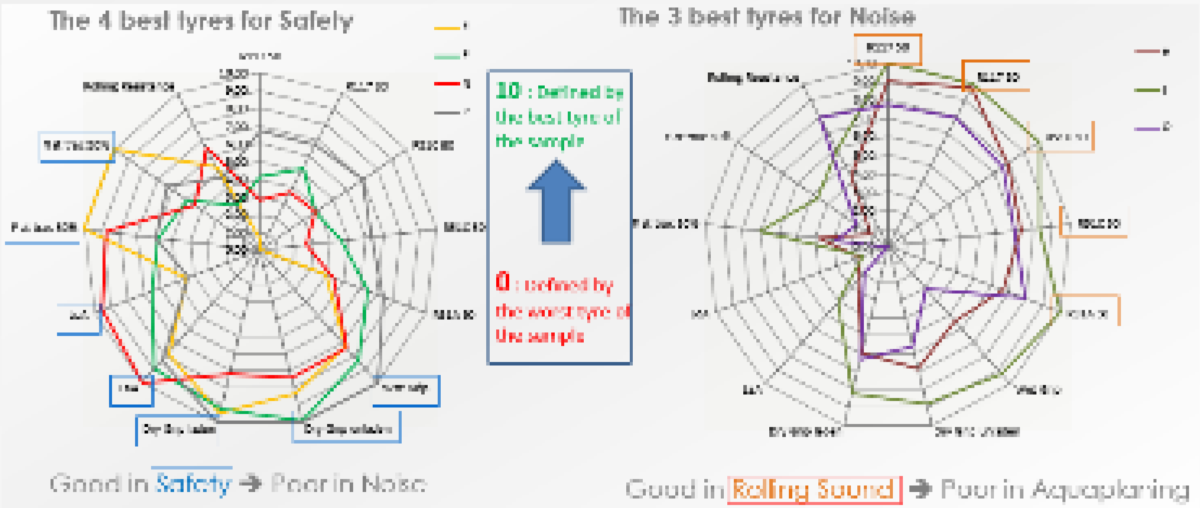
Conclusions

Measurement Program

- This new study offers a comprehensive toolbox to evaluate the relationship between rolling sound and the main other tyre performances according to standard measurement protocols.

- A correlation analysis shows that the 5 acoustic characteristics concerning R51.03 (Vehicle measurement) and R117 (Tyre measurement) at different velocities are correlated and can be represented by only one.

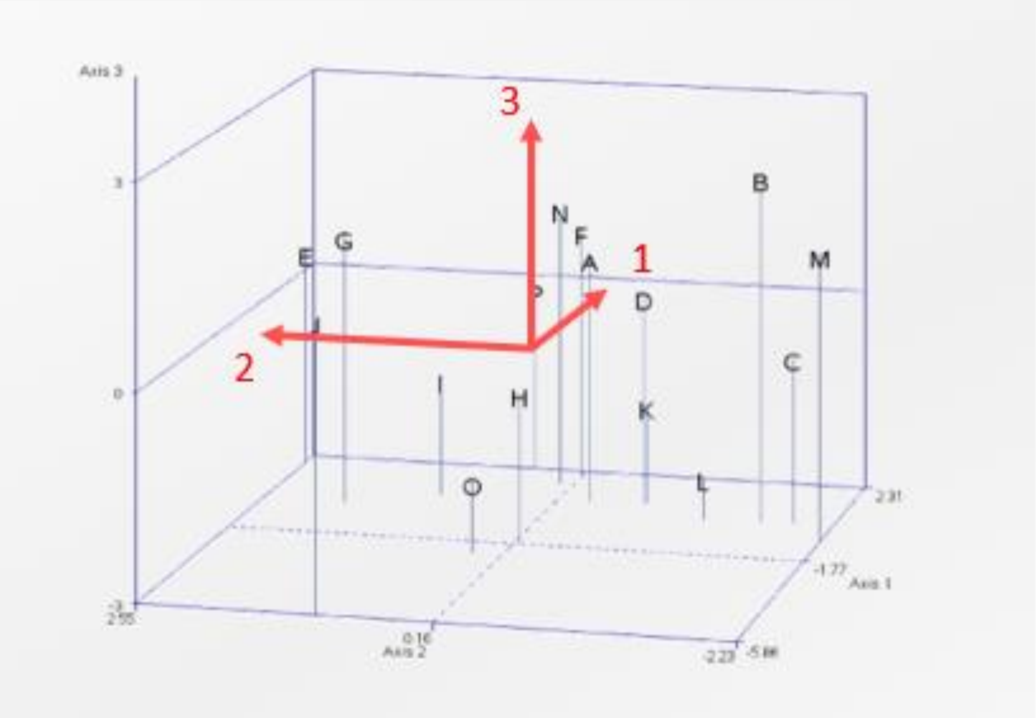




Conclusions

Statistical analysis

- We have described the relationship between the characteristics through 3 variables with a good level of representativeness (inertia of 88%)
- The main table, the spider diagrams and the Principal Components Analysis show **a conflict between rolling sound** (R117) **and Safety performances** (Wet Grip, Dry Grip, Lateral Aquaplaning)
- Simple conclusions regarding rolling sound, rolling resistance and Safety performance (Longitudinal Aquaplaning) cannot be drawn



Conclusions

Main conclusion

- Obtaining **a low level of Rolling Sound performance without a compromise** regarding other parameters essential **for vehicle safety and CO_2 emission reduction could not be proven as feasible** by this Study

Conclusions

General conclusions

- ACEA Tyre Performance Study is the first study to analyze the inter-dependency of the parameters of the tyre with accurate reliable repeatable measurement methods
- ACEA Tyre Performance Study conclusions are consistent with the outcomes of the Literature Study regarding Rolling Sound and Vehicle Safety
- The ACEA Tyre Performance Study has not observed or deduced any correlation between Rolling Sound and Rolling Resistance as claimed by the FEHRL Study

Remark: WLTP has caused a shift in tyre technology in recent years, in order to provide improved Rolling Resistance. The tyres in the study may have been designed before this shift.

Conclusions

Suggestions

- To prove that the conclusions of this study are also **valid for other tyre types,** the test program needs to be expanded to
  - Class C1 tyres with bigger outer diameter, tyre width, and lower rolling resistance
  - Class C1 tyres (winter and reinforced tyres)
  - Class C2 tyres and Class C3 tyres with bigger outer diameter and tyre width
- As suggested already, to confirm the tendency, wear study should be extended based on more mileage and for a larger number & variety of tyres. This will strengthen the results of the Principal Component Analysis.

THANK YOU FOR YOUR ATTENTION