FINAL REPORT
RESEARCH PROJECT

DETERMINATION OF THE STATE-OF-THE-ART CONCERNING ROLLING NOISE, ROLLING-RESISTANCE AND SAFETY PROPERTIES OF MODERN PASSENGER CAR TYRES

TÜV AUTOMOTIVE

Umwelt Bundes Amt
Für Mensch und Umwelt

Environmental research plan
of the Federal Minister for the Environment,
Nature Conservation and Nuclear Safety

Research report 201 54 112

Determination of the state-of-the-art concerning rolling noise, rolling-resistance and safety properties of modern passenger car tyres

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This project is part of a common project for the development of a procedure determining the wet grip of passenger car tyres in cooperation with BASt (D), DFT (GB) and RDW (NL).

Berichtsnummer UBA-FB 201 54 112		

Titel des Berichts

Ermittlung des aktuellen Standes der Technik im Hinblick auf Abrollgeräusch, Rollwiderstand sowie Sicherheitseigenschaften moderner Pkw-Reifen

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Zusätzliche Angaben

Kurzfassung

Es sollen in den Dimensionen 155/60 R14, 165/70 R14, 185/60 R14, 195/65 R15, 205/55 R16 und 225/45 R17 Geräusch, Rollwiderstand sowie Aquaplaning und Nassbremsverhalten an marktverbreiteten Pkw-Reifen (Sommer- und Winterreifen) untersucht werden. Die Kollektive umfassen zwischen 3 und 11 Reifenmarken und wurden nach marktrelevanten Gesichtspunkten zusammengestellt. Sie decken einen breiten Bereich von herausragenden bis zu unterdurchschnittlichen Leistungen in den einzelnen Kriterien ab.

Schlagwörter

Reifen, Rollgeräusch, Rollwiderstand, Aquaplaning, Nassbremsen

Preis

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Abstract: The aim of the study is to investigate rolling noise, rolling-resistance, aquaplaning and wet-braking characteristics of various tyres in the dimensions155/60 R14, 165/70 R14, 185/60 R14, 195/65 R15, 205/55 R16 und 225/45 R17. Each tyre population comprised between 3 and 11 tyre brands selected according to market relevance, covering a broad range from outstanding to poor performance in the single criteria.		
Keywords: Tyres, rolling noise, rolling resistance, aquaplaning, wet braking		
Price:		

VOL. 1 (REPORT)

I GENERAL PART

I.1 INDEX

Chapter Page

VOL. 1 (REPORT)

VOLUME 2 (TABLES AND DIAGRAMS)

I.2 ABBREVIATIONS

ABS Anti-lock braking system

dB Decibel

$\mathbf{c_R}$ Coefficient of rolling resistance

$\mathbf{v_{Aqu.}}$ Floating speed

a Deceleration

FA Front axle

RA Rear axle

II MAIN PART

II.1 INITIAL POSITION AND NECESSITY

Subsequent to the research report 20505808 „Determination of noise and rolling resistance coefficients of passenger car tyres“ from 1998, the present research project is supposed to give information about the current standard of environmental compatibility and safety of a representative selection of prevalent passenger car tyres on the roads of Germany.

With regard to the intended extension of the EC Directive 92/23 (2001/43), more and more stringent demands on the environmental and safety standards of passenger car tyres will be imposed in the near future. Besides the noise regulations being already in force, limit values for e.g. the wet grip properties of tyres are expected and being prepared.

Within the scope of progress work for the extension of this directive, TÜV Automotive GmbH, Tire-/Wheel-Test-Center collaborates in advisory function in an Ad-hoc group of the GRRF/ECE and carried out research projects dealing with the wet braking performance of passenger car tyres.

As a past research project in year 1998 has shown, today’s tyres are producing noticeable differences in rolling noise, even if tyres of the same size are compared. Also the rolling resistance and the associated influence on a vehicle’s fuel consumption - a considerable criterion from the ecological point of view - is, as experience shows, subject to these differences. However, an optimisation of these mentioned properties is essential with regard to an immission reduction of the population and a conservation of resources.

Under all these environmental viewpoints, the safety aspect must not be neglected. It is a well known and challenging problem for the tyre industry to solve the conflict between low rolling noise and good wet grip. When manufacturers being confronted with the necessity to fulfil noise requirements, but being not willing or able for economic or know-how reasons to make use of high-quality raw material and sophisticated production technology, the possible risk of developing a tyre predominantly targeting to the fulfilment of the noise regulations, at the expense of the safety properties, cannot be denied. However, up to now, in several research projects of the tyre industry or research institutes, no quantifiable correlation between those properties was possible to be determined.

The realisation and implementation of the gained insights with view to the above mentioned explanations should stimulate, after completion of the project, the optimisation of tyre properties with the aim of a reduction of immissions on the population and the entire environment, and at the same time, adequate usage and safety properties. Moreover, important information with regard to the amendment of the directive 92/23 EEC is expected to be gained.

II.2 SELECTION OF TEST TYRES

The tyre size 175/70 R13 already tested within the scope of the mentioned past research project is still one of the most sold tyres. However, it is becoming increasingly less important and is found as original equipment only at niche models.

Today, even vehicles of the lower middle class come equipped with 195/65 R15 tyres. Similarly, the size 205/55 R16 has developed to the standard size of middle class vehicles and will gain increasing importance within the next years. As a so called “development size”, it enjoys special priority among the tyre manufacturers. All technical innovations and improvements are initially tested on this size and enter into the serial production after successful testing.

The selection of the test tyres was supposed to represent a realistic and preferably wide range of the market segment, with view to the chosen dimensions as well as the range of manufacturers and also with regard of future developments.

For this reason, importance was attached to involve so called “premium” brands on the one side, but also domestic and foreign low price tyres into the test program. For this, the selection contains tyres, which are used, as the same type of tyre, as original equipment (OE) by the car industry, as well as tyres of the aftermarket, which are not used for original equipment. The tests were performed with summer and winter tyres, moreover, in some selected sizes, so called “all-season” tyres were included.

On special request of the federal environmental agency, three tyres in the dimension 155/60 R14 were included in the test program, which are OE-tyres of the so called “3-litre-cars”. These tyres are considered to be particularly environmentally friendly with regard to a claimed low rolling resistance and are also sold under such labelling (e.g. Eco, energy or similar)

Beyond the mere determination of measurement values it was also tried to establish certain coherences and possible interdependencies among the properties of the tested tyres. For this reason, a classification of all tyres into three different classes was made, in order to be able to investigate with view to manufacturer and market position of the single tyres.

The tested tyres were purchased without exemption at free dealers of the aftermarket, under conventional conditions and without giving indications of a special usage, in order to exclude influences by third party.

The tests were carried out from January to April 2002.

They were carried out each on one sample set without consideration of quality variation in the serial production. Therefore, a statistic evaluation of the exemplarily determined results or a general quality statement cannot be made. Please note that single tyre types might have gone out of production in the meantime.

All indoor and outdoor tests have been carried out according to TÜV internal procedures, unless being exactly defined by existing EC directives or ISO standards. Details of the test implementation can be seen in chapter II.5

II.3 TEST TYRE COLLECTIVES

After consultation with the clients, the following dimensions and tyre types were chosen and composed to the test collectives (see table 1 to 10) listed in the following:

II.3.1 SUMMER TYRES 155/60 R14

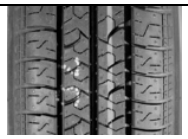
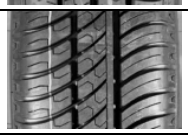
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
DS 1	Continental	ECO Contact EP	75 T	
DS 2	Bridgestone	B 381 Ecopia	75 T	
DS 3	Michelin	Energy XT-1	75 T	

Table 1

II.3.2 SUMMER TYRES 165/70 R14

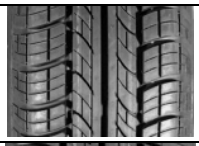
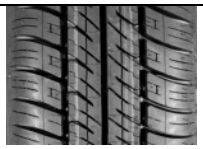
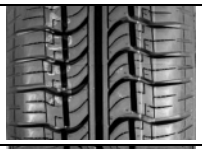
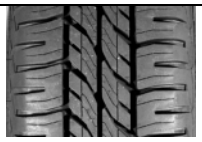
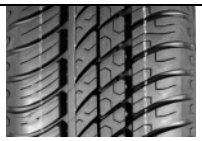
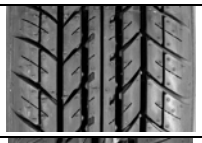
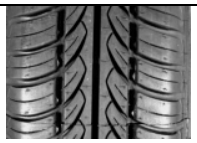
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
AS 1	Continental	ECO Contact EP	81 T	
AS 2	Dunlop	SP 10 3e	81 T	
AS 3	Pirelli	P 3000 Energy	81 T	
AS 4	Goodyear	GT 3	81 T	
AS 5	Michelin	Energy XT-1	81 T	
AS 6	Toyo	330	81 T	
AS 7	Yokohama	S 306	81 T	
AS 8	Kumho	758 Power Star	81 T	
AS 9	Marangoni	Trio	81 T	
AS 10	Uniroyal	Rallye 580	81 T	

Table 2

II.3.3 WINTER AND ALL SEASON TYRES 165/70 R14

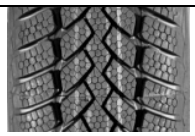
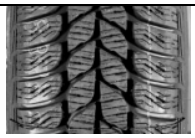
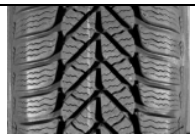
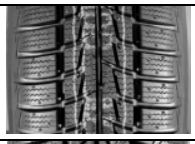
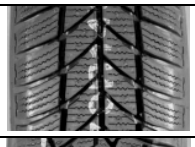
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
AW 1	Continental	Winter Contact TS 780	81 T	
AW2	Dunlop	Winter Sport M2	81 T	
AW	Pirelli	Winter 190 Snowcontrol	81 T	
AW 4	Goodyear	Ultra Grip 5	81 T	
AW 5	Michelin	Alpin	81 Q	
AW 6	Toyo	S 940	81 T	
AW 7	Vredestein	Snowtrac	81 T	
AW 8	Hankook	W 400	81 Q	
AW 9	Firestone	FW 930 Winter	81 T	
AG 1	Goodyear	Vector 5	81 T	
AG 2	Pirelli	P 2500 Euro	81 T	

Table 3

II.3.4 SUMMER TYRES 185/60 R 14

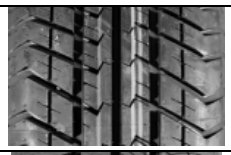
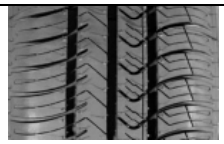
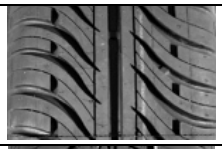
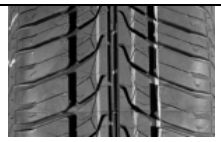
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
ES 1	Continental	Eco Contact CP	82 H	
ES 2	Bridgestone	RE 720	82 H	
ES 3	Sava	Rapidtex R2	82 H	
ES 4	Kleber	Viaxer	82 H	
ES 5	Stunner	SV 198	82 H	
ES 6	Fulda	Diadem Linero	82 T	
ES 7	Yokohama	A 539	82 H	

Table 4

II.3.5 WINTER AND ALL SEASON TYRES 185/60 R 14

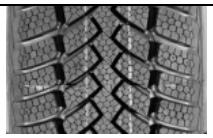
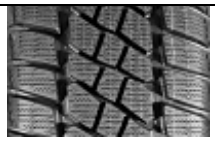
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
EW 1	Continental	Winter Contact TS 780	82 T	
EW 2	Bridgestone	LM 18	82 T	
EW 3	Pirelli	Winter Snow Sport	82 T	
EW 4	Kleber	Krisalp	82 T	
EW 5	Pneumant	P M+S 100	82 T	
EW 6	Nokian	Hakkapeliitta	82 H	
EW 7	Gislaved	Euro Frost 2	82 T	

Table 5

II.3.6 SUMMER TYRES DER DIMENSION 195/65 R15

Internal code	Manufacturer	Type	Load/speed index	Tread pattern
BS 1	Continental	Premium Contact	91 H	
BS 2	Dunlop	SP Sport 200 E	91 H	
BS 3	Goodyear	Eagle NCT 5	91 H	
BS 4	Michelin	Pilot Primacy	91 H	
BS 5	Toyo	Roadpro 610	91 H	
BS 6	GT Radial	Champiro 65	91 H	
BS 7	Barum	OR 58	91 H	
BS 8	Marangoni	Heron	91 H	
BS 9	Firestone	Firehawk FH 700	91 H	
BS 10	Pirelli	P 6	91 H	

Table 6

II.3.7 WINTER AND ALL SEASON TYRES 195/65 R15

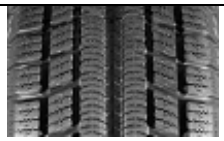
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
BW 1	Continental	Winter Contact TS 790	91 T	
BW 2	Dunlop	SP Winter Sport M3	91 T	
BW 3	Goodyear	Ultra Grip 6	91 T	
BW 4	Michelin	Alpin	91 T	
BW 5	Toyo	S 940	91 T	
BW 6	Marangoni	Meteo Grip	91 T	
BW 7	Marshall	KW 15	91 T	
BW 8	Yokohama	AVS Winter	91 T	
BW 9	Vredestein	Snowtrac	91 T	
BG 1	Goodyear	Vector 5	91 T	
BG 2	Dunlop	All Season M2	91 T	

Table 7

II.3.8 SUMMER TYRES 205/55 R16

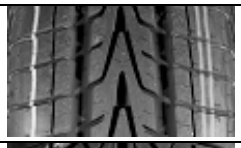
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
CS 1	Continental	Premium Contact	91 W	
CS 2	Dunlop	SP Sport 9000	91 W	
CS 3	Pirelli	P7	91 W	
CS 4	Michelin	Pilot Primacy	91 W	
CS 5	Toyo	T 1-S	91 W	
CS 6	GT Radial	Champiro 55	91 H	
CS 7	Vredestein	Sporttrac	91 W	
CS 8	Hankook	K 102	91 W	

Table 8

II.3.9 WINTER TYRES 205/55 R16

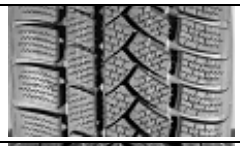
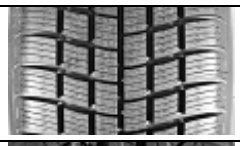
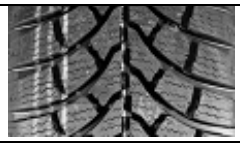
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
CW 1	Continental	Winter Contact TS 790	91 H	
CW 2	Dunlop	SP Winter Sport M3	91 H	
CW 3	Pirelli	Winter 210 Snowsport	91 H	
CW 4	Michelin	Pilot Alpin	91 H	
CW 5	Toyo	S 950	91 H	
CW 6	Vredestein	Wintrac	91 H	
CW 7	Hankook	W 400	91 H	
CW 8	Firestone	FW 930 Winter	91 H	

Table 9

II.3.10 SUMMER TYRES 225/45 R17

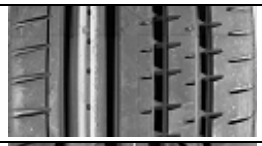
Internal code	Manufacturer	Type	Load/speed index	Tread pattern
HS 1	Continental	Sport Contact 2	91 Y	
HS 2	Bridgestone	SO-3	91 Y	
HS 3	Pirelli	P Zero Rosso Asimmetrico	91 Y	
HS 4	Falken	FK 451	91 Y	
HS 5	Pneumant	PN 950 Tritec	91 W	
HS 6	Fulda	Carat Extremo	91 ZR	
HS 7	Marangoni	Zeta ESC	91 W	

Table 10

II.4 TEST SCOPE AND PROCEDURE

In the present project, all above mentioned tyres are tested with view to different properties.

These are on the one hand those properties, which are, as already mentioned, of particular interest from the environmental point of view. This concerns e.g. the rolling resistance and in this context the tyre weight, which influence the fuel consumption of a vehicle to a considerable extent. A further criterion here is the tyre rolling noise emission, whose compliance is required for the EC type approval by the directive 92/23 EEC (amended by 2001/43 EC).

As an environmental compliance must not result in the negligence of safety properties especially on wet surface, the aquaplaning behaviour in longitudinal direction was tested from the safety relevant field. Moreover, the wet braking performance represents a very important part of driving and traffic safety and was therefore also included in the test program.

Further details of applied procedures and the test implementation can be taken from the following articles.

II.4.1 ROLLING RESISTANCE

The classification of the rolling resistance results from the determination of the rolling resistance coefficient c_R. This coefficient c_R [%] is calculated from the average values of the rolling resistance force in Newton [N] (of 10 min with 50 km/h, 20 min with 90 km/h und 20 min with 120 km/h) divided by the test load in [N] multiplied by 100 [%]:

$$c_R = \frac{\text{Rolling resistance [N]}}{\text{Test load [kg]} \times g\left[\frac{m}{s^2}\right]} \times 100\%$$

The mean weight of all four tyres of one set is determined prior to the rolling resistance measurements on controlled and calibrated scales.

Prior to the actual measurement, the tyres are run in under test conditions over 60 minutes with 80 km/h and conditioned hereafter for 3 hours under the conditions of the test lab.

The rolling resistance measurement is done on a drum test rig with a drum diameter of 2000 mm, according ISO 8767 (Fig. 1). Here, the electric power input of the pressed and the lifted tyre is measured. The rolling resistance is determined by the difference.

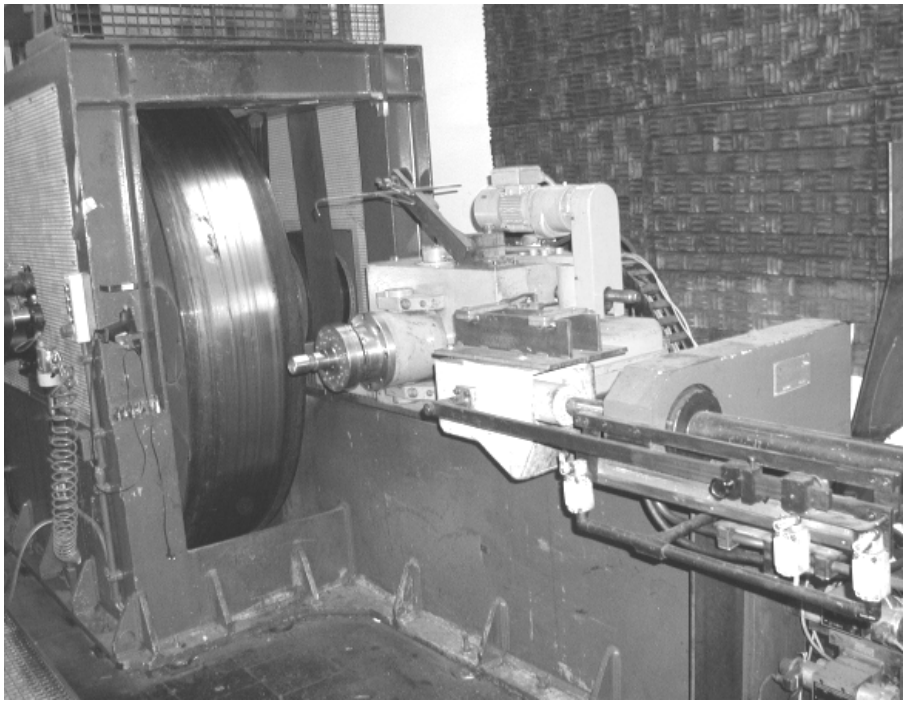


Fig.1: Drum test rig for rolling resistance

The measurement was performed each on two tyres of the same type. The adjustment of the inflation was done in a conditioned status, during the test a free pressure build-up was ensured.

II.4.2 NOISE MEASUREMENTS

The tyre rolling noise according directive 92/23 ECE (amended with 2001/43 EC) was measured. The test track used corresponds the requirements of ISO 10844. The measuring equipment corresponds class 1 of ISO 651.

The microphones are arranged in a distance of 7.5 m to the centre line in a height of 1.2 m above the road surface and are calibrated prior to the measurements.

The tyres were run in before the tests on public rods for approx. 100 km, in order to remove mould-release agents, mould discharges etc. from the tyres and to transfer the material's structure by the heating into a stable and definite status.

For the actual measurement, the test vehicles are rolling with turned-off engine and neutral gear through the measuring track (fig. 2). The maximum acoustic pressure level in db(A) is recorded for the right and the left side of the vehicle along with the speed.

Fig.2: Test vehicle on the noise measuring track

The described measurement is carried out 8 times at different speeds between 70 and 90 km/h. whereby the single speeds are distributed evenly to the most possible extent within the speed range. The results are referred to the reference speed by means of regression analysis.

The vehicles are loaded for the measurements in such a way that the wheel load is between 70 and 90 % of the maximum allowed tyre load index. The relevant tyre inflation is calculated from the actual existing wheel load by means of a given formula. The respective axle loads and inflation values - as well as for the remaining tests - are described in detail in chapter II.5.3.

Further explanations about the calculation formula and other details of the test implementation of tyre/road rolling noise measurements can be taken from the already mentioned EC directive 92/23 (with amendment 2001/43).

Note: The results of the noise measurements listed in III.2 and the relevant annexes are, in contrary to the directive, not subject to a reduction by one db(A) for consideration of possible measurement errors. They represent the actually measured, mathematically rounded results.

II.4.3 AQUAPLANING LONGITUDINAL

For the determination of the aquaplaning behaviour in longitudinal direction, the test vehicles are equipped with rotational speed sensors on both wheels of the front axle.

For the measurement of the floating speed as criterion for the aquaplaning behaviour, the vehicle is driven in the test track with a defined, predetermined speed. The right front wheel is running in a water basin with 8mm water depth (see fig. 3). When reaching the basin, the vehicle is accelerated maximally in 3rd or 4th gear (in dependence on the engine power and speed of the test vehicle). During the acceleration, the slip of the wheel running in the water basin is recorded.

Fig.3: Test vehicle during aquaplaning measurement

As floating speed $v_{Aqu.}$ that speed is defined, at which a slip of 15% is reached. The slip is defined as the ratio between the difference of wheel rotational speed of left and right wheel and the wheel rotational speed of the wheel which is not running in the water basin. For each tyre set, at least 6 valid measurements are performed.

II.4.4 WET BRAKING

The wet braking tests were performed on an artificially rained asphalt surface. The water depth was permanently kept below 1.5 mm, in order to exclude falsifying influences on the results by effects of aquaplaning.

The vehicle was decelerated by the equipped 4-wheel ABS from approx. 85 km/h to standstill, speed and braking distance were measured from 80 to 10 km/h with a satellite-based measuring device. The mean deceleration was calculated.

For each tyre set, at least 6 valid, i.e. lying within the chosen prediction capability measurements are performed.

Fig. 4: Test vehicle on wetted test track

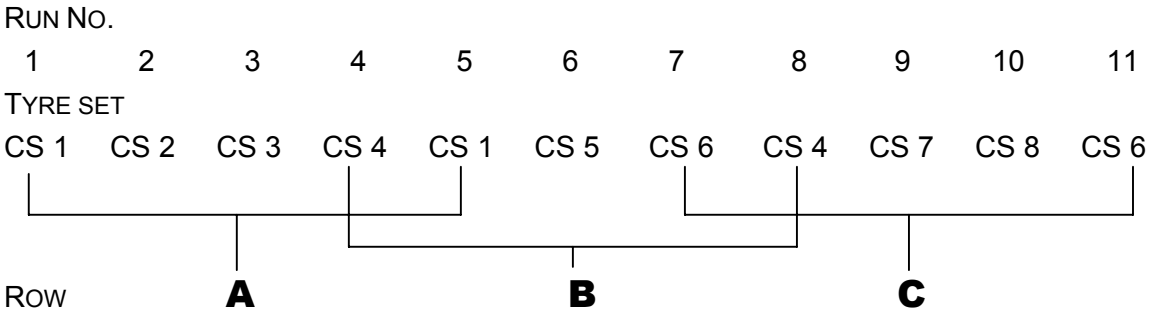
The measurements of the deceleration on wet surface are part of a further research project in the frame of the work of an ad-hoc group dealing with the development of a method to determine the wet grip of passenger car tyres. With consideration of the results of selected partial collectives on further test tracks, a method was to be developed which allowed a realistic and -to the most possible extent- track-independent classification of the wet braking properties of a tyre. For this reason, the test sequence and the mode of correction (with view to consider changes of the test conditions such as temperatures, surface etc.) took place in a special way designed by TÜV Automotive prior to the start of the project.

The necessity of the development of a new method results from certain deficiencies of the so far used standard reference test tyre (SRTT), which were detected already in former research projects. In the present project it was now tried to exclude the influences on the final results arising from the use of the SRTT for correction purposes. Therefore, the use of this tyre for correction is abandoned, in favour of a floating correction basing on collective tyres and considering the changes of test conditions.

Test sequence and proceeding are explained in detail in the following article.

II.4.5 TEST SEQUENCE AND MODE OF CORRECTION AT BRAKING

TEST SEQUENCE:



For securing and comparing purposes, the SRTT is integrated more than once into the test sequence. Periodically it is tested within the CTC tyres (in the above mentioned example before tyre run 1, between run 4 and 5, run 6 and 7 and after run 11). However, the evaluation and the correction takes place without the SRTT.

MODE OF CORRECTION:

1. At first, for each tyre which forms beginning and end of a floating correction, the percentage change of the mean deceleration from the first to the second measurement is determined. The result of the first measurement always represents 100%.

2. For each first-time measured tyre set lying in between, a correction factor K_i is formed by linear interpolation.

Example:

A **Tyre T_i**	**T_1 (1.)**	**T_2**	**T_3**	**T_4**	**T_1(2.)**
Mean deceleration a_i [m/s²]	8,67	8,80	8,02	7,70	8,50
Correction factor K_i	100 %	99,5 %	99,0%	98,5 %	98,0 %

B **Tyre T_i**	**T_4(1.)**	**T_1(2.)**	**T_5**	**T_6**	**T_4(2.)**
Mean deceleration a_i [m/s²]	7,70	8,50	6,89	7,98	7,61
Correction factor K_i	100 %		99,6%	99,2%	98,8 %

etc.

3. To link one row to the antecedent, the correction factors of the row are multiplied by the correction factor K_i of that tyre, which had already been measured in the previous row (in the above named example K_4 with 98,5%). By this, for each tyre a factor $K_{i,\,ges}$ can be determined.

4. The corrected mean deceleration $a_{i,korr}$ is: $$\mathbf{a_{i,korr} = \frac{a_i}{K_{i,ges}}}$$

By this, the mentioned example results in:

T_i	T_1 (1.)	T_2	T_3	T_4	T_1(2.)	T_5	T_6	T_4(2.)
a_i[m/s²]	8,67	8,80	8,02	7,70	8,50	6,89	7,98	7,61
K_i	100 %	99,5 %	99,0%	98,5 %	98,0 %			
K_i				100%		99,6%	99,2%	98,8 %
$K_{i,\,ges}$	100,0%	99,5%	99,0%	98,5%		98,1%	97,7%	
$a_{i,\,korr}$ [m/s²]	**8,67**	**8,84**	**8,10**	**7,82**		**7,02**	**8,17**	

5. For determining the average of the collective, the arithmetic mean a_{CTC} of all corrected deceleration values is formed.

II.5 TECHNICAL TEST DETAILS AND CONDITIONS

II.5.1 TEST EQUIPMENT AND TRACKS

WEIGHT DETERMINATION

Scales: Sartorius F1505-x 02, Nr. QS-06 M 0027
Test location: Test lab of Tire-/Wheel-Test-Center of TÜV Automotive, Munich

ROLLING REISTANCE

Standard: ISO 8767

Outside drum test rig:
Diameter: 2000 mm
Surface: smooth steel

Temperature: min.: 20,2 °C max.: 24,1°C

Test location: Test lab of Tire-/Wheel-Test-Center of TÜV Automotive, Munich

ROLLING NOISE

Test surface: Asphalt acc. ISO10844

Temperatures:

Air:	min.: 4,8°C	max.: 20,6°C
Surface:	min.: 8,2°C	max.: 30,7°C

Test location: Noise test track of TÜV Automotive, Munich-Allach

AQUAPLANING

Surface: smooth concrete, water basin on the right, water depth 8 mm

Temperatures:

Air:	min.: 5,0°C	max.: 17,0°C
Surface:	min.: 8,0°C	max.: 16,0°C

Test location: Tyre proving ground in Traiskirchen(A)

WET BRAKING

Surface: Asphalt, artificially rained, water depth < 1,5 mm

Temperatures:

Air:	min.: 5,0°C	max.: 17,5°C
Surface :	min.: 8,0°C	max.: 14,0°C

Test location: Tyre proving ground in Traiskirchen(A)

II.5.2 TEST VEHICLES

The following vehicles are used for the relevant tyre dimensions:

NOISE MEASUREMENT

- VW Polo 1.2 (47 kW)
  Dimension: 155/60 R14
- Skoda Fabia 1.4 MPI (50 kW)
  Dimensions: 165/70 R14, 185/60 R14
- VW Golf TDI (74 kW)
  Dimension: 195/65 R15
- BMW 320d (110 kW)
  Dimensions: 205/55 R16, 225/45 R17

AQUAPLANING AND BRAKING

- VW Polo TDI (55 kW)
  Dimensions: 155/60 R14, 165/70 R14, 185/60 R14
- VW Golf TDI (74 kW) and Golf 1.4 (55 kW)
  Dimension: 195/65 R15
- BMW 320d (110 kW)
  Dimensions: 205/55 R16, 225/45 R17

II.5.3 VEHICLE LOAD UND TYRE INFLATION

ROLLING REISTANCE MEASUREMENTS

Test load and tyre inflation were set according to the descriptions of the international testing standard ISO 8767:

- ***Test collective155/60 R14 (DS)***
  Test load: 310 kg
  Inflation: 2,2 bar

- ***Test collective165/70 R14 (AS, AW, AG)***
  Test load: 370 kg
  Inflation: 2,2 bar

- ***Test collective185/60 R14 (ES, EW)***
  Test load: 380 kg
  Inflation: 2,2 bar

- ***Test collective195/65 R15 (BS, BW, BG)***
  Test load: 492 kg
  Inflation: 2,2 bar

- ***Test collective205/55 R16 (CS, CW)***
  Test load: 492 kg
  Inflation: 2,2 bar

- ***Test collective225/45 R17 (HS)***
  Test load: 492 kg
  Inflation: 2,2 bar

NOISE MEASUREMENTS

The calculation of required vehicle load and tyre inflation was made according to the formula given in EC directive 92/23. For the single test collectives, the values are as follows:

- ***Test collective155/60 R14 (DS)***
  Vehicle load FA: 690 kg RA: 540 kg
  Inflation: FA: 2,4 bar RA: 1,8 bar

- ***Test collective165/70 R14 (AS, AW, AG)***
  Vehicle load FA: 710 kg RA: 670 kg
  Inflation: FA: 1,9 bar RA: 1,9 bar

- ***Test collective185/60 R14 (ES, EW)***
  Vehicle load FA: 710 kg RA: 670 kg
  Inflation: FA: 1,8 bar RA: 1,8 bar

  Test collective195/65 R15 (BS, BW, BG)
  Vehicle load FA: 950 kg RA: 900 kg
  Inflation: FA: 1,9 bar RA: 1,9 bar

- ***Test collective205/55 R16 (CS, CW)***
  Vehicle load FA: 950 kg RA: 900 kg
  Inflation: FA: 1,9 bar RA: 1,9 bar

- ***Test collective225/45 R17 (HS)***
  Vehicle load FA: 850 kg RA: 880 kg
  Inflation: FA: 1,7 bar RA: 1,8 bar

AQUAPLANING

The test vehicles are loaded with the driver and measuring equipment. The tyre inflation is set as compromise between the car manufacturer's recommendations and a practicable test implementation:

- ***Test collective155/60 R14 (DS)***
  Vehicle load FA: 750 kg RA: 480 kg
  Inflation: FA: 2,5 bar RA: 2,5 bar

- ***Test collective165/70 R14 (AS, AW, AG)***
  Vehicle load FA: 820 kg RA: 480 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective185/60 R14 (ES, EW)***
  Vehicle load FA: 820 kg RA: 480 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective195/65 R15 (BS, BW, BG)***
  Vehicle load FA: 950 kg RA: 750 kg
  Inflation: FA: 1,8 bar RA: 1,8 bar

- ***Test collective205/55 R16 (CS, CW)***
  Vehicle load FA: 800 kg RA: 800 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective225/45 R17 (HS)***
  Vehicle load FA: 800 kg RA: 800 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

WET BRAKING

According to the ISO proposal “Passenger car: Method for measuring relative wet grip“, which bases on the load/inflation conditions given in the ETRTO manual, the values for tyre inflation and axle loads are as follows:

- ***Test collective155/60 R14 (DS)***
  Vehicle load FA: 750 kg RA: 730 kg
  Inflation: FA: 2,5 bar RA: 2,5 bar

- ***Test collective165/70 R14 (AS, AW, AG)***
  Vehicle load FA: 770 kg RA: 670 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective185/60 R14 (ES, EW)***
  Vehicle load 770 kg RA: 670 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective195/65 R15 (BS, BW, BG)***
  Vehicle load FA: 950 kg RA: 750 kg
  Inflation: FA: 1,8 bar RA: 1,8 bar

- ***Test collective205/55 R16 (CS, CW)***
  Vehicle load FA: 890 kg RA: 900 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

- ***Test collective225/45 R17 (HS)***
  Vehicle load FA: 890 kg RA: 900 kg
  Inflation: FA: 2,0 bar RA: 2,0 bar

III RESULTS

III.1 WEIGHT AND ROLLING RESISTANCE ACC. ISO 8767

III.1.1 SUMMER TYRES155/60 R14

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
DS 1	Conti Eco Contact EP	5,80	1,11
DS 2	Bridgestone B 381 Ecopia	5,35	0,87
DS 3	Michelin Energy XT-1	5,59	0,99
∅ collective		5,58	0,99

III.1.2 SUMMER TYRES 165/70 R14

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
AS 1	Conti Eco Contact EP	6,27	0,99
AS 2	Dunlop SP 10 3e	6,80	1,07
AS 3	Pirelli P 300 Energy	6,61	1,20
AS 4	Goodyear GT 3	6,12	0,99
AS 5	Michelin Energy XT-1	6,64	1,00
AS 6	Toyo 330	6,32	1,20
AS 7	Yokohama S 306	6,81	1,18
AS 8	Kumho 758 Powerstar	6,24	1,14
AS 9	Marangoni Trio	6,21	1,17
AS 10	Uniroyal Rallye 580	6,27	1,19
∅ collective		6,43	1,11

III.1.3 WINTER AND ALL-SEASON TYRES 165/70 R14

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
AW 1	Conti Winter Contact TS 780	6,50	1,10
AW 2	Dunlop Winter Sport M2	6,71	1,30
AW 3	Pirelli Winter 190 Snowcontrol	6,86	1,26
AW 4	Goodyear Ultra Grip 5	6,10	1,18
AW 5	Michelin Alpin	6,54	1,11
AW 6	Toyo S 940	6,20	1,17
AW 7	Vredestein Snowtrac	6,22	1,18
AW 8	Hankook W400	6,93	1,10
AW 9	Firestone FW 930 Winter	7,07	1,22
AG 1	Goodyear Vector 5	6,22	1,20
AG2	Pirelli P 2500 Euro	7,10	1,31
∅ collective		6,54	1,19

III.1.4 SUMMER TYRES 185/60 R 14

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
ES 1	Conti Eco Contact CP	6,79	1,15
ES 2	Bridgestone RE 720	7,68	1,24
ES 3	Sava Rapidtex R2	7,28	1,41
ES 4	Kleber Viaxer	6,91	1,35
ES 5	Stunner SV 198	7,13	1,30
ES 6	Fulda Diadem Linero	6,48	1,21
ES 7	Yokohama A 539	7,57	1,16
∅ collective		7,12	1,26

III.1.5 WINTER TYRES 185/60 R 14

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
EW 1	Conti Winter Contact TS 780	7.09	1,07
EW 2	Bridgestone LM 18	8,09	1,35
EW 3	Pirelli Winter 190 Snowsport	7,67	1,21
EW 4	Kleber Krisalp	6,35	1,27
EW 5	Pneumant P M+S 100	7,24	1,21
EW 6	Nokian Hakkapeliitta	7,13	1,15
EW 7	Gislaved Euro Frost 2	6,40	1,09
∅ collective		7,14	1,19

III.1.6 SUMMER TYRES 195/65 R15

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
BS 1	Conti Premium Contact	7.82	0,97
BS 2	Dunlop SP Sport 200 E	8,82	1,12
BS 3	Goodyear Eagle NCT 5	8,64	1,15
BS 4	Michelin Pilot Primacy	8,76	1,12
BS 5	Toyo Roadpro 610	8,42	1,15
BS 6	GT Radial Champiro 65	9,40	1,13
BS 7	Barum OR 58	8,18	1,15
BS 8	Marangoni Heron	9,40	1,22
BS 9	Firestone Firehawk FH 700	8,86	1,28
BS 10	Pirelli P6	9,00	1,07
∅ collective		8,73	1,13

III.1.7 WINTER AND ALL-SEASON TYRES 195/65 R15

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
BW 1	Conti Winter Contact TS 790	8,85	1,19
BW 2	Dunlop SP Winter Sport M3	8,86	1,12
BW 3	Goodyear Ultra Grip 6	8,49	0,98
BW 4	Michelin Alpin	8,53	1,20
BW 5	Toyo S 940	8,74	1,00
BW 6	Marangoni Meteo Grip	8,88	1,17
BW 7	Marshall KW 15	9,40	1,10
BW 8	Yokohama AVS Winter	9,32	1,01
BW 9	Vredestein Snowtrac	8,85	1,06
BG 1	Goodyear Vector 5	8,85	1,23
BG 2	Dunlop All Season M2	8,84	1,24
∅ collective		8,88	1,12

III.1.8 SUMMER TYRES 205/55 R16

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
CS 1	Conti Premium Contact	9,13	1,07
CS 2	Dunlop SP Sport 9000	9,41	1,06
CS 3	Pirelli P7	9,95	1,30
CS 4	Michelin Pilot Primacy	9,12	0,97
CS 5	Toyo T1-S	9,51	1,22
CS 6	GT Radial Champiro 55	10,63	1,23
CS 7	Vredestein Sporttrac	9,26	1,07
CS 8	Hankook K 102	10,19	1,17
∅ collective		9,65	1,13

III.1.9 WINTER TYRES 205/55 R16

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
CW 1	Conti Winter Contact TS 790	9,36	1,06
CW 2	Dunlop SP Winter Sport M3	9,98	1,12
CW 3	Pirelli Winter 210 Snowsport	8,90	1,06
CW 4	Michelin Pilot Alpin	10,66	1,07
CW 5	Toyo S 950	9,96	1,01
CW 6	Vredestein Wintrac	8,92	1,03
CW 7	Hankook W 400	10,07	1,04
CW 8	Firestone FW 930 Winter	10,36	1,14
∅ collective		9,68	1,06

III.1.10 SUMMER TYRES 225/45 R17

Internal code	Make	Weight [kg]	Coefficient of rolling resistance c_R [%]
HS 1	Conti Sport Contact 2	9,67	1,19
HS 2	Bridgestone SO-3	11,14	1,36
HS 3	Pirelli P Zero Asimmetrico	9,63	1,28
HS 4	Falken FK 451	11,86	1,42
HS 5	Pneumant PN 950 Tritec	10,64	1,24
HS 6	Fulda Carat Extremo	9,66	1,32
HS 7	Marangoni Zeta ESC	11,07	1,37
∅ collective		10,52	1,31

III.2 NOISE MEASUREMENTS

III.2.1 SUMMER TYRES 155/60 R14

Internal code	Make	Noise [dB]	rounded [dB]
DS 1	Conti Eco Contact EP	71,04	71
DS 2	Bridgestone B 381 Ecopia	69,87	70
DS 3	Michelin Energy XT-1	70,60	71
∅ collective (energetic)		70,53	

III.2.2 SUMMER TYRES 165/70 R14

Internal code	Make	Noise [dB]	rounded [dB]
AS 1	Conti Eco Contact EP	71,96	72
AS 2	Dunlop SP 10 3e	71,00	71
AS 3	Pirelli P 300 Energy	73,49	73
AS 4	Goodyear GT 3	71,10	71
AS 5	Michelin Energy	71,06	71
AS 6	Toyo 330	71,06	71
AS 7	Yokohama S 306	71,66	72
AS 8	Kumho 758 Powerstar	71,23	71
AS 9	Marangoni Trio	72,30	72
AS 10	Uniroyal Rallye 580	72,30	72
∅ collective (energetic)		71,79	

III.2.3 WINTER AND ALL-SEASON TYRES 165/70 R14

Internal code	Make	Noise [dB]	rounded [dB]
AW 1	Conti Winter Contact TS 780	70,56	71
AW 2	Dunlop Winter Sport M2	71,27	71
AW 3	Pirelli Winter 190 Snowcontrol	70,67	71
AW 4	Goodyear Ultra Grip 5	72,96	73
AW 5	Michelin Alpin	71,64	72
AW 6	Toyo S 940	71,17	71
AW 7	Vredestein Snowtrac	71,85	72
AW 8	Hankook W400	69,01	69
AW 9	Firestone FW 930 Winter	69,94	70
AG 1	Goodyear Vector 5	70,99	71
AG2	Pirelli P 2500 Euro	70,84	71
∅ collective (energetic)		71,10	

III.2.4 SUMMER TYRES 185/60 R 14

Internal code	Make	Noise [dB]	rounded [dB]
ES 1	Conti Eco Contact CP	73,39	73
ES 2	Bridgestone RE 720	71,60	72
ES 3	Sava Rapidtex R2	74,43	74
ES 4	Kleber Viaxer	73,95	74
ES 5	Stunner SV 198	71,83	72
ES 6	Fulda Diadem Linero	72,05	72
ES 7	Yokohama A 539	71,37	71
∅ collective (energetic)		72,81	

III.2.5 WINTER TYRES 185/60 R 14

Internal code	Make	Noise [dB]	rounded [dB]
EW 1	Conti Winter Contact TS 780	73,94	74
EW 2	Bridgestone LM 18	70,43	70
EW 3	Pirelli Winter 190 Snowsport	71,67	72
EW 4	Kleber Krisalp	71,77	72
EW 5	Pneumant P M+S 100	70,13	70
EW 6	Nokian Hakkapeliitta	72,04	72
EW 7	Gislaved Euro Frost 2	72,23	72
∅ collective (energetic)		71,91	

III.2.6 SUMMER TYRES 195/65 R15

Internal code	Make	Noise [dB]	rounded [dB]
BS 1	Conti Premium Contact	72,00	72
BS 2	Dunlop SP Sport 200 E	71,02	71
BS 3	Goodyear Eagle NCT 5	73,51	74
BS 4	Michelin Pilot Primacy	71,15	71
BS 5	Toyo Roadpro 610	70,99	71
BS 6	GT Radial Champiro 65	70,91	71
BS 7	Barum OR 58	71,47	71
BS 8	Marangoni Heron	70,98	71
BS 9	Firestone Firehawk FH 700	72,13	72
BS 10	Pirelli P6	72,11	72
∅ collective (energetic)		71,70	

III.2.7 WINTER AND ALL-SEASON TYRES 195/65 R15

Internal code	Make	Noise [dB]	rounded [dB]
BW 1	Conti Winter Contact TS 790	72,36	72
BW 2	Dunlop SP Winter Sport M3	72,28	72
BW 3	Goodyear Ultra Grip 6	71,48	71
BW 4	Michelin Alpin	72,13	72
BW 5	Toyo S 940	70,90	71
BW 6	Marangoni Meteo Grip	73,05	73
BW 7	Marshall KW 15	71,57	72
BW 8	Yokohama AVS Winter	71,53	72
BW 9	Vredestein Snowtrac	72,27	72
BG 1	Goodyear Vector	69,66	70
BG 2	Dunlop All Season M2	73,65	74
∅ collective (energetic)		72,01	

III.2.8 SUMMER TYRES 205/55 R16

Internal code	Make	Noise [dB]	rounded [dB]
CS 1	Conti Premium Contact	71,59	72
CS 2	Dunlop SP Sport 9000	72,29	72
CS 3	Pirelli P7	72,76	73
CS 4	Michelin Pilot Primacy	71,69	72
CS 5	Toyo T1-S	72,12	72
CS 6	GT Radial Champiro 55	71,98	72
CS 7	Vredestein Sporttrac	74,04	74
CS 8	Hankook K 102	71,19	71
∅ collective (energetic)		72,28	

III.2.9 WINTER TYRES 205/55 R16

Internal code	Make	Noise [dB]	rounded [dB]
CW 1	Conti Winter Contact TS 790	74,40	74
CW 2	Dunlop SP Winter Sport M3	72,09	72
CW 3	Pirelli Winter 210 Snowsport	73,73	74
CW 4	Michelin Pilot Alpin	72,82	73
CW 5	Toyo S 950	71,92	72
CW 6	Vredestein Wintrac	73,53	74
CW 7	Hankook W 400	73,52	74
CW 8	Firestone FW 930 Winter	70,77	71
∅ collective (energetic)		72,98	

III.2.10 SUMMER TYRES 225/45 R17

Internal code	Make	Noise [dB]	rounded [dB]
HS 1	Conti Sport Contact 2	72,54	73
HS 2	Bridgestone SO-3	71,49	71
HS 3	Pirelli P Zero Asimmetrico	72,71	73
HS 4	Falken FK 451	69,61	70
HS 5	Pneumant PN 950 Tritec	70,67	71
HS 6	Fulda Carat Extremo	73,37	73
HS 7	Marangoni Zeta ESC	69,71	70
∅ collective (energetic)		71,66	

III.3 AQUAPLANING

Because of the fact that all tested tyres were new tyres with a relevant profile depth of more than 7 mm, the tests partly resulted in only slight differences. It can be assumed that with increasing mileage and the resulting decrease of profile depth, the differences among the single tyres would be getting clearer.

III.3.1 SUMMER TYRES 155/60 R14

Internal code	Make	$v_{Aqu.}$ [km/h]
DS 1	Conti Eco Contact EP	100,05
DS 2	Bridgestone B 381 Ecopia	90,80
DS 3	Michelin Energy XT-1	98,72
∅ collective		96,52

III.3.2 SUMMER TYRES 165/70 R14

Internal code	Make	$v_{Aqu.}$ [km/h]
AS 1	Conti Eco Contact EP	94,47
AS 2	Dunlop SP 10 3e	92,85
AS 3	Pirelli P 300 Energy	97,62
AS 4	Goodyear GT 3	93,73
AS 5	Michelin Energy	93,45
AS 6	Toyo 330	96,57
AS 7	Yokohama S 306	95,62
AS 8	Kumho 758 Powerstar	95,20
AS 9	Marangoni Trio	100,20
AS 10	Uniroyal Rallye 580	101,07
∅ collective		96,08

III.3.3 WINTER AND ALL-SEASON TYRES 165/70 R14

Internal code	Make	$v_{Aqu.}$ [km/h]
AW 1	Conti Winter Contact TS 780	101,67
AW 2	Dunlop Winter Sport M2	96,33
AW 3	Pirelli Winter 190 Snowcontrol	105,05
AW 4	Goodyear Ultra Grip 5	100,17
AW 5	Michelin Alpin	109,92
AW 6	Toyo S 940	99,98
AW 7	Vredestein Snowtrac	98,48
AW 8	Hankook W400	93,12
AW 9	Firestone FW 930 Winter	97,17
AG 1	Goodyear Vector 5	98,92
AG2	Pirelli P 2500 Euro	103,75
∅ collective		100,41

III.3.4 SUMMER TYRES 185/60 R 14

Internal code	Make	$v_{Aqu.}$ [km/h]
ES 1	Conti Eco Contact CP	91,88
ES 2	Bridgestone RE 720	91,57
ES 3	Sava Rapidtex R2	93,35
ES 4	Kleber Viaxer	93,60
ES 5	Stunner SV 198	93,08
ES 6	Fulda Diadem Linero	90,12
ES 7	Yokohama A 539	87,80
∅ collective		91,63

III.3.5 WINTER TYRES 185/60 R 14

Internal code	Make	$v_{Aqu.}$ [km/h]
EW 1	Conti Winter Contact TS 780	89,53
EW 2	Bridgestone LM 18	93,15
EW 3	Pirelli Winter 190 Snowsport	91,50
EW 4	Kleber Krisalp	91,87
EW 5	Pneumant P M+S 100	85,13
EW 6	Nokian Hakkapeliitta	89,18
EW 7	Gislaved Euro Frost 2	86,42
∅ collective		89,54

III.3.6 SUMMER TYRES 195/65 R15

Internal code	Make	$v_{Aqu.}$ [km/h]
BS 1	Conti Premium Contact	85,35
BS 2	Dunlop SP Sport 200 E	86,35
BS 3	Goodyear Eagle NCT 5	85,50
BS 4	Michelin Pilot Primacy	86,37
BS 5	Toyo Roadpro 610	82,43
BS 6	GT Radial Champiro 65	77,02
BS 7	Barum OR 58	88,38
BS 8	Marangoni Heron	85,98
BS 9	Firestone Firehawk FH 700	88,82
BS 10	Pirelli P6	88,28
∅ collective		85,45

III.3.7 WINTER AND ALL-SEASON TYRES 195/65 R15

Internal code	Make	$v_{Aqu.}$ [km/h]
BW 1	Conti Winter Contact TS 790	87,30
BW 2	Dunlop SP Winter Sport M3	94,08
BW 3	Goodyear Ultra Grip 6	92,77
BW 4	Michelin Alpin	91,08
BW 5	Toyo S 940	85,73
BW 6	Marangoni Meteo Grip	91,27
BW 7	Marshall KW 15	88,83
BW 8	Yokohama AVS Winter	87,67
BW 9	Vredestein Snowtrac	89,05
BG 1	Goodyear Vector	88,67
BG 2	Dunlop All Season M2	84,98
∅ collective		89,22

III.3.8 SUMMER TYRES 205/55 R16

Internal code	Make	$v_{Aqu.}$ [km/h]
CS 1	Conti Premium Contact	93,63
CS 2	Dunlop SP Sport 9000	93,97
CS 3	Pirelli P7	94,48
CS 4	Michelin Pilot Primacy	93,87
CS 5	Toyo T1-S	95,48
CS 6	GT Radial Champiro 55	91,53
CS 7	Vredestein Sporttrac	97,87
CS 8	Hankook K 102	95,23
∅ collective		94,51

III.3.9 WINTER TYRES 205/55 R16

Internal code	Make	$v_{Aqu.}$ [km/h]
CW 1	Conti Winter Contact TS 790	90,32
CW 2	Dunlop SP Winter Sport M3	94,60
CW 3	Pirelli Winter 210 Snowsport	92,48
CW 4	Michelin Pilot Alpin	91,38
CW 5	Toyo S 950	91,03
CW 6	Vredestein Wintrac	90,72
CW 7	Hankook W 400	90,00
CW 8	Firestone FW 930 Winter	90,58
∅ collective		91,39

III.3.10 SUMMER TYRES 225/45 R17

Internal code	Make	$v_{Aqu.}$ [km/h]
HS 1	Conti Sport Contact 2	89.98
HS 2	Bridgestone SO-3	90,70
HS 3	Pirelli P Zero Asimmetrico	89,85
HS 4	Falken FK 451	91,87
HS 5	Pneumant PN 950 Tritec	90,58
HS 6	Fulda Carat Extremo	88,95
HS 7	Marangoni Zeta ESC	87,75
∅ collective		89,95

III.4 BRAKING ON WET SURFACE

As already mentioned, the correction of the results for the coverage of changing test conditions was carried out in the way described in chapter II.4.5.

The comparability of the deceleration values of the single collectives among each other is, caused by the high number of test tyres, only possible to a very low extent. With proceeding test duration it was clearly noticeable that the surface grip of the used test lane was affected considerably by the high number of braking runs. After a certain number of runs, it was even necessary to swap the lane, which implicated a considerable change of the surface properties and consequently also of the reachable deceleration values. With involvement of the floating corrections it was well possible to ensure constant test conditions for the tyres within one collective, however not for the single collectives towards each other.

The continuously measured SRTT cannot be taken as reliable reference for correction purposes. Due to its inadequate braking performance and the incapability to depict the changes of the surface over a longer term with such a high number of braking runs as required for the present project, a falsifying influence on the final results has to be expected.

III.4.1 SUMMER TYRES 155/60 R14

As this collective was tested at nearly the same time and conditions as collectives AS und AW/AG, a comparison to the deceleration values of those collectives is valid to some degree.

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
DS 1	Conti Eco Contact EP	7,66	31,7
DS 2	Bridgestone B 381 Ecopia	6,87	35,4
DS 3	Michelin Energy XT-1	7,52	32,3
∅ collective		7,35	33,1

III.4.2 SUMMER TYRES 165/70 R14

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
AS 1	Conti Eco Contact EP	8,16	29,8
AS 2	Dunlop SP 10 3e	7,74	31,4
AS 3	Pirelli P 300 Energy	8,36	29,1
AS 4	Goodyear GT 3	7,90	30,8
AS 5	Michelin Energy	7,83	31,0
AS 6	Toyo 330	7,18	33,9
AS 7	Yokohama S 306	7,09	34,3
AS 8	Kumho 758 Powerstar	7,12	34,1
AS 9	Marangoni Trio	7,43	32,7
AS 10	Uniroyal Rallye 580	6,98	34,8
∅ collective		7,58	32,1

III.4.3 WINTER AND ALL-SEASON TYRES 165/70 R14

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
AW 1	Conti Winter Contact TS 780	7,61	31,9
AW 2	Dunlop Winter Sport M2	7,61	31,9
AW 3	Pirelli Winter 190 Snowcontrol	7,70	31,6
AW 4	Goodyear Ultra Grip 5	7,27	33,4
AW 5	Michelin Alpin	7,66	31,7
AW 6	Toyo S 940	7,44	32,7
AW 7	Vredestein Snowtrac	7,73	31,4
AW 8	Hankook W400	6,83	35,6
AW 9	Firestone FW 930 Winter	7,88	30,8
AG 1	Goodyear Vector 5	7,64	31,8
AG2	Pirelli P 2500 Euro	7,80	31,2
∅ collective		7,56	32,2

III.4.4 SUMMER TYRES 185/60 R 14

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
ES 1	Conti Eco Contact CP	8,80	27,6
ES 2	Bridgestone RE 720	8,43	28,8
ES 3	Sava Rapidtex R2	8,30	29,3
ES 4	Kleber Viaxer	8,12	29,9
ES 5	Stunner SV 198	8,49	28,6
ES 6	Fulda Diadem Linero	8,06	30,2
ES 7	Yokohama A 539	8,43	28,8
∅ collective		8,38	29,0

III.4.5 WINTER TYRES 185/60 R 14

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
EW 1	Conti Winter Contact TS 780	8,19	29,7
EW 2	Bridgestone LM 18	8,27	29,4
EW 3	Pirelli Winter 190 Snowsport	7,98	30,5
EW 4	Kleber Krisalp	8,19	29,7
EW 5	Pneumant P M+S 100	8,24	29,5
EW 6	Nokian Hakkapeliitta	8,00	30,4
EW 7	Gislaved Euro Frost 2	8,11	30,0
∅ collective		8,14	29,9

III.4.6 SUMMER TYRES 195/65 R15

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
BS 1	Conti Premium Contact CP	9,08	26,8
BS 2	Dunlop SP Sport 200 E	8,56	28,4
BS 3	Goodyear Eagle NCT 5	8,92	27,2
BS 4	Michelin Pilot Primacy	8,99	27,0
BS 5	Toyo Roadpro 610	8,61	28,2
BS 6	GT Radial Champiro 65	7,13	34,1
BS 7	Barum OR 58	6,85	35,5
BS 8	Marangoni Heron	8,33	29,2
BS 9	Firestone Firehawk FH 700	7,97	30,5
BS 10	Pirelli P6	7,92	30,7
∅ collective		8,24	29,5

III.4.7 WINTER AND ALL-SEASON TYRES 195/65 R15

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
BW 1	Conti Winter Contact TS 790	8,27	29,4
BW 2	Dunlop SP Winter Sport M3	8,30	29,3
BW 3	Goodyear Ultra Grip 6	8,40	28,9
BW 4	Michelin Alpin	8,11	30,0
BW 5	Toyo S 940	8,05	30,2
BW 6	Marangoni Meteo Grip	8,33	29,2
BW 7	Marshall KW 15	7,77	31,3
BW 8	Yokohama AVS Winter	7,89	30,8
BW 9	Vredestein Snowtrac	8,13	29,9
BG 1	Goodyear Vector	8,42	28,9
BG 2	Dunlop All Season M2	8,04	30,2
∅ collective		8,16	29,8

III.4.8 SUMMER TYRES 205/55 R16

Note: The extremely high deceleration values in the measurements of this collective are resulting predominantly from the fact that this collective was the first one which was measured on a completely new lane with practically unused surface and therefore an extremely high grip level.
However, the comparability of the tyres of this collective among each other remains unaffected by this.

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
CS 1	Conti Premium Contact	10,06	24,2
CS 2	Dunlop SP Sport 9000	10,46	23,2
CS 3	Pirelli P7	9,66	25,2
CS 4	Michelin Pilot Primacy	10,40	23,4
CS 5	Toyo T1-S	8,99	27,0
CS 6	GT Radial Champiro 55	8,84	27,5
CS 7	Vredestein Sporttrac	9,47	25,7
CS 8	Hankook K 102	9,59	25,3
∅ collective		9,68	25,1

III.4.9 WINTER TYRES 205/55 R16

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
CW 1	Conti Winter Contact TS 790	7,28	33,4
CW 2	Dunlop SP Winter Sport M3	7,51	32,4
CW 3	Pirelli Winter 210 Snowsport	7,47	32,5
CW 4	Michelin Pilot Alpin	7,63	31,9
CW 5	Toyo S 950	7,39	32,9
CW 6	Vredestein Wintrac	7,58	32,1
CW 7	Hankook W 400	6,73	36,1
CW 8	Firestone FW 930 Winter	7,97	30,5
∅ collective		7,45	32,6

III.4.10 SUMMER TYRES 225/45 R17

Internal code	Make	Mean deceleration [m/s²] (corrected)	Braking dist. 80-10 km/h [m] (corrected)
HS 1	Conti Sport Contact 2	7,96	30,5
HS 2	Bridgestone SO-3	7,27	33,4
HS 3	Pirelli P Zero Asimmetrico	8,05	30,2
HS 4	Falken FK 451	7,60	32,0
HS 5	Pneumant PN 950 Tritec	7,64	31,8
HS 6	Fulda Carat Extremo	7,06	34,4
HS 7	Marangoni Zeta ESC	7,59	32,0
∅ collective		7,60	33,1

III.5 SUMMARY TABLE WITH CLASSIFICATION

The coloured markings of the single results in the following tables 11 to 13 are giving information about the ranking in relation to the average of the relevant collective. Additionally, the colour of the tyre make indicates information about the sales price:

Column/colour	Meaning
Tyre make	more than 20 % more expensive
c_R	more than 10 % higher
m	more than 10 % heavier
L	more than 20 % louder*
$v_{Aqu.}$	more than 5 % lower
a	more than 5 % lower
Tyre make	10 to 20 % more expensive
c_R	5 to 10 % higher
m	5 to 10 % heavier
L	10 to 20 % louder*
$v_{Aqu.}$	2,5 to 5% lower
a	2,5 to 5% lower
Tyre make	less than 10 % more expensive to less than 10 % cheaper
c_R	less than 5% higher to less than 5% lower
m	less than 5 % heavier to less than 5 % lighter
L	less than 10 % louder to less than 10 % lower*
$v_{Aqu.}$	less than 2,5 % higher to less than 2,5 % lower
a	less than 2,5 % higher to less than 2,5 % lower
Tyre make	10 to 20 % cheaper
c_R	5 to 10 % lower
m	5 to 10 % lighter
L	10 to 20 % lower*
$v_{Aqu.}$	2,5 to 5% higher
a	2,5 to 5% higher
Tyre make	more than 20 % cheaper
c_R	more than 10 % lower
m	more than 10 % lighter
L	more than 20 % lower*
$v_{Aqu.}$	more than 5 % higher
a	more than 5 % higher

* the classification of the relative noise emission is made from the energetic point of view

Internal code	Tyre make	c_R [%]	m [kg]	L [dB]	$v_{Aqu.}$ [km/h]	a [m/s²]
155/60 R14 Summer tyres						
DS 1	Conti Eco Contact EP	1,11	5,80	71,04	100,05	7,66
DS 2	Bridgestone B 381 Ecopia	0,87	5,35	69,87	90,80	6,87
DS 3	Michelin Energy XT-1	0,99	5,59	70,60	98,72	7,52
165/70 R14 Summer tyres						
AS 1	Conti Eco Contact EP	0,99	6,27	71,96	94,47	8,16
AS 2	Dunlop SP 10 3e	1,07	6,80	71,00	92,85	7,74
AS 3	Pirelli P 300 Energy	1,20	6,61	73,49	97,62	8,36
AS 4	Goodyear GT 3	0,99	6,12	71,10	93,73	7,90
AS 5	Michelin Energy XT-1	1,00	6,64	71,06	93,45	7,83
AS 6	Toyo 330	1,20	6,32	71,06	96,57	7,18
AS 7	Yokohama S 306	1,18	6,81	71,66	95,62	7,09
AS 8	Kumho 758 Powerstar	1,14	6,24	71,23	95,20	7,12
AS 9	Marangoni Trio	1,17	6,21	72,30	100,20	7,43
AS 10	Uniroyal Rallye 580	1,19	6,27	72,30	101,07	6,98
165/70 R14 Winter and all-season tyres						
AW 1	Conti Winter Contact TS 780	1,10	6,50	70,56	101,67	7,61
AW 2	Dunlop Winter Sport M2	1,30	6,71	71,27	96,33	7,61
AW 3	Pirelli Winter 190 Snowcont.	1,26	6,86	70,67	105,05	7,70
AW 4	Goodyear Ultra Grip 5	1,18	6,10	72,96	100,17	7,27
AW 5	Michelin Alpin	1,11	6,54	71,64	109,92	7,66
AW 6	Toyo S 940	1,17	6,20	71,17	99,98	7,44
AW 7	Vredestein Snowtrac	1,18	6,22	71,85	98,48	7,73
AW 8	Hankook W400	1,10	6,93	69,01	93,12	6,83
AW 9	Firestone FW 930 Winter	1,22	7,07	69,94	97,17	7,88
AG 1	Goodyear Vector 5	1,20	6,22	70,99	98,92	7,64
AG2	Pirelli P 2500 Euro	1,31	7,10	70,84	103,75	7,80
185/60 R14 Summer tyres						
ES 1	Conti Eco Contact CP	1,15	6,79	73,39	91,88	8,80
ES 2	Bridgestone RE 720	1,24	7,68	71,60	91,57	8,43
ES 3	Sava Rapidtex R2	1,41	7,28	74,43	93,35	8,30
ES 4	Kleber Viaxer	1,35	6,91	73,95	93,60	8,12
ES 5	Stunner SV 198	1,30	7,13	71,83	93,08	8,49
ES 6	Fulda Diadem Linero	1,21	6,48	72,05	90,12	8,06
ES 7	Yokohama A 539	1,16	7,57	71,37	87,80	8,43

Table 11

Internal code	Tyre make	c_R [%]	m [kg]	L [dB]	$v_{Aqu.}$ [km/h]	a [m/s²]
185/60 R14 Winter tyres						
EW 1	Conti Winter Contact TS 780	1,07	7,09	73,94	89,53	8,19
EW 2	Bridgestone LM 18	1,35	8,09	70,43	93,15	8,27
EW 3	Pirelli Winter 190 Snowsport	1,21	7,67	71,67	91,50	7,98
EW 4	Kleber Krisalp	1,27	6,35	71,77	91,87	8,19
EW 5	Pneumant P M+S 100	1,21	7,24	70,13	85,13	8,24
EW 6	Nokian Hakkapeliitta	1,15	7,13	72,04	89,18	8,00
EW 7	Gislaved Euro Frost 2	1,09	6,40	72,23	86,42	8,11
195/65 R15 Summer tyres						
BS 1	Conti Premium Contact	0,97	7,82	72,00	85,35	9,08
BS 2	Dunlop SP Sport 200 E	1,12	8,82	71,02	86,35	8,56
BS 3	Goodyear Eagle NCT 5	1,15	8,64	73,51	85,50	8,92
BS 4	Michelin Pilot Primacy	1,12	8,76	71,15	86,37	8,99
BS 5	Toyo Roadpro 610	1,15	8,42	70,99	82,43	8,61
BS 6	GT Radial Champiro 65	1,13	9,40	70,91	77,02	7,13
BS 7	Barum OR 58	1,15	8,18	71,47	88,38	6,85
BS 8	Marangoni Heron	1,22	9,40	70,98	85,98	8,33
BS 9	Firestone Firehawk FH 700	1,28	8,86	72,13	88,82	7,97
BS 10	Pirelli P6	1,07	9,00	72,11	88,28	7,92
195/65 R15 Winter tyres						
BW 1	Conti Winter Contact TS 790	1,19	8,85	72,36	87,30	8,27
BW 2	Dunlop SP Winter Sport M3	1,12	8,86	72,28	94,08	8,30
BW 3	Goodyear Ultra Grip 6	0,98	8,49	71,48	92,77	8,40
BW 4	Michelin Alpin	1,20	8,53	72,13	91,08	8,11
BW 5	Toyo S 940	1,00	8,74	70,90	85,73	8,05
BW 6	Marangoni Meteo Grip	1,17	8,88	73,05	91,27	8,33
BW 7	Marshall KW 15	1,10	9,40	71,57	88,83	7,77
BW 8	Yokohama AVS Winter	1,01	9,32	71,53	87,67	7,89
BW 9	Vredestein Snowtrac	1,06	8,85	72,27	89,05	8,13
BG 1	Goodyear Vector 5	1,23	8,85	69,66	88,67	8,42
BG 2	Dunlop All Season M2	1,24	8,84	73,65	84,98	8,04

Table 12

Internal code	Tyre make	c_R [%]	m [kg]	L [dB]	$v_{Aqu.}$ [km/h]	a [m/s²]
205/55 R16 Summer tyres						
CS 1	Conti Premium Contact	1,07	9,13	71,59	93,63	10,06
CS 2	Dunlop SP Sport 9000	1,06	9,41	72,29	93,97	10,46
CS 3	Pirelli P7	1,30	9,95	72,76	94,48	9,66
CS 4	Michelin Pilot Primacy	0,97	9,12	71,69	93,87	10,40
CS 5	Toyo T1-S	1,22	9,51	72,12	95,48	8,99
CS 6	GT Radial Champiro 55	1,23	10,63	71,89	91,53	8,84
CS 7	Vredestein Sporttrac	1,07	9,26	74,04	97,87	9,47
CS 8	Hankook K 102	1,17	10,19	71,19	95,23	9,59
205/55 R16 Summer tyres						
CW 1	Conti Winter Contact TS 790	1,06	9,36	74,40	90,32	7,28
CW 2	Dunlop SP Winter Sport M3	1,12	9,98	72,09	94,60	7,51
CW 3	Pirelli Winter 210 Snowsport	1,06	8,90	73,73	92,48	7,47
CW 4	Michelin Pilot Alpin	1,07	10,66	72,82	91,38	7,63
CW 5	Toyo S 950	1,01	9,96	71,92	91,03	7,39
CW 6	Vredestein Wintrac	1,03	8,92	73,53	90,72	7,58
CW 7	Hankook W 400	1,04	10,07	73,52	90,00	6,73
CW 8	Firestone FW 930 Winter	1,14	10,36	70,77	90,58	7,97
225/45 R17 Summer tyres						
HS 1	Conti Sport Contact 2	1,19	9,67	72,54	89,98	7,96
HS 2	Bridgestone SO-3	1,36	11,14	71,49	90,70	7,27
HS 3	Pirelli P Zero Asimmetrico	1,28	9,63	72,71	89,85	8,05
HS 4	Falken FK 451	1,42	11,86	69,91	91,87	7,60
HS 5	Pneumant PN 950 Tritec	1,24	10,64	70,67	90,58	7,64
HS 6	Fulda Carat Extremo	1,32	9,66	73,37	88,95	7,06
HS 7	Marangoni Zeta ESC	1,37	11,07	69,71	87,75	7,59

Table 13

IV ADDITIONAL EVALUATIONS

IV.1 COMPARISONS WITH VIEW TO MANUFACTURER/DISTRIBUTION

In order to be able to make a representative comparison about the complete population of the tested tyres, a classification into the following different categories was made:

PREMIUM-CATEGORY:
This category is defined among other things by the large percentage in original equipment.
A further criterion is, that the tyres of these manufacturers are forming the top in price of the total population.

Consisting of:

- Bridgestone (J)
- Continental (D)
- Dunlop (GB)
- Goodyear (USA)
- Michelin (F)
- Pirelli (I)

MEDIUM CATEGORY:
The important role in the after market characterises the tyres of this category. Concerning the sales price, they are representing the medium range.

Consisting of:

- Falken (J)
- Firestone (USA)
- Fulda (D)
- Gislaved (S)
- Hankook (ROK)
- Kleber (F)
- Kumho (ROK)
- Nokian (SF)
- Toyo (J)
- Uniroyal (D)
- Vredestein (NL)
- Yokohama(J)

BUDGET-CATEGORY:
As this category is composed among others by secondary brands of manufacturers of the premium and medium category, it is predominantly characterised by a low price. Moreover it contains brands of less known and common manufacturers.

Consisting of:

- Barum (CZ)
- GT Radial (RI)
- Marangoni (I)
- Marshall (ROK)
- Pneumant (D)
- Sava (SLO)
- Stunner (I)

Concerning the composition of the single categories, we would like to annotate that the categories are lying close to each other and the lines between them are blurred. The classification is therefore of course underlying a subjective view by TÜV Automotive. There is no denying that single manufacturer can be classified differently with certain tyre types, but with view to a uniform presentation of the results it was not possible to consider this individually.

The classification in price bases on the sales prices that were actually paid for the relevant tyres by TÜV Automotive. In dependence on the tyre set, in particular cases some variations are possible.

The results mentioned in the following diagrams are referring to the arithmetic mean of all tyres of the relevant collective. Please note that at the results of the noise emission the average as well as the level values are to be seen from the energetic point of view (unlogarithmed), i.e. a difference of +/- 3 dB corresponds a doubling respectively halving of the emitted sound energy.

For these investigations only 9 out of 10 collectives could be used, as the collective of summer tyres in size 155/60 R14 was made up only of products of the premium category, which made such examination here invalid.

For the understanding of the single criteria:

The basis of 100% always represents the average of the relevant collective. The single criteria are to be assessed as follows:

-Relative noise emission:
a higher percentage means a higher noise emission (i.e. >100% is worse)

-Relative deceleration:
a higher percentage means a better braking performance (i.e. >100% is better)

-Relative rolling resistance:
a higher percentage means a higher the rolling resistance (i.e. >100% is worse)

-Relative floating speed:
a higher percentage means a better aquaplaning behaviour (i.e. >100% is better)

-Relative sales price:
a higher percentage means a higher sales price (i.e. >100% is worse)

IV.1.1 SUMMER TYRES 165/70 R14

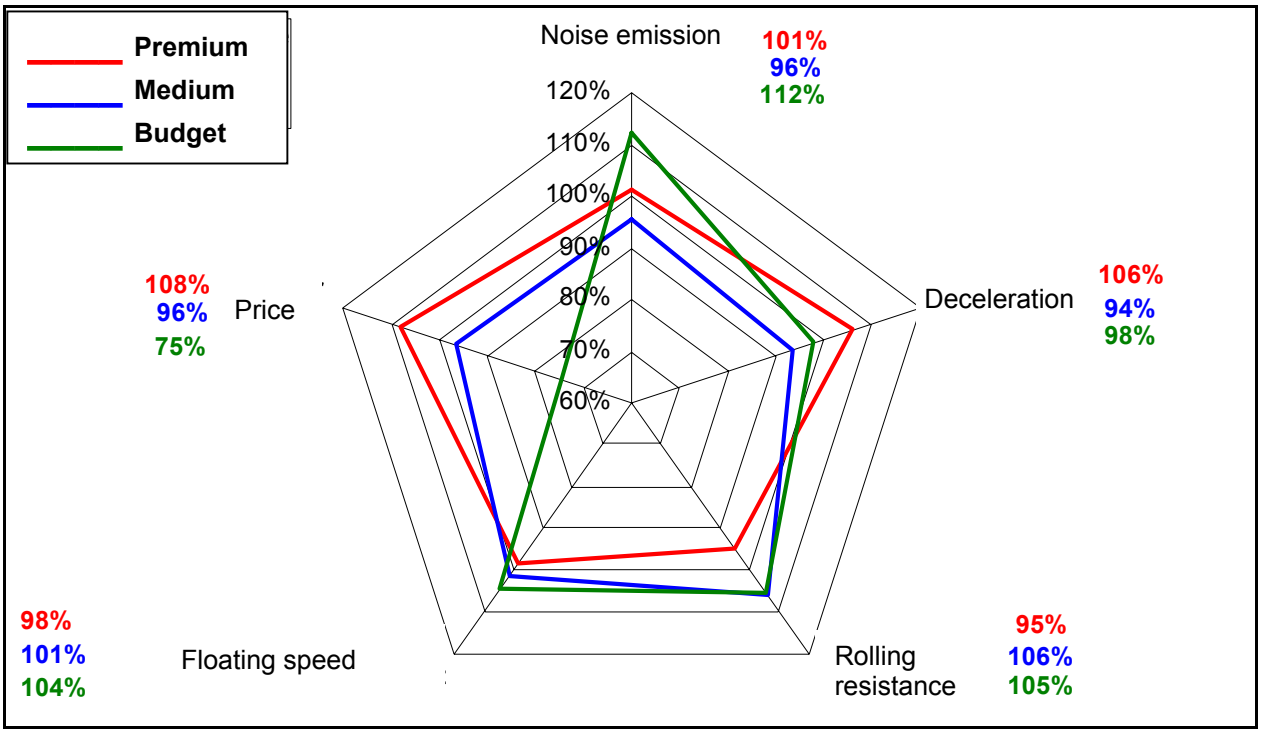


Diagram 1

IV.1.2 WINTER AND ALL-SEASON TYRES 165/70 R14

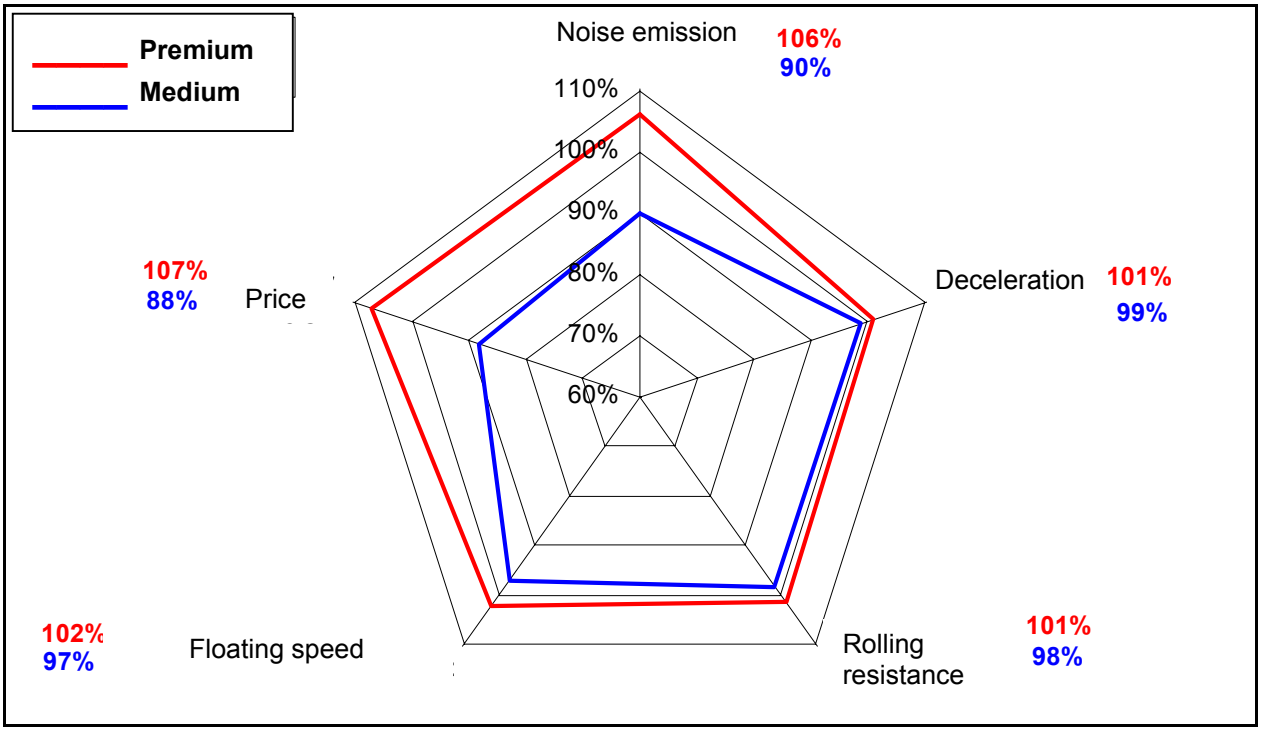


Diagram 2

IV.1.3 SUMMER TYRES 185/60 R14

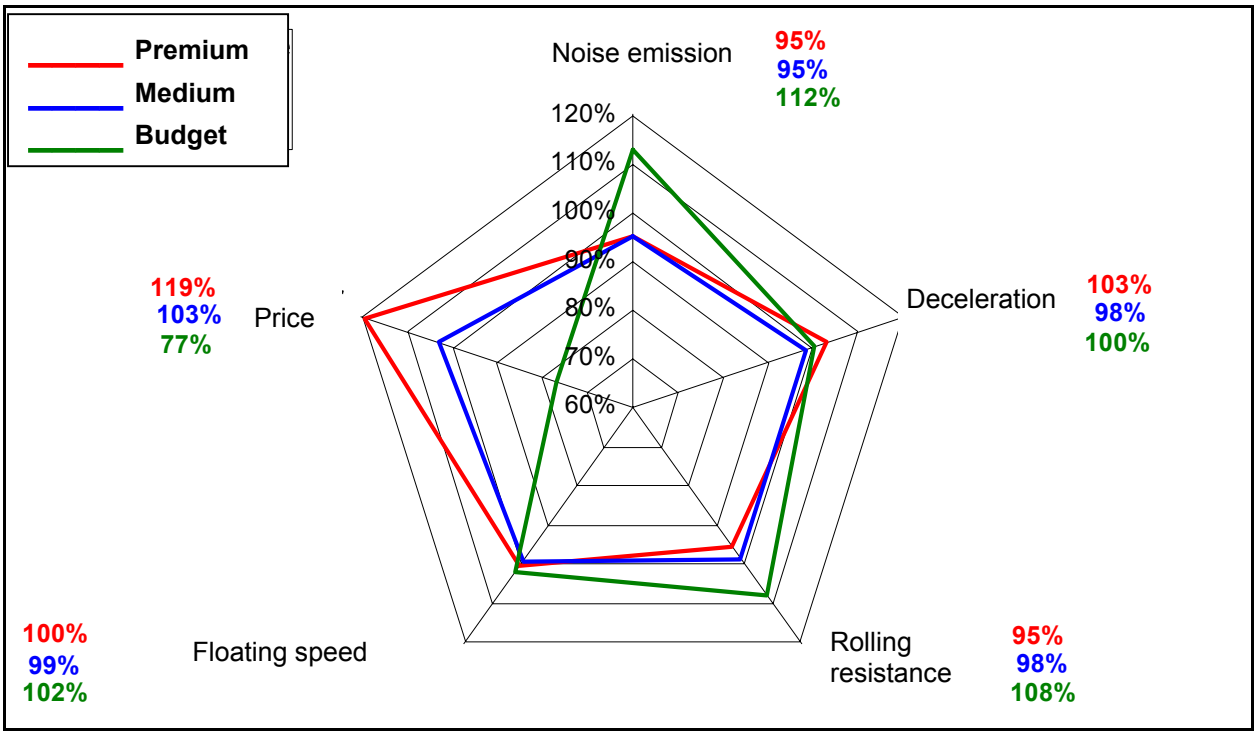


Diagram 3

IV.1.4 WINTER TYRES 185/60 R14

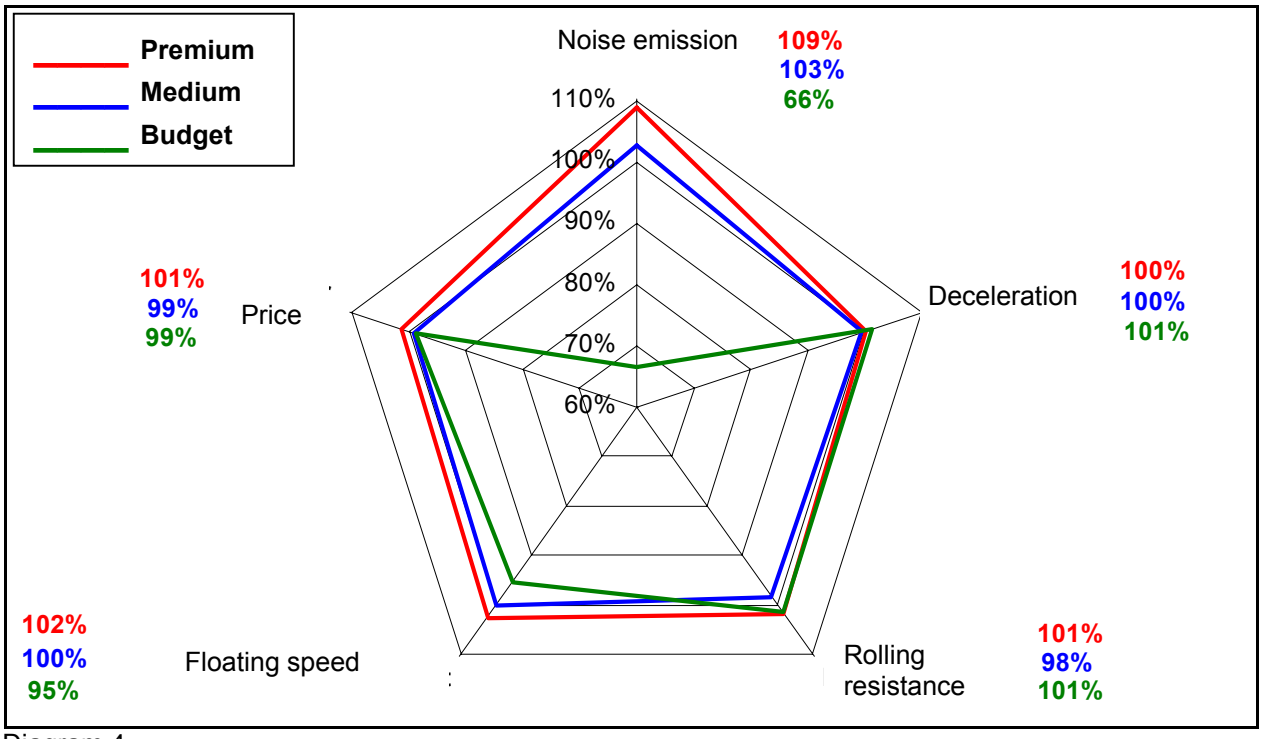


Diagram 4

IV.1.5 SUMMER TYRES 195/65 R15

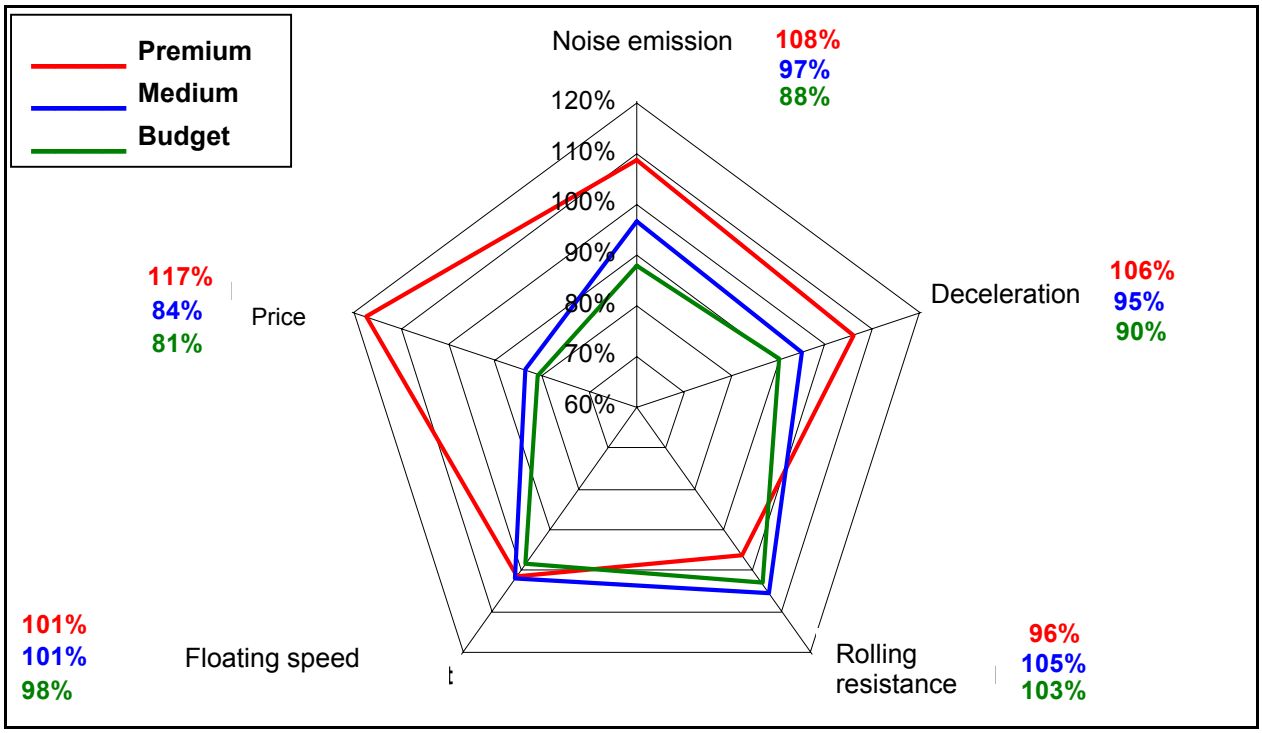


Diagram 5

IV.1.6 WINTER AND ALL-SEASON TYRES 195/65 R15

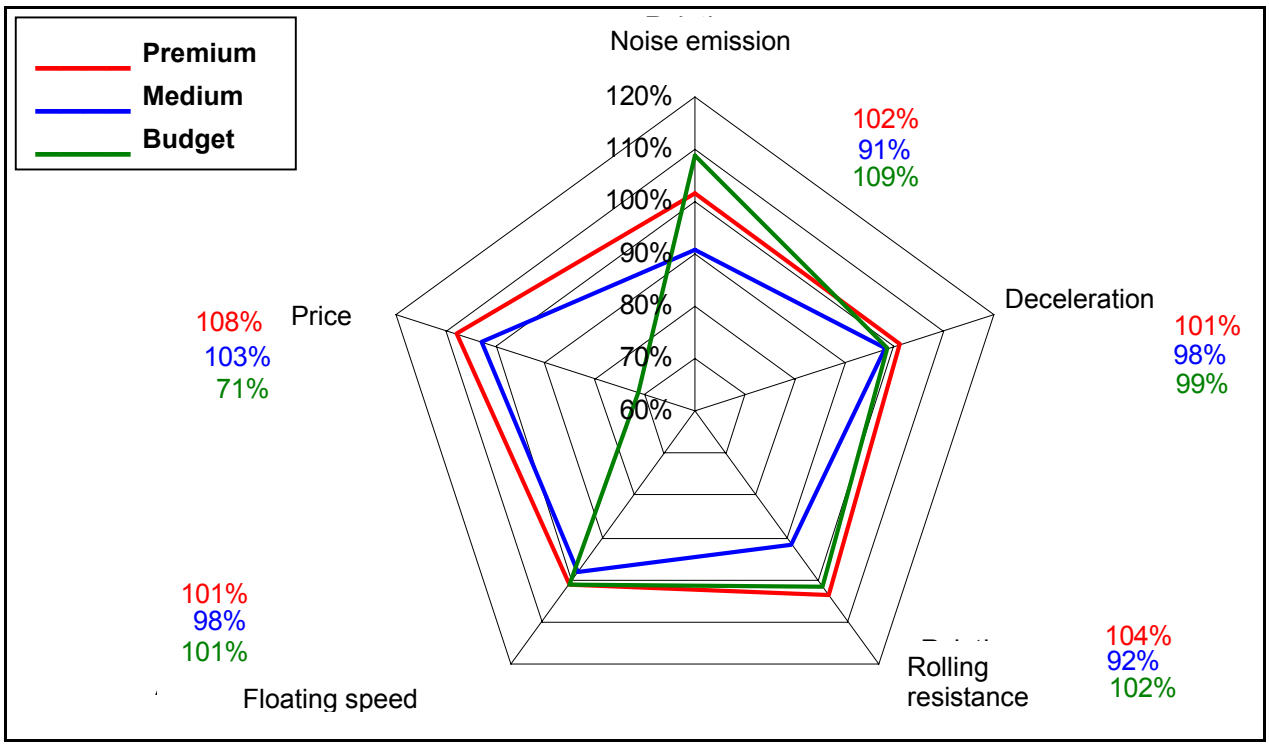


Diagram 6

IV.1.7 SUMMER TYRES 205/55 R16

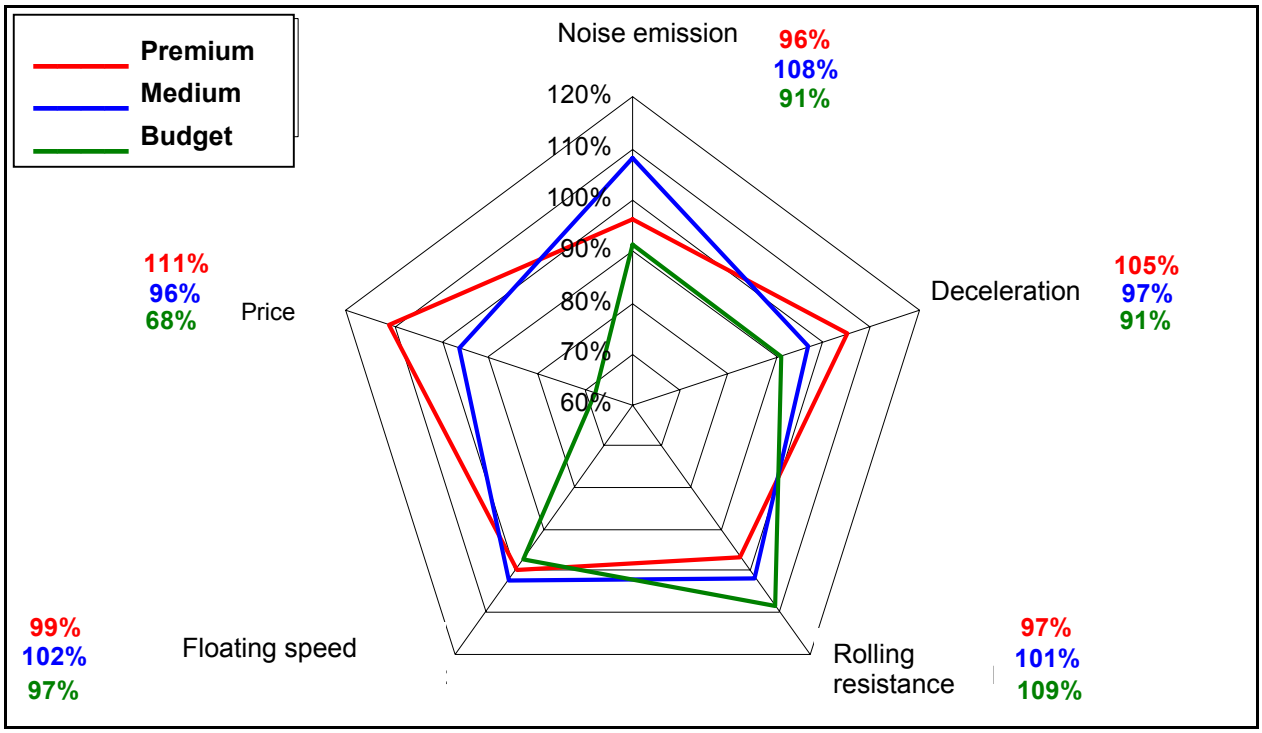


Diagram 7

IV.1.8 WINTER TYRES 205/55 R16

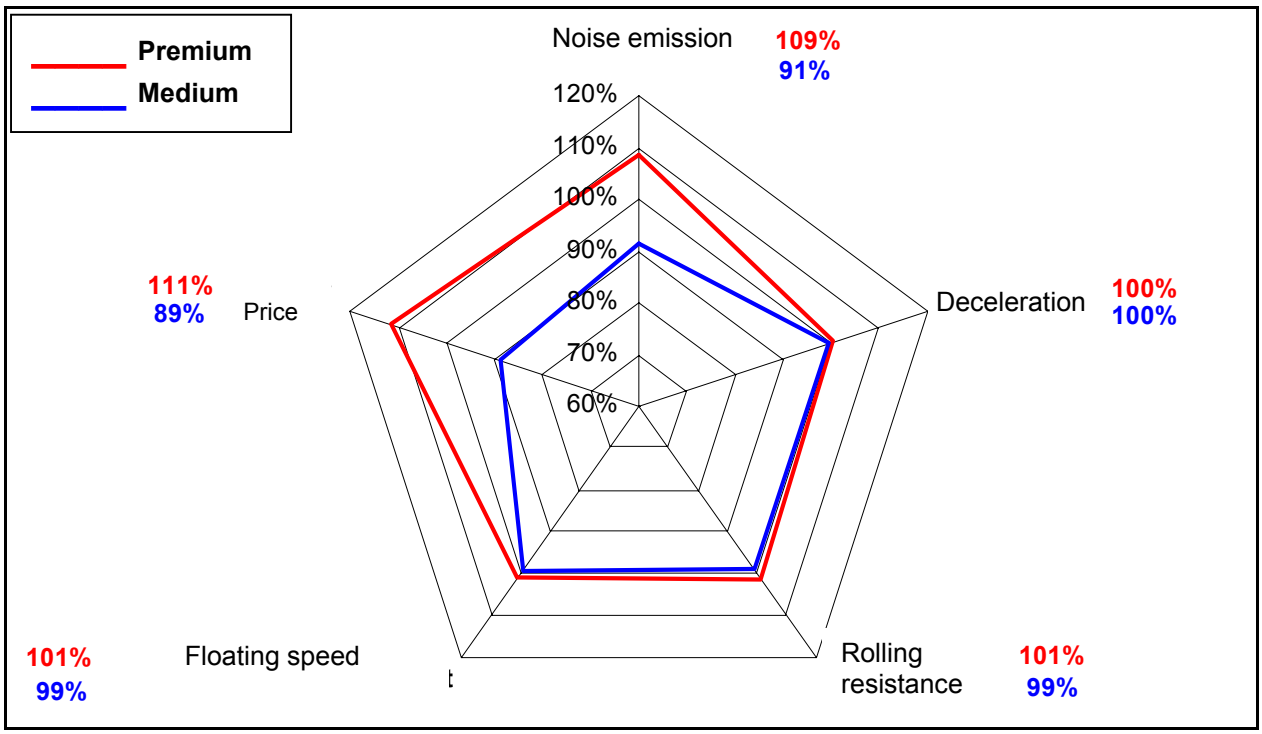


Diagram 8

IV.1.9 SUMMER TYRES 225/45 R17

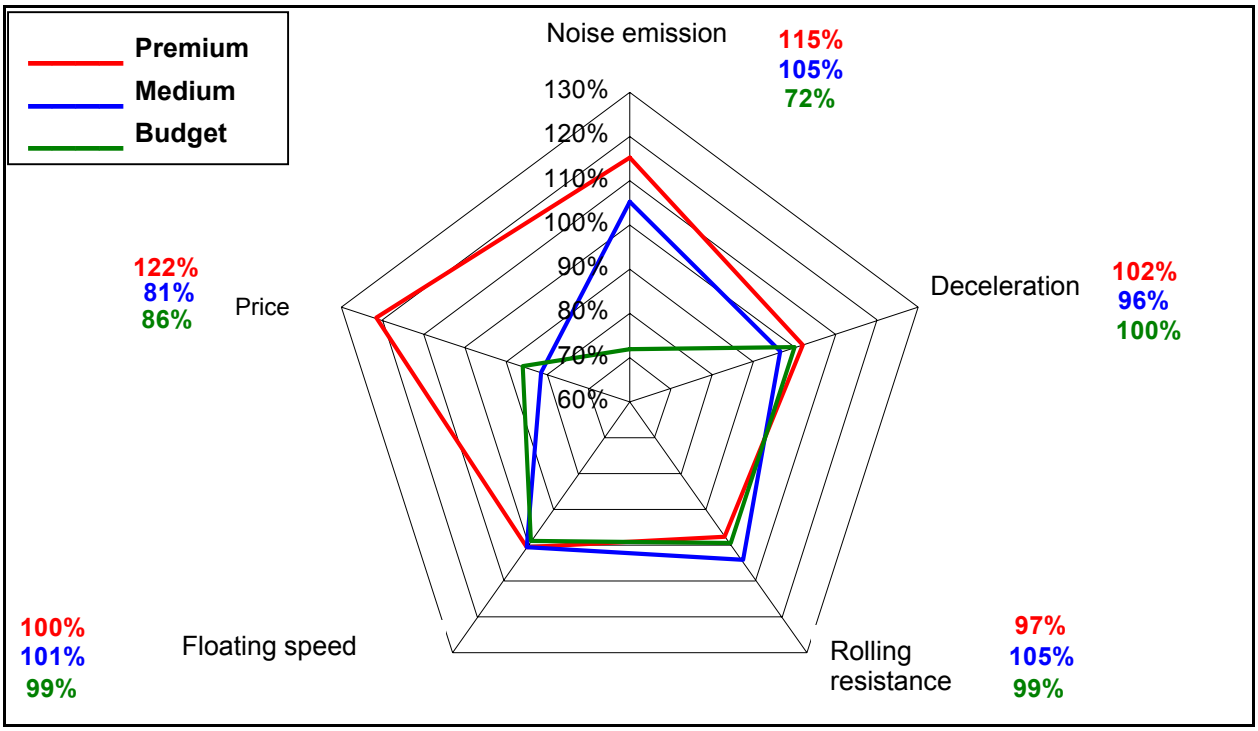


Diagram 9

IV.1.10 TOTAL POPULATION

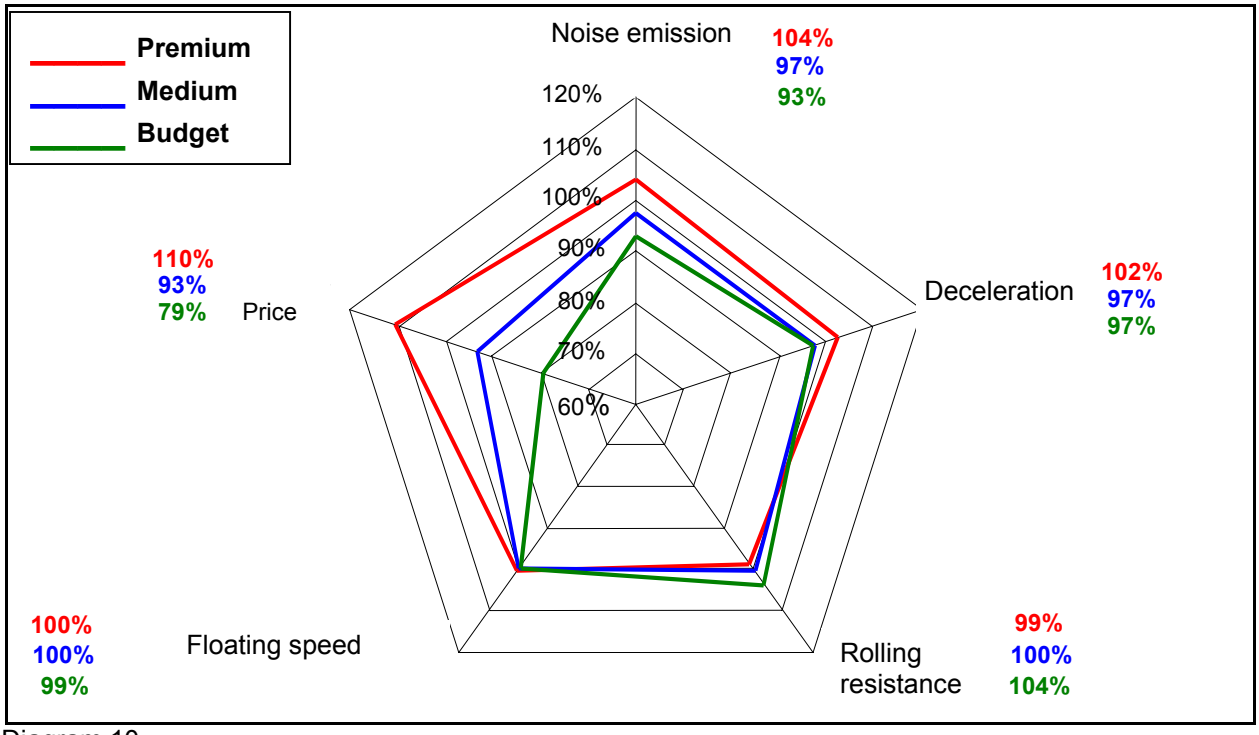


Diagram 10

IV.2 COMPARISONS WITH VIEW TO THE TYRE WIDTH

Further comparisons concerning the tyre width and its influence on the tested properties were made. It must be noticed that here not all results allow an unrestricted comparability, as - in contrary to the indoor tests - e.g. at the braking measurements the test conditions were not identical for all test collectives due to the changing surface properties.
The main focus of the following evaluations deals on the one hand with the environmentally relevant properties such as noise emission and rolling resistance and the effects of tyre size and width thereon, additionally it was also possible to a certain extent to consider the aquaplaning behaviour in dependence to the tyre width.
For all mentioned comparisons, the conditions for the compared tyre widths were identical or similar, i.e. the same test load during the rolling resistance tests and largely the same wheel loads for aquaplaning.

IV.2.1 TYRE WIDTH – ROLLING RESISTANCE

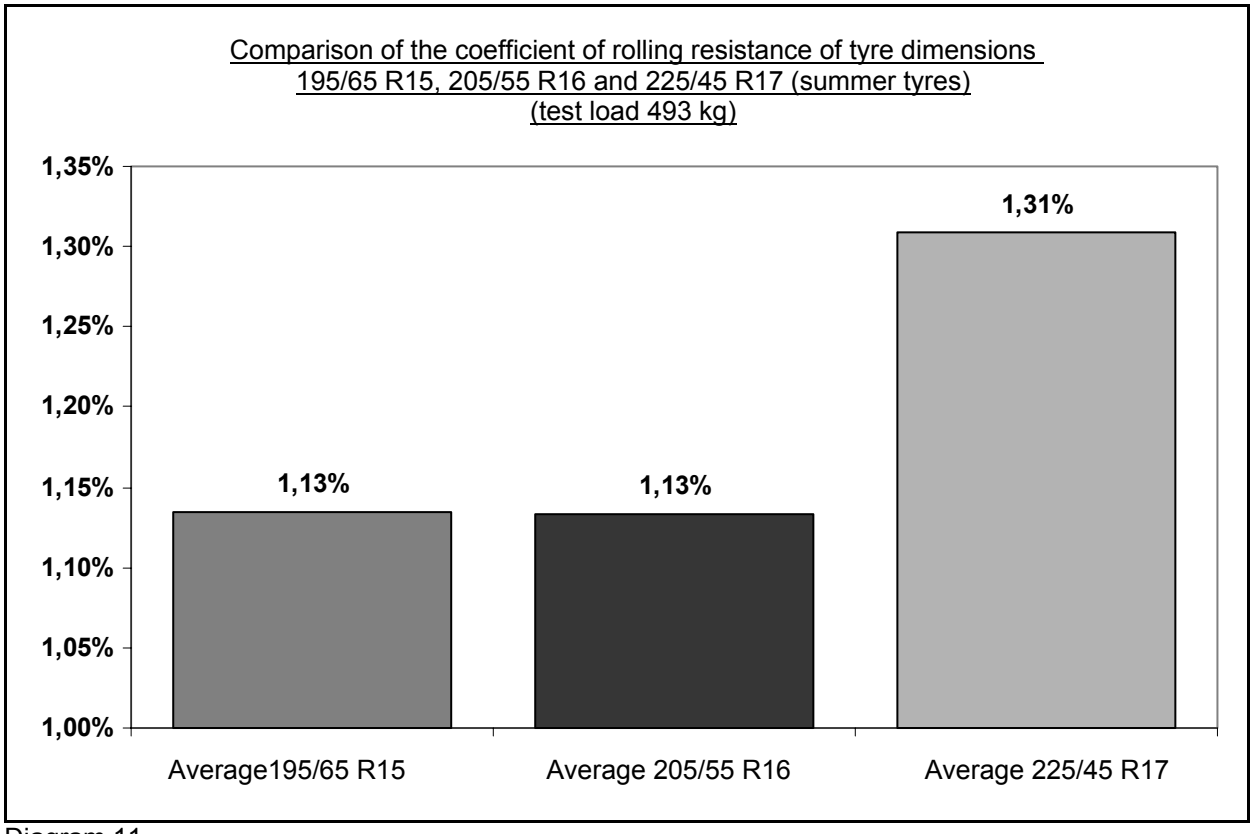


Diagram 11

IV.2.2 TYRE WIDTH – ROLLING NOISE

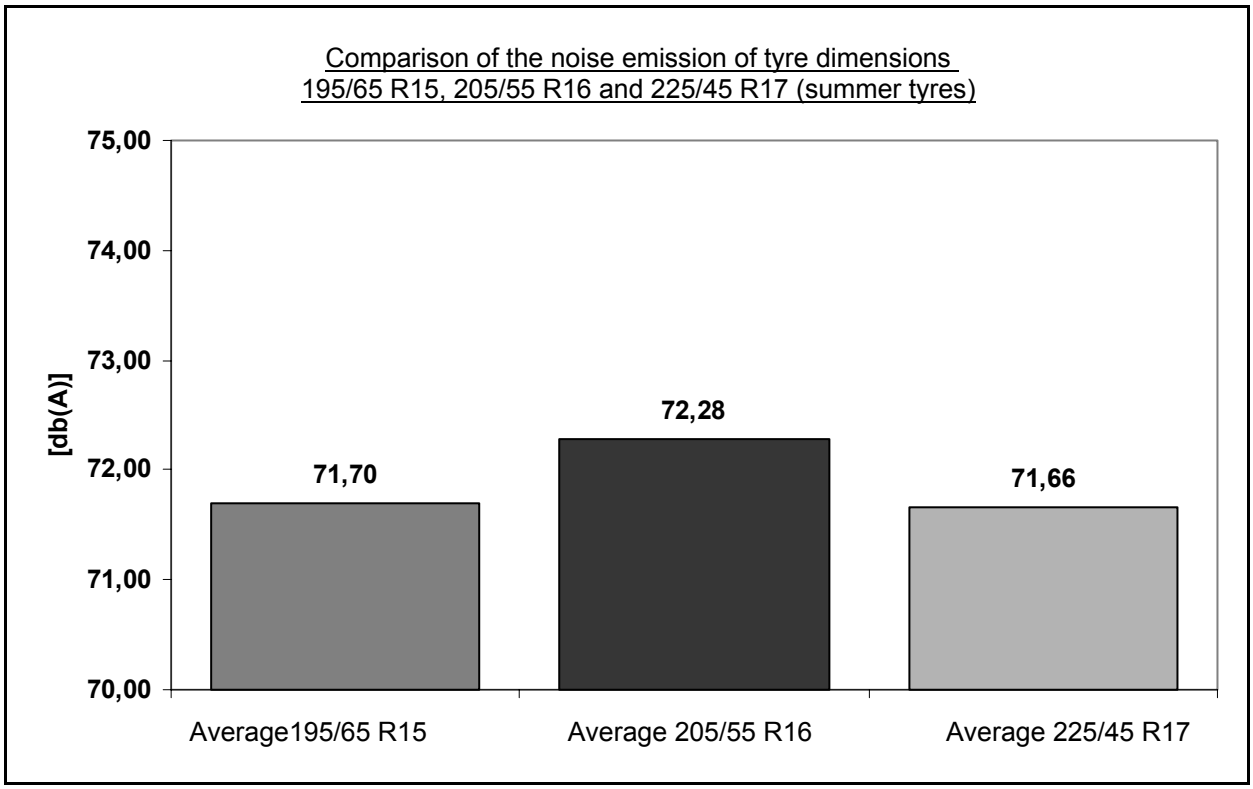


Diagram 12

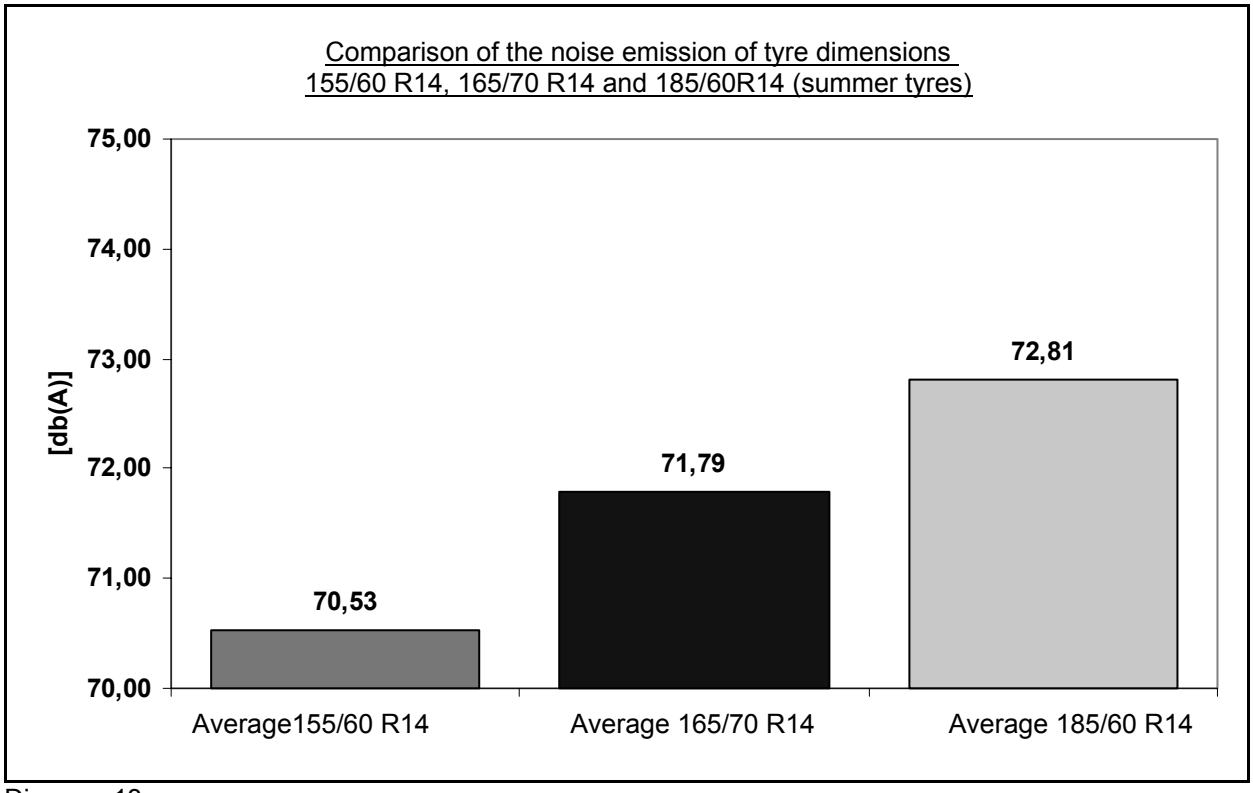


Diagram 13

IV.2.3 TYRE WIDTH – AQUAPLANING BEHAVIOUR

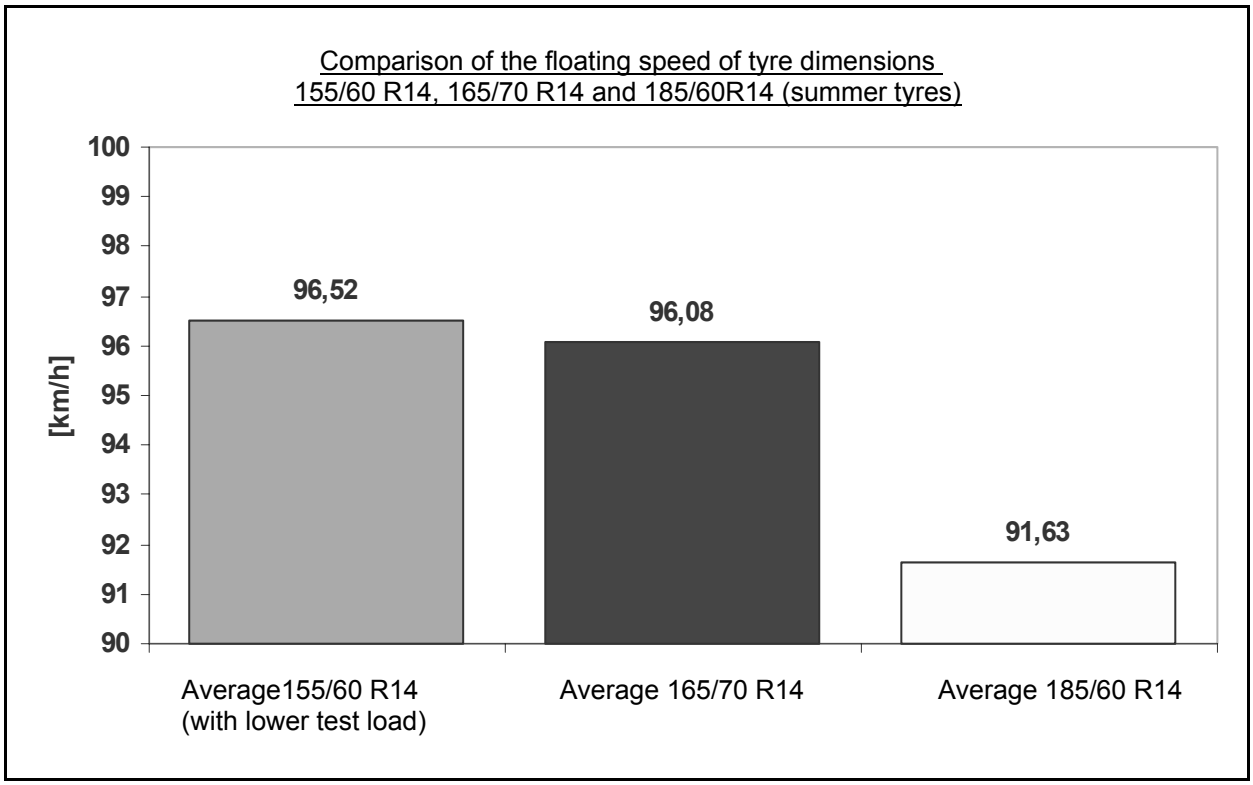


Diagram 14

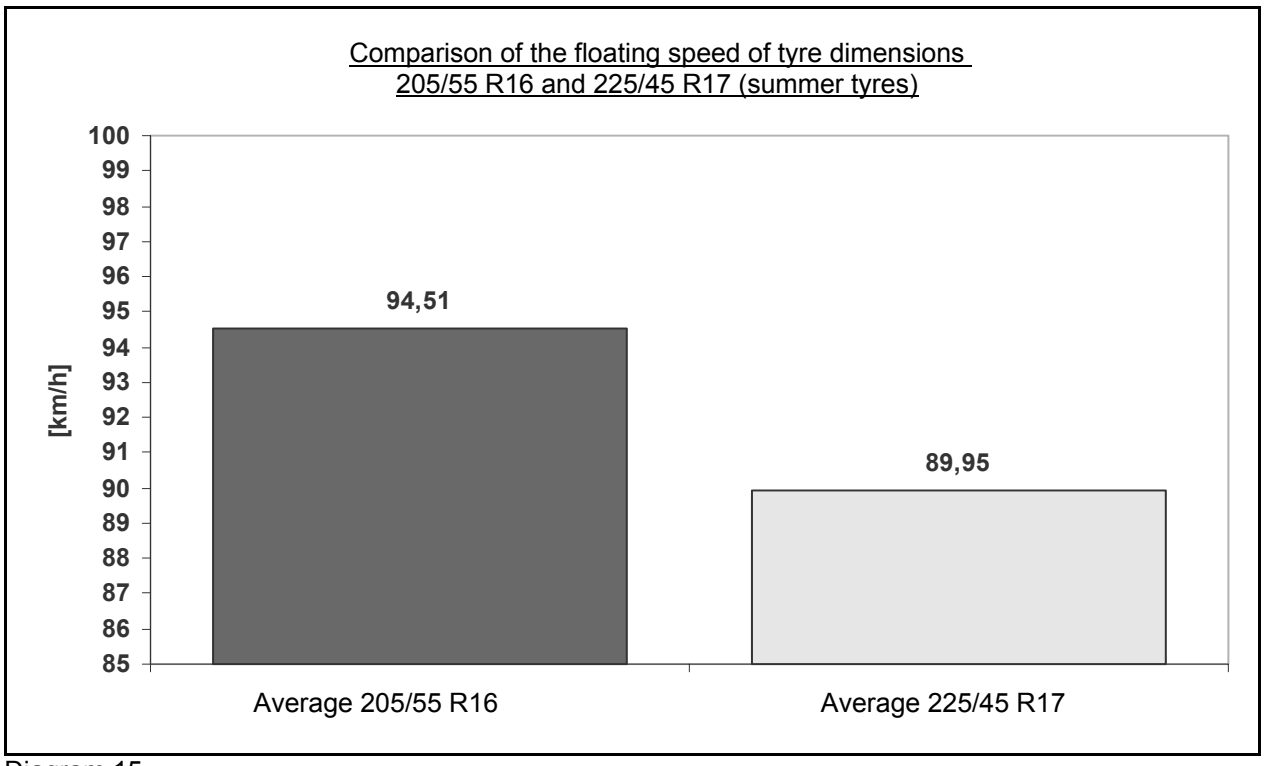


Diagram 15