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Summary of Tire Testing for California's Replacement Tire Efficiency Program per Assembly Bill 844 January 2023: Phase 2 – Correlated to the European Virtual Machine

Smithers File No. F53018BS

Prepared for:

California Energy Commission

Funded by:

Pacific Gas and Electric

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Reference: F53018BS

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1.0 Subject

Smithers File F53018BS, addressing the statement of work regarding Assembly Bill 844.

2.0 Objective

The objective was to assist the Pacific Gas and Electric Company ("PG&E"), in consultation with the California Energy Commission ("CEC"), in understanding a California focused tire population in regards to both rolling resistance and wet traction.

3.0 Background

Under the authority granted by Assembly Bill 844 (Nation, 2003), the California Energy Commission is mandated to adopt and implement a statewide Replacement Tire Efficiency Program for replacement tires for passenger cars and light-duty trucks, to ensure that replacement tires sold in California are at least as energy efficient as the tires sold as original equipment on the vehicles.[1]

Through the Clean Transportation Program, the California Energy Commission has sought to facilitate collaboration and information exchange with industry stakeholders including tire manufacturers, retail tire businesses, tire test labs, consumer information organizations, environmental interest groups, air districts, electric utilities, and government agencies, expressly for the Commission to fulfill its statutory mandate under AB 844. [2]

Smithers MSE Inc. was contracted to provide rolling resistance testing, tire technology consultations and project management to the Pacific Gas and Electric Company, in consultation with the California Energy Commission regarding the Replacement Tire Efficiency Program.

The project discussed herein was conducted as a second phase (Phase 2) of work to expand the database of tire rolling resistance and tire wet traction results documented in the Phase 1 Smithers Report, Reference: F49432BS-01VAU issued 03March23. This Phase 2 work encompasses the test data and analyses from investigating 30 tire SKUs. The original Phase 1 work encompassed 149 SKUs.

The Pacific Gas and Electric Company, in consultation with the California Energy Commission, purchased a variety of passenger car and light truck tires and submitted them to Smithers MSE for testing, and assistance in studying any correlations between rolling resistance and other tire characteristics.

3.0 Background (continued)

Smithers MSE work herein documented in this report encompasses:

- Tire identifications: including sizes, manufacturers, design names, SKU (stock keeping unit) labels, and stamping information.
- Measurements including tire weights and tread depths.
- Test Results
  Four (4) tires each of 30 unique tire SKUs were submitted for testing. Three (3) tires per SKU (total 90 tires) were tested for rolling resistance and one (1) tire per SKU (total 30 tires) was tested for wet traction.
  - Rolling resistance: ISO 28580(2018) “Passenger Car, Truck and Bus Tyre Rolling Resistance Measurement Method — Single Point Test and Correlation of Measurement Results.” Testing was conducted by Smithers MSE, Inc.
  - Tire wet grip test: ISO 23671(2021) “Passenger Car Tyres - Method for Measuring Relative Wet Grip Performance - Loaded New Tyres” (Trailer method).
- Efforts to identify correlations between rolling resistance, wet traction and a number of other tire parameters.

Note, definitions of terminology and test specifications may be found in Appendix Section 5.

It should be further noted that in addressing rolling resistance data, “lower” is directionally desirable. In addressing wet traction, a “higher” wet grip index is directionally desirable.

The rolling resistance coefficient data contained in this report was correlated to the European virtual machine utilizing the Smithers EU correlation.

4.0 Procedures

4.1 Rolling Resistance Test Protocol

Test Protocol	ISO 28580:2018 “Passenger Car, Truck and Bus Tyre Rolling Resistance Measurement Method — Single Point Test and Correlation of Measurement Results.”
Laboratory Certification	ISO 17025
Number Tires Tested	Three (3) per SKU
Number SKUs Tested	30
Description	ISO 28580:2018 specifies methods for measuring rolling resistance, under controlled laboratory conditions, for new pneumatic tires designed primarily for use on passenger cars, trucks and buses. Measurement of tires using this method enables comparisons to be made between the rolling resistance of new test tires when they are free-rolling straight ahead, in a position perpendicular to the drum outer surface, and in steady-state conditions.
Test Drum	• Smithers tested to this protocol using a dynamometer with a cylindrical drum of 1.7m diameter. Per ISO 28580, the equation located in section 9.3 was utilized as a correlation adjustment of the rolling resistance coefficient from the test drum of 1.7m diameter to a dynamometer drum diameter of 2.0m. • 80 grit surface paper was used as permitted by ISO 28580.
Test Preparation	• All tires were mounted and tested on aluminum wheels. Wheel widths were determined by ISO 4000-1 for passenger and ISO 4209-1 for truck/bus. • Tires were inflated to the required cold pressure and the appropriate load was applied per the Table 2 of ISO 28580. • 80km/h speed was used for testing • Tires were allowed to thermally condition in the test environment for a minimum of 3hrs for passenger and 6hrs for truck/bus. • Ambient temperature was maintained between 70°-80°F. Test data was corrected to a standard of 77°F using the correction equation per ISO 28580
Warm-up	• Once the tire was mounted on the dynamometer, a warm-up was performed per Table 3 of ISO 28580.
Testing	• See ISO 28580:2018
Documentation	• Forces were recorded at the machine spindle and used to calculate the rolling resistance force, which is then divided by the test load and multiplied by 1000 to calculate the rolling resistance coefficient.

4.2 Wet Traction Test Protocol*

Test Protocol	ISO 23671:2021 “Passenger Car Tyres - Method for Measuring Relative Wet Grip Performance - Loaded New Tyres” (Trailer method)
Number Tires Tested	One (1) per SKU
Number SKUs Tested	30
Description	ISO 23671:2021 specifies the method for measuring relative wet grip braking performance index to a reference under loaded conditions for new tires for use on passenger cars on a wet-paved surface.
Test Preparation	• Test surface utilized was asphalt per ISO 23671. • External watering of asphalt surface • Ambient test temperature was between 5°C and 35°C.
Testing	• Cold inflation test pressure was 180kPa for standard load tires and 220kPa for extra load tires • Speed at the start of braking was 65±2km/h • Test load was 75±5% of load capacity based upon tire load index
Documentation	• Dynamic tire braking force was recorded in real time and was divided by the dynamic vertical load in real time to calculate the dynamic tire braking force coefficient in real time. The peak braking force coefficient was determined and used to calculate the wet grip index as compared to the reference tire peak braking force.

*Testing was outsourced by Smithers.

4.3 Tire SKU Selections for Program

Tire SKUs were chosen by the California Energy Commission. Smithers MSE was advised that the selections were made with consideration to the bead diameter and types of tires including light truck, classified as “LT” tires. Tire purchases were conducted in California between July of 2023 and August of 2023.

4.4 Correlation Studies

Attempts were made to individually correlate rolling resistance results to several other tire characteristics. Quantitative correlations include linear correlation analyses with trend lines and with trend line r-squared values identified.

Quantitative Correlation

- wet traction tested
- price actual price
- UTQG treadwear rating tire stamping
- diameter at bead tire stamping

Definitions of these tire characteristics may be found in Appendix Section 5.

4.4.1 Quantitative Correlation: Wet Traction

Results as tested by ISO 23671:2021

4.4.2 Quantitative Correlation: Price

Actual price paid per tire, excluding sales tax and shipping.

4.4.3 Quantitative Correlation: UTQG Treadwear Rating

Uniform Tire Quality Grading (UTQG) Treadwear Rating as identified by tire stamping on sidewall; example UTQG rating: 560 A B; 560 is treadwear rating. The rating is a numeric index of how well a tire wears in comparison to a reference tire.

4.4.4 Quantitative Correlation: Diameter at Bead

Identified by tire stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge

5.0 Results

Quantitative correlations have been studied using rolling resistance plots where each plotted point depicts the mean value of the three (3) tires tested per set (SKU), and traction charts that depict the results of the one (1) tire tested per set.
Best-fit linear trendlines have been created using Excel to identify R^2 values for each correlation studied. R^2 is an indicator of "goodness of fit" of the linear trendline by measuring the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive. Slopes of the trendlines may be interpreted as follows:

1. A trend line with a positive slope indicates a positive correlation between the variables.
2. A trend line with a negative slope indicates a negative correlation between the two variables.

The steepness of the slope of a trendlines represents the sensitivity of the dependent variable (frequently rolling resistance or traction responses plotted along the Y-axis) to changes in the independent variable (plotted along X-axis).

For example, a trendline with a relatively high R^2 value and a steep positive slope suggests a correlation with a reasonable linear fit to the actual data results, a positive correlation between the dependent and independent variables and a strong sensitivity in the dependent variable to changes in the independent variable.

5.1 Rolling Resistance Test Data Overview

Graphs 5.1A and 5.1B depict histograms of the tested tire rolling resistance coefficients for the passenger and LT tire SKUs, respectively. These graphs represent the combined data from Phases 1 and 2 of the program.

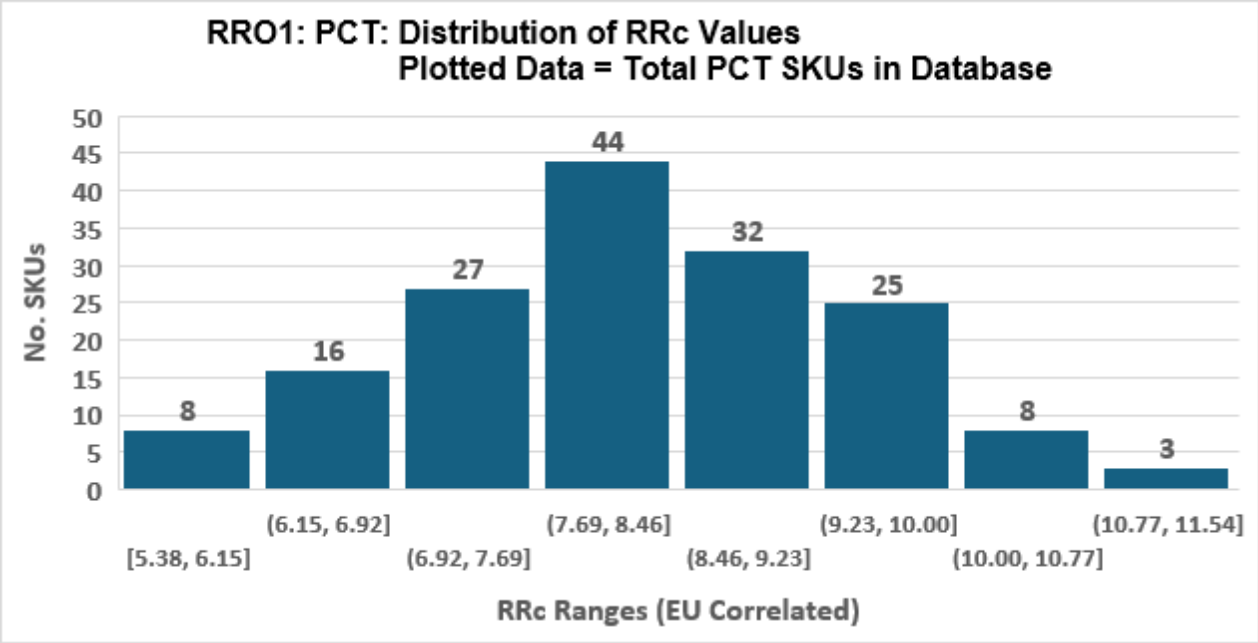

Chart 5.1A

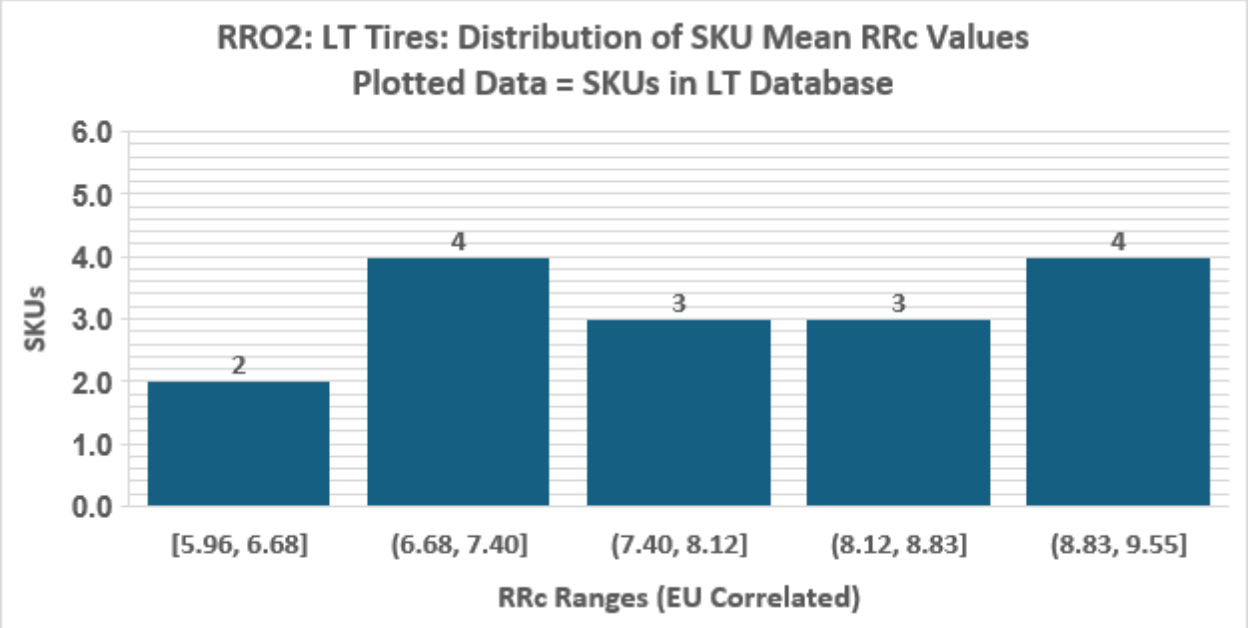

Chart 5.1B

5.2 Bead Diameter Studies

Bead Diameter vs Rolling Resistance (See Chart 5.2A)
Graph 5.2A depicts tire rolling resistance coefficients vs bead diameters for all passenger car tires in Phase 1 and Phase 1 + Phase 2. The linear trendline exhibited slope, with lower RRC correlation to higher bead diameter tires. The quality of the correlation from a significance perspective was low: R^2=0.07 Phase 1 + Phase 2). Phase 2 introduction of the 14" tires into the data population did not significantly impact the findings.

Bead Diameter vs Wet Traction (See Chart 5.2B)
Graph 5.2B depicts tire wet traction index vs bead diameters for all passenger car tires in Phase 1 and Phase 1 + Phase 2. The linear trendline exhibited negligible slope. The quality of the correlation fit from a significance perspective was very low: R^2=0.02 (Phase 1 + Phase 2). Phase 2 introduction of the 14" tires into the data population did not significantly impact the findings.

Bead Diameter vs UTQG Treadwear (See Chart 5.2C)
Graph 5.2C depicts UTQG treadwear stamping values vs bead diameters for all passenger car tires in Phase 1 and Phase 1 + Phase 2. The linear trendline exhibited negligible slope. The quality of the correlation fit from a significance perspective was very low: R^2=0.002 (Phase 1 + Phase 2). Phase 2 introduction of the 14" tires into the data population did not significantly impact the findings.

Rolling Resistance vs Wet Traction Index (See Chart 5.2D)
Graph 5.2D depicts tire rolling resistance coefficients vs tire wet traction indices for all passenger car tires Phase 1 + Phase 2. The linear trendline exhibited negative slope: lower RRC levels weakly correlated with increasing wet traction indices. The quality of the correlation fit from a significance perspective was very low: R^2=0.05 (Phase 1 + Phase 2). Phase 2 introduction of the 14" tires into the data population did not significantly impact the findings.

Rolling Resistance vs UTQG Treadwear (See Chart 5.2E)
Graph 5.2E depicts tire rolling resistance coefficients vs UTQG treadwear stamping values for all passenger car tires Phase 1 + Phase 2. The linear trendline exhibited negligible slope: RRC levels did not correlate with UTQG values. The quality of the correlation fit from a significance perspective was very low: R^2=0.005 (Phase 1 + Phase 2).

5.2 Bead Diameter Studies (continued)

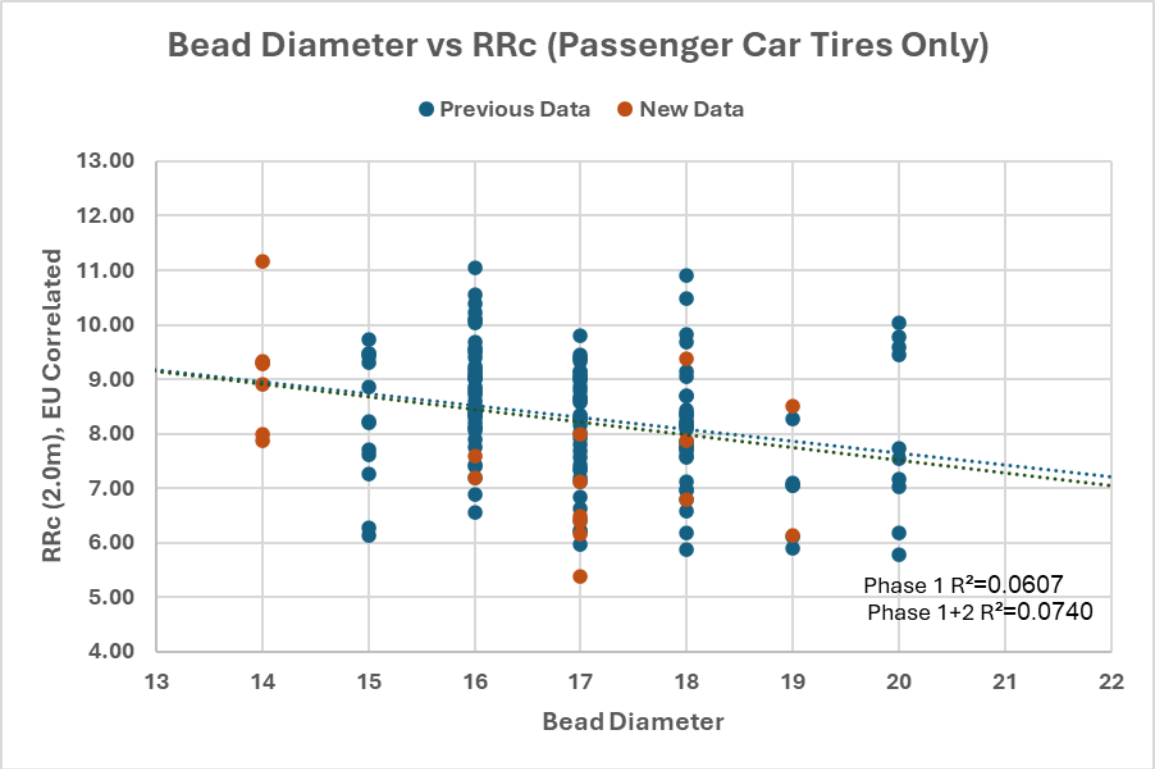

Chart 5.2A

- Rolling resistance coefficient data adjusted per EU correlation
- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents the mean value of three (3) tires tested.
- Tire rolling resistance test protocol: ISO 28580:2018

5.2 Bead Diameter Studies (continued)

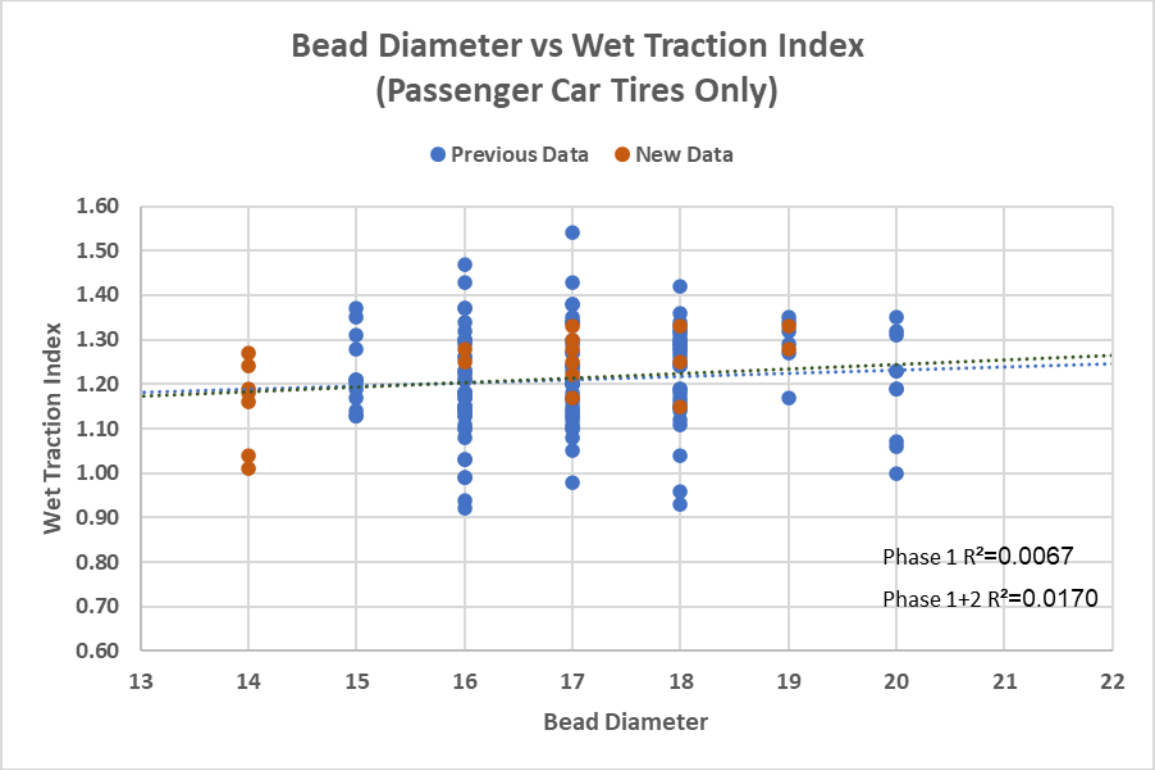

Chart 5.2B

- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents one (1) tire tested.
- Wet grip index test protocol: ISO 23671:2021

5.2 Bead Diameter Studies (continued)

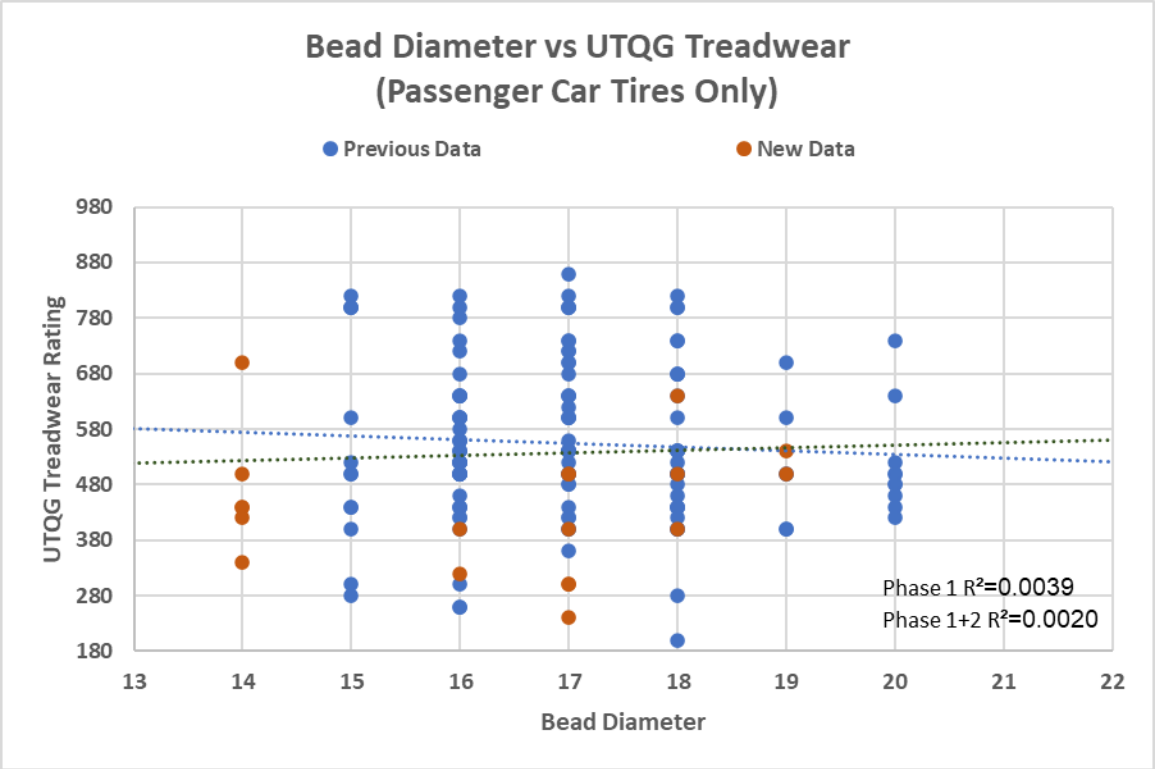

Chart 5.2C

- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- Uniform Tire Quality Grading (UTQG) Treadwear Rating as identified by tire stamping on sidewall; example UTQG rating: 560 A B; 560 is treadwear rating. The rating is a numeric index of how well a tire wears in comparison to a reference tire.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.2 Bead Diameter Studies (continued)

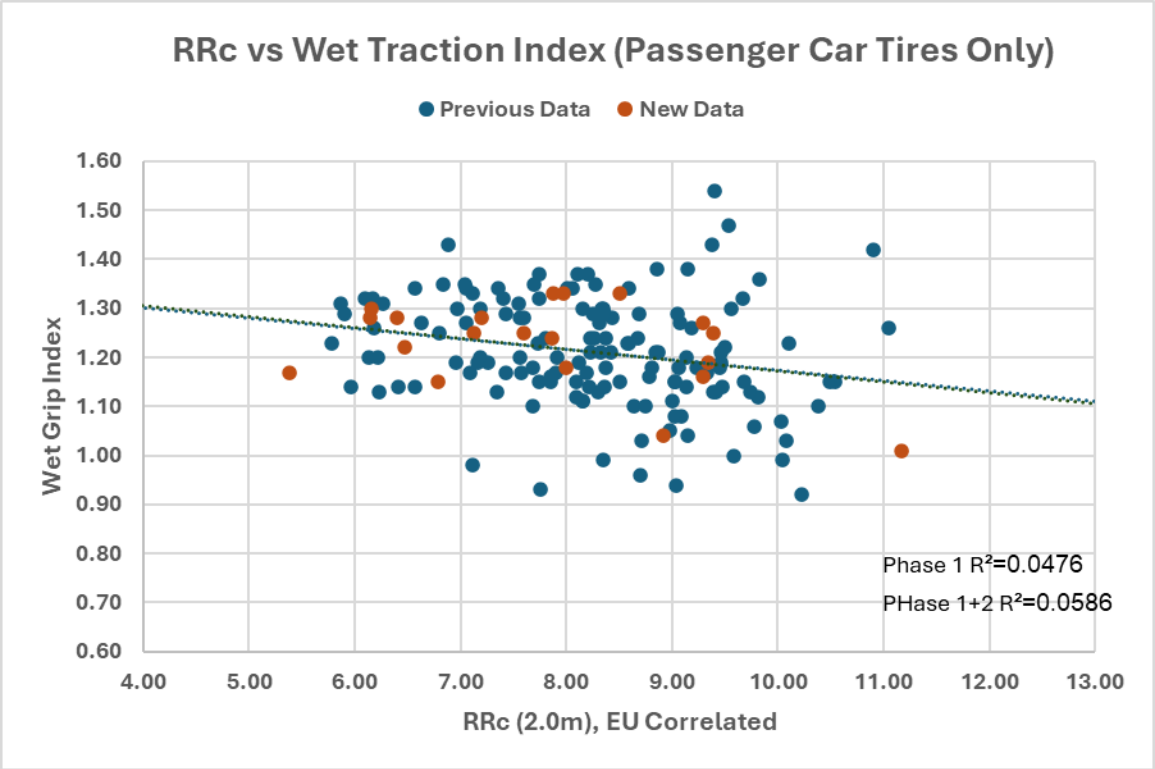

Chart 5.2D

- Rolling resistance coefficient data adjusted per EU correlation
- Tire rolling resistance test protocol: ISO 28580:2018
- Wet grip index test protocol: ISO 23671:2021
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.2 Bead Diameter Studies (continued)

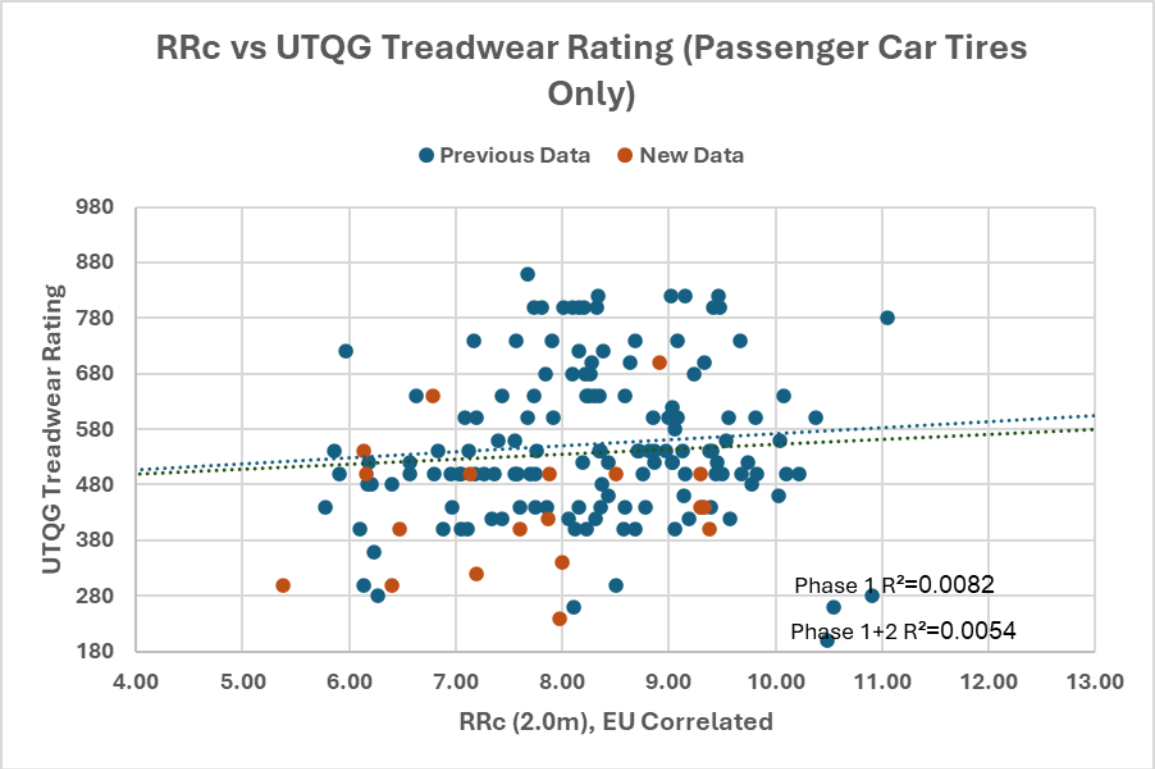

Chart 5.2E

- Rolling resistance coefficient data adjusted per EU correlation
- Tire rolling resistance test protocol: ISO 28580:2018
- Uniform Tire Quality Grading (UTQG) Treadwear Rating as identified by tire stamping on sidewall; example UTQG rating: 560 A B; 560 is treadwear rating. The rating is a numeric index of how well a tire wears in comparison to a reference tire.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.3 Light Truck Studies

Bead Diameter vs Rolling Resistance (See Chart 5.3A)
Graph 5.3A depicts tire rolling resistance coefficients (as a function of bead diameters) for all LT tires in Phase 1 + Phase 2 and compared to all passenger tires from Phase 1 + Phase 2. The LT trendline exhibited negligible slope, thus no correlation between the bead diameters studied and rolling resistance. As previously noted in 5.1A, the passenger tire correlation study yielded linear trendline with slope: lower RRC was noted with higher bead diameter tires. The quality of the correlations from a significance perspective were low.

Bead Diameter vs Wet Traction Index (See Chart 5.3B)
Graph 5.3B depicts tire wet traction index vs bead diameters for all light truck tires in Phase 1 and Phase 1 + Phase 2 and compared to all passenger tires from Phase 1 + Phase 2. The linear trendline representing the LT tires exhibited a steeper trend of increasing wet traction with increasing bead diameter as compared to passenger tires. The quality of the correlation fit from a significance perspective was moderate for the LT correlation: R^2=0.233, and very low for the passenger tires: R^2=0.017. It should be noted that the range of LT bead diameters was limited to 16", 17" and 18".

Rolling Resistance vs Wet Traction Index (See Chart 5.3C)
Graph 5.3C depicts tire rolling resistance coefficients vs tire wet traction indices for all light truck tires from Phase 1 + Phase 2. Also included are the passenger tire results for comparative purposes. The linear trendline representing the LT tires exhibited negative slope: lower RRC levels correlated with increasing wet traction indices. The quality of the correlation fit from a significance perspective was low for the LT tires: R^2=0.168 (Phase 1 + Phase 2), and very low for the passenger tires: R^2=0.059 (Phase 1 + Phase 2).

5.3 Light Truck Studies (continued)

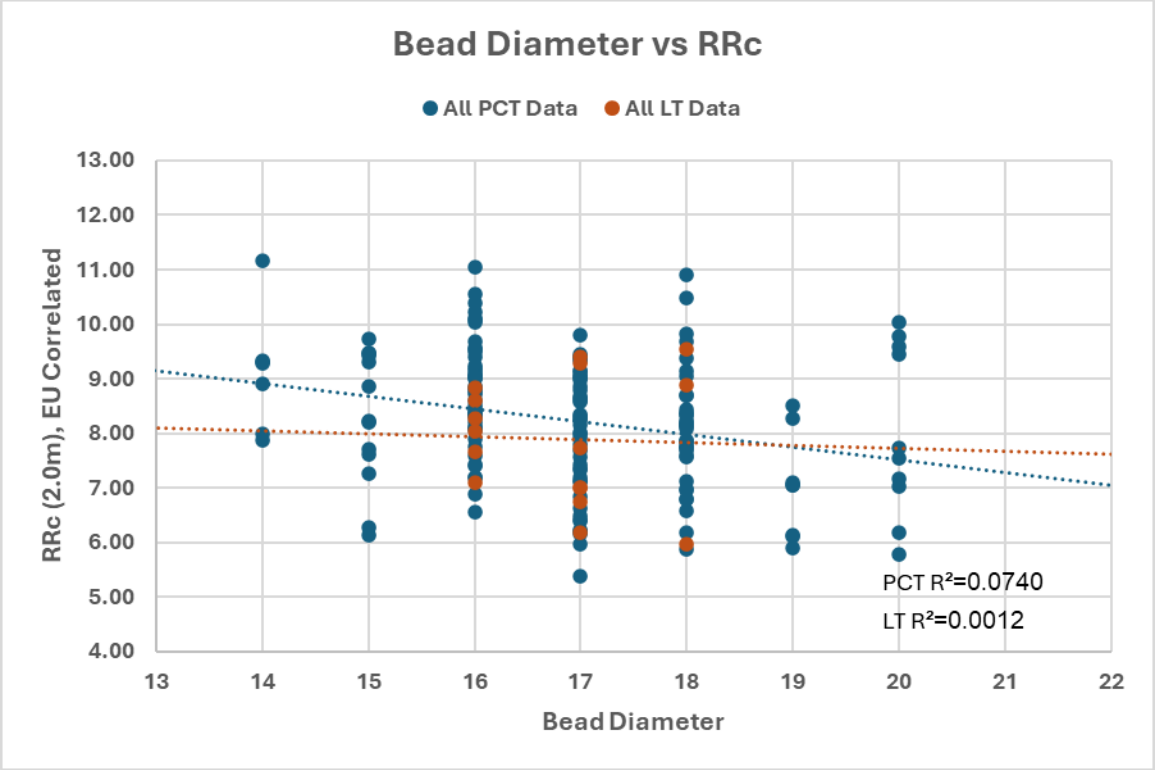

Chart 5.3A

- Rolling resistance coefficient data adjusted per EU correlation
- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents the mean value of three (3) tires tested.
- Tire rolling resistance test protocol: ISO 28580:2018

5.3 Light Truck Studies (continued)

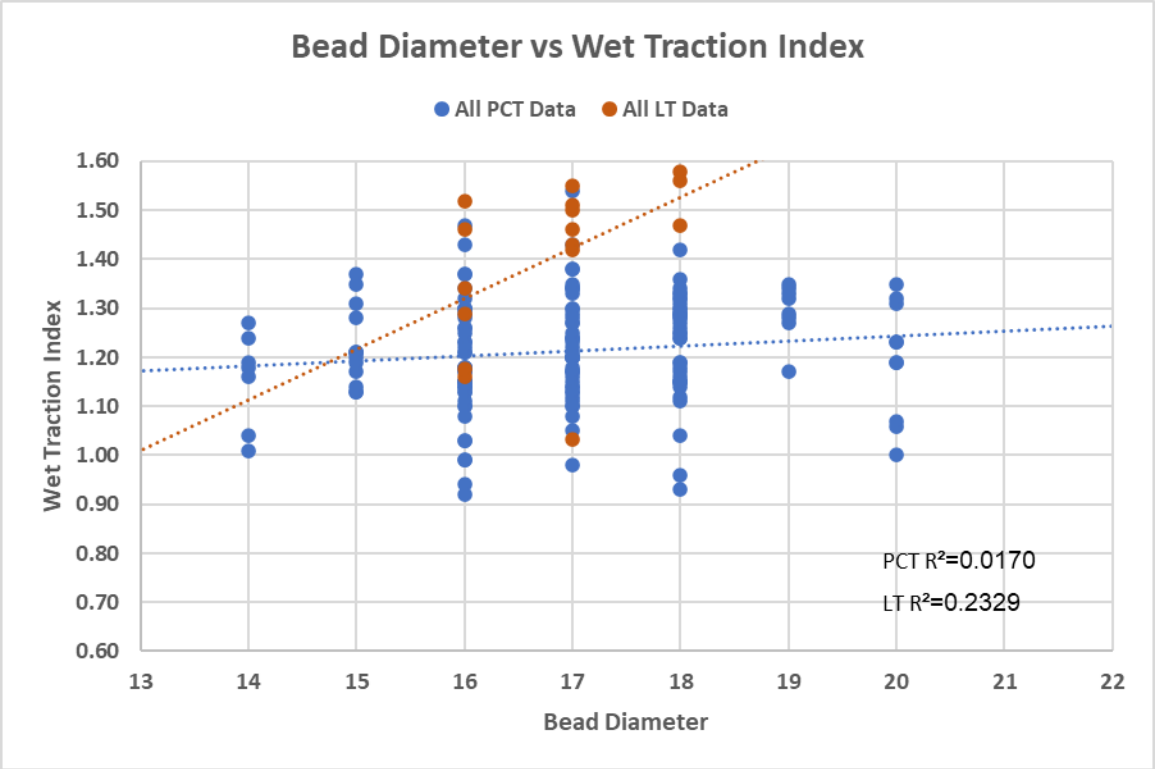

Chart 5.3B

- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents one (1) tire tested.
- Wet grip index test protocol: ISO 23671:2021

5.3 Light Truck Studies (continued)

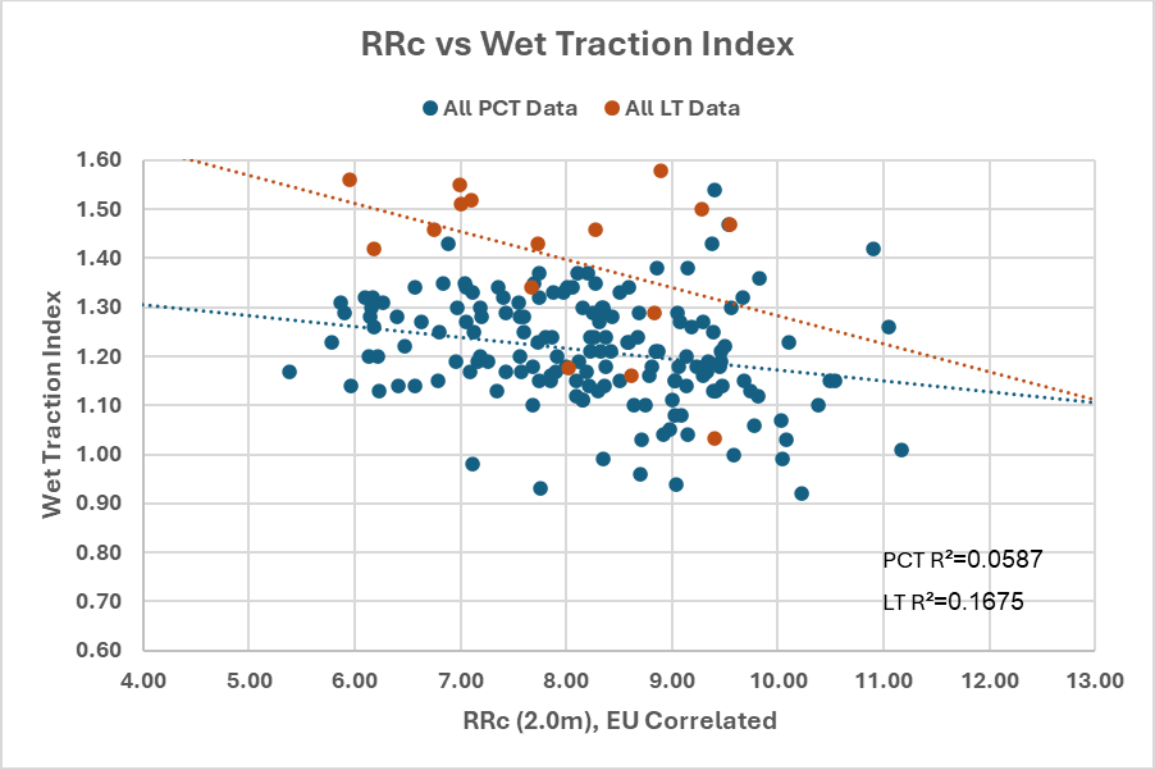

Chart 5.3C

- Rolling resistance coefficient data adjusted per EU correlation
- Tire rolling resistance test protocol: ISO 28580:2018
- Wet grip index test protocol: ISO 23671:2021
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.4 OE Tire Studies

Bead Diameter vs Rolling Resistance (See Chart 5.4A)
Graph 5.4A depicts tire rolling resistance coefficients vs bead diameters for all passenger car tires in Phase 1 + Phase 2. The population of SKUs has been divided into three categories: OE replacement and efficient tires. Linear trendlines have been applied for the OE and replacement tire categories. The efficient tire population was too small to create the correlation.

The linear trendlines for the OE and replacement populations exhibited negative slope with lower RRC values associated with higher bead diameter tires. The slopes of the OE and replacement trendlines were similar with 1-2 points of RRC difference at each bead diameter (lower RRCs for OE tires). The quality of the correlation from a significance perspective was low for both trendlines: R^2=0.041 for OE and R^2=0.072 for replacement tires.

Bead Diameter vs Wet Grip Index (See Chart 5.4B)
Graph 5.4B depicts tire traction indices vs bead diameters for all passenger car tires in Phase 1 + Phase 2. Linear trendlines have been applied for the OE and replacement tire categories. The efficient tire population was too small to create the correlation.

The linear trendlines for the OE and replacement populations exhibited negligible slope and thus no directional correlation. The quality of the correlations were very low for both trendlines.

Bead Diameter vs UTQG Treadwear (See Chart 5.4C)
Graph 5.4C depicts UTQG treadwear ratings vs bead diameters for all passenger car tires in Phase 1 + Phase 2. The population of SKUs has again been divided into three categories: OE replacement and efficient tires. Linear trendlines have been applied for the OE and replacement tire categories. The efficient tire population was too small to create the correlation.

The linear trendlines for the OE SKUs exhibited positive slope with higher UTQG treadwear ratings associated with higher bead diameter tires. The slope and the R^2 value of the replacement tire trendline was negligible and thus no correlation. The quality of the correlation from a significance perspective was low for the OE tires: R^2=0.122.

5.4 OE Tire Studies (continued)

Rolling Resistance vs Wet Grip Index (See Chart 5.4D)
Graph 5.4D depicts tire rolling resistance coefficients vs tire wet traction indices for all passenger car tires Phase 1 + Phase 2. The population of SKUs has again been divided into three categories: OE replacement and efficient tires. Linear trendlines have been applied for the OE and replacement tire categories. The efficient tire population was too small to create the correlation.

The linear trendlines representing both OE and replacement tire SKUs exhibited negligible slope: RRC levels did not correlate with wet traction indices. The quality of the correlations from a significance perspective was very low for both OE and replacement categories.

Rolling Resistance vs UTQG Treadwear (See Chart 5.4E)
Graph 5.4E depicts tire rolling resistance coefficients vs UTQG treadwear stamping values for all passenger car tires Phase 1 + Phase 2. The population of SKUs has again been divided into three categories: OE replacement and efficient tires. Linear trendlines have been applied for the OE and replacement tire categories. The efficient tire population was too small to create the correlation.

Both OE and replacement trendlines exhibited minor negative slope, lower RRC levels weakly correlated with higher labeled UTQG treadwear values. The quality of the correlation fit from a significance perspective was low for both OE and replacement tires.

5.4 OE Tire Studies (continued)

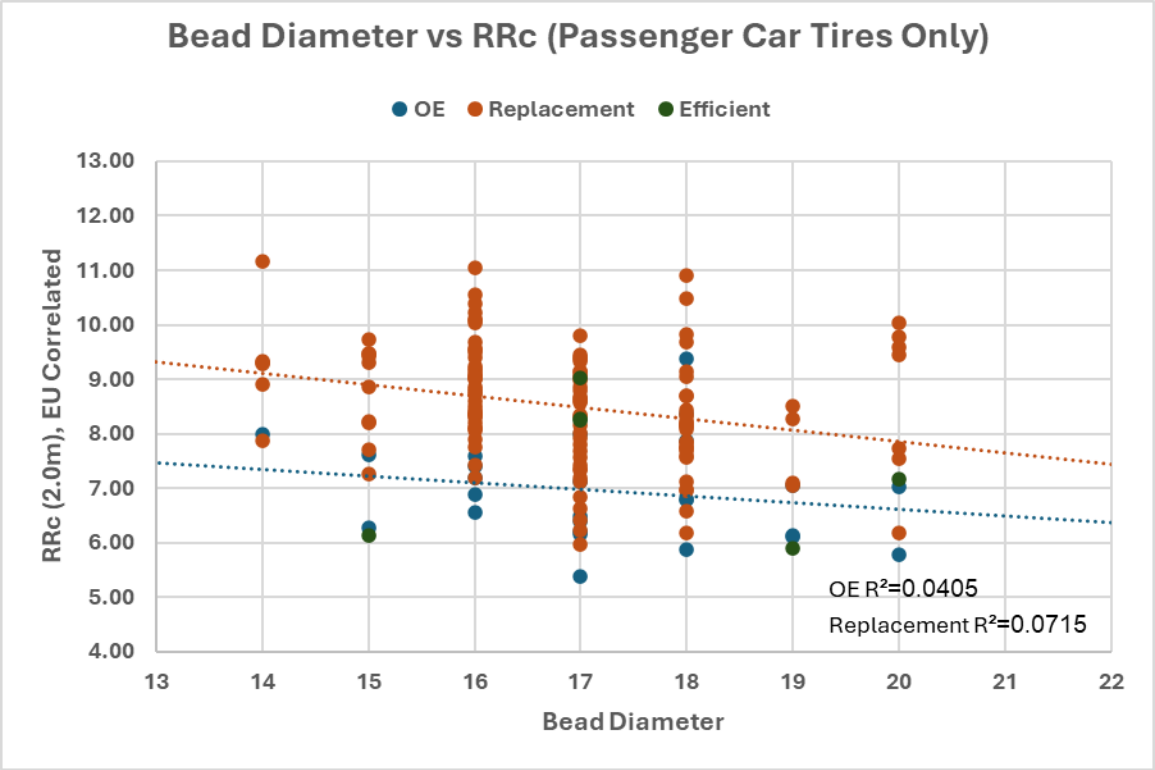

Chart 5.4A

- Rolling resistance coefficient data adjusted per EU correlation
- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents the mean value of three (3) tires tested.
- Tire rolling resistance test protocol: ISO 28580:2018

5.4 OE Tire Studies (continued)

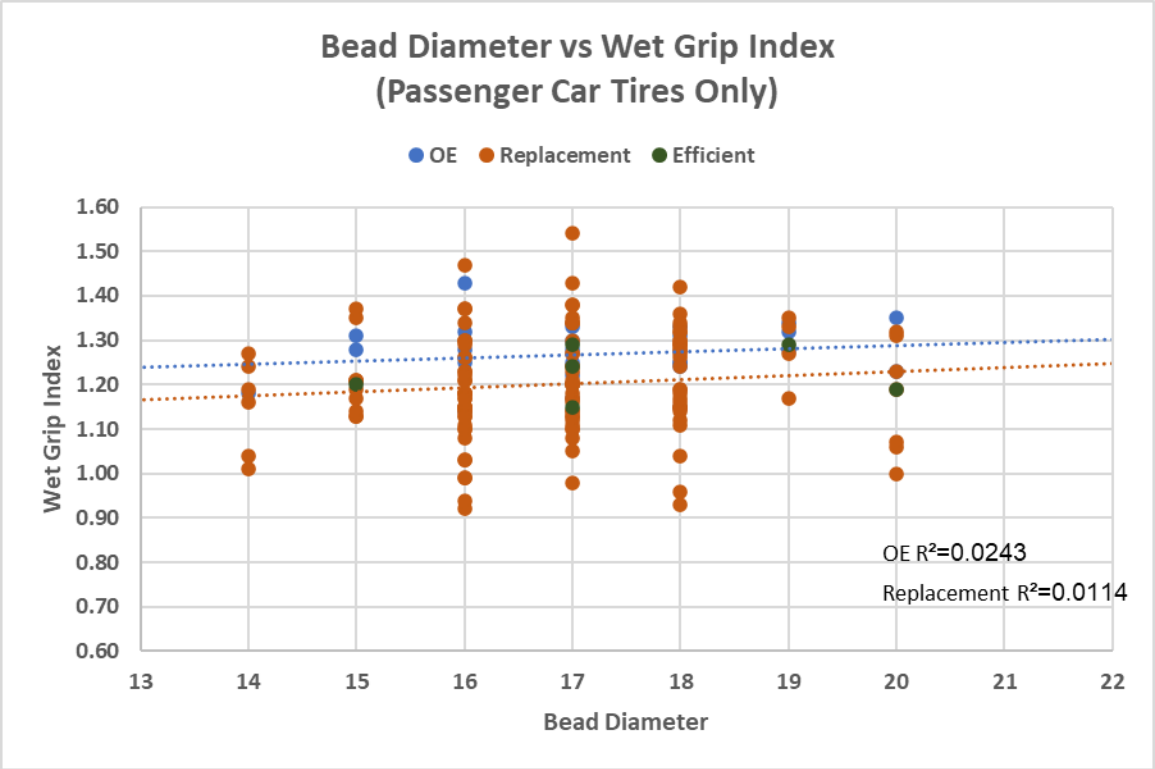

Chart 5.4B

- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents one (1) tire tested.
- Wet grip index test protocol: ISO 23671:2021

5.4 OE Tire Studies (continued)

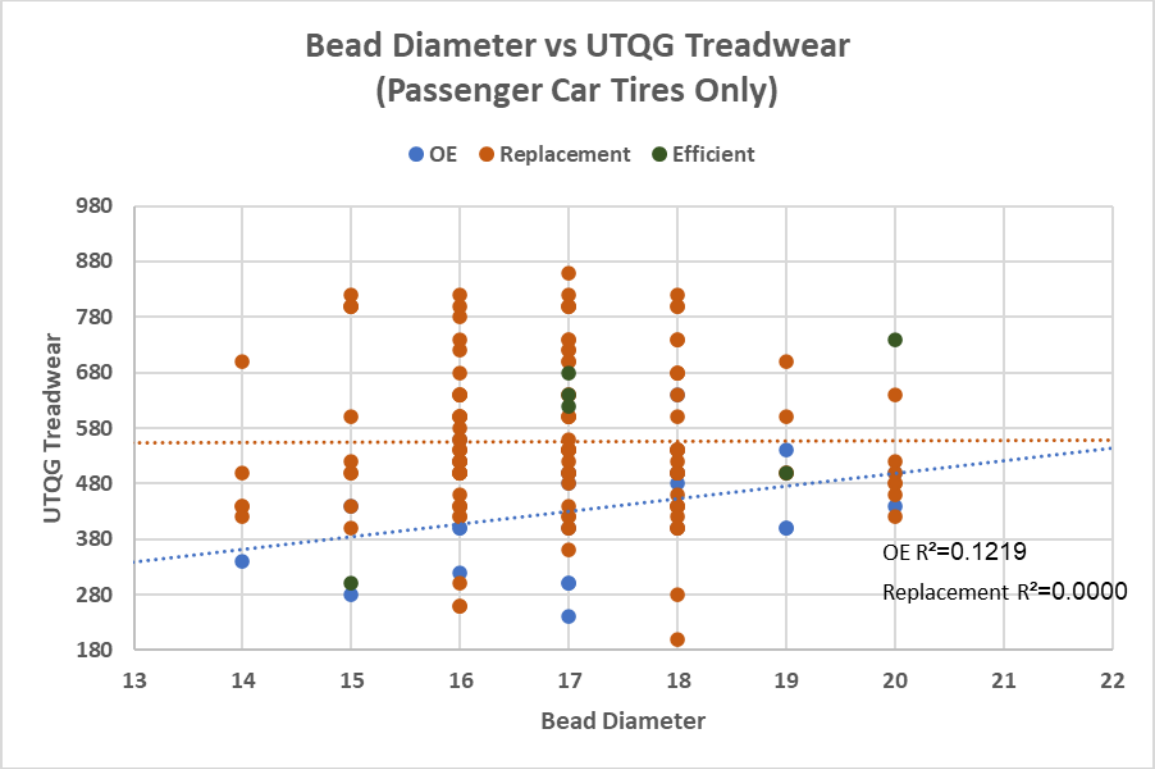

Chart 5.4C

- Bead diameter identified by tire size stamping on sidewall; example: 265/75R17: 17 inch wheel diameter at bead ledge.
- Uniform Tire Quality Grading (UTQG) Treadwear Rating as identified by tire stamping on sidewall; example UTQG rating: 560 A B; 560 is treadwear rating. The rating is a numeric index of how well a tire wears in comparison to a reference tire.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.4 OE Tire Studies (continued)

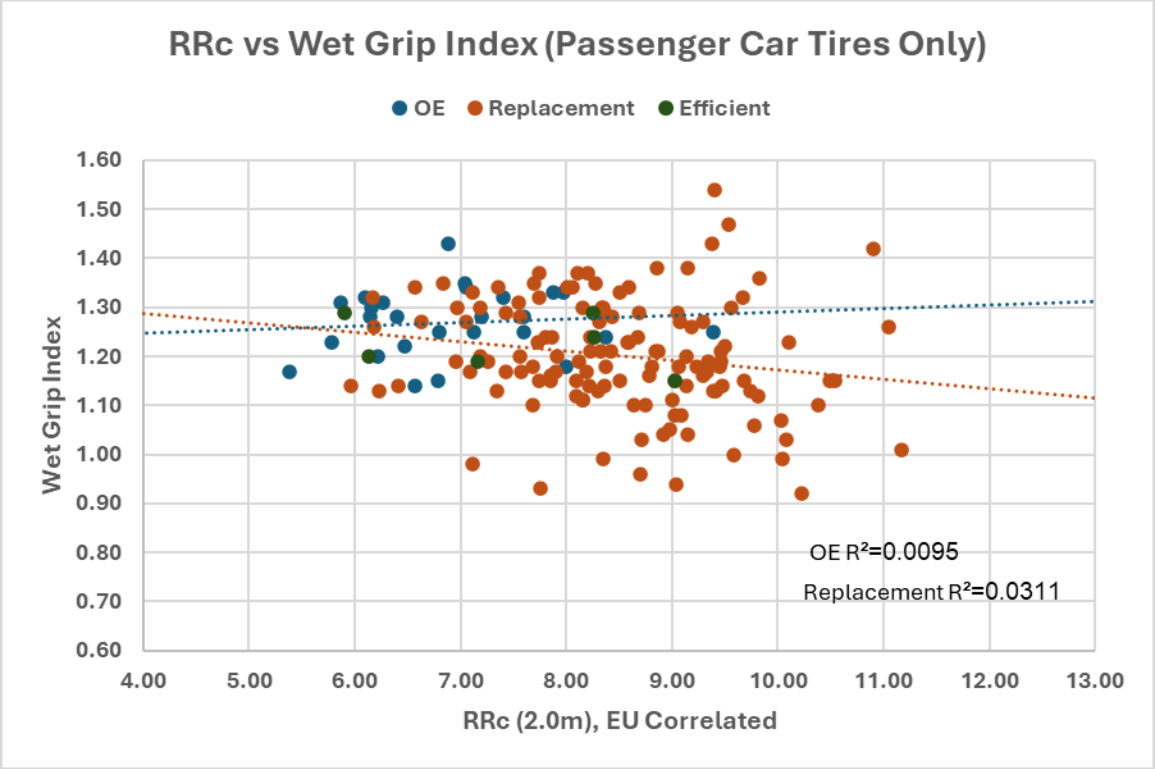

Chart 5.4D

- Rolling resistance coefficient data adjusted per EU correlation
- Tire rolling resistance test protocol: ISO 28580:2018
- Wet grip index test protocol: ISO 23671:2021
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.4 OE Tire Studies (continued)

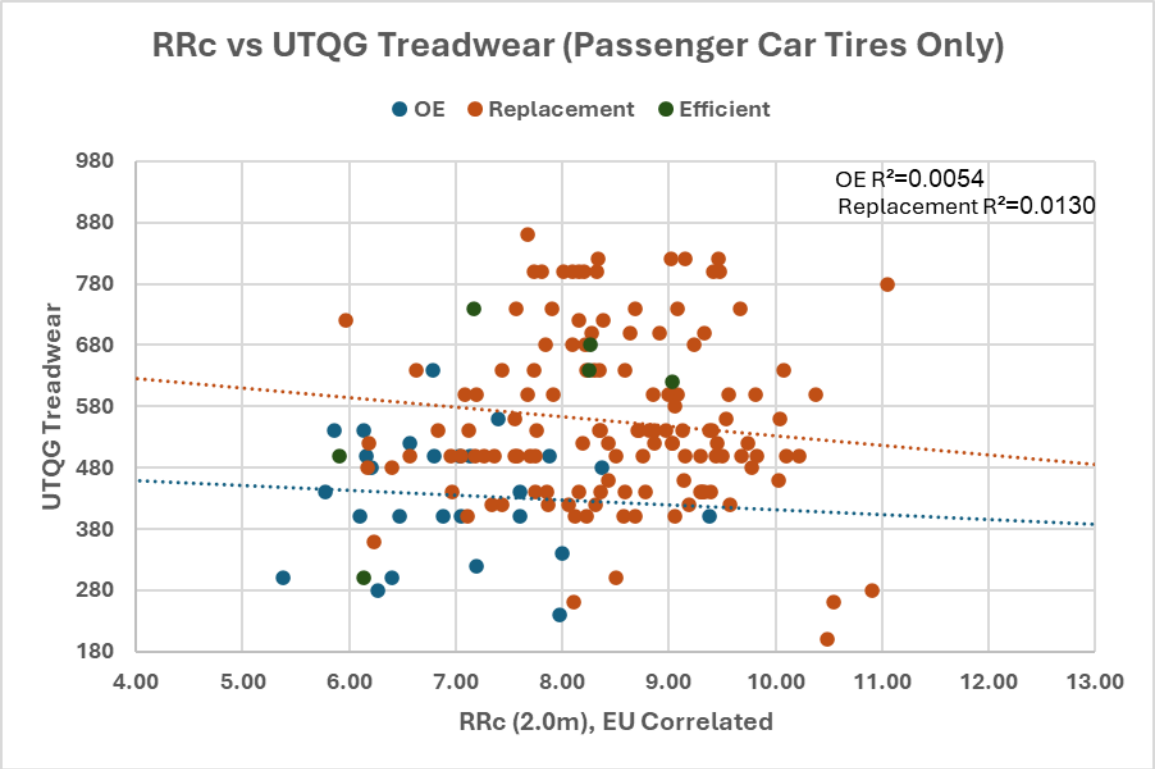

Chart 5.4E

- Rolling resistance coefficient data adjusted per EU correlation
- Tire rolling resistance test protocol: ISO 28580:2018
- Uniform Tire Quality Grading (UTQG) Treadwear Rating as identified by tire stamping on sidewall; example UTQG rating: 560 A B; 560 is treadwear rating. The rating is a numeric index of how well a tire wears in comparison to a reference tire.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.

5.5 Price Studies

Rolling Resistance vs Price (See Chart 5.5A)
Graph 5.5A depicts a correlation study of tire price as a function of measured rolling resistance RRC values. The population represents all passenger tire SKUs from Phase 1 + Phase 2.

The trendline exhibited a negative slope, with increasing price for lower rolling resistance.

Wet Grip Index vs Price (See Chart 5.5B)
Graph 5.5B depicts a correlation study of tire price as a function of measured wet traction values. The population represents all passenger tire SKUs from Phase 1 + Phase 2.

The trendline exhibited a positive slope, with increasing price for lower rolling resistance. The correlation quality was low: $R^2 = 0.036$.

UTQG Treadwear vs Price (See Charts 5.5C)
Graph 5.5C depicts a correlation study of tire price as a function of labeled UTQG treadwear ratings. The population represents all passenger tire SKUs from Phase 1 + Phase 2.

The linear trendline exhibited a negligible slope, and the correlation quality was low: $R^2 = 0.005$. No correlation was noted.

5.5 Price Studies (continued)

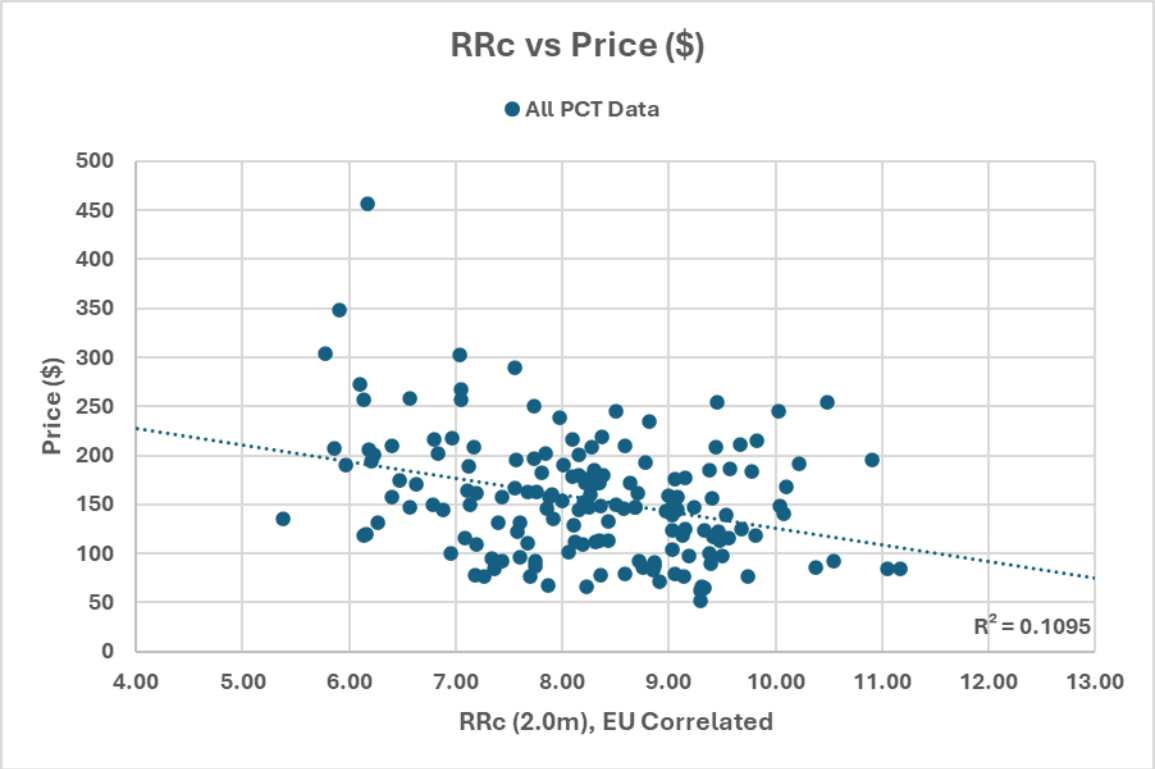

Chart 5.5A

- Rolling resistance coefficient data adjusted per EU correlation
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents three (3) tires tested.
- Tire rolling resistance test protocol: ISO 28580:2018

5.5 Price Studies (continued)

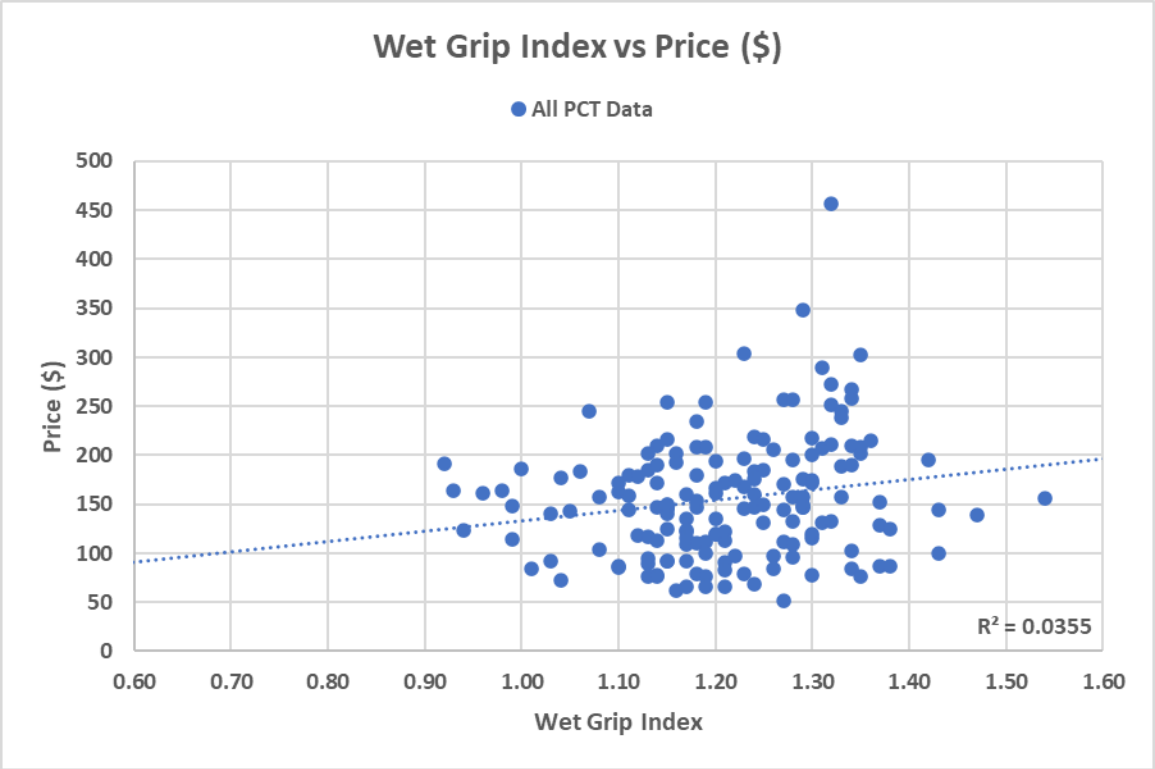

Chart 5.5B

- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents one (1) tire tested.
- Wet grip index test protocol: ISO 23671:2021

5.5 Price Studies (continued)

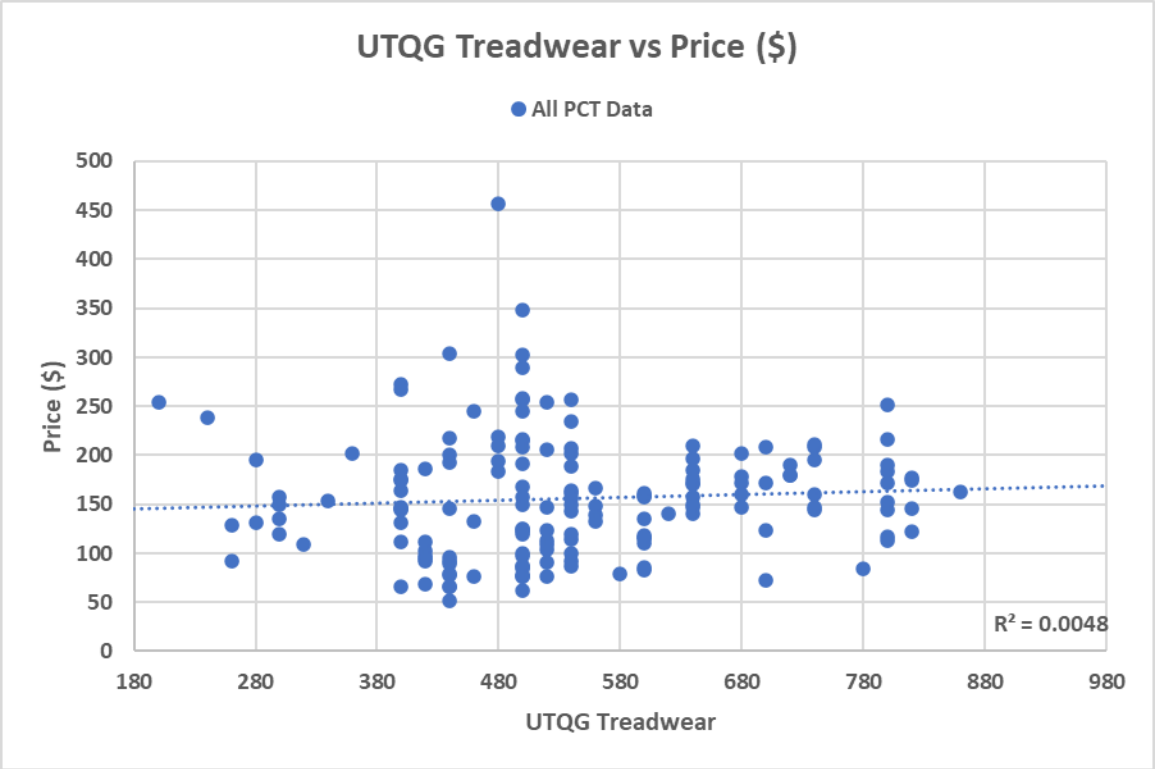

Chart 5.5C

- Tread depth measured in millimeters with a tread depth gauge: measured to groove bottom.
- R^2 measures the proportion of variation in the dependent variable that can be attributed to the independent variable. The R-squared value R^2 is always between 0 and 1 inclusive.
- Each plotted point represents the mean value of three (3) tires tested.
- Tire rolling resistance test protocol: ISO 28580:2018

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Appendix

1. Individual Tire Information and Test Data (Phase 2 Only)
2. Complete Set Data Charts (Results Section)
3. Tire Group Descriptive Statistics of Tire Rolling Resistance (RRC Values)
4. EU Rolling Resistance Correlation
5. Definitions
6. References

Appendix

1. Individual Tire Information and Test Data (Phase 2 Only)

    - Rolling Resistance Data
    - Wet Grip Data
    - Other Tire Group Information

Rolling Resistance Data

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	RR Force (N)	RRC (2.0 meter)	RRC (2.0 meter), EU Correlated	Price ($)
150	2303886	LT285/70R17	121/118	Q	12.70	55.50	81.8	6.77	6.12	150.00
150	2303887	LT285/70R17	121/118	Q	12.70	55.90	81.9	6.78	6.13	150.00
150	2303888	LT285/70R17	121/118	Q	12.70	55.66	84.1	6.96	6.30	150.00
151	2303889	LT315/70R17	121/118	S	12.70	66.85	88.9	7.36	6.68	270.00
151	2303890	LT315/70R17	121/118	S	12.70	66.75	89.2	7.38	6.71	270.00
151	2303891	LT315/70R17	121/118	S	12.70	66.65	91.0	7.53	6.85	270.00
152	2303892	LT225/75R16	115/112	R	11.91	36.60	78.7	7.77	7.08	221.00
152	2303893	LT225/75R16	115/112	R	11.91	36.75	79.0	7.80	7.10	221.00
152	2303894	LT225/75R16	115/112	R	11.91	36.60	79.0	7.80	7.11	221.00
153	2303895	LT255/75R17	111/108	Q	14.29	49.05	93.3	9.78	9.01	316.33
153	2303896	LT255/75R17	111/108	Q	14.29	48.80	92.2	10.15	9.36	316.33
153	2303897	LT255/75R17	111/108	Q	14.29	48.00	88.9	10.26	9.47	316.33
154	2303898	LT275/70R18	125/122	S	11.91	55.10	132.4	9.59	8.83	221.41
154	2303899	LT275/70R18	125/122	S	11.91	55.55	134.1	9.63	8.86	221.41
154	2303900	LT275/70R18	125/122	S	11.91	55.90	131.9	9.75	8.98	221.41
155	2303901	LT285/70R17	121/118	S	13.49	57.25	91.0	7.53	6.85	255.00
155	2303902	LT285/70R17	121/118	S	13.49	57.85	94.4	7.71	7.02	255.00
155	2303903	LT285/70R17	121/118	S	13.49	57.05	93.1	7.81	7.12	255.00
156	2303904	LT315/70R17	126/123	R	12.70	67.65	118.8	8.38	7.67	343.90
156	2303905	LT315/70R17	126/123	R	12.70	67.05	120.7	8.44	7.73	343.90
156	2303906	LT315/70R17	126/123	R	12.70	67.00	119.6	8.52	7.80	343.90
157	2303907	LT225/75R16	115/112	S	9.53	37.20	90.6	8.94	8.21	115.00
157	2303910	LT225/75R16	115/112	S	9.53	37.80	92.9	8.95	8.21	115.00
157	2303911	LT225/75R16	115/112	S	9.53	37.95	90.6	9.18	8.43	115.00
158	2303912	LT275/70R18	125/122	S	9.53	52.30	91.2	6.54	5.90	303.01
158	2303913	LT275/70R18	125/122	S	9.53	52.75	91.3	6.63	5.98	303.01
158	2303914	LT275/70R18	125/122	S	9.53	52.60	90.0	6.64	5.99	303.01
159	2303915	LT255/75R17	111/108	T	11.91	40.10	68.4	7.53	6.85	264.08

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	RR Force (N)	RRC (2.0 meter)	RRC (2.0 meter), EU Correlated	Price ($)
159	2303920	LT255/75R17	111/108	T	11.91	41.25	70.7	7.78	7.09	264.08
159	2303921	LT255/75R17	111/108	T	11.91	40.45	70.7	7.78	7.09	264.08
160	2304575	175/65R14	82	T	7.94	15.70	35.2	9.45	8.69	72.00
160	2304576	175/65R14	82	T	7.94	15.75	36.0	9.65	8.89	72.00
160	2304577	175/65R14	82	T	7.94	15.95	37.0	9.94	9.16	72.00
161	2304578	195/60R17	90	H	7.14	17.50	28.5	5.94	5.32	135.37
161	2304579	195/60R17	90	H	7.14	17.30	28.0	6.02	5.40	135.37
161	2304580	195/60R17	90	H	7.14	17.40	28.3	6.06	5.44	135.37
162	2304581	235/55R19	101	H	7.14	28.60	43.6	6.73	6.08	257.44
162	2304582	235/55R19	101	H	7.14	28.75	43.8	6.77	6.12	257.44
162	2304583	235/55R19	101	H	7.14	29.10	44.5	6.87	6.22	257.44
163	2304584	215/55R17	94	V	7.14	21.15	35.9	6.80	6.14	119.69
163	2304585	215/55R17	94	V	7.14	21.30	35.8	6.80	6.15	119.69
163	2304586	215/55R17	94	V	7.14	21.35	35.7	6.84	6.18	119.69
164	2304588	235/40R19	96	W	7.14	25.75	51.3	9.20	8.45	245.00
164	2304589	235/40R19	96	W	7.14	25.60	51.2	9.22	8.47	245.00
164	2304590	235/40R19	96	W	7.14	25.50	52.0	9.34	8.58	245.00
165	2304591	235/50ZR18	97	W	7.94	28.75	57.7	9.99	9.22	185.00
165	2304592	235/50ZR18	97	W	7.94	28.25	59.8	10.08	9.30	185.00
165	2304593	235/50ZR18	97	W	7.94	27.95	57.3	10.44	9.64	185.00
166	2304594	P235/65R17	103	T	7.94	28.55	53.5	7.72	7.03	150.08
166	2304595	P235/65R17	103	T	7.94	28.85	54.6	7.79	7.10	150.08
166	2304596	P235/65R17	103	T	7.94	27.90	53.0	7.95	7.26	150.08
167	2304597	225/65R17	102	H	7.14	25.05	47.8	6.88	6.22	156.99
167	2304598	225/65R17	102	H	7.14	24.90	47.6	7.14	6.47	156.99
167	2304587	225/65R17	102	H	7.14	25.20	45.9	7.17	6.50	156.99
168	2304599	225/65R17	102	H	7.14	26.25	47.8	7.12	6.46	174.90
168	2304600	225/65R17	102	H	7.14	25.60	47.6	7.14	6.48	174.90
168	2304601	225/65R17	102	H	7.14	25.85	47.5	7.16	6.50	174.90
169	2304602	185/70R14	88	T	7.14	17.35	44.7	10.03	9.25	65.51

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	RR Force (N)	RRC (2.0 meter)	RRC (2.0 meter), EU Correlated	Price ($)
169	2304603	185/70R14	88	T	7.14	17.50	44.1	10.16	9.38	65.51
169	2304604	185/70R14	88	T	7.14	17.40	44.7	10.17	9.38	65.51
170	2304605	P185/70R14	87	T	8.73	19.45	51.5	11.93	11.07	84.00
170	2304606	P185/70R14	87	T	8.73	19.75	51.0	12.04	11.18	84.00
170	2304607	P185/70R14	87	T	8.73	19.45	51.9	12.13	11.27	84.00
171	2304608	175/65R14	82	T	6.35	14.70	36.9	9.90	9.13	52.00
171	2304609	175/65R14	82	T	6.35	14.95	38.0	10.12	9.34	52.00
171	2304610	175/65R14	82	T	6.35	14.95	37.7	10.20	9.41	52.00
172	2304612	255/60R18	108	H	7.94	32.95	58.4	7.43	6.76	150.09
172	2304617	255/60R18	108	H	7.94	32.55	58.9	7.45	6.77	150.09
172	2304618	255/60R18	108	H	7.94	32.85	58.3	7.50	6.83	150.09
173	2304619	165/65R14	79	S	7.14	13.00	29.7	8.65	7.93	153.88
173	2304620	165/65R14	79	S	7.14	13.10	29.9	8.71	7.99	153.88
173	2304621	165/65R14	79	S	7.14	13.15	30.2	8.81	8.08	153.88
174	2304622	175/70R14	88	H	7.14	15.70	37.4	8.52	7.80	68.03
174	2304623	175/70R14	88	H	7.14	15.75	37.9	8.62	7.90	68.03
174	2304624	175/70R14	88	H	7.14	15.40	37.9	8.63	7.90	68.03
175	2304625	225/40R18	92	H	7.14	21.20	42.7	8.58	7.86	157.66
175	2304626	225/40R18	92	H	7.14	20.85	42.4	8.59	7.87	157.66
175	2304627	225/40R18	92	H	7.14	20.60	42.4	8.64	7.91	157.66
176	2304628	185/65R14	86	H	7.14	16.50	39.9	9.60	8.84	62.66
176	2304629	185/65R14	86	H	7.14	16.45	40.2	9.67	8.91	62.66
176	2304630	185/65R14	86	H	7.14	16.25	45.6	10.96	10.14	62.66
177	2304631	205/60R16	92	H	7.14	20.40	41.2	8.28	7.57	131.10
177	2304632	205/60R16	92	H	7.14	20.15	40.9	8.30	7.59	131.10
177	2304633	205/60R16	92	H	7.14	20.10	41.0	8.35	7.63	131.10
178	2304634	215/60R16	95	H	7.14	21.05	42.3	7.81	7.12	109.50
178	2304635	215/60R16	95	H	7.14	20.90	42.8	7.90	7.21	109.50
178	2304636	215/60R16	95	H	7.14	21.00	43.2	7.97	7.28	109.50

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	RR Force (N)	RRC (2.0 meter)	RRC (2.0 meter), EU Correlated	Price ($)
179	2304637	205/45R17	88	W	7.14	20.70	38.5	8.67	7.94	238.99
179	2304638	205/45R17	88	W	7.14	20.75	38.1	8.68	7.95	238.99
179	2304639	205/45R17	88	W	7.14	20.40	38.1	8.77	8.04	238.99

Wet Traction Index Data

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	Wet Grip	Price ($)
150	wet-150	LT285/70R17	121/118	Q	12.70	55.66	1.42	150.00
151	wet-151	LT315/70R17	121/118	S	12.70	66.65	1.46	270.00
152	wet-152	LT225/75R16	115/112	R	11.91	36.60	1.52	221.00
153	wet-153	LT255/75R17	111/108	Q	14.29	48.00	1.5	316.33
154	wet-154	LT275/70R18	125/122	S	11.91	55.90	1.58	221.41
155	wet-155	LT285/70R17	121/118	S	13.49	57.05	1.55	255.00
156	wet-156	LT315/70R17	126/123	R	12.70	67.00	1.43	343.90
157	wet-157	LT225/75R16	115/112	S	9.53	37.95	1.46	115.00
158	wet-158	LT275/70R18	125/122	S	9.53	52.60	1.56	303.01
159	wet-159	LT255/75R17	111/108	T	11.91	40.45	1.51	264.08
160	wet-160	175/65R14	82	T	7.94	15.95	1.04	72.00
161	wet-161	195/60R17	90	H	7.14	17.40	1.17	135.37
162	wet-162	235/55R19	101	H	7.14	29.10	1.28	257.44
163	wet-163	215/55R17	94	V	7.14	21.35	1.3	119.69
164	wet-164	235/40R19	96	W	7.14	25.50	1.33	245.00
165	wet-165	235/50ZR18	97	W	7.94	27.95	1.25	185.00
166	wet-166	P235/65R17	103	T	7.94	27.90	1.25	150.08
167	wet-167	225/65R17	102	H	7.14	25.20	1.28	156.99
168	wet-168	225/65R17	102	H	7.14	25.85	1.22	174.90
169	wet-169	185/70R14	88	T	7.14	17.40	1.19	65.51
170	wet-170	P185/70R14	87	T	8.73	19.45	1.01	84.00
171	wet-171	175/65R14	82	T	6.35	14.95	1.27	52.00
172	wet-172	255/60R18	108	H	7.94	32.85	1.15	150.09
173	wet-173	165/65R14	79	S	7.14	13.15	1.18	153.88
174	wet-174	175/70R14	88	H	7.14	15.40	1.24	68.03
175	wet-175	225/40R18	92	H	7.14	20.60	1.33	157.66
176	wet-176	185/65R14	86	H	7.14	16.25	1.16	62.66
177	wet-177	205/60R16	92	H	7.14	20.10	1.25	131.10

Smithers Group ID	Smithers Tire ID	Tire Size	Load Index	Speed Rating	Tread Depth (mm)	Tire Weight (lbs)	Wet Grip	Price ($)
178	wet-178	215/60R16	95	H	7.14	21.00	1.28	109.50
179	wet-179	205/45R17	88	W	7.14	20.40	1.33	238.99

Other Tire Group Information

Smithers Group ID	Smithers Tire ID	Tire Size	Treadwear	Traction	Temp	Tire Market Category	Tire Usage Category	Manufacturer Tier	Run Flat (Y/N)
150	wet-150	LT285/70R17				All Terrain	Replacement	3	N
151	wet-151	LT315/70R17				All Terrain	Replacement	2	N
152	wet-152	LT225/75R16				Highway	Replacement	1	N
153	wet-153	LT255/75R17				All Terrain	OE	1	N
154	wet-154	LT275/70R18				All Terrain	Replacement	3	N
155	wet-155	LT285/70R17				All Terrain	Replacement	3	N
156	wet-156	LT315/70R17				All Terrain	Replacement	3	N
157	wet-157	LT225/75R16				Highway	Replacement	3	N
158	wet-158	LT275/70R18				All Terrain	OE	1	N
159	wet-159	LT255/75R17				All Terrain	Replacement	1	N
160	wet-160	175/65R14	700	A	B	Touring	Replacement	3	N
161	wet-161	195/60R17	300	B	A	Touring	OE	3	N
162	wet-162	235/55R19	540	A	A	EV	OE	1	N
163	wet-163	215/55R17	500	A	A	EV	OE	3	N
164	wet-164	235/40R19	500	A	A	EV	Replacement	1	N
165	wet-165	235/50ZR18	400	AA	A	UHP	OE	2	N
166	wet-166	P235/65R17	500	A	B	Touring	OE	2	N
167	wet-167	225/65R17	300	A	A	Highway	OE	3	N
168	wet-168	225/65R17	400	B	A	Touring	OE	2	N
169	wet-169	185/70R14	440	A	B	Economy	Replacement	3	N
170	wet-170	P185/70R14				Highway	Replacement	1	N
171	wet-171	175/65R14	440	A	B	Economy	Replacement	3	N

Smithers Group ID	Smithers Tire ID	Tire Size	Treadwear	Traction	Temp	Tire Market Category	Tire Usage Category	Manufacturer Tier	Run Flat (Y/N)
172	wet-172	255/60R18	640	A	A	Highway	OE	3	N
173	wet-173	165/65R14	340	A	B	Highway	OE	2	N
174	wet-174	175/70R14	420	A	A	Economy	Replacement	3	N
175	wet-175	225/40R18	500	A	A	Touring	OE	1	N
176	wet-176	185/65R14	500	A	A	Economy	Replacement	2	N
177	wet-177	205/60R16	400	A	A	Highway	OE	3	N
178	wet-178	215/60R16	320	A	A	Touring	OE	2	N
179	wet-179	205/45R17	240	AA	A	EV	OE	3	N

Appendix

2. Data Charts from Results Section

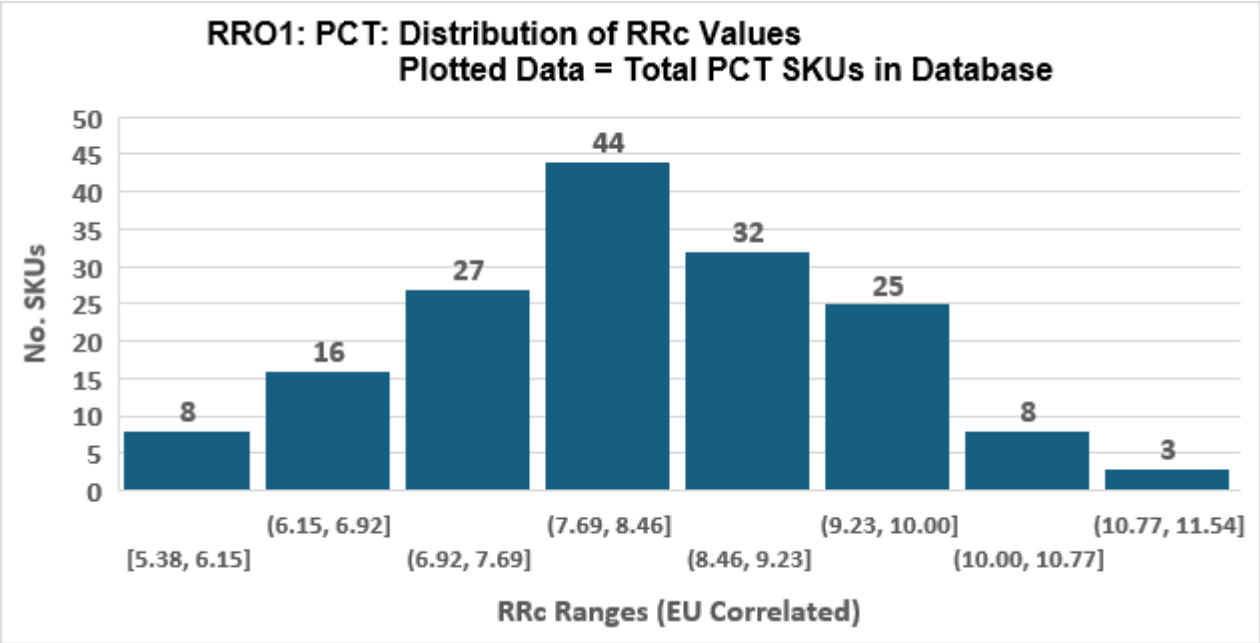


Chart 5.1A

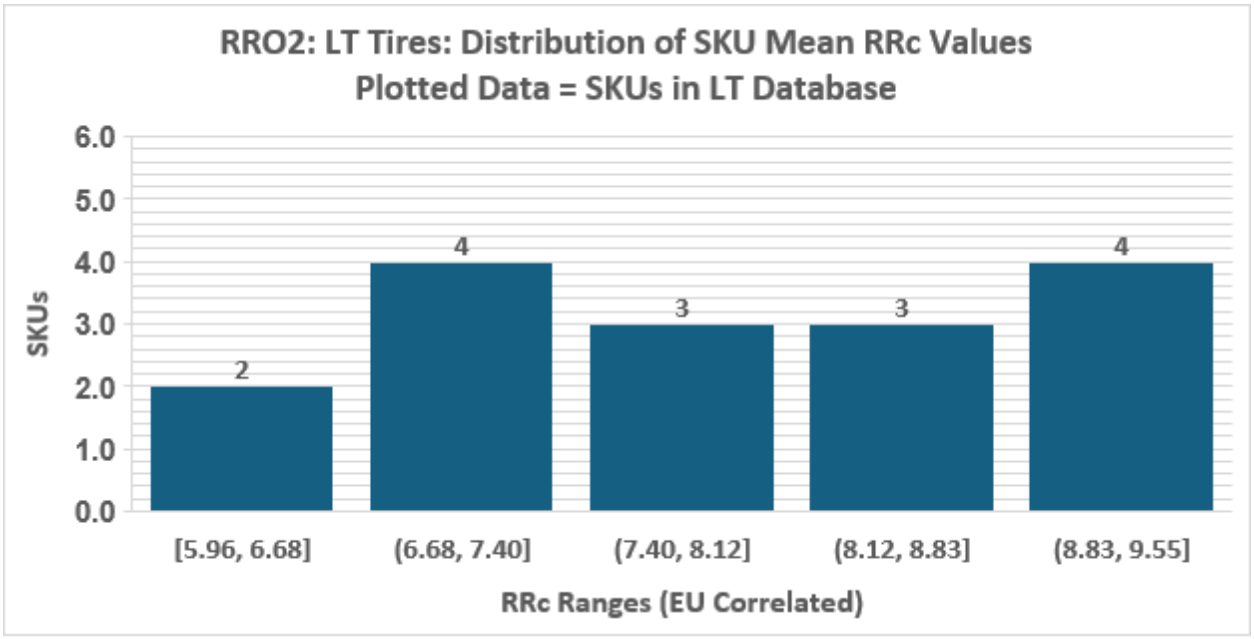


Chart 5.1B

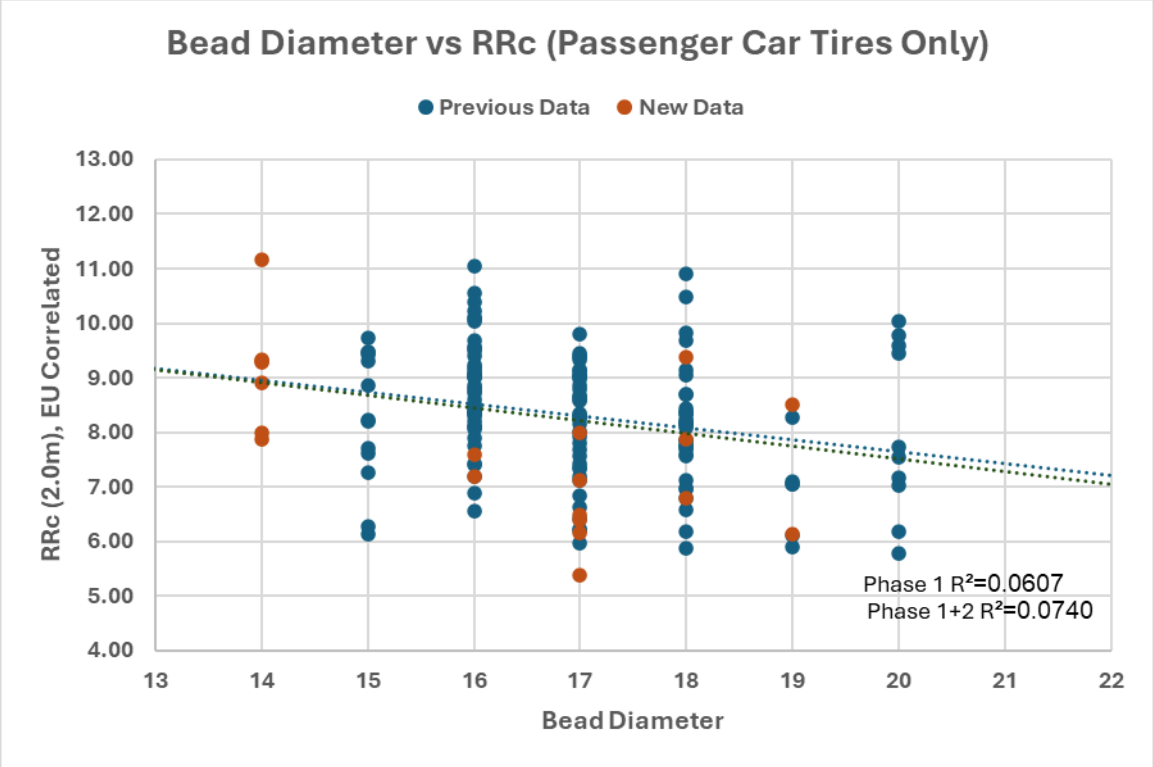


Chart 5.2A

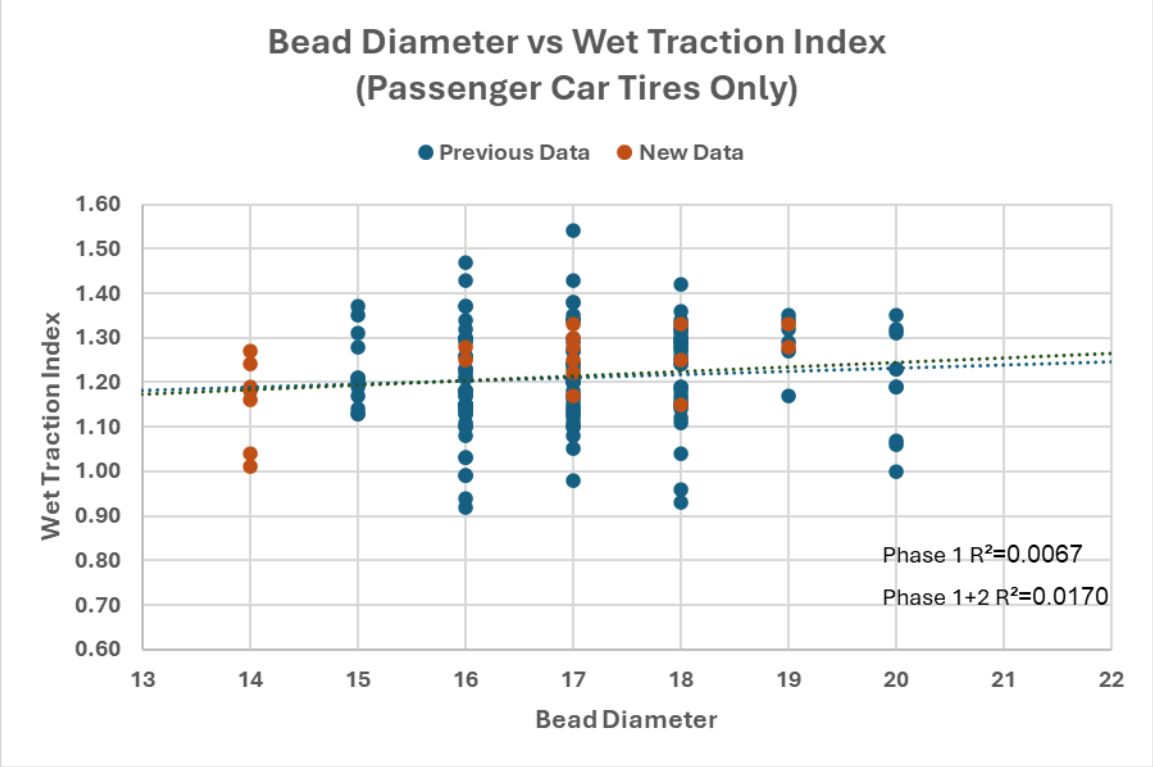


Chart 5.2B

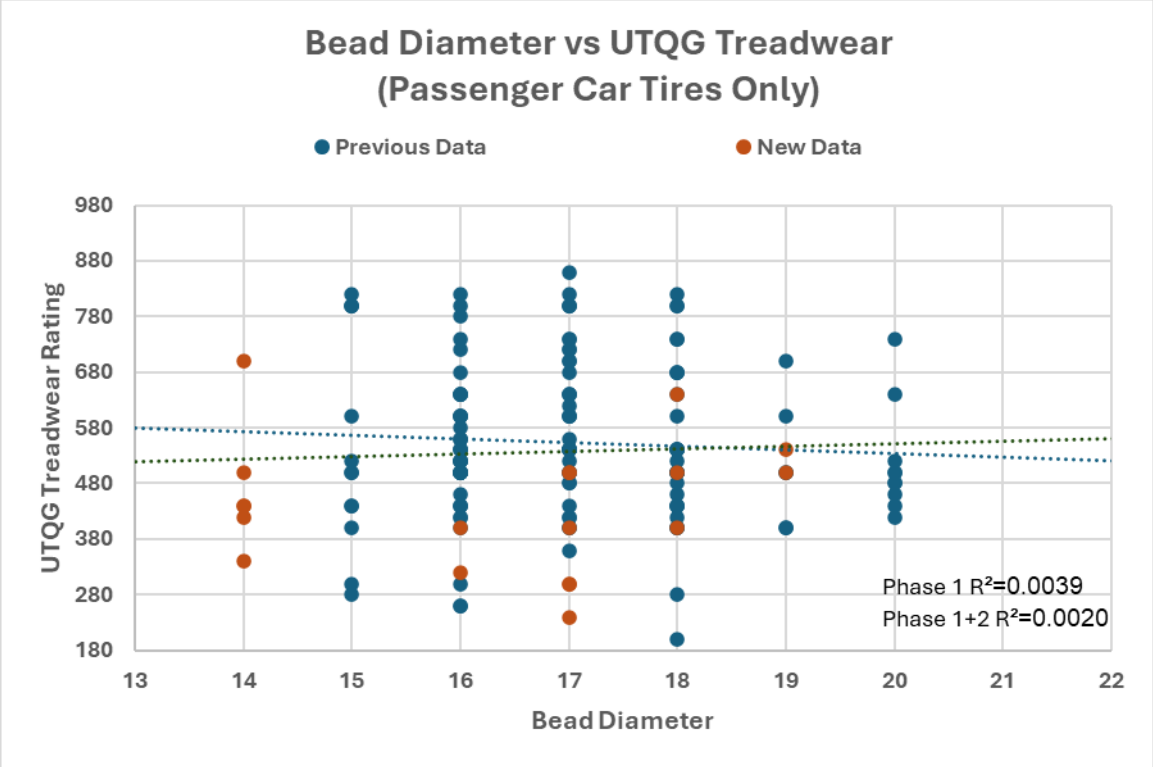


Chart 5.2C

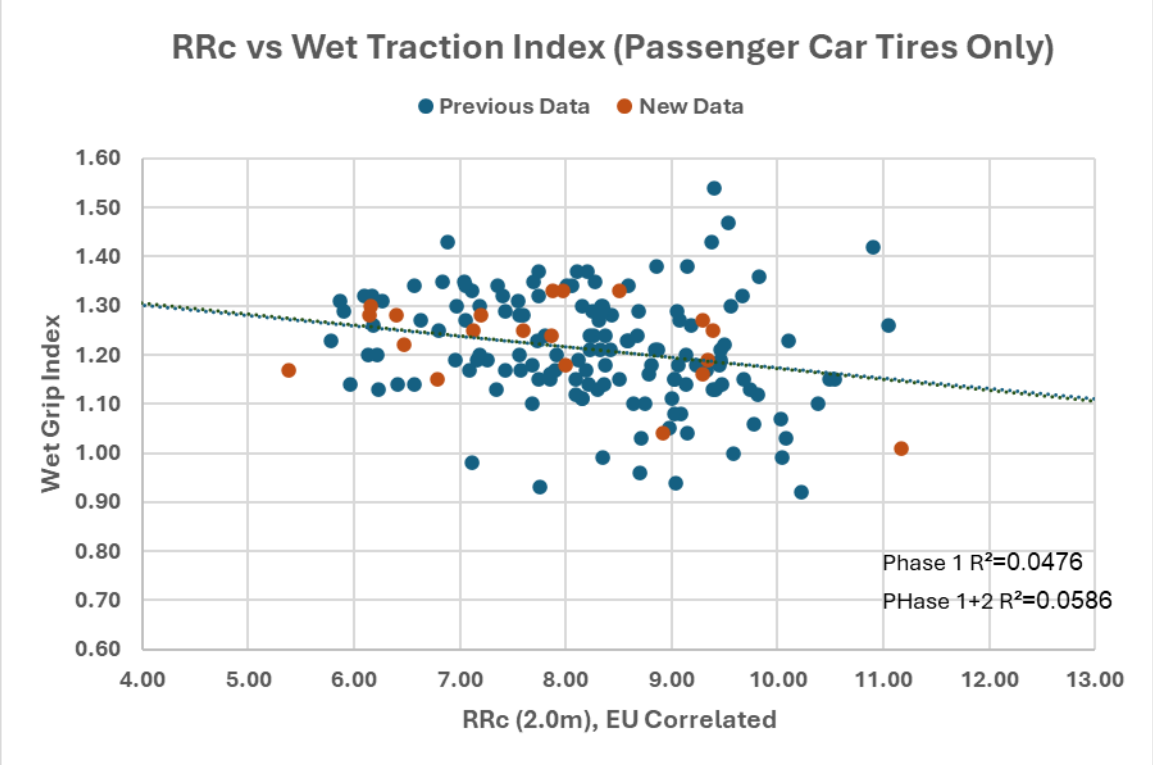


Chart 5.2D

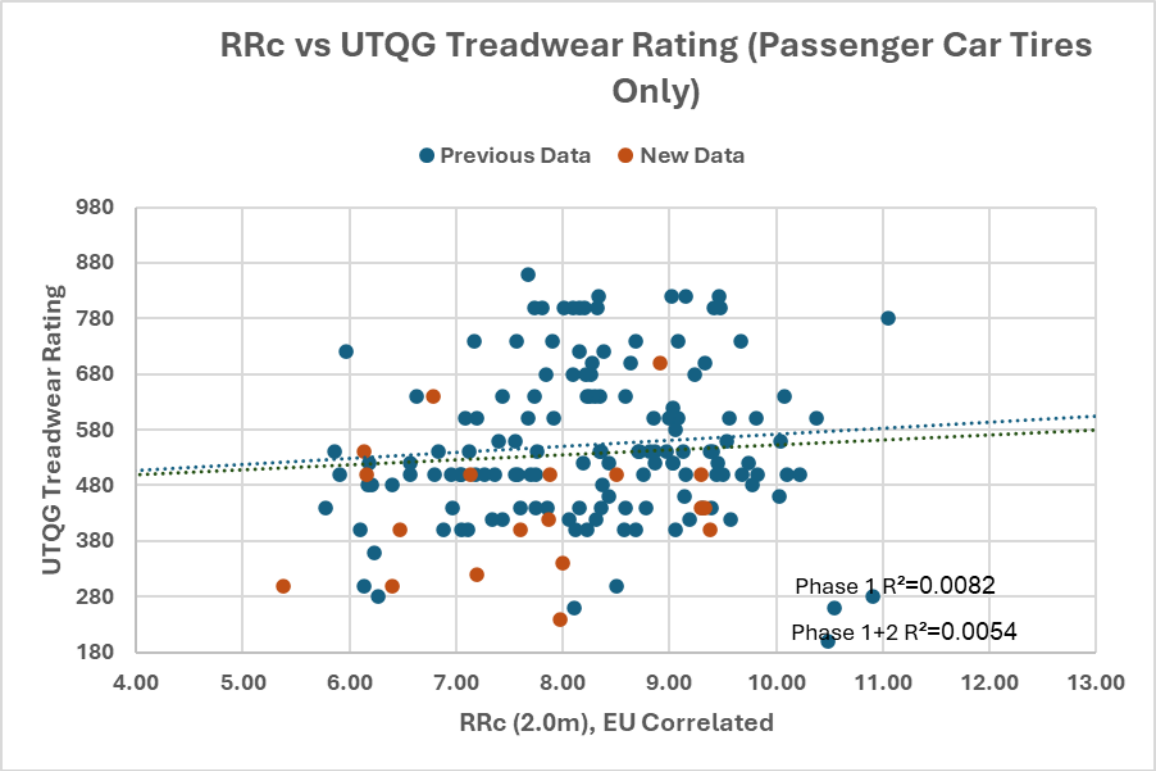


Chart 5.2E

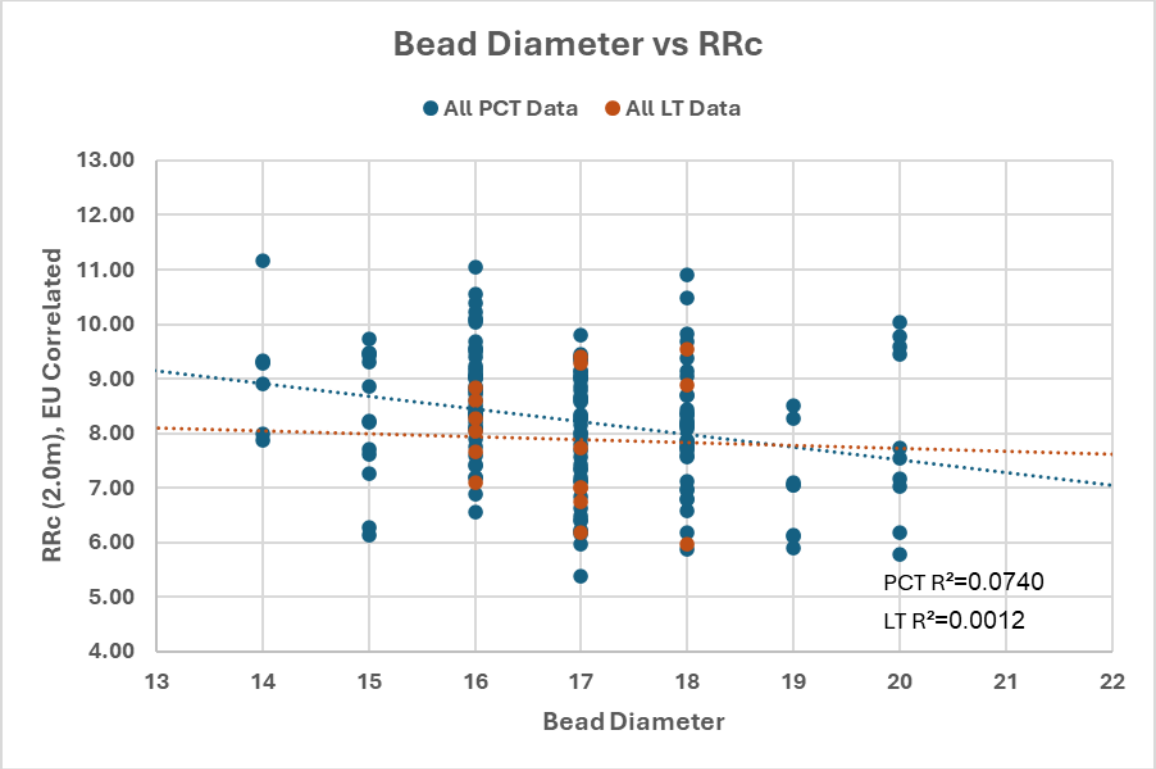


Chart 5.3A

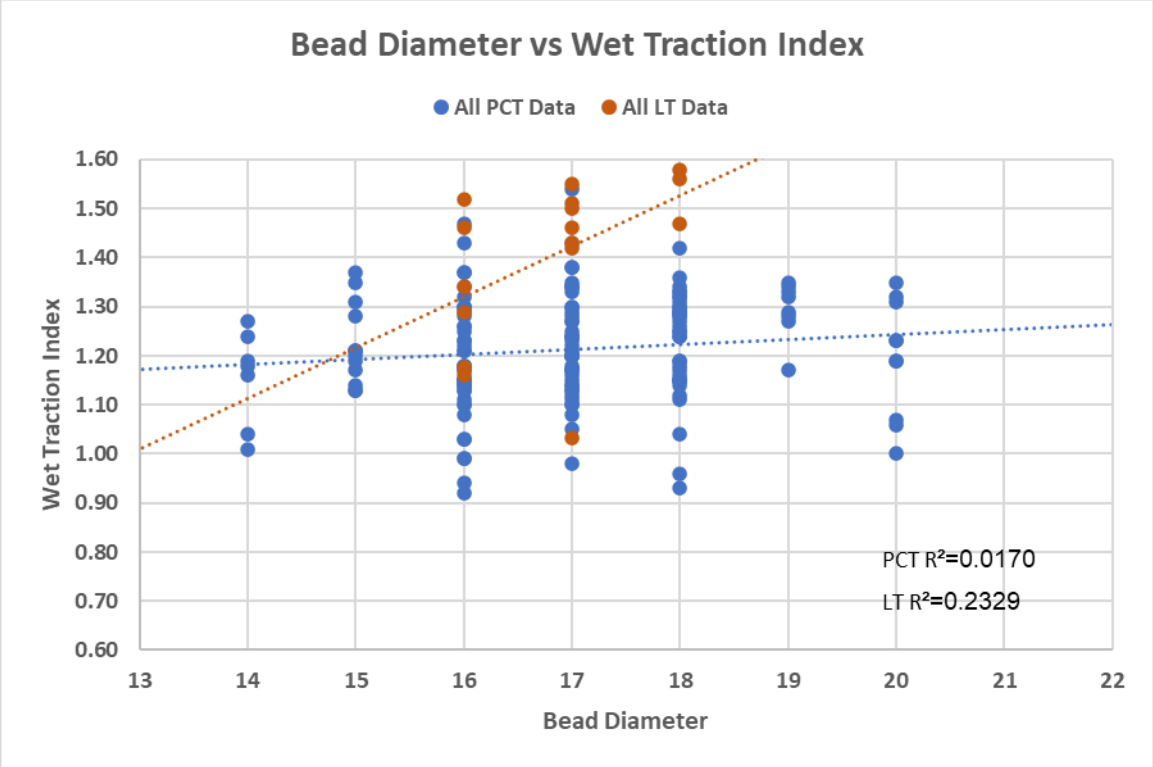


Chart 5.3B

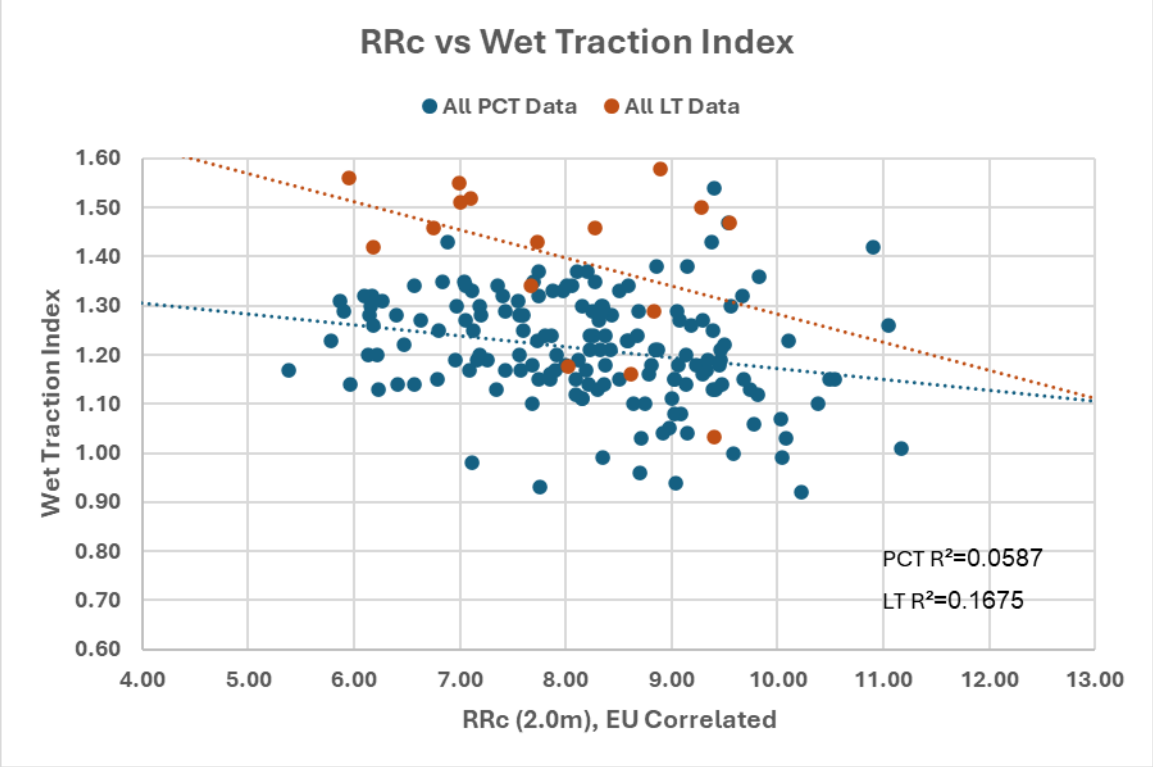
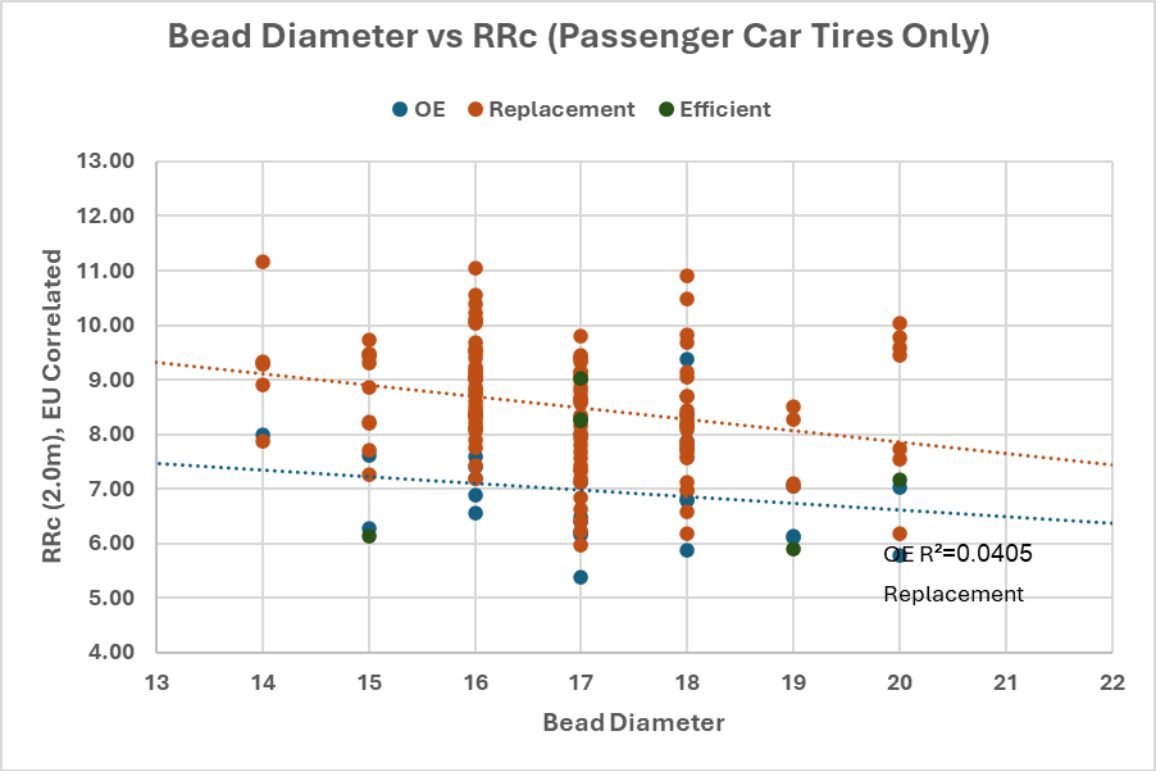


Chart 5.3C



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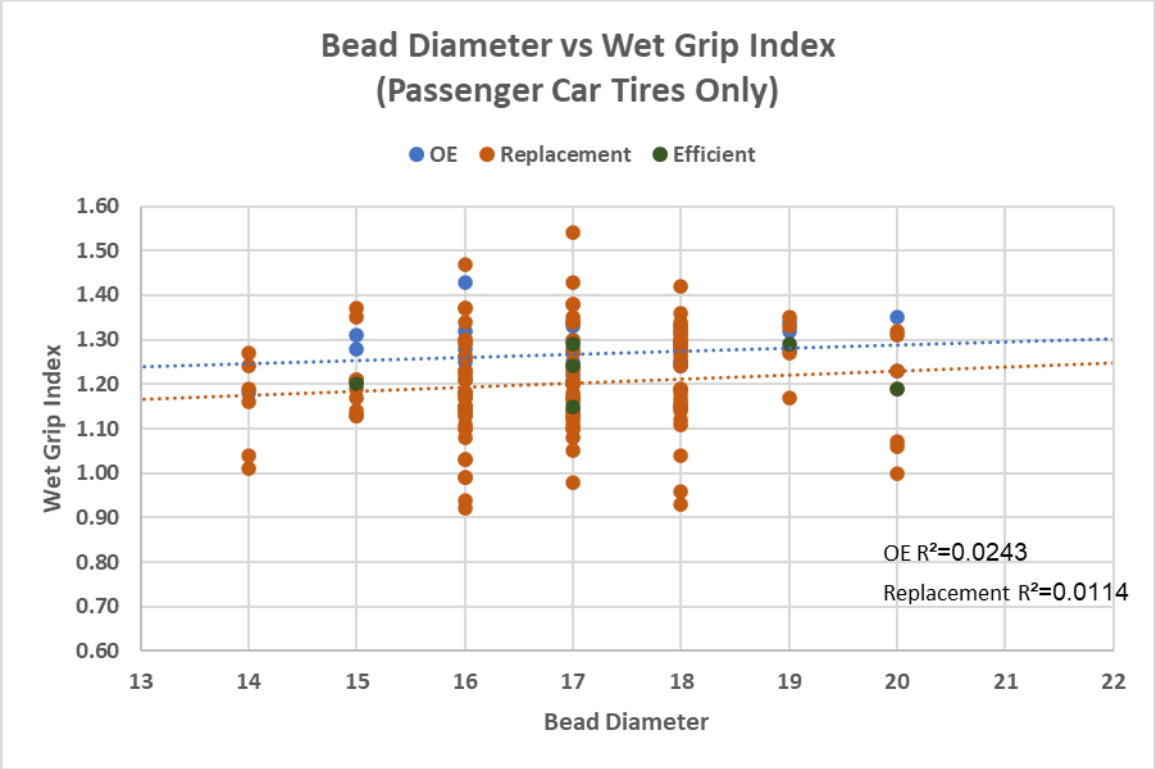

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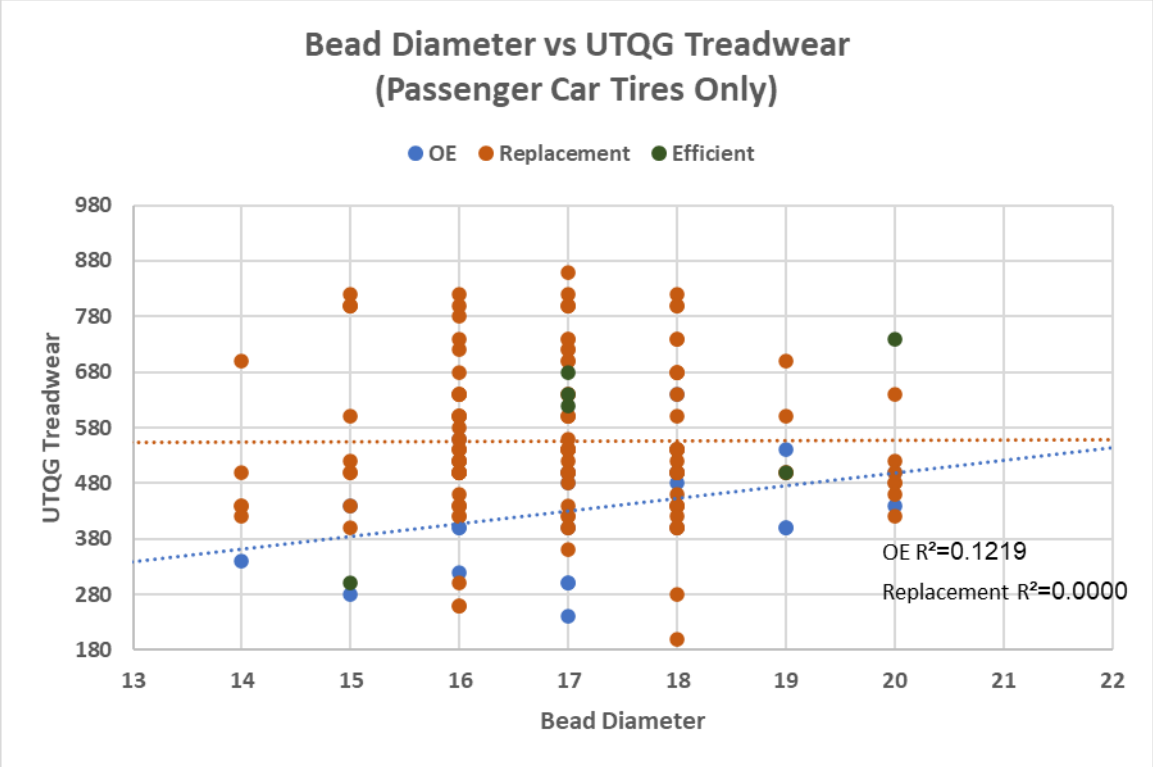

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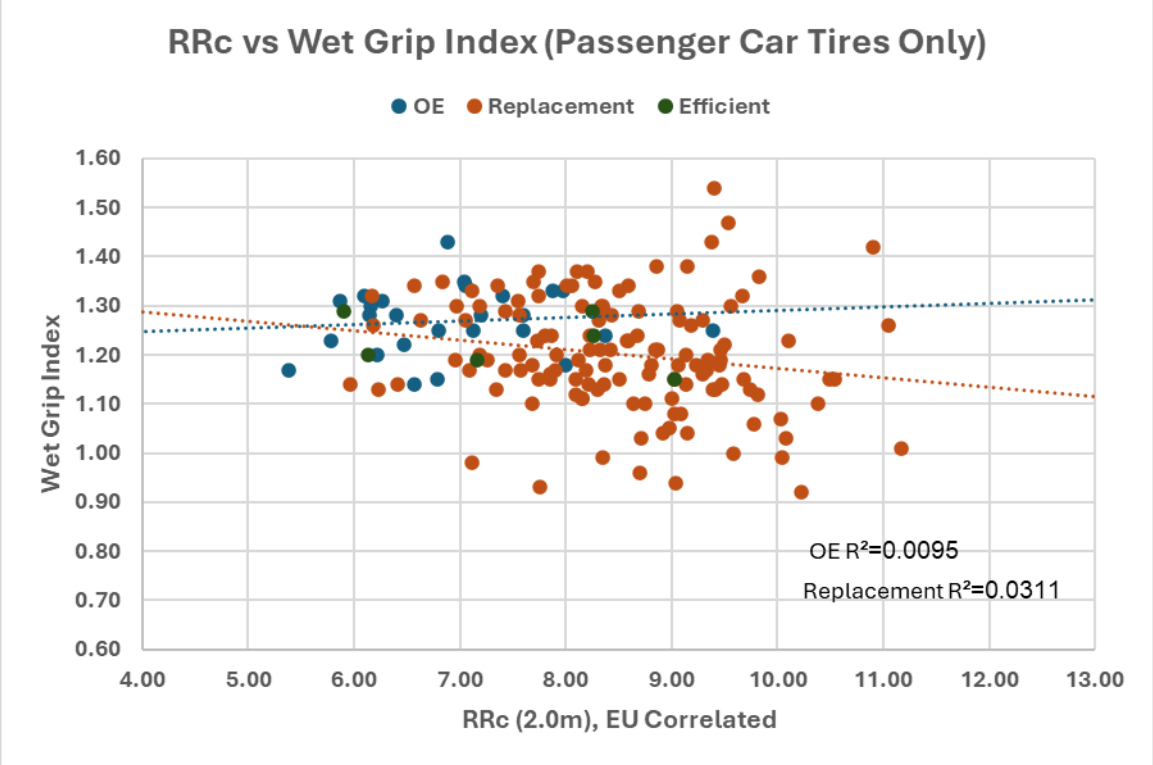

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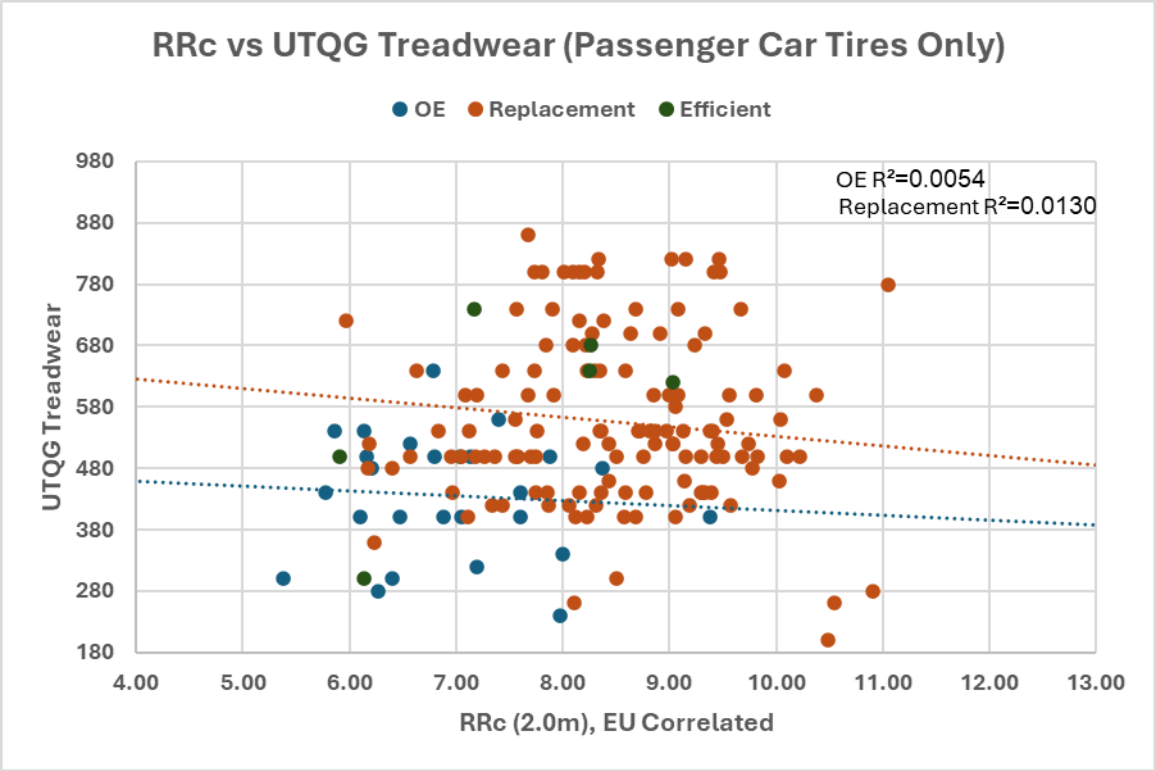

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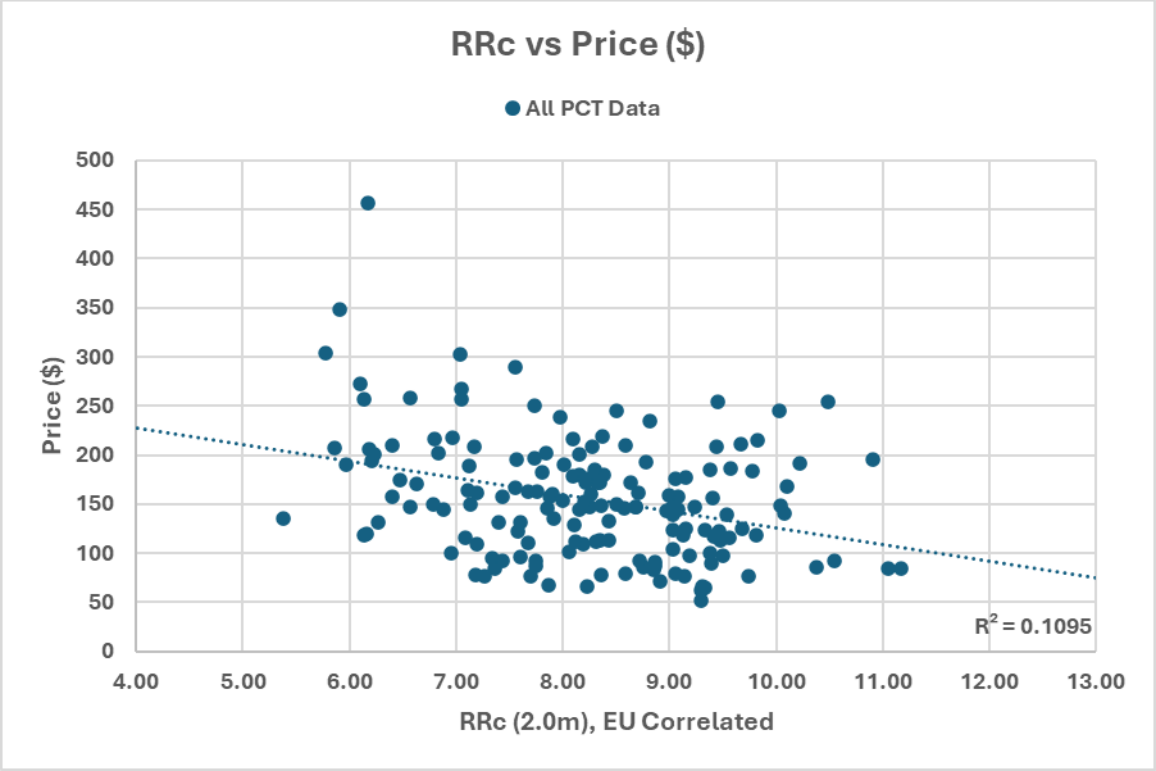

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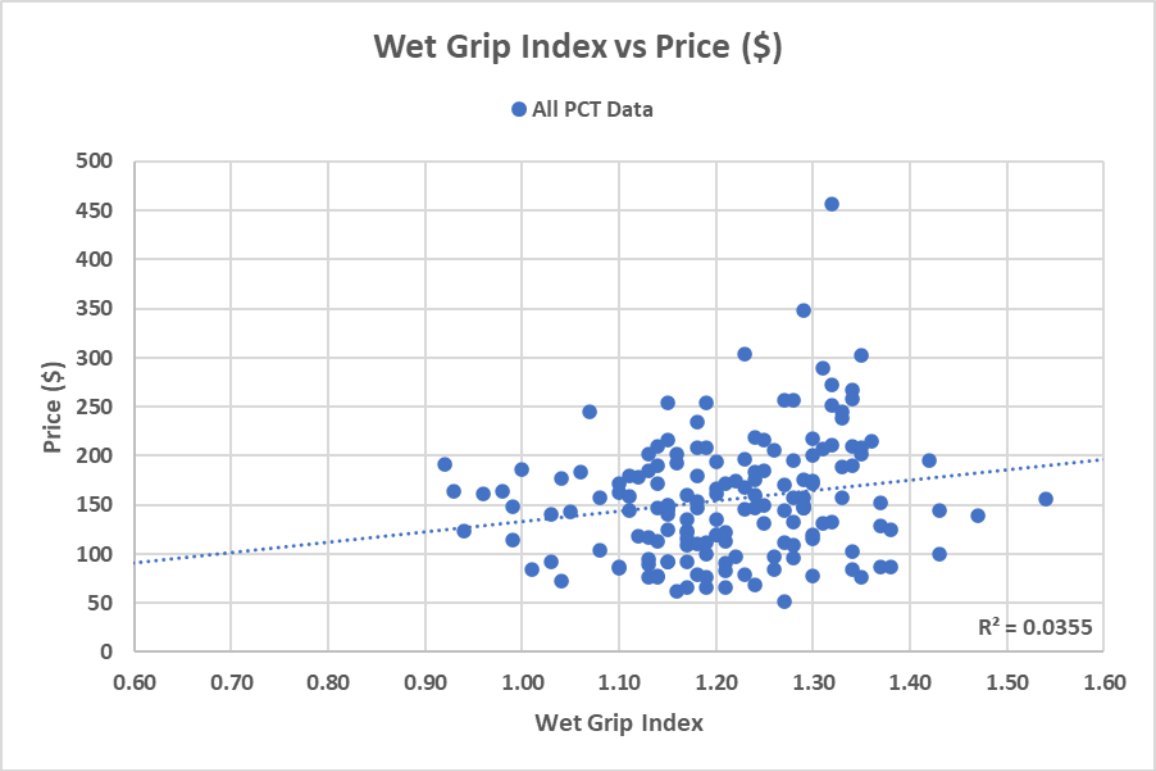

Chart 5.5B

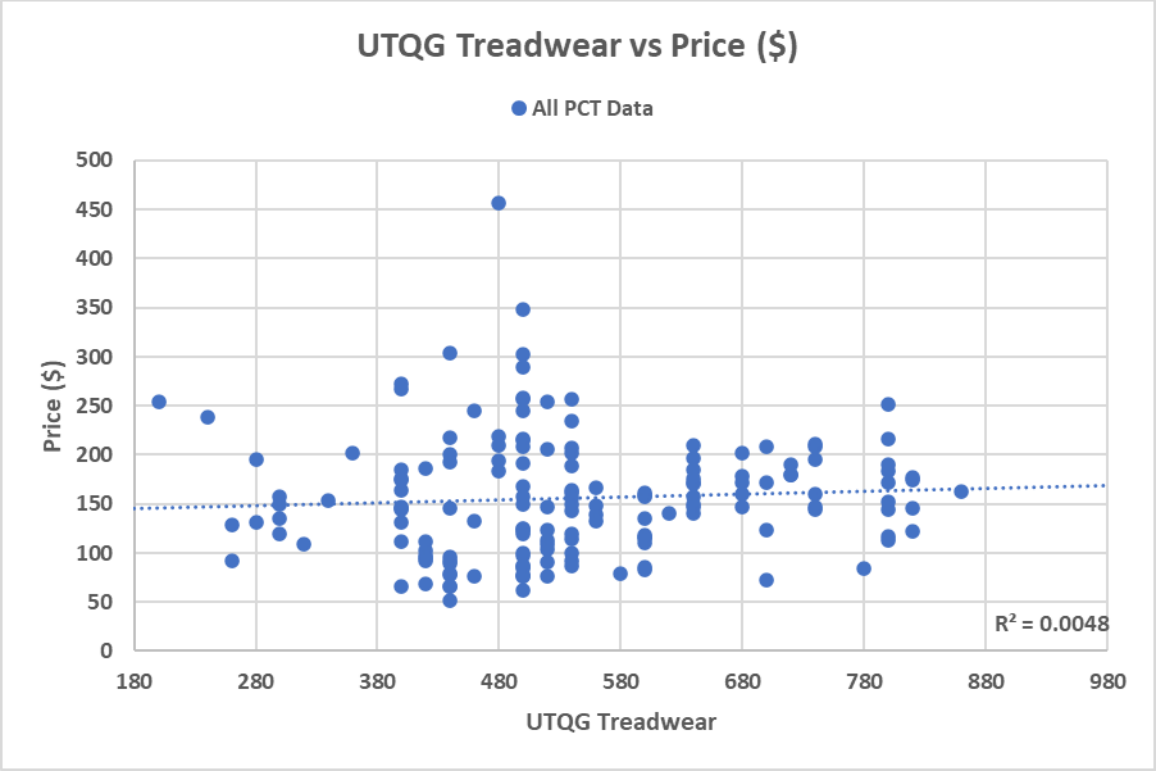

Chart 5.5C

Appendix

3.0 Tire Group Descriptive Statistics of Tire Rolling Resistance (RRC Values)

Column	Size	Mean	Std Dev	Std. Error	C.I. of Mean	Range	Max	Min	Median	Skewness	K-S Dist.	K-S Prob.	SWilk W	SWilk Prob	Sum	Sum of Squares
150	3	6.184	0.1020	0.0590	0.254	0.180	6.302	6.122	6.128	1.725	0.375	0.108	0.775	0.057	18.553	114.755
151	3	6.748	0.0897	0.0518	0.223	0.167	6.850	6.683	6.710	1.561	0.330	0.217	0.866	0.286	20.243	136.613
152	3	7.100	0.0145	0.0084	0.036	0.028	7.112	7.084	7.105	-1.221	0.284	0.375	0.934	0.502	21.301	151.239
153	3	9.284	0.2410	0.1390	0.598	0.461	9.474	9.014	9.365	-1.335	0.297	0.325	0.916	0.440	27.853	258.706
154	3	8.890	0.0791	0.0457	0.196	0.152	8.978	8.827	8.864	1.310	0.294	0.337	0.920	0.454	26.669	237.087
155	3	6.996	0.1370	0.0792	0.341	0.271	7.120	6.849	7.019	-0.732	0.233	0.552	0.979	0.722	20.988	146.866
156	3	7.732	0.0652	0.0376	0.162	0.130	7.800	7.670	7.726	0.386	0.201	0.628	0.994	0.857	23.195	179.347
157	3	8.282	0.1280	0.0741	0.319	0.224	8.430	8.206	8.209	1.731	0.381	0.097	0.761	0.024	24.845	205.790
158	3	5.958	0.0499	0.0288	0.124	0.090	5.991	5.901	5.983	-1.685	0.357	0.144	0.814	0.149	17.875	106.510
159	3	7.010	0.1400	0.0807	0.347	0.243	7.091	6.848	7.090	-1.732	0.384	0.091	0.753	0.007	21.029	147.443
160	3	8.914	0.2380	0.1370	0.591	0.474	9.164	8.690	8.889	0.481	0.210	0.612	0.991	0.821	26.743	238.508
161	3	5.385	0.0568	0.0328	0.141	0.112	5.435	5.323	5.396	-0.860	0.246	0.512	0.970	0.669	16.155	87.001
162	3	6.140	0.0713	0.0412	0.177	0.139	6.219	6.080	6.121	1.121	0.272	0.417	0.946	0.552	18.421	113.115
163	3	6.159	0.0213	0.0123	0.053	0.039	6.183	6.144	6.148	1.665	0.352	0.158	0.826	0.178	18.476	113.783
164	3	8.503	0.0708	0.0409	0.176	0.131	8.584	8.453	8.471	1.597	0.337	0.198	0.855	0.253	25.508	216.890
165	3	9.385	0.2260	0.1310	0.562	0.425	9.643	9.217	9.295	1.503	0.321	0.246	0.882	0.331	28.155	264.343
166	3	7.130	0.1140	0.0659	0.284	0.223	7.256	7.033	7.102	1.039	0.264	0.449	0.955	0.590	21.391	152.550
167	3	6.399	0.1530	0.0885	0.381	0.278	6.500	6.223	6.475	-1.676	0.355	0.150	0.820	0.162	19.198	122.900
168	3	6.478	0.0194	0.0112	0.048	0.039	6.499	6.460	6.476	0.580	0.219	0.591	0.987	0.782	19.434	125.898
169	3	9.338	0.0733	0.0423	0.182	0.130	9.382	9.253	9.377	-1.722	0.373	0.112	0.780	0.068	28.013	261.578
170	3	11.175	0.0983	0.0567	0.244	0.196	11.269	11.073	11.182	-0.310	0.194	0.638	0.996	0.886	33.524	374.649
171	3	9.293	0.1460	0.0840	0.362	0.282	9.412	9.130	9.335	-1.209	0.282	0.380	0.935	0.508	27.878	259.101
172	3	6.785	0.0357	0.0206	0.089	0.067	6.825	6.758	6.771	1.473	0.316	0.261	0.889	0.353	20.354	138.098
173	3	7.997	0.0760	0.0439	0.189	0.151	8.077	7.926	7.988	0.535	0.215	0.601	0.989	0.800	23.990	191.854
174	3	7.867	0.0570	0.0329	0.142	0.101	7.902	7.801	7.897	-1.721	0.372	0.113	0.782	0.073	23.600	185.655
175	3	7.878	0.0296	0.0171	0.073	0.055	7.912	7.856	7.866	1.515	0.322	0.240	0.879	0.322	23.634	186.191
176	3	9.297	0.7350	0.4250	1.827	1.309	10.145	8.836	8.910	1.713	0.367	0.122	0.792	0.096	27.890	260.372
177	3	7.598	0.0333	0.0192	0.083	0.066	7.633	7.567	7.593	0.650	0.225	0.574	0.984	0.755	22.793	173.175
178	3	7.201	0.0788	0.0455	0.196	0.157	7.276	7.119	7.207	-0.348	0.198	0.634	0.995	0.871	21.602	155.556
179	3	7.980	0.0540	0.0311	0.134	0.098	8.042	7.943	7.954	1.653	0.349	0.165	0.832	0.193	23.939	191.033

Appendix

4.0 EU Rolling Resistance Correlation

EU Rolling Resistance Correlation

Smithers worked with a partner to develop a correlation to the EU virtual machine used for European Labelling.

EU Correlation: L2 RRC = 0.9605 x SmithersMC – 0.3828

Validity period: **Correlation Valid Through 31st of Dec 2023**

- The rolling resistance coefficient corrections, within the ranges studied, range from: -0.63 to -0.86.

- The candidate Smithers Lab machine is a test position dedicated for C1 and C2 tire classes.
- The reference machine MC#04.A (correlation machine) is a test position dedicated for C1 and C2 tire classes.
- Attention: the so called "Light Truck" or "LT/C" tires belong to the C3 tire class category: those tires **shall NOT** be tested in the Smithers machine object of this correlation, as it would lead to inconsistency in test results alignment. (Note, no C3 tires are currently present in this study)
- Class C3 tires are a European designation EU Regulation N0 661/2009 Article 8.

(c) class C3 tyres — tyres designed primarily for vehicles of categories M_2, M_3, N, O_3 and O_4 with one of the following load capacity indices:

(i) a load capacity index in single formation ≤ 121 and the speed category symbol ≤ 'M';

(ii) a load capacity index in single formation ≥ 122.

- No C3 Class tires were studied in this program
- Based on the test results, the Smithers lab machine complies with the repeatability requirements of the Regulation (EU) 2020/740.
- The correlation established permits alignment of test results from our Smithers lab machine to our partner in Europe, and afterwards, the alignment to the virtual EC Reference Laboratory.
- This correlation is **valid for Rolling Resistance Coefficient (RRC) in N/kN**. A set of **C1/C2 tires** was used for this study.
- The test procedure was following the ISO28580, standard test for rolling resistance and labeling (in line with the R117). The test plan was developed following labelling regulations in place.
- The correlation has a R-Square > 0.99.
- Attention: Period of validity of correlations shall be respected, as defined in the Regulation (EU) 2020/740. If the correlation comes to expiration, the data generated from Smithers lab will not be usable for labelling until next correlation is established.
- Other parameters were compared apart from RRC (rolling force, loaded radius, etc.) and resulted very close in terms of absolute values and repeatability.

Appendix

5.0 Definitions

Definitions

Aspect ratio. A tire's section height divided by its section width, multiplied by 100. Aspect ratio is listed in the size designation on the passenger tire sidewall. Typical tire aspect ratios range from 35 for tires used on sports cars to 75 for tires used on utility-type vehicles.
Bead. A ring of steel wire that anchors the tire carcass plies to the rim.
Belt. An assembly of plies extending from shoulder to shoulder of a tire and providing a reinforcing foundation for the tread. In radial-ply tires, the belts are typically reinforced with fine steel wire having high tensile strength.
Bias-ply tire. A pneumatic tire in which the ply cords that extend to the beads are laid at alternate angles substantially less than 90 degrees to the centerline of the tread. The bias-ply tire was the predominant passenger tire in the United States before 1980 but is no longer in common use; it has been supplanted by the radial-ply tire.
Carbon black. A very fine, nano-size particulate carbon used as a reinforcing filler in rubber compounds to provide abrasion resistance and other favorable properties.
Carcass or casing. The tire structure, except tread and sidewall rubber, that bears the load when the tire is inflated.
Coastdown. A process in which a vehicle or test machine is allowed to slow down freely from a high to a low speed without application of external power or braking.
Coefficient of friction. The ratio of friction force to normal force to cause sliding expressed as a unitless value (i.e., friction force generated between tire tread rubber and the road surface divided by vertical load).
Corporate average fuel economy (CAFE). A federal program that sets a minimum performance requirement for passenger vehicle fuel economy. Each automobile manufacturer must achieve an average level of fuel economy for all specified vehicles manufactured in a given model year. The National Highway Traffic Safety Administration administers the CAFE program. The U.S. Environmental Protection Agency develops the vehicle fuel economy test procedures.
EPA. U.S. Environmental Protection Agency. EPA is responsible for developing the federal test procedures for measuring and rating the fuel economy of new passenger cars and light trucks. The federal test procedures are used for new vehicle fuel economy labeling and the corporate average fuel economy program.
FMVSS. Federal Motor Vehicle Safety Standards. The FMVSS include regulations governing passenger tire safety.
High-performance tire. A passenger tire designed for the highest speed and handling, generally having the speed symbol W, Y, or Z in the United States.
Hysteresis. A characteristic of a deformable material such that the energy of deformation is greater than the energy of recovery. The rubber compound in a tire exhibits hysteresis. As the tire rotates under the weight of the vehicle, it experiences repeated cycles of deformation and recovery, and it dissipates the hysteresis energy loss as heat. Hysteresis is the main cause of energy loss associated with rolling resistance and is attributed to the viscoelastic characteristics of the rubber.
Light truck (LT) tire. A tire constructed for heavy loads and rough terrain that is usually used on medium-duty trucks in commercial service. These tires contain the prefix LT before the metric size designation molded on the tire sidewall and are inflated to higher pressures than are normal passenger tires.

NHTSA. National Highway Traffic Safety Administration. Among its responsibilities, NHTSA administers the Federal Motor Vehicle Safety Standards, the Uniform Tire Quality Grading system, and the corporate average fuel economy program.
Original equipment manufacturer (OEM). An automobile manufacturer.
Original equipment (OE) passenger tire. A tire that is provided as original equipment on new passenger vehicles. Such tires are often designed for particular vehicles to the specifications of the automobile manufacturer.
Passenger tire. A tire constructed and approved for use on passenger vehicles and that usually contains the prefix P before the metric size designation on the tire sidewall. Federal Motor Vehicle Safety Standards and Uniform Tire Quality Grading standards are established specifically for passenger tires.
Passenger vehicle. For the purposes of this report, a car or light truck used primarily for passenger transportation. Most of these vehicles use passenger tires. Most vans, pickup trucks, and sport utility vehicles that are categorized as light trucks by the federal government are considered passenger vehicles. Light trucks that exceed 6,000 pounds in gross vehicle weight are usually used for non-passenger commercial service. They are usually equipped with light truck (LT) tires.
Performance tire. A passenger tire intended to provide superior handling and higher speed capabilities and generally having a speed symbol of H or V in the United States.
Ply. A sheet of rubber-coated parallel tire cords. Tire body plies are layered.
Radial-ply construction. A pneumatic tire construction under which the ply cords that extend to the beads are laid at approximately 90 degrees to the centerline of the tread. Two or more plies of reinforced belts are applied, encircling the tire under the tread. Radial-ply tires were introduced in Europe during the 1950s and came into common use in the United States during the 1970s.
Reinforcing filler. Material added to rubber compounds to provide favorable properties, including resistance to abrasion. The two most common reinforcing fillers are carbon black and silica.
Replacement passenger tire. A tire purchased in the aftermarket to replace an original equipment tire.
Rim diameter. The diameter of a wheel measured at the intersection of the bead seat and the flange. The rim diameter is listed in the size designation on the passenger tire sidewall. Common rim diameters for passenger tires range from 13 to 20 inches.
RMA. Rubber Manufacturers Association. RMA is the national trade association for the rubber products industry in the United States. Most domestic and foreign tire makers who produce tires in the United States are members of the association.
Rolling resistance. The force at the axle in the direction of travel required to make a loaded tire roll.
Run-flat tire. A type of pneumatic tire constructed of special materials, supports, and configurations that allow it to travel for a limited distance and speed after experiencing a loss of most or all inflation pressure. While these tires usually have greater weight and resultant rolling resistance, they permit the elimination of storage space and weight associated with a spare tire and jack.
SAE. Society of Automotive Engineers. SAE technical committees have developed standardized test practices for measuring the rolling resistance of tires.
Section height. The linear distance between an inflated unloaded tire's overall (outside) tread diameter and the intersection of the bead seat and the flange.
Section width. The linear distance between the outside sidewalls of an inflated unloaded tire (not including decorations such as lettering) when mounted on the measuring rim. Treads are always narrower than the section width.
Sidewall. The portion of the tire between the bead and the tread. The tire's name, safety codes, and size designation are molded on the sidewall.

Silane. An organo-silicate compound that is sometimes mixed with silica to promote dispersion and bonding.
Silica. A very fine, nano-size particle, silicon dioxide, used as a reinforcing filler in rubber compounding.
Speed rating. A letter assigned to a tire denoting the maximum speed for which the use of the tire is rated (e.g., S = 112 mph, H = 130 mph). The speed rating is contained in the tire size designation molded on the sidewall.
Tire pressure monitoring system (TPMS). A warning system in motor vehicles that indicates to the operator when a tire is significantly underinflated. Some systems use sensors in the tire to transmit pressure information to a receiver. Some do not have pressure sensors but rely on wheel speed sensors to detect and compare differences in wheel rotational speeds, which can be correlated to differences in tire pressure.
Traction. The ability of a loaded tire to generate vehicle control forces through frictional interaction with a road surface.
Tread. The peripheral portion of the tire designed to contact the road surface. The tread band consists of a pattern of protruding ribs and grooved channels on top of a base. Tread depth is measured on the basis of groove depth. Traction is provided by the tread.
Tread compound. The general term that refers to the chemical formula of the tread material. The compound consists of polymers, reinforcing fillers, and other additives that aid in processing and slow degradations from heat, oxygen, moisture, and ozone.
Tread wear life. Total miles traveled by a tire until its tread wears out, which is usually defined as a remaining groove depth of 2/32 inch for a passenger car tire that exhibits even wear.
Uniform Tire Quality Grade (UTQG). A passenger tire rating system that grades a tire's performance in tread wear durability, traction, and temperature resistance. UTQG ratings are required by the federal government for most types of passenger tires and are molded on the tire's sidewall. The tread wear grade is a numeric rating, with a higher number suggesting longer tread wear capability. Most tires receive grades between 100 and 800. The traction grade is assigned on the basis of results of skid tests on wet pavements. Tires are graded AA, A, B, or C, with AA indicating superior wet traction. The temperature grade is assigned to tires tested at various speeds to determine the ability of a tire to dissipate heat. Tires are graded A, B, or C, with A indicating an ability to dissipate heat at higher speeds.
USDOT. U.S. Department of Transportation. The National Highway Traffic Safety Administration is an agency of USDOT.
Vehicle fuel economy. The average number of miles a vehicle travels per gallon of motor fuel (typically gasoline or diesel fuel).
Viscoelastic. A viscoelastic material is characterized by possessing both viscous and elastic behavior. A purely elastic material is one in which all energy stored in the material during loading is returned when the load is removed. In contrast, a purely viscous material stores no strain energy, and all of the energy required to deform the material is simultaneously converted into heat. Some of the energy stored in a viscoelastic system is recovered on removal of the load, and the remainder is dissipated as heat. Rubber is a viscoelastic material.
Wear resistance. Resistance of the tread to abrasion from use on a normal road surface.
Wet traction. The ability of a loaded tire to generate vehicle control forces through frictional interaction with a wet road surface

Source: Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance, TRB Special Report 286 2006

Coefficient of Variation. The standard deviation divided by the mean.
ISO 28580. A recommended practice of ISO that defines a standardized method for testing tire rolling resistance under controlled laboratory conditions.
ISO 23671. A recommended practice of ISO that defines a standardized method for testing tire wet grip braking performance index relative to a control tire.
Rolling resistance coefficient (RRC). The tested rolling resistance force divided by the test load.
RRC 2.0m. A calculated rolling resistance coefficient (basis of a 2.0m test drum) using the test data generated on a Smithers 1.7m test drum.

Appendix

6.0 References

References

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8. Transportation Research Board, TRB Special Report: “Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance” Special Report 286 dated 2006.

9. US Department of Transportation; National Highway Traffic Safety Administration; “Consumer Guide to Uniform Tire Quality Grading” DOT HS 812 210, dated November 2015.

10. US Department of Transportation; National Highway Traffic Safety Administration; “Consumer Guide to Uniform Tire Quality Grading” DOT HS 812 325, dated August 2016.

11. U.S. Department Of Transportation; National Highway Traffic Safety Administration; “Laboratory Test Procedure **TP-UTQG-T-02 for Tire Traction Testing”; Consumer Information Regulations Part 575.104 Uniform Tire Quality Grading; dated August 16, 2022.**