APPENDIX 1: ADDITIONAL INFORMATION ON STATISTICAL TESTS

Tests giving information on the dataset (before analysis)

- Normality tests
  - Z-value (skewness and Kurtosis) by dividing the statistic value by the standard error.
    (Ghasemi and Zahediasl, 2012; Rose et al., 2015)
  - Histogram
    Univariate inspection of variables – graphical – continuous variable (Eric Fransen and Roelant, 2014)
  - Q-Q plot
    Quantile-quantile plots to determine if observations are normally distributed. Quantiles of observations versus quantiles of normal distribution. (Eric Fransen and Roelant, 2014)
  - Kolmogorov-Smirnov and Shapiro-Wilk Normality test
- Others
  - Koenker test
    Testing homoscedasticity. *"The assumption of homoscedasticity (literally, same variance) is central to linear regression models. Homoscedasticity describes a situation in which the error term (that is, the "noise" or random disturbance in the relationship between the independent variables and the dependent variable) is the same across all values of the independent variables."* (Statistics Solutions, 2013).
    The macro written in SPSS syntax by Ahmad Daryanto is used (Daryanto, 2013).

a. Independent or paired variables
   Example: ITS value of asphalt piece before and ITS value of the same asphalt piece after conditioning. The ITS value is a continuous variable. The groups are based on conditioning (e.g. before = 0, after = 1). The same samples are used in group 0 and group 1. This is an example of paired variables.
   The ITS value of samples without conditioning and the ITS value of other samples with conditioning, is an example of independent variables.

b. Parametric or non-parametric variables (Erik Fransen and Roelant, 2014a)
   - Sample size and distribution
     - $N > 40$: data in each group are normally distributed or central limit theorem can be used → parametric
     - $10 < N \leq 40$:
       - data in each group are normally distributed → parametric
       - distribution is skewed (not normal) → non-parametric
     - $N < 10$ → non-parametric
   - Determination of the population variances in the two groups: Levene's test or boxplot
     - Equal variances assumed → parametric
     - Equal variances not-assumed → non-parametric

Association between continuous and categorical variable

1. Two levels

variables	Independent	Paired
Parametric	Independent sample T-test	Paired sample T-test
Non-parametric	Mann-Witney test	Wilcoxon signed rank test

1.1. Independent samples T-test
Statistically significant difference in mean of continuous variable in the two groups.

1.2. Mann-Witney test (name SPSS: ‘2 independent samples test’)
Statistically significant difference in median of continuous variable in the two groups.

2. More than two levels

See also a. and b. in previous section for determination parametric or non-parametric test.

variables	Test	Post-hoc
Parametric	Anova	Equal variances: Bonferroni, LSD, Tukey Equal variances not assumed: Games-Howel
Non-parametric	Kruskal-Wallis test	

2.1. Anova = (one-way) analysis of variance ~ Independent Samples T-test for equal population variances (parametric) with more than 2 groups).
If the Anova test turns out significant, there are significant differences between the mean of different groups. Post-hoc tests must be used to know which groups differ in mean.
Note: When using SPSS, the test value ‘f’ gives an indication on homo- or heteroscedasticity.

2.2. Kruskal-Wallis test

2.3. Post-hoc tests
Testing difference in means/median of groups two by two. The homogeneity of variances is important to choose a post-hoc test in the parametric Anova test. Contrary to association variables in 2 groups, the parametric test (Anova) is used, even if no equal variances are assumed.

Association between 2 continuous variables

1. Correlation

   https://www.graphpad.com/support/faqid/1141/

   Correlation quantifies the degree to which two variables are related. Correlation does not fit a line through the data points. You simply are computing a correlation coefficient (r) that tells you how much one variable tends to change when the other one does. When r is 0.0, there is no relationship. When r is positive, there is a trend that one variable goes up as the other one goes up. When r is negative, there is a trend that one variable goes up as the other one goes down.

   With correlation, you don't have to think about cause and effect. It doesn't matter which of the two variables you call "X" and which you call "Y". You'll get the same correlation coefficient if you swap the two.
   The decision of which variable you call "X" and which you call "Y" matters in regression, as you'll get a different best-fit line if you swap the two. The line that best predicts Y from X is not the same as the line that predicts X from Y (however both those lines have the same value for R2)

   1.1. Pearson's r correlation
   Used for normally distributed variables with a linear relationship.
   → Sig (2-tailed) = P-value, compare to the level of significance of the study you do, e.g. 0.05 of 0.01 = α; if sig. is greater than the chosen value, correlation is not statistically significant
   → 2-tailed: it is not specified if the correlation is positive or negative

   1.2. Spearman's rho test
   Used for variables that are NOT Normally distributed and/or NOT Linear relationship
   Spearman's rho correlation coefficient (r_s) indicates how much one variable tends to change based on a linear relationship when the other one changes. The coefficient indicates the strength of the correlation.

   → the two tailed significance level p of the correlation is important to determine if the correlation is statistically significant by comparing to the α (bv. α=0.05; the correlation is significant if $p \leq 0.05$).
   → Correlation effect size ESr

   - Independent parameters (%RAP, %O/N): continuous, non-normal distributed
   - Depending parameters (rutting, stiffness and fatigue): continuous, normal distributed

2. Multiple linear regression

   Conditions (model check):
   - There must be a linear relation between the dependent variable and the independent variables. Linearity can be checked by looking at a scatterplot of outcome versus predictor (Erik Fransen and Roelant, 2014b)
   - The data must be homoscedastic. Homoscedasticity of data is tested with the Koenker test, using a macro in SPSS, based on the syntax written by Ahmad Daryanto. If the data are found to be heteroscedastic, the standard error in the linear regression model is adapted to be

heteroscedasticity-consistent by using the SPSS syntax written by Andrew F. Hayes (Hayes and Cai, 2007).

- The data must be normal distributed. Normal distribution of the residuals can be checked with a Q-Q plot or a histogram of the unstandardized residuals, or with the Kolmogorov-Smirnov test. (Eric Fransen and Roelant, 2014; Erik Fransen and Roelant, 2014b)
- The independent variables cannot be collinear. This means that different independent variables cannot be correlated with each other. The collinearity of the statistics are given in the 'coefficients' table in SPSS with the output of the multiple linear regression. If the factor 'tolerance' is higher than 0.20, there is no collinearity.
- There cannot be serial or autocorrelation. This means that within one independent variable, there cannot be a correlation between successive values. This serial correlation is typically seen in time series. Serial correlation can be tested with the Durbin-Watson test in SPSS. If the test result is in the range of 1.5 to 2.5, If a time scale is part of the data, the unstandardized residuals versus the time scale can be used for a scatter plot. If the point are a birds nest, if no pattern is seen, there is no serial correlation in the data.

References

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