Automatic and manual transmissions: comparative study

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Executive Summary

The report explores relationship between transmission type (manual or automatic) and miles per gallon (MPG). The analysis is based on the mtcars dataset. The following questions were addressed in the report: define which type of transmission is better for MPG, and quantify the difference in MPG. The simple linear regression and the multiple regression models with hypothesis testing will be used in the analysis. Both models ultimately confirmed that the cars in this study with manual transmissions had on average significantly higher MPG's than the cars with automatic transmissions. Data visualisation is presented in the Appendix section.

Loading, processing and exloring the data

```
data(mtcars)
head(mtcars, n = 3)
```

```
##                mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4     21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710    22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
```

```
summary(mtcars)
```

```
##       mpg             cyl             disp             hp       
##  Min.   :10.40   Min.   :4.000   Min.   : 71.1   Min.   : 52.0  
##  1st Qu.:15.43   1st Qu.:4.000   1st Qu.:120.8   1st Qu.: 96.5  
##  Median :19.20   Median :6.000   Median :196.3   Median :123.0  
##  Mean   :20.09   Mean   :6.188   Mean   :230.7   Mean   :146.7  
##  3rd Qu.:22.80   3rd Qu.:8.000   3rd Qu.:326.0   3rd Qu.:180.0  
##  Max.   :33.90   Max.   :8.000   Max.   :472.0   Max.   :335.0  
##       drat             wt             qsec             vs        
##  Min.   :2.760   Min.   :1.513   Min.   :14.50   Min.   :0.0000  
##  1st Qu.:3.080   1st Qu.:2.581   1st Qu.:16.89   1st Qu.:0.0000  
##  Median :3.695   Median :3.325   Median :17.71   Median :0.0000  
##  Mean   :3.597   Mean   :3.217   Mean   :17.85   Mean   :0.4375  
##  3rd Qu.:3.920   3rd Qu.:3.610   3rd Qu.:18.90   3rd Qu.:1.0000  
##  Max.   :4.930   Max.   :5.424   Max.   :22.90   Max.   :1.0000  
##        am              gear            carb      
##  Min.   :0.0000   Min.   :3.000   Min.   :1.000  
##  1st Qu.:0.0000   1st Qu.:3.000   1st Qu.:2.000  
##  Median :0.0000   Median :4.000   Median :2.000  
##  Mean   :0.4062   Mean   :3.688   Mean   :2.812  
##  3rd Qu.:1.0000   3rd Qu.:4.000   3rd Qu.:4.000  
##  Max.   :1.0000   Max.   :5.000   Max.   :8.000
```

Analysis

Simple linear regression

```
ModelFit <- lm(mpg ~ am, data = mtcars)
summary(ModelFit)
```

```
##
## Call:
## lm(formula = mpg ~ am, data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.3923 -3.0923 -0.2974  3.2439  9.5077
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   17.147      1.125  15.247 1.13e-15 ***
## am             7.245      1.764   4.106 0.000285 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.902 on 30 degrees of freedom
## Multiple R-squared:  0.3598, Adjusted R-squared:  0.3385
## F-statistic: 16.86 on 1 and 30 DF,  p-value: 0.000285
```

```
summary(ModelFit)$coeff
```

```
##              Estimate Std. Error   t value     Pr(>|t|)
## (Intercept) 17.147368   1.124603 15.247492 1.133983e-15
## am           7.244939   1.764422  4.106127 2.850207e-04
```

The Beta0/intercept coefficient is mean MPG for cars with automatic transmissions; the Beta1/am coefficient is the mean increase in MPG for cars with manual transmissions (am = 1). (Beta0 + beta1) is the mean MPG for cars with manual transmissions. So, the mean difference in MPG is 7.244939.

Thus, the 95% confidence interval for beta1 (mean MPG difference) is following:

```
alpha <- 0.05
n <- length(mtcars$mpg)
pe <- coef(summary(ModelFit))["am", "Estimate"]
se <- coef(summary(ModelFit))["am", "Std. Error"]
t <- qt(1 - alpha/2, n - 2)
pe + c(-1, 1) * (se * t)
```

```
## [1]  3.64151 10.84837
```

Based on the results, we can reject the null hyposthesis in favor of the alternative one: that there is a significant difference in MPG between the two groups at alpha = 0.05.

Multiple regression

The following predictor variables will be included into analysis: wt (weight), qsec (1/4 mile time) and am (transmission type).The following step-by-step approach will be used in the modelling: 1) Start with the predictor whose correlation with mpg is highest (wt) 2) The variables that are highly correlated with wt are to be removed 3) Add the remaining predictor, qsec 4) Finally add am, to see if it is a significant predictor.

```
MultiFit <- lm(mpg ~ wt + qsec + am, data=mtcars)
summary(MultiFit)
```

```
##
## Call:
## lm(formula = mpg ~ wt + qsec + am, data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.4811 -1.5555 -0.7257  1.4110  4.6610
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   9.6178     6.9596   1.382 0.177915
## wt           -3.9165     0.7112  -5.507 6.95e-06 ***
## qsec          1.2259     0.2887   4.247 0.000216 ***
## am            2.9358     1.4109   2.081 0.046716 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.459 on 28 degrees of freedom
## Multiple R-squared:  0.8497, Adjusted R-squared:  0.8336
## F-statistic: 52.75 on 3 and 28 DF,  p-value: 1.21e-11
```

```
coef(summary(MultiFit))
```

```
##              Estimate Std. Error   t value     Pr(>|t|)
## (Intercept)  9.617781  6.9595930  1.381946 1.779152e-01
## wt          -3.916504  0.7112016 -5.506882 6.952711e-06
## qsec         1.225886  0.2886696  4.246676 2.161737e-04
## am           2.935837  1.4109045  2.080819 4.671551e-02
```

So, the mean difference in MPG is 2.935837. Thus, the 95% confidence interval for beta1 (mean MPG difference) is following:

```
alpha <- 0.05
n <- length(mtcars$mpg)
pe <- coef(summary(MultiFit))["am", "Estimate"]
se <- coef(summary(MultiFit))["am", "Std. Error"]
t <- qt(1 - alpha/2, n - 2)
pe + c(-1, 1) * (se * t)
```

```
## [1] 0.05438576 5.81728862
```

Based on the results, we can also reject null hypothesis in favor of the alternative one: that there is a significant difference in MPG between the two groups at alpha = 0.05.

Conclusion

The analysis performed confirmed that there is difference in MPG associated with transmission type.In the simple model, the mean MPG difference is 7.25 MPG, while the multiple regression model delivers the difference of 2.93 MPG.

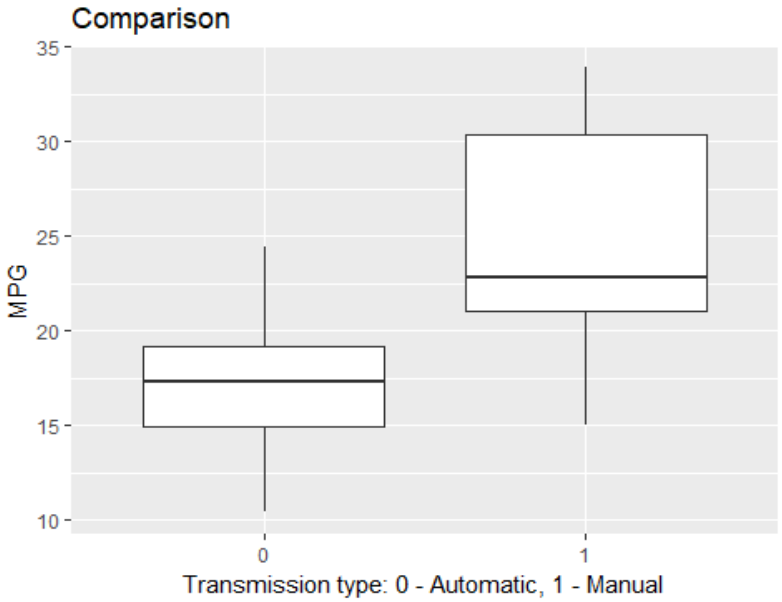
Appendix

This section contains basic exploratory data analysis and all the required visualisations supporting the final conclusion.

1. Exploratory comparison of Automatic and Manual transmission MPG

The presented boxplots based on the observations of our data set demonstrate that on average the cars with manual transmission generally have higher MPG.

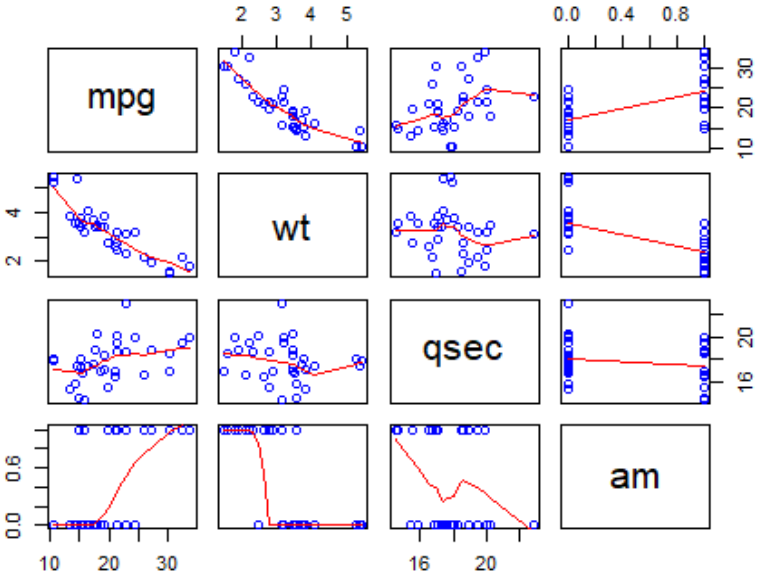
```
library(ggplot2)
ggplot(data = mtcars, aes(x = as.factor(mtcars$am), y = mtcars$mpg)) + geom_boxplot() +
labs(x = "Transmission type: 0 - Automatic, 1 - Manual", y = "MPG") +
ggtitle("Comparison")
```



2. Scatterplots

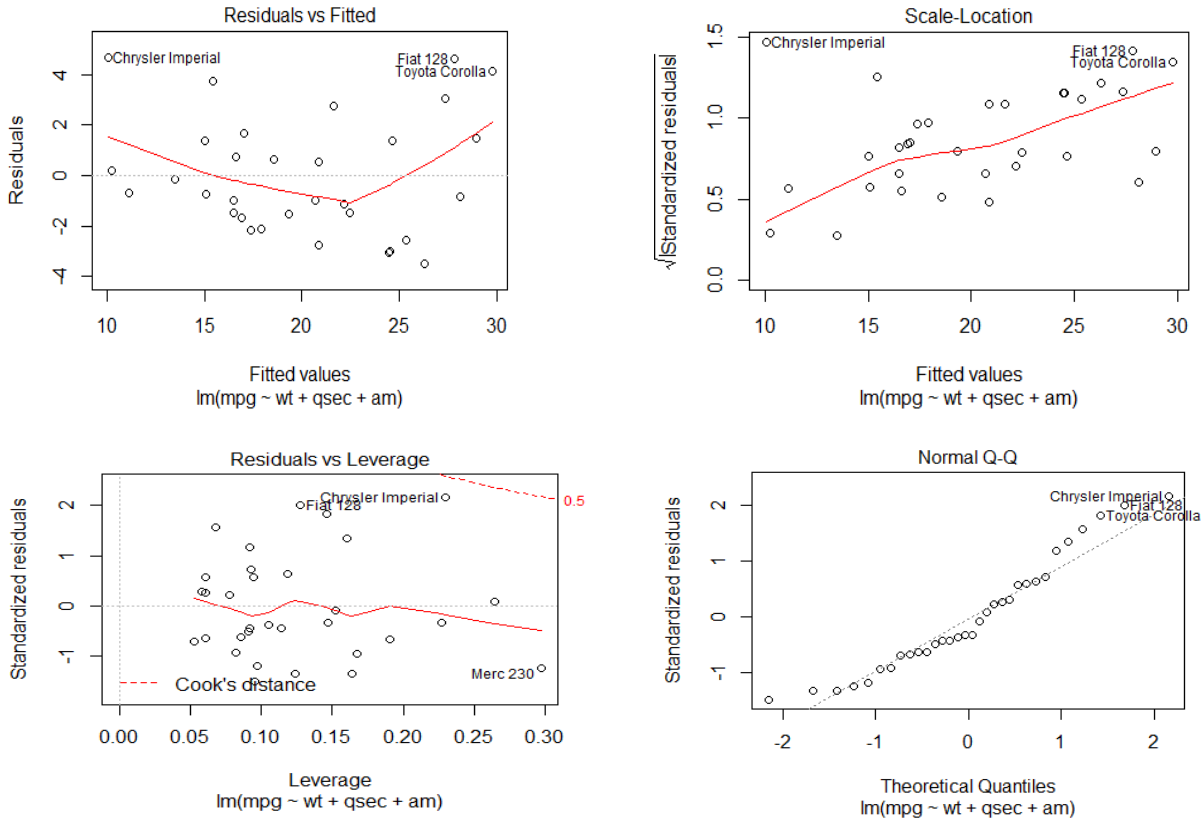
The presented scatterplots visually demonstrate correlations: moderate association can be noticed

```
mtcarsv <- mtcars[, c(1, 6, 7, 9)]
pairs(mtcarsv, panel = panel.smooth, col = "blue")
```



3. Residual diagnostics

```
plot(MultiFit)
```



The following plots lead us to the following conclusion that the residuals and fitted values are independent. The points of the Normal Q-Q plot following closely to the line conclude that the distribution of residuals is normal.The Scale-Location plot random distribution confirms the constant variance assumption. As all the points are within the 0.05, the Residuals vs. Leverage plot demostrates that there are no outliers.