# Transmission Type fuel effiecieny Analysis

*Francois Schonken*

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### Executive Summary

Using the Motor Trends data this report endeavours to find out whether automatic or manual transmission is better for MPG? This report will further more attempt to quantify the MPG difference between automatic and manual transmissions.

In an effort to keep the report consise most R code is not show, please feel free to visit this GitHub Repo for the complete R Markdown code.

### Data Dictionary

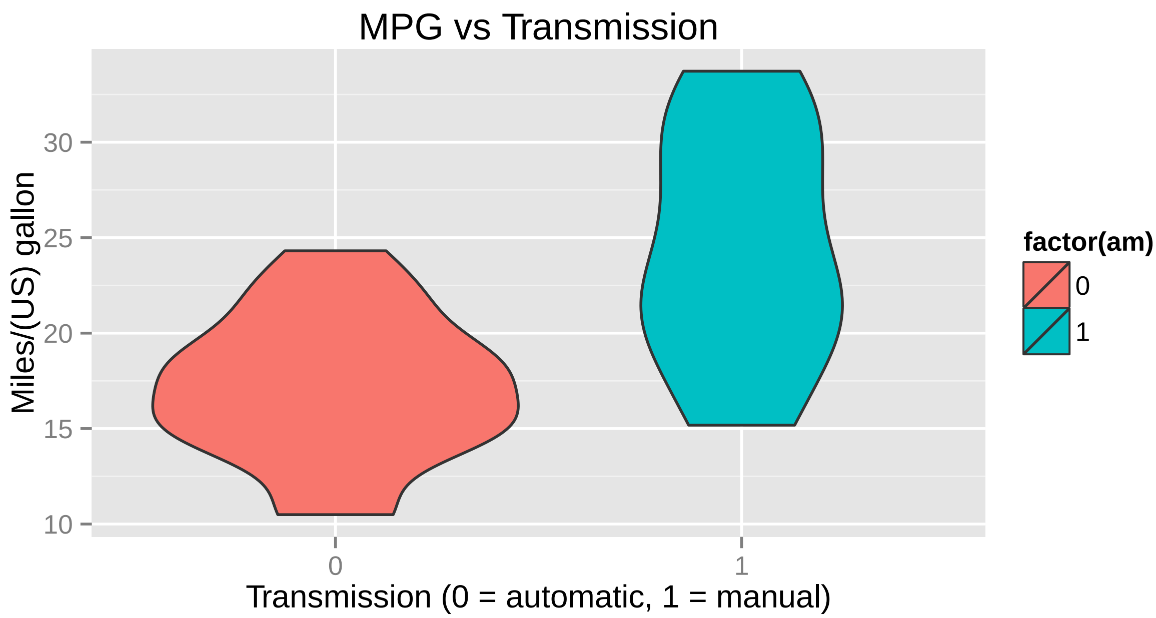
The Motor Trends data consists of 32 observations. For a full description of the data definition please refer to the Motor Trends Data Documentation.

| Field | Definition | Field | Definition |
|---|---|---|---|
| mpg | Miles/(US) gallon | cyl | Number of cylinders |
| disp | Displacement (cu.in.) | hp | Gross horsepower |
| drat | Rear axle ratio | wt | Weight (lb/1000) |
| qsec | 1/4 mile time in seconds | vs | V/S (0 = V-engine, 1 = straight engine) |
| am | Transmission (0 = automatic, 1 = manual) | gear | Number of forward gears |
| carb | Number of carburetors | | |

### Exploring the Motor Trend data

Let's start by getting a feel for the dataset by running `summuary()` on a few of the more interesting fields followed by a violin plot to get an idea of the role transmission plays in MPG.

```
##     cars.mpg       cars.cyl      cars.disp        cars.hp
##  Min.   :10.4   Min.   :4.00   Min.   : 71.1   Min.   : 52.0
##  1st Qu.:15.4   1st Qu.:4.00   1st Qu.:120.8   1st Qu.: 96.5
##  Median :19.2   Median :6.00   Median :196.3   Median :123.0
##  Mean   :20.1   Mean   :6.19   Mean   :230.7   Mean   :146.7
##  3rd Qu.:22.8   3rd Qu.:8.00   3rd Qu.:326.0   3rd Qu.:180.0
##  Max.   :33.9   Max.   :8.00   Max.   :472.0   Max.   :335.0
##    cars.drat       cars.wt       cars.qsec      cars.carb
##  Min.   :2.76   Min.   :1.51   Min.   :14.5   Min.   :1.00
##  1st Qu.:3.08   1st Qu.:2.58   1st Qu.:16.9   1st Qu.:2.00
##  Median :3.69   Median :3.33   Median :17.7   Median :2.00
##  Mean   :3.60   Mean   :3.22   Mean   :17.8   Mean   :2.81
##  3rd Qu.:3.92   3rd Qu.:3.61   3rd Qu.:18.9   3rd Qu.:4.00
##  Max.   :4.93   Max.   :5.42   Max.   :22.9   Max.   :8.00
```




We find that the mean MPG for our Automatic transmisions is 17.1474 and 24.3923 for our Manual transmissions giving us a 7.2449 mean MPG difference with the Automatic transmission being less effiecient. This extremely simple comparison is just the beginning of our journey.

**Regression Modeling**

We iteratively run linear regressions starting with `summary(lm(mpg ~ cyl + disp + hp + drat + wt + qsec + vs + am + gear + carb, data = cars))$coef`, in each subsequent run we remove the entry (field) with the largest `Pr(>|t|)` score until we have only one left, namely `wt`. Next we use the `anova()` function to find the cut-off point in terms regression variables. We find that including the `gear` is not beneficial to our regression model and when it is not specified the Transmission type `am` scrapes in just under 5%.

| Field | Pr(>F) for (mpg ~ wt, qsec, am) | Pr(>F) for (mpg ~ wt, qsec, am, gear) |
|---|---|---|
| wt | NA | NA |
| qsec | $9.2862 \times 10\text{-}4$ | 0.0011 |
| am | 0.0467 | 0.0508 |
| gear | | 0.8897 |

The fields `wt`, `qsec` and `am` feel like the right set of variables to be looking at but a linear coeficient against `qsec` seems odd. One would expect diminishing returns for the fuel consumed as the `qsec` gets smaller (i.e. increased accelaration). In an effort to model these diminishing returns I introduce a new variable named `qsec.2.I` which represents the inverse of the square of `qsec` ($1/qsec^2$). The following two tables detail the coeficients of the respective linear regression models. We see that using the variable `qsec.2.I` as opposed to `qsec` yields a tighter fit to our data as evidenced by every single `Pr(>|t|)` being almost halved.

```
##             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)    9.618     6.9596   1.382 1.779e-01
## wt            -3.917     0.7112  -5.507 6.953e-06
## qsec           1.226     0.2887   4.247 2.162e-04
## am             2.936     1.4109   2.081 4.672e-02
```

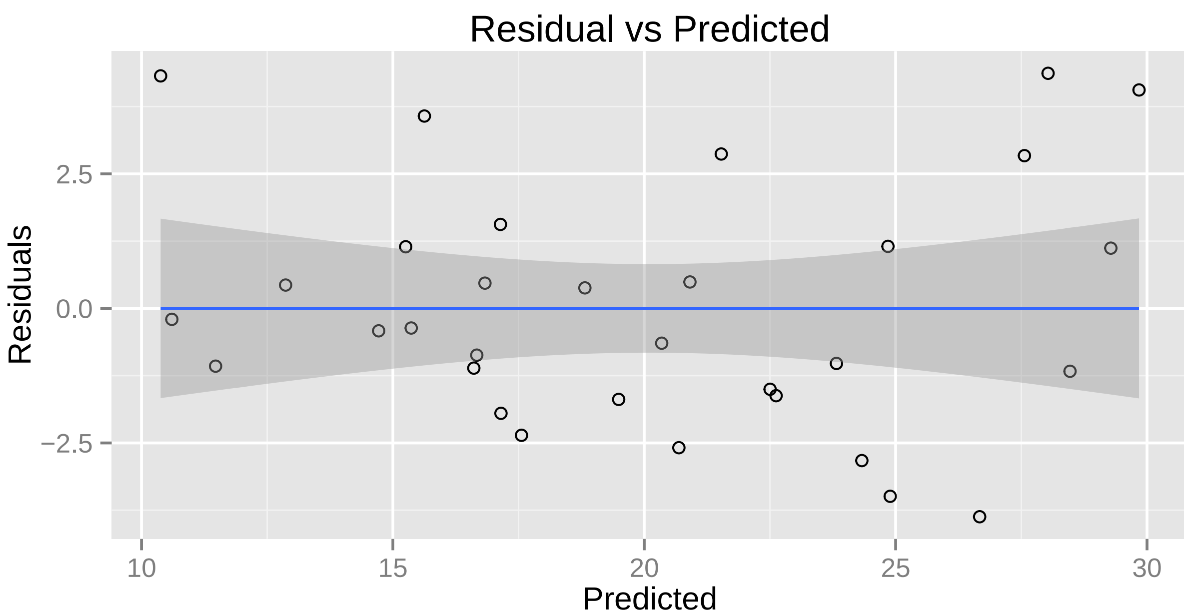
```
##               Estimate Std. Error t value  Pr(>|t|)
## (Intercept)    42.806     2.6020  16.451 6.347e-16
## wt             -3.845     0.6806  -5.649 4.719e-06
## qsec.2.I    -3603.694   767.4360  -4.696 6.370e-05
## am              3.191     1.3612   2.344 2.639e-02
```

Using the `qsec` based regression we arive at a model that reads for each `wt` (1000 lb) increase MPG decreases by -3.9165. For each additional second in `qsec` (1/4 mile time in seconds) MPG increases by 1.2259 and Manual transmissions yield a 2.9358 MPG benefit over Automatic transmissions.

#### Confidence

The $R^2$ for the `qsec` and `qsec.2.I` regression models are 0.8497 and 0.8617 respectively. The $R^2$ for the `qsec.2.I` based regression model is marinally stronger (by 0.0121) and with this model explaining 0.8617 of the variability this is a highly predictive model. We opt to use the `qsec.2.I` based regression model going forward.

#### Residuals




The Residuals vs. Predicted look good for this model and I believe we can in good concience use it.

#### Conclusion

Using our `qsec.2.I` based regression model we find that Manual transmissions yeild better MPG in the amount of 3.1909 MPG.