STAT 526 HW 1

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Library import

```
library("tidyverse")
library("dplyr")
library("car")
library("ggplot2")
library("reshape2")
library("caTools")
library("Rcmdr")
library("MASS")
```

data import

```
data(Cars93, package = "MASS")
Cars93
```

```
##     Manufacturer          Model    Type Min.Price Price Max.Price MPG.city
## 1          Acura        Integra   Small      12.9  15.9      18.8       25
## 2          Acura         Legend Midsize      29.2  33.9      38.7       18
## 3           Audi             90 Compact      25.9  29.1      32.3       20
## 4           Audi            100 Midsize      30.8  37.7      44.6       19
## 5            BMW           535i Midsize      23.7  30.0      36.2       22
## 6          Buick        Century Midsize      14.2  15.7      17.3       22
## 7          Buick        LeSabre   Large      19.9  20.8      21.7       19
## 8          Buick     Roadmaster   Large      22.6  23.7      24.9       16
## 9          Buick        Riviera Midsize      26.3  26.3      26.3       19
## 10      Cadillac        DeVille   Large      33.0  34.7      36.3       16
## 11      Cadillac        Seville Midsize      37.5  40.1      42.7       16
## 12     Chevrolet       Cavalier Compact       8.5  13.4      18.3       25
## 13     Chevrolet        Corsica Compact      11.4  11.4      11.4       25
## 14     Chevrolet         Camaro  Sporty      13.4  15.1      16.8       19
## 15     Chevrolet         Lumina Midsize      13.4  15.9      18.4       21
## 16     Chevrolet     Lumina_APV     Van      14.7  16.3      18.0       18
## 17     Chevrolet          Astro     Van      14.7  16.6      18.6       15
## 18     Chevrolet        Caprice   Large      18.0  18.8      19.6       17
## 19     Chevrolet       Corvette  Sporty      34.6  38.0      41.5       17
## 20      Chrylser       Concorde   Large      18.4  18.4      18.4       20
## 21      Chrysler        LeBaron Compact      14.5  15.8      17.1       23
## 22      Chrysler       Imperial   Large      29.5  29.5      29.5       20
## 23         Dodge           Colt   Small       7.9   9.2      10.6       29
## 24         Dodge         Shadow   Small       8.4  11.3      14.2       23
```

```
## 25         Dodge         Spirit Compact      11.9  13.3      14.7       22
## 26         Dodge        Caravan     Van      13.6  19.0      24.4       17
## 27         Dodge        Dynasty Midsize      14.8  15.6      16.4       21
## 28         Dodge        Stealth  Sporty      18.5  25.8      33.1       18
## 29         Eagle         Summit   Small       7.9  12.2      16.5       29
## 30         Eagle         Vision   Large      17.5  19.3      21.2       20
## 31          Ford        Festiva   Small       6.9   7.4       7.9       31
## 32          Ford         Escort   Small       8.4  10.1      11.9       23
## 33          Ford          Tempo Compact      10.4  11.3      12.2       22
## 34          Ford        Mustang  Sporty      10.8  15.9      21.0       22
## 35          Ford          Probe  Sporty      12.8  14.0      15.2       24
## 36          Ford       Aerostar     Van      14.5  19.9      25.3       15
## 37          Ford         Taurus Midsize      15.6  20.2      24.8       21
## 38          Ford Crown_Victoria   Large      20.1  20.9      21.7       18
## 39           Geo          Metro   Small       6.7   8.4      10.0       46
## 40           Geo          Storm  Sporty      11.5  12.5      13.5       30
## 41         Honda        Prelude  Sporty      17.0  19.8      22.7       24
## 42         Honda          Civic   Small       8.4  12.1      15.8       42
## 43         Honda         Accord Compact      13.8  17.5      21.2       24
## 44       Hyundai          Excel   Small       6.8   8.0       9.2       29
## 45       Hyundai        Elantra   Small       9.0  10.0      11.0       22
## 46       Hyundai         Scoupe  Sporty       9.1  10.0      11.0       26
## 47       Hyundai         Sonata Midsize      12.4  13.9      15.3       20
## 48      Infiniti            Q45 Midsize      45.4  47.9      50.4       17
## 49         Lexus          ES300 Midsize      27.5  28.0      28.4       18
## 50         Lexus          SC300 Midsize      34.7  35.2      35.6       18
## 51       Lincoln    Continental Midsize      33.3  34.3      35.3       17
## 52       Lincoln       Town_Car   Large      34.4  36.1      37.8       18
## 53         Mazda            323   Small       7.4   8.3       9.1       29
## 54         Mazda        Protege   Small      10.9  11.6      12.3       28
## 55         Mazda            626 Compact      14.3  16.5      18.7       26
## 56         Mazda            MPV     Van      16.6  19.1      21.7       18
## 57         Mazda          RX-7  Sporty      32.5  32.5      32.5       17
## 58 Mercedes-Benz          190E Compact      29.0  31.9      34.9       20
## 59 Mercedes-Benz          300E Midsize      43.8  61.9      80.0       19
## 60       Mercury          Capri  Sporty      13.3  14.1      15.0       23
## 61       Mercury         Cougar Midsize      14.9  14.9      14.9       19
## 62    Mitsubishi         Mirage   Small       7.7  10.3      12.9       29
## 63    Mitsubishi       Diamante Midsize      22.4  26.1      29.9       18
## 64        Nissan         Sentra   Small       8.7  11.8      14.9       29
## 65        Nissan         Altima Compact      13.0  15.7      18.3       24
## 66        Nissan          Quest     Van      16.7  19.1      21.5       17
## 67        Nissan         Maxima Midsize      21.0  21.5      22.0       21
## 68    Oldsmobile        Achieva Compact      13.0  13.5      14.0       24
## 69    Oldsmobile  Cutlass_Ciera Midsize      14.2  16.3      18.4       23
## 70    Oldsmobile     Silhouette     Van      19.5  19.5      19.5       18
## 71    Oldsmobile   Eighty-Eight   Large      19.5  20.7      21.9       19
## 72      Plymouth          Laser  Sporty      11.4  14.4      17.4       23
## 73       Pontiac         LeMans   Small       8.2   9.0       9.9       31
## 74       Pontiac        Sunbird Compact       9.4  11.1      12.8       23
## 75       Pontiac       Firebird  Sporty      14.0  17.7      21.4       19
## 76       Pontiac     Grand_Prix Midsize      15.4  18.5      21.6       19
## 77       Pontiac     Bonneville   Large      19.4  24.4      29.4       19
## 78          Saab            900 Compact      20.3  28.7      37.1       20
```

```
## 79        Saturn             SL   Small       9.2  11.1      12.9       28
## 80        Subaru          Justy   Small       7.3   8.4       9.5       33
## 81        Subaru         Loyale   Small      10.5  10.9      11.3       25
## 82        Subaru         Legacy Compact      16.3  19.5      22.7       23
## 83        Suzuki          Swift   Small       7.3   8.6      10.0       39
## 84        Toyota         Tercel   Small       7.8   9.8      11.8       32
## 85        Toyota         Celica  Sporty      14.2  18.4      22.6       25
## 86        Toyota          Camry Midsize      15.2  18.2      21.2       22
## 87        Toyota         Previa     Van      18.9  22.7      26.6       18
## 88    Volkswagen            Fox   Small       8.7   9.1       9.5       25
## 89    Volkswagen        Eurovan     Van      16.6  19.7      22.7       17
## 90    Volkswagen         Passat Compact      17.6  20.0      22.4       21
## 91    Volkswagen        Corrado  Sporty      22.9  23.3      23.7       18
## 92         Volvo            240 Compact      21.8  22.7      23.5       21
## 93         Volvo            850 Midsize      24.8  26.7      28.5       20
##    MPG.highway            AirBags DriveTrain Cylinders EngineSize Horsepower
## 1           31               None      Front         4        1.8        140
## 2           25 Driver & Passenger      Front         6        3.2        200
## 3           26        Driver only      Front         6        2.8        172
## 4           26 Driver & Passenger      Front         6        2.8        172
## 5           30        Driver only       Rear         4        3.5        208
## 6           31        Driver only      Front         4        2.2        110
## 7           28        Driver only      Front         6        3.8        170
## 8           25        Driver only       Rear         6        5.7        180
## 9           27        Driver only      Front         6        3.8        170
## 10          25        Driver only      Front         8        4.9        200
## 11          25 Driver & Passenger      Front         8        4.6        295
## 12          36               None      Front         4        2.2        110
## 13          34        Driver only      Front         4        2.2        110
## 14          28 Driver & Passenger       Rear         6        3.4        160
## 15          29               None      Front         4        2.2        110
## 16          23               None      Front         6        3.8        170
## 17          20               None        4WD         6        4.3        165
## 18          26        Driver only       Rear         8        5.0        170
## 19          25        Driver only       Rear         8        5.7        300
## 20          28 Driver & Passenger      Front         6        3.3        153
## 21          28 Driver & Passenger      Front         4        3.0        141
## 22          26        Driver only      Front         6        3.3        147
## 23          33               None      Front         4        1.5         92
## 24          29        Driver only      Front         4        2.2         93
## 25          27        Driver only      Front         4        2.5        100
## 26          21        Driver only        4WD         6        3.0        142
## 27          27        Driver only      Front         4        2.5        100
## 28          24        Driver only        4WD         6        3.0        300
## 29          33               None      Front         4        1.5         92
## 30          28 Driver & Passenger      Front         6        3.5        214
## 31          33               None      Front         4        1.3         63
## 32          30               None      Front         4        1.8        127
## 33          27               None      Front         4        2.3         96
## 34          29        Driver only       Rear         4        2.3        105
## 35          30        Driver only      Front         4        2.0        115
## 36          20        Driver only        4WD         6        3.0        145
## 37          30        Driver only      Front         6        3.0        140
## 38          26        Driver only       Rear         8        4.6        190
```

```
## 39          50               None      Front         3        1.0         55
## 40          36        Driver only      Front         4        1.6         90
## 41          31 Driver & Passenger      Front         4        2.3        160
## 42          46        Driver only      Front         4        1.5        102
## 43          31 Driver & Passenger      Front         4        2.2        140
## 44          33               None      Front         4        1.5         81
## 45          29               None      Front         4        1.8        124
## 46          34               None      Front         4        1.5         92
## 47          27               None      Front         4        2.0        128
## 48          22        Driver only       Rear         8        4.5        278
## 49          24        Driver only      Front         6        3.0        185
## 50          23 Driver & Passenger       Rear         6        3.0        225
## 51          26 Driver & Passenger      Front         6        3.8        160
## 52          26 Driver & Passenger       Rear         8        4.6        210
## 53          37               None      Front         4        1.6         82
## 54          36               None      Front         4        1.8        103
## 55          34        Driver only      Front         4        2.5        164
## 56          24               None        4WD         6        3.0        155
## 57          25        Driver only       Rear    rotary        1.3        255
## 58          29        Driver only       Rear         4        2.3        130
## 59          25 Driver & Passenger       Rear         6        3.2        217
## 60          26        Driver only      Front         4        1.6        100
## 61          26               None       Rear         6        3.8        140
## 62          33               None      Front         4        1.5         92
## 63          24        Driver only      Front         6        3.0        202
## 64          33        Driver only      Front         4        1.6        110
## 65          30        Driver only      Front         4        2.4        150
## 66          23               None      Front         6        3.0        151
## 67          26        Driver only      Front         6        3.0        160
## 68          31               None      Front         4        2.3        155
## 69          31        Driver only      Front         4        2.2        110
## 70          23               None      Front         6        3.8        170
## 71          28        Driver only      Front         6        3.8        170
## 72          30               None        4WD         4        1.8         92
## 73          41               None      Front         4        1.6         74
## 74          31               None      Front         4        2.0        110
## 75          28 Driver & Passenger       Rear         6        3.4        160
## 76          27               None      Front         6        3.4        200
## 77          28 Driver & Passenger      Front         6        3.8        170
## 78          26        Driver only      Front         4        2.1        140
## 79          38        Driver only      Front         4        1.9         85
## 80          37               None        4WD         3        1.2         73
## 81          30               None        4WD         4        1.8         90
## 82          30        Driver only        4WD         4        2.2        130
## 83          43               None      Front         3        1.3         70
## 84          37        Driver only      Front         4        1.5         82
## 85          32        Driver only      Front         4        2.2        135
## 86          29        Driver only      Front         4        2.2        130
## 87          22        Driver only        4WD         4        2.4        138
## 88          33               None      Front         4        1.8         81
## 89          21               None      Front         5        2.5        109
## 90          30               None      Front         4        2.0        134
## 91          25               None      Front         6        2.8        178
## 92          28        Driver only       Rear         4        2.3        114
```

```
## 93          28 Driver & Passenger      Front         5       2.4       168
##     RPM Rev.per.mile Man.trans.avail Fuel.tank.capacity Passengers Length
## 1  6300         2890             Yes               13.2          5    177
## 2  5500         2335             Yes               18.0          5    195
## 3  5500         2280             Yes               16.9          5    180
## 4  5500         2535             Yes               21.1          6    193
## 5  5700         2545             Yes               21.1          4    186
## 6  5200         2565              No               16.4          6    189
## 7  4800         1570              No               18.0          6    200
## 8  4000         1320              No               23.0          6    216
## 9  4800         1690              No               18.8          5    198
## 10 4100         1510              No               18.0          6    206
## 11 6000         1985              No               20.0          5    204
## 12 5200         2380             Yes               15.2          5    182
## 13 5200         2665             Yes               15.6          5    184
## 14 4600         1805             Yes               15.5          4    193
## 15 5200         2595              No               16.5          6    198
## 16 4800         1690              No               20.0          7    178
## 17 4000         1790              No               27.0          8    194
## 18 4200         1350              No               23.0          6    214
## 19 5000         1450             Yes               20.0          2    179
## 20 5300         1990              No               18.0          6    203
## 21 5000         2090              No               16.0          6    183
## 22 4800         1785              No               16.0          6    203
## 23 6000         3285             Yes               13.2          5    174
## 24 4800         2595             Yes               14.0          5    172
## 25 4800         2535             Yes               16.0          6    181
## 26 5000         1970              No               20.0          7    175
## 27 4800         2465              No               16.0          6    192
## 28 6000         2120             Yes               19.8          4    180
## 29 6000         2505             Yes               13.2          5    174
## 30 5800         1980              No               18.0          6    202
## 31 5000         3150             Yes               10.0          4    141
## 32 6500         2410             Yes               13.2          5    171
## 33 4200         2805             Yes               15.9          5    177
## 34 4600         2285             Yes               15.4          4    180
## 35 5500         2340             Yes               15.5          4    179
## 36 4800         2080             Yes               21.0          7    176
## 37 4800         1885              No               16.0          5    192
## 38 4200         1415              No               20.0          6    212
## 39 5700         3755             Yes               10.6          4    151
## 40 5400         3250             Yes               12.4          4    164
## 41 5800         2855             Yes               15.9          4    175
## 42 5900         2650             Yes               11.9          4    173
## 43 5600         2610             Yes               17.0          4    185
## 44 5500         2710             Yes               11.9          5    168
## 45 6000         2745             Yes               13.7          5    172
## 46 5550         2540             Yes               11.9          4    166
## 47 6000         2335             Yes               17.2          5    184
## 48 6000         1955              No               22.5          5    200
## 49 5200         2325             Yes               18.5          5    188
## 50 6000         2510             Yes               20.6          4    191
## 51 4400         1835              No               18.4          6    205
## 52 4600         1840              No               20.0          6    219
```

```
## 53 5000         2370            Yes               13.2          4    164
## 54 5500         2220            Yes               14.5          5    172
## 55 5600         2505            Yes               15.5          5    184
## 56 5000         2240             No               19.6          7    190
## 57 6500         2325            Yes               20.0          2    169
## 58 5100         2425            Yes               14.5          5    175
## 59 5500         2220             No               18.5          5    187
## 60 5750         2475            Yes               11.1          4    166
## 61 3800         1730             No               18.0          5    199
## 62 6000         2505            Yes               13.2          5    172
## 63 6000         2210             No               19.0          5    190
## 64 6000         2435            Yes               13.2          5    170
## 65 5600         2130            Yes               15.9          5    181
## 66 4800         2065             No               20.0          7    190
## 67 5200         2045             No               18.5          5    188
## 68 6000         2380             No               15.2          5    188
## 69 5200         2565             No               16.5          5    190
## 70 4800         1690             No               20.0          7    194
## 71 4800         1570             No               18.0          6    201
## 72 5000         2360            Yes               15.9          4    173
## 73 5600         3130            Yes               13.2          4    177
## 74 5200         2665            Yes               15.2          5    181
## 75 4600         1805            Yes               15.5          4    196
## 76 5000         1890            Yes               16.5          5    195
## 77 4800         1565             No               18.0          6    177
## 78 6000         2910            Yes               18.0          5    184
## 79 5000         2145            Yes               12.8          5    176
## 80 5600         2875            Yes                9.2          4    146
## 81 5200         3375            Yes               15.9          5    175
## 82 5600         2330            Yes               15.9          5    179
## 83 6000         3360            Yes               10.6          4    161
## 84 5200         3505            Yes               11.9          5    162
## 85 5400         2405            Yes               15.9          4    174
## 86 5400         2340            Yes               18.5          5    188
## 87 5000         2515            Yes               19.8          7    187
## 88 5500         2550            Yes               12.4          4    163
## 89 4500         2915            Yes               21.1          7    187
## 90 5800         2685            Yes               18.5          5    180
## 91 5800         2385            Yes               18.5          4    159
## 92 5400         2215            Yes               15.8          5    190
## 93 6200         2310            Yes               19.3          5    184
##    Wheelbase Width Turn.circle Rear.seat.room Luggage.room Weight  Origin
## 1        102    68          37           26.5           11   2705 non-USA
## 2        115    71          38           30.0           15   3560 non-USA
## 3        102    67          37           28.0           14   3375 non-USA
## 4        106    70          37           31.0           17   3405 non-USA
## 5        109    69          39           27.0           13   3640 non-USA
## 6        105    69          41           28.0           16   2880     USA
## 7        111    74          42           30.5           17   3470     USA
## 8        116    78          45           30.5           21   4105     USA
## 9        108    73          41           26.5           14   3495     USA
## 10       114    73          43           35.0           18   3620     USA
## 11       111    74          44           31.0           14   3935     USA
## 12       101    66          38           25.0           13   2490     USA
```

```
## 13      103    68          39          26.0          14   2785     USA
## 14      101    74          43          25.0          13   3240     USA
## 15      108    71          40          28.5          16   3195     USA
## 16      110    74          44          30.5          NA   3715     USA
## 17      111    78          42          33.5          NA   4025     USA
## 18      116    77          42          29.5          20   3910     USA
## 19       96    74          43            NA          NA   3380     USA
## 20      113    74          40          31.0          15   3515     USA
## 21      104    68          41          30.5          14   3085     USA
## 22      110    69          44          36.0          17   3570     USA
## 23       98    66          32          26.5          11   2270     USA
## 24       97    67          38          26.5          13   2670     USA
## 25      104    68          39          30.5          14   2970     USA
## 26      112    72          42          26.5          NA   3705     USA
## 27      105    69          42          30.5          16   3080     USA
## 28       97    72          40          20.0          11   3805     USA
## 29       98    66          36          26.5          11   2295     USA
## 30      113    74          40          30.0          15   3490     USA
## 31       90    63          33          26.0          12   1845     USA
## 32       98    67          36          28.0          12   2530     USA
## 33      100    68          39          27.5          13   2690     USA
## 34      101    68          40          24.0          12   2850     USA
## 35      103    70          38          23.0          18   2710     USA
## 36      119    72          45          30.0          NA   3735     USA
## 37      106    71          40          27.5          18   3325     USA
## 38      114    78          43          30.0          21   3950     USA
## 39       93    63          34          27.5          10   1695 non-USA
## 40       97    67          37          24.5          11   2475 non-USA
## 41      100    70          39          23.5           8   2865 non-USA
## 42      103    67          36          28.0          12   2350 non-USA
## 43      107    67          41          28.0          14   3040 non-USA
## 44       94    63          35          26.0          11   2345 non-USA
## 45       98    66          36          28.0          12   2620 non-USA
## 46       94    64          34          23.5           9   2285 non-USA
## 47      104    69          41          31.0          14   2885 non-USA
## 48      113    72          42          29.0          15   4000 non-USA
## 49      103    70          40          27.5          14   3510 non-USA
## 50      106    71          39          25.0           9   3515 non-USA
## 51      109    73          42          30.0          19   3695     USA
## 52      117    77          45          31.5          22   4055     USA
## 53       97    66          34          27.0          16   2325 non-USA
## 54       98    66          36          26.5          13   2440 non-USA
## 55      103    69          40          29.5          14   2970 non-USA
## 56      110    72          39          27.5          NA   3735 non-USA
## 57       96    69          37            NA          NA   2895 non-USA
## 58      105    67          34          26.0          12   2920 non-USA
## 59      110    69          37          27.0          15   3525 non-USA
## 60       95    65          36          19.0           6   2450     USA
## 61      113    73          38          28.0          15   3610     USA
## 62       98    67          36          26.0          11   2295 non-USA
## 63      107    70          43          27.5          14   3730 non-USA
## 64       96    66          33          26.0          12   2545 non-USA
## 65      103    67          40          28.5          14   3050 non-USA
## 66      112    74          41          27.0          NA   4100 non-USA
```

```
## 67       104    69          41          28.5          14   3200 non-USA
## 68       103    67          39          28.0          14   2910     USA
## 69       105    70          42          28.0          16   2890     USA
## 70       110    74          44          30.5          NA   3715     USA
## 71       111    74          42          31.5          17   3470     USA
## 72        97    67          39          24.5           8   2640     USA
## 73        99    66          35          25.5          17   2350     USA
## 74       101    66          39          25.0          13   2575     USA
## 75       101    75          43          25.0          13   3240     USA
## 76       108    72          41          28.5          16   3450     USA
## 77       111    74          43          30.5          18   3495     USA
## 78        99    67          37          26.5          14   2775 non-USA
## 79       102    68          40          26.5          12   2495     USA
## 80        90    60          32          23.5          10   2045 non-USA
## 81        97    65          35          27.5          15   2490 non-USA
## 82       102    67          37          27.0          14   3085 non-USA
## 83        93    63          34          27.5          10   1965 non-USA
## 84        94    65          36          24.0          11   2055 non-USA
## 85        99    69          39          23.0          13   2950 non-USA
## 86       103    70          38          28.5          15   3030 non-USA
## 87       113    71          41          35.0          NA   3785 non-USA
## 88        93    63          34          26.0          10   2240 non-USA
## 89       115    72          38          34.0          NA   3960 non-USA
## 90       103    67          35          31.5          14   2985 non-USA
## 91        97    66          36          26.0          15   2810 non-USA
## 92       104    67          37          29.5          14   2985 non-USA
## 93       105    69          38          30.0          15   3245 non-USA
##                        Make
## 1              Acura Integra
## 2               Acura Legend
## 3                    Audi 90
## 4                   Audi 100
## 5                   BMW 535i
## 6              Buick Century
## 7              Buick LeSabre
## 8           Buick Roadmaster
## 9              Buick Riviera
## 10          Cadillac DeVille
## 11          Cadillac Seville
## 12        Chevrolet Cavalier
## 13         Chevrolet Corsica
## 14          Chevrolet Camaro
## 15          Chevrolet Lumina
## 16     Chevrolet Lumina_APV
## 17           Chevrolet Astro
## 18         Chevrolet Caprice
## 19        Chevrolet Corvette
## 20         Chrylser Concorde
## 21          Chrysler LeBaron
## 22         Chrysler Imperial
## 23                Dodge Colt
## 24              Dodge Shadow
## 25              Dodge Spirit
## 26             Dodge Caravan
```

```
## 27            Dodge Dynasty
## 28            Dodge Stealth
## 29             Eagle Summit
## 30             Eagle Vision
## 31             Ford Festiva
## 32              Ford Escort
## 33                Ford Tempo
## 34             Ford Mustang
## 35                Ford Probe
## 36            Ford Aerostar
## 37              Ford Taurus
## 38      Ford Crown_Victoria
## 39                Geo Metro
## 40                Geo Storm
## 41            Honda Prelude
## 42              Honda Civic
## 43             Honda Accord
## 44            Hyundai Excel
## 45          Hyundai Elantra
## 46           Hyundai Scoupe
## 47           Hyundai Sonata
## 48             Infiniti Q45
## 49              Lexus ES300
## 50              Lexus SC300
## 51      Lincoln Continental
## 52         Lincoln Town_Car
## 53                Mazda 323
## 54            Mazda Protege
## 55                Mazda 626
## 56                Mazda MPV
## 57               Mazda RX-7
## 58       Mercedes-Benz 190E
## 59       Mercedes-Benz 300E
## 60            Mercury Capri
## 61           Mercury Cougar
## 62         Mitsubishi Mirage
## 63      Mitsubishi Diamante
## 64            Nissan Sentra
## 65            Nissan Altima
## 66             Nissan Quest
## 67            Nissan Maxima
## 68       Oldsmobile Achieva
## 69 Oldsmobile Cutlass_Ciera
## 70    Oldsmobile Silhouette
## 71  Oldsmobile Eighty-Eight
## 72           Plymouth Laser
## 73           Pontiac LeMans
## 74          Pontiac Sunbird
## 75         Pontiac Firebird
## 76       Pontiac Grand_Prix
## 77       Pontiac Bonneville
## 78                 Saab 900
## 79                Saturn SL
## 80             Subaru Justy
```

```
## 81            Subaru Loyale
## 82            Subaru Legacy
## 83             Suzuki Swift
## 84            Toyota Tercel
## 85            Toyota Celica
## 86             Toyota Camry
## 87            Toyota Previa
## 88           Volkswagen Fox
## 89       Volkswagen Eurovan
## 90        Volkswagen Passat
## 91       Volkswagen Corrado
## 92                Volvo 240
## 93                Volvo 850
```

data display

```
View(Cars93)
# number of rows
nrow(Cars93)
```

```
## [1] 93
```

```
# data type of each column
str(Cars93)
```

```
## 'data.frame':    93 obs. of  27 variables:
##  $ Manufacturer      : Factor w/ 32 levels "Acura","Audi",..: 1 1 2 2 3 4 4 4 4 5 ...
##  $ Model             : Factor w/ 93 levels "100","190E","240",..: 49 56 9 1 6 24 54 74 73 35 ...
##  $ Type              : Factor w/ 6 levels "Compact","Large",..: 4 3 1 3 3 3 2 2 3 2 ...
##  $ Min.Price         : num  12.9 29.2 25.9 30.8 23.7 14.2 19.9 22.6 26.3 33 ...
##  $ Price             : num  15.9 33.9 29.1 37.7 30 15.7 20.8 23.7 26.3 34.7 ...
##  $ Max.Price         : num  18.8 38.7 32.3 44.6 36.2 17.3 21.7 24.9 26.3 36.3 ...
##  $ MPG.city          : int  25 18 20 19 22 22 19 16 19 16 ...
##  $ MPG.highway       : int  31 25 26 26 30 31 28 25 27 25 ...
##  $ AirBags           : Factor w/ 3 levels "Driver & Passenger",..: 3 1 2 1 2 2 2 2 2 2 ...
##  $ DriveTrain        : Factor w/ 3 levels "4WD","Front",..: 2 2 2 2 3 2 2 3 2 2 ...
##  $ Cylinders         : Factor w/ 6 levels "3","4","5","6",..: 2 4 4 4 2 2 4 4 4 5 ...
##  $ EngineSize        : num  1.8 3.2 2.8 2.8 3.5 2.2 3.8 5.7 3.8 4.9 ...
##  $ Horsepower        : int  140 200 172 172 208 110 170 180 170 200 ...
##  $ RPM               : int  6300 5500 5500 5500 5700 5200 4800 4000 4800 4100 ...
##  $ Rev.per.mile      : int  2890 2335 2280 2535 2545 2565 1570 1320 1690 1510 ...
##  $ Man.trans.avail   : Factor w/ 2 levels "No","Yes": 2 2 2 2 2 1 1 1 1 1 ...
##  $ Fuel.tank.capacity: num  13.2 18 16.9 21.1 21.1 16.4 18 23 18.8 18 ...
##  $ Passengers        : int  5 5 5 6 4 6 6 6 5 6 ...
##  $ Length            : int  177 195 180 193 186 189 200 216 198 206 ...
##  $ Wheelbase         : int  102 115 102 106 109 105 111 116 108 114 ...
##  $ Width             : int  68 71 67 70 69 69 74 78 73 73 ...
##  $ Turn.circle       : int  37 38 37 37 39 41 42 45 41 43 ...
##  $ Rear.seat.room    : num  26.5 30 28 31 27 28 30.5 30.5 26.5 35 ...
##  $ Luggage.room      : int  11 15 14 17 13 16 17 21 14 18 ...
##  $ Weight            : int  2705 3560 3375 3405 3640 2880 3470 4105 3495 3620 ...
##  $ Origin            : Factor w/ 2 levels "USA","non-USA": 2 2 2 2 2 1 1 1 1 1 ...
##  $ Make              : Factor w/ 93 levels "Acura Integra",..: 1 2 4 3 5 6 7 9 8 10 ...
```

```r
# if there is null values in the dataset
# is.na(Cars93)
# name of the columns in the dataset
names(Cars93)
```

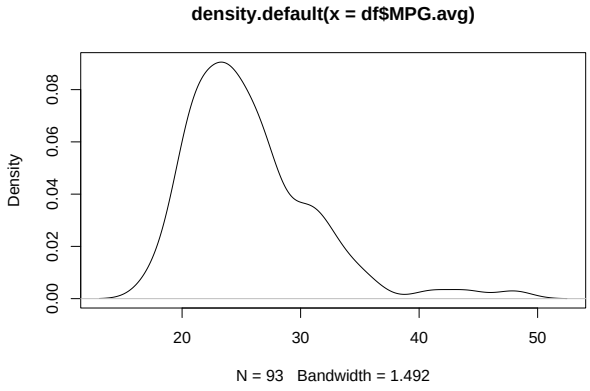
```
##  [1] "Manufacturer"       "Model"              "Type"
##  [4] "Min.Price"          "Price"              "Max.Price"
##  [7] "MPG.city"           "MPG.highway"        "AirBags"
## [10] "DriveTrain"         "Cylinders"          "EngineSize"
## [13] "Horsepower"         "RPM"                "Rev.per.mile"
## [16] "Man.trans.avail"    "Fuel.tank.capacity" "Passengers"
## [19] "Length"             "Wheelbase"          "Width"
## [22] "Turn.circle"        "Rear.seat.room"     "Luggage.room"
## [25] "Weight"             "Origin"             "Make"
```

create the response variable "MPG.avg" by averaging "MPG.city" and "MPG.highway"

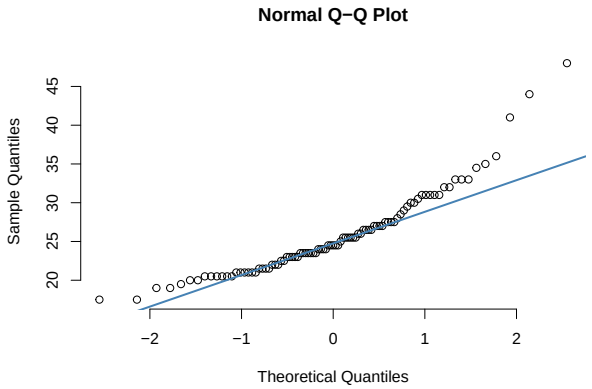
```r
df <- Cars93 %>%
        mutate(MPG.avg = (Cars93$MPG.highway + Cars93$MPG.city) / 2)
```

check the distribution of response (histogram, qq-plot) → box-cox

```r
plot(density(df$MPG.avg))
```




```r
qqnorm(df$MPG.avg, pch = 1, frame = FALSE)
qqline(df$MPG.avg, col = "steelblue", lwd = 2)
```



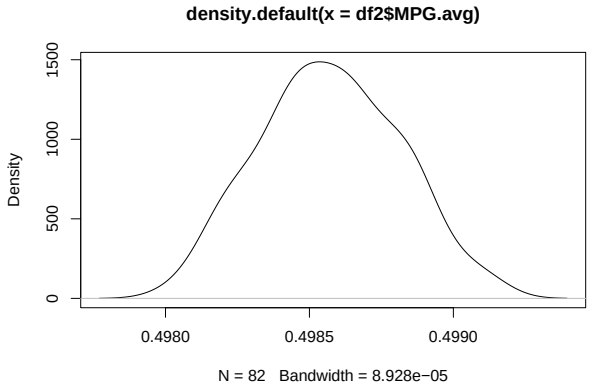
box-cox

```
## there is no 0 in MPG.avg
min(df$MPG.avg); max(df$MPG.avg)
```

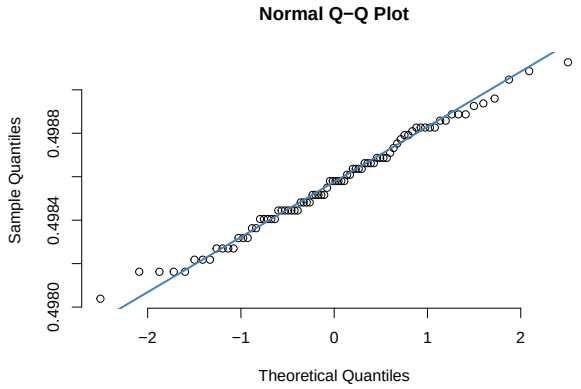
```
## [1] 17.5
```

```
## [1] 48
```

```
df2 <- df %>%
        na.omit() %>%
        mutate(Cylinders = as.numeric(.$Cylinders)) %>%
        subset(select = -c(MPG.city, MPG.highway, Min.Price, Max.Price, Manufacturer, Model, Make))

# boxcox
p1 <- powerTransform(df2$MPG.avg)
df2$MPG.avg <- bcPower(df2$MPG.avg, p1$lambda)

# ggplot(data = df2, aes(x = (MPG.avg^lambda -1)/lambda)) + geom_histogram(fill = "blue", bins = 15)

# plot again
plot(density(df2$MPG.avg))
```

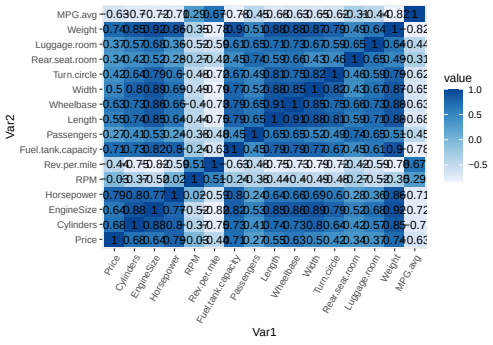


```
qqnorm(df2$MPG.avg, pch = 1, frame = FALSE)
qqline(df2$MPG.avg, col = "steelblue", lwd = 2)
```



check the Pairwise Pearson Correlations From the Person Correlation matrix, there appears to be a significant amount of correlated relations between the predictor variables. It will thus be necessary to ensure that multicollinearity can be a concern later in my model.

```
df %>%
    na.omit() %>%
    mutate(Cylinders = as.numeric(.$Cylinders)) %>%
    subset(select = -c(MPG.city, MPG.highway, Min.Price, Max.Price, Manufacturer, Model, Make)) %>%
    # remove the non-numerical variables
    # https://bit.ly/3ZXRAMH
    .[, colnames(.)[!grepl("factor|logical|character", sapply(., class))]] %>%
    cor(., ) %>%
    round(., 2) %>%
    melt() %>%
    ggplot(., aes(x = Var1, y = Var2, fill = value)) +
        geom_tile() +
        scale_fill_distiller(direction = +1) +
        geom_text(aes(Var2, Var1, label = value), color = "black", size = 4) +
        theme(axis.text.x = element_text(angle = 60, hjust = 1))
```



Linear Models to grasp the trend

```
# simple linear model
# I use my intuition for now. Simply, I suppose the size of a car and engine and fuel tank are correlat
```

```r
simple <- lm(MPG.avg ~ Weight + Width + Length +
                    Fuel.tank.capacity + Horsepower,
                    data = df2
                    )
# Only weight is significant
summary(simple)
```

```
##
## Call:
## lm(formula = MPG.avg ~ Weight + Width + Length + Fuel.tank.capacity +
##     Horsepower, data = df2)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.840e-04 -7.125e-05  5.640e-06  6.970e-05  3.739e-04
##
## Coefficients:
##                       Estimate Std. Error  t value Pr(>|t|)
## (Intercept)          4.991e-01  3.568e-04 1398.637  < 2e-16 ***
## Weight              -3.337e-07  8.790e-08   -3.797 0.000293 ***
## Width                7.138e-06  7.763e-06    0.920 0.360736
## Length               2.018e-06  2.150e-06    0.938 0.351016
## Fuel.tank.capacity -1.808e-05  9.370e-06   -1.930 0.057356 .
## Horsepower         -5.212e-07  5.308e-07   -0.982 0.329205
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0001096 on 76 degrees of freedom
## Multiple R-squared:  0.8035, Adjusted R-squared:  0.7906
## F-statistic: 62.17 on 5 and 76 DF,  p-value: < 2.2e-16
```

```r
# Regression Diagnostics
simple.infl <- influence.measures(simple)
# print(simple.infl)

# check the vif. In fact, Weight has the highest vif (16.69)
vif(simple)
```

```
##             Weight              Width             Length Fuel.tank.capacity
##          16.692146           5.546023           7.275453           5.366428
##         Horsepower
##           4.953250
```

```r
# get rid of the weight parameter
simple_v2 <- lm(MPG.avg ~ Width + Length +
                    Fuel.tank.capacity + Horsepower,
                    data = df2
                    )
# Indeed, Fuel.tank.capacity and Horsepower became significant. Yet, this model is not preferrable in t
summary(simple_v2)
```

```
##
```

```
## Call:
## lm(formula = MPG.avg ~ Width + Length + Fuel.tank.capacity +
##     Horsepower, data = df2)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -3.329e-04 -8.941e-05  1.314e-05  7.026e-05  3.344e-04
##
## Coefficients:
##                       Estimate Std. Error  t value Pr(>|t|)
## (Intercept)          4.998e-01  3.323e-04 1503.792  < 2e-16 ***
## Width               -3.313e-07  8.137e-06   -0.041 0.967632
## Length              -2.040e-06  2.022e-06   -1.009 0.316263
## Fuel.tank.capacity -3.361e-05  9.135e-06   -3.680 0.000431 ***
## Horsepower          -1.820e-06  4.398e-07   -4.137 8.89e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0001187 on 77 degrees of freedom
## Multiple R-squared:  0.7663, Adjusted R-squared:  0.7541
## F-statistic: 63.11 on 4 and 77 DF,  p-value: < 2.2e-16
```

```
# check the vif. There are none high vif variables
vif(simple_v2)
```

```
##              Width             Length Fuel.tank.capacity         Horsepower
##           5.189839           5.478482           4.343808           2.896575
```

stepwise with AIC and BIC

```
# use stepwise methods based on AIC and BIC
m1 <- lm(data = df2, MPG.avg ~ .)
M1_BIC <- stepwise(m1, direction = "forward/backward", criterion = "BIC")
```

```
##
## Direction:  forward/backward
## Criterion:  BIC
##
## Start:  AIC=-1363.87
## MPG.avg ~ 1
##
##                       Df  Sum of Sq        RSS     AIC
## + Weight               1 3.5969e-06 1.0487e-06 -1481.5
## + Fuel.tank.capacity   1 3.2658e-06 1.3799e-06 -1459.0
## + Cylinders            1 3.1450e-06 1.5006e-06 -1452.1
## + EngineSize           1 3.1017e-06 1.5439e-06 -1449.8
## + Horsepower           1 3.0577e-06 1.5879e-06 -1447.5
## + Price                1 2.6052e-06 2.0404e-06 -1426.9
## + Type                 4 2.7563e-06 1.8893e-06 -1420.0
## + Length               1 2.4066e-06 2.2390e-06 -1419.3
## + Width                1 2.3643e-06 2.2814e-06 -1417.8
## + Wheelbase            1 2.2472e-06 2.3985e-06 -1413.7
## + Rev.per.mile         1 2.1306e-06 2.5150e-06 -1409.8
```

```
## + Turn.circle         1 1.9762e-06 2.6695e-06 -1404.9
## + Man.trans.avail     1 1.1600e-06 3.4856e-06 -1383.0
## + Luggage.room        1 1.0447e-06 3.6010e-06 -1380.3
## + AirBags             2 1.0519e-06 3.5937e-06 -1376.1
## + Passengers          1 8.2490e-07 3.8207e-06 -1375.5
## + Rear.seat.room      1 6.5460e-07 3.9910e-06 -1371.9
## + DriveTrain          2 7.4690e-07 3.8987e-06 -1369.4
## + RPM                 1 3.6850e-07 4.2771e-06 -1366.2
## <none>                             4.6456e-06 -1363.9
## + Origin              1 1.7970e-07 4.4659e-06 -1362.7
##
## Step:  AIC=-1481.51
## MPG.avg ~ Weight
##
##                       Df  Sum of Sq        RSS     AIC
## + Wheelbase           1 1.2320e-07 9.2550e-07 -1487.3
## + Price               1 1.0170e-07 9.4700e-07 -1485.5
## + Cylinders           1 1.0160e-07 9.4720e-07 -1485.5
## + Length              1 6.0600e-08 9.8820e-07 -1482.0
## + Luggage.room        1 5.8500e-08 9.9020e-07 -1481.8
## <none>                             1.0487e-06 -1481.5
## + Horsepower          1 5.3700e-08 9.9500e-07 -1481.4
## + Fuel.tank.capacity  1 5.2700e-08 9.9600e-07 -1481.3
## + Width               1 4.9900e-08 9.9890e-07 -1481.1
## + Man.trans.avail     1 2.2700e-08 1.0261e-06 -1478.9
## + Turn.circle         1 1.9700e-08 1.0291e-06 -1478.7
## + Rear.seat.room      1 1.6600e-08 1.0321e-06 -1478.4
## + Passengers          1 4.7000e-09 1.0440e-06 -1477.5
## + RPM                 1 3.3000e-09 1.0455e-06 -1477.4
## + EngineSize          1 3.2000e-09 1.0456e-06 -1477.3
## + Rev.per.mile        1 1.9000e-09 1.0468e-06 -1477.2
## + Origin              1 1.4000e-09 1.0473e-06 -1477.2
## + AirBags             2 3.7300e-08 1.0114e-06 -1475.7
## + DriveTrain          2 1.8000e-09 1.0470e-06 -1472.8
## + Type                4 7.6100e-08 9.7260e-07 -1470.1
## - Weight              1 3.5969e-06 4.6456e-06 -1363.9
##
## Step:  AIC=-1487.35
## MPG.avg ~ Weight + Wheelbase
##
##                       Df  Sum of Sq        RSS     AIC
## + Cylinders           1 9.2680e-08 8.3282e-07 -1491.6
## + Price               1 8.8800e-08 8.3670e-07 -1491.2
## + Fuel.tank.capacity  1 5.4600e-08 8.7090e-07 -1487.9
## <none>                             9.2550e-07 -1487.3
## + EngineSize          1 2.6110e-08 8.9939e-07 -1485.3
## + Passengers          1 1.4050e-08 9.1145e-07 -1484.2
## + Horsepower          1 1.1400e-08 9.1409e-07 -1484.0
## + Width               1 1.0420e-08 9.1508e-07 -1483.9
## + Luggage.room        1 7.3800e-09 9.1811e-07 -1483.6
## + Rear.seat.room      1 6.5800e-09 9.1892e-07 -1483.5
## + Turn.circle         1 5.8900e-09 9.1961e-07 -1483.5
## + Length              1 1.6900e-09 9.2381e-07 -1483.1
## + Origin              1 1.4700e-09 9.2402e-07 -1483.1
```

```
## + RPM                 1 4.2000e-10 9.2508e-07 -1483.0
## + Rev.per.mile        1 4.0000e-11 9.2546e-07 -1483.0
## + Man.trans.avail     1 2.0000e-11 9.2548e-07 -1483.0
## + AirBags             2 4.2190e-08 8.8331e-07 -1482.4
## - Wheelbase           1 1.2325e-07 1.0487e-06 -1481.5
## + DriveTrain          2 1.5190e-08 9.1031e-07 -1479.9
## + Type                4 4.6120e-08 8.7938e-07 -1473.9
## - Weight              1 1.4730e-06 2.3985e-06 -1413.7
##
## Step:  AIC=-1491.6
## MPG.avg ~ Weight + Wheelbase + Cylinders
##
##                       Df  Sum of Sq        RSS     AIC
## + Fuel.tank.capacity  1 7.4610e-08 7.5821e-07 -1494.9
## + Price               1 6.4180e-08 7.6864e-07 -1493.8
## <none>                             8.3282e-07 -1491.6
## + Width               1 4.0150e-08 7.9267e-07 -1491.2
## + Passengers          1 1.5610e-08 8.1721e-07 -1488.7
## + Luggage.room        1 1.5240e-08 8.1758e-07 -1488.7
## + Rev.per.mile        1 6.5300e-09 8.2629e-07 -1487.8
## + Rear.seat.room      1 4.4400e-09 8.2838e-07 -1487.6
## + Man.trans.avail     1 4.2100e-09 8.2861e-07 -1487.6
## + Turn.circle         1 3.5500e-09 8.2926e-07 -1487.5
## - Cylinders           1 9.2680e-08 9.2550e-07 -1487.3
## + Length              1 1.4500e-09 8.3137e-07 -1487.3
## + RPM                 1 8.6000e-10 8.3195e-07 -1487.3
## + Horsepower          1 8.4000e-10 8.3198e-07 -1487.3
## + EngineSize          1 2.0000e-11 8.3280e-07 -1487.2
## + Origin              1 0.0000e+00 8.3282e-07 -1487.2
## - Wheelbase           1 1.1436e-07 9.4718e-07 -1485.5
## + AirBags             2 2.6390e-08 8.0643e-07 -1485.4
## + Type                4 9.2140e-08 7.4067e-07 -1483.6
## + DriveTrain          2 6.6300e-09 8.2619e-07 -1483.4
## - Weight              1 5.8118e-07 1.4140e-06 -1452.6
##
## Step:  AIC=-1494.89
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity
##
##                       Df  Sum of Sq        RSS     AIC
## + Price               1 4.3942e-08 7.1427e-07 -1495.4
## <none>                             7.5821e-07 -1494.9
## + Width               1 3.7818e-08 7.2039e-07 -1494.7
## + Luggage.room        1 2.7203e-08 7.3101e-07 -1493.5
## + Passengers          1 1.8140e-08 7.4007e-07 -1492.5
## - Fuel.tank.capacity  1 7.4605e-08 8.3282e-07 -1491.6
## + Origin              1 4.9060e-09 7.5330e-07 -1491.0
## + Rear.seat.room      1 3.6240e-09 7.5459e-07 -1490.9
## + Length              1 1.5500e-09 7.5666e-07 -1490.7
## + Turn.circle         1 4.7100e-10 7.5774e-07 -1490.5
## + RPM                 1 2.0900e-10 7.5800e-07 -1490.5
## + Horsepower          1 1.4100e-10 7.5807e-07 -1490.5
## + Man.trans.avail     1 1.3500e-10 7.5808e-07 -1490.5
## + Rev.per.mile        1 1.2200e-10 7.5809e-07 -1490.5
## + EngineSize          1 6.3000e-11 7.5815e-07 -1490.5
```

```
## - Cylinders           1 1.1269e-07 8.7090e-07 -1487.9
## + AirBags             2 1.5281e-08 7.4293e-07 -1487.7
## - Wheelbase           1 1.1557e-07 8.7378e-07 -1487.7
## + DriveTrain          2 6.2620e-09 7.5195e-07 -1486.8
## + Type                4 6.0867e-08 6.9734e-07 -1484.1
## - Weight              1 1.6390e-07 9.2211e-07 -1483.2
##
## Step:  AIC=-1495.38
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price
##
##                       Df  Sum of Sq        RSS     AIC
## <none>                               7.1427e-07 -1495.4
## - Price               1 4.3942e-08 7.5821e-07 -1494.9
## + Origin              1 3.2587e-08 6.8168e-07 -1494.8
## + Passengers          1 2.9341e-08 6.8493e-07 -1494.4
## - Fuel.tank.capacity  1 5.4371e-08 7.6864e-07 -1493.8
## + Luggage.room        1 1.3624e-08 7.0065e-07 -1492.5
## + Horsepower          1 1.2159e-08 7.0211e-07 -1492.4
## + Width               1 9.8340e-09 7.0444e-07 -1492.1
## + RPM                 1 9.5100e-09 7.0476e-07 -1492.1
## + Rev.per.mile        1 5.0770e-09 7.0919e-07 -1491.5
## + Rear.seat.room      1 3.7200e-09 7.1055e-07 -1491.4
## + Turn.circle         1 3.0280e-09 7.1124e-07 -1491.3
## + EngineSize          1 1.9850e-09 7.1228e-07 -1491.2
## + Length              1 1.1750e-09 7.1309e-07 -1491.1
## + Man.trans.avail     1 5.2000e-11 7.1422e-07 -1491.0
## + AirBags             2 3.5308e-08 6.7896e-07 -1490.7
## - Cylinders           1 8.5761e-08 8.0003e-07 -1490.5
## - Wheelbase           1 1.0719e-07 8.2146e-07 -1488.3
## + DriveTrain          2 4.1200e-09 7.1015e-07 -1487.0
## - Weight              1 1.3345e-07 8.4772e-07 -1485.7
## + Type                4 4.2409e-08 6.7186e-07 -1482.8
```

```
M1_AIC <- stepwise(m1, direction = "forward/backward", criterion = "AIC")
```

```
##
## Direction:  forward/backward
## Criterion:  AIC
##
## Start:  AIC=-1366.28
## MPG.avg ~ 1
##
##                       Df  Sum of Sq        RSS     AIC
## + Weight              1 3.5969e-06 1.0487e-06 -1486.3
## + Fuel.tank.capacity  1 3.2658e-06 1.3799e-06 -1463.8
## + Cylinders           1 3.1450e-06 1.5006e-06 -1456.9
## + EngineSize          1 3.1017e-06 1.5439e-06 -1454.6
## + Horsepower          1 3.0577e-06 1.5879e-06 -1452.3
## + Type                4 2.7563e-06 1.8893e-06 -1432.1
## + Price               1 2.6052e-06 2.0404e-06 -1431.7
## + Length              1 2.4066e-06 2.2390e-06 -1424.1
## + Width               1 2.3643e-06 2.2814e-06 -1422.6
## + Wheelbase           1 2.2472e-06 2.3985e-06 -1418.5
```

```
## + Rev.per.mile        1 2.1306e-06 2.5150e-06 -1414.6
## + Turn.circle         1 1.9762e-06 2.6695e-06 -1409.7
## + Man.trans.avail     1 1.1600e-06 3.4856e-06 -1387.8
## + Luggage.room        1 1.0447e-06 3.6010e-06 -1385.2
## + AirBags             2 1.0519e-06 3.5937e-06 -1383.3
## + Passengers          1 8.2490e-07 3.8207e-06 -1380.3
## + Rear.seat.room      1 6.5460e-07 3.9910e-06 -1376.7
## + DriveTrain          2 7.4690e-07 3.8987e-06 -1376.7
## + RPM                 1 3.6850e-07 4.2771e-06 -1371.0
## + Origin              1 1.7970e-07 4.4659e-06 -1367.5
## <none>                             4.6456e-06 -1366.3
##
## Step:  AIC=-1486.32
## MPG.avg ~ Weight
##
##                       Df  Sum of Sq        RSS     AIC
## + Wheelbase           1 1.2320e-07 9.2550e-07 -1494.6
## + Price               1 1.0170e-07 9.4700e-07 -1492.7
## + Cylinders           1 1.0160e-07 9.4720e-07 -1492.7
## + Length              1 6.0600e-08 9.8820e-07 -1489.2
## + Luggage.room        1 5.8500e-08 9.9020e-07 -1489.0
## + Horsepower          1 5.3700e-08 9.9500e-07 -1488.6
## + Fuel.tank.capacity  1 5.2700e-08 9.9600e-07 -1488.5
## + Width               1 4.9900e-08 9.9890e-07 -1488.3
## <none>                             1.0487e-06 -1486.3
## + Man.trans.avail     1 2.2700e-08 1.0261e-06 -1486.1
## + Turn.circle         1 1.9700e-08 1.0291e-06 -1485.9
## + Rear.seat.room      1 1.6600e-08 1.0321e-06 -1485.6
## + AirBags             2 3.7300e-08 1.0114e-06 -1485.3
## + Passengers          1 4.7000e-09 1.0440e-06 -1484.7
## + RPM                 1 3.3000e-09 1.0455e-06 -1484.6
## + EngineSize          1 3.2000e-09 1.0456e-06 -1484.6
## + Type                4 7.6100e-08 9.7260e-07 -1484.5
## + Rev.per.mile        1 1.9000e-09 1.0468e-06 -1484.5
## + Origin              1 1.4000e-09 1.0473e-06 -1484.4
## + DriveTrain          2 1.8000e-09 1.0470e-06 -1482.5
## - Weight              1 3.5969e-06 4.6456e-06 -1366.3
##
## Step:  AIC=-1494.57
## MPG.avg ~ Weight + Wheelbase
##
##                       Df  Sum of Sq        RSS     AIC
## + Cylinders           1 9.2680e-08 8.3282e-07 -1501.2
## + Price               1 8.8800e-08 8.3670e-07 -1500.8
## + Fuel.tank.capacity  1 5.4600e-08 8.7090e-07 -1497.6
## + EngineSize          1 2.6110e-08 8.9939e-07 -1494.9
## <none>                             9.2550e-07 -1494.6
## + AirBags             2 4.2190e-08 8.8331e-07 -1494.4
## + Passengers          1 1.4050e-08 9.1145e-07 -1493.8
## + Horsepower          1 1.1400e-08 9.1409e-07 -1493.6
## + Width               1 1.0420e-08 9.1508e-07 -1493.5
## + Luggage.room        1 7.3800e-09 9.1811e-07 -1493.2
## + Rear.seat.room      1 6.5800e-09 9.1892e-07 -1493.2
## + Turn.circle         1 5.8900e-09 9.1961e-07 -1493.1
```

```
## + Length              1 1.6900e-09 9.2381e-07 -1492.7
## + Origin              1 1.4700e-09 9.2402e-07 -1492.7
## + RPM                 1 4.2000e-10 9.2508e-07 -1492.6
## + Rev.per.mile        1 4.0000e-11 9.2546e-07 -1492.6
## + Man.trans.avail     1 2.0000e-11 9.2548e-07 -1492.6
## + DriveTrain          2 1.5190e-08 9.1031e-07 -1491.9
## + Type                4 4.6120e-08 8.7938e-07 -1490.8
## - Wheelbase           1 1.2325e-07 1.0487e-06 -1486.3
## - Weight              1 1.4730e-06 2.3985e-06 -1418.5
##
## Step:  AIC=-1501.22
## MPG.avg ~ Weight + Wheelbase + Cylinders
##
##                       Df  Sum of Sq        RSS     AIC
## + Fuel.tank.capacity  1 7.4610e-08 7.5821e-07 -1506.9
## + Price               1 6.4180e-08 7.6864e-07 -1505.8
## + Width               1 4.0150e-08 7.9267e-07 -1503.3
## + Type                4 9.2140e-08 7.4067e-07 -1502.8
## <none>                             8.3282e-07 -1501.2
## + Passengers          1 1.5610e-08 8.1721e-07 -1500.8
## + Luggage.room        1 1.5240e-08 8.1758e-07 -1500.7
## + Rev.per.mile        1 6.5300e-09 8.2629e-07 -1499.9
## + AirBags             2 2.6390e-08 8.0643e-07 -1499.9
## + Rear.seat.room      1 4.4400e-09 8.2838e-07 -1499.7
## + Man.trans.avail     1 4.2100e-09 8.2861e-07 -1499.6
## + Turn.circle         1 3.5500e-09 8.2926e-07 -1499.6
## + Length              1 1.4500e-09 8.3137e-07 -1499.4
## + RPM                 1 8.6000e-10 8.3195e-07 -1499.3
## + Horsepower          1 8.4000e-10 8.3198e-07 -1499.3
## + EngineSize          1 2.0000e-11 8.3280e-07 -1499.2
## + Origin              1 0.0000e+00 8.3282e-07 -1499.2
## + DriveTrain          2 6.6300e-09 8.2619e-07 -1497.9
## - Cylinders           1 9.2680e-08 9.2550e-07 -1494.6
## - Wheelbase           1 1.1436e-07 9.4718e-07 -1492.7
## - Weight              1 5.8118e-07 1.4140e-06 -1459.8
##
## Step:  AIC=-1506.92
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity
##
##                       Df  Sum of Sq        RSS     AIC
## + Price               1 4.3942e-08 7.1427e-07 -1509.8
## + Width               1 3.7818e-08 7.2039e-07 -1509.1
## + Luggage.room        1 2.7203e-08 7.3101e-07 -1507.9
## <none>                             7.5821e-07 -1506.9
## + Passengers          1 1.8140e-08 7.4007e-07 -1506.9
## + Type                4 6.0867e-08 6.9734e-07 -1505.8
## + Origin              1 4.9060e-09 7.5330e-07 -1505.5
## + Rear.seat.room      1 3.6240e-09 7.5459e-07 -1505.3
## + Length              1 1.5500e-09 7.5666e-07 -1505.1
## + Turn.circle         1 4.7100e-10 7.5774e-07 -1505.0
## + RPM                 1 2.0900e-10 7.5800e-07 -1504.9
## + Horsepower          1 1.4100e-10 7.5807e-07 -1504.9
## + Man.trans.avail     1 1.3500e-10 7.5808e-07 -1504.9
## + Rev.per.mile        1 1.2200e-10 7.5809e-07 -1504.9
```

```
## + EngineSize          1 6.3000e-11 7.5815e-07 -1504.9
## + AirBags             2 1.5281e-08 7.4293e-07 -1504.6
## + DriveTrain          2 6.2620e-09 7.5195e-07 -1503.6
## - Fuel.tank.capacity  1 7.4605e-08 8.3282e-07 -1501.2
## - Cylinders           1 1.1269e-07 8.7090e-07 -1497.6
## - Wheelbase           1 1.1557e-07 8.7378e-07 -1497.3
## - Weight              1 1.6390e-07 9.2211e-07 -1492.9
##
## Step:  AIC=-1509.82
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price
##
##                       Df  Sum of Sq        RSS     AIC
## + Origin               1 3.2587e-08 6.8168e-07 -1511.6
## + Passengers           1 2.9341e-08 6.8493e-07 -1511.3
## + AirBags              2 3.5308e-08 6.7896e-07 -1510.0
## <none>                              7.1427e-07 -1509.8
## + Luggage.room         1 1.3624e-08 7.0065e-07 -1509.4
## + Horsepower           1 1.2159e-08 7.0211e-07 -1509.2
## + Width                1 9.8340e-09 7.0444e-07 -1509.0
## + RPM                  1 9.5100e-09 7.0476e-07 -1508.9
## + Rev.per.mile         1 5.0770e-09 7.0919e-07 -1508.4
## + Rear.seat.room       1 3.7200e-09 7.1055e-07 -1508.2
## + Turn.circle          1 3.0280e-09 7.1124e-07 -1508.2
## + EngineSize           1 1.9850e-09 7.1228e-07 -1508.0
## + Length               1 1.1750e-09 7.1309e-07 -1508.0
## + Man.trans.avail      1 5.2000e-11 7.1422e-07 -1507.8
## - Price                1 4.3942e-08 7.5821e-07 -1506.9
## + Type                 4 4.2409e-08 6.7186e-07 -1506.8
## + DriveTrain           2 4.1200e-09 7.1015e-07 -1506.3
## - Fuel.tank.capacity   1 5.4371e-08 7.6864e-07 -1505.8
## - Cylinders            1 8.5761e-08 8.0003e-07 -1502.5
## - Wheelbase            1 1.0719e-07 8.2146e-07 -1500.3
## - Weight               1 1.3345e-07 8.4772e-07 -1497.8
##
## Step:  AIC=-1511.64
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price + Origin
##
##                       Df  Sum of Sq        RSS     AIC
## + Width                1 2.6144e-08 6.5554e-07 -1512.8
## + Passengers           1 2.0480e-08 6.6120e-07 -1512.2
## + AirBags              2 3.4964e-08 6.4672e-07 -1512.0
## + Luggage.room         1 1.8816e-08 6.6287e-07 -1511.9
## <none>                              6.8168e-07 -1511.6
## + Rear.seat.room       1 8.3430e-09 6.7334e-07 -1510.7
## + Horsepower           1 8.1790e-09 6.7350e-07 -1510.6
## + Man.trans.avail      1 2.3010e-09 6.7938e-07 -1509.9
## + Rev.per.mile         1 1.9250e-09 6.7976e-07 -1509.9
## + RPM                  1 1.6490e-09 6.8003e-07 -1509.8
## - Origin               1 3.2587e-08 7.1427e-07 -1509.8
## + Length               1 2.2100e-10 6.8146e-07 -1509.7
## + Turn.circle          1 5.7000e-11 6.8163e-07 -1509.7
## + EngineSize           1 0.0000e+00 6.8168e-07 -1509.6
```

```
## + DriveTrain          2 5.6270e-09 6.7606e-07 -1508.3
## + Type                4 3.4725e-08 6.4696e-07 -1507.9
## - Cylinders           1 6.3835e-08 7.4552e-07 -1506.3
## - Fuel.tank.capacity  1 6.9588e-08 7.5127e-07 -1505.7
## - Price               1 7.1622e-08 7.5330e-07 -1505.5
## - Weight              1 1.1255e-07 7.9423e-07 -1501.1
## - Wheelbase           1 1.2947e-07 8.1115e-07 -1499.4
##
## Step:  AIC=-1512.85
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price + Origin + Width
##
##                       Df  Sum of Sq        RSS     AIC
## + Luggage.room         1 1.9303e-08 6.3623e-07 -1513.3
## <none>                              6.5554e-07 -1512.8
## + Passengers           1 1.3850e-08 6.4169e-07 -1512.6
## + Horsepower           1 6.3430e-09 6.4919e-07 -1511.7
## - Width                1 2.6144e-08 6.8168e-07 -1511.6
## + Man.trans.avail      1 4.8680e-09 6.5067e-07 -1511.5
## + AirBags              2 1.8781e-08 6.3676e-07 -1511.2
## + RPM                  1 2.8370e-09 6.5270e-07 -1511.2
## + Rev.per.mile         1 2.7150e-09 6.5282e-07 -1511.2
## + Rear.seat.room       1 2.1540e-09 6.5338e-07 -1511.1
## + Turn.circle          1 1.3180e-09 6.5422e-07 -1511.0
## + EngineSize           1 7.3100e-10 6.5481e-07 -1510.9
## - Price                1 3.2221e-08 6.8776e-07 -1510.9
## + Length               1 4.9900e-10 6.5504e-07 -1510.9
## + DriveTrain           2 1.1626e-08 6.4391e-07 -1510.3
## - Origin               1 4.8897e-08 7.0444e-07 -1509.0
## + Type                 4 2.6404e-08 6.2913e-07 -1508.2
## - Wheelbase            1 7.5177e-08 7.3072e-07 -1506.0
## - Fuel.tank.capacity   1 8.0802e-08 7.3634e-07 -1505.3
## - Cylinders            1 8.7154e-08 7.4269e-07 -1504.6
## - Weight               1 1.3596e-07 7.9150e-07 -1499.4
##
## Step:  AIC=-1513.3
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price + Origin + Width + Luggage.room
##
##                       Df  Sum of Sq        RSS     AIC
## + Passengers           1 2.9462e-08 6.0677e-07 -1515.2
## + Horsepower           1 2.0658e-08 6.1558e-07 -1514.0
## <none>                              6.3623e-07 -1513.3
## - Luggage.room         1 1.9303e-08 6.5554e-07 -1512.8
## + Rear.seat.room       1 1.1420e-08 6.2481e-07 -1512.8
## + RPM                  1 1.0403e-08 6.2583e-07 -1512.7
## - Price                1 2.3548e-08 6.5978e-07 -1512.3
## + AirBags              2 2.1390e-08 6.1484e-07 -1512.1
## - Width                1 2.6632e-08 6.6287e-07 -1511.9
## + Rev.per.mile         1 3.7590e-09 6.3248e-07 -1511.8
## + Man.trans.avail      1 2.1180e-09 6.3412e-07 -1511.6
## + EngineSize           1 1.7030e-09 6.3453e-07 -1511.5
## + Turn.circle          1 1.5090e-09 6.3473e-07 -1511.5
## + Length               1 1.2390e-09 6.3500e-07 -1511.5
```

```
## - Wheelbase           1 3.4682e-08 6.7092e-07 -1511.0
## + DriveTrain          2 1.0575e-08 6.2566e-07 -1510.7
## - Origin              1 5.5092e-08 6.9133e-07 -1508.5
## + Type                4 2.1003e-08 6.1523e-07 -1508.0
## - Fuel.tank.capacity  1 9.4151e-08 7.3039e-07 -1504.0
## - Cylinders           1 9.8016e-08 7.3425e-07 -1503.5
## - Weight              1 1.2035e-07 7.5658e-07 -1501.1
##
## Step:  AIC=-1515.19
## MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price + Origin + Width + Luggage.room + Passengers
##
##                       Df  Sum of Sq        RSS     AIC
## <none>                                6.0677e-07 -1515.2
## + Horsepower          1 1.3481e-08 5.9329e-07 -1515.0
## - Width               1 1.7164e-08 6.2394e-07 -1514.9
## + RPM                 1 1.1195e-08 5.9558e-07 -1514.7
## + Man.trans.avail     1 1.0231e-08 5.9654e-07 -1514.6
## + AirBags             2 2.3228e-08 5.8354e-07 -1514.4
## + Rev.per.mile        1 3.5450e-09 6.0323e-07 -1513.7
## + DriveTrain          2 1.6993e-08 5.8978e-07 -1513.5
## + EngineSize          1 2.0910e-09 6.0468e-07 -1513.5
## - Price               1 2.8187e-08 6.3496e-07 -1513.5
## + Turn.circle         1 1.3750e-09 6.0540e-07 -1513.4
## - Passengers          1 2.9462e-08 6.3623e-07 -1513.3
## + Rear.seat.room      1 5.6900e-10 6.0620e-07 -1513.3
## + Length              1 1.2000e-11 6.0676e-07 -1513.2
## + Type                4 4.1545e-08 5.6523e-07 -1513.0
## - Luggage.room        1 3.4915e-08 6.4169e-07 -1512.6
## - Origin              1 3.9418e-08 6.4619e-07 -1512.0
## - Wheelbase           1 5.4895e-08 6.6167e-07 -1510.1
## - Fuel.tank.capacity  1 9.6051e-08 7.0282e-07 -1505.1
## - Cylinders           1 9.9320e-08 7.0609e-07 -1504.8
## - Weight              1 1.1637e-07 7.2314e-07 -1502.8
```

```
# check the summary. M1_AIC has insignificant variable; hence, do not use M1_AIC this time. Interpret M
summary(M1_BIC)
```

```
##
## Call:
## lm(formula = MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price, data = df2)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.579e-04 -5.886e-05  1.269e-05  6.431e-05  2.312e-04
##
## Coefficients:
##                       Estimate Std. Error  t value Pr(>|t|)
## (Intercept)          4.987e-01  2.641e-04 1888.156  < 2e-16 ***
## Weight              -2.547e-07  6.760e-08   -3.768 0.000323 ***
## Wheelbase            1.182e-05  3.499e-06    3.377 0.001157 **
## Cylinders           -5.507e-05  1.823e-05   -3.021 0.003433 **
## Fuel.tank.capacity -2.021e-05  8.402e-06   -2.405 0.018595 *
```

```
## Price              -3.566e-06  1.649e-06   -2.162 0.033741 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.694e-05 on 76 degrees of freedom
## Multiple R-squared:  0.8462, Adjusted R-squared:  0.8361
## F-statistic: 83.66 on 5 and 76 DF,  p-value: < 2.2e-16
```

```
summary(M1_AIC)
```

```
##
## Call:
## lm(formula = MPG.avg ~ Weight + Wheelbase + Cylinders + Fuel.tank.capacity +
##     Price + Origin + Width + Luggage.room + Passengers, data = df2)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.312e-04 -5.271e-05  2.142e-05  6.387e-05  2.091e-04
##
## Coefficients:
##                       Estimate Std. Error  t value Pr(>|t|)
## (Intercept)         4.981e-01  4.225e-04 1178.954  < 2e-16 ***
## Weight             -2.547e-07  6.854e-08   -3.716 0.000397 ***
## Wheelbase           1.108e-05  4.341e-06    2.552 0.012826 *
## Cylinders          -6.612e-05  1.926e-05   -3.433 0.000993 ***
## Fuel.tank.capacity -2.828e-05  8.378e-06   -3.376 0.001188 **
## Price              -3.540e-06  1.935e-06   -1.829 0.071563 .
## Originnon-USA       5.764e-05  2.665e-05    2.163 0.033885 *
## Width               1.121e-05  7.858e-06    1.427 0.157861
## Luggage.room        1.139e-05  5.597e-06    2.035 0.045487 *
## Passengers         -3.956e-05  2.116e-05   -1.870 0.065583 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.18e-05 on 72 degrees of freedom
## Multiple R-squared:  0.8694, Adjusted R-squared:  0.8531
## F-statistic: 53.25 on 9 and 72 DF,  p-value: < 2.2e-16
```

```
# vif
vif(M1_BIC)
```

```
##             Weight          Wheelbase          Cylinders Fuel.tank.capacity
##          12.614474           4.412349           3.680002           5.513076
##              Price
##           2.324593
```

```
# since Weight's vif is higher than 10 so I will try to remove some of variables while maintaing R-squa
m2 <- lm(data = df2, MPG.avg ~ Price + Cylinders + Wheelbase + Weight)
M2_BIC <- stepwise(m2, direction = "forward/backward", criterion = "BIC")
```

```
##
## Direction:  forward/backward
```

```
## Criterion:  BIC
##
## Start:  AIC=-1363.87
## MPG.avg ~ 1
##
##             Df  Sum of Sq        RSS     AIC
## + Weight     1 3.5969e-06 1.0487e-06 -1481.5
## + Cylinders  1 3.1450e-06 1.5006e-06 -1452.1
## + Price      1 2.6052e-06 2.0404e-06 -1426.9
## + Wheelbase  1 2.2472e-06 2.3985e-06 -1413.7
## <none>                    4.6456e-06 -1363.9
##
## Step:  AIC=-1481.51
## MPG.avg ~ Weight
##
##             Df  Sum of Sq        RSS     AIC
## + Wheelbase  1 1.2320e-07 9.2550e-07 -1487.3
## + Price      1 1.0170e-07 9.4700e-07 -1485.5
## + Cylinders  1 1.0160e-07 9.4720e-07 -1485.5
## <none>                    1.0487e-06 -1481.5
## - Weight     1 3.5969e-06 4.6456e-06 -1363.9
##
## Step:  AIC=-1487.35
## MPG.avg ~ Weight + Wheelbase
##
##             Df  Sum of Sq        RSS     AIC
## + Cylinders  1 9.2680e-08 8.3282e-07 -1491.6
## + Price      1 8.8800e-08 8.3670e-07 -1491.2
## <none>                    9.2550e-07 -1487.3
## - Wheelbase  1 1.2325e-07 1.0487e-06 -1481.5
## - Weight     1 1.4730e-06 2.3985e-06 -1413.7
##
## Step:  AIC=-1491.6
## MPG.avg ~ Weight + Wheelbase + Cylinders
##
##             Df  Sum of Sq        RSS     AIC
## + Price      1 6.4180e-08 7.6864e-07 -1493.8
## <none>                    8.3282e-07 -1491.6
## - Cylinders  1 9.2680e-08 9.2550e-07 -1487.3
## - Wheelbase  1 1.1436e-07 9.4718e-07 -1485.5
## - Weight     1 5.8118e-07 1.4140e-06 -1452.6
##
## Step:  AIC=-1493.77
## MPG.avg ~ Weight + Wheelbase + Cylinders + Price
##
##             Df  Sum of Sq        RSS     AIC
## <none>                    7.6864e-07 -1493.8
## - Price      1 6.4180e-08 8.3282e-07 -1491.6
## - Cylinders  1 6.8060e-08 8.3670e-07 -1491.2
## - Wheelbase  1 1.0474e-07 8.7338e-07 -1487.7
## - Weight     1 3.9963e-07 1.1683e-06 -1463.8
```

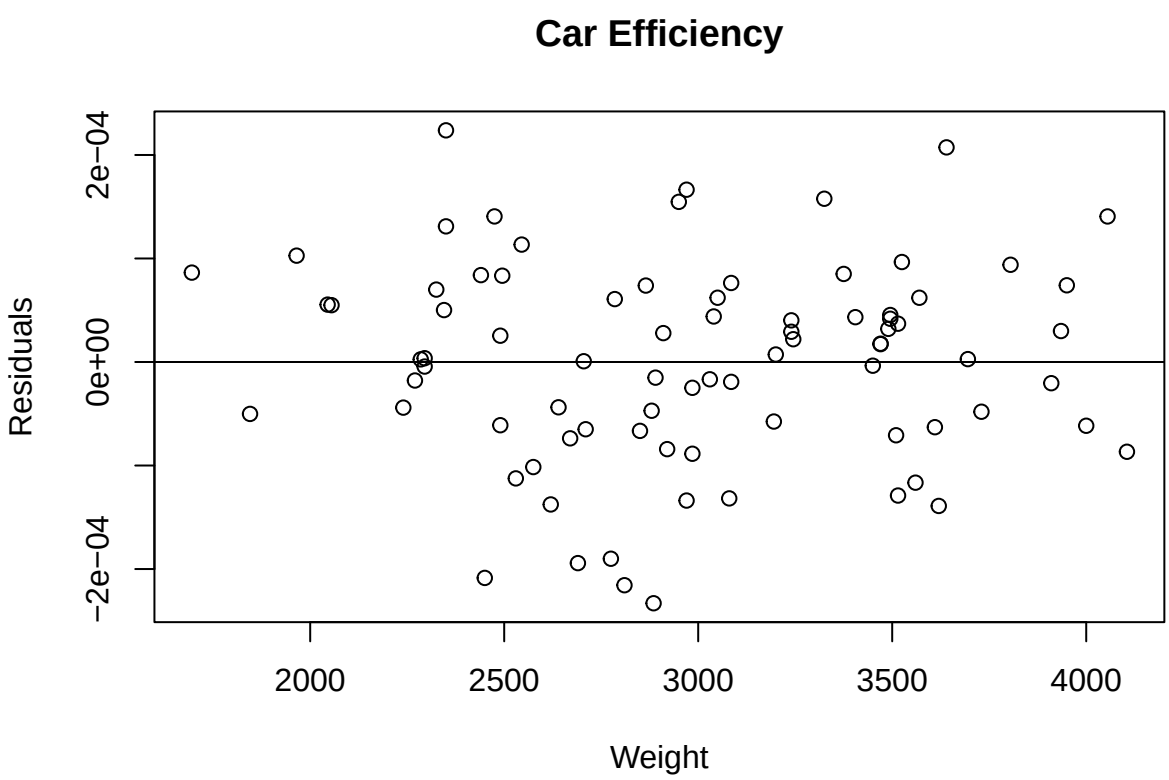
```
# vif of Weight become under 10.
vif(M2_BIC)
```

```
##    Weight Wheelbase Cylinders     Price
##  8.062370  4.411181  3.597503  2.256325
```

```
# check the summary
summary(M2_BIC)
```

```
##
## Call:
## lm(formula = MPG.avg ~ Weight + Wheelbase + Cylinders + Price,
##     data = df2)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -2.330e-04 -6.264e-05  5.455e-06  6.208e-05  2.238e-04
##
## Coefficients:
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept)  4.986e-01  2.720e-04 1833.399  < 2e-16 ***
## Weight      -3.524e-07  5.570e-08   -6.327 1.51e-08 ***
## Wheelbase    1.168e-05  3.605e-06    3.239  0.00177 **
## Cylinders   -4.851e-05  1.858e-05   -2.611  0.01084 *
## Price       -4.245e-06  1.674e-06   -2.536  0.01325 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.991e-05 on 77 degrees of freedom
## Multiple R-squared:  0.8345, Adjusted R-squared:  0.8259
## F-statistic:  97.1 on 4 and 77 DF,  p-value: < 2.2e-16
```

```
# check the normality by residual plot
plot(df2$Weight, resid(M2_BIC), ylab = "Residuals", xlab = "Weight", main = "Car Efficiency")
abline(0, 0)
```


Car Efficiency
Residuals
2e−04
0e+00
−2e−04
2000
2500
3000
3500
4000
Weight