ILLINOIS STATE UNIVERSITY

FACULTY OF ARTS AND SCIENCES

DEPARTMENT OF APPLIED STATISTIC

MAT 450

COMPARISON OF FUEL ECONOMY FOR TOYOTA AND HONDA VEHICLES.

BY

AGYEMANG, ERIC

eagyem2@ilstu.edu

MAY 1, 2020

CHAPTER ONE

1.1 Background

The description of ‘‘fuel economy’’ of vehicles driven in the United States (US) is often measured in miles per gallon (mpg). This represents the number of miles a vehicle is expected to cover on a single gallon of fuel. When using a measure expressed as distance per fuel unit, a higher number means more efficient, while a lower number means less efficient and when expressed as units of fuel per fixed distance (L/100 km etc.), a lower number means more efficient, while a higher number means less efficient. The fuel is gasoline and can be purchased at a specific price per gallon from petroleum stations across the country.

A vehicle’s fuel economy may be viewed in two distinct ways. One observed on the expected mileage the vehicle can travel on a highway setting and the other representing the expected mileage the vehicle can travel within a city environment. The later is typically less than the forma due to the fact that it is attributed to the increase in stops and the zones of low speeding limits encountered in cities. Highway driving can be expected to have less frequent stops and areas of road in which a driver can travel upon at much higher speeds. This form of drive essentially optimizes the energy obtained from fuel better than driving in a city environment.

For this study, two popular Japanese automobile makes Toyota and Honda are taken into consideration. Toyota is a multinational automobile manufacturer headquartered in Toyota Aichi, Japan. It is the largest automobile manufacturer in Japan, and the second largest in the world behind Volkswagen. As at December, 2019, Toyota was the tenth-largest company in the world by revenue (Statista. *Retrieved December, 2019*). Honda on the other hand is a public multinational conglomerate corporation and the first Japanese automobile manufacturer to release a dedicated luxury brand, Acura, in 1986 (*OICA,2011*). In 2013, Honda invested about 5.7% (US$6.8 billion) of its revenues in research and development. It became the first Japanese automaker to be a net exporter from the United States, exporting 108,705 Honda and Acura models (Ross, Jeffrey N. 29 January, 2014).

1.2 Research Questions

The study was guided by the following questions.

- Which of the two companies Honda and Toyota manufacture the vehicle with the better, overall city and highway fuel economy?
- Which companies manufacture the vehicle with the better city and highway fuel economy based upon individual class?

1.3 Significance of The Study

Most people all over the world and therefore the US usually think of fuel economy of vehicles which influence their decision in purchasing and using vehicles since not all vehicles possess the same fuel economy values. The purpose of this study is to compare two popular Japanese multinational automobile makes; Toyota and Honda in an effort to show potential consumers which of the two makes produce better-performing vehicle in the field of fuel economy. By estimating the total cost expected for both options, this study's conclusion can be used as a means for consumers wanting to make the smartest and economically as possible choice by presenting them with the cheapest available option.

CHAPTER TWO

METHODOLOGY

2.1 Data Description

Vehicles of various classes belonging to Toyota and Honda were observed for the analysis. Data from the years 2014 to 2018 was gathered from TrueCar.com and United States Environmental Protection Agency (EPA) database through the Kaggle.com. A total population of 49662 Honda vehicles and 49127 Toyota vehicles where obtained for the study. Each vehicle occupies an individual row and only the year, make, model, class, city fuel economy, and highway fuel economy for each vehicle were considered for this study. The data was imported onto R version 3.6.3 and SAS version 9.4 where analysis begun.

2.1.1 Kernel Density Estimation

Kernel density estimation is a fundamental data smoothing problem where inferences about the population are made, based on a finite data sample. It is used in this study to show the shape of the estimated population of City mpg and Highway mpg of the two vehicle makes. It is used to overcome the discreteness of the other methods like histogram by centering a smooth kernel function at each data point then summing to get a density estimate. The basic kernel estimator can be expressed as $\widehat{\boldsymbol{f_{kde}}}\,(\boldsymbol{x}) = \frac{\mathbf{1}}{\boldsymbol{n}} \sum_{\boldsymbol{n}}^{\boldsymbol{i}=\mathbf{1}} \boldsymbol{K}(\frac{\boldsymbol{x}-\boldsymbol{x_i}}{\boldsymbol{h}})$

where K is the kernel and h is the bandwidth (h=4 in our case). The kernel is a symmetric, usually positive function that integrates to one. Other common kernel functions are uniform, triangle, Epanechnikov, biweight, Gaussian(normal) and cosine. The bandwidth, h, is the smoothing parameter. Hence, large bandwidth result in very smooth estimates while small values result in wiggly estimates.

2.2 Sampling Techniques.

While an original population of possible observations is designated at the start of this study, it should be considered unrealistic in a real-world setting to measure each member of the population. As a result, a subsection of this population was chosen and observed as a sample. The goal of taking this sample is to obtain information that is closely representative of the population's true values, while also keeping the use of time and resources to a minimum for parsimony

While several strategies can be implemented to take samples, some can be proven more efficient than others based on the nature of the population being studied. This study utilizes Simple Random Sampling (SRS) and Stratified Sampling methods for the analysis.

2.2.1 Sample Size

In order to get a good representation of the population of Honda and Toyota vehicles, an overall proportion was decided upon before determining sample sizes for each vehicle class. The resulting number is designated as n. For comparative purpose, the value calculated from this proportion was kept the same for both the simple random sample (SRS) and a stratified sample. A margin of error of 0.10 was set up for the sample size and using the R package (*samplingbook)* and the function (*sample.size.mean)*, we set up the margin of error to 0.10, population standard deviation, total population and the level of 0.95, and so we are able to compute the sample sizes required for the analysis. For Honda City mpg, a sample size selected was 15300 while Honda Highway mpg, a sample size of 15806 was chosen. For Toyota City mpg, the sample size selected was 10149 while Toyota Highway mpg had a sample size of 12154.

2.2.2 Simple Random Sampling (SRS) Method

A Simple Random Sampling Replacement (SRS) is used as our basic method for our probability sampling where every possible subset of *n* distinct units in the population has the same probability of being selected as the sample. There are $\binom{N}{n}$ possible ways and the probability of selecting an individual sample is p(S)= $\frac{1}{\binom{N}{n}}$ where N is the total population and n sample size.

2.2.3 Stratified Sampling Method

Suppose the population is partitioned into disjoint sets of sampling units called strata. If a sample is selected within each stratum, then this sampling procedure is known as stratified sampling. Each potential observation within a stratum can only belong to that strata. This method ensures a good representation of the population.

2.2.3.1 Designation of the Strata

The strata created for this project were established based upon the class in which each vehicle belongs to. Vehicles from both Honda and Toyota were determined to fit into one of eleven common classes. These classes were identified as:

Stratum A: Compact Cars

Stratum B: Large Cars

Stratum C: Midsize Station Wagons

Stratum D: Small Station Wagon

Stratum E: Small Pickup Truck 2WD

Stratum F: Small sport Utility Cars

Stratum G: Large Sport Utility cars

Stratum H: Standard Pickup Truck 4WD

Stratum I: Standard Utility cars 4WD

Stratum J: Two Seaters

Stratum K: Van Cars

While the stratum Large Cars is present in Honda but not present in Toyota, Midsize Cars on the other side is present in Toyota but are present in Honda. Each class was designated as its own strata, containing only vehicles which were of that specific class. There were eleven classes in both cases.

2.2.3.2 Neyman Allocation to Strata

This project assumes equal amount of cost of measuring a vehicle for a sample for every measurement made and so a special case of the optimal allocation (the Neyman allocation) was employed. The Neyman allocation is a type of optimal allocation which hold the sample chosen from a stratum, n_h, proportional to the stratum size N_h multiplied by the population standard deviation (s_h) in that same stratum.

$\boldsymbol{n_h} = \frac{\boldsymbol{N_h S_h}}{\sum_{h=1}^{H}(\boldsymbol{N_h S_h})}$***n** and was calculated for all stratum for all the four cases Honda City mpg and Highway mpg, Toyota City mpg and Highway mpg. The sample quantities chosen from each stratum were selected such that the sum of all 11 samples equaled $\boldsymbol{n}$ (the total sample size). Using the R package *strAlloc,* we are able to compute $\boldsymbol{n_h}$ are compute all h stratum.

2.3 Confidence Interval for Sample Means

Another measure which can gauge the effectiveness of the SRS and the Stratified Random Sample is the computation of a confidence interval for the sample means which are the average fuel economy ascertained. Since the overall population mean $\bar{Y}_U$ can be estimated with the calculation of $\bar{Y}_{SRS}$ fort the simple random sample case and $\bar{Y}_{str}$ for the Stratified Random Sampled case, the $100(1-\alpha)\%$ confidence interval determined by using:

$\boldsymbol{\bar{Y}_{SRS}} \pm \boldsymbol{Z_{\frac{\alpha}{2}}}$***SE(**$\boldsymbol{\bar{Y}_{SRS}}$) **and** $\boldsymbol{\bar{Y}_{str}} \pm \boldsymbol{Z_{\frac{\alpha}{2}}}$***SE(**$\boldsymbol{\bar{Y}_{str}}$**)** respectively where $\boldsymbol{\alpha = 0.05}$ and so $\boldsymbol{Z_{\frac{\alpha}{2}}}$ **=1.96** from the normal distribution table.

2.4 Comparison of The SRS and Stratified Random Sample Estimates

For each of the four cases considered, the calculated estimates are compared to the true values corresponding to what each estimate is attempting to represent. The two-specific variance (variance for SRS and Stratified Random Sample) can be used in determining the efficiency of the stratified random sample taken. The stratified random sampling can be compared to a simple random sample of the same sample size by: ***Ratio Of Relative Gain From Stratification*** = $\frac{\boldsymbol{The\ estimated\ variance\ from\ the\ stratified\ Sampling}}{\boldsymbol{The\ estimated\ variance\ from\ the\ SRS}}.$

The resulting ratio can then be multiplied by the common n chosen for both samples in order to determine what sample size would be needed with a stratified sample in order to obtain the same precision with an SRS of size n. Ideally, this ratio should be below 1 as this would show that taking a stratified random sample would require less of a sample size than a simple random sample to obtain a desired result.

Another approach is the design effect which provides a measure of the precision gained or lost by the use of a more complicated design instead of an SRS. Although it is a useful concept, it is not a way to avoid calculating variances. We need an estimate of the variance from the complex design to find the design effect. It is given as: $\boldsymbol{Deff}(\mathbf{plan}, \hat{\hat{y}}) = \frac{\mathbf{V}(\mathbf{estimator\ from\ sampling\ plan})}{\boldsymbol{V}(\boldsymbol{Estimator\ from\ an\ SRS\ with\ same\ number\ of\ observation\ Unit})}$

Different quantities in the same survey may have different design effects. In a stratified sampling, unless all of the stratum means are equal, the design effect for a stratified sample will usually be less than one. stratification generally gives more precision per observation unit than an SRS.

CHAPTER THREE

3.1 RESULTS AND DISCUSSION

3.1.1 Kernel Density Estimation

The results from the [1]Kernel density estimate provided in the analysis of this paper shows a bandwidth 4 for all four cases. The plots obtained for Honda and Toyota City mpg and Highway mpg's are normally distributed across vehicles at that bandwidth. Hence the data is smoothed and is underfitted with the bandwidth of 4.

3.1.2 Comparison of estimates

From the SAS and R output for our data, the questions posed earlier in this paper can be formally addressed. The first question, which ask in a broad sense, "Which of the two companies Honda and Toyota manufacture the vehicle with the better, overall city and highway fuel economy?", can be answered with the results obtained from the simple random sample. From the simple random sample conducted, it was found that the estimated total fuel economy for Honda city driving was 2868441mpg with a standard error of 5487.9 and an average fuel economy of 17.795mpg with a confidence interval of (17.7279, 17.86136). On the other hand, Toyota vehicles produced over the same period with the simple random sample shows an estimated total fuel economy of 3972278mpg for city driving with a standard error of 6191.1 and an average city driving fuel economy of 16.704mpg with a confidence interval of (16.65305, 16.7551). Based on these results, it can be concluded that Honda produced a better, overall city fuel economy, in regard to city driving, during the period of 2014-2018.

Next, using the same simple random sample, it was found that the estimated total fuel economy for Honda highway was 3711570mpg with a standard error of 5487.9 and an average city fuel economy across

[1] Refer Kernel Density Estimation from Appendix A, figure 1 to 4

all vehicles of 23.787mpg with a confidence interval of (23.71821, 23.85486). For Toyota vehicles produced over the same period, the simple random sample showed that the estimated total fuel economy for highway driving was 5345873mpg with a standard error of 6956.4 and an average city fuel economy across all vehicles of 22.48mpg with a confidence interval of (22.42293, 22.5376). Based on these results, it can be concluded that Honda had produced the more fuel-efficient vehicles, in regard to highway driving, during the period of 2014-2018. Since Honda wins in both categories, the company can be considered the better option over Toyota if one were to compare the two makes in only a general sense.

The second question, "Which companies manufacture the vehicle with the better city and highway fuel economy based upon individual class?" can be considered more specific than the first question. This can be answered using the stratification method used in our analysis. It was found that the estimated total fuel economy for Honda city driving was 3573468mpg with a standard error of 7063.7 and an average city fuel economy across all vehicles of 17.732mpg with a confidence interval of (17.66293, 17.80033). For Toyota vehicles produced over the same period, the stratified sampling method showed the estimated total fuel economy for city driving was 4052515mpg with a standard error of 6104.5 and an average city fuel economy across all vehicles of 16.647mpg with a confidence interval of (16.59789, 16.69619). Based on these results, it can be concluded that Honda had produced the more fuel-efficient vehicles, in regard to city driving using stratified sampling technique. Once again, even after vehicles were broken down by class and analyzed separated, the combined results gathered from each of the 11 strata showed that Honda had produced the more fuel-efficient vehicles, in regard to city driving, during the period.

A similar outcome can be seen for highway fuel economy. From the stratified random sample It was found that the estimated total fuel economy for Honda highway driving was 4125383mpg with a standard error of 6083.6 and an average highway fuel economy across all vehicles of 23.741mpg with a confidence interval of (23.67229, 23.80953). For Toyota vehicles produced over the same period, the stratified sampling method showed the estimated total fuel economy for highway driving was 5345873mpg with a standard error of 6956.4 and an average city fuel economy across all vehicles of 22.48mpg with a confidence interval of (22.42293, 22.5376). Again, Honda had produced the more fuel-efficient vehicles, in regard to highway driving for the stratified sampling technique, during the period of 2014-2018.

3.1.2 Gain from Stratification

The results produced from the analysis of this project shows that the gain from stratification for Honda vehicles City mpg and Highway mpg are 0.1008905and 0.1021133, respectively. These imply that if the value of the estimated variance from the stratified sampling and that from SRS were the population variances, we will expect that we would need $15300 * 0.1008905 = 1543$ observations and $15300 * 0.1021133 = 1562$ observations respectively with the stratified sample to obtain the same precision as from an SRS of 15300 observations.

Also, the results produced shows that the gain from stratification for Toyota vehicles City mpg and Highway mpg are 0.97222 and 0.04136722, respectively. These imply that if the value of the estimated var iance from the stratified sampling and that from SRS were the population variances, we would expect that we would need only $10149 * 0.97222 = 9867$ observations and$10149 * 0.04136722 = 420$ observatio ns respectively with the stratified sample to obtain the same precision as from an SRS 14898 observations.

3.2 CONCLUSION AND RECOMMENDATION

The results from all techniques used in this project express the same results. Therefore, using the results presented in this project, it can be concluded that buying a Honda vehicle would be the better option over Toyota in terms of fuel economy cost efficiency. Hence, this paper recommends buyers to buy Honda vehicles to minimize cost.

Reference

1. Sampling: Design and Analysis: Edition 2 Sharon L. Lohr December 9, 2009
2. https://vita.had.co.nz/papers/density-estimation.Pdf
3. https://www.kaggle.com/epa/fuel-economy
4. https://www.kaggle.com/jpayne/852k-used-car-listings
5. https://en.wikipedia.org/wiki/Fuel_economy_in_automobiles

Appendix A

1. SAS OUTPUT

Table 1 DESCRIPTIVE STATISTICS FOR THE MAKES (HONDA AND TOYOTA)

The MEANS Procedure

Make	N Obs	Variable	Mean	Variance	Std Dev	Lower 95% CL for Mean	Upper 95% CL for Mean
Honda	49662	Price	19804.31	35755327.98	26.8323234	19751.71	19856.90
		Year	2014.88	0.9020238	0.0042618	2014.87	2014.89
		Mileage	33723.94	426405922	92.6615394	33542.32	33905.55
		City mpg	17.7946317	57.5607911	0.0340448	17.7279034	17.8613600
		Highway mpg	23.7865370	60.3502160	0.0348600	23.7182110	23.8548630
Toyota	49127	Price	22794.60	82722914.85	41.0348445	22714.17	22875.03
		Year	2015.21	0.9928105	0.0044954	2015.20	2015.22
		Mileage	32665.02	369091505	86.6776050	32495.13	32834.91
		City mpg	16.7040731	33.2982497	0.0260346	16.6530450	16.7551012
		Highway mpg	22.4802654	42.0393807	0.0292528	22.4229295	22.5376014

Table 2 Descriptive Statistics of HONDA

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
Price	49662	19804.31	5979.58	4950	99999
Year	49662	2014.88	0.9497493	2014	2018
Mileage	49662	33723.94	20649.60	5	389781
City mpg	49662	17.7946317	7.5868828	8	132
High mpg	49662	23.7865370	7.7685401	10	110

Table 3 **Descriptive Statistics of HONDA on City_Mpg Based on Class**

The MEANS Procedure

Analysis Variable : City_mpg							
Class	**N Obs**	**Median**	**Mean**	**Variance**	**Std Dev**	**Lower 95% CL for Mean**	**Upper 95% CL for Mean**
Compact Car	**4961**	17	18.50	70.9351308	8.4222996	18.2660810	18.7349269
Large Cars	**7022**	17	18.525	80.7607016	8.9866958	18.3154047	18.7358627
Midsize Station Wagons	**80**	15	16.275	14.0753165	3.7517085	15.4400982	17.1099018
Small Station Wagon	**3070**	15	16.842	49.4866013	7.0346714	16.5930799	17.0909592
Small Pickup Truck 2WD	**7106**	15	16.902	45.3145433	6.7316078	16.7455135	17.0585957
Small Sport Utility Cars	**1528**	15	15.776	16.3895873	4.0484055	15.5736834	15.9799815
Large Sport U cars	**10988**	16	17.855	55.8592519	7.4739047	17.7148082	17.9943290
Standard Pickup Truck 4WD	**11566**	16	17.993	51.4480294	7.1727282	17.8624363	18.1239030
Standard U cars 4WD	**560**	17	18.759	109.0634264	10.4433436	17.8920965	19.6257607
Two Seaters	**1385**	17	18.088	45.3477265	6.7340721	17.7331254	18.4430479
Van Cars	**1396**	16	17.7485	60.9525069	7.8072087	17.3386671	18.1584675

Table 4 **Descriptive Statistics of HONDA on High_mpg Based on Class**

The MEANS Procedure

Analysis Variable : High_mpg							
Class	**N Obs**	**Median**	**Mean**	**Variance**	**Std Dev**	**Lower 95% CL for Mean**	**Upper 95% CL for Mean**
Compact Car	**4961**	23	24.6736545	67.8670659	8.2381470	24.4443572	24.9029518
Large Cars	**7022**	23	24.5944175	74.3063525	8.6201133	24.3927642	24.7960709
Midsize Station Wagons	**80**	20	21.7125000	27.6757911	5.2607786	20.5417711	22.8832289
Small Station Wagon	**3070**	21	22.7462541	51.7423695	7.1932169	22.4917039	23.0008042
Small Pickup Truck 2WD	**7106**	21	22.7303687	50.4472043	7.1026195	22.5651999	22.8955375
Small Sport Utility Cars	**1528**	20	21.3560209	31.4527339	5.6082737	21.0745977	21.6374442
Large Sport U cars	**10988**	23	23.8704041	60.1064399	7.7528343	23.7254277	24.0153804
Standard Pickup Truck 4WD	**11566**	23	24.0180702	58.0286401	7.6176532	23.8792275	24.1569129
Standard U cars 4WD	**560**	24	24.9660714	91.4818522	9.5646146	24.1721768	25.7599661
Two Seaters	**1385**	23	24.1018051	54.1088479	7.3558717	23.7140680	24.4895421
Van Cars	**1396**	23	23.6489971	59.5154183	7.7146237	23.2439579	24.0540364

Table 5 **Descriptive Statistics For TOYOTA**

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
Price	49127	22794.60	9095.21	5814.00	183710.00
Year	49127	2015.21	0.9963988	2014.00	2018.00
Mileage	49127	32665.02	19211.75	5.00	475636.00
City_mpg	49127	16.7040731	5.7704636	8.00	128.00
High_mpg	49127	22.4802654	6.4837783	10.00	110.00

Table 6 **Descriptive Statistics for TOYOTA on City_mpg Based on Class**

The MEANS Procedure

Analysis Variable: City_mpg						
Class	**N Obs**	**Mean**	**Variance**	**Std Dev**	**Lower 95% CL for Mean**	**Upper 95% CL for Mean**
Compact Car	**7981**	16.4136073	26.7791582	5.1748583	16.3000582	16.5271564
Large Sport Utility cars	**2139**	15.6568490	13.9130623	3.7300218	15.4986878	15.8150102
Midsize Car	**6578**	17.5185467	39.3796925	6.2753241	17.3668705	17.6702228
Midsize Station Wagons	**908**	16.2147577	19.5977092	4.4269300	15.9264291	16.5030863
Small Pickup Truck 2WD	**3469**	16.5269530	17.6553431	4.2018262	16.3870795	16.6668266
Small Standard Wagons	**6769**	16.9392820	42.9997111	6.5574165	16.7830406	17.0955235
Small Sport Utility Cars	**5233**	16.7729792	42.3956994	6.5111980	16.5965241	16.9494342
Standard Pickup Truck 4WD	**7106**	16.0963974	31.6575606	5.6265052	15.9655551	16.2272397
Standard Utility cars 4WD	**3109**	16.3965905	29.8983281	5.4679364	16.2043122	16.5888689
Two Seaters	**5054**	17.5182034	36.7618890	6.0631583	17.3510045	17.6854023
Van Cars	**781**	16.0204866	29.7124003	5.4509082	15.6376037	16.4033694

Table 7 **Descriptive Statistics For TOYOTA on High_mpg Based on Class**

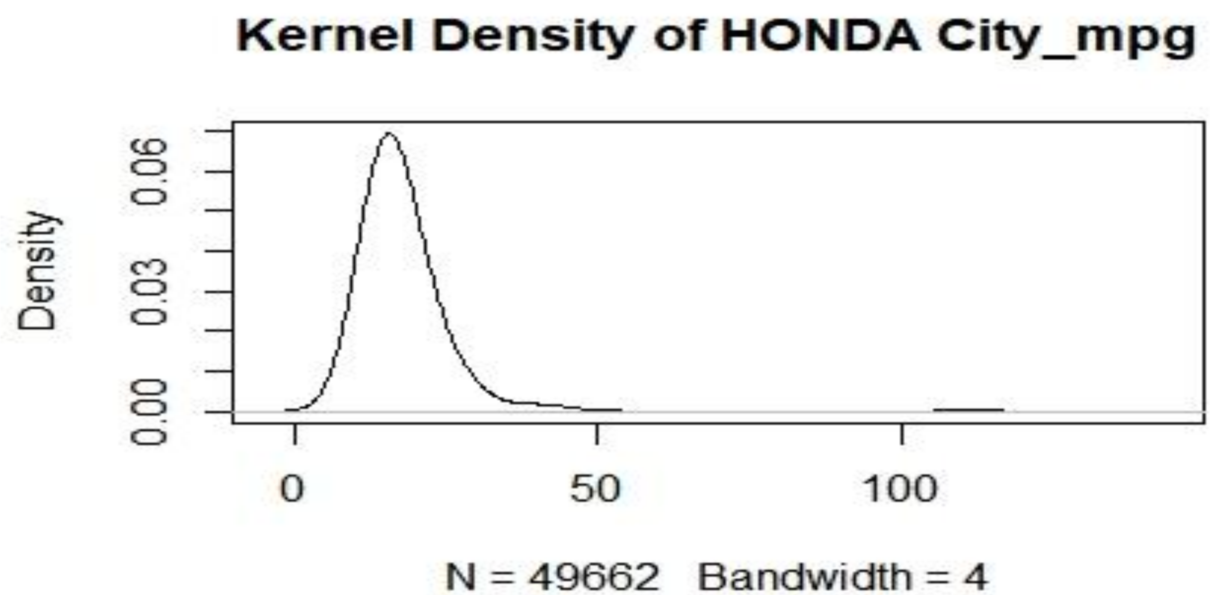
The MEANS Procedure

Analysis Variable : High_mpg						
Class	**N Obs**	**Mean**	**Variance**	**Std Dev**	**Lower 95% CL for Mean**	**Upper 95% CL for Mean**
Compact Car	**7981**	22.3124922	38.4584768	6.2014899	22.1764162	22.4485681
Large Sport Utility cars	**2139**	21.3749416	27.6993905	5.2630210	21.1517778	21.5981054
Midsize Car	**6578**	22.9702037	43.9696153	6.6309589	22.8099318	23.1304756
Midsize Station Wagons	**908**	21.8755507	33.4828415	5.7864360	21.4986766	22.2524247
Small Pickup Truck 2WD	**3469**	22.1640242	30.8401587	5.5533916	21.9791587	22.3488897
Small Standard Wagons	**6769**	23.0717979	50.6349152	7.1158215	22.9022515	23.2413443
Small Sport Utility Cars	**5233**	22.6287025	50.4410491	7.1021862	22.4362315	22.8211734
Standard Pickup Truck 4WD	**7106**	21.8335210	40.3831183	6.3547713	21.6857431	21.9812988
Standard Utility cars 4WD	**3109**	22.3116758	40.3201371	6.3498139	22.0883865	22.5349651
Two Seaters	**5054**	23.1228730	41.6969515	6.4573177	22.9448047	23.3009413
Van Cars	**781**	21.4788732	37.8832069	6.1549335	21.0465383	21.9112082

R OUTPUT

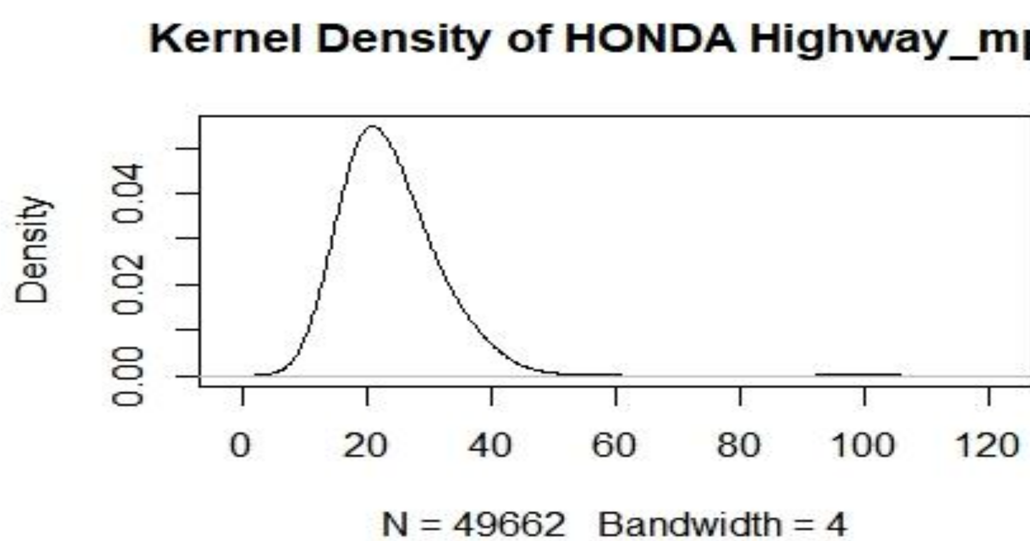
#FIGURE 1: R-CODE FOR KERNEL DENSITY ESTIMATION

```
> #The Kernel Density Estimation of Honda City Mpg
  > den_H1 <- density(HONDA$City_mpg, bw = 4, na.rm = TRUE)
> plot1=plot(den_H1, main="Kernel Density of HONDA City_mpg", ylab =
"Density")
```

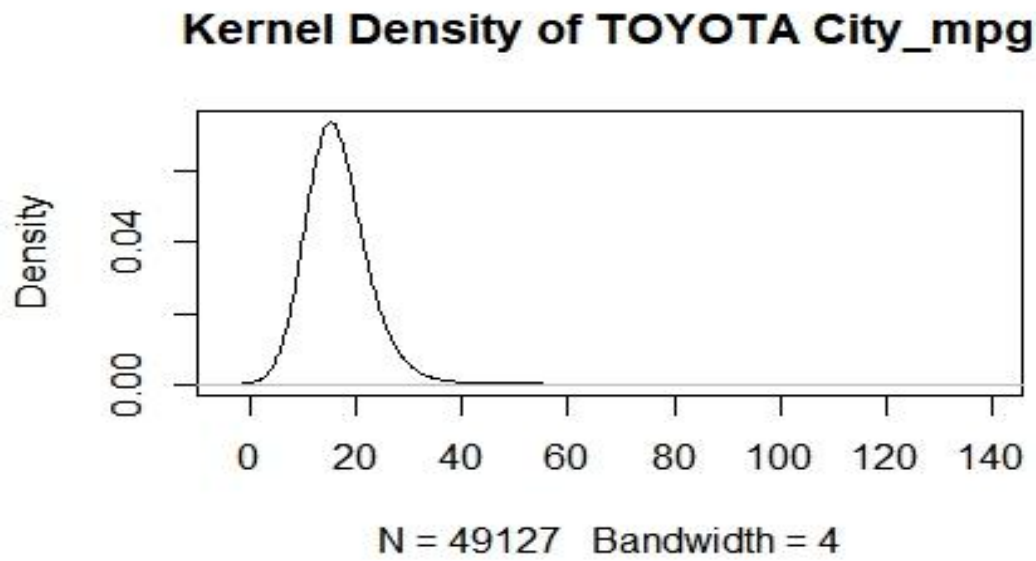


 # FIGURE 2: The Kernel Density Estimation of Honda Highway Mpg

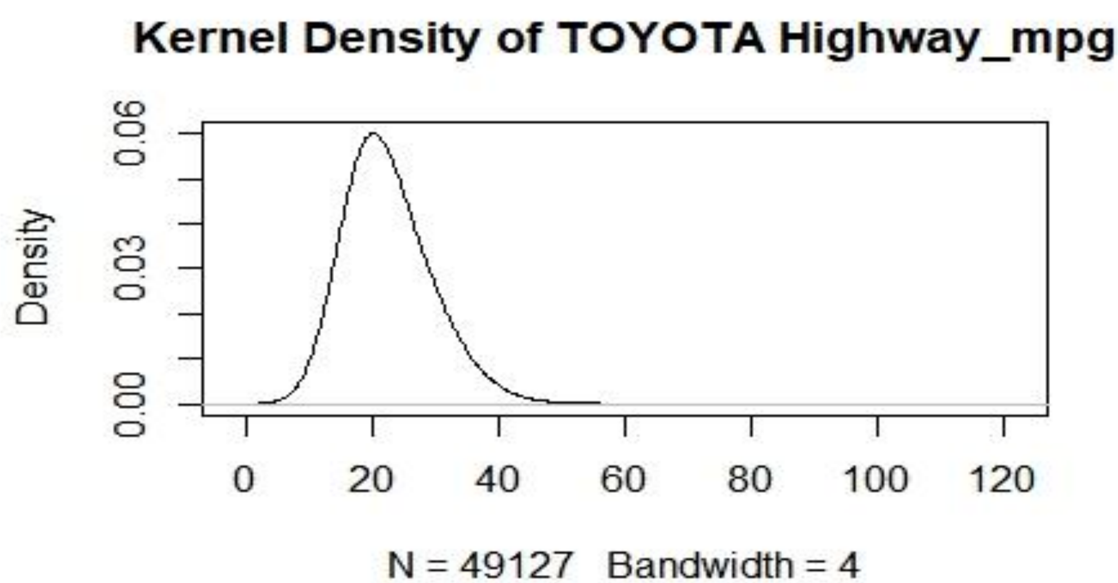
```
> den_H2 <- density(HONDA$High_mpg, bw = 4, na.rm = TRUE)
> plot1=plot(den_H2, main="Kernel Density of HONDA Highway_mpg", ylab = "Dens
ity")
```



```
#######################################################################
> # FIGURE 3:  The Kernel Density Estimation of Toyota City Mpg
> den_T1 <- density(TOYOTA$City_mpg, bw = 4, na.rm = TRUE)
> plot1=plot(den_T1, main="Kernel Density of TOYOTA City_mpg", ylab = "Densit
y")
>
```




```
# FIGURE 4:  The Kernel Density Estimation of Toyota Highway Mpg
> den_T2 <- density(TOYOTA$High_mpg, bw = 4, na.rm = TRUE)
> plot1=plot(den_T2, main="Kernel Density of TOYOTA Highway_mpg", ylab = "Density")
```



Appendix B

i) R-OUTPUT FROM THE ANALYSIS OF THIS PROJECT

```
> ####STRATIFIED RANDOM SAMPLE FOR HONDA VEHICLE MAKE ##########
>
> library(stratification)
> library(PracTools)
> #Sample Size Estimation#
> var(HONDA$City_mpg)
[1] 57.56079
> library(samplingbook)
> sample.size.mean(e= 0.10 , S=sqrt(57.56079), N= 49662, level= 0.95)

sample.size.mean object: Sample size for mean estimate
With finite population correction: N=49662, precision e=0.1 and standard deviation S=
7.5869

Sample size needed: 15300

> #Neyman Allocation,Stratified Sampling#
> Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")
> Nh = c(4961, 7022, 80, 3070, 7106, 1528, 10988,11566,560,1385,1396)
> Sh = c(8.422, 8.9867, 3.752, 7.035, 6.732, 4.049, 7.474, 7.173, 10.443, 6.734, 7.80
7)
> sample=strAlloc(n.tot = 15300, Nh = Nh, Sh = Sh, alloc = "neyman")
> sample


                      allocation = neyman
                         Nh = 4961, 7022, 80, 3070, 7106, 1528, 10988, 11566, 560, 13
85, 1396
                         Sh = 8.4220, 8.9867, 3.7520, 7.0350, 6.7320, 4.0490, 7.4740,
7.1730, 10.4430, 6.7340, 7.8070

                         nh = 1718.57901, 2595.64986, 12.34633, 888.35697, 1967.67945
, 254.48147, 3377.97774, 3412.47170, 240.54611, 383.62590, 448.28544
                         nh/n = 0.1123254255, 0.1696503178, 0.0008069496, 0.058062547
4, 0.1286064999, 0.0166327760, 0.2207828589, 0.2230373658, 0.0157219682, 0.0250735885
, 0.0292997022

anticipated SE of estimated mean = 0.05016355
>
> #Survey Design Stratified FOR HONDA CITY MPG#
> HONDA$P <- NA
>
> #input Stratum weights#
> HONDA$P[HONDA$Class=="Compact Car"] <- 4961/1719
> HONDA$P[HONDA$Class=="Large Cars"] <- 7022/2596
> HONDA$P[HONDA$Class=="Large Sport Ucars"] <- 80/12
> HONDA$P[HONDA$Class=="Midsize Station Wagons"] <- 3070/888
> HONDA$P[HONDA$Class=="Small Pickup Truck 2WD"] <- 7106/1968
> HONDA$P[HONDA$Class=="Small sport Utility Cars"] <- 1528/254
> HONDA$P[HONDA$Class=="Small Station Wagon"] <- 10988/3378
> HONDA$P[HONDA$Class=="Standard Pickup Truck 4WD"]<- 11566/3412
> HONDA$P[HONDA$Class=="Standard Ucars 4WD"] <- 560/241
> HONDA$P[HONDA$Class=="Two Seaters"] <- 1385/384
> HONDA$P[HONDA$Class=="Van Cars"] <- 1396/448
```

```
> ####STRATIFIED RANDOM SAMPLING DESIGN FOR HONDA CITY MPG######
> stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=HONDA)
>
> #Mean Estimate of Str#
> ybar_str=svymean(~HONDA$City_mpg, design = stat_stra)
> ybar_str
                   mean     SE
HONDA$City_mpg 17.732 0.0351
>
> #Variance of the estimated mean
> var_ybar_str=svyvar(svymean(~HONDA$City_mpg, design = stat_stra))
> var_ybar_str
[1] 0.00123201

 #Confidence Interval of the Estimate mean#
 > confint(ybar_str)
                    2.5 %   97.5 %
 HONDA$City_mpg 17.66293 17.80033
 >
 > #Estimated total of Str
 > t_cup_str=svytotal(~HONDA$City_mpg, design = stat_stra)
 > t_cup_str
                   total     SE
 HONDA$City_mpg 3573468 7063.7

 #Variance of the estimated total
 > var_t_cup_str=svyvar(svytotal(~HONDA$City_mpg, design = stat_stra))
 > var_t_cup_str
 [1] 3038523

 >
 > #########SIMPLE RANDOM SAMPLE FOR HONDA CITY MPG#############
 >
 > ####estimate the statistics quantities for SRS FOR HONDA CITY MPG
 > N=49662
 > n=15300
 > HONDA$fpc_srs=N
 > HONDA$wgt_stra=N/n
 > View(HONDA)

 > srs_design=svydesign(ids=~1, weights =~wgt_srs, data=HONDA)

 > #Estimates SRS#
 > #Mean Estimate of SRS#
 > ybar_srs=svymean(~HONDA$City_mpg,srs_design)
 > ybar_srs
                   mean    SE
 HONDA$City_mpg 17.795 0.034


  > #Confidence interval of the mean eastimate
  > confint(svymean(~HONDA$City_mpg,srs_design),df=degf(srs_design))
                     2.5 %   97.5 %
  HONDA$City_mpg 17.7279 17.86136

  >

  > #Total Estimate of SRS#
  > t_cup_srs=svytotal(~City_mpg,srs_design)
  > t_cup_srs
             total     SE
  City_mpg 2868441 5487.9
```

```
> #Variance of the  eastimated total for SRS for Honda City mpg
> var_t_cup_srs=5487.9^2
> var_t_cup_srs
[1] 30117046
```

####STRATIFIED RANDOM SAMPLE HONDA VEHICLE MAKE HIGHWAY MPG #######

```
>
> library(stratification)
> library(PracTools)
> #Sample Size Estimation#
> var(HONDA$High_mpg)
[1] 60.35022
> sample.size.mean(e= 0.10, S=sqrt(60.35022), N= 49662, level= 0.95)

sample.size.mean object: Sample size for mean estimate
With finite population correction: N=49662, precision e=0.1 and standard deviation
S=7.7685

Sample size needed: 15806

> #Neyman Allocation,Stratified Sampling#
> Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")
> Nh =c(4961, 7022, 80, 3070, 7106, 1528, 10988,11566,560,1385,1396)
> Sh = c(8.2381470, 8.6201133, 5.2607786, 7.1932169, 7.1026195, 5.6082737, 7.752834
3, 7.6176532, 9.5646146, 7.3558717, 7.7146237)
> sample=strAlloc(n.tot = 15806, Nh = Nh, Sh = Sh, alloc = "neyman")
> sample


                      allocation = neyman
                              Nh = 4961, 7022, 80, 3070, 7106, 1528, 10988, 11566,
560, 1385, 1396
                              Sh = 8.238147, 8.620113, 5.260779, 7.193217, 7.102620
, 5.608274, 7.752834, 7.617653, 9.564615, 7.355872, 7.714624
                              nh = 1688.61274, 2500.95051, 17.38887, 912.41587, 208
5.33124, 354.06570, 3519.73892, 3640.28749, 221.30274, 420.93517,
444.97075
                            nh/n = 0.106833654, 0.158227920, 0.001100143,
 0.057725918, 0.131932889, 0.022400715, 0.222683723, 0.230310483, 0.014001186, 0.02
6631353, 0.028152015
anticipated SE of estimated mean = 0.05050903
```

```
 #Survey Design Stratified#
 > HONDA$P <- NA
 >
 > #input Stratum weights#
 > HONDA$P[HONDA$Class=="Compact Car"] <- 4961/1689
 > HONDA$P[HONDA$Class=="Large Cars"] <- 7022/2501
 > HONDA$P[HONDA$Class=="Large Sport Ucars"] <- 80/17
 > HONDA$P[HONDA$Class=="Midsize Station Wagons"] <- 3070/913
 > HONDA$P[HONDA$Class=="Small Pickup Truck 2WD"] <-7106/2085
 > HONDA$P[HONDA$Class=="Small sport Utility Cars"]<-1528/354
 > HONDA$P[HONDA$Class=="Small Station Wagon"] <- 10988/3520
 > HONDA$P[HONDA$Class=="Standard Pickup Truck 4WD"]<-11566/3640
 > HONDA$P[HONDA$Class=="Standard Ucars 4WD"] <- 560/221
 > HONDA$P[HONDA$Class=="Two Seaters"] <- 1385/421
 > HONDA$P[HONDA$Class=="Van Cars"] <- 1396/445


 >
```

```
> ###STRATIFIED RANDOM SAMPLING DESIG FOR HONDA HIGHWAY MPG###
> stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=HONDA)
>
> #Mean Estimate of Str#
> ybar_str=svymean(~HONDA$High_mpg, design = stat_stra)
> ybar_str
                  mean    SE
HONDA$High_mpg 23.741 0.035


> #Variance of the estimated mean
> var_ybar_str=0.035^2
> var_ybar_str
[1] 0.001225

> #Confidence Interval of the Estimate mean#
> confint(ybar_str)
                   2.5 %   97.5 %
HONDA$High_mpg 23.67229 23.80953
>
>
> #Estimated total of Stratified sampling
> t_cup_str=svytotal(~HONDA$High_mpg, design = stat_stra)
> t_cup_str
                  total     SE
HONDA$High_mpg 4125383    1738.6

>
> #Variance of the estimated total
> var_t_cup_str=1738.6^2
> var_t_cup_str
[1] 3021234
```

ii)

```
> #######SIMPLE RANDOM SAMPLE FOR HONDA HIGHWAY MPG#######
>
> ####estimate the statistics quantities for SRS ########
> N=49662
> n=15806
> HONDA$fpc_srs=N
> HONDA$wgt_stra=N/n
> srs_design=svydesign(ids=~1,weights=~wgt_stra, data=HONDA)
>
> #Estimates SRS#
> #Mean Estimate of SRS#
> ybar_srs=svymean(~HONDA$High_mpg,srs_design)
> ybar_srs
                  mean     SE
HONDA$High_mpg 23.787 0.0349
>
> #Confidence interval of the mean eastimate
> confint(svymean(~HONDA$High_mpg,srs_design),df=degf(srs_design))
                   2.5 %   97.5 %
HONDA$High_mpg 23.71821 23.85486
>
> #Total Estimate of SRS#
> t_cup_srs=svytotal(~High_mpg,srs_design)
> t_cup_srs
            total      SE
```

```
High_mpg 3711570 5439.4
```

```
> #Variance of the  eastimate
> var_t_cup_srs=5439.4^2
> var_t_cup_srs
[1] 29587072
```

iii)

```
###SRATIFIED RANDOM SAMPLE FOR TOYOTA VEHICLE MAKE CITY MPG ###
> library(stratification)
> library(PracTools)
>
> #Sample Size Estimation#
> var(TOYOTA$City_mpg)
[1] 33.29825
> library(samplingbook)
> sample.size.mean(e= 0.10 , S=sqrt(33.29825), N= 49127, level= 0.95)

sample.size.mean object: Sample size for mean estimate
With finite population correction: N=49127, precision e=0.1 and standard deviati
on S=5.7705

Sample size needed: 10149

>
> #Neyman Allocation,Stratified Sampling#
> Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")
> Nh = c(7981, 2139, 6578, 908, 3469, 6769, 5233, 7106,3109, 5054,781)
> Sh = c(5.1748583, 3.7300218, 6.2753241, 4.4269300, 4.2018262, 6.5574165, 6.511
1980, 5.6265052, 5.4679364, 6.0631583, 5.4509082)
> sample=strAlloc(n.tot = 10149, Nh = Nh, Sh = Sh, alloc = "neyman")
> sample


                      allocation = neyman
                              Nh = 7981, 2139, 6578, 908, 3469, 6769, 5233, 7106
, 3109, 5054, 781
                              Sh = 5.174858, 3.730022, 6.275324, 4.426930, 4.201
826, 6.557417, 6.511198, 5.626505, 5.467936, 6.063158, 5.450908

                              nh = 1499.6950, 289.7139, 1498.9157, 145.9606, 529
.2850, 1611.7752, 1237.2539, 1451.8144, 617.2930, 1112.7083, 154.5849

                            nh/n = 0.14776777, 0.02854605, 0.14769098, 0.0143817
7, 0.05215144, 0.15881123, 0.12190894, 0.14305000, 0.06082304, 0.10963724, 0.015
23154

anticipated SE of estimated mean = 0.05017404
```

```
> #Survey Design Stratified#
> TOYOTA$P <- NA
> #input Stratum weights#
> TOYOTA$P[TOYOTA$Class == "Compact Car"] <- 7981/1500
> TOYOTA$P[TOYOTA$Class == "Large Sport Utility cars"] <- 2139/290
> TOYOTA$P[TOYOTA$Class == "Midsize Car"] <- 6578/1499
> TOYOTA$P[TOYOTA$Class == "Midsize Station Wagons"] <- 908/146
> TOYOTA$P[TOYOTA$Class == "Small Pickup Truck 2WD"] <- 3469/529
> TOYOTA$P[TOYOTA$Class == "Small Standard Wagons"] <- 6769/1612
> TOYOTA$P[TOYOTA$Class == "Small Sport Utility Cars"] <- 5233/1237
```

```
> TOYOTA$P[TOYOTA$Class == "Standard Pickup Truck 4WD"] <- 7106/1452
> TOYOTA$P[TOYOTA$Class == "Standard Utility cars 4WD"] <- 3109/617
> TOYOTA$P[TOYOTA$Class == "Two Seaters"] <- 5054/1112
> TOYOTA$P[TOYOTA$Class == "Van Cars"] <- 781/154
>
> #######STRATIFIED RANDOM SAMPLING DESIGN FOR TOYOTA CITY MPG######
> stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=TOYOTA)
> #Mean Estimate of Str#
> ybar_str=svymean(~TOYOTA$City_mpg, design = stat_stra)
> ybar_str
                  mean     SE
TOYOTA$City_mpg 16.647 0.0251


 > ##Variance of the estimated mean
 > var_ybar_str=0.0251^2
 > var_ybar_str
 [1] 0.00063001


 > #Confidence interval of the mean eastimate
 > confint(svymean(~TOYOTA$City_mpg,stat_stra),df=degf(stat_stra))
                    2.5 %   97.5 %
 TOYOTA$City_mpg 16.59789 16.69619


  > #Estimated total of Str
  > t_cup_str=svytotal(~TOYOTA$City_mpg, design = stat_stra)
  > t_cup_str
                    total     SE
  TOYOTA$City_mpg 4052515 6104.5

  >


 > #Variance of the estimated total
 > var_t_cup_str=6104.5^2
 > var_t_cup_str
 [1] 37264920
```

iv)

```
> ####################SIMPLE RANDOM SAMPLING FOR TOYOTA CITY MPG####
>
> ####estimate the statistics quantities for SRS ########
> N=49127
> n=10149
> TOYOTA$fpc_srs=N
> TOYOTA$wgt_stra=N/n
>
> srs_design=svydesign(ids=~1, weights =~wgt_stra, data=TOYOTA)
>
> #Estimates SRS#
> #Mean Estimate of SRS#
> ybar_srs=svymean(~TOYOTA$City_mpg,srs_design)
> ybar_srs
                  mean    SE
TOYOTA$City_mpg 16.704 0.026
>

> #Confidence interval of the mean eastimate
```

```
> confint(svymean(~TOYOTA$City_mpg,srs_design),df=degf(srs_design))
                     2.5 %  97.5 %
TOYOTA$City_mpg 16.65305 16.7551

> ####Variance of the estimated mean
> var_ybar_srs=0.026^2
> var_ybar_srs
[1] 0.000676




>
> #Total Estimate of SRS#
> t_cup_srs=svytotal(~City_mpg,srs_design)
> t_cup_srs
           total     SE
City_mpg 3972278 6191.1
>
> #Variance of the  eastimated total for SRS for TOYOTA City mpg
> var_t_cup_srs=6191.1^2
> var_t_cup_srs
[1] 38329719
```

v)

```
###STRATIFIED RANDOM SAMPLING FOR TOYOTA VEHICLE MAKE HIGHWAY MPG ##
> library(stratification)
> library(PracTools)
>
> #Sample Size Estimation#
> var(TOYOTA$High_mpg)
[1] 42.03938
> library(samplingbook)
> sample.size.mean(e= 0.10 , S=sqrt(42.03938), N= 49127, level= 0.95)

sample.size.mean object: Sample size for mean estimate
With finite population correction: N=49127, precision e=0.1 and standard deviation
S=6.4838

Sample size needed: 12154

> #Neyman Allocation,Stratified Sampling#
> Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")
> Nh = c(7981, 2139, 6578, 908, 3469, 6769, 5233, 7106,3109, 5054,781)
> Sh = c(6.2014899, 5.2630210, 6.6309589, 5.7864360, 5.5533916, 7.1158215, 7.10218
62, 6.3547713, 6.3498139, 6.4573177, 6.1549335)
> sample=strAlloc(n.tot = 12154, Nh = Nh, Sh = Sh, alloc = "neyman")
> sample

                      allocation = neyman
                              Nh = 7981, 2139, 6578, 908, 3469, 6769, 5233, 7106,
3109, 5054, 781
                              Sh = 6.201490, 5.263021, 6.630959, 5.786436, 5.55339
2, 7.115822, 7.102186, 6.354771, 6.349814, 6.457318, 6.154934
                              nh = 1900.2602, 432.2207, 1674.6726, 201.7236, 739.6
433, 1849.3081, 1426.9294, 1733.7435, 757.9515, 1252.9886, 184.5585
                            nh/n = 0.15634854, 0.03556202, 0.13778777, 0.01659730,
0.06085595, 0.15215634, 0.11740410, 0.14264797, 0.06236231, 0.10309269, 0.01518500
anticipated SE of estimated mean = 0.05065602


>
```

```
####STRATIFIED RANDOM SAMPLING DESIGN FOR TOYOTA HIGHWAY MPG####
> stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=TOYOTA)
>
> #Mean Estimate of Str#
> ybar_str=svymean(~TOYOTA$High_mpg, design = stat_stra)
>
> ybar_str
                  mean     SE
TOYOTA$High_mpg 22.418 0.0288

>
> #Variance of the estimated mean
> var_ybar_str=0.0288^2
> var_ybar_str
[1] 0.00082944

> #Confidence Interval of the Estimate mean#
> confint(ybar_str)
                  2.5 %   97.5 %
TOYOTA$High_mpg 22.36108 22.47402

 >
 #Estimated total of Stratified sampling
 > t_cup_str=svytotal(~TOYOTA$High_mpg, design = stat_stra)
 > t_cup_str
                  total    SE
 TOYOTA$High_mpg 5457274 1414.86

 >
 #Variance of the estimated total
 > var_t_cup_str=7014^2
 > var_t_cup_str
 [1] 2001822

 >
```

vi)

```
 ##############SIMPLE RANDOM SAMPLE FOR TOYOTA HIGHWAY MPG#######
 > N=49127
 > n=10149
 > TOYOTA$fpc_srs=N
 > TOYOTA$wgt_stra=N/n
 >
 > srs_design=svydesign(ids=~1, weights =~wgt_stra, data=TOYOTA)
 >
 > #Estimates SRS#
 > #Mean Estimate of SRS#
 > ybar_srs=svymean(~TOYOTA$High_mpg,srs_design)
 > ybar_srs
                  mean     SE
 TOYOTA$High_mpg 22.48 0.0293
 >
 > #Confidence interval of the mean eastimate
 > confint(svymean(~TOYOTA$High_mpg,srs_design),df=degf(srs_design))
                   2.5 %  97.5 %
 TOYOTA$High_mpg 22.42293 22.5376
 >
 > var_ybar_srs=0.0293^2
```

```
> var_ybar_srs
[1] 0.00085849


#Total Estimate of SRS#
> t_cup_srs=svytotal(~High_mpg,srs_design)
> t_cup_srs
           total     SE
High_mpg 5345873 6956.4


> #Variance of the  eastimate
> var_t_cup_srs=6956.4^2
> var_t_cup_srs
[1] 48391501
```

vii)

```
> ####Gain from Stratification#####
> # The Relative Gain From Stratification For Honda City Mpg
> Gain_from_str=var_t_cup_str/var_t_cup_srs
> Gain_from_str=3038523/30117046
> Gain_from_str
[1] 0.1008905
>
> # The Relative Gain From Stratification For Honda Highway Mpg
> Gain_from_str=var_t_cup_str/var_t_cup_srs
> Gain_from_str=3021234/29587072
> Gain_from_str
[1] 0.1021133
>
> # The Relative Gain From Stratification For TOYOTA City Mpg
> Gain_from_str=var_t_cup_str/var_t_cup_srs
> Gain_from_str=37264920/38329719
> Gain_from_str
[1] 0.97222
>
> # The Relative Gain From Stratification For TOYOTA City Mpg
> Gain_from_str=var_t_cup_str/var_t_cup_srs
> Gain_from_str=2001822/48391501
> Gain_from_str
[1] 0.04136722

>
```

Appendix C

1. SAS CODES FOR DESCRIPTIVE STATISTICS OF THE DATA

```
/* Generated Code (IMPORT) */

/* Source File: MAIN.xlsx */

/* Source Path: /home/u45193287 */

/* Code generated on: 4/21/20, 2:33 AM */

%web_drop_table(WORK.IMPORT1);

FILENAME REFFILE '/home/u45193287/MAIN.xlsx';


PROC IMPORT DATAFILE=REFFILE

	DBMS=XLSX

	OUT=WORK.IMPORT1;

	GETNAMES=YES;

RUN;


PROC CONTENTS DATA=WORK.IMPORT1; RUN;

%web_open_table(WORK.IMPORT1);

******************************************************************************

TITLE"Descriptive Statistics Of Main Dataset on City_Mpg Based on Make";

proc means Data=WORK.IMPORT1 MEAN VAR STD CLM;

CLASS Make;

var City_Mpg;

Run;


FILENAME REFFILE '/home/u45193287/HONDA.xlsx';

PROC IMPORT DATAFILE=REFFILE

	DBMS=XLSX
```

```
        OUT=WORK.IMPORT;
        GETNAMES=YES;
RUN;
PROC CONTENTS DATA=WORK.IMPORT; RUN;
%web_open_table(WORK.IMPORT);
TITLE"Descriptive Statistics For HONDA on City_Mpg Based on Class";
Proc means Data=WORK.IMPORT;
RUN;

proc means Data=WORK.IMPORT Median MEAN VAR STD CLM;
CLASS Class;
var City_mpg;
run;

proc means Data=WORK.IMPORT Median MEAN VAR STD CLM;
CLASS Class;
var High_mpg;
Run;
FILENAME REFFILE '/home/u45193287/TOYOTA.xlsx';
PROC IMPORT DATAFILE=REFFILE
DBMS=XLSX
OUT=WORK.IMPORT;
GETNAMES=YES;
RUN;
PROC CONTENTS DATA=WORK.IMPORT; RUN;
%web_open_table(WORK.IMPORT);
TITLE"Descriptive Statistics For TOYOTA on City_mpg Based on Class";
proc means Data=WORK.IMPORT MEAN VAR STD CLM;
```

CLASS Class;

var City_mpg;

run;

 # R-CODES FOR KERNEL DENSITY ESTIMATION

#The Kernel Density Estimation of Honda City Mpg

den_H1 <- density(HONDA$City_mpg, bw = 4, na.rm = TRUE)

plot1=plot(den_H1, main="Kernel Density of HONDA City_mpg", ylab = "Density")

#The Kernel Density Estimation of Honda Highway Mpg

den_H2 <- density(HONDA$High_mpg, bw = 4, na.rm = TRUE)

plot1=plot(den_H2, main="Kernel Density of HONDA Highway_mpg", ylab = "Density")

###

#The Kernel Density Estimation of Toyota City Mpg

den_T1 <- density(TOYOTA$City_mpg, bw = 4, na.rm = TRUE)

plot1=plot(den_T1, main="Kernel Density of TOYOTA City_mpg", ylab = "Density")

#The Kernel Density Estimation of Toyota Highway Mpg

den_T2 <- density(TOYOTA$High_mpg, bw = 4, na.rm = TRUE)

plot1=plot(den_T2, main="Kernel Density of TOYOTA Highway_mpg", ylab = "Density")

2. R-CODES FOR SAMPLE SIZE DETERMINATION AND ESTIMATIONS

```
library(ggplot2)
library(funModeling)
library(tidyverse)
library(Hmisc)
library(dplyr)
library(plotly)
library(nnet)
library(ordinal)
library(leaps)
library(MASS)
library(lubridate)
library(survey)
library(SDaA)
library(magrittr)

####################### HONDA VEHICLE MAKE CITY MPG ###################
library(stratification)
library(PracTools)

#Sample Size Estimation#
var(HONDA$City_mpg)
library(samplingbook)
sample.size.mean(e= 0.10 , S=sqrt(57.56079), N= 49662, level= 0.95)

#Neyman Allocation,Stratified Sampling#
Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")
Nh = c(4961, 7022, 80, 3070, 7106, 1528, 10988,11566,560,1385,1396)
Sh = c(8.422, 8.9867, 3.752, 7.035, 6.732, 4.049, 7.474, 7.173, 10.443, 6.734, 7.807)
```

sample=strAlloc(n.tot = 15300, Nh = Nh, Sh = Sh, alloc = "neyman")

sample

#Survey Design Stratified#

HONDA$P <- NA

#input Stratum weights#

HONDA$P[HONDA$Class == "Compact Car"] <- 4961/1719

HONDA$P[HONDA$Class == "Large Cars"] <- 7022/2596

HONDA$P[HONDA$Class == "Large Sport Ucars"] <- 80/12

HONDA$P[HONDA$Class == "Midsize Station Wagons"] <- 3070/888

HONDA$P[HONDA$Class == "Small Pickup Truck 2WD"] <- 7106/1968

HONDA$P[HONDA$Class == "Small sport Utility Cars"] <- 1528/254

HONDA$P[HONDA$Class == "Small Station Wagon"] <- 10988/3378

HONDA$P[HONDA$Class == "Standard Pickup Truck 4WD"] <- 11566/3412

HONDA$P[HONDA$Class == "Standard Ucars 4WD"] <- 560/241

HONDA$P[HONDA$Class == "Two Seaters"] <- 1385/384

HONDA$P[HONDA$Class == "Van Cars"] <- 1396/448

head(HONDA)

#######STRATIFIED RANDOM SAMPLING DESIGN FOR HONDA CITY MPG##########

stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=HONDA)

#Mean Estimate of Str#

ybar_str=svymean(~HONDA$City_mpg, design = stat_stra)

ybar_str

#Variance of the estimated mean

var_ybar_str=svyvar(svymean(~HONDA$City_mpg, design = stat_stra))

var_ybar_str

#Confidence Interval of the Estimate mean#

confint(ybar_str)

#Estimated total of Str

t_cup_str=svytotal(~HONDA$City_mpg, design = stat_stra)

t_cup_str

#Variance of the estimated total

var_t_cup_str=svyvar(svytotal(~HONDA$City_mpg, design = stat_stra))

var_t_cup_str

#Design Effect#

svymean(~HONDA$City_mpg, design = stat_stra, deff = TRUE)

###density plot and smoothing

dens<-svysmooth(~City_mpg, stat_stra, bandwidth=4)

plot(dens)

#######SIMPLE RANDOM SAMPLING FOR HONDA CITY MPG##

####estimate the statistics quantities for SRS ########

N=49662

n=15300

HONDA$fpc_srs=N

HONDA$wgt_stra=N/n

srs_design=svydesign(ids=~1, weights =~wgt_stra, data=HONDA)

#Estimates SRS#

#Mean Estimate of SRS#

```
ybar_srs=svymean(~HONDA$City_mpg,srs_design)

ybar_srs
```

#Confidence interval of the mean eastimate

```
confint(svymean(~HONDA$City_mpg,srs_design),df=degf(srs_design))
```

#Total Estimate of SRS#

```
t_cup_srs=svytotal(~City_mpg,srs_design)

t_cup_srs
```

#Variance of the eastimated total for SRS for Honda City mpg

```
var_t_cup_srs=5487.9^2

var_t_cup_srs
```

###################### HONDA VEHICLE MAKE HIGHWAY MPG ###################

library(stratification)

library(PracTools)

#Sample Size Estimation#

```
var(HONDA$High_mpg)

library(samplingbook)

sample.size.mean(e= 0.10 , S=sqrt(60.35022), N= 49662, level= 0.95)
```

#Neyman Allocation,Stratified Sampling#

```
Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")

Nh = c(4961, 7022, 80, 3070, 7106, 1528, 10988,11566,560,1385,1396)
```

Sh = c(8.2381470, 8.6201133, 5.2607786, 7.1932169, 7.1026195, 5.6082737, 7.7528343, 7.6176532, 9.5646146, 7.3558717, 7.7146237)

sample=strAlloc(n.tot = 15806, Nh = Nh, Sh = Sh, alloc = "neyman")

sample

#Survey Design Stratified#

HONDA$P <- NA

#input Stratum weights#

HONDA$P[HONDA$Class == "Compact Car"] <- 4961/1689

HONDA$P[HONDA$Class == "Large Cars"] <- 7022/2501

HONDA$P[HONDA$Class == "Large Sport Ucars"] <- 80/17

HONDA$P[HONDA$Class == "Midsize Station Wagons"] <- 3070/913

HONDA$P[HONDA$Class == "Small Pickup Truck 2WD"] <- 7106/2085

HONDA$P[HONDA$Class == "Small sport Utility Cars"] <- 1528/354

HONDA$P[HONDA$Class == "Small Station Wagon"] <- 10988/3520

HONDA$P[HONDA$Class == "Standard Pickup Truck 4WD"] <- 11566/3640

HONDA$P[HONDA$Class == "Standard Ucars 4WD"] <- 560/221

HONDA$P[HONDA$Class == "Two Seaters"] <- 1385/421

HONDA$P[HONDA$Class == "Van Cars"] <- 1396/445

head(HONDA)

#######STRATIFIED RANDOM SAMPLING DESIGN FOR HONDA HIGHWAY MPG##########

stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=HONDA)

#Mean Estimate of Str#

ybar_str=svymean(~HONDA$High_mpg, design = stat_stra)

ybar_str

#Variance of the estimated mean

var_ybar_str=0.035^2

var_ybar_str

#Confidence Interval of the Estimate mean#

confint(ybar_str)

#Estimated total of Stratified sampling

t_cup_str=svytotal(~HONDA$High_mpg, design = stat_stra)

t_cup_str

#Variance of the estimated total

var_t_cup_str=6083.6^2

var_t_cup_str

#############SIMPLE RANDOM SAMPLE FOR HONDA HIGHWAY MPG########

N=49662

n=15806

HONDA$fpc_srs=N

HONDA$wgt_stra=N/n

srs_design=svydesign(ids=~1, weights =~wgt_stra, data=HONDA**)**

#Estimates SRS#

#Mean Estimate of SRS#

ybar_srs=svymean(~HONDA$High_mpg,srs_design)

ybar_srs

#Confidence interval of the mean eastimate

confint(svymean(~HONDA$High_mpg,srs_design),df=degf(srs_design))

#Total Estimate of SRS#

t_cup_srs=svytotal(~High_mpg,srs_design)

t_cup_srs

#Variance of the eastimate

var_t_cup_srs=5439.4^2

var_t_cup_srs

###################### TOYOTA VEHICLE MAKE CITY MPG ###################

library(stratification)

library(PracTools)

#Sample Size Estimation#

var(TOYOTA$City_mpg)

library(samplingbook)

sample.size.mean(e= 0.10 , S=sqrt(33.29825), N= 49127, level= 0.95)

#Neyman Allocation,Stratified Sampling#

Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")

Nh = c(7981, 2139, 6578, 908, 3469, 6769, 5233, 7106,3109, 5054,781)

Sh = c(5.1748583, 3.7300218, 6.2753241, 4.4269300, 4.2018262, 6.5574165, 6.5111980, 5.6265052, 5.4679364, 6.0631583, 5.4509082)

sample=strAlloc(n.tot = 10149, Nh = Nh, Sh = Sh, alloc = "neyman")

sample

#Survey Design Stratified#

TOYOTA$P <- NA

#input Stratum weights#

TOYOTA$P[TOYOTA$Class == "Compact Car"] <- 7981/1500

TOYOTA$P[TOYOTA$Class == "Large Sport Utility cars"] <- 2139/290

TOYOTA$P[TOYOTA$Class == "Midsize Car"] <- 6578/1499

TOYOTA$P[TOYOTA$Class == "Midsize Station Wagons"] <- 908/146

TOYOTA$P[TOYOTA$Class == "Small Pickup Truck 2WD"] <- 3469/529

TOYOTA$P[TOYOTA$Class == "Small Standard Wagons"] <- 6769/1612

```
TOYOTA$P[TOYOTA$Class == "Small Sport Utility Cars"] <- 5233/1237
TOYOTA$P[TOYOTA$Class == "Standard Pickup Truck 4WD"] <- 7106/1452
TOYOTA$P[TOYOTA$Class == "Standard Utility cars 4WD"] <- 3109/617
TOYOTA$P[TOYOTA$Class == "Two Seaters"] <- 5054/1112
TOYOTA$P[TOYOTA$Class == "Van Cars"] <- 781/154
head(TOTOTA)
```

#######STRATIFIED RANDOM SAMPLING DESIGN FOR TOYOTA CITY MPG##########

```
stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=TOYOTA)
```

#Mean Estimate of Str#

```
ybar_str=svymean(~TOYOTA$City_mpg, design = stat_stra)
ybar_str
```

##Variance of the estimated mean

```
var_ybar_str=0.0251^2
var_ybar_str
```

#Confidence interval of the mean eastimate

```
confint(svymean(~TOYOTA$City_mpg,stat_stra),df=degf(stat_stra))
```

#Estimated total of Str

```
t_cup_str=svytotal(~TOYOTA$City_mpg, design = stat_stra)
t_cup_str
```

#Variance of the estimated total

```
var_t_cup_str=6104.5^2
var_t_cup_str
```

##########SIMPLE RANDOM SAMPLING FOR TOYOTA CITY MPG ########################

####estimate the statistics quantities for SRS ########

N=49127

n=10149

TOYOTA$fpc_srs=N

TOYOTA$wgt_stra=N/n

srs_design=svydesign(ids=~1, weights =~wgt_stra, data=TOYOTA)

#Estimates SRS#

#Mean Estimate of SRS#

ybar_srs=svymean(~TOYOTA$City_mpg,srs_design)

ybar_srs

#Confidence interval of the mean eastimate

confint(svymean(~TOYOTA$City_mpg,srs_design),df=degf(srs_design))

####Variance of the estimated mean

var_ybar_srs=0.026^2

var_ybar_srs

#Total Estimate of SRS#

t_cup_srs=svytotal(~City_mpg,srs_design)

t_cup_srs

#Variance of the eastimated total for SRS for TOYOTA City mpg

var_t_cup_srs=6191.1^2

var_t_cup_srs

###################### TOYOTA VEHICLE MAKE HIGHWAY MPG ###################

library(stratification)

library(PracTools)

#Sample Size Estimation#

var(TOYOTA$High_mpg)

library(samplingbook)

sample.size.mean(e= 0.10 , S=sqrt(42.03938), N= 49127, level= 0.95)

#Neyman Allocation,Stratified Sampling#

Stratum=c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J","K")

Nh = c(7981, 2139, 6578, 908, 3469, 6769, 5233, 7106,3109, 5054,781)

Sh = c(6.2014899, 5.2630210, 6.6309589, 5.7864360, 5.5533916, 7.1158215, 7.1021862, 6.3547713, 6.3498139, 6.4573177, 6.1549335)

sample=strAlloc(n.tot = 12154, Nh = Nh, Sh = Sh, alloc = "neyman")

sample

#Survey Design Stratified#

TOYOTA$P <- NA

#input Stratum weights#

TOYOTA$P[TOYOTA$Class == "Compact Car"] <- 7981/1900

TOYOTA$P[TOYOTA$Class == "Large Sport Utility cars"] <- 2139/432

TOYOTA$P[TOYOTA$Class == "Midsize Car"] <- 6578/1675

TOYOTA$P[TOYOTA$Class == "Midsize Station Wagons"] <- 908/202

TOYOTA$P[TOYOTA$Class == "Small Pickup Truck 2WD"] <- 3469/740

TOYOTA$P[TOYOTA$Class == "Small Standard Wagons"] <- 6769/1849

TOYOTA$P[TOYOTA$Class == "Small Sport Utility Cars"] <- 5233/1427

TOYOTA$P[TOYOTA$Class == "Standard Pickup Truck 4WD"] <- 7106/1734

TOYOTA$P[TOYOTA$Class == "Standard Utility cars 4WD"] <- 3109/758

```
TOYOTA$P[TOYOTA$Class == "Two Seaters"] <- 5054/1253
TOYOTA$P[TOYOTA$Class == "Van Cars"] <- 781/184
head(TOTOTA)
```

#######STRATIFIED RANDOM SAMPLING DESIGN FOR TOYOTA HIGHWAY MPG##########

```
stat_stra=svydesign(id=~1, strata=~Class, weights=~P, data=TOYOTA)
```

#Mean Estimate of Str#

```
ybar_str=svymean(~TOYOTA$High_mpg, design = stat_stra)
ybar_str
```

#Variance of the estimated mean

```
var_ybar_str=0.0288^2
var_ybar_str
```

#Confidence Interval of the Estimate mean#

```
confint(ybar_str)
```

#Estimated total of Stratified sampling

```
t_cup_str=svytotal(~TOYOTA$High_mpg, design = stat_stra)
t_cup_str
```

#Variance of the estimated total

```
var_t_cup_str=7014^2
var_t_cup_str
```

#############SIMPLE RANDOM SAMPLE FOR TOYOTA HIGHWAY MPG########

```
N=49127
n=10149
TOYOTA$fpc_srs=N
TOYOTA$wgt_stra=N/n
```

srs_design=svydesign(ids=~1, weights =~wgt_stra, data=TOYOTA)

#Estimates SRS#

#Mean Estimate of SRS#

ybar_srs=svymean(~TOYOTA$High_mpg,srs_design)

ybar_srs

var_ybar_srs=0.0293^2

var_ybar_srs

#Confidence interval of the mean eastimate

confint(svymean(~TOYOTA$High_mpg,srs_design),df=degf(srs_design))

#Total Estimate of SRS#

t_cup_srs=svytotal(~High_mpg,srs_design)

t_cup_srs

#Variance of the eastimate

var_t_cup_srs=6956.4^2

var_t_cup_srs

####Gain from Stratification#####

 # The Relative Gain From Stratification For Honda City Mpg

Gain_from_str=var_t_cup_str/var_t_cup_srs

Gain_from_str=3038523/30117046

Gain_from_str

 # The Relative Gain From Stratification For Honda Highway Mpg

Gain_from_str=var_t_cup_str/var_t_cup_srs

Gain_from_str=3021234/29587072

Gain_from_str

 # The Relative Gain From Stratification For TOYOTA City Mpg

Gain_from_str=var_t_cup_str/var_t_cup_srs

Gain_from_str=37264920/38329719

Gain_from_str

 # The Relative Gain From Stratification For TOYOTA City Mpg

Gain_from_str=var_t_cup_str/var_t_cup_srs

Gain_from_str=2001822/48391501

Gain_from_str