Northumbria University
NEWCASTLE

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COURSE: MSc in Data Science

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Question Number 1

Introduction

This report gives the records from a six-month investigation carried by a local gym in other to find out if different modes of exercise (attending exercise classes vs. gym only workouts) have different effects on weight loss within gym members. The investigation involved 107 participants, shared between exercise classes (45 members) and gym only workout (62 members). the main metrics analysed include mean weight loss, mode weight loss, and variability in weight loss, as measured by the standard deviation.

Objective

The main aim is to examine which exercise modality is more effective in helping gym members lose weight.

Methods

The study concerns two different groups: 45 participants who attended exercise classes, and 62 who engaged in gym only workout. Weight loss data were gathered at the end of the six-months, emphasising on mean weight loss, mode weight loss, and standard deviation to evaluate the variation in weight loss across participants.

Results

Results shows that individuals who worked out alone (gym only workout) recorded higher average weight loss (2.5 kg) when compared to those in exercise classes (1.8 kg). The mode weight loss also followed suit, with gym only workouts at 1.7 kg and exercise classes at 1.5 kg. furthermore, compared to the exercise classes, the gym only individual exhibited greater variability in weight loss outcomes, as seen by a higher standard deviation (1.33 kg), compared to the exercise classes participants (1.03 kg).

Discussions

The findings imply that, when compared to exercise class members, gym only workout can be more successful in promoting weight reduction. This is further supported by the larger mean and median weight decreases that were seen in the gym-only group. Even while some individuals in the gym only group lost a considerable amount of weight, others did not, which may be due to discrepancy in training intensity, length, and personal dedication. This is indicated by the greater variability within the group.

Due to participant self-selection of their exercise mode, bias may have been introduced into the study. The results might have been influenced by those who choose individual workouts because they were more driven or because they had prior success with self-guided workouts. Moreover, the statistical robustness and representativeness of the results may have been impacted by the different research group sizes.

Limitations

A number of limitations were present in the study, like the possibility of self-selection bias and the effect of different group sizes on the results. In addition, the study did not account for outside factors that might have a substantial impact on weight reduction results, such as individuals' diets, lifestyle choices, or pre-existing levels of fitness.

Recommendations

Future studies should take into account a randomized controlled trial design to reduce selection biases and guarantee balanced representation across groups in order to overcome these limitations and get a deeper understanding of the effect of exercise modalities on weight reduction. Furthermore, incorporating controls for lifestyle and nutrition variables will yield a more thorough comprehension of the variables impacting weight reduction. Creating fitness regimens that are tailored to each person's tastes and level of fitness may help increase participant adherence and motivation, which might result in more reliable and effective weight reduction results.

In summary

Although the results imply that gym only workout may be more beneficial for weight reduction, the impact of self-selection and variations in group sizes point to the necessity for more study. These preliminary findings can be confirmed by applying more stringent research designs and taking into account broader lifestyle characteristics. This will facilitate the development of personalised exercise programs that successfully helps weight reduction and overall health.

Question Number 2

In statistical analysis, missing data presents a major difficulty that affects the precision and dependability of the results. One useful method for handling with missing data in statistical analysis is imputation, in Imputation, the missing values are filled with substituted values (Patrician, 2002). The easiest form of imputation is mean imputation, here missing values in a dataset are filled with the mean value of the current data points. This technique is useful when the dataset is big and the amount of missing data is minimal, making sure that the whole statistical properties of the dataset like the mean and variance are not significantly altered.

Advantages

- It is simple to comprehend and implement.
- No Data will be Lost as It allows researchers to keep all cases by adding missing values, thus retaining sample size and power.

Disadvantages

- Estimate of variances and covariance could be biased which can negatively affect statistical tests and confidence intervals.
- Errors could be underestimated by imputing mean values.
- It may not be suitable for all kind of analysis

Question Number 3

The dataset was gotten from the blackboard in a doc format. It was changed into a txt format and then imported into the R environment

Basic statistics was performed as seen below.

```
> # Load data from a text file
> cystic_fibrosis_data <- read.table("C:/Users/user/Downloads/Data_for_Question_3.txt", header
= TRUE, sep = "", na.strings = "NA", dec = ".", strip.white = TRUE)
> head(cystic_fibrosis_data)
  age sex height weight bmp fev1  rv frc tlc pemax
1   7   0    109   13.1  68   32 258 183 137    95
2   7   1    112   12.9  65   19 449 245 134    85
3   8   0    124   14.1  64   22 441 268 147   100
4   8   1    125   16.2  67   41 234 146 124    85
5   8   0    127   21.5  93   52 202 131 104    95
6   9   0    130   17.5  68   44 308 155 118    80
> # The summary statistics for each variable
> summary(cystic_fibrosis_data)
      age              sex            height          weight          bmp
 Min.   : 7.00   Min.   :0.00   Min.   :109.0   Min.   :12.9   Min.   :64.00
 1st Qu.:11.00   1st Qu.:0.00   1st Qu.:139.0   1st Qu.:25.1   1st Qu.:68.00
 Median :14.00   Median :0.00   Median :156.0   Median :37.2   Median :71.00
 Mean   :14.48   Mean   :0.44   Mean   :152.8   Mean   :38.4   Mean   :78.28
 3rd Qu.:17.00   3rd Qu.:1.00   3rd Qu.:174.0   3rd Qu.:51.1   3rd Qu.:90.00
 Max.   :23.00   Max.   :1.00   Max.   :180.0   Max.   :73.8   Max.   :97.00
      fev1             rv             frc             tlc            pemax
 Min.   :18.00   Min.   :158.0   Min.   :104.0   Min.   : 81   Min.   : 65.0
 1st Qu.:26.00   1st Qu.:188.0   1st Qu.:127.0   1st Qu.:101   1st Qu.: 85.0
 Median :33.00   Median :225.0   Median :139.0   Median :113   Median : 95.0
 Mean   :34.72   Mean   :255.2   Mean   :155.4   Mean   :114   Mean   :109.1
 3rd Qu.:44.00   3rd Qu.:305.0   3rd Qu.:183.0   3rd Qu.:128   3rd Qu.:130.0
 Max.   :57.00   Max.   :449.0   Max.   :268.0   Max.   :147   Max.   :195.0
>
```

```
> summary(cystic_fibrosis_data$age)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   7.00   11.00   14.00   14.48   17.00   23.00
```

The age range is from 7 – 23 years and median age is 14 years and mean age exceeds the median slightly at 14.48 years, this may suggest a little skewness to the right. The interquartile range spreads from 11 – 17 years suggesting moderate variability in age within the participants.

```
summary(cystic_fibrosis_data$sex)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  0.00    0.00    0.00    0.44    1.00    1.00
```

The summary statistics for sex in the cystic fibrosis dataset show that it's binary. 0 is representing the male and 1 representing the female. The mean shows a little majority of the male (0.44), while the dataset contains both male and female, with male being more prevalent.

```
summary(cystic_fibrosis_data$weight)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  12.9    25.1    37.2    38.4    51.1    73.8
```

Weight shows a range of 12.9 – 73.8 kg, median 37.2 kg and mean weight 38.4kg. the quartiles are indicating that most weigh within 25 – 51 kg.

```
summary(cystic_fibrosis_data$bmp)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 64.00   68.00   71.00   78.28   90.00   97.00
```

The summary statistics for bmp shows a range from 64 to 97. with median blood pressure 71. The mean blood pressure is a little higher at 78.28. The first quartile is 68, and third quartile is 90.

```
summary(cystic_fibrosis_data$fev1)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 18.00   26.00   33.00   34.72   44.00   57.00
```

For FEV1 values range from 18 - 57. The median FEV1 is 33, and the mean is slightly higher at 34.72 suggesting that they may be some outliers in the dataset. The first quartile is 26, while the third quartile is 44.

```
> summary(cystic_fibrosis_data$rv)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 158.0   188.0   225.0   255.2   305.0   449.0
```

For RV, values are ranging from 158 to 449. The median RV is 225, the mean is higher at 255.2. The first quartile is 188, while the third quartile is 305.

```
summary(cystic_fibrosis_data$frc)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  104.0   127.0   139.0   155.4   183.0   268.0
```

For FRC, the values are ranging from 104 to 268. The median FRC is 139, while the mean FRC is higher at 155.4. This indicates a potential right skew in the distribution. The first quartile is 127, and the third quartile is 183, showing where the middle 50% of the data lies.

```
> summary(cystic_fibrosis_data$tlc)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
     81     101     113     114     128     147
```

The summary statistics show that values are ranging from 81 - 147. The median is 113, the mean is close at 114. This indicates a relatively symmetrical distribution. The first quartile is 101, and the third quartile is 128.

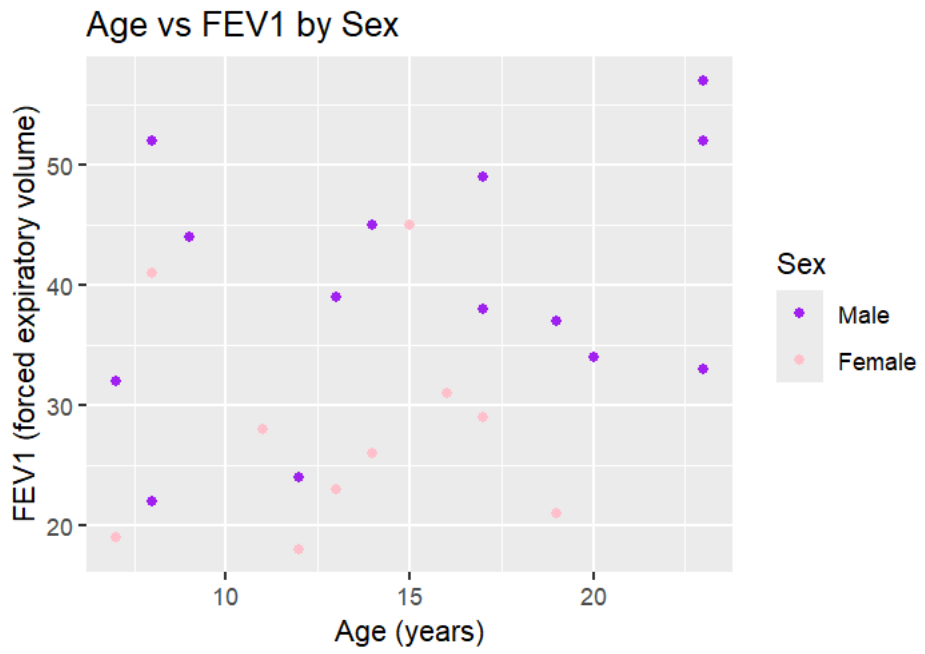
```
> summary(cystic_fibrosis_data$pemax)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   65.0    85.0    95.0   109.1   130.0   195.0
```

This shows values ranging from 65 - 195. The median Pemax is 95, the mean Pemax is higher at 109.1, suggesting a potential right skew in the distribution, with some higher values influencing the mean. The first quartile is 85, the third quartile is 130.

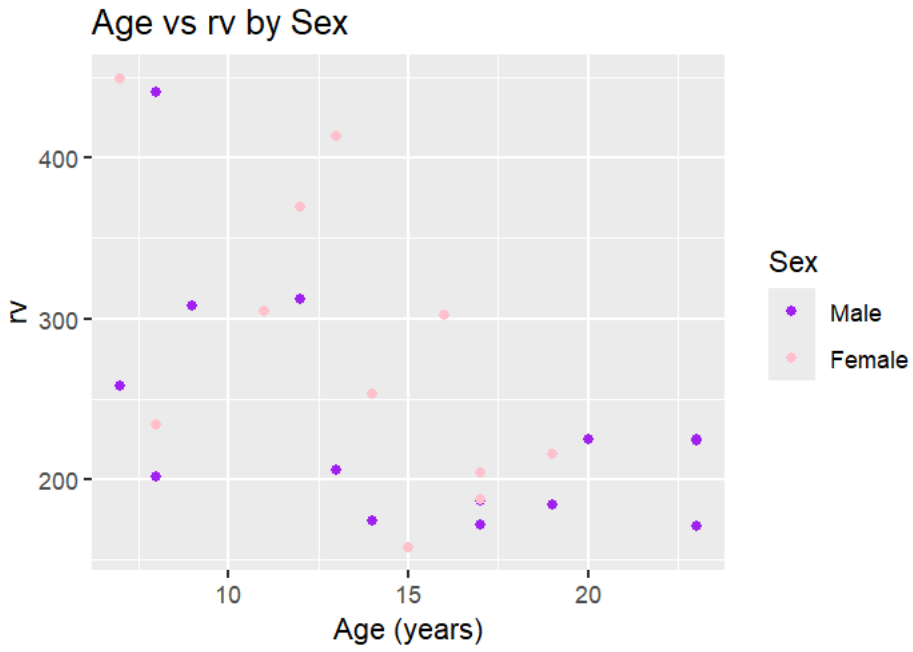
Question number 4

Section A: Scatterplots Our main objective is to investigate the relationships between different variables, including age, height, weight, and lung function measurements (fev1, rv, frc, tlc, pemax).

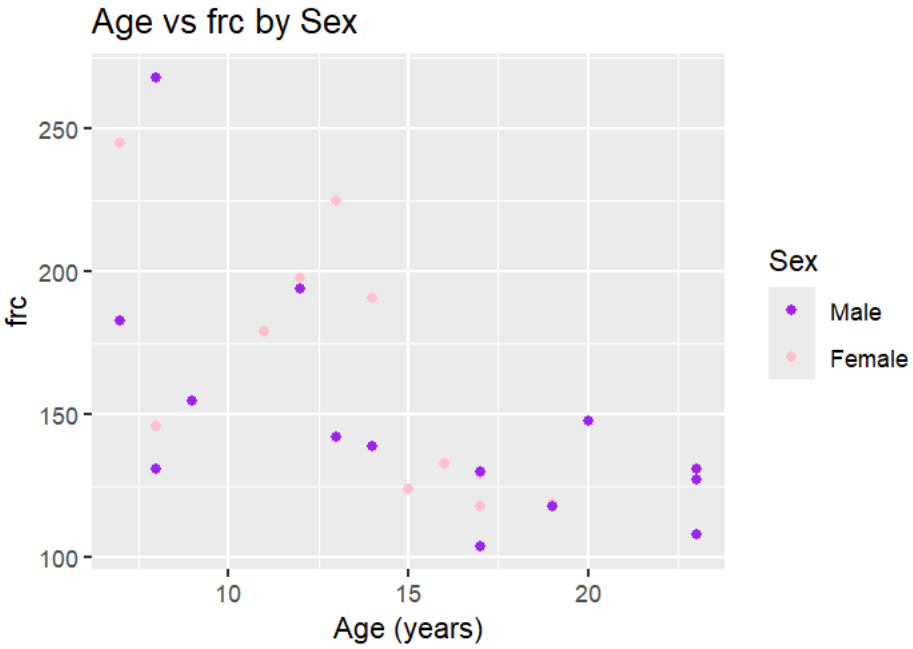
```
ggplot(cystic_fibrosis_data, aes(x = age, y = height, color = factor(sex))) +
  geom_point() +
  labs(title = "Relationship Between Age and Height, Differentiated by Gender",
       x = "Age in Years", y = "Height in Centimeters", color = "Gender") +
  scale_color_manual(labels = c("Males", "Females"), values = c("green", "orange"))

ggplot(cystic_fibrosis_data, aes(x = age, y = weight, color = factor(sex))) +
  geom_point() +
  labs(title = "How Age Influences Weight Across Genders",
       x = "Age in Years", y = "Weight in Kilograms", color = "Gender") +
  scale_color_manual(labels = c("Males", "Females"), values = c("darkred", "yellow"))

ggplot(cystic_fibrosis_data, aes(x = age, y = rv, color = factor(sex))) +
  geom_point() +
  labs(title = "Age vs Residual Volume by Gender",
       x = "Age (Years)", y = "RV (Residual Volume in mL)", color = "Gender") +
  scale_color_manual(labels = c("Males", "Females"), values = c("purple", "lightblue"))

ggplot(cystic_fibrosis_data, aes(x = age, y = frc, color = factor(sex))) +
  geom_point() +
  labs(title = "Functional Residual Capacity Over Age, Segregated by Gender",
       x = "Age (Years)", y = "FRC (Functional Residual Capacity in mL)", color = "Gender") +
  scale_color_manual(labels = c("Males", "Females"), values = c("cyan", "magenta"))

ggplot(cystic_fibrosis_data, aes(x = age, y = tlc, color = factor(sex))) +
  geom_point() +
  labs(title = "Total Lung Capacity vs Age, Analyzed by Gender",
       x = "Age in Years", y = "TLC (Total Lung Capacity in mL)", color = "Gender") +
  scale_color_manual(labels = c("Males", "Females"), values = c("navy", "gold"))

ggplot(cystic_fibrosis_data, aes(x = age, y = pemax, color = factor(sex))) +
  geom_point() +
```



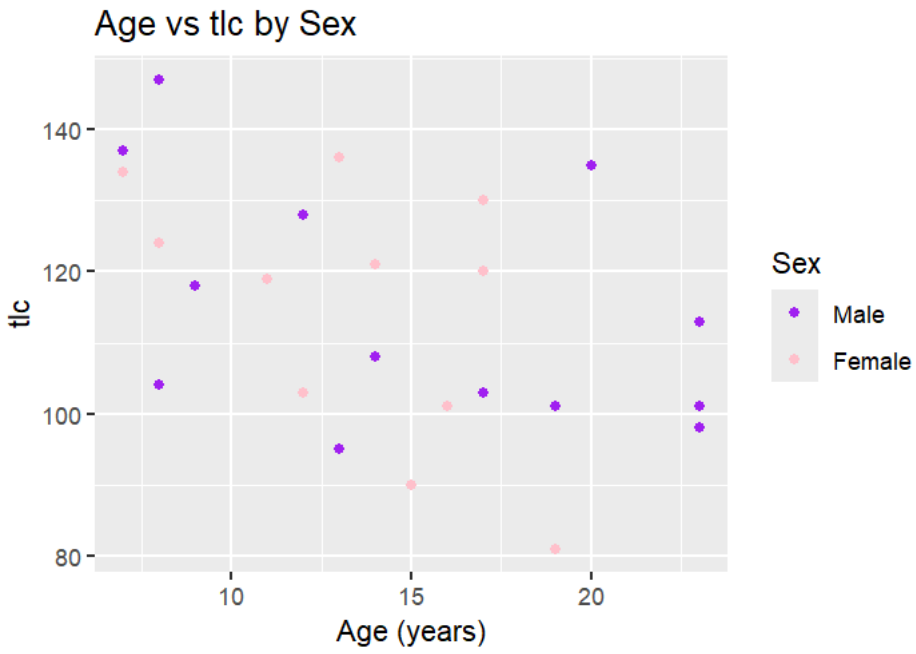
Age vs FEV1 by Sex-- FEV1 increases with age for both sexes with males generally showing higher FEV1 values than females.



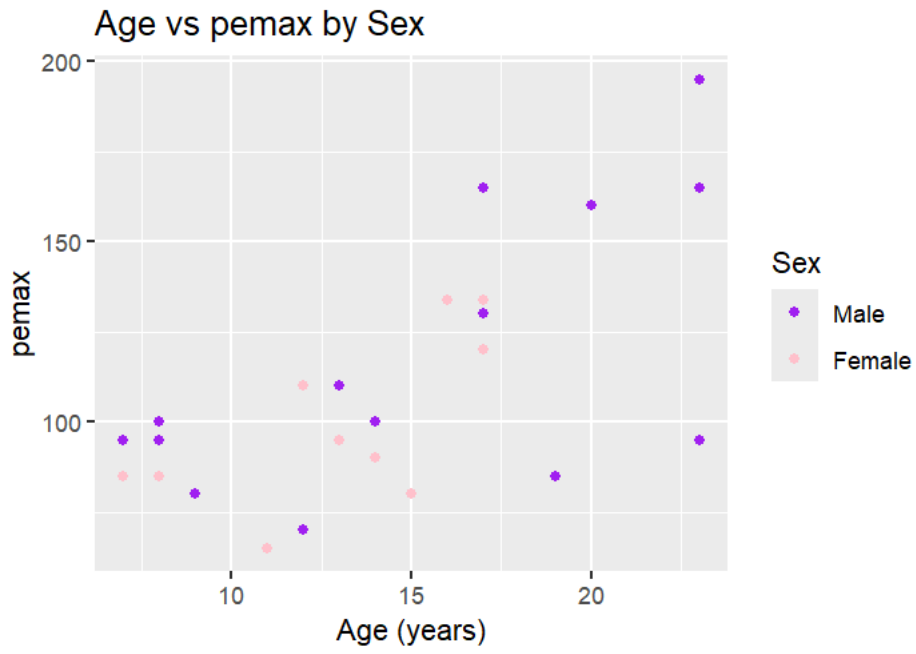
Age vs rv by Sex-- rv appears to be higher in females than males at most ages but does not show a clear trend with age for either sex.



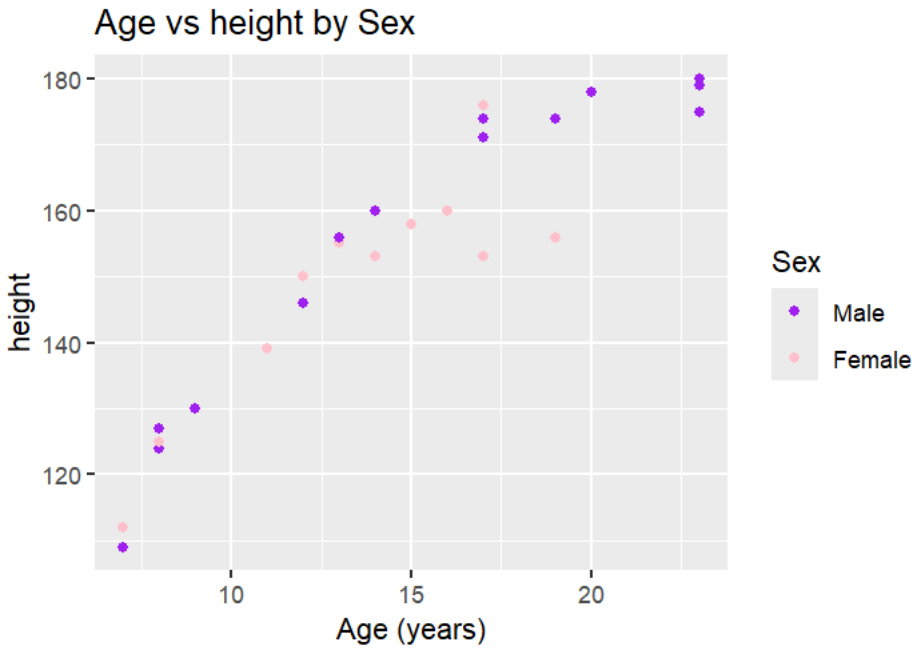
Age vs frc by Sex-- frc tends to decrease with age for both sexes, with males showing slightly higher frc values than females at younger ages.



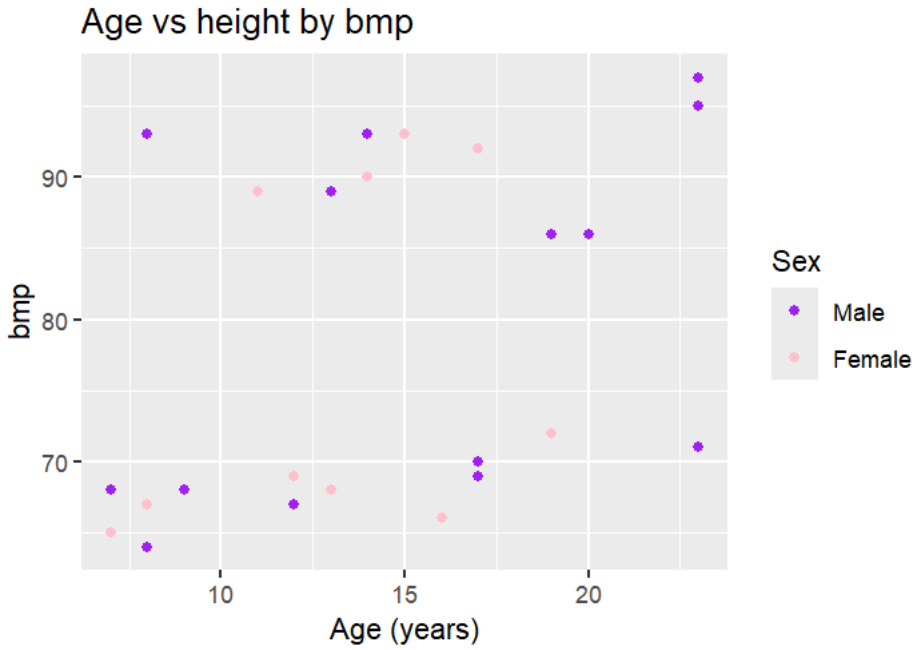
Age vs tlc by Sex-- There is no clear trend of tlc with age for either sex but males generally have higher tlc values compared to females across most age groups.



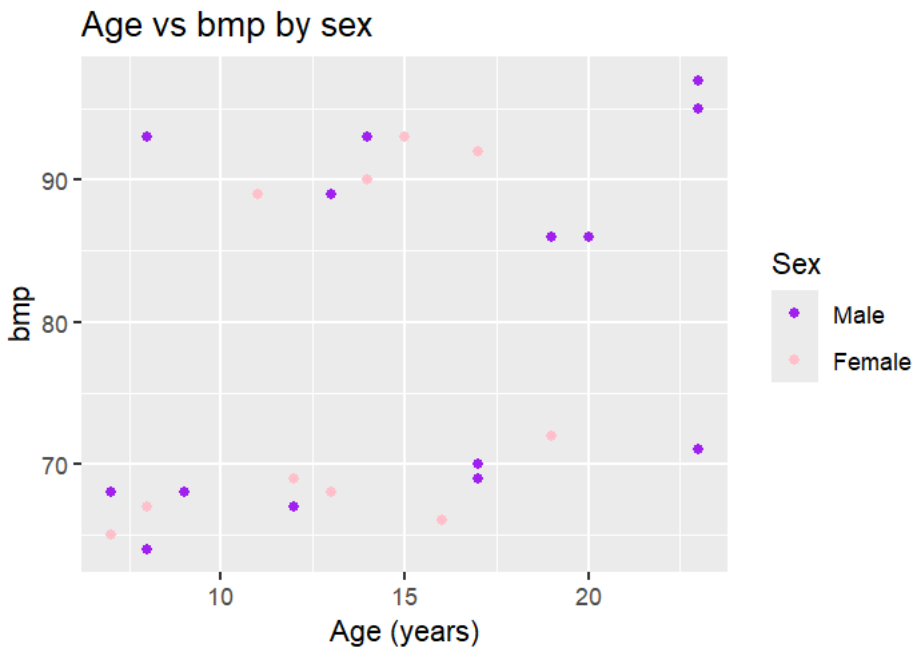
Age vs pemax by Sex-- pemax increases with age with males generally exhibiting higher pemax values than females.



Age vs height by Sex-- Height increases with age for both sexes with males generally being taller than females and especially after age 15.



Age vs height by bmp-- There is no clear relationship between age and bmp (beats per minute) but males tend to have higher bmp values than females at most ages.



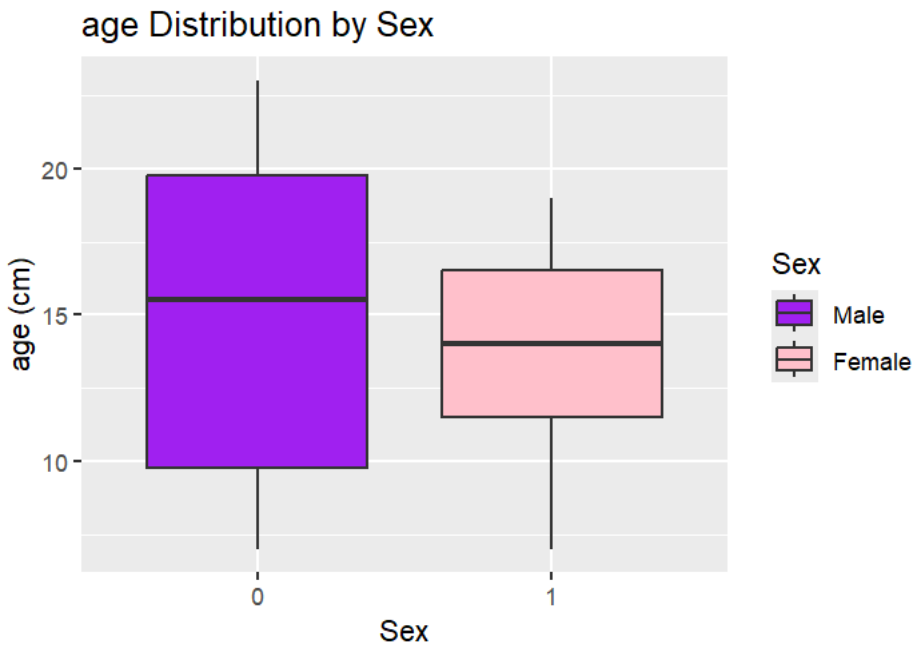
Age vs bmp by Sex-- bmp (beats per minute) does not show a clear trend with age for either sex but males generally have higher bmp values compared to females across most age groups.

Boxplots

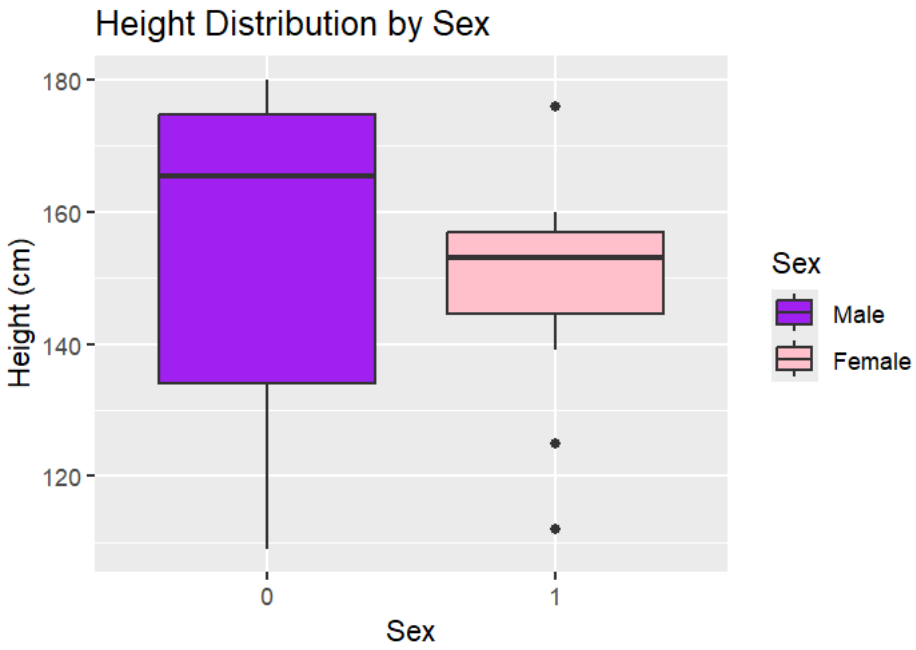
Below are boxplots of variables stratified by sex. This will help us find any signs of outlying observations.

A box plot is sometime called box and whisker plot and it is a visual tool that is frequently used in statistics to summarize and compare sets of data. it highlights a summarised visual depiction of the distribution of a dataset by highlighting its key summary (Nuzzo, 2016). It uses the median, approximate quartiles, and extreme data points to depict the level, spread, and symmetry of a dataset. This concise graphic also helps in spotting outliers as well (Hu, 2020).

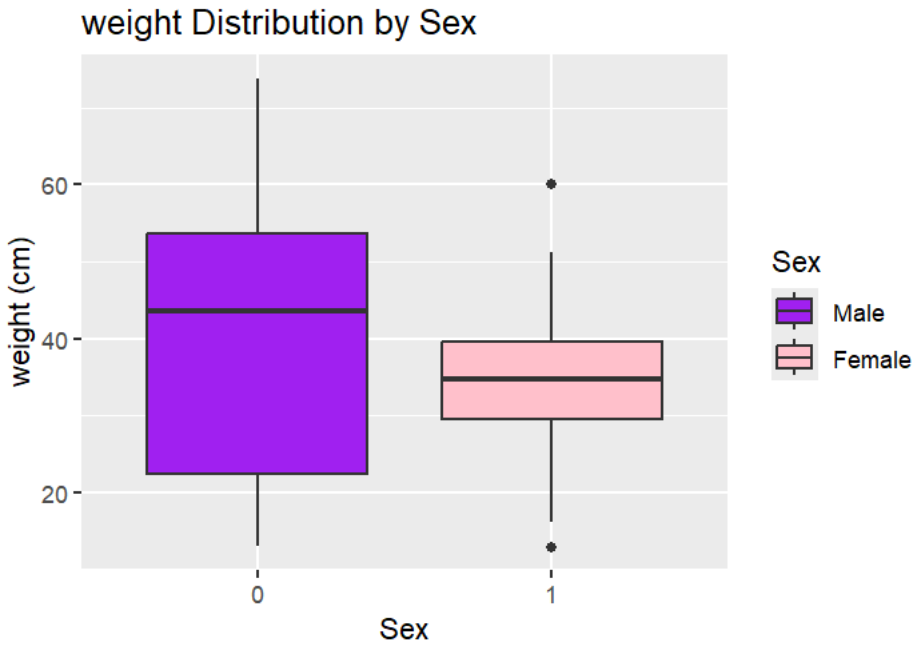
```r
# FRC Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = frc, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "FRC Distribution by Sex", x = "Sex", y = "FRC", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# TLC Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = tlc, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "TLC Distribution by Sex", x = "Sex", y = "TLC", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# PEMAX Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = pemax, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "PEMAX Distribution by Sex", x = "Sex", y = "PEMAX", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))
# Height Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = height, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "Height Distribution by Sex", x = "Sex", y = "Height (cm)", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# Weight Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = weight, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "Weight Distribution by Sex", x = "Sex", y = "Weight (kg)", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# BMP Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = bmp, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "BMP Distribution by Sex", x = "Sex", y = "BMP", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# FEV1 Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = fev1, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "FEV1 Distribution by Sex", x = "Sex", y = "FEV1", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# RV Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = rv, fill = factor(sex))) +
  geom_boxplot() +
  labs(title = "RV Distribution by Sex", x = "Sex", y = "RV", fill = "Sex") +
  scale_fill_manual(labels = c("Males", "Females"), values = c("purple", "yellow"))

# FRC Distribution by Sex
ggplot(cystic_fibrosis_data, aes(x = factor(sex), y = frc, fill = factor(sex))) +
```



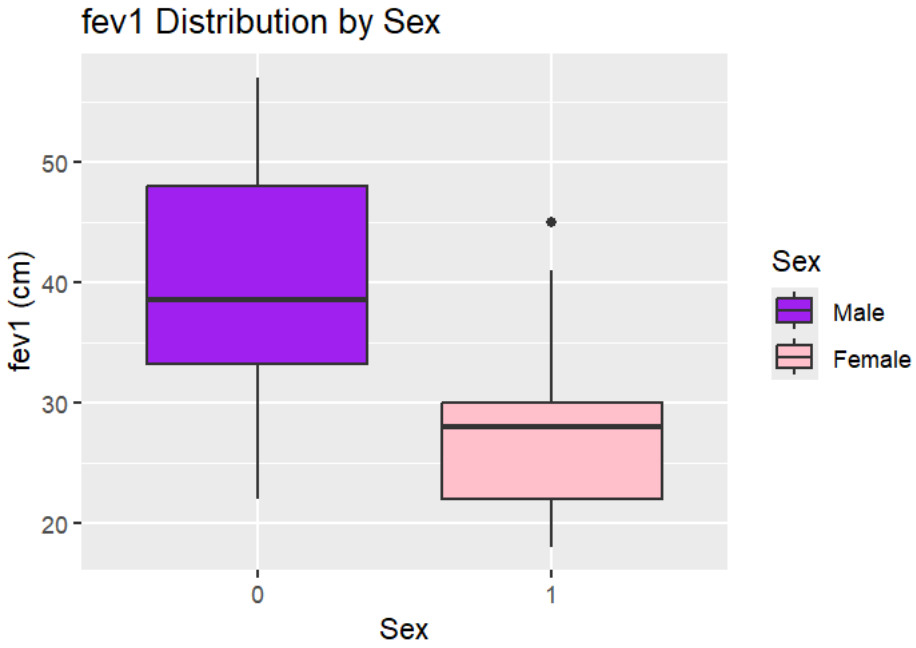
Age Distribution by Sex-- Males have a wider age distribution with a higher median age compared to females.



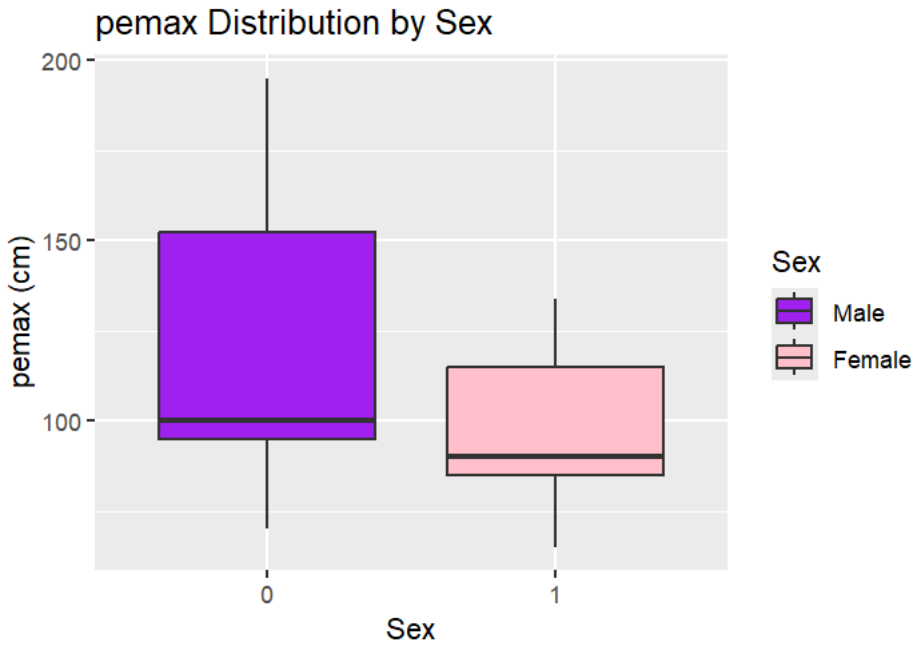
Height Distribution by Sex-- Males are generally taller with a wider range of height values and higher median height compared to females.



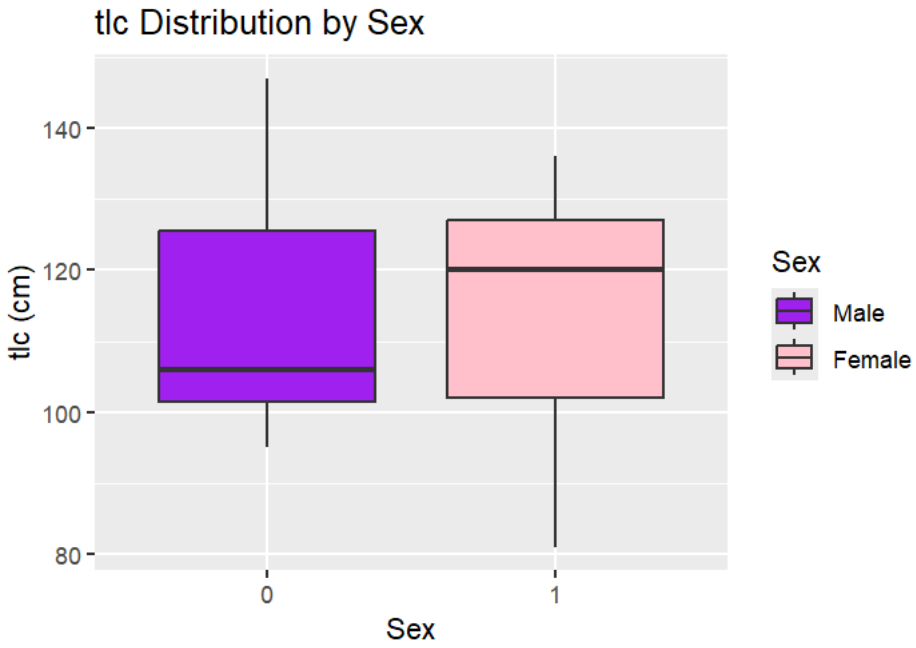
Weight Distribution by Sex-- Males have a wider weight distribution and a higher median weight compared to females.



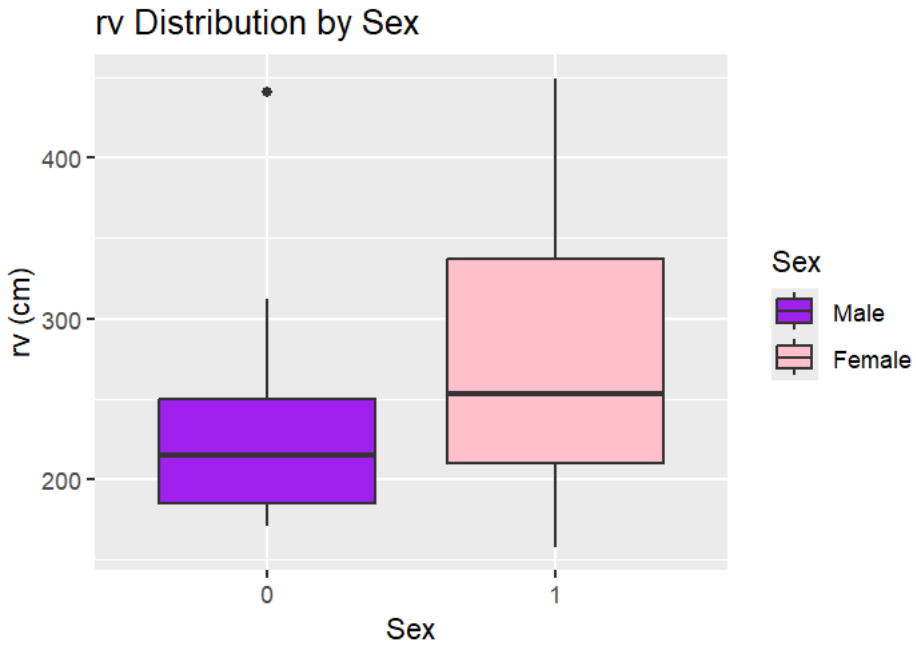
FEV1 Distribution by Sex-- Males have a wider distribution and higher median FEV1 values compared to females.



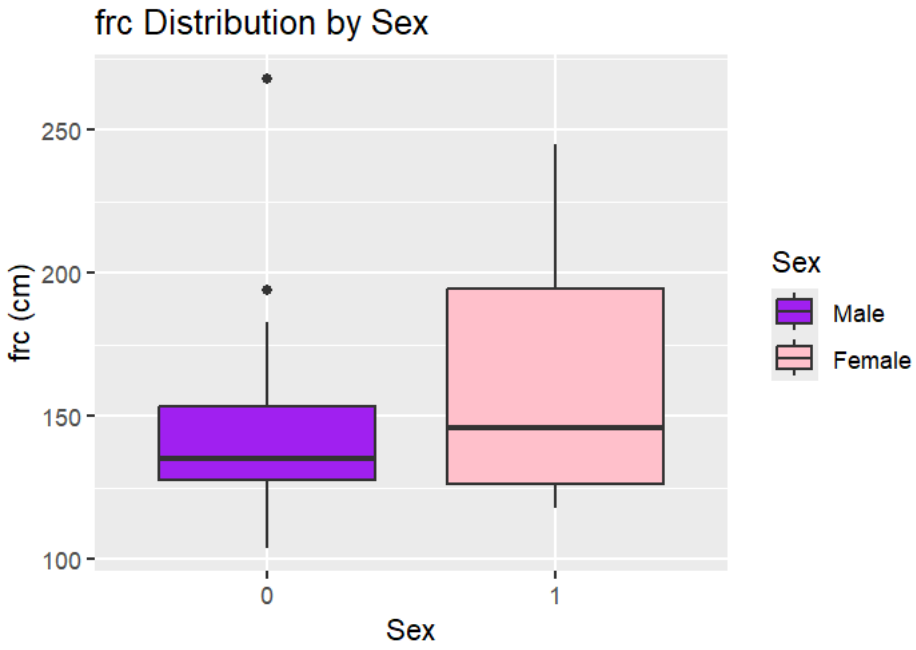
Pemax Distribution by Sex-- Males have a wider distribution and higher median pemax values compared to females.



TLC Distribution by Sex-- Males have a wider distribution of TLC values while females have a slightly higher median TLC value compared to males.



rv Distribution by Sex-- Females have a wider distribution and higher median rv values compared to males.



FRC Distribution by Sex-- Females have a wider distribution and higher median FRC values compared to males.

Question Number 5

This task involves determining the likelihood of a specific outcome in relation to a delicate heart operation. Given that the chance of a patient to recover from this operation is 0.87, we're to determine the probability that exactly 5 out of the following 8 patients survive the operation. This problem is best solved utilizing the binomial distribution formula because, it is works well for situations where there is a fixed number of trials (n), and each trial has two possible outcomes which is either success or failure, the probability of success (p) is constant, and the trials are independent.

The binomial probability formula is:

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

```
31
32  # Parameters
33  n <- 8   # Total number of patients (trials)
34  k <- 5   # Number of patients we're interested in recovering (successes)
35  p <- 0.87 # Probability of recovery (success)
36
37  # Calculating the probability
38  probability <- dbinom(k, n, p)
39
40  # Printing the result
41  probability
42
```

39:1 (Top Level)

Console Terminal Background Jobs

R 4.3.2 · ~/RWORK/Arka/

```
> # Parameters
> n <- 8   # Total number of patients (trials)
> k <- 5   # Number of patients we're interested in recovering (successes)
> p <- 0.87 # Probability of recovery (success)
>
> # Calculating the probability
> probability <- dbinom(k, n, p)
>
> # Printing the result
> probability
[1] 0.06132172
>
```

Question Number 6

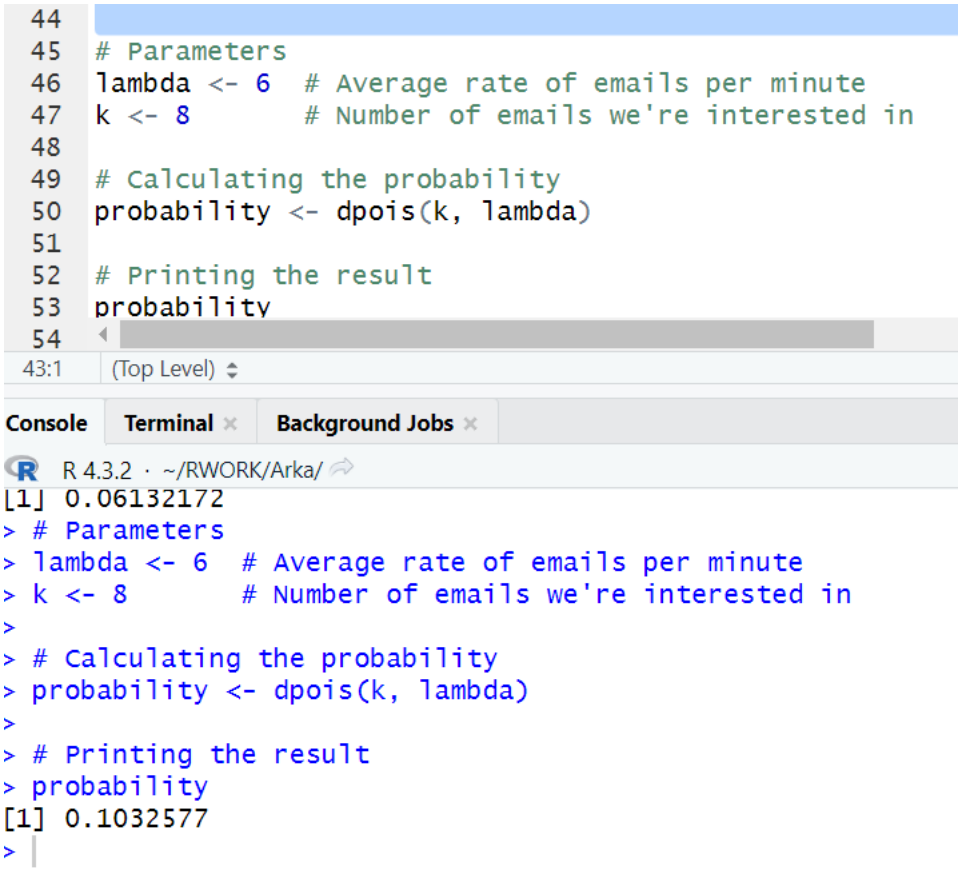
This task has to do with the probability of receiving a particular number of emails within a given minute, based on an average rate of occurrence. Specifically, we want to determine

the likelihood of receiving 8 emails in any given minute, given the average rate is 6 emails per minute.

The Poisson distribution, which counts the number of events that occur in a specified span of time or space given the average number of times the event happens throughout that interval (Thompson, 2001). Will be a suitable model for this situation.

The probability mass function (PMF) for the Poisson distribution is:

$$ P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!} $$



Question Number 7

Finding the probability that a fuel station, which sells 14,600 litters of fuel on average per day with a standard variation of 2,600 litters, would sell more than 10,000 litters in a single day is task entails. It is crucial to take into account both the manager's stored quantity of 20,000 litters as the upper bound and the usual lower selling bound of 10,000 litters for this activity. We can properly estimate the sales by using the normal distribution to examine this continuous data collection. The cumulative distribution function (CDF) of the normal

distribution gives us an understanding of the likelihood that a random variable—in this example, daily fuel sales won't surpass a given number. The likelihood of surpassing a specific sales volume may be calculated by deducting the CDF from 1. The CDF provides the likelihood of selling up to the lower bound (10,000 liters), which we deduct from 1 to obtain the probability of selling more. On the other hand, the chance of selling up to the upper bound (20,000 liters) is directly provided by the CDF. The difference between the likelihood of not surpassing the upper bound and the likelihood of exceeding the lower constraint represents the actual chance of sales lying within these boundaries.

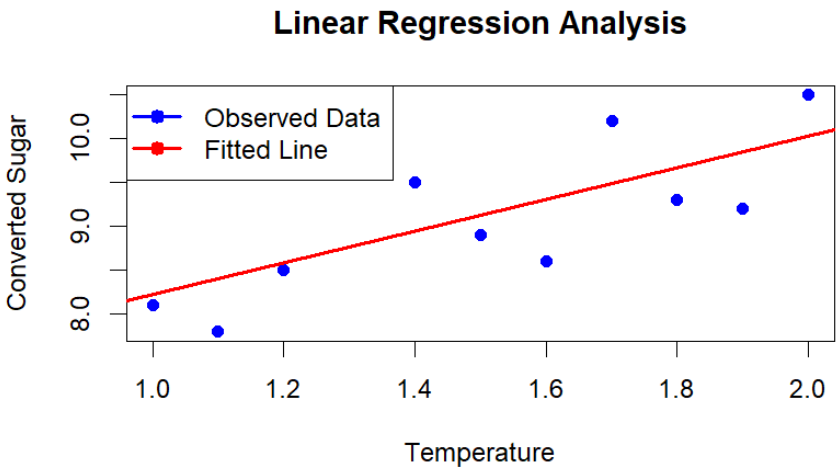
```
> # Parameters
> mean_sales <- 14600  # Mean daily sales in liters
> sd_sales <- 2600     # Standard deviation of daily sales in liters
> lower_bound <- 10000 # Lower sales bound
> upper_bound <- 20000 # Upper sales bound stocked by the manager
>
> # Calculate the probability of selling more than the lower bound
> probability_more_than_lower_bound <- 1 - pnorm(lower_bound, mean_sales, sd_sales)
>
> # Calculate the probability of selling up to the upper bound
> probability_less_than_upper_bound <- pnorm(upper_bound, mean_sales, sd_sales)
>
> # The probability of sales falling between the lower and upper bounds
> probability_between_bounds <- probability_less_than_upper_bound - (1 - probability
_more_than_lower_bound)
>
> # Output the result
> probability_between_bounds
[1] 0.942668
```

Using the normal distribution assumption for daily sales, we can deduce that the fuel station has a 94.27% probability of selling between 10,000 and 20,000 litters of fuel on that particular day.

Question Number 8

Here we fit a linear regression model to the data, and the outputs is a summary of the model

```
> # Sample data vectors for temperature and converted sugar
> temperature <- c(1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0)
> converted_sugar <- c(8.1, 7.8, 8.5, 9.8, 9.5, 8.9, 8.6, 10.2, 9.3, 9.2, 10.5)
>
> # Perform linear regression analysis
> regression_model <- lm(converted_sugar ~ temperature)
>
> # Summary of the linear regression model
> summary_regression <- summary(regression_model)
>
> # Print the summary to view the regression equation coefficients and statistics
> print(summary_regression)

Call:
lm(formula = converted_sugar ~ temperature)

Residuals:
    Min      1Q  Median      3Q     Max
-0.7082 -0.4868 -0.1227  0.5109  1.0346

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   6.4136     0.9246   6.936 6.79e-05 ***
temperature   1.8091     0.6032   2.999    0.015 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6326 on 9 degrees of freedom
Multiple R-squared:  0.4999,    Adjusted R-squared:  0.4443
F-statistic: 8.996 on 1 and 9 DF,  p-value: 0.01497

>
```



A scatter plot including a linear regression line is included to show the correlation between temperature and converted sugar.

Question 8b

Because we want to estimate from a known value, we would be Using the approx() for linear interpolation to estimate the quantity of converted sugar at a temperature of 1.75. Since the interpolation yields a single estimated value for a specific temperature, the mean of this value is the estimated value itself.

```
> # Using linear interpolation to estimate the converted sugar at temperature 1.75
> estimated_sugar <- approx(temperature, converted_sugar, xout = 1.75)$y
>
> # Since we're estimating for a single temperature, the mean of the estimated value
is the value itself
> mean_estimated_sugar <- mean(estimated_sugar)
>
> # Output the mean estimated amount of converted sugar
> print(paste("The mean estimated amount of converted sugar at temperature 1.75 i
s:", mean_estimated_sugar))
[1] "The mean estimated amount of converted sugar at temperature 1.75 is: 9.75"
```

Question Number 9

The coefficient of correlation, specifically Pearson's correlation coefficient (r), can be said to be the measures of the strength and direction of a linear relationship between two quantitative variables. It has a range from -1 to +1, where: +1 shows a perfect positive linear relationship, -1 shows a perfect negative linear relationship, 0 implies that there is no linear relationship.

```
# Define the data
advert <- c(0, 10, 4, 5, 2, 7, 3, 6)
purchase <- c(4, 12, 5, 10, 1, 3, 4, 8)

# Calculate the Pearson correlation coefficient
correlation_coefficient <- cor(advert, purchase)

# Print the correlation coefficient
print(correlation_coefficient)
1] 0.6790033

# Create a scatter plot to visualize the relationship
plot(advert, purchase, main = "Advertisements vs. Purchases",
     xlab = "Number of Advertisements", ylab = "Number of Purchases", pch = 19, co
= "blue")
```

Given the Correlation_Coeffient 0.679, it suggests a moderate to strong correlation given that the value is closer to 1 that it is to 0. It shows a substantial linear relationship but not a perfect one.

Question Number 10

M1 Speed Analysis Report

Introduction

Delivering goods in timely and efficiently is very important for a major manufacturing organization. So, as a director it is important to ensure the goals are achieved smoothly. Based on the requirement one of the major customers based on London needs lorries for delivery via the M1 motorway. So in order to understand the speed of the road, data has been collected from official England traffic website. So basically this reports deals with the sampling strategy, data collection, statistical analysis, conclusions, and relevant background research.

Sampling Strategy

For obtaining a representative sample from the M1 motorway for the traffic speeds and keeping the dataset small. we are using the below methods:-

1. **Systematic Sampling**: Data was collected at fixed intervals. Captured twice a day in order to capture the variations in traffic speed during different times of the day (morning and evening).
2. **Stratified Sampling**: Data was collected from different junctions (J1 to J48), ensuring the coverage of the entire length of the M1 motorway.

Systematic sampling helps in capturing periodic fluctuations in traffic speed. Systematic sampling ensures a balanced representation of peak and off-peak times. Stratified sampling ensures that data from various junctions, which might have different traffic patterns, are included. This combined approach enhances the reliability and representativeness of the sample. According to Cochran (1977), systematic sampling is particularly useful for reducing the standard error in cases where there are periodic trends in the population.

Data Collection

Collecting data at different times of the day ensures that we account for variations in traffic patterns. Morning and evening rush hours typically experience higher traffic volumes leading to slower speeds, while off-peak times often show higher speeds due to less congestion. This approach is supported by transport studies that highlight the significant impact of time-of-day on traffic flow (Arnott, De Palma, & Lindsey, 1993).

Source: Data was collected manually from the Traffic England website (http://www.trafficengland.com/traffic-report).

Data Points (Columns):

- **Datetime**: Timestamp of the data collection (like 2024-04-18 12:00:00).
- **Northbound Speed**: Speed of traffic heading north via M1 highway (eg – 60, 70).
- **Southbound Speed**: Speed of traffic heading south via M1 highway (eg – 60, 70).
- **From Junction**: The junction where the data was collected (like J1, J4,J34) .

Descriptive Statistics

Descriptive statistics offer insights into the central tendency, dispersion, and overall shape of the distribution of traffic speeds. The mean provides an average speed while the median indicates the middle value in the dataset. The standard deviation measures the extent of variation or dispersion from the mean. High standard deviation values in Southbound speeds indicate greater variability possibly due to varying traffic conditions or roadworks (Field, 2013).

Analysis

1. The higher mean and median speeds for Northbound traffic suggest that traffic flows more smoothly in that direction.
2. The greater standard deviation in Southbound speeds indicates more variability, suggesting potential issues such as congestion or varying road conditions affecting traffic flow.

The calculated key statistical metrics for Northbound and Southbound speeds. Here are the results:

- **Northbound Speeds**:
  - Mean: 63.26 mph
  - Standard Deviation: 6.99 mph
  - Median: 66 mph
- **Southbound Speeds**:
  - Mean: 58.85 mph
  - Standard Deviation: 10.62 mph
  - Median: 61 mph

```
> descriptive_stats <- data %>%
+   summarise(
+     Northbound_mean = mean(Northbound, na.rm = TRUE),
+     Southbound_mean = mean(Southbound, na.rm = TRUE),
+     Northbound_std = sd(Northbound, na.rm = TRUE),
+     Southbound_std = sd(Southbound, na.rm = TRUE),
+     Northbound_median = median(Northbound, na.rm = TRUE),
+     Southbound_median = median(Southbound, na.rm = TRUE)
+   )
>
> # get the  descriptive statistics results
> print(descriptive_stats)
# A tibble: 1 × 6
  Northbound_mean Southbound_mean Northbound_std Southbound_std Northbound_median Southbound_median
            <dbl>           <dbl>          <dbl>          <dbl>             <dbl>             <dbl>
1            63.3            58.9           6.99           10.6                66                61
```

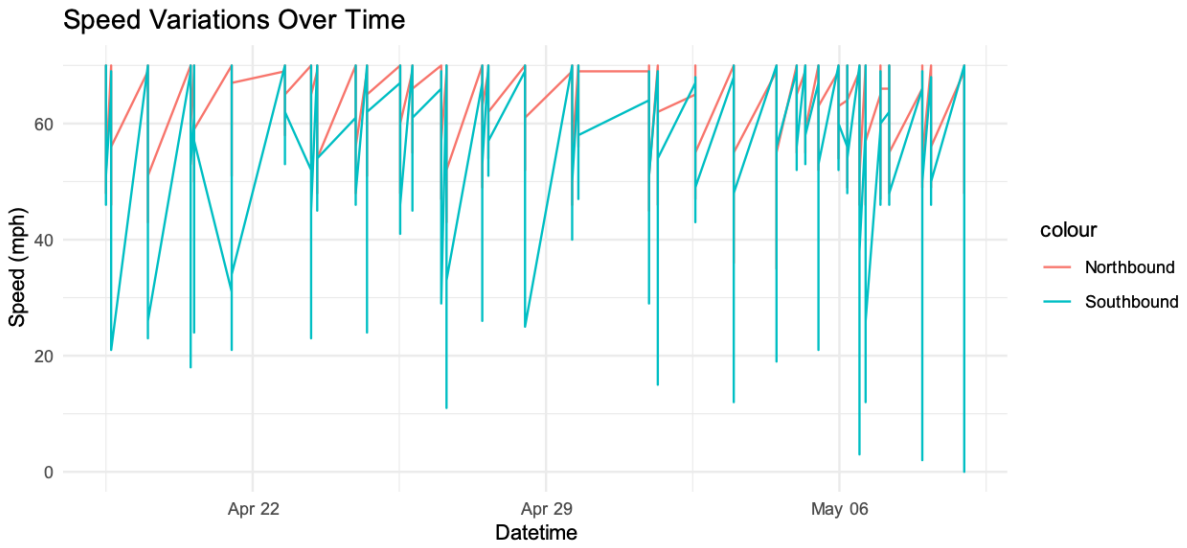
Visualizations and Insights

Visualizations help in identifying patterns and trends that are not immediately evident from raw data. For instance line graphs can show trends over time and box plots can display distributions and outliers and bar charts can compare different categories effectively. These visual tools are essential for making data-driven decisions (Tufte, 2001).

1. Speed Variations Over Time

This plot shows the variations in Northbound and Southbound speeds over time. Peaks and troughs indicate times of high and low traffic speeds, respectively.

```
> # Speed variations over time
> p1 <- ggplot(data, aes(x = Datetime)) +
+   geom_line(aes(y = Northbound, color = "Northbound")) +
+   geom_line(aes(y = Southbound, color = "Southbound")) +
+   labs(title = "Speed Variations Over Time", x = "Datetime", y = "Speed (mph)") +
+   theme_minimal()
>
> print(p1)
>
```



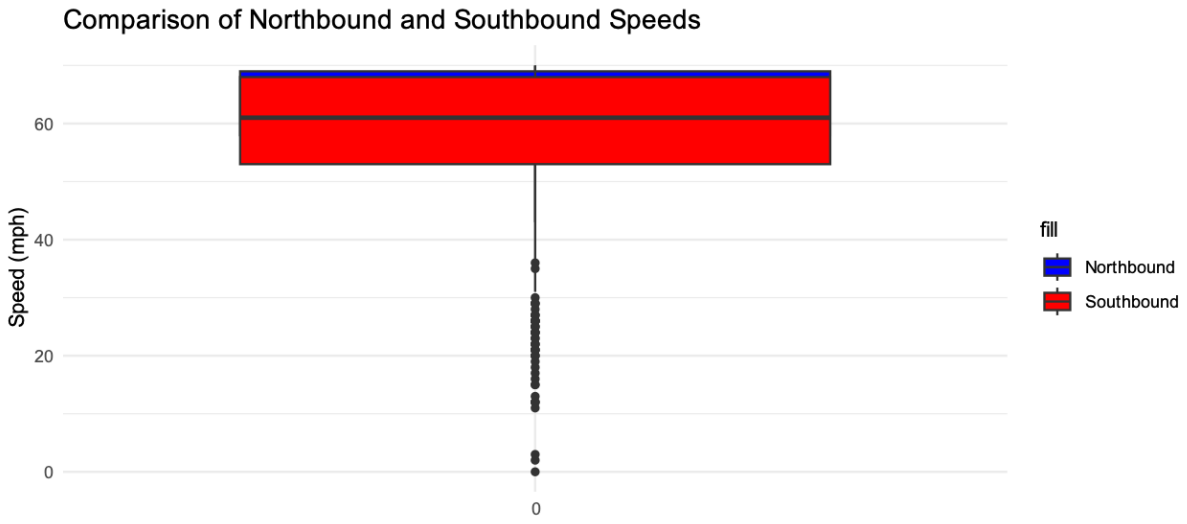
Insights-

1. Traffic speeds vary significantly over time.
2. Morning and evening rush hours show lower speeds due to higher congestion.
3. Off-peak hours demonstrate higher speeds indicating smoother traffic flow.

2. Comparison of Northbound and Southbound Speeds

The box plot compares the distribution of speeds for Northbound and Southbound traffic.

```
> # Comparison of Northbound and Southbound speeds
> p2 <- ggplot(data, aes(x = factor(0))) +
+   geom_boxplot(aes(y = Northbound, fill = "Northbound")) +
+   geom_boxplot(aes(y = Southbound, fill = "Southbound")) +
+   labs(title = "Comparison of Northbound and Southbound Speeds", x = "", y = "Speed (mph)") +
+   scale_fill_manual(values = c("Northbound" = "blue", "Southbound" = "red")) +
+   theme_minimal()
>
> print(p2)
```



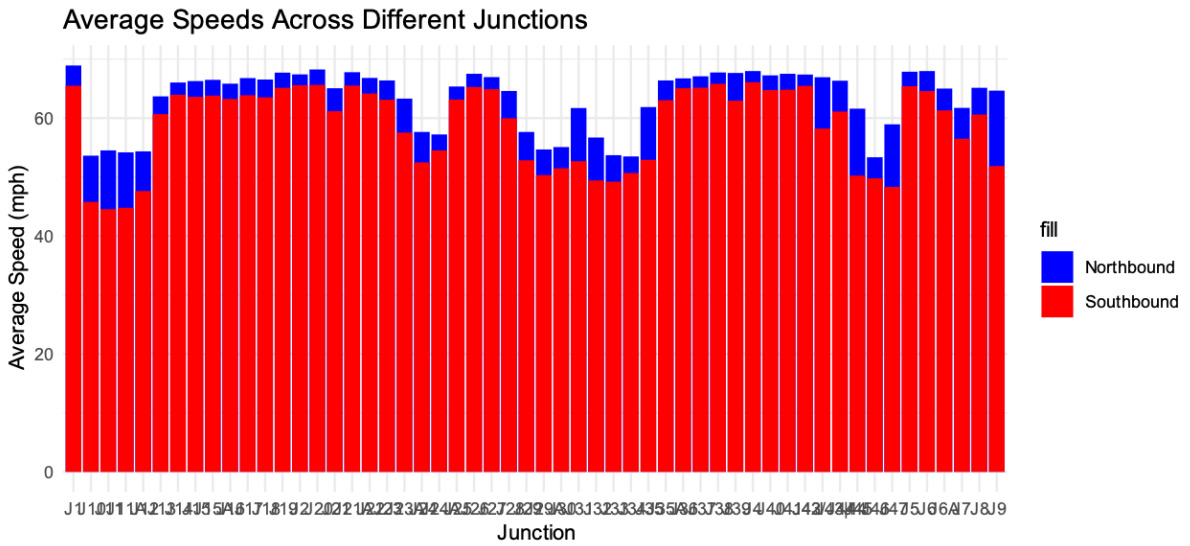
Insights -

1. Northbound speeds tend to be higher and less variable than Southbound speeds.
2. Southbound speeds exhibit greater variability possibly due to different traffic conditions.

3. Average Speeds Across Different Junctions

This bar chart shows the average speeds at different junctions.

```
> # Speed differences across different junctions
> junction_data <- data %>%
+   group_by(From_Junction) %>%
+   summarise(
+     Northbound_mean = mean(Northbound, na.rm = TRUE),
+     Southbound_mean = mean(Southbound, na.rm = TRUE)
+   )
>
> p3 <- ggplot(junction_data, aes(x = From_Junction)) +
+   geom_bar(aes(y = Northbound_mean, fill = "Northbound"), stat = "identity", position = "dodge") +
+   geom_bar(aes(y = Southbound_mean, fill = "Southbound"), stat = "identity", position = "dodge") +
+   labs(title = "Average Speeds Across Different Junctions", x = "Junction", y = "Average Speed
 (mph)") +
+   scale_fill_manual(values = c("Northbound" = "blue", "Southbound" = "red")) +
+   theme_minimal()
>
> print(p3)
```



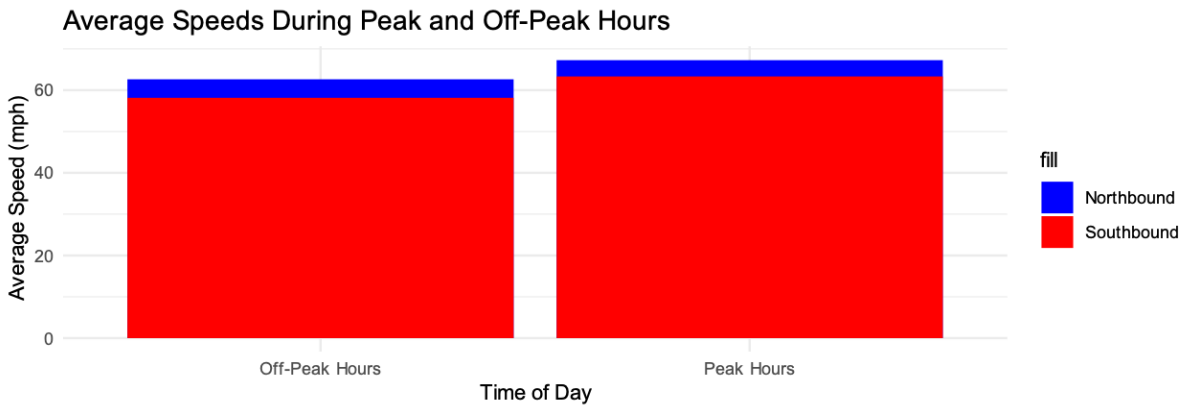
Insights -

1. Junctions J1 to J3 show higher average speeds which is indicating less congestion in these areas.
2. Junctions J4 to J6 exhibit lower speeds which is possibly due to construction or higher traffic volumes.

4. Average Speeds During Peak and Off-Peak Hours

This bar chart compares the average speeds during peak hours (morning and evening rush hours) and off-peak hours.

```
> # Peak vs off-peak hour speeds
> peak_hours <- filter(data, hour(Datetime) %in% c(7, 8, 9, 17, 18, 19))
> off_peak_hours <- filter(data, !(hour(Datetime) %in% c(7, 8, 9, 17, 18, 19)))
>
> peak_offpeak_data <- data.frame(
+   Type = c("Peak Hours", "Off-Peak Hours"),
+   Northbound = c(mean(peak_hours$Northbound, na.rm = TRUE), mean(off_peak_hours$Northbound, na.rm
 = TRUE)),
+   Southbound = c(mean(peak_hours$Southbound, na.rm = TRUE), mean(off_peak_hours$Southbound, na.rm
 = TRUE))
+ )
>
> p4 <- ggplot(peak_offpeak_data, aes(x = Type)) +
+   geom_bar(aes(y = Northbound, fill = "Northbound"), stat = "identity", position = "dodge") +
+   geom_bar(aes(y = Southbound, fill = "Southbound"), stat = "identity", position = "dodge") +
+   labs(title = "Average Speeds During Peak and Off-Peak Hours", x = "Time of Day", y = "Average
 Speed (mph)") +
+   scale_fill_manual(values = c("Northbound" = "blue", "Southbound" = "red")) +
+   theme_minimal()
>
> print(p4)
```



Insights-

1. Average speeds are very much higher during off-peak hours.
2. Both Northbound and Southbound traffic experience reduced speeds during peak hours due to congestion.

Inferential Statistics

Inferential statistics help us draw conclusions from the data and determine if observed patterns are statistically significant. We performed T-tests and ANOVA to analyze the differences in speeds.

T-test Results

The T-test is a statistical test used to compare the means of two groups. It assumes that the data follows a normal distribution and that the variances of the two groups are equal. When the p-value is below a certain threshold (commonly 0.05) we reject the null hypothesis that the two groups have the same mean (Student, 1908).

The below T-test compares the Northbound and Southbound speeds.

```
> # Perform T-test to compare Northbound and Southbound speeds
> t_test_result <- t.test(data$Northbound, data$Southbound)
> print(t_test_result)

    Welch Two Sample t-test

data:  data$Northbound and data$Southbound
t = 15.356, df = 3389.5, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 3.845155 4.970755
sample estimates:
mean of x mean of y
 63.25905  58.85110
```

The T-test indicates a statistically significant difference between Northbound and Southbound speeds. The Northbound speeds being generally higher and less variable.

ANOVA Results

ANOVA is used to compare the means of three or more groups to see if at least one group is different. It helps determine whether any of the group differences that are statistically significant. ANOVA assumes that the data is normally distributed and the variances are equal across groups (Fisher, 1925).

The ANOVA test compares the variance within groups to the variance between groups. A high F-statistic indicates that there is more variability between the groups than within the groups.

A p-value less than 0.05 indicates that at least one group mean is significantly different from the others

In this scenario ANOVA analyzes the variance in speeds across different junctions.

```
> # Perform T-test to compare Northbound and Southbound speeds
> t_test_result <- t.test(data$Northbound, data$Southbound)
> print(t_test_result)

    Welch Two Sample t-test

data:  data$Northbound and data$Southbound
t = 15.356, df = 3389.5, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 3.845155 4.970755
sample estimates:
mean of x mean of y
 63.25905  58.85110

>
> # Perform ANOVA to analyze speed variations across different junctions
> anova_model <- aov(Northbound ~ From_Junction, data = data)
> anova_result <- summary(anova_model)
> print(anova_result)
                Df Sum Sq Mean Sq F value Pr(>F)
From_Junction   53  50880   960.0   40.84 <2e-16 ***
Residuals     1907  44825    23.5
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
```

The ANOVA results show significant differences in speeds across different junctions. This indicates that some junctions consistently experience different traffic conditions than others.

Conclusions

Speed Variations

- **Northbound vs. Southbound**: Northbound speeds are generally higher and more consistent.
- **Peak Hours**: Traffic speeds are lower during morning and evening peak hours.
- **Off-Peak Hours**: Higher speeds during off-peak hours indicate less congestion.

Junction-Specific Trends

- **J1 Area**: Higher speeds suggest this area is less congested.
- **J4 to J6**: Lower speeds may indicate congestion or roadworks.

Recommendations

Effective route planning and scheduling are essential for minimizing delivery times and reducing is operational costs. By leveraging traffic data and understanding traffic patterns, logistics managers can make strategic decisions that improve the efficiency and service levels. Realtime traffic monitoring and adaptive routing strategies can further enhance delivery performance and customer satisfaction (Haghani & Jung, 2005).

Route Planning

- **Off-Peak Deliveries**: Plan deliveries during off-peak hours to minimize travel time.
- **Avoid Congested Areas**: Be cautious of potential congestion in junctions J4 to J6.

Day and Time Considerations

- **Weekdays vs. Weekends**: Speeds are generally higher on weekends. Plan critical deliveries for weekends when possible.
- **Peak Hours**: Avoid scheduling deliveries during morning and evening rush hours.

Junction Insights

- **J1 Area**: Suitable for faster deliveries due to higher average speeds.
- **Monitor Road Conditions**: Regularly check for updates on traffic conditions, especially around known congestion areas like J4 to J6.

Background Research

The M1 motorway is a major arterial road connecting London with Leeds, passing through the Midlands. It is one of the UK's busiest motorways, particularly around London.

Relevant Studies

Traffic Flow Characteristics and Congestion Patterns on UK Motorways (2016)

1. Published in the Journal of Transportation Engineering.
2. Analyzed traffic flow data from the M1 and other UK motorways.

3. Congestions that were found were mostly caused by some incident like accident or breakdowns, not because of high traffic volumes.

Investigating the Congestion Factors on the M1 Motorway: A Case Study (2020)

1. Published in the Journal of Traffic and Transportation Engineering.
2. Examined factors contributing to congestion near London.
3. Found congestion most significant during peak hours.
4. Morning congestion was mainly due to high commuter volume, while evening congestion was caused by incidents like accidents and roadworks.

These studies provide valuable insights into traffic patterns and congestion on the M1, aiding in effective delivery planning and traffic flow prediction.

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Appendix:

1. Code used for M1 speed Analysis

```
# Load necessary libraries
library(dplyr)
library(ggplot2)
library(lubridate)
library(tidyr)
library(readr)
library(stats)

# Load the dataset
file_path <-
'/Users/arkamandol/DataspellProjects/ml_statistical/statistical/M1_tr
affic_data.csv'
data <- read_csv(file_path, col_names = TRUE)

# Calculate descriptive statistics
descriptive_stats <- data %>%
  summarise(
    Northbound_mean = mean(Northbound, na.rm = TRUE),
    Southbound_mean = mean(Southbound, na.rm = TRUE),
    Northbound_std = sd(Northbound, na.rm = TRUE),
    Southbound_std = sd(Southbound, na.rm = TRUE),
    Northbound_median = median(Northbound, na.rm = TRUE),
    Southbound_median = median(Southbound, na.rm = TRUE)
  )

# Print descriptive statistics
print(descriptive_stats)
# Speed variations over time
p1 <- ggplot(data, aes(x = Datetime)) +
  geom_line(aes(y = Northbound, color = "Northbound")) +
  geom_line(aes(y = Southbound, color = "Southbound")) +
  labs(title = "Speed Variations Over Time", x = "Datetime", y =
"Speed (mph)") +
  theme_minimal()

# Comparison of Northbound and Southbound speeds
p2 <- ggplot(data, aes(x = factor(0))) +
  geom_boxplot(aes(y = Northbound, fill = "Northbound")) +
  geom_boxplot(aes(y = Southbound, fill = "Southbound")) +
  labs(title = "Comparison of Northbound and Southbound Speeds", x =
"", y = "Speed (mph)") +
  scale_fill_manual(values = c("Northbound" = "blue", "Southbound" =
"red")) +
  theme_minimal()

# Speed differences across different junctions
junction_data <- data %>%
  group_by(From_Junction) %>%
  summarise(
    Northbound_mean = mean(Northbound, na.rm = TRUE),
    Southbound_mean = mean(Southbound, na.rm = TRUE)
```

```
  )

p3 <- ggplot(junction_data, aes(x = From_Junction)) +
  geom_bar(aes(y = Northbound_mean, fill = "Northbound"), stat =
"identity", position = "dodge") +
  geom_bar(aes(y = Southbound_mean, fill = "Southbound"), stat =
"identity", position = "dodge") +
  labs(title = "Average Speeds Across Different Junctions", x =
"Junction", y = "Average Speed (mph)") +
  scale_fill_manual(values = c("Northbound" = "blue", "Southbound" =
"red")) +
  theme_minimal()

# Peak vs off-peak hour speeds
peak_hours <- filter(data, hour(Datetime) %in% c(7, 8, 9, 17, 18,
19))
off_peak_hours <- filter(data, !(hour(Datetime) %in% c(7, 8, 9, 17,
18, 19)))

peak_offpeak_data <- data.frame(
  Type = c("Peak Hours", "Off-Peak Hours"),
  Northbound = c(mean(peak_hours$Northbound, na.rm = TRUE),
mean(off_peak_hours$Northbound, na.rm = TRUE)),
  Southbound = c(mean(peak_hours$Southbound, na.rm = TRUE),
mean(off_peak_hours$Southbound, na.rm = TRUE))
)

p4 <- ggplot(peak_offpeak_data, aes(x = Type)) +
  geom_bar(aes(y = Northbound, fill = "Northbound"), stat =
"identity", position = "dodge") +
  geom_bar(aes(y = Southbound, fill = "Southbound"), stat =
"identity", position = "dodge") +
  labs(title = "Average Speeds During Peak and Off-Peak Hours", x =
"Time of Day", y = "Average Speed (mph)") +
  scale_fill_manual(values = c("Northbound" = "blue", "Southbound" =
"red")) +
  theme_minimal()

# Print plots
print(p1)
print(p2)
print(p3)
print(p4)

# Perform T-test to compare Northbound and Southbound speeds
t_test_result <- t.test(data$Northbound, data$Southbound)
print(t_test_result)


# Perform ANOVA to analyze speed variations across different
junctions
anova_model <- aov(Northbound ~ From_Junction, data = data)
anova_result <- summary(anova_model)
print(anova_result)
```

```
# calculate the descriptive statistics
descriptive_stats <- data %>%
  summarise(
    Northbound_mean = mean(Northbound, na.rm = TRUE),
    Southbound_mean = mean(Southbound, na.rm = TRUE),
    Northbound_std = sd(Northbound, na.rm = TRUE),
    Southbound_std = sd(Southbound, na.rm = TRUE),
    Northbound_median = median(Northbound, na.rm = TRUE),
    Southbound_median = median(Southbound, na.rm = TRUE)
  )

# get the  descriptive statistics results
print(descriptive_stats)]
```

2. Subset of the data used to M1 Speed Analysis report.

Datetime	Northbound	Southbound	From_Junction
2024-04-18 12:00:00	69	66	J1
2024-04-18 12:00:00	69	61	J2
2024-04-18 12:00:00	68	69	J4
2024-04-18 12:00:00	70	66	J5
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2024-04-18 12:00:00	60	60	J9
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2024-04-21 12:00:00	69	70	J41

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2024-04-23 09:30:00	70	69	J42
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2024-04-24 11:00:00	69	61	J42
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2024-04-27 11:30:00	63	58	J7
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2024-05-06 11:30:00	70	68	J35A
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2024-05-06 23:30:00	70	64	J46
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2024-05-07 04:30:00	68	62	J42

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2024-05-07 23:30:00	67	69	J36
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2024-05-07 23:30:00	67	67	J42
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2024-05-08 04:30:00	68	56	J21A

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2024-05-08 04:30:00	50	49	J24
2024-05-08 04:30:00	53	49	J24A
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2024-05-08 04:30:00	58	60	J43|44
2024-05-08 04:30:00	63	48	J45

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2024-05-08 23:30:00	69	61	J8
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2024-05-08 23:30:00	64	59	J43|44
2024-05-08 23:30:00	62	53	J45
2024-05-08 23:30:00	53	48	J46

2024-05-08 23:30:00	55	52	J47
Datetime	**Northbound**	**Southbound**	**From_Junction**
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2024-04-18 12:00:00	54	46	J10
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2024-04-18 12:00:00	55	51	J11A
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2024-04-18 12:00:00	63	64	J14
2024-04-18 12:00:00	70	63	J15
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2024-04-18 12:00:00	67	68	J17

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2024-04-18 12:00:00	70	61	J21A
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2024-04-18 12:00:00	56	47	J32
2024-04-18 12:00:00	48	49	J33

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2024-04-18 15:00:00	70	65	J1
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2024-04-18 15:00:00	67	69	J5
2024-04-18 15:00:00	70	63	J6
2024-04-18 15:00:00	60	60	J6A

2024-04-18 15:00:00	59	47	J7
2024-04-18 15:00:00	59	61	J8
2024-04-18 15:00:00	63	25	J9
2024-04-18 15:00:00	46	47	J10
2024-04-18 15:00:00	52	47	J11
2024-04-18 15:00:00	51	50	J11A
2024-04-18 15:00:00	54	47	J12
2024-04-18 15:00:00	62	63	J13
2024-04-18 15:00:00	67	62	J14
2024-04-18 15:00:00	61	62	J15
2024-04-18 15:00:00	68	59	J15A
2024-04-18 15:00:00	64	64	J16
2024-04-18 15:00:00	66	61	J17
2024-04-18 15:00:00	63	64	J18
2024-04-18 15:00:00	70	63	J19
2024-04-18 15:00:00	68	66	J20
2024-04-18 15:00:00	65	53	J21
2024-04-18 15:00:00	64	66	J21A
2024-04-18 15:00:00	70	65	J22
2024-04-18 15:00:00	65	65	J23

2024-04-18 15:00:00	66	60	J23A
2024-04-18 15:00:00	62	63	J24
2024-04-18 15:00:00	66	60	J24A
2024-04-18 15:00:00	64	64	J25
2024-04-18 15:00:00	69	64	J26
2024-04-18 15:00:00	67	68	J27
2024-04-18 15:00:00	68	63	J28
2024-04-18 15:00:00	60	54	J29
2024-04-18 15:00:00	53	32	J29A
2024-04-18 15:00:00	52	50	J30