Plane Crash Analysis: Does your seat matter?

Inferential Statistics 2025/2026

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1 Introduction

The Aviation industry is one of the safest in the world. The systems that it has in place to learn lessons from accidents and make sure they never happen again is well-established and highly regarded. This has made traveling by plane the safest way to travel. https://flyfright.com/plane-crash-statistics/#:~:text=Based%20on%20statistics%20from%202015,unharmed%2C%20injured%2C%20or%20killed

But perhaps due to these high safety standards, when an aircraft accident happens it makes headlines all over the world. Anxious passengers fear it's going to happen to them as well and they can't help but ask themselves if there is something they could do to have a safer flight.

One of the most frequent question that gets asked is : is there a part of the plane that is "safer" than other parts? Can the seating location make a difference in an accident? There are many articles where experts in the field give their opinions, and most answer that "yes, there are areas that give a higher chance of survival in case of an aircraft accident". But there are also studies that suggest that there is no safest seats on an airplane.

So, who is right? We are going to try to answer this question using statistics.

2 Vocabulary

Before starting the analysis, the meaning of some terms must be clarified

- Flight : A flight a trip made by an aircraft that connects two airports. It is identified by a number. (Example : AirFrance 225 is the name of the regular service from New Deli to Paris)
- Accident : An Accident is an occurrence where a person is fatally or seriously injured, the aircraft sustains significant structural damage, or the aircraft goes missing.
- Incident : An incident is a dangerous situation where no one is seriously hurt and the plane isn't badly damaged.
- Crash : A crash is a type of accident where an aircraft strikes the ground, water, or an obstacle with enough force to cause severe damage or total destruction.
- Accident flight : when a serious accident happens on a flight, usually the companies save the flight number to refer to that flight, and change the flight number for new flights. (Example : Air France 447 was the name of the connection from Rio to Paris, after the 2009 accident the flight became Air France 445)
- Serious injury : Any injury requiring more than 48 hours of hospitalization or involving broken bones (other than fingers/toes)
- Survivability : an accident is defined as survivable if the forces are within human limits and if the structure remained substantially intact
- CREEP factors : factors that influence the survivability of an accident. They are
  - Container : amount of cabin deformation
  - Restraints : analysis of the seating structure
  - Environment : presence of lethal contact points
  - Energy Absorption : G-load mitigation by fuselarge or landing gear
  - Post Crash : Other factors (We considered : airport proximity, presence of fire, daytime, phase of flight)

3 Perspective

We are studying if the seating in an airplane has an effect on the survivability of an aircraft accident. To study this, we need to look at all aircraft accidents, then rule out the accidents where every passenger survived, and every accident in which every passenger died. This is an extremely narrow data set of accidents. Of these accidents, we gathered the seatings arrangements and survivor seating maps for 47 crashes.

If 47 crashes look like a lot, we should consider the greater perspective of air travel safety in general.

https://flyfright.com/plane-crash-statistics/#tve-jump-18c020d9166 reported these figures studying the US General aviation data between 2015 and 2020 :

- $\frac{1}{260256}$: chance of boarding any flight and it being an accident flight
- $\frac{1}{6,864,250}$: chance of being on a plane involved in an accident that results in at least 1 fatality (possible case study of this study)
- $\frac{1}{816,545,929}$ chance of you specifically, dying in a plane crash

```r
data <- read.csv("AllCREEP_cleaned.csv")
# trasform the variables that are categorical into factors
data$fonte <- as.factor(data$fonte)
data$PhaseOfFlight <- as.factor(data$PhaseOfFlight)
data$Time <- as.factor(data$Time)
data$Place <- as.factor(data$Place)
data$HasFire <- as.factor(data$HasFire)
data$Environment <- as.factor(data$Environment)
data$Energy_absorption <- as.factor(data$Energy_absorption)
```

```r
str(data)
```

```
## 'data.frame':    47 obs. of  26 variables:
##  $ Airline          : chr  "singapore airlines" "british airtours" "british midland" "china airlines
##  $ NumVolo          : int  6 28 92 120 123 129 140 148 191 204 ...
##  $ X1.terzo.lievi   : int  17 36 0 0 0 4 0 0 0 3 ...
##  $ X1.terzo.gravi   : int  2 0 11 0 0 0 0 0 0 0 ...
##  $ X1.terzo.morti   : int  15 0 22 0 136 14 18 16 55 33 ...
##  $ X2.terzo.lievi   : int  1 30 4 5 0 5 7 1 0 25 ...
##  $ X2.terzo.gravi   : int  15 0 30 0 0 0 0 0 8 0 ...
##  $ X2.terzo.morti   : int  64 16 13 8 214 60 139 34 51 1 ...
##  $ X3.terzo.lievi   : int  26 10 0 5 36 24 0 8 10 29 ...
##  $ X3.terzo.gravi   : int  17 0 27 0 0 0 0 0 7 0 ...
##  $ X3.terzo.morti   : int  0 36 11 21 109 43 91 30 16 0 ...
##  $ X1.meta.lievi    : int  17 56 32 3 0 7 7 1 0 7 ...
##  $ X1.meta.gravi    : int  3 0 0 0 0 0 0 0 1 0 ...
##  $ X1.meta.morti    : int  41 8 34 6 226 23 95 36 79 35 ...
##  $ X2.meta.lievi    : int  26 20 39 7 4 26 0 7 10 46 ...
##  $ X2.meta.gravi    : int  31 0 0 0 0 0 0 0 14 0 ...
##  $ X2.meta.morti    : int  34 44 13 23 225 90 145 46 48 0 ...
##  $ fonte            : Factor w/ 4 levels "","fr","r","w": 4 4 4 4 4 4 4 4 4 4 ...
##  $ PhaseOfFlight    : Factor w/ 2 levels "landing","takeoff": 2 2 1 1 2 1 1 1 2 1 ...
##  $ Time             : Factor w/ 2 levels "day","night": 2 1 2 1 2 1 1 2 1 1 ...
##  $ Place            : Factor w/ 2 levels "airport","outside": 1 2 2 1 2 2 1 2 2 2 ...
##  $ HasFire          : Factor w/ 2 levels "fire","no-fire": 1 1 1 1 1 1 1 2 1 1 ...
##  $ Crushed_fuselage : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Restraint_intact : int  0 0 0 1 0 0 0 0 0 0 ...
##  $ Environment      : Factor w/ 2 levels "clear","dangerous": 2 2 2 1 2 2 2 2 1 2 ...
##  $ Energy_absorption: Factor w/ 2 levels "gear","nogear": 2 2 1 2 2 2 1 2 2 2 ...
```

```r
summary(data)
```

```
##    Airline             NumVolo     X1.terzo.lievi   X1.terzo.gravi
##  Length:47          Min.   :   6   Min.   :  0.00   Min.   : 0.000
##  Class :character   1st Qu.: 227   1st Qu.:  0.00   1st Qu.: 0.000
##  Mode  :character   Median : 812   Median :  4.00   Median : 0.000
##                     Mean   :1591   Mean   : 12.87   Mean   : 2.553
##                     3rd Qu.:1603   3rd Qu.: 17.00   3rd Qu.: 4.000
##                     Max.   :9642   Max.   :141.00   Max.   :16.000
```

```
##  X1.terzo.morti   X2.terzo.lievi   X2.terzo.gravi   X2.terzo.morti
##  Min.   :  0.00   Min.   :  0.00   Min.   : 0.000   Min.   :  0.00
##  1st Qu.:  1.50   1st Qu.:  1.00   1st Qu.: 0.000   1st Qu.:  2.00
##  Median : 11.00   Median :  7.00   Median : 2.000   Median : 12.00
##  Mean   : 16.15   Mean   : 22.11   Mean   : 4.638   Mean   : 28.62
##  3rd Qu.: 19.00   3rd Qu.: 26.50   3rd Qu.: 8.000   3rd Qu.: 31.00
##  Max.   :136.00   Max.   :174.00   Max.   :30.000   Max.   :214.00
##  X3.terzo.lievi  X3.terzo.gravi   X3.terzo.morti   X1.meta.lievi
##  Min.   :  0.0   Min.   : 0.000   Min.   :  0.00   Min.   :  0.00
##  1st Qu.:  3.0   1st Qu.: 0.000   1st Qu.:  1.50   1st Qu.:  1.50
##  Median : 10.0   Median : 0.000   Median :  8.00   Median : 11.00
##  Mean   : 20.4   Mean   : 3.872   Mean   : 19.83   Mean   : 29.23
##  3rd Qu.: 27.0   3rd Qu.: 4.500   3rd Qu.: 24.50   3rd Qu.: 40.50
##  Max.   :142.0   Max.   :27.000   Max.   :113.00   Max.   :221.00
##  X1.meta.gravi   X1.meta.morti    X2.meta.lievi    X2.meta.gravi
##  Min.   : 0.00   Min.   :  0.00   Min.   :  0.00   Min.   : 0.000
##  1st Qu.: 0.00   1st Qu.:  5.00   1st Qu.:  6.50   1st Qu.: 0.000
##  Median : 0.00   Median : 20.00   Median : 14.00   Median : 0.000
##  Mean   : 4.34   Mean   : 28.57   Mean   : 28.98   Mean   : 5.234
##  3rd Qu.: 7.00   3rd Qu.: 35.00   3rd Qu.: 37.50   3rd Qu.: 7.500
##  Max.   :34.00   Max.   :226.00   Max.   :184.00   Max.   :31.000
##  X2.meta.morti    fonte   PhaseOfFlight    Time        Place       HasFire
##  Min.   :  0.00     : 8   landing:30    day  :36   airport:25   fire   :33
##  1st Qu.:  3.50   fr: 4   takeoff:17    night:11   outside:22   no-fire:14
##  Median : 15.00   r : 1
##  Mean   : 36.53   w :34
##  3rd Qu.: 45.00
##  Max.   :225.00
##  Crushed_fuselage Restraint_intact    Environment Energy_absorption
##  Min.   :0.0000   Min.   :0.0000   clear    : 5   gear  :29
##  1st Qu.:1.0000   1st Qu.:0.0000   dangerous:42   nogear:18
##  Median :1.0000   Median :0.0000
##  Mean   :0.9362   Mean   :0.1702
##  3rd Qu.:1.0000   3rd Qu.:0.0000
##  Max.   :1.0000   Max.   :1.0000
```

```
#> data <- read.csv("Aerei_Final.csv")
## 'data.frame': 47 obs. of 26 variables:
## $ Airline : chr "Singapore Airlines" "British Airtours" "British Midland" "China Airlines"
## $ NumVolo : int 6 28 92 120 123 129 140 148 191 204 ...
## $ X1.terzo.lievi : int 17 36 0 0 0 4 0 0 0 3 ...
## $ X1.terzo.gravi : int 2 0 11 0 0 0 0 0 0 0 ...
## $ X1.terzo.morti : int 15 0 22 0 136 14 18 16 55 33 ...
## $ X2.terzo.lievi : int 1 30 4 5 0 5 7 1 0 25 ...
## $ X2.terzo.gravi : int 15 0 30 0 0 0 0 0 8 0 ...
## $ X2.terzo.morti : int 64 16 13 8 214 60 139 34 51 1 ...
## $ X3.terzo.lievi : int 26 10 0 5 36 24 0 8 10 29 ...
## $ X3.terzo.gravi : int 17 0 27 0 0 0 0 0 7 0 ...
## $ X3.terzo.morti : int 0 36 11 21 109 43 91 30 16 0 ...
## $ X1.meta.lievi : int 17 56 32 3 0 7 7 1 0 7 ...
## $ X1.meta.gravi : int 3 0 0 0 0 0 0 0 1 0 ...
## $ X1.meta.morti : int 41 8 34 6 226 23 95 36 79 35 ...
## $ X2.meta.lievi : int 26 20 39 7 4 26 0 7 10 46 ...
## $ X2.meta.gravi : int 31 0 0 0 0 0 0 0 14 0 ...
```

```
## $ X2.meta.morti : int 34 44 13 23 225 90 145 46 48 0 ...
## $ fonte : chr "W" "W" "W" "W" ...
## $ PhaseOfFlight : chr "Takeoff" "Takeoff" "Landing" "Landing" ...
## $ Time : chr "Night" "Day" "Night" "Day" ...
2
```

```
## [1] 2
```

```
## $ Place : chr "Airport " "Outside" "Outside" "Airport " ...
## $ HasFire : chr "Fire" "Fire" "Fire" "Fire" ...
## $ Crushed_fuselage : int 1 1 1 1 1 1 1 1 1 1 ...
## $ Restraint_intact : int 0 0 0 1 0 0 0 0 0 0 ...
## $ Environment : chr "dangerous" "dangerous" "dangerous" "clear" ...
## $ Energy_absorption: chr "nogear" "nogear" "gear" "nogear"
```

Some random text. . . .

```
# add a colum of # of seat for each airplain section

data$X1.third.total <- data$X1.terzo.lievi + data$X1.terzo.gravi + data$X1.terzo.morti
data$X2.third.total <- data$X2.terzo.lievi + data$X2.terzo.gravi + data$X2.terzo.morti
data$X3.third.total <- data$X3.terzo.lievi + data$X3.terzo.gravi + data$X3.terzo.morti
data$X1.half.total <- data$X1.meta.lievi + data$X1.meta.gravi + data$X1.meta.morti
data$X2.half.total <- data$X2.meta.lievi + data$X2.meta.gravi + data$X2.meta.morti

str(data)
```

```
## 'data.frame':    47 obs. of  31 variables:
##  $ Airline          : chr  "singapore airlines" "british airtours" "british midland" "china airlines
##  $ NumVolo          : int  6 28 92 120 123 129 140 148 191 204 ...
##  $ X1.terzo.lievi   : int  17 36 0 0 0 4 0 0 0 3 ...
##  $ X1.terzo.gravi   : int  2 0 11 0 0 0 0 0 0 0 ...
##  $ X1.terzo.morti   : int  15 0 22 0 136 14 18 16 55 33 ...
##  $ X2.terzo.lievi   : int  1 30 4 5 0 5 7 1 0 25 ...
##  $ X2.terzo.gravi   : int  15 0 30 0 0 0 0 0 8 0 ...
##  $ X2.terzo.morti   : int  64 16 13 8 214 60 139 34 51 1 ...
##  $ X3.terzo.lievi   : int  26 10 0 5 36 24 0 8 10 29 ...
##  $ X3.terzo.gravi   : int  17 0 27 0 0 0 0 0 7 0 ...
##  $ X3.terzo.morti   : int  0 36 11 21 109 43 91 30 16 0 ...
##  $ X1.meta.lievi    : int  17 56 32 3 0 7 7 1 0 7 ...
##  $ X1.meta.gravi    : int  3 0 0 0 0 0 0 0 1 0 ...
##  $ X1.meta.morti    : int  41 8 34 6 226 23 95 36 79 35 ...
##  $ X2.meta.lievi    : int  26 20 39 7 4 26 0 7 10 46 ...
##  $ X2.meta.gravi    : int  31 0 0 0 0 0 0 0 14 0 ...
##  $ X2.meta.morti    : int  34 44 13 23 225 90 145 46 48 0 ...
##  $ fonte            : Factor w/ 4 levels "","fr","r","w": 4 4 4 4 4 4 4 4 4 4 ...
##  $ PhaseOfFlight    : Factor w/ 2 levels "landing","takeoff": 2 2 1 1 2 1 1 1 2 1 ...
##  $ Time             : Factor w/ 2 levels "day","night": 2 1 2 1 2 1 1 2 1 1 ...
##  $ Place            : Factor w/ 2 levels "airport","outside": 1 2 2 1 2 2 1 2 2 2 ...
##  $ HasFire          : Factor w/ 2 levels "fire","no-fire": 1 1 1 1 1 1 1 2 1 1 ...
##  $ Crushed_fuselage : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Restraint_intact : int  0 0 0 1 0 0 0 0 0 0 ...
```

```
##  $ Environment      : Factor w/ 2 levels "clear","dangerous": 2 2 2 1 2 2 2 2 1 2 ...
##  $ Energy_absorption: Factor w/ 2 levels "gear","nogear": 2 2 1 2 2 2 1 2 2 2 ...
##  $ X1.third.total   : int  34 36 33 0 136 18 18 16 55 36 ...
##  $ X2.third.total   : int  80 46 47 13 214 65 146 35 59 26 ...
##  $ X3.third.total   : int  43 46 38 26 145 67 91 38 33 29 ...
##  $ X1.half.total    : int  61 64 66 9 226 30 102 37 80 42 ...
##  $ X2.half.total    : int  91 64 52 30 229 116 145 53 72 46 ...
```

```r
summary(data)
```

```
##    Airline             NumVolo     X1.terzo.lievi   X1.terzo.gravi
##  Length:47          Min.   :   6   Min.   :  0.00   Min.   : 0.000
##  Class :character   1st Qu.: 227   1st Qu.:  0.00   1st Qu.: 0.000
##  Mode  :character   Median : 812   Median :  4.00   Median : 0.000
##                     Mean   :1591   Mean   : 12.87   Mean   : 2.553
##                     3rd Qu.:1603   3rd Qu.: 17.00   3rd Qu.: 4.000
##                     Max.   :9642   Max.   :141.00   Max.   :16.000
##  X1.terzo.morti   X2.terzo.lievi   X2.terzo.gravi   X2.terzo.morti
##  Min.   :  0.00   Min.   :  0.00   Min.   : 0.000   Min.   :  0.00
##  1st Qu.:  1.50   1st Qu.:  1.00   1st Qu.: 0.000   1st Qu.:  2.00
##  Median : 11.00   Median :  7.00   Median : 2.000   Median : 12.00
##  Mean   : 16.15   Mean   : 22.11   Mean   : 4.638   Mean   : 28.62
##  3rd Qu.: 19.00   3rd Qu.: 26.50   3rd Qu.: 8.000   3rd Qu.: 31.00
##  Max.   :136.00   Max.   :174.00   Max.   :30.000   Max.   :214.00
##  X3.terzo.lievi  X3.terzo.gravi   X3.terzo.morti   X1.meta.lievi
##  Min.   :  0.0   Min.   : 0.000   Min.   :  0.00   Min.   :  0.00
##  1st Qu.:  3.0   1st Qu.: 0.000   1st Qu.:  1.50   1st Qu.:  1.50
##  Median : 10.0   Median : 0.000   Median :  8.00   Median : 11.00
##  Mean   : 20.4   Mean   : 3.872   Mean   : 19.83   Mean   : 29.23
##  3rd Qu.: 27.0   3rd Qu.: 4.500   3rd Qu.: 24.50   3rd Qu.: 40.50
##  Max.   :142.0   Max.   :27.000   Max.   :113.00   Max.   :221.00
##  X1.meta.gravi   X1.meta.morti    X2.meta.lievi    X2.meta.gravi
##  Min.   : 0.00   Min.   :  0.00   Min.   :  0.00   Min.   : 0.000
##  1st Qu.: 0.00   1st Qu.:  5.00   1st Qu.:  6.50   1st Qu.: 0.000
##  Median : 0.00   Median : 20.00   Median : 14.00   Median : 0.000
##  Mean   : 4.34   Mean   : 28.57   Mean   : 28.98   Mean   : 5.234
##  3rd Qu.: 7.00   3rd Qu.: 35.00   3rd Qu.: 37.50   3rd Qu.: 7.500
##  Max.   :34.00   Max.   :226.00   Max.   :184.00   Max.   :31.000
##  X2.meta.morti    fonte   PhaseOfFlight    Time        Place       HasFire
##  Min.   :  0.00     : 8   landing:30    day  :36   airport:25   fire   :33
##  1st Qu.:  3.50   fr: 4   takeoff:17    night:11   outside:22   no-fire:14
##  Median : 15.00   r : 1
##  Mean   : 36.53   w :34
##  3rd Qu.: 45.00
##  Max.   :225.00
##  Crushed_fuselage Restraint_intact    Environment Energy_absorption
##  Min.   :0.0000   Min.   :0.0000   clear    : 5   gear  :29
##  1st Qu.:1.0000   1st Qu.:0.0000   dangerous:42   nogear:18
##  Median :1.0000   Median :0.0000
##  Mean   :0.9362   Mean   :0.1702
##  3rd Qu.:1.0000   3rd Qu.:0.0000
##  Max.   :1.0000   Max.   :1.0000
##  X1.third.total   X2.third.total   X3.third.total   X1.half.total
##  Min.   :  0.00   Min.   :  4.00   Min.   :  2.00   Min.   :  5.00
```

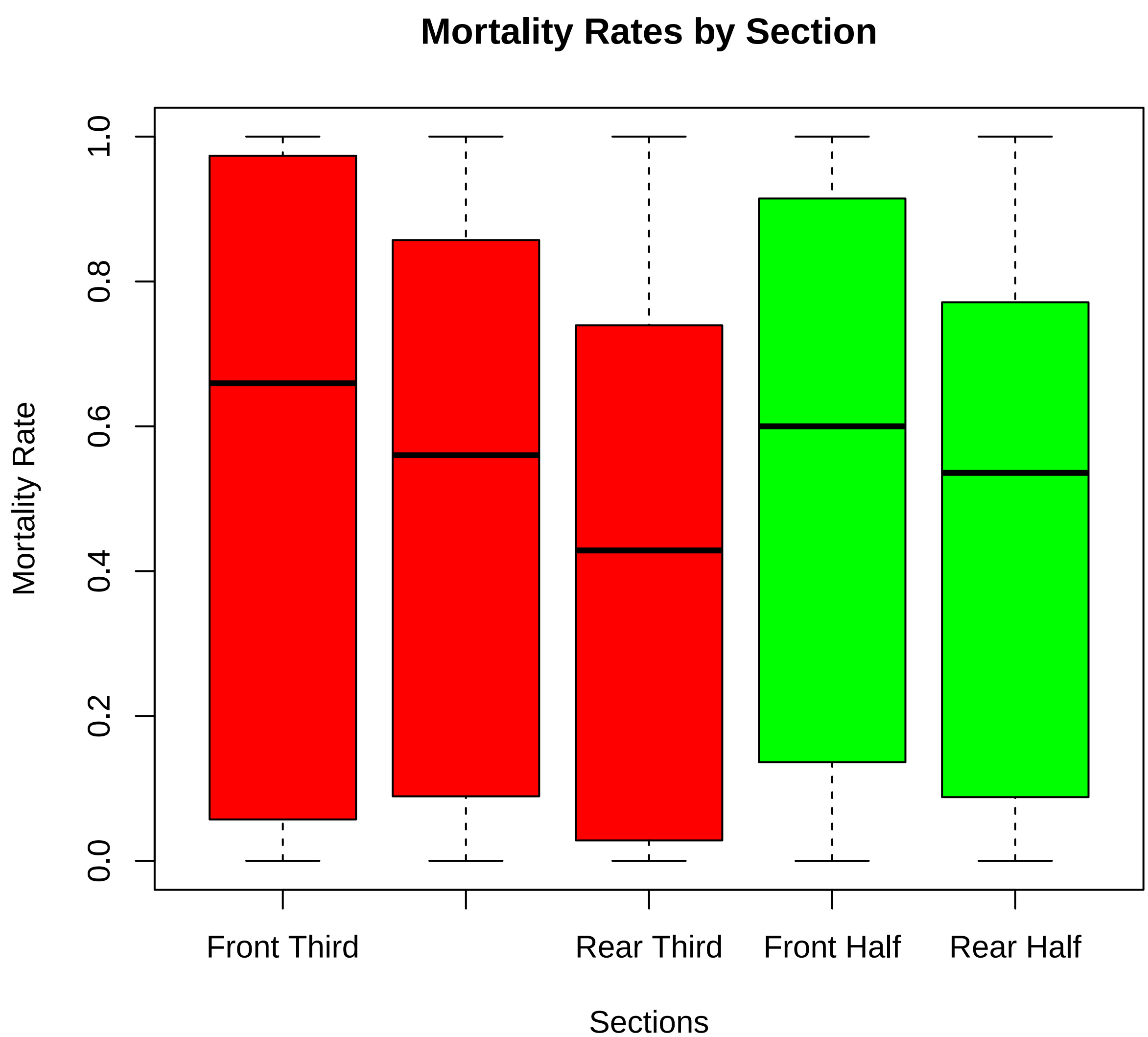
```
##  1st Qu.: 14.50   1st Qu.: 22.00   1st Qu.: 21.50   1st Qu.: 27.50
##  Median : 24.00   Median : 35.00   Median : 30.00   Median : 48.00
##  Mean   : 31.57   Mean   : 55.36   Mean   : 44.11   Mean   : 62.15
##  3rd Qu.: 36.00   3rd Qu.: 73.50   3rd Qu.: 53.00   3rd Qu.: 68.00
##  Max.   :141.00   Max.   :214.00   Max.   :145.00   Max.   :226.00
##  X2.half.total
##  Min.   :  7.00
##  1st Qu.: 30.50
##  Median : 46.00
##  Mean   : 70.74
##  3rd Qu.:106.50
##  Max.   :229.00
```

```r
# now make a colum of mortality rate for each section

data$X1.third.mortality.rate <- data$X1.terzo.morti / data$X1.third.total
data$X2.third.mortality.rate <- data$X2.terzo.morti / data$X2.third.total
data$X3.third.mortality.rate <- data$X3.terzo.morti / data$X3.third.total
data$X1.half.mortality.rate <- data$X1.meta.morti / data$X1.half.total
data$X2.half.mortality.rate <- data$X2.meta.morti / data$X2.half.total



head(data)
```

```
##             Airline NumVolo X1.terzo.lievi X1.terzo.gravi X1.terzo.morti
## 1 singapore airlines       6             17              2             15
## 2   british airtours      28             36              0              0
## 3    british midland      92              0             11             22
## 4     china airlines     120              0              0              0
## 5    japan air lines     123              0              0            136
## 6          air china     129              4              0             14
##   X2.terzo.lievi X2.terzo.gravi X2.terzo.morti X3.terzo.lievi X3.terzo.gravi
## 1              1             15             64             26             17
## 2             30              0             16             10              0
## 3              4             30             13              0             27
## 4              5              0              8              5              0
## 5              0              0            214             36              0
## 6              5              0             60             24              0
##   X3.terzo.morti X1.meta.lievi X1.meta.gravi X1.meta.morti X2.meta.lievi
## 1              0            17             3            41            26
## 2             36            56             0             8            20
## 3             11            32             0            34            39
## 4             21             3             0             6             7
## 5            109             0             0           226             4
## 6             43             7             0            23            26
##   X2.meta.gravi X2.meta.morti fonte PhaseOfFlight  Time   Place HasFire
## 1            31            34     w       takeoff night airport    fire
## 2             0            44     w       takeoff   day outside    fire
## 3             0            13     w       landing night outside    fire
## 4             0            23     w       landing   day airport    fire
## 5             0           225     w       takeoff night outside    fire
## 6             0            90     w       landing   day outside    fire
##   Crushed_fuselage Restraint_intact Environment Energy_absorption
```

```
## 1                 1                0   dangerous             nogear
## 2                 1                0   dangerous             nogear
## 3                 1                0   dangerous               gear
## 4                 1                1       clear             nogear
## 5                 1                0   dangerous             nogear
## 6                 1                0   dangerous             nogear
##   X1.third.total X2.third.total X3.third.total X1.half.total X2.half.total
## 1             34             80             43            61            91
## 2             36             46             46            64            64
## 3             33             47             38            66            52
## 4              0             13             26             9            30
## 5            136            214            145           226           229
## 6             18             65             67            30           116
##   X1.third.mortality.rate X2.third.mortality.rate X3.third.mortality.rate
## 1               0.4411765               0.8000000               0.0000000
## 2               0.0000000               0.3478261               0.7826087
## 3               0.6666667               0.2765957               0.2894737
## 4                     NaN               0.6153846               0.8076923
## 5               1.0000000               1.0000000               0.7517241
## 6               0.7777778               0.9230769               0.6417910
##   X1.half.mortality.rate X2.half.mortality.rate
## 1              0.6721311              0.3736264
## 2              0.1250000              0.6875000
## 3              0.5151515              0.2500000
## 4              0.6666667              0.7666667
## 5              1.0000000              0.9825328
## 6              0.7666667              0.7758621
```

```r
## Plot mortality rates as scatter plots for each section
## they must be separated on the x axis by group

boxplot(data$X1.third.mortality.rate,
  data$X2.third.mortality.rate,
  data$X3.third.mortality.rate,
  data$X1.half.mortality.rate,
  data$X2.half.mortality.rate,
  names = c("Front Third", "Middle Third", "Rear Third", "Front Half", "Rear Half"),
  main = "Mortality Rates by Section",
  ylab = "Mortality Rate",
  xlab = "Sections",
  col = c("red", "red", "red", "green", "green"))
```




```r
# Perform ANOVA to test if there are significant differences in mortality rates between sections (only
mortality_data <- data.frame(
  Section = rep(c("Front Third", "Middle Third", "Rear Third"), each = nrow(data)),
  MortalityRate = c(data$X1.third.mortality.rate, data$X2.third.mortality.rate, data$X3.third.mortality
)
str(mortality_data)
```

```
## 'data.frame':    141 obs. of  2 variables:
##  $ Section      : chr  "Front Third" "Front Third" "Front Third" "Front Third" ...
##  $ MortalityRate: num  0.441 0 0.667 NaN 1 ...
```

```r
mortality_data$Section <- as.factor(mortality_data$Section)

anova_result <- aov(MortalityRate ~ Section, data = mortality_data)
summary(anova_result)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## Section       2  0.364  0.1818   1.251  0.289
## Residuals   137 19.906  0.1453
## 1 observation deleted due to missingness
```

```r
library(multcomp)
```

```
## Loading required package: mvtnorm

## Loading required package: survival

## Loading required package: TH.data

## Loading required package: MASS

##
## Attaching package: 'TH.data'

## The following object is masked from 'package:MASS':
##
##     geyser
```

```r
test_result <- glht(anova_result, linfct = mcp(Section = "Tukey"))
summary(test_result)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: aov(formula = MortalityRate ~ Section, data = mortality_data)
##
## Linear Hypotheses:
##                                 Estimate Std. Error t value Pr(>|t|)
## Middle Third - Front Third == 0 -0.04032    0.07906  -0.510    0.867
## Rear Third - Front Third == 0   -0.12252    0.07906  -1.550    0.271
## Rear Third - Middle Third == 0  -0.08220    0.07863  -1.045    0.550
## (Adjusted p values reported -- single-step method)
```

```r
#half sections
mortality_data_half <- data.frame(
  Section = rep(c("Front Half", "Rear Half"), each = nrow(data)),
  MortalityRate = c(data$X1.half.mortality.rate, data$X2.half.mortality.rate)
)
anova_result_half <- aov(MortalityRate ~ Section, data = mortality_data_half)
summary(anova_result_half)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Section      1  0.056 0.05591   0.409  0.524
## Residuals   92 12.581 0.13675
```

```r
#try using non-parametric test if ANOVA assumptions are not met
kruskal_result <- kruskal.test(MortalityRate ~ Section, data = mortality_data)
kruskal_result_half <- kruskal.test(MortalityRate ~ Section, data = mortality_data_half)
kruskal_result
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  MortalityRate by Section
## Kruskal-Wallis chi-squared = 2.9755, df = 2, p-value = 0.2259
```

```r
kruskal_result_half
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  MortalityRate by Section
## Kruskal-Wallis chi-squared = 0.65567, df = 1, p-value = 0.4181
```

```r
#oneway test

oneway_result <- oneway.test(MortalityRate ~ Section, data = mortality_data, var.equal = FALSE)
oneway_result_half <- oneway.test(MortalityRate ~ Section, data = mortality_data_half, var.equal = FALSE
oneway_result
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  MortalityRate and Section
## F = 1.2857, num df = 2.000, denom df = 91.026, p-value = 0.2814
```

```r
oneway_result_half
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  MortalityRate and Section
## F = 0.40883, num df = 1.000, denom df = 91.667, p-value = 0.5242
```

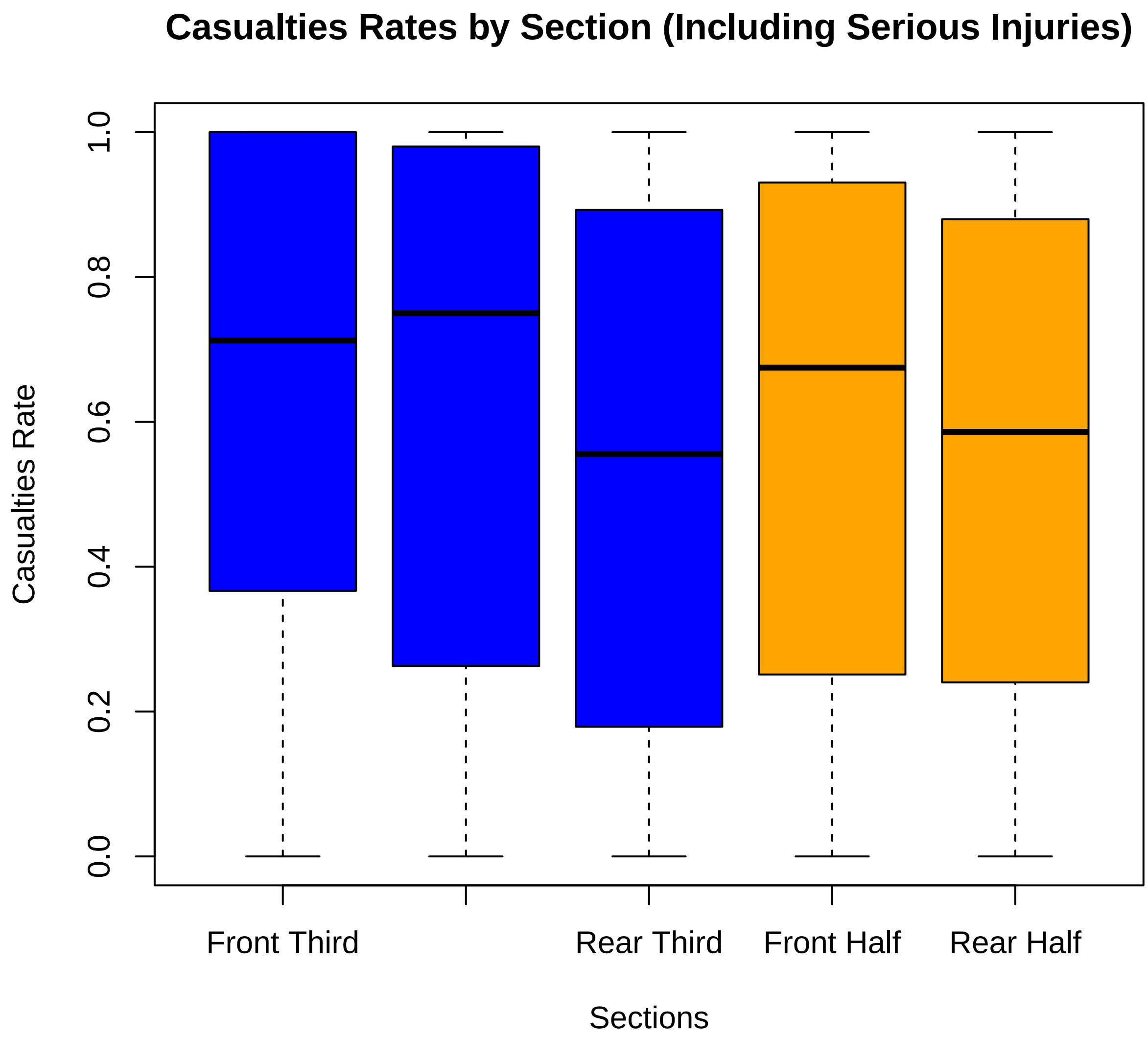
```r
# now we do the same thing but considering the "gravi" as casualties too

data$X1.casualties_rate_new <- (data$X1.terzo.morti + data$X1.terzo.gravi) / data$X1.third.total
data$X2.casualties_rate_new <- (data$X2.terzo.morti + data$X2.terzo.gravi) / data$X2.third.total
data$X3.casualties_rate_new <- (data$X3.terzo.morti + data$X3.terzo.gravi) / data$X3.third.total
data$X1.half.casualties_rate_new <- (data$X1.meta.morti + data$X1.meta.gravi) / data$X1.half.total
data$X2.half.casualties_rate_new <- (data$X2.meta.morti + data$X2.meta.gravi) / data$X2.half.total

head(data)
```

```
##              Airline NumVolo X1.terzo.lievi X1.terzo.gravi X1.terzo.morti
```

```
## 1 singapore airlines       6           17             2            15
## 2   british airtours      28           36             0             0
## 3    british midland      92            0            11            22
## 4     china airlines     120            0             0             0
## 5    japan air lines     123            0             0           136
## 6          air china     129            4             0            14
##   X2.terzo.lievi X2.terzo.gravi X2.terzo.morti X3.terzo.lievi X3.terzo.gravi
## 1              1             15             64             26             17
## 2             30              0             16             10              0
## 3              4             30             13              0             27
## 4              5              0              8              5              0
## 5              0              0            214             36              0
## 6              5              0             60             24              0
##   X3.terzo.morti X1.meta.lievi X1.meta.gravi X1.meta.morti X2.meta.lievi
## 1              0            17             3            41            26
## 2             36            56             0             8            20
## 3             11            32             0            34            39
## 4             21             3             0             6             7
## 5            109             0             0           226             4
## 6             43             7             0            23            26
##   X2.meta.gravi X2.meta.morti fonte PhaseOfFlight  Time   Place HasFire
## 1            31            34     w       takeoff night airport    fire
## 2             0            44     w       takeoff   day outside    fire
## 3             0            13     w       landing night outside    fire
## 4             0            23     w       landing   day airport    fire
## 5             0           225     w       takeoff night outside    fire
## 6             0            90     w       landing   day outside    fire
##   Crushed_fuselage Restraint_intact Environment Energy_absorption
## 1                1                0   dangerous            nogear
## 2                1                0   dangerous            nogear
## 3                1                0   dangerous              gear
## 4                1                1       clear            nogear
## 5                1                0   dangerous            nogear
## 6                1                0   dangerous            nogear
##   X1.third.total X2.third.total X3.third.total X1.half.total X2.half.total
## 1             34             80             43            61            91
## 2             36             46             46            64            64
## 3             33             47             38            66            52
## 4              0             13             26             9            30
## 5            136            214            145           226           229
## 6             18             65             67            30           116
##   X1.third.mortality.rate X2.third.mortality.rate X3.third.mortality.rate
## 1               0.4411765               0.8000000               0.0000000
## 2               0.0000000               0.3478261               0.7826087
## 3               0.6666667               0.2765957               0.2894737
## 4                     NaN               0.6153846               0.8076923
## 5               1.0000000               1.0000000               0.7517241
## 6               0.7777778               0.9230769               0.6417910
##   X1.half.mortality.rate X2.half.mortality.rate X1.casualties_rate_new
## 1              0.6721311              0.3736264              0.5000000
## 2              0.1250000              0.6875000              0.0000000
## 3              0.5151515              0.2500000              1.0000000
## 4              0.6666667              0.7666667                    NaN
## 5              1.0000000              0.9825328              1.0000000
```

```
## 6             0.7666667             0.7758621             0.7777778
##   X2.casualties_rate_new X3.casualties_rate_new X1.half.casualties_rate_new
## 1             0.9875000             0.3953488                   0.7213115
## 2             0.3478261             0.7826087                   0.1250000
## 3             0.9148936             1.0000000                   0.5151515
## 4             0.6153846             0.8076923                   0.6666667
## 5             1.0000000             0.7517241                   1.0000000
## 6             0.9230769             0.6417910                   0.7666667
##   X2.half.casualties_rate_new
## 1                  0.7142857
## 2                  0.6875000
## 3                  0.2500000
## 4                  0.7666667
## 5                  0.9825328
## 6                  0.7758621
```

```r
# Plot new casualties rates as scatter plots for each section
boxplot(data$X1.casualties_rate_new,
  data$X2.casualties_rate_new,
  data$X3.casualties_rate_new,
  data$X1.half.casualties_rate_new,
  data$X2.half.casualties_rate_new,
  names = c("Front Third", "Middle Third", "Rear Third", "Front Half", "Rear Half"),
  main = "Casualties Rates by Section (Including Serious Injuries)",
  ylab = "Casualties Rate",
  xlab = "Sections",
  col = c("blue", "blue", "blue", "orange", "orange"))
```




```
# Perform ANOVA to test if there are significant differences in casualties rates between sections (only
casualties_data <- data.frame(
  Section = rep(c("Front Third", "Middle Third", "Rear Third"), each = nrow(data)),
  CasualtiesRate = c(data$X1.casualties_rate_new, data$X2.casualties_rate_new, data$X3.casualties_rate_n
)
anova_casualties_result <- aov(CasualtiesRate ~ Section, data = casualties_data)
summary(anova_casualties_result)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## Section       2   0.33  0.1648   1.228  0.296
## Residuals   137  18.38  0.1342
## 1 observation deleted due to missingness
```

```
#half sections
casualties_data_half <- data.frame(
  Section = rep(c("Front Half", "Rear Half"), each = nrow(data)),
```

```r
  CasualtiesRate = c(data$X1.half.casualties_rate_new, data$X2.half.casualties_rate_new)
)
anova_casualties_result_half <- aov(CasualtiesRate ~ Section, data = casualties_data_half)
summary(anova_casualties_result_half)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Section      1  0.039 0.03904   0.318  0.574
## Residuals   92 11.283 0.12264
```

```r
#try using non-parametric test if ANOVA assumptions are not met
kruskal_casualties_result <- kruskal.test(CasualtiesRate ~ Section, data = casualties_data)
kruskal_casualties_result_half <- kruskal.test(CasualtiesRate ~ Section, data = casualties_data_half)
kruskal_casualties_result
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  CasualtiesRate by Section
## Kruskal-Wallis chi-squared = 2.6064, df = 2, p-value = 0.2717
```

```r
kruskal_casualties_result_half
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  CasualtiesRate by Section
## Kruskal-Wallis chi-squared = 0.4796, df = 1, p-value = 0.4886
```

```r
#oneway test
oneway_casualties_result <- oneway.test(CasualtiesRate ~ Section, data = casualties_data, var.equal = F
oneway_casualties_result_half <- oneway.test(CasualtiesRate ~ Section, data = casualties_data_half, var
oneway_casualties_result
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  CasualtiesRate and Section
## F = 1.2205, num df = 2.000, denom df = 91.313, p-value = 0.2999
```

```r
oneway_casualties_result_half
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  CasualtiesRate and Section
## F = 0.31829, num df = 1.000, denom df = 91.975, p-value = 0.574
```

```r
# t.test only the fisrts third against the rears third
t_test_result <- t.test(data$X1.third.mortality.rate, data$X3.third.mortality.rate, var.equal = FALSE)
t_test_result
```

```
##
##  Welch Two Sample t-test
##
## data:  data$X1.third.mortality.rate and data$X3.third.mortality.rate
## t = 1.5556, df = 89.487, p-value = 0.1233
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.03396324  0.27900140
## sample estimates:
## mean of x mean of y
## 0.5434137 0.4208946
```

```
#use non-parametric test if t-test assumptions are not met
wilcox_test_result <- wilcox.test(data$X1.third.mortality.rate, data$X3.third.mortality.rate)
```

```
## Warning in wilcox.test.default(data$X1.third.mortality.rate,
## data$X3.third.mortality.rate): cannot compute exact p-value with ties
```

```
wilcox_test_result
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  data$X1.third.mortality.rate and data$X3.third.mortality.rate
## W = 1291, p-value = 0.1052
## alternative hypothesis: true location shift is not equal to 0
```

```
# now we want to test if there is a difference in mortality rate based on the other variables
# PhaseOfFlight, Time, Place, HasFire
# using the total mortality rate, only deaths, do this for evwey third

out <- lm(data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Time + data$Place + data$HasFire + da
summary(out)
```

```
##
## Call:
## lm(formula = data$X1.third.mortality.rate ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.70350 -0.16771  0.04745  0.27778  0.59358
##
## Coefficients:
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  0.49130    0.31703   1.550   0.1297
## data$PhaseOfFlighttakeoff   -0.20082    0.12363  -1.624   0.1128
## data$Timenight               0.05967    0.13300   0.449   0.6563
## data$Placeoutside            0.13799    0.13606   1.014   0.3171
## data$HasFireno-fire         -0.20853    0.13763  -1.515   0.1382
## data$Environmentdangerous   -0.05387    0.20839  -0.258   0.7975
```

```
## data$Energy_absorptionnogear  0.02816    0.14494   0.194   0.8470
## data$Crushed_fuselage         0.21220    0.26274   0.808   0.4245
## data$Restraint_intact        -0.32888    0.17213  -1.911   0.0638 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3645 on 37 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.3156, Adjusted R-squared:  0.1676
## F-statistic: 2.133 on 8 and 37 DF,  p-value: 0.05704
```

```
##simpify the model susins stepwise regression

out_simple <- step(out)
```

```
## Start:  AIC=-84.86
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Energy_absorption  1   0.00501 4.9218 -86.808
## - data$Environment        1   0.00888 4.9257 -86.772
## - data$Time               1   0.02675 4.9435 -86.606
## - data$Crushed_fuselage   1   0.08668 5.0035 -86.051
## - data$Place              1   0.13668 5.0535 -85.594
## <none>                                4.9168 -84.855
## - data$HasFire            1   0.30505 5.2218 -84.086
## - data$PhaseOfFlight      1   0.35065 5.2674 -83.686
## - data$Restraint_intact   1   0.48509 5.4019 -82.527
##
## Step:  AIC=-86.81
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Environment + data$Crushed_fuselage +
##     data$Restraint_intact
##
##                         Df Sum of Sq    RSS     AIC
## - data$Environment       1   0.00855 4.9304 -88.729
## - data$Time              1   0.02934 4.9511 -88.535
## - data$Crushed_fuselage  1   0.08307 5.0049 -88.038
## <none>                               4.9218 -86.808
## - data$Place             1   0.22427 5.1461 -86.759
## - data$HasFire           1   0.30017 5.2220 -86.085
## - data$PhaseOfFlight     1   0.37687 5.2987 -85.414
## - data$Restraint_intact  1   0.49450 5.4163 -84.404
##
## Step:  AIC=-88.73
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Crushed_fuselage + data$Restraint_intact
##
##                         Df Sum of Sq    RSS     AIC
## - data$Time              1   0.02464 4.9550 -90.499
## - data$Crushed_fuselage  1   0.07675 5.0071 -90.018
## - data$Place             1   0.21873 5.1491 -88.732
```

```
## <none>                              4.9304 -88.729
## - data$HasFire           1   0.31767 5.2480 -87.856
## - data$PhaseOfFlight     1   0.37350 5.3039 -87.369
## - data$Restraint_intact  1   0.49100 5.4214 -86.362
##
## Step:  AIC=-90.5
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Place +
##     data$HasFire + data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Crushed_fuselage  1   0.09032 5.0453 -91.668
## <none>                               4.9550 -90.499
## - data$Place             1   0.22427 5.1793 -90.463
## - data$HasFire           1   0.34331 5.2983 -89.418
## - data$PhaseOfFlight     1   0.40733 5.3623 -88.865
## - data$Restraint_intact  1   0.47156 5.4266 -88.317
##
## Step:  AIC=-91.67
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$Place +
##     data$HasFire + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Place             1   0.20996 5.2553 -91.793
## <none>                               5.0453 -91.668
## - data$PhaseOfFlight     1   0.41043 5.4557 -90.071
## - data$HasFire           1   0.54679 5.5921 -88.935
## - data$Restraint_intact  1   0.73385 5.7792 -87.422
##
## Step:  AIC=-91.79
## data$X1.third.mortality.rate ~ data$PhaseOfFlight + data$HasFire +
##     data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## <none>                               5.2553 -91.793
## - data$HasFire           1   0.38822 5.6435 -90.514
## - data$PhaseOfFlight     1   0.44635 5.7016 -90.043
## - data$Restraint_intact  1   0.94626 6.2015 -86.177
```

```r
summary(out_simple)
```

```
##
## Call:
## lm(formula = data$X1.third.mortality.rate ~ data$PhaseOfFlight +
##     data$HasFire + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.74242 -0.18669  0.06875  0.25758  0.66594
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  0.7424     0.0781   9.506 4.98e-12 ***
## data$PhaseOfFlighttakeoff   -0.2059     0.1090  -1.889  0.06585 .
## data$HasFireno-fire         -0.2025     0.1149  -1.761  0.08544 .
```

```
## data$Restraint_intact      -0.4028     0.1465  -2.750  0.00875 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3537 on 42 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.2685, Adjusted R-squared:  0.2163
## F-statistic: 5.139 on 3 and 42 DF,  p-value: 0.004063
```

```
out_2 <- lm(data$X2.third.mortality.rate ~ data$PhaseOfFlight + data$Time + data$Place + data$HasFire +
summary(out_2)
```

```
##
## Call:
## lm(formula = data$X2.third.mortality.rate ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64500 -0.23262  0.06522  0.30156  0.56033
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     0.32793    0.32393   1.012   0.3178
## data$PhaseOfFlighttakeoff      -0.02475    0.12161  -0.204   0.8398
## data$Timenight                  0.09171    0.13546   0.677   0.5025
## data$Placeoutside               0.02624    0.13675   0.192   0.8488
## data$HasFireno-fire            -0.11753    0.14040  -0.837   0.4078
## data$Environmentdangerous      -0.03709    0.20188  -0.184   0.8552
## data$Energy_absorptionnogear    0.12627    0.13811   0.914   0.3663
## data$Crushed_fuselage           0.24011    0.26278   0.914   0.3666
## data$Restraint_intact          -0.32094    0.17037  -1.884   0.0673 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3733 on 38 degrees of freedom
## Multiple R-squared:  0.2229, Adjusted R-squared:  0.05931
## F-statistic: 1.363 on 8 and 38 DF,  p-value: 0.244
```

```
out_2_simple <- step(out_2)
```

```
## Start:  AIC=-84.62
## data$X2.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Environment        1   0.00470 5.2996 -86.578
## - data$Place              1   0.00513 5.3000 -86.575
## - data$PhaseOfFlight      1   0.00577 5.3006 -86.569
## - data$Time               1   0.06387 5.3587 -86.057
## - data$HasFire            1   0.09764 5.3925 -85.761
```

```
## - data$Crushed_fuselage   1   0.11633 5.4112 -85.599
## - data$Energy_absorption  1   0.11647 5.4113 -85.598
## <none>                            5.2949 -84.620
## - data$Restraint_intact   1   0.49449 5.7894 -82.424
##
## Step:  AIC=-86.58
## data$X2.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Energy_absorption + data$Crushed_fuselage +
##     data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Place              1   0.00403 5.3036 -88.543
## - data$PhaseOfFlight      1   0.00637 5.3059 -88.522
## - data$Time               1   0.05930 5.3589 -88.055
## - data$HasFire            1   0.10700 5.4066 -87.639
## - data$Crushed_fuselage   1   0.11286 5.4124 -87.588
## - data$Energy_absorption  1   0.12287 5.4224 -87.501
## <none>                            5.2996 -86.578
## - data$Restraint_intact   1   0.52252 5.8221 -84.159
##
## Step:  AIC=-88.54
## data$X2.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$HasFire + data$Energy_absorption + data$Crushed_fuselage +
##     data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$PhaseOfFlight      1   0.00883 5.3124 -90.465
## - data$Time               1   0.05980 5.3634 -90.016
## - data$HasFire            1   0.10298 5.4066 -89.639
## - data$Crushed_fuselage   1   0.11164 5.4152 -89.564
## - data$Energy_absorption  1   0.18847 5.4921 -88.902
## <none>                            5.3036 -88.543
## - data$Restraint_intact   1   0.57974 5.8834 -85.667
##
## Step:  AIC=-90.46
## data$X2.third.mortality.rate ~ data$Time + data$HasFire + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Time               1   0.06693 5.3794 -91.876
## - data$HasFire            1   0.09568 5.4081 -91.626
## - data$Crushed_fuselage   1   0.11097 5.4234 -91.493
## - data$Energy_absorption  1   0.18015 5.4926 -90.897
## <none>                            5.3124 -90.465
## - data$Restraint_intact   1   0.58539 5.8978 -87.551
##
## Step:  AIC=-91.88
## data$X2.third.mortality.rate ~ data$HasFire + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$HasFire            1   0.11136 5.4907 -92.913
## - data$Crushed_fuselage   1   0.13348 5.5129 -92.724
## - data$Energy_absorption  1   0.18538 5.5647 -92.284
```

```
## <none>                                5.3794 -91.876
## - data$Restraint_intact   1   0.56169 5.9411 -89.208
##
## Step:  AIC=-92.91
## data$X2.third.mortality.rate ~ data$Energy_absorption + data$Crushed_fuselage +
##     data$Restraint_intact
##
##                           Df Sum of Sq    RSS     AIC
## - data$Energy_absorption  1   0.13638 5.6271 -93.760
## <none>                                5.4907 -92.913
## - data$Crushed_fuselage   1   0.28032 5.7710 -92.573
## - data$Restraint_intact   1   0.53410 6.0248 -90.550
##
## Step:  AIC=-93.76
## data$X2.third.mortality.rate ~ data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Crushed_fuselage  1   0.22563 5.8527 -93.912
## <none>                               5.6271 -93.760
## - data$Restraint_intact  1   0.57197 6.1991 -91.210
##
## Step:  AIC=-93.91
## data$X2.third.mortality.rate ~ data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## <none>                               5.8527 -93.912
## - data$Restraint_intact  1   0.96097 6.8137 -88.767
```

```
summary(out_2_simple)
```

```
##
## Call:
## lm(formula = data$X2.third.mortality.rate ~ data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.56785 -0.25564  0.03215  0.31435  0.43215
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.56785    0.05775   9.833 8.78e-13 ***
## data$Restraint_intact -0.38048    0.13997  -2.718  0.00929 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3606 on 45 degrees of freedom
## Multiple R-squared:  0.141,  Adjusted R-squared:  0.1219
## F-statistic: 7.389 on 1 and 45 DF,  p-value: 0.009288
```

```
out_3 <- lm(data$X3.third.mortality.rate ~ data$PhaseOfFlight + data$Time + data$Place + data$HasFire +
summary(out_3)
```

```
##
```

```
## Call:
## lm(formula = data$X3.third.mortality.rate ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.61335 -0.26873  0.02205  0.25488  0.63675
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   0.27928    0.32115   0.870    0.390
## data$PhaseOfFlighttakeoff    -0.04307    0.12056  -0.357    0.723
## data$Timenight               -0.06231    0.13430  -0.464    0.645
## data$Placeoutside             0.02994    0.13557   0.221    0.826
## data$HasFireno-fire          -0.15616    0.13920  -1.122    0.269
## data$Environmentdangerous     0.10748    0.20015   0.537    0.594
## data$Energy_absorptionnogear  0.08976    0.13693   0.656    0.516
## data$Crushed_fuselage         0.10689    0.26053   0.410    0.684
## data$Restraint_intact        -0.15400    0.16891  -0.912    0.368
##
## Residual standard error: 0.3701 on 38 degrees of freedom
## Multiple R-squared:  0.119,  Adjusted R-squared:  -0.06646
## F-statistic: 0.6417 on 8 and 38 DF,  p-value: 0.7378
```

```
out_3_simple <- step(out_3)
```

```
## Start:  AIC=-85.43
## data$X3.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$Place + data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Place              1  0.006677 5.2111 -87.370
## - data$PhaseOfFlight      1  0.017477 5.2219 -87.272
## - data$Crushed_fuselage   1  0.023057 5.2275 -87.222
## - data$Time               1  0.029485 5.2339 -87.164
## - data$Environment        1  0.039495 5.2439 -87.075
## - data$Energy_absorption  1  0.058857 5.2633 -86.901
## - data$Restraint_intact   1  0.113848 5.3183 -86.413
## - data$HasFire            1  0.172367 5.3768 -85.899
## <none>                               5.2044 -85.430
##
## Step:  AIC=-87.37
## data$X3.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## - data$Crushed_fuselage   1  0.022037 5.2331 -89.171
## - data$PhaseOfFlight      1  0.022982 5.2341 -89.163
## - data$Time               1  0.029871 5.2410 -89.101
## - data$Environment        1  0.044424 5.2555 -88.971
## - data$Energy_absorption  1  0.104431 5.3155 -88.437
```

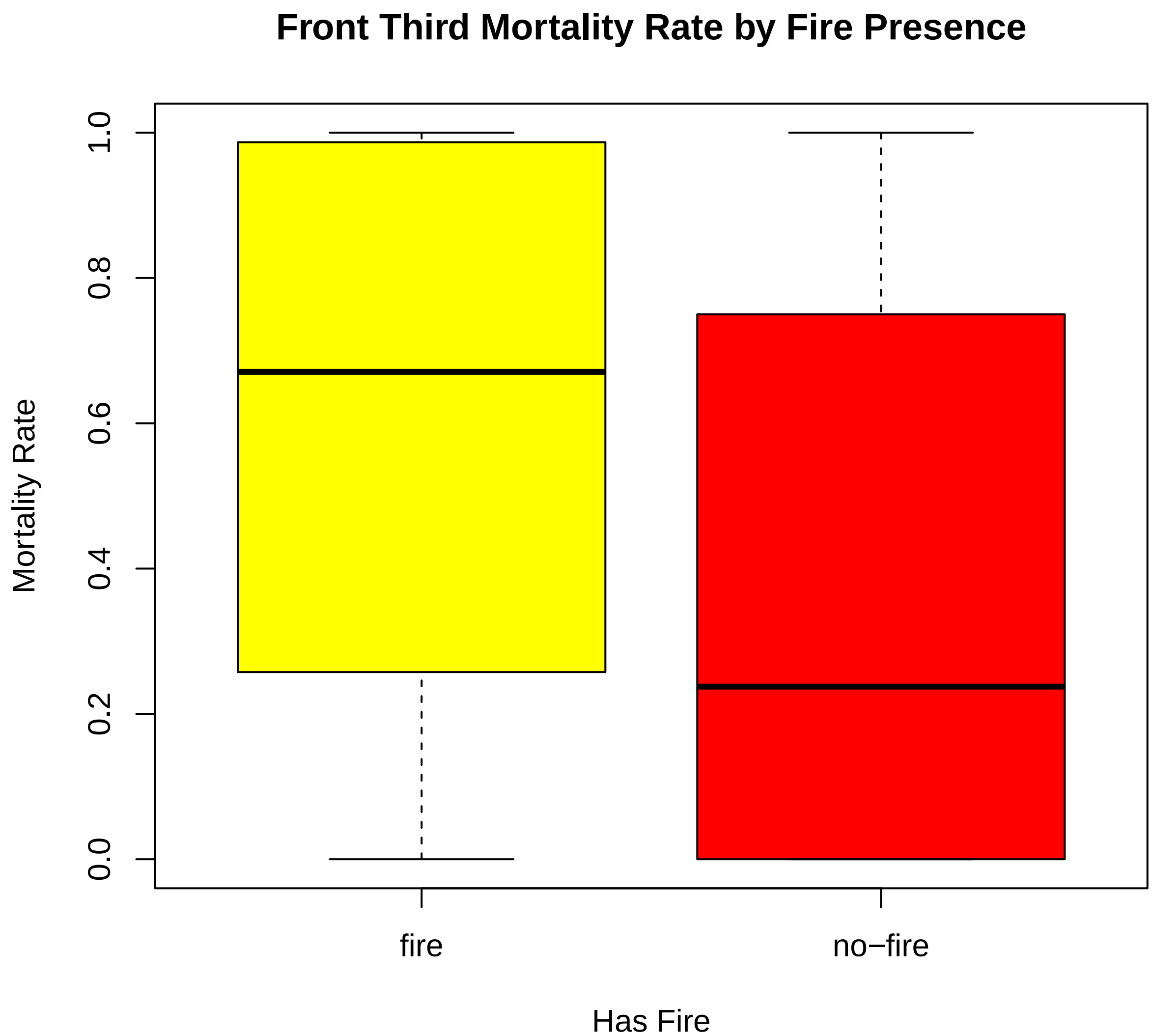
```
## - data$Restraint_intact   1  0.128672 5.3398 -88.223
## - data$HasFire            1  0.165738 5.3768 -87.898
## <none>                             5.2111 -87.370
##
## Step:  AIC=-89.17
## data$X3.third.mortality.rate ~ data$PhaseOfFlight + data$Time +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Restraint_intact
##
##                           Df Sum of Sq    RSS     AIC
## - data$PhaseOfFlight      1  0.022625 5.2558 -90.969
## - data$Time               1  0.025610 5.2588 -90.942
## - data$Environment        1  0.050967 5.2841 -90.716
## - data$Energy_absorption  1  0.098403 5.3315 -90.296
## - data$Restraint_intact   1  0.176090 5.4092 -89.616
## <none>                             5.2331 -89.171
## - data$HasFire            1  0.245032 5.4782 -89.021
##
## Step:  AIC=-90.97
## data$X3.third.mortality.rate ~ data$Time + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Restraint_intact
##
##                           Df Sum of Sq    RSS     AIC
## - data$Time               1  0.020026 5.2758 -92.790
## - data$Environment        1  0.048949 5.3047 -92.533
## - data$Energy_absorption  1  0.080509 5.3363 -92.254
## - data$Restraint_intact   1  0.181840 5.4376 -91.370
## - data$HasFire            1  0.225635 5.4814 -90.993
## <none>                             5.2558 -90.969
##
## Step:  AIC=-92.79
## data$X3.third.mortality.rate ~ data$HasFire + data$Environment +
##     data$Energy_absorption + data$Restraint_intact
##
##                           Df Sum of Sq    RSS     AIC
## - data$Environment        1  0.037371 5.3132 -94.458
## - data$Energy_absorption  1  0.078442 5.3542 -94.096
## - data$Restraint_intact   1  0.200180 5.4760 -93.040
## - data$HasFire            1  0.209267 5.4851 -92.962
## <none>                             5.2758 -92.790
##
## Step:  AIC=-94.46
## data$X3.third.mortality.rate ~ data$HasFire + data$Energy_absorption +
##     data$Restraint_intact
##
##                           Df Sum of Sq    RSS     AIC
## - data$Energy_absorption  1   0.07360 5.3868 -95.811
## - data$HasFire            1   0.19113 5.5043 -94.797
## <none>                             5.3132 -94.458
## - data$Restraint_intact   1   0.32988 5.6430 -93.627
##
## Step:  AIC=-95.81
## data$X3.third.mortality.rate ~ data$HasFire + data$Restraint_intact
##
```

```
##                          Df Sum of Sq    RSS     AIC
## - data$HasFire           1   0.14501 5.5318 -96.563
## <none>                               5.3868 -95.811
## - data$Restraint_intact  1   0.33883 5.7256 -94.944
##
## Step:  AIC=-96.56
## data$X3.third.mortality.rate ~ data$Restraint_intact
##
##                          Df Sum of Sq    RSS     AIC
## <none>                               5.5318 -96.563
## - data$Restraint_intact  1   0.37573 5.9075 -95.474
```

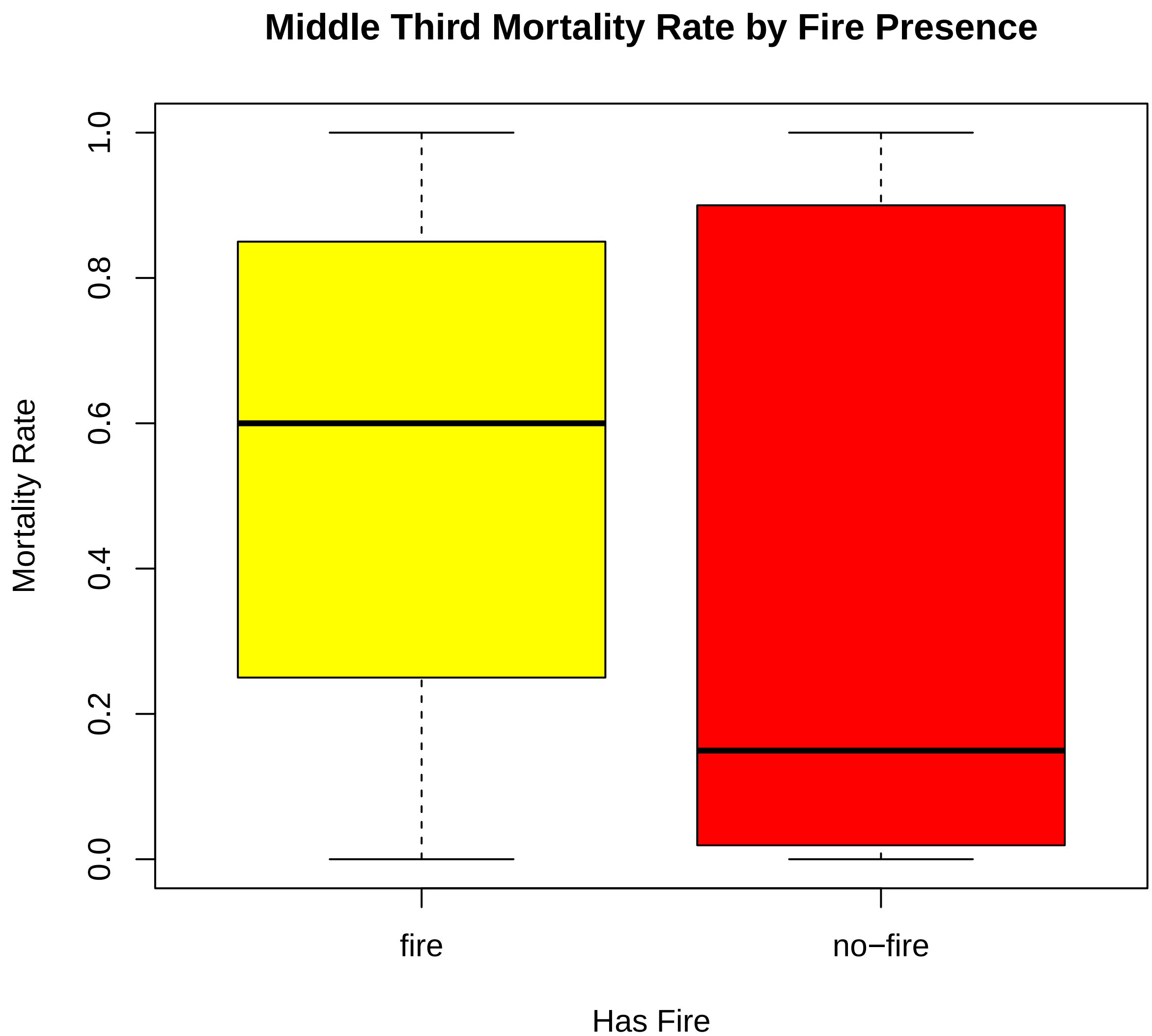
```r
summary(out_3_simple)
```

```
##
## Call:
## lm(formula = data$X3.third.mortality.rate ~ data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.46139 -0.25910 -0.03282  0.27811  0.70985
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.46139    0.05614   8.218 1.66e-10 ***
## data$Restraint_intact -0.23791    0.13608  -1.748   0.0872 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3506 on 45 degrees of freedom
## Multiple R-squared:  0.0636, Adjusted R-squared:  0.04279
## F-statistic: 3.056 on 1 and 45 DF,  p-value: 0.08723
```

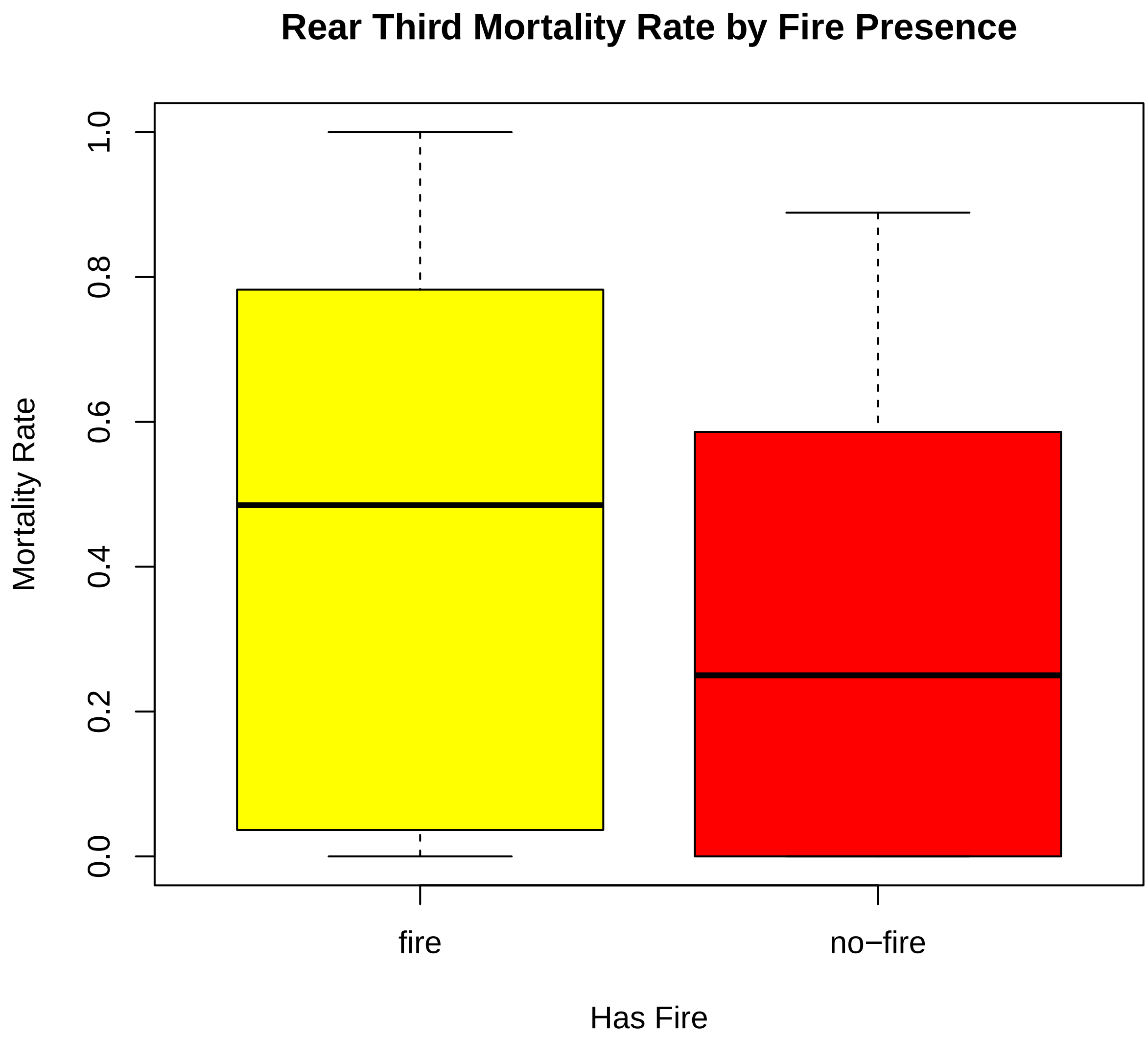
```r
#plot the mortality rates based on HasFire
boxplot(data$X1.third.mortality.rate ~ data$HasFire,
        main = "Front Third Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("yellow", "red"))
```



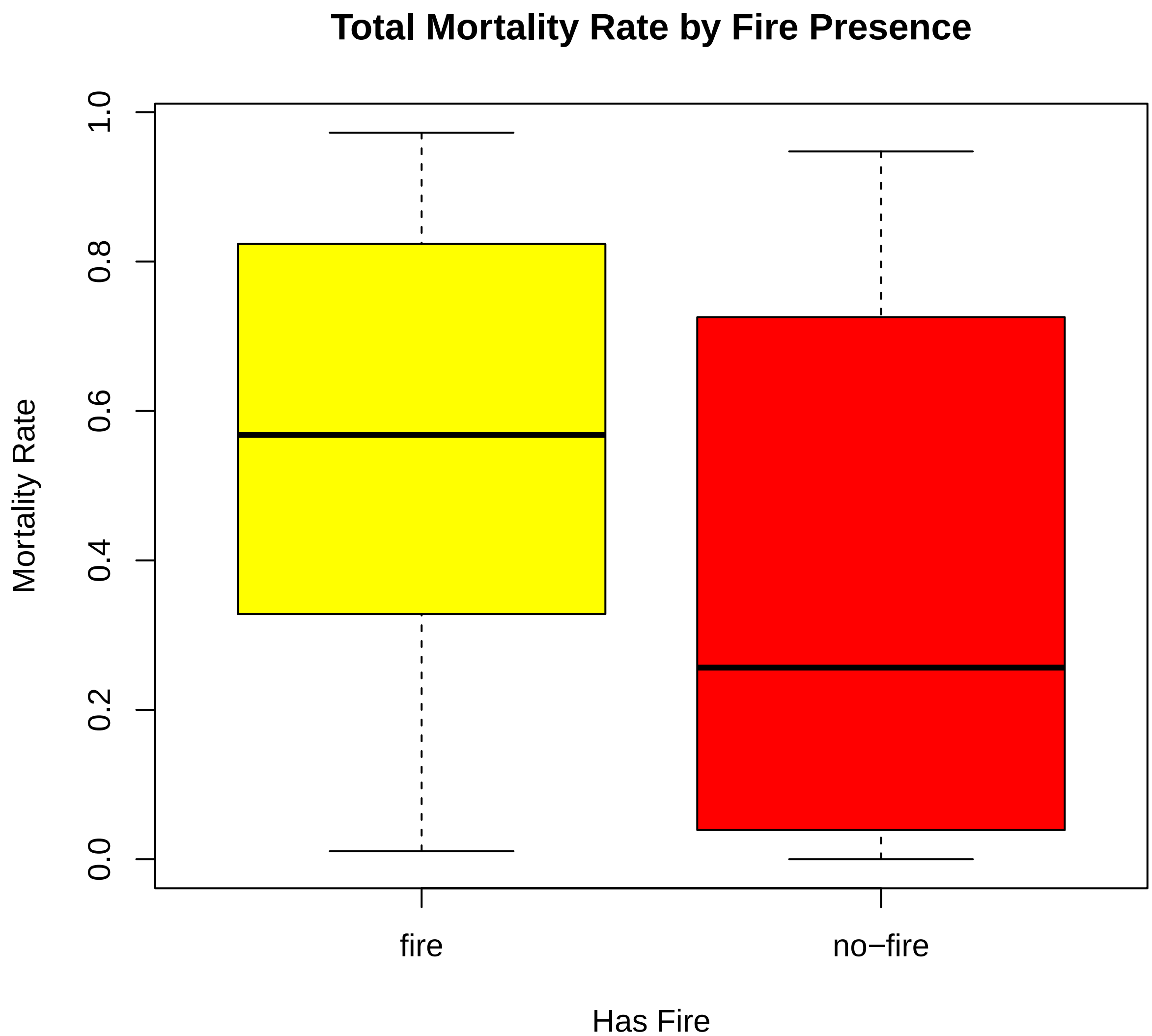

```
boxplot(data$X2.third.mortality.rate ~ data$HasFire,
        main = "Middle Third Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("yellow", "red"))
```




```r
boxplot(data$X3.third.mortality.rate ~ data$HasFire,
        main = "Rear Third Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("yellow", "red"))
```




```r
#and full plane mortality rate
data$Total.mortality.rate <- (data$X1.terzo.morti + data$X2.terzo.morti + data$X3.terzo.morti) / (data$X

boxplot(data$Total.mortality.rate ~ data$HasFire,
        main = "Total Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("yellow", "red"))
```




```
# now for the halves
out_half_1 <- lm(data$X1.half.mortality.rate ~ data$PhaseOfFlight + data$Time + data$Place + data$HasFi
summary(out_half_1)
```

```
##
## Call:
## lm(formula = data$X1.half.mortality.rate ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64724 -0.27567  0.05323  0.24465  0.49986
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)                     0.39237    0.30871   1.271    0.211
## data$PhaseOfFlighttakeoff      -0.10967    0.11590  -0.946    0.350
## data$Timenight                  0.09219    0.12910   0.714    0.480
## data$Placeoutside               0.12520    0.13033   0.961    0.343
## data$HasFireno-fire            -0.16634    0.13381  -1.243    0.221
## data$Environmentdangerous      -0.10597    0.19240  -0.551    0.585
## data$Energy_absorptionnogear    0.11735    0.13162   0.892    0.378
## data$Crushed_fuselage           0.25487    0.25044   1.018    0.315
## data$Restraint_intact          -0.30047    0.16237  -1.851    0.072 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3558 on 38 degrees of freedom
## Multiple R-squared:  0.2789, Adjusted R-squared:  0.1271
## F-statistic: 1.837 on 8 and 38 DF,  p-value: 0.1
```

```r
#simplify the model using stepwise regression
out_half_1_simple <- step(out_half_1 , direction = "both", trace = 0)
summary(out_half_1_simple)
```

```
##
## Call:
## lm(formula = data$X1.half.mortality.rate ~ data$HasFire + data$Restraint_intact +
##     data$Place)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.7304 -0.2254  0.0637  0.2457  0.4820
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.55394    0.07845   7.061 1.05e-08 ***
## data$HasFireno-fire   -0.21241    0.11879  -1.788   0.0808 .
## data$Restraint_intact -0.30672    0.13964  -2.196   0.0335 *
## data$Placeoutside      0.17643    0.11074   1.593   0.1185
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3486 on 43 degrees of freedom
## Multiple R-squared:  0.2164, Adjusted R-squared:  0.1617
## F-statistic: 3.958 on 3 and 43 DF,  p-value: 0.01408
```

```r
out_half_2 <- lm(data$X2.half.mortality.rate ~ data$PhaseOfFlight + data$Time + data$Place + data$HasFi
summary(out_half_2)
```

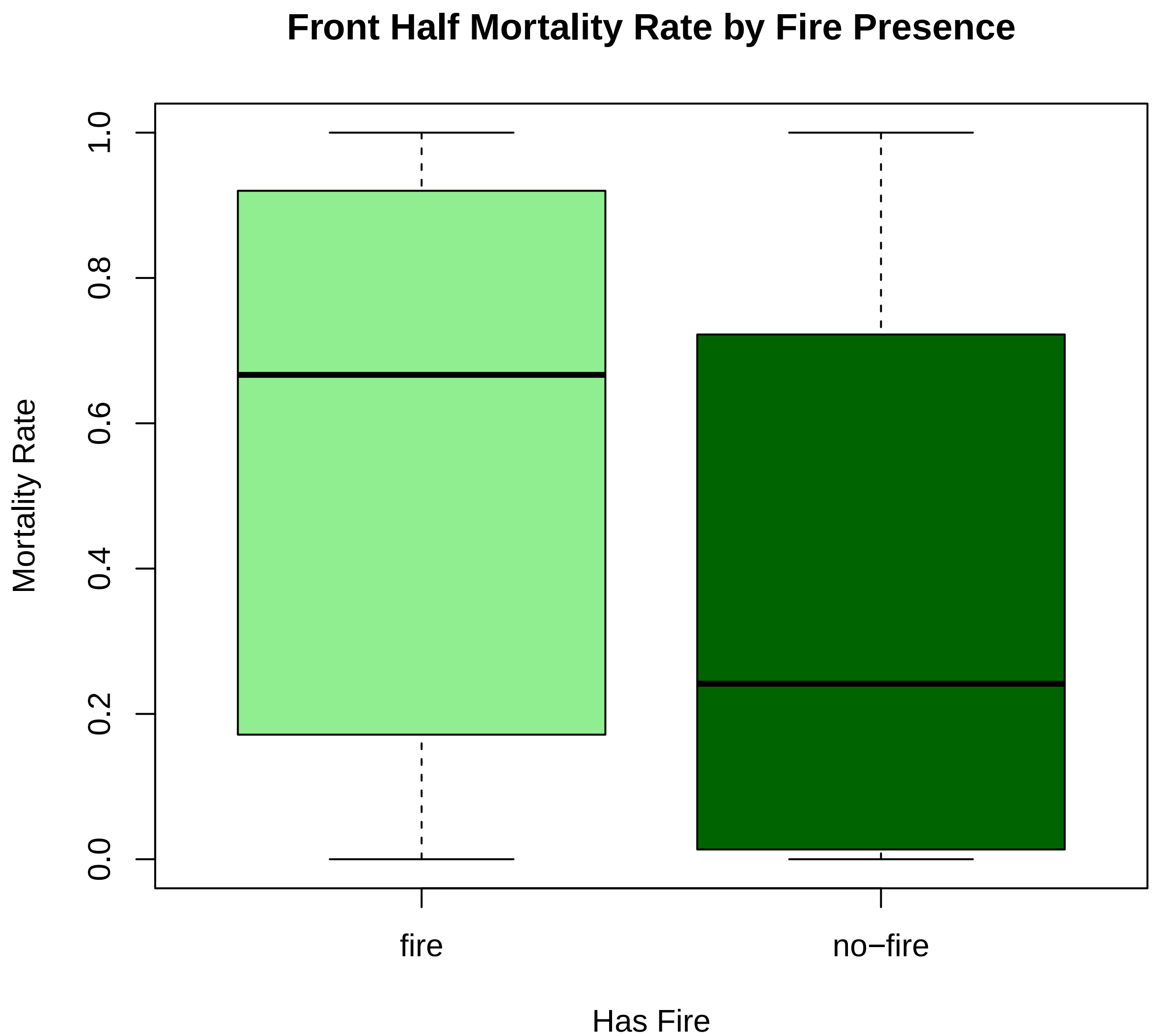
```
##
## Call:
## lm(formula = data$X2.half.mortality.rate ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
```

```
## -0.67138 -0.26653  0.05965  0.25924  0.55600
##
## Coefficients:
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  0.32146    0.31271   1.028    0.310
## data$PhaseOfFlighttakeoff   -0.03733    0.11740  -0.318    0.752
## data$Timenight              -0.01337    0.13077  -0.102    0.919
## data$Placeoutside            0.01529    0.13201   0.116    0.908
## data$HasFireno-fire         -0.16999    0.13554  -1.254    0.217
## data$Environmentdangerous    0.06064    0.19489   0.311    0.757
## data$Energy_absorptionnogear 0.11617    0.13333   0.871    0.389
## data$Crushed_fuselage        0.15782    0.25368   0.622    0.538
## data$Restraint_intact       -0.20860    0.16447  -1.268    0.212
##
## Residual standard error: 0.3604 on 38 degrees of freedom
## Multiple R-squared:  0.1653, Adjusted R-squared:  -0.01045
## F-statistic: 0.9405 on 8 and 38 DF,  p-value: 0.4954
```

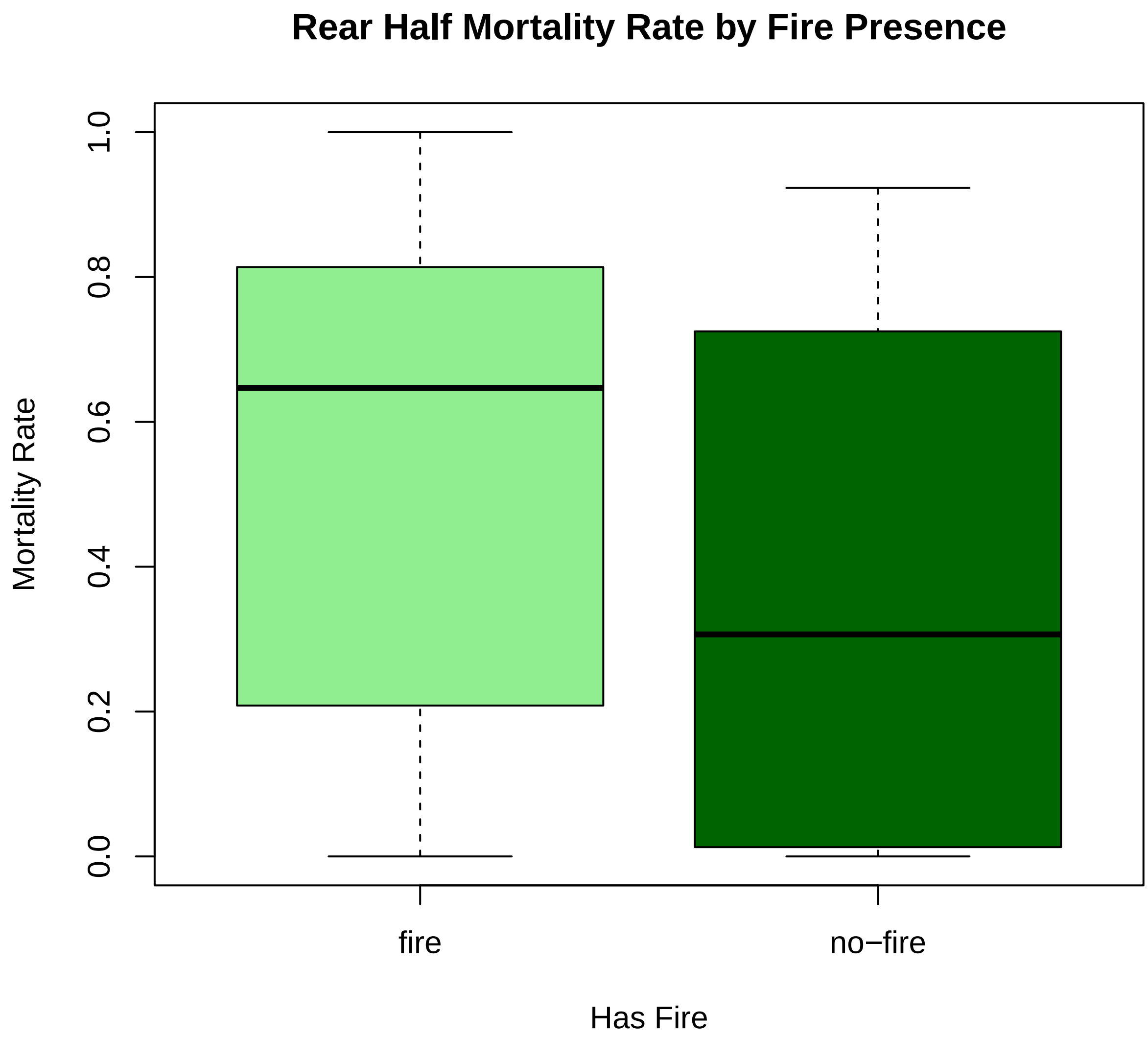
```
#simplify the model using stepwise regression
out_half_2_simple <- step(out_half_2 , direction = "both", trace = 0)
summary(out_half_2_simple)
```

```
##
## Call:
## lm(formula = data$X2.half.mortality.rate ~ data$HasFire + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.56445 -0.29203  0.02176  0.30033  0.55661
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)             0.5645     0.0628   8.987 1.62e-11 ***
## data$HasFireno-fire    -0.1545     0.1093  -1.414   0.1644
## data$Restraint_intact  -0.2711     0.1330  -2.038   0.0476 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3417 on 44 degrees of freedom
## Multiple R-squared:  0.131,  Adjusted R-squared:  0.09146
## F-statistic: 3.315 on 2 and 44 DF,  p-value: 0.04558
```

```
#boxplots for halves
boxplot(data$X1.half.mortality.rate ~ data$HasFire,
        main = "Front Half Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("lightgreen", "darkgreen"))
```




```
boxplot(data$X2.half.mortality.rate ~ data$HasFire,
        main = "Rear Half Mortality Rate by Fire Presence",
        xlab = "Has Fire",
        ylab = "Mortality Rate",
        col = c("lightgreen", "darkgreen"))
```




```r
###############################################################

#same analysis but using glm with binomial family

out_glm <- glm(cbind(data$X1.terzo.morti, data$X1.third.total - data$X1.terzo.morti) ~ data$PhaseOfFlig

summary(out_glm)
```

```
##
## Call:
## glm(formula = cbind(data$X1.terzo.morti, data$X1.third.total -
##     data$X1.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
```

```
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                    -0.8306     0.7566  -1.098 0.272279
## data$PhaseOfFlighttakeoff      -0.9277     0.1554  -5.969 2.39e-09 ***
## data$Timenight                  0.7371     0.1666   4.425 9.66e-06 ***
## data$Placeoutside               0.5409     0.1758   3.078 0.002086 **
## data$HasFireno-fire            -1.5783     0.1871  -8.437  < 2e-16 ***
## data$Environmentdangerous      -0.9189     0.3485  -2.637 0.008373 **
## data$Energy_absorptionnogear    0.7448     0.2031   3.667 0.000245 ***
## data$Crushed_fuselage           2.2584     0.6505   3.472 0.000517 ***
## data$Restraint_intact          -2.6567     0.3059  -8.684  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 1354.33  on 45  degrees of freedom
## Residual deviance:  770.31  on 37  degrees of freedom
## AIC: 867.09
##
## Number of Fisher Scoring iterations: 6
```

```r
out_glm_simple <- step(out_glm, direction = "both", trace = 0)
summary(out_glm_simple)
```

```
##
## Call:
## glm(formula = cbind(data$X1.terzo.morti, data$X1.third.total -
##     data$X1.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                    -0.8306     0.7566  -1.098 0.272279
## data$PhaseOfFlighttakeoff      -0.9277     0.1554  -5.969 2.39e-09 ***
## data$Timenight                  0.7371     0.1666   4.425 9.66e-06 ***
## data$Placeoutside               0.5409     0.1758   3.078 0.002086 **
## data$HasFireno-fire            -1.5783     0.1871  -8.437  < 2e-16 ***
## data$Environmentdangerous      -0.9189     0.3485  -2.637 0.008373 **
## data$Energy_absorptionnogear    0.7448     0.2031   3.667 0.000245 ***
## data$Crushed_fuselage           2.2584     0.6505   3.472 0.000517 ***
## data$Restraint_intact          -2.6567     0.3059  -8.684  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 1354.33  on 45  degrees of freedom
## Residual deviance:  770.31  on 37  degrees of freedom
## AIC: 867.09
##
## Number of Fisher Scoring iterations: 6
```

```r
out_glm_2 <- glm(cbind(data$X2.terzo.morti, data$X2.third.total - data$X2.terzo.morti) ~ data$PhaseOfFli

summary(out_glm_2)
```

```
##
## Call:
## glm(formula = cbind(data$X2.terzo.morti, data$X2.third.total -
##     data$X2.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                                Estimate Std. Error z value Pr(>|z|)
## (Intercept)                     -2.9647     0.4492  -6.600 4.12e-11 ***
## data$PhaseOfFlighttakeoff       -0.3976     0.1165  -3.412 0.000644 ***
## data$Timenight                   0.4412     0.1273   3.465 0.000531 ***
## data$Placeoutside               -0.6270     0.1337  -4.691 2.72e-06 ***
## data$HasFireno-fire             -1.1922     0.1400  -8.514  < 2e-16 ***
## data$Environmentdangerous        1.2655     0.1869   6.770 1.28e-11 ***
## data$Energy_absorptionnogear     2.3175     0.1556  14.897  < 2e-16 ***
## data$Crushed_fuselage            1.9840     0.4008   4.950 7.40e-07 ***
## data$Restraint_intact           -2.2188     0.2108 -10.527  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2358.0  on 46  degrees of freedom
## Residual deviance: 1487.3  on 38  degrees of freedom
## AIC: 1623.8
##
## Number of Fisher Scoring iterations: 6
```

```r
out_glm_2_simple <- step(out_glm_2, direction = "both", trace = 0)
summary(out_glm_2_simple)
```

```
##
## Call:
## glm(formula = cbind(data$X2.terzo.morti, data$X2.third.total -
##     data$X2.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                                Estimate Std. Error z value Pr(>|z|)
## (Intercept)                     -2.9647     0.4492  -6.600 4.12e-11 ***
## data$PhaseOfFlighttakeoff       -0.3976     0.1165  -3.412 0.000644 ***
## data$Timenight                   0.4412     0.1273   3.465 0.000531 ***
## data$Placeoutside               -0.6270     0.1337  -4.691 2.72e-06 ***
## data$HasFireno-fire             -1.1922     0.1400  -8.514  < 2e-16 ***
## data$Environmentdangerous        1.2655     0.1869   6.770 1.28e-11 ***
## data$Energy_absorptionnogear     2.3175     0.1556  14.897  < 2e-16 ***
```

```
## data$Crushed_fuselage          1.9840     0.4008   4.950 7.40e-07 ***
## data$Restraint_intact         -2.2188     0.2108 -10.527  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2358.0  on 46  degrees of freedom
## Residual deviance: 1487.3  on 38  degrees of freedom
## AIC: 1623.8
##
## Number of Fisher Scoring iterations: 6
```

```r
out_glm_3 <- glm(cbind(data$X3.terzo.morti, data$X3.third.total - data$X3.terzo.morti) ~ data$PhaseOfFl

summary(out_glm_3)
```

```
##
## Call:
## glm(formula = cbind(data$X3.terzo.morti, data$X3.third.total -
##     data$X3.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                              Estimate Std. Error z value Pr(>|z|)
## (Intercept)                   -3.2131     0.5016  -6.405 1.50e-10 ***
## data$PhaseOfFlighttakeoff     -0.6487     0.1109  -5.851 4.89e-09 ***
## data$Timenight                -0.4351     0.1256  -3.464 0.000532 ***
## data$Placeoutside             -0.5781     0.1269  -4.557 5.19e-06 ***
## data$HasFireno-fire           -1.0688     0.1498  -7.135 9.65e-13 ***
## data$Environmentdangerous      1.4949     0.2058   7.264 3.76e-13 ***
## data$Energy_absorptionnogear   1.3861     0.1376  10.072  < 2e-16 ***
## data$Crushed_fuselage          2.1168     0.4423   4.786 1.70e-06 ***
## data$Restraint_intact         -0.7993     0.1910  -4.186 2.84e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 1573.7  on 46  degrees of freedom
## Residual deviance: 1235.2  on 38  degrees of freedom
## AIC: 1367.9
##
## Number of Fisher Scoring iterations: 5
```

```r
out_glm_3_simple <- step(out_glm_3, direction = "both", trace = 0)
summary(out_glm_3_simple)
```

```
##
## Call:
## glm(formula = cbind(data$X3.terzo.morti, data$X3.third.total -
##     data$X3.terzo.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
```

```
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                    -3.2131     0.5016  -6.405 1.50e-10 ***
## data$PhaseOfFlighttakeoff      -0.6487     0.1109  -5.851 4.89e-09 ***
## data$Timenight                 -0.4351     0.1256  -3.464 0.000532 ***
## data$Placeoutside              -0.5781     0.1269  -4.557 5.19e-06 ***
## data$HasFireno-fire            -1.0688     0.1498  -7.135 9.65e-13 ***
## data$Environmentdangerous       1.4949     0.2058   7.264 3.76e-13 ***
## data$Energy_absorptionnogear    1.3861     0.1376  10.072  < 2e-16 ***
## data$Crushed_fuselage           2.1168     0.4423   4.786 1.70e-06 ***
## data$Restraint_intact          -0.7993     0.1910  -4.186 2.84e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 1573.7  on 46  degrees of freedom
## Residual deviance: 1235.2  on 38  degrees of freedom
## AIC: 1367.9
##
## Number of Fisher Scoring iterations: 5
```

```r
# now for the halves
out_glm_half_1 <- glm(cbind(data$X1.meta.morti, data$X1.half.total - data$X1.meta.morti) ~ data$PhaseOfF
summary(out_glm_half_1)
```

```
##
## Call:
## glm(formula = cbind(data$X1.meta.morti, data$X1.half.total -
##     data$X1.meta.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                   -2.41859    0.45781  -5.283 1.27e-07 ***
## data$PhaseOfFlighttakeoff     -0.49204    0.10618  -4.634 3.59e-06 ***
## data$Timenight                 0.87752    0.11819   7.425 1.13e-13 ***
## data$Placeoutside             -0.03882    0.11680  -0.332    0.740
## data$HasFireno-fire           -1.07155    0.13588  -7.886 3.12e-15 ***
## data$Environmentdangerous      0.19113    0.18260   1.047    0.295
## data$Energy_absorptionnogear   1.67010    0.13965  11.959  < 2e-16 ***
## data$Crushed_fuselage          2.12817    0.41173   5.169 2.36e-07 ***
## data$Restraint_intact         -2.24930    0.20331 -11.063  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2419.2  on 46  degrees of freedom
## Residual deviance: 1521.6  on 38  degrees of freedom
```

```
## AIC: 1666.5
##
## Number of Fisher Scoring iterations: 5
```

```r
out_glm_half_1_simple <- step(out_glm_half_1 , direction = "both", trace = 0)
summary(out_glm_half_1_simple)
```

```
##
## Call:
## glm(formula = cbind(data$X1.meta.morti, data$X1.half.total -
##     data$X1.meta.morti) ~ data$PhaseOfFlight + data$Time + data$HasFire +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact,
##     family = binomial)
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                    -2.2322     0.4134  -5.399 6.69e-08 ***
## data$PhaseOfFlighttakeoff      -0.4911     0.1050  -4.677 2.91e-06 ***
## data$Timenight                  0.8942     0.1155   7.742 9.80e-15 ***
## data$HasFireno-fire            -1.0567     0.1320  -8.004 1.20e-15 ***
## data$Energy_absorptionnogear    1.6200     0.1199  13.516  < 2e-16 ***
## data$Crushed_fuselage           2.1134     0.4102   5.153 2.57e-07 ***
## data$Restraint_intact          -2.2543     0.2016 -11.185  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2419.2  on 46  degrees of freedom
## Residual deviance: 1522.8  on 40  degrees of freedom
## AIC: 1663.7
##
## Number of Fisher Scoring iterations: 5
```

```r
out_glm_half_2 <- glm(cbind(data$X2.meta.morti, data$X2.half.total - data$X2.meta.morti) ~ data$PhaseOf
summary(out_glm_half_2)
```

```
##
## Call:
## glm(formula = cbind(data$X2.meta.morti, data$X2.half.total -
##     data$X2.meta.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                   -3.12911    0.38777  -8.069 7.06e-16 ***
## data$PhaseOfFlighttakeoff     -0.49258    0.09316  -5.287 1.24e-07 ***
## data$Timenight                -0.23531    0.10107  -2.328 0.019899 *
## data$Placeoutside             -0.40883    0.10666  -3.833 0.000127 ***
## data$HasFireno-fire           -1.25211    0.11649 -10.749  < 2e-16 ***
## data$Environmentdangerous      1.42342    0.15768   9.028  < 2e-16 ***
## data$Energy_absorptionnogear   1.60742    0.11899  13.509  < 2e-16 ***
```

```
## data$Crushed_fuselage         2.21113    0.34247   6.456 1.07e-10 ***
## data$Restraint_intact        -1.24378    0.16142  -7.705 1.30e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2525.9  on 46  degrees of freedom
## Residual deviance: 1773.6  on 38  degrees of freedom
## AIC: 1936.3
##
## Number of Fisher Scoring iterations: 5
```

```
out_glm_half_2_simple <- step(out_glm_half_2 , direction = "both", trace = 0)
summary(out_glm_half_2_simple)
```

```
##
## Call:
## glm(formula = cbind(data$X2.meta.morti, data$X2.half.total -
##     data$X2.meta.morti) ~ data$PhaseOfFlight + data$Time + data$Place +
##     data$HasFire + data$Environment + data$Energy_absorption +
##     data$Crushed_fuselage + data$Restraint_intact, family = binomial)
##
## Coefficients:
##                              Estimate Std. Error z value Pr(>|z|)
## (Intercept)                  -3.12911    0.38777  -8.069 7.06e-16 ***
## data$PhaseOfFlighttakeoff    -0.49258    0.09316  -5.287 1.24e-07 ***
## data$Timenight               -0.23531    0.10107  -2.328 0.019899 *
## data$Placeoutside            -0.40883    0.10666  -3.833 0.000127 ***
## data$HasFireno-fire          -1.25211    0.11649 -10.749  < 2e-16 ***
## data$Environmentdangerous     1.42342    0.15768   9.028  < 2e-16 ***
## data$Energy_absorptionnogear  1.60742    0.11899  13.509  < 2e-16 ***
## data$Crushed_fuselage         2.21113    0.34247   6.456 1.07e-10 ***
## data$Restraint_intact        -1.24378    0.16142  -7.705 1.30e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2525.9  on 46  degrees of freedom
## Residual deviance: 1773.6  on 38  degrees of freedom
## AIC: 1936.3
##
## Number of Fisher Scoring iterations: 5
```

```
#same lm analysis but considering casualties (deaths + serious injuries)
out_casualties <- lm(data$X1.casualties_rate_new ~ data$PhaseOfFlight + data$Time + data$Place + data$Ha
summary(out_casualties)
```

```
##
## Call:
## lm(formula = data$X1.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
```

```
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64202 -0.23185  0.08631  0.22109  0.45624
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  0.424639   0.286966   1.480   0.1474
## data$PhaseOfFlighttakeoff   -0.181421   0.111905  -1.621   0.1135
## data$Timenight               0.126730   0.120387   1.053   0.2993
## data$Placeoutside            0.082089   0.123158   0.667   0.5092
## data$HasFireno-fire         -0.098266   0.124580  -0.789   0.4353
## data$Environmentdangerous    0.024271   0.188631   0.129   0.8983
## data$Energy_absorptionnogear  0.006028   0.131198   0.046   0.9636
## data$Crushed_fuselage        0.286416   0.237821   1.204   0.2361
## data$Restraint_intact       -0.296951   0.155808  -1.906   0.0645 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.33 on 37 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.3317, Adjusted R-squared:  0.1872
## F-statistic: 2.296 on 8 and 37 DF,  p-value: 0.04157
```

```
#simpify the model susins stepwise regression
out_casualties_simple <- step(out_casualties, direction = "both", trace = 0)
summary(out_casualties_simple)
```

```
##
## Call:
## lm(formula = data$X1.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.69526 -0.21933  0.05932  0.21384  0.51919
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                0.41047    0.20915   1.963   0.0563 .
## data$PhaseOfFlighttakeoff -0.19215    0.09792  -1.962   0.0564 .
## data$Crushed_fuselage      0.37569    0.20652   1.819   0.0760 .
## data$Restraint_intact     -0.30535    0.14212  -2.148   0.0375 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3198 on 42 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.2873, Adjusted R-squared:  0.2364
## F-statistic: 5.643 on 3 and 42 DF,  p-value: 0.002423
```

```r
out_casualties_2 <- lm(data$X2.casualties_rate_new ~ data$PhaseOfFlight + data$Time + data$Place + data$
summary(out_casualties_2)
```

```
##
## Call:
## lm(formula = data$X2.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.69998 -0.17672  0.09558  0.22373  0.39474
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    0.43487    0.29447   1.477   0.1480
## data$PhaseOfFlighttakeoff     -0.01900    0.11055  -0.172   0.8645
## data$Timenight                 0.17890    0.12314   1.453   0.1545
## data$Placeoutside              0.01615    0.12431   0.130   0.8973
## data$HasFireno-fire           -0.03324    0.12763  -0.260   0.7960
## data$Environmentdangerous     -0.07364    0.18353  -0.401   0.6905
## data$Energy_absorptionnogear   0.09803    0.12555   0.781   0.4398
## data$Crushed_fuselage          0.26302    0.23888   1.101   0.2778
## data$Restraint_intact         -0.38744    0.15488  -2.502   0.0168 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3393 on 38 degrees of freedom
## Multiple R-squared:  0.2929, Adjusted R-squared:  0.1441
## F-statistic: 1.968 on 8 and 38 DF,  p-value: 0.0777
```

```r
out_casualties_2_simple <- step(out_casualties_2, direction = "both", trace = 0)
summary(out_casualties_2_simple)
```

```
##
## Call:
## lm(formula = data$X2.casualties_rate_new ~ data$Time + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64720 -0.16568  0.07195  0.27434  0.39970
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)             0.64720    0.05813  11.134 2.19e-14 ***
## data$Timenight          0.19574    0.11202   1.747  0.08755 .
## data$Restraint_intact -0.43152    0.12621  -3.419  0.00136 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3251 on 44 degrees of freedom
## Multiple R-squared:  0.2484, Adjusted R-squared:  0.2143
## F-statistic: 7.272 on 2 and 44 DF,  p-value: 0.001868
```

```r
out_casualties_3 <- lm(data$X3.casualties_rate_new ~ data$PhaseOfFlight + data$Time + data$Place + data$
summary(out_casualties_3)
```

```
##
## Call:
## lm(formula = data$X3.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.74307 -0.21754  0.04781  0.28802  0.67549
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    0.42067    0.31490   1.336    0.190
## data$PhaseOfFlighttakeoff     -0.05061    0.11822  -0.428    0.671
## data$Timenight                 0.01145    0.13168   0.087    0.931
## data$Placeoutside              0.10401    0.13294   0.782    0.439
## data$HasFireno-fire           -0.20774    0.13649  -1.522    0.136
## data$Environmentdangerous      0.04541    0.19626   0.231    0.818
## data$Energy_absorptionnogear   0.04761    0.13426   0.355    0.725
## data$Crushed_fuselage          0.12538    0.25545   0.491    0.626
## data$Restraint_intact         -0.21634    0.16562  -1.306    0.199
##
## Residual standard error: 0.3629 on 38 degrees of freedom
## Multiple R-squared:  0.1886, Adjusted R-squared:  0.0178
## F-statistic: 1.104 on 8 and 38 DF,  p-value: 0.382
```

```r
out_casualties_3_simple <- step(out_casualties_3, direction = "both", trace = 0)
summary(out_casualties_3_simple)
```

```
##
## Call:
## lm(formula = data$X3.casualties_rate_new ~ data$HasFire + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.63264 -0.29136  0.00915  0.32658  0.65800
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.63264    0.06346   9.970 7.33e-13 ***
## data$HasFireno-fire   -0.17444    0.11044  -1.579    0.121
## data$Restraint_intact -0.29065    0.13439  -2.163    0.036 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3452 on 44 degrees of freedom
## Multiple R-squared:  0.1496, Adjusted R-squared:  0.1109
## F-statistic: 3.869 on 2 and 44 DF,  p-value: 0.02831
```

```r
# now for the halves
out_casualties_half_1 <- lm(data$X1.half.casualties_rate_new ~ data$PhaseOfFlight + data$Time + data$Pl
summary(out_casualties_half_1)
```

```
##
## Call:
## lm(formula = data$X1.half.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.68911 -0.21398  0.07866  0.24077  0.43735
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   0.38679    0.28382   1.363   0.1810
## data$PhaseOfFlighttakeoff    -0.11592    0.10655  -1.088   0.2835
## data$Timenight                0.12004    0.11869   1.011   0.3182
## data$Placeoutside             0.05593    0.11982   0.467   0.6433
## data$HasFireno-fire          -0.12375    0.12302  -1.006   0.3208
## data$Environmentdangerous    -0.05439    0.17689  -0.307   0.7601
## data$Energy_absorptionnogear  0.12646    0.12101   1.045   0.3026
## data$Crushed_fuselage         0.29808    0.23024   1.295   0.2033
## data$Restraint_intact        -0.27608    0.14927  -1.849   0.0722 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3271 on 38 degrees of freedom
## Multiple R-squared:  0.2912, Adjusted R-squared:  0.142
## F-statistic: 1.951 on 8 and 38 DF,  p-value: 0.08022
```

```r
#simplify the model using stepwise regression
out_casualties_half_1_simple <- step(out_casualties_half_1 , direction = "both", trace = 0)
summary(out_casualties_half_1_simple)
```

```
##
## Call:
## lm(formula = data$X1.half.casualties_rate_new ~ data$Crushed_fuselage +
##     data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.66325 -0.17536  0.05897  0.28004  0.33675
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)             0.3073     0.2068   1.486   0.1444
## data$Crushed_fuselage   0.3559     0.2055   1.732   0.0903 .
## data$Restraint_intact  -0.2725     0.1337  -2.038   0.0475 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.3232 on 44 degrees of freedom
## Multiple R-squared:  0.1983, Adjusted R-squared:  0.1619
## F-statistic: 5.443 on 2 and 44 DF,  p-value: 0.007722
```

```
out_casualties_half_2 <- lm(data$X2.half.casualties_rate_new ~ data$PhaseOfFlight + data$Time + data$Pla
summary(out_casualties_half_2)
```

```
##
## Call:
## lm(formula = data$X2.half.casualties_rate_new ~ data$PhaseOfFlight +
##     data$Time + data$Place + data$HasFire + data$Environment +
##     data$Energy_absorption + data$Crushed_fuselage + data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.73633 -0.25383  0.00972  0.25974  0.55273
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   0.452846   0.298985   1.515    0.138
## data$PhaseOfFlighttakeoff    -0.043533   0.112245  -0.388    0.700
## data$Timenight                0.004543   0.125031   0.036    0.971
## data$Placeoutside            -0.054305   0.126219  -0.430    0.669
## data$HasFireno-fire          -0.169190   0.129591  -1.306    0.200
## data$Environmentdangerous    -0.036055   0.186340  -0.193    0.848
## data$Energy_absorptionnogear  0.164263   0.127477   1.289    0.205
## data$Crushed_fuselage         0.209584   0.242548   0.864    0.393
## data$Restraint_intact        -0.210573   0.157251  -1.339    0.188
##
## Residual standard error: 0.3445 on 38 degrees of freedom
## Multiple R-squared:  0.187,  Adjusted R-squared:  0.01582
## F-statistic: 1.092 on 8 and 38 DF,  p-value: 0.3895
```

```
#simplify the model using stepwise regression
out_casualties_half_2_simple <- step(out_casualties_half_2 , direction = "both", trace = 0)
summary(out_casualties_half_2_simple)
```

```
##
## Call:
## lm(formula = data$X2.half.casualties_rate_new ~ data$HasFire +
##     data$Restraint_intact)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64816 -0.21341  0.03934  0.29064  0.50918
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)             0.6482     0.0607  10.678  8.5e-14 ***
## data$HasFireno-fire    -0.1854     0.1056  -1.755   0.0863 .
## data$Restraint_intact  -0.2323     0.1286  -1.807   0.0776 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.3303 on 44 degrees of freedom
## Multiple R-squared:  0.135,  Adjusted R-squared:  0.09572
## F-statistic: 3.435 on 2 and 44 DF,  p-value: 0.04111
```

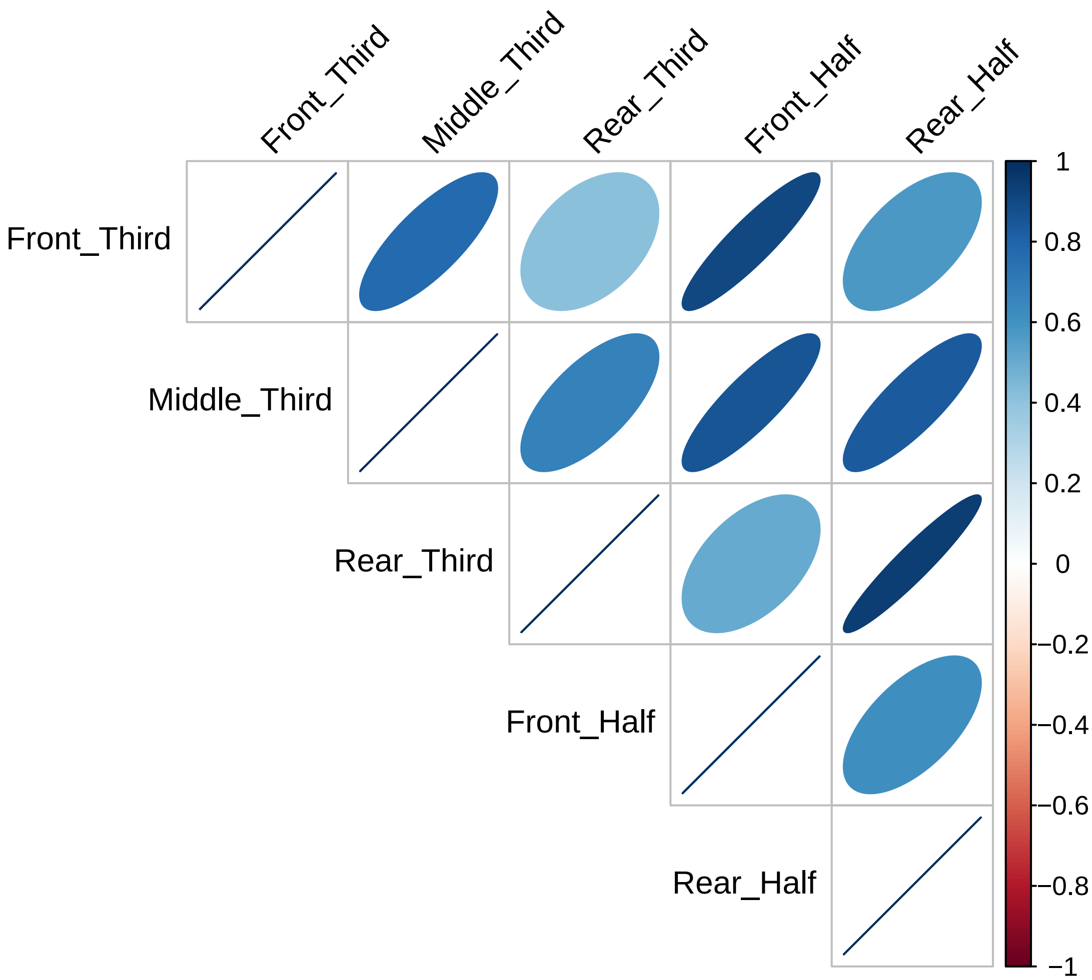
```r
# now we wnar to study the correlation between the different sections mortality rates
correlation_matrix <- data.frame(
  Front_Third = data$X1.third.mortality.rate,
  Middle_Third = data$X2.third.mortality.rate,
  Rear_Third = data$X3.third.mortality.rate,
  Front_Half = data$X1.half.mortality.rate,
  Rear_Half = data$X2.half.mortality.rate

)
correlation_results <- cor(correlation_matrix, use = "complete.obs")
correlation_results
```

```
##              Front_Third Middle_Third Rear_Third Front_Half Rear_Half
## Front_Third    1.0000000    0.7764119  0.4186839  0.9044428 0.5754482
## Middle_Third   0.7764119    1.0000000  0.6707028  0.8548248 0.8309324
## Rear_Third     0.4186839    0.6707028  1.0000000  0.5021073 0.9446734
## Front_Half     0.9044428    0.8548248  0.5021073  1.0000000 0.6126933
## Rear_Half      0.5754482    0.8309324  0.9446734  0.6126933 1.0000000
```

```r
## cor plot
library(corrplot)
```

```
## corrplot 0.95 loaded
```

```r
corrplot(correlation_results, method = "ellipse", type = "upper", tl.col = "black", tl.srt = 45)
```

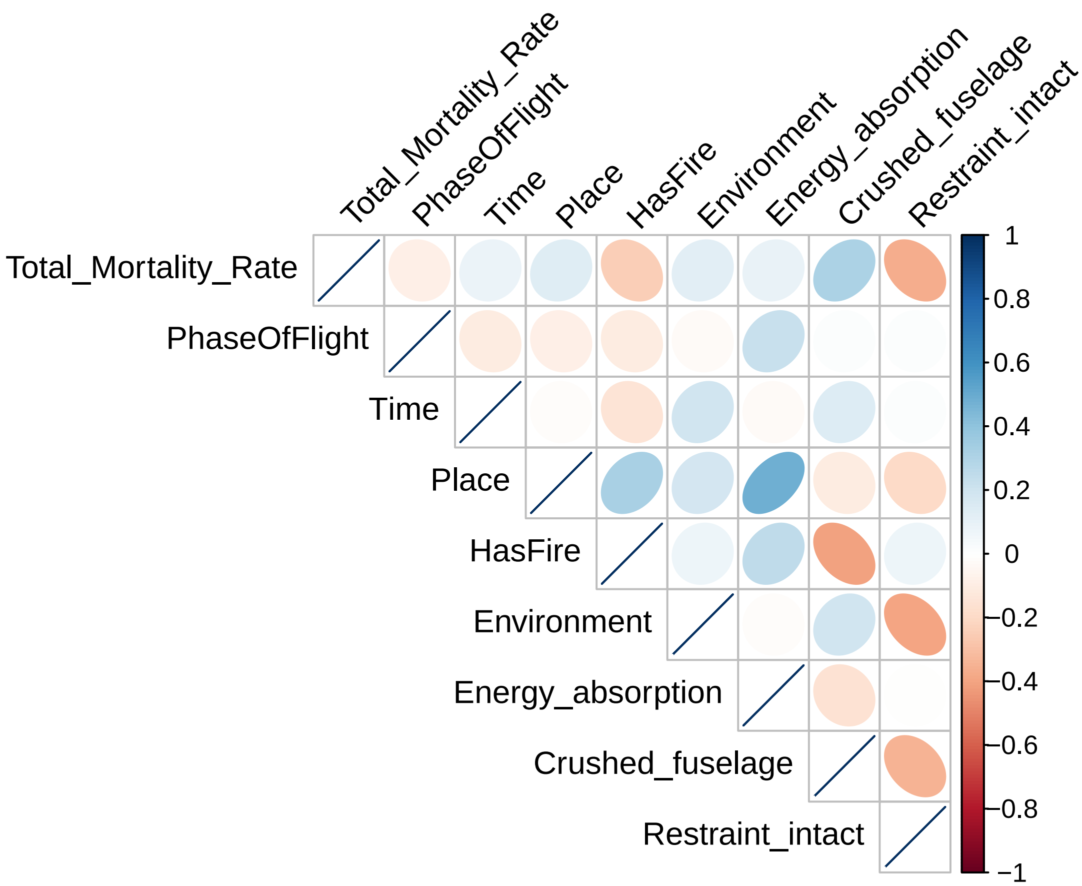



```
## now study the correlation between the other variables and the total mortality rate
correlation_matrix_2 <- data.frame(
  Total_Mortality_Rate = data$Total.mortality.rate,
  PhaseOfFlight = as.numeric(as.factor(data$PhaseOfFlight)),
  Time = as.numeric(as.factor(data$Time)),
  Place = as.numeric(as.factor(data$Place)),
  HasFire = as.numeric(as.factor(data$HasFire)),
  Environment = as.numeric(as.factor(data$Environment)),
  Energy_absorption = as.numeric(as.factor(data$Energy_absorption)),
  Crushed_fuselage = as.numeric(as.factor(data$Crushed_fuselage)),
  Restraint_intact = as.numeric(as.factor(data$Restraint_intact))
)
correlation_results_2 <- cor(correlation_matrix_2, use = "complete.obs")
correlation_results_2
```

```
##                      Total_Mortality_Rate PhaseOfFlight       Time      Place
## Total_Mortality_Rate           1.00000000   -0.08666607 0.08261213 0.13102220
```

```
## PhaseOfFlight                -0.08666607    1.00000000 -0.10235879 -0.08496618
## Time                          0.08261213   -0.10235879  1.00000000 -0.01499923
## Place                         0.13102220   -0.08496618 -0.01499923  1.00000000
## HasFire                      -0.24919279   -0.10300633 -0.14027577  0.32137544
## Environment                   0.12500715   -0.02750095  0.19072405  0.18537431
## Energy_absorption             0.09710791    0.22675952 -0.02199466  0.48897279
## Crushed_fuselage              0.31917293    0.01541658  0.14433757 -0.10391775
## Restraint_intact             -0.36849986    0.01253452  0.01706972 -0.19794987
##                          HasFire Environment Energy_absorption Crushed_fuselage
## Total_Mortality_Rate -0.24919279  0.12500715       0.097107907       0.31917293
## PhaseOfFlight        -0.10300633 -0.02750095       0.226759516       0.01541658
## Time                 -0.14027577  0.19072405      -0.021994655       0.14433757
## Place                 0.32137544  0.18537431       0.488972793      -0.10391775
## HasFire               1.00000000  0.07384094       0.252502362      -0.40089186
## Environment           0.07384094  1.00000000      -0.012081340       0.19219999
## Energy_absorption     0.25250236 -0.01208134       1.000000000      -0.15238344
## Crushed_fuselage     -0.40089186  0.19219999      -0.152383440       1.00000000
## Restraint_intact      0.07638353 -0.39457942      -0.007433763      -0.34493223
##                      Restraint_intact
## Total_Mortality_Rate     -0.368499856
## PhaseOfFlight             0.012534517
## Time                      0.017069719
## Place                    -0.197949865
## HasFire                   0.076383528
## Environment              -0.394579419
## Energy_absorption        -0.007433763
## Crushed_fuselage         -0.344932231
## Restraint_intact          1.000000000
```

```r
corrplot(correlation_results_2, method = "ellipse", type = "upper", tl.col = "black", tl.srt = 45)
```



4 Data Description & Analysis

Firstly, let's take a look at the data gathered,in particular its structure and meaning:

```r
accident_data <- read.csv("AllCREEP_cleaned_eng.csv")
str(accident_data)
```

```
## 'data.frame':    47 obs. of  26 variables:
##  $ Airline          : chr  "singapore airlines" "british airtours" "british midland" "china airlines"
##  $ FlightNum        : int  6 28 92 120 123 129 140 148 191 204 ...
##  $ X1.third.minor   : int  17 36 0 0 0 4 0 0 0 3 ...
##  $ X1.third.major   : int  2 0 11 0 0 0 0 0 0 0 ...
##  $ X1.third.dead    : int  15 0 22 0 136 14 18 16 55 33 ...
##  $ X2.third.minor   : int  1 30 4 5 0 5 7 1 0 25 ...
##  $ X2.third.major   : int  15 0 30 0 0 0 0 0 8 0 ...
```

```
##  $ X2.third.dead   : int  64 16 13 8 214 60 139 34 51 1 ...
##  $ X3.third.minor  : int  26 10 0 5 36 24 0 8 10 29 ...
##  $ X3.third.major  : int  17 0 27 0 0 0 0 0 7 0 ...
##  $ X3.third.dead   : int  0 36 11 21 109 43 91 30 16 0 ...
##  $ X1.half.minor   : int  17 56 32 3 0 7 7 1 0 7 ...
##  $ X1.half.major   : int  3 0 0 0 0 0 0 0 1 0 ...
##  $ X1.half.dead    : int  41 8 34 6 226 23 95 36 79 35 ...
##  $ X2.half.minor   : int  26 20 39 7 4 26 0 7 10 46 ...
##  $ X2.half.major   : int  31 0 0 0 0 0 0 0 14 0 ...
##  $ X2.half.dead    : int  34 44 13 23 225 90 145 46 48 0 ...
##  $ DataOrigin      : chr  "w" "w" "w" "w" ...
##  $ PhaseOfFlight   : chr  "takeoff" "takeoff" "landing" "landing" ...
##  $ Time            : chr  "night" "day" "night" "day" ...
##  $ Place           : chr  "airport" "outside" "outside" "airport" ...
##  $ HasFire         : chr  "fire" "fire" "fire" "fire" ...
##  $ CrushedFuselage : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ RestraintIntact : int  0 0 0 1 0 0 0 0 0 0 ...
##  $ Environment     : chr  "dangerous" "dangerous" "dangerous" "clear" ...
##  $ EnergyAbsorption: chr  "nogear" "nogear" "gear" "nogear" ...
```

```
#
#> str(accident_data)
#'data.frame':   47 obs. of  26 variables:
# $ Airline          : chr  "singapore airlines" "british airtours" "british midland" "china airlines"
# $ FlightNum        : int  6 28 92 120 123 129 140 148 191 204 ...
# $ X1.third.minor   : int  17 36 0 0 0 4 0 0 0 3 ...
# $ X1.third.major   : int  2 0 11 0 0 0 0 0 0 0 ...
# $ X1.third.dead    : int  15 0 22 0 136 14 18 16 55 33 ...
# $ X2.third.minor   : int  1 30 4 5 0 5 7 1 0 25 ...
# $ X2.third.major   : int  15 0 30 0 0 0 0 0 8 0 ...
# $ X2.third.dead    : int  64 16 13 8 214 60 139 34 51 1 ...
# $ X3.third.minor   : int  26 10 0 5 36 24 0 8 10 29 ...
# $ X3.third.major   : int  17 0 27 0 0 0 0 0 7 0 ...
# $ X3.third.dead    : int  0 36 11 21 109 43 91 30 16 0 ...
# $ X1.half.minor    : int  17 56 32 3 0 7 7 1 0 7 ...
# $ X1.half.major    : int  3 0 0 0 0 0 0 0 1 0 ...
# $ X1.half.dead     : int  41 8 34 6 226 23 95 36 79 35 ...
# $ X2.half.minor    : int  26 20 39 7 4 26 0 7 10 46 ...
# $ X2.half.major    : int  31 0 0 0 0 0 0 0 14 0 ...
# $ X2.half.dead     : int  34 44 13 23 225 90 145 46 48 0 ...
# $ DataOrigin       : chr  "w" "w" "w" "w" ...
# $ PhaseOfFlight    : chr  "takeoff" "takeoff" "landing" "landing" ...
# $ Time             : chr  "night" "day" "night" "day" ...
# $ Place            : chr  "airport" "outside" "outside" "airport" ...
# $ HasFire          : chr  "fire" "fire" "fire" "fire" ...
# $ CrushedFuselage : int  1 1 1 1 1 1 1 1 1 1 ...
# $ RestraintIntact : int  0 0 0 1 0 0 0 0 0 0 ...
# $ Environment      : chr  "dangerous" "dangerous" "dangerous" "clear" ...
# $ EnergyAbsorption: chr  "nogear" "nogear" "gear" "nogear" ...
#>
#
```

The data consists of 47 observations (aircraft accidents) and 26 variables, that are the focus of our analysis. We want to remark that the data consists only of aircraft accidents where there were at least one survival.

The variables consists of:

- **Airline & FlightNum** : identification of the crash, usefull to retrive more information about the accident if needed
- **X variables** : these variables represent the number and the type of casualties in each section of the airplane. The plane is divided in two different ways : in thirds and in halves. For each section, there are three variables representing the number of minor injuries, major injuries and deaths for that section. The format is the following : `X{section}.{part}.{type of injury}`, where section is 1,2,3 for the thirds and 1,2 for the halves, part is "third" or "half", and type of injury is "minor", "major" or "dead".
- **DataOrigin** : source of the data, [to complete]
- **PhaseOfFlight** : phase of flight when the accident happened, The possible values are "takeoff" or "landing", landing includes possible emergency landings.
- **Time** : time of the day when the accident happened, possible values are "day" or "night". This is intended to signal if natural light was present or not.
- **Place** : location where the accident happened, possible values are "airport" or "outside". "Airport" means that the accident happened on the runway or in the immediate vicinity of the airport, "outside" means that the accident happened far from any airport.
- **HasFire** : indicates if there was a fire during or after the accident, possible values are "fire" or "no-fire".

Now we include also 4 other variables useful to determine the severity of an aircraft accident:

- **CrushedFuselage** : indicates if the fuselage was crushed during the accident, possible values are 1 (yes) or 0 (no).
- **RestraintIntact** : indicates if the restraint system was intact, and thus effective at retain the passengers, during the accident, possible values are 1 (yes) or 0 (no).
- **Environment** : indicates the environmental conditions during the accident, possible values are "clear" or "dangerous".
- **EnergyAbsorption** : indicates if the landing gear was developed to absorb energy during the accident, if not the airplane is considerd to have done a "belly landing".

To start the analysis, let's prepare the data by adding some useful variables, and trasform some variables into a more manageable format.

```r
# add a colum of # of passengers for each airplain section
accident_data <- within(accident_data, {
  X2.half.total  <- X2.half.minor  + X2.half.major  + X2.half.dead
  X1.half.total  <- X1.half.minor  + X1.half.major  + X1.half.dead
  X3.third.total <- X3.third.minor + X3.third.major + X3.third.dead
  X2.third.total <- X2.third.minor + X2.third.major + X2.third.dead
  X1.third.total <- X1.third.minor + X1.third.major + X1.third.dead
})

# now we transform the variables that are categorical into factors
factor_cols <- c("PhaseOfFlight", "Time", "Place", "HasFire", "Environment",
                 "EnergyAbsorption", "CrushedFuselage", "RestraintIntact")

accident_data[factor_cols] <- lapply(accident_data[factor_cols], as.factor)
```

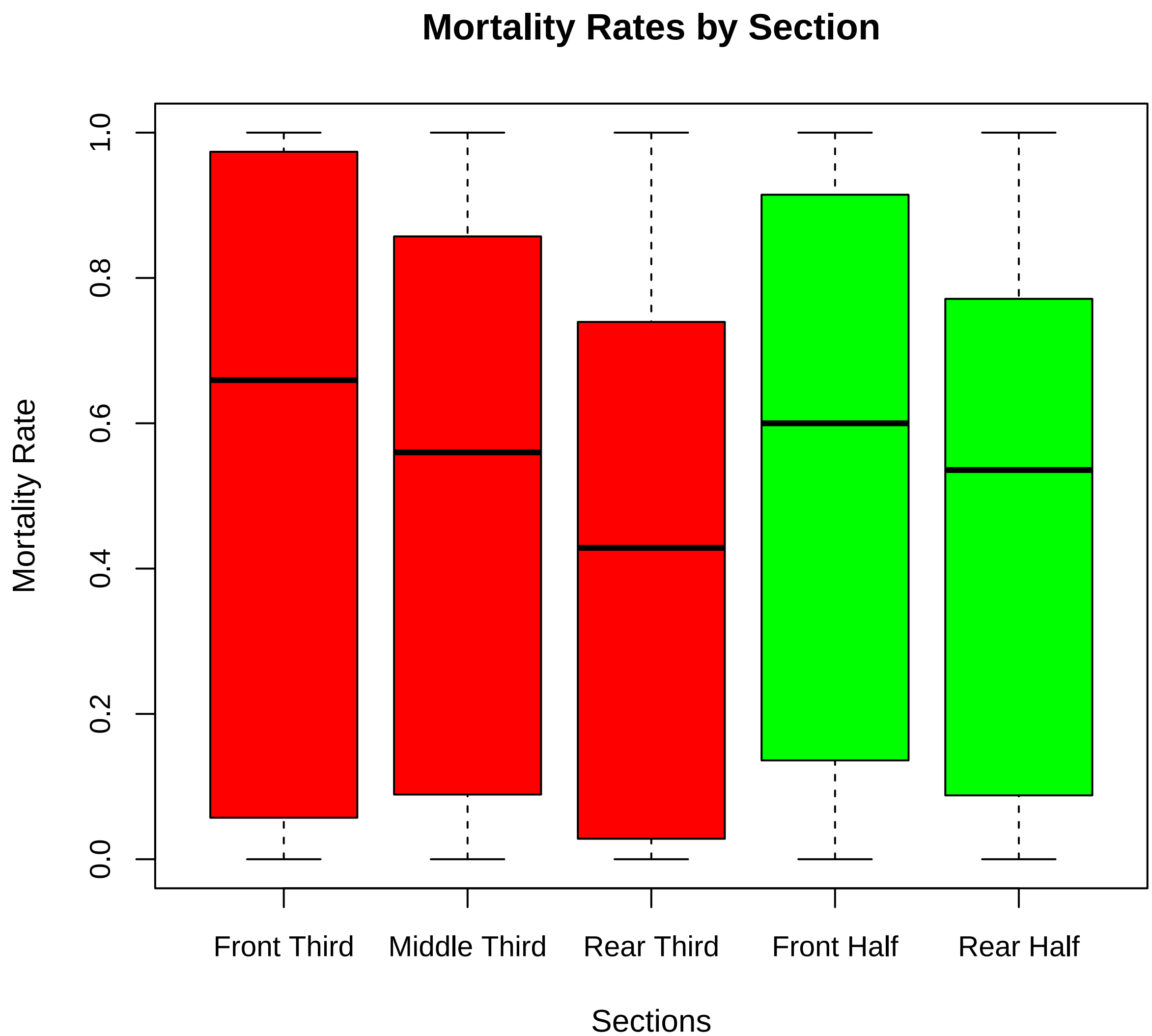
Now we can add a new variable that will be the center of our analysis : the mortality rate for each section of the airplane. The mortality rate is defined as the number of deaths divided by the total number of passengers in that section. Note that some of this aircraft where not full, so there might be sections with very few passengers or possibly empty. Thats why we are considering rates per total passengers instead of per number of seats.

```
accident_data <- within(accident_data, {
  X1.third.mortality.rate <- X1.third.dead / X1.third.total
  X2.third.mortality.rate <- X2.third.dead / X2.third.total
  X3.third.mortality.rate <- X3.third.dead / X3.third.total
  X1.half.mortality.rate  <- X1.half.dead  / X1.half.total
  X2.half.mortality.rate  <- X2.half.dead  / X2.half.total
})
```

4.1 Exploratory Data Analysis

The first step we can do is to plot some feature of the data to have a visual understanding of it. We might get some useful insights and also check for possible outliers or anomalies in the data.

```
with(accident_data, {
  boxplot(X1.third.mortality.rate,
          X2.third.mortality.rate,
          X3.third.mortality.rate,
          X1.half.mortality.rate,
          X2.half.mortality.rate,
          names = c("Front Third", "Middle Third", "Rear Third", "Front Half", "Rear Half"),
          main = "Mortality Rates by Section",
          ylab = "Mortality Rate",
          xlab = "Sections",
          col = c("red", "red", "red", "green", "green"),
          cex.axis = 0.9)
})
```



Intestingly, there seems to be a general trend of lower mortality rates the more rear the section is. This is seen in both the third and half divisions of the airplane.

Now we can try to test the kind of population distribution of the mortality rates, to see if they follow a normal distribution or not. This will help us choose the right statistical tests for our analysis.

We will try the standard Shapiro-Wilk test for normality.

```
# shapiro test for normality, p-value extrated and lableled
shapiro_results <- data.frame(
  Section = c("Front Third", "Middle Third", "Rear Third", "Front Half", "Rear Half"),
  P_Value = c(
    shapiro.test(accident_data$X1.third.mortality.rate)$p.value,
    shapiro.test(accident_data$X2.third.mortality.rate)$p.value,
    shapiro.test(accident_data$X3.third.mortality.rate)$p.value,
    shapiro.test(accident_data$X1.half.mortality.rate)$p.value,
    shapiro.test(accident_data$X2.half.mortality.rate)$p.value
  )
```

```
)
shapiro_results
```

```
##        Section      P_Value
## 1  Front Third 1.873378e-05
## 2 Middle Third 5.727713e-05
## 3   Rear Third 1.964064e-04
## 4   Front Half 8.609941e-05
## 5    Rear Half 2.491057e-04
```

All of the p-values are far below the standard threshold of 0.05, indicating that we can reject the null hypothesis of normality for all sections. This means that the mortality rates do not follow a normal distribution, let's try to plot a histogram for one of the sections to visualize an aproximately of the distribution.

```
par(mfrow = c(1, 2))

colums <- c("X1.third.mortality.rate", "X3.third.mortality.rate")

for( c in colums){
  hist(accident_data[[c]],
       main = paste("Histogram of", gsub("\\.", " ", c)),
       xlab = "Mortality Rate",
       col = "lightblue",
       border = "black",
       breaks = 10)
}
```

There seems that there is no clear distribution pattern, but we can se that the data is more concentrated at either ends of the mortality rate values, expecially for the front third section.

4.2 Statistical Analysis

Now that we have a better understanding of the data, we can proceed with the statistical analysis to test if there are significant differences in mortality rates between the different sections of the airplane. Also we will try to see if there is some correlation between the mortality rates and the other variables in the dataset.

4.2.1 Analysis of differences in mortality rates between sections

Since the distribution of the mortality rates is not normal, we will not use test that assume normality, like t-tests or ANOVA. For this reason, we will use the Kruskal-Wallis test, which is a non-parametric test to compare the distribution of two or more groups. The null hypothesis of the Kruskal-Wallis test is that all the populations have the same distribution.

```r
# Kruskal-Wallis test for differences in mortality rates between sections (only thirds)
mortality_data_third <- data.frame(
  SectionThird = rep(c("Front Third", "Middle Third", "Rear Third"), each = nrow(accident_data)),
  MortalityRateThird = c(accident_data$X1.third.mortality.rate,
                    accident_data$X2.third.mortality.rate,
                    accident_data$X3.third.mortality.rate)
)

kruskal_result_third <- kruskal.test(MortalityRateThird ~ SectionThird, data = mortality_data_third)
kruskal_result_third
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  MortalityRateThird by SectionThird
## Kruskal-Wallis chi-squared = 2.9755, df = 2, p-value = 0.2259
```

```r
# Kruskal-Wallis test for differences in mortality rates between sections (only halves)
mortality_data_half <- data.frame(
  SectionHalf = rep(c("Front Half", "Rear Half"), each = nrow(accident_data)),
  MortalityRateHalf = c(accident_data$X1.half.mortality.rate,
                    accident_data$X2.half.mortality.rate)
)

kruskal_result_half <- kruskal.test(MortalityRateHalf ~ SectionHalf, data = mortality_data_half)
kruskal_result_half
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  MortalityRateHalf by SectionHalf
## Kruskal-Wallis chi-squared = 0.65567, df = 1, p-value = 0.4181
```

[Interpretation of results to be added here, OR later in the report]

4.2.2 Modeling the mortality rates

Now we will try to fit a model to possibly discover the effect of the other variables on the mortality rates of the different sections. The focus is not specifically on prediction, but rather on trying to find other significant difference between the sections. Now the questions are:

- Are there variable that significantly affect the mortality rate?
- If so, do they affect differently the various sections of the airplane?

We will try to fit a Generalized Linear Model (GLM) with binomial family, since the mortality rate is a proportion (number of deaths / total number of passengers). Unfortunately, for the nature of the data, the assumptions of the binomial distribution are not met, since the passenger's deaths are not independent events. To account for this, we will use the quasibinomial family, which is a more flexible version of the binomial family that allows for overdispersion and corrects the standard errors and p-values accordingly.

```
### test glm with binomial family to see the effect of other variables on mortality rate for each secti

## also print the varius confidence intervals for the coefficients, and trasform them into odds ratios
glm_third_1 <- glm(cbind(accident_data$X1.third.dead, accident_data$X1.third.total - accident_data$X1.th
                    #accident_data$PhaseOfFlight +
                    #accident_data$Time +
                    #accident_data$Place +
                    accident_data$HasFire +
                    #accident_data$Environment +
                    accident_data$EnergyAbsorption +
                    accident_data$CrushedFuselage +
                    accident_data$RestraintIntact,
                  family = quasibinomial(link = "logit"))

glm_third_2 <- glm(cbind(accident_data$X2.third.dead, accident_data$X2.third.total - accident_data$X2.th
                    #accident_data$PhaseOfFlight +
                    #accident_data$Time +
                    #accident_data$Place +
                    accident_data$HasFire +
                    #accident_data$Environment +
                    accident_data$EnergyAbsorption +
                    accident_data$CrushedFuselage +
                    accident_data$RestraintIntact,
                  family = quasibinomial(link = "logit"))

glm_third_3 <- glm(cbind(accident_data$X3.third.dead, accident_data$X3.third.total - accident_data$X3.th
                    #accident_data$PhaseOfFlight +
                    #accident_data$Time +
                    #accident_data$Place +
                    accident_data$HasFire +
                    #accident_data$Environment +
                    accident_data$EnergyAbsorption +
                    accident_data$CrushedFuselage +
                    accident_data$RestraintIntact,
                  family = quasibinomial(link = "logit"))

# now try to model the total mortality rate

glm_total <- glm(cbind(accident_data$X1.third.dead + accident_data$X2.third.dead + accident_data$X3.thi
                      accident_data$X1.third.total + accident_data$X2.third.total + accident_data$X3.th
                        (accident_data$X1.third.dead + accident_data$X2.third.dead + accident_data$X3.t
                  #accident_data$PhaseOfFlight +
                  #accident_data$Time +
                  #accident_data$Place +
```

```r
                   accident_data$HasFire +
                   #accident_data$Environment +
                   accident_data$EnergyAbsorption +
                   accident_data$CrushedFuselage +
                   accident_data$RestraintIntact,
                 family = quasibinomial(link = "logit"))
```

```r
summary(glm_third_1)
```

```
## Warning in summary.glm(glm_third_1): observations with zero weight not used for
## calculating dispersion
```

```
## 
## Call:
## glm(formula = cbind(accident_data$X1.third.dead, accident_data$X1.third.total -
##     accident_data$X1.third.dead) ~ accident_data$HasFire + accident_data$EnergyAbsorption +
##     accident_data$CrushedFuselage + accident_data$RestraintIntact,
##     family = quasibinomial(link = "logit"))
## 
## Coefficients:
##                                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)                          -1.9872     2.7344  -0.727   0.4715
## accident_data$HasFireno-fire         -1.2185     0.7003  -1.740   0.0894 .
## accident_data$EnergyAbsorptionnogear  0.9057     0.5688   1.592   0.1190
## accident_data$CrushedFuselage1        2.4226     2.6803   0.904   0.3714
## accident_data$RestraintIntact1       -2.2228     1.1712  -1.898   0.0648 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## (Dispersion parameter for quasibinomial family taken to be 18.04978)
## 
##     Null deviance: 1354.33  on 45  degrees of freedom
## Residual deviance:  849.89  on 41  degrees of freedom
## AIC: NA
## 
## Number of Fisher Scoring iterations: 5
```

```r
summary(glm_third_2)
```

```
## 
## Call:
## glm(formula = cbind(accident_data$X2.third.dead, accident_data$X2.third.total -
##     accident_data$X2.third.dead) ~ accident_data$HasFire + accident_data$EnergyAbsorption +
##     accident_data$CrushedFuselage + accident_data$RestraintIntact,
##     family = quasibinomial(link = "logit"))
## 
## Coefficients:
##                                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)                          -1.8743     2.2596  -0.829  0.41151
## accident_data$HasFireno-fire         -1.0375     0.7351  -1.411  0.16553
## accident_data$EnergyAbsorptionnogear  1.6822     0.6219   2.705  0.00982 **
## accident_data$CrushedFuselage1        1.9259     2.2170   0.869  0.38995
```

```
## accident_data$RestraintIntact1        -2.2223     1.2069  -1.841  0.07263 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 32.73325)
##
##     Null deviance: 2358.0  on 46  degrees of freedom
## Residual deviance: 1588.4  on 42  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 5
```

```r
summary(glm_third_3)
```

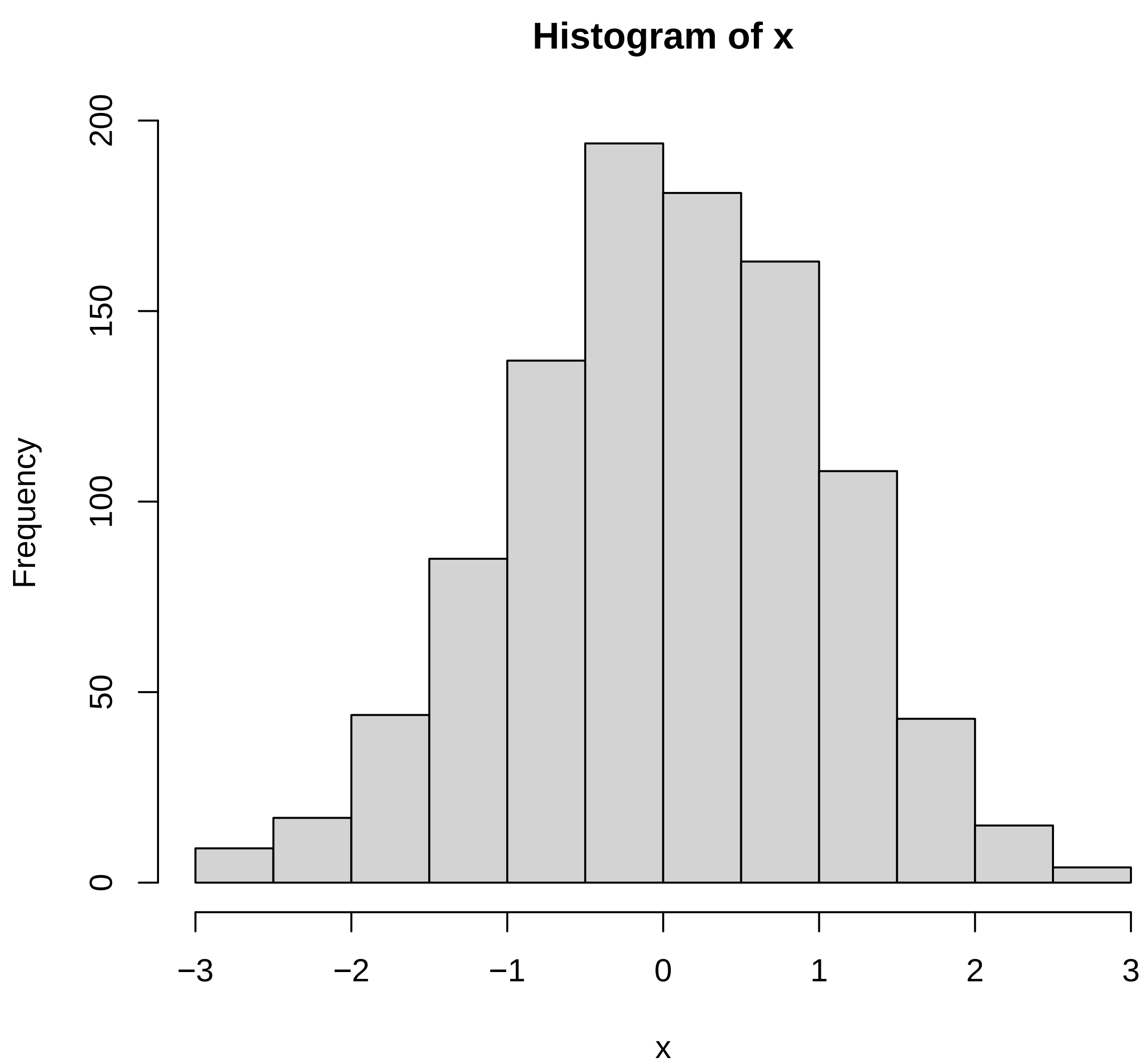
```
##
## Call:
## glm(formula = cbind(accident_data$X3.third.dead, accident_data$X3.third.total -
##     accident_data$X3.third.dead) ~ accident_data$HasFire + accident_data$EnergyAbsorption +
##     accident_data$CrushedFuselage + accident_data$RestraintIntact,
##     family = quasibinomial(link = "logit"))
##
## Coefficients:
##                                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)                            -1.9307     2.2409  -0.862    0.394
## accident_data$HasFireno-fire           -0.7861     0.6864  -1.145    0.259
## accident_data$EnergyAbsorptionnogear    0.6255     0.5193   1.205    0.235
## accident_data$CrushedFuselage1          1.8392     2.1924   0.839    0.406
## accident_data$RestraintIntact1         -0.8980     0.9222  -0.974    0.336
##
## (Dispersion parameter for quasibinomial family taken to be 26.04673)
##
##     Null deviance: 1573.7  on 46  degrees of freedom
## Residual deviance: 1350.8  on 42  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 5
```

```r
summary(glm_total)
```

```
##
## Call:
## glm(formula = cbind(accident_data$X1.third.dead + accident_data$X2.third.dead +
##     accident_data$X3.third.dead, accident_data$X1.third.total +
##     accident_data$X2.third.total + accident_data$X3.third.total -
##     (accident_data$X1.third.dead + accident_data$X2.third.dead +
##         accident_data$X3.third.dead)) ~ accident_data$HasFire +
##     accident_data$EnergyAbsorption + accident_data$CrushedFuselage +
##     accident_data$RestraintIntact, family = quasibinomial(link = "logit"))
##
## Coefficients:
##                                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)                            -1.9728     2.0101  -0.981   0.3320
## accident_data$HasFireno-fire           -0.9866     0.6040  -1.634   0.1098
```

```
## accident_data$EnergyAbsorptionnogear   1.1101     0.4819   2.304   0.0263 *
## accident_data$CrushedFuselage1         2.0553     1.9685   1.044   0.3024
## accident_data$RestraintIntact1        -1.6568     0.9158  -1.809   0.0776 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 57.72175)
##
##     Null deviance: 4184.2  on 46  degrees of freedom
## Residual deviance: 2795.4  on 42  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 5
```

```r
x <- rnorm(1000)
hist(x)
```



5 Analysis

6 Results

7 Conclusions