# Algorithm

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### Importing necessary packages/Libraries

```
invisible(library(dplyr))
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
invisible(library(lubridate))
```

```
##
## Attaching package: 'lubridate'

## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
invisible(library(caTools))
invisible(library(data.table))
```

```
##
## Attaching package: 'data.table'

## The following objects are masked from 'package:lubridate':
##
##     hour, isoweek, mday, minute, month, quarter, second, wday, week,
##     yday, year

## The following objects are masked from 'package:dplyr':
##
##     between, first, last
```

```r
invisible(library(rpart))
invisible(library(rpart.plot))
invisible(library(ggplot2))
invisible(library(reshape2))
```

```
##
## Attaching package: 'reshape2'
```

```
## The following objects are masked from 'package:data.table':
##
##     dcast, melt
```

## Generating the dataset

Data description:

- speed: Real-time speed of the bus in commute .
- dist_prev: The distance between the current bus and the previous bus on the same route.
- dist_next: The distance between the current bus and the next bus on the same route.
- crowd_curr: The number of passengers currently in the bus.
- crowd_next: The number of passengers in the next bus on the same route.
- schd_time: The scheduled arrival time specified for bus at previous stop on their route.
- arr_time: The actual arrival time of the bus at the previous stop on their route.
- on_time: Whether the bus arrived on time or not at the previous stop on their route.
- time_delay: The difference between the actual arrival time and the scheduled arrival time.

```r
set.seed(1)
speed = round(rnorm(1000,50,15),2)
dist_prev = abs(round(rnorm(1000,2,1),2))
dist_next = abs(round(rnorm(1000,2,1),2))
crowd_curr = rpois(1000,25)
crowd_next = rpois(1000,25)
schd_time = sample(seq(strptime('01/01/2018',format = "%d/%m/%Y"),
                       strptime('01/01/2019',format = "%d/%m/%Y"),
                       by="hour"), 1000, replace = T)
arr_time = schd_time+(rnorm(1000,300,350)*-1)
on_time = ifelse(difftime(arr_time,schd_time)<=0,1,0)
time_delay = difftime(arr_time,schd_time)
data = data.frame(crowd_curr,crowd_next,
                  dist_prev, dist_next,speed,
                  schd_time,arr_time,on_time,time_delay)
head(select(data,crowd_curr,crowd_next,on_time),10)
```

```
##    crowd_curr crowd_next on_time
## 1          28         27       0
## 2          26         24       1
## 3          31         21       1
## 4          20         28       1
## 5          27         21       0
## 6          23         21       0
## 7          22         23       1
```

```
## 8          34          37        0
## 9          32          21        1
## 10         27          15        0
```

### Generating an algorithm to label the datasets

Each record is considered as a bus and the label is the indication given to the bus driver whether to maintain speed, decrease speed, or to increase represented by 0,1,2 respectively

```
data = data %>% mutate(.,indicate = with(.,case_when(
  (dist_next<1.8 & dist_prev<1.8 & crowd_next<25 & crowd_curr<28) ~ 0,
  (dist_next<1.8 & dist_prev<1.8 & crowd_next<25 & crowd_curr>28) ~ 0,
  (dist_next<1.8 & dist_prev<1.8 & crowd_next>25 & crowd_curr<28) ~ 2,
  (dist_next<1.8 & dist_prev<1.8 & crowd_next>25 & crowd_curr>28) ~ 0,
  (dist_next<1.8 & dist_prev>1.8 & crowd_next<25 & crowd_curr<28) ~ 1,
  (dist_next<1.8 & dist_prev>1.8 & crowd_next<25 & crowd_curr>28) ~ 1,
  (dist_next<1.8 & dist_prev>1.8 & crowd_next>25 & crowd_curr<28) ~ 2,
  (dist_next<1.8 & dist_prev>1.8 & crowd_next>25 & crowd_curr>28) ~ 1,
  (dist_next>1.8 & dist_prev<1.8 & crowd_next<25 & crowd_curr<28) ~ 2,
  (dist_next>1.8 & dist_prev<1.8 & crowd_next<25 & crowd_curr>28) ~ 0,
  (dist_next>1.8 & dist_prev<1.8 & crowd_next>25 & crowd_curr<28) ~ 2,
  (dist_next>1.8 & dist_prev<1.8 & crowd_next>25 & crowd_curr>28) ~ 2,
  (dist_next>1.8 & dist_prev>1.8 & crowd_next<25 & crowd_curr<28) ~ 0,
  (dist_next>1.8 & dist_prev>1.8 & crowd_next<25 & crowd_curr>28) ~ 0,
  (dist_next>1.8 & dist_prev>1.8 & crowd_next>25 & crowd_curr<28) ~ 2,
  (dist_next>1.8 & dist_prev>1.8 & crowd_next>25 & crowd_curr>28) ~ 0,
)))

head(select(data,crowd_curr,on_time,indicate),10)
```

```
##    crowd_curr on_time indicate
## 1          28       0       NA
## 2          26       1        1
## 3          31       1        0
## 4          20       1        2
## 5          27       0        0
## 6          23       0        2
## 7          22       1        0
## 8          34       0        0
## 9          32       1        0
## 10         27       0        1
```

The table below indicates the indications that each of the bus instances receive

```
data$indicate = factor(data$indicate,
                       levels=c(0,1,2),
                       labels = c("Maintain Speed",
                                  "Slow Down",
```

```
                                    "Speed Up"))
table(data$indicate)
```

```
##
## Maintain Speed      Slow Down       Speed Up
##            314            124            412
```

Thus we obtain the following observations from above table:

- Number of buses instructed to “Maintain Speed” : 314
- Number of buses instructed to “Slow Down” : 123
- Number of buses instructed to “Speed Up” : 412

## Modelling a decision tree algorithm to make future scheduling

Splitting the data into train and test

```
set.seed(1)
split = sample.split(data$indicate, SplitRatio = 0.75)
train = data[split,]
test = data[!split,]
```

Creating a penalty matrix to avoid miscalculation

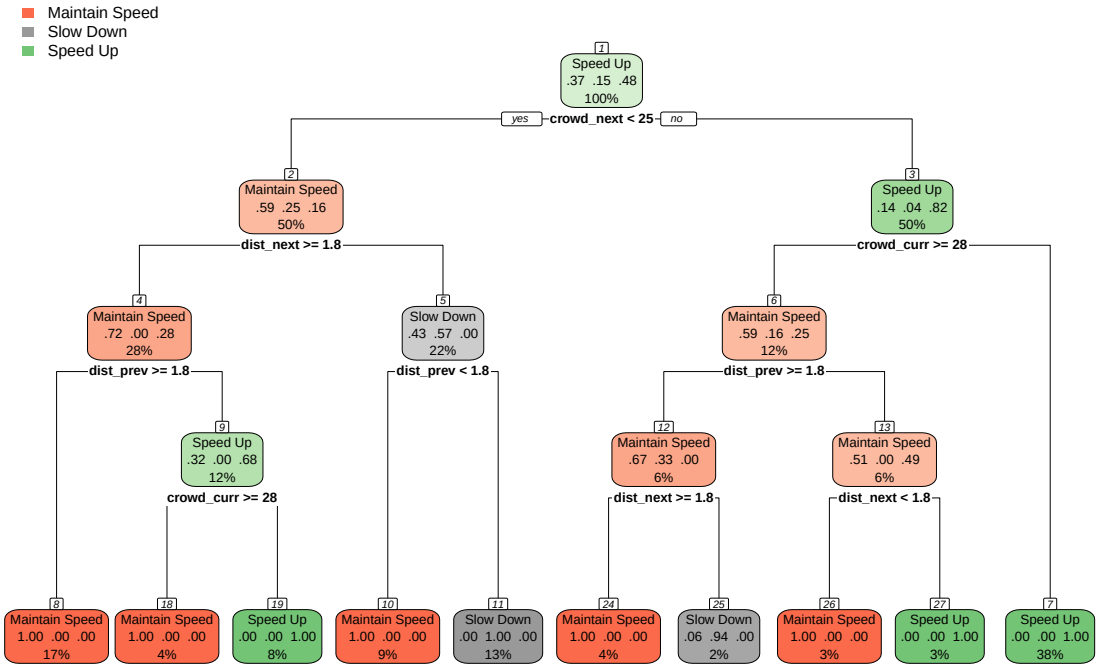
```
penalty.matrix <- matrix(c(1,1,0,10,0,10,0,0,0), byrow=TRUE, nrow=3)
```

Building the decision tree model with rpart

```
dtree <- rpart(indicate~.,data=data,method = "class")
```

Visualizing the decision tree

```
rpart.plot(dtree, nn=TRUE)
```




## Using speed and on_time parameters

The speed and on_time parameters can be used for further analysis and using a regression model, we can provide the driver with recommended speed indication to maintain their schedule, and to keep them aware of whether they're on time or not

```
head(select(data,speed,on_time))
```

```
##   speed on_time
## 1 40.60       0
## 2 52.75       1
## 3 37.47       1
## 4 73.93       1
## 5 54.94       0
## 6 37.69       0
```

## Bus re-rerouting

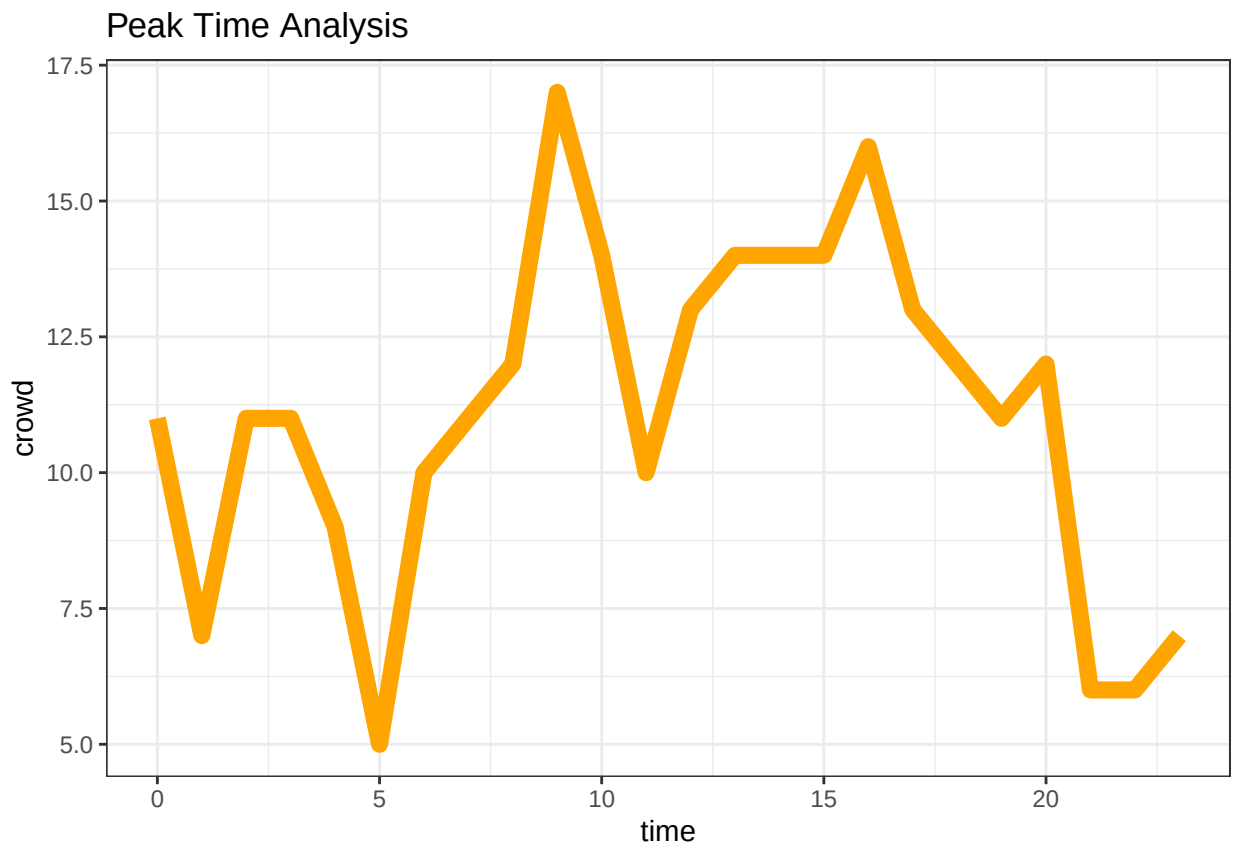
Consider each bus to be part of an area(a cluster), and each area has n number of buses, there are several routes in a given area, each route has predetermined number of buses plying through them.

Creating dummy dataset

```
set.seed(0)
data_route_1 = data.frame(time = 0:23, crowd = c(round(rnorm(6,8,2)),round(rnorm(6,12,2)),round(rnorm(6
data_route_2 = data.frame(time = 0:23, crowd = c(round(rnorm(6,8,2)),round(rnorm(6,12,2)),round(rnorm(6
data_route_2[15,2] = 13
data_route_3 = data.frame(time = 0:23, crowd = c(round(rnorm(6,8,2)),round(rnorm(6,12,2)),round(rnorm(6
data_route_3[7,2] = 17
data_route_3[16,2] = 12
```

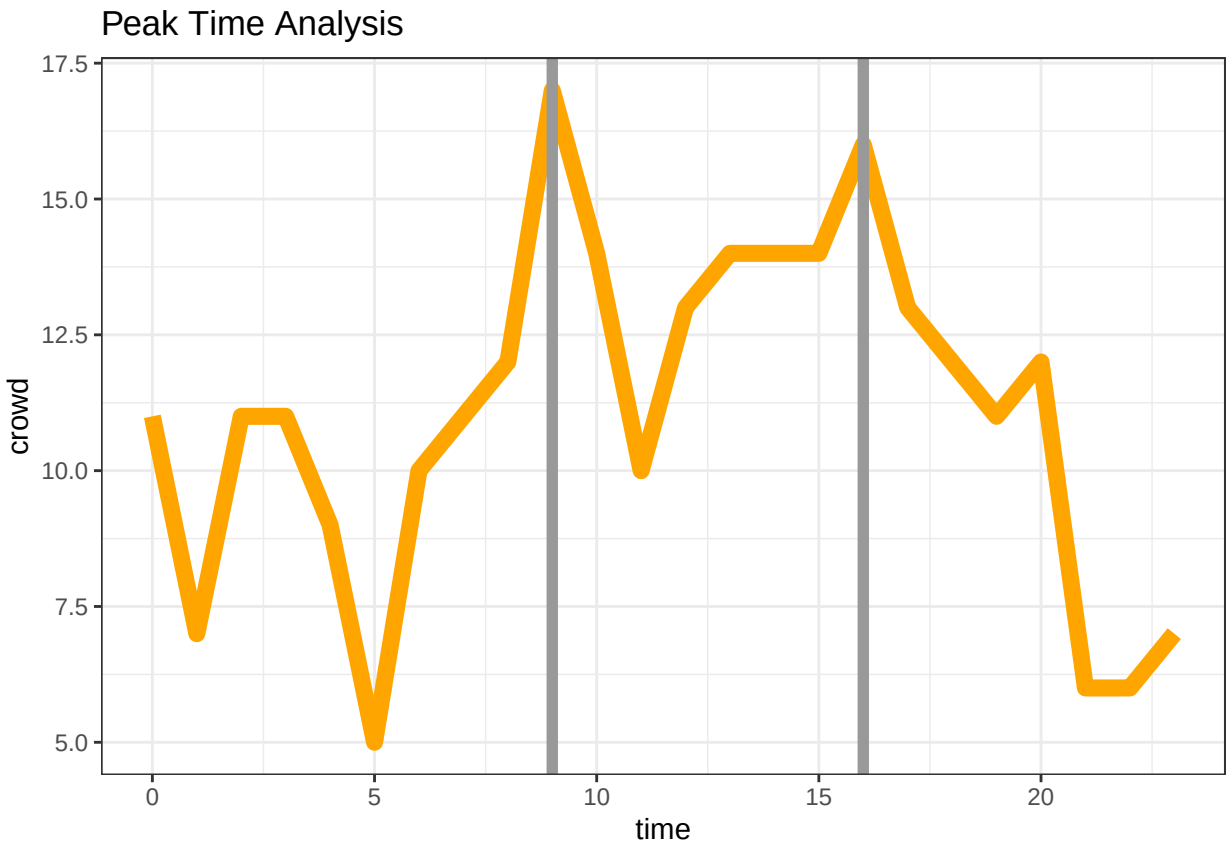
Using data analytics we determine the peak time of each route

```
g1 = ggplot(
  data_route_1,
      aes(
        x = time,
        y = crowd
      )
)
g1 = g1 + geom_line(color = "orange", size = 3) + theme_bw() + ggtitle("Peak Time Analysis")
g1
```



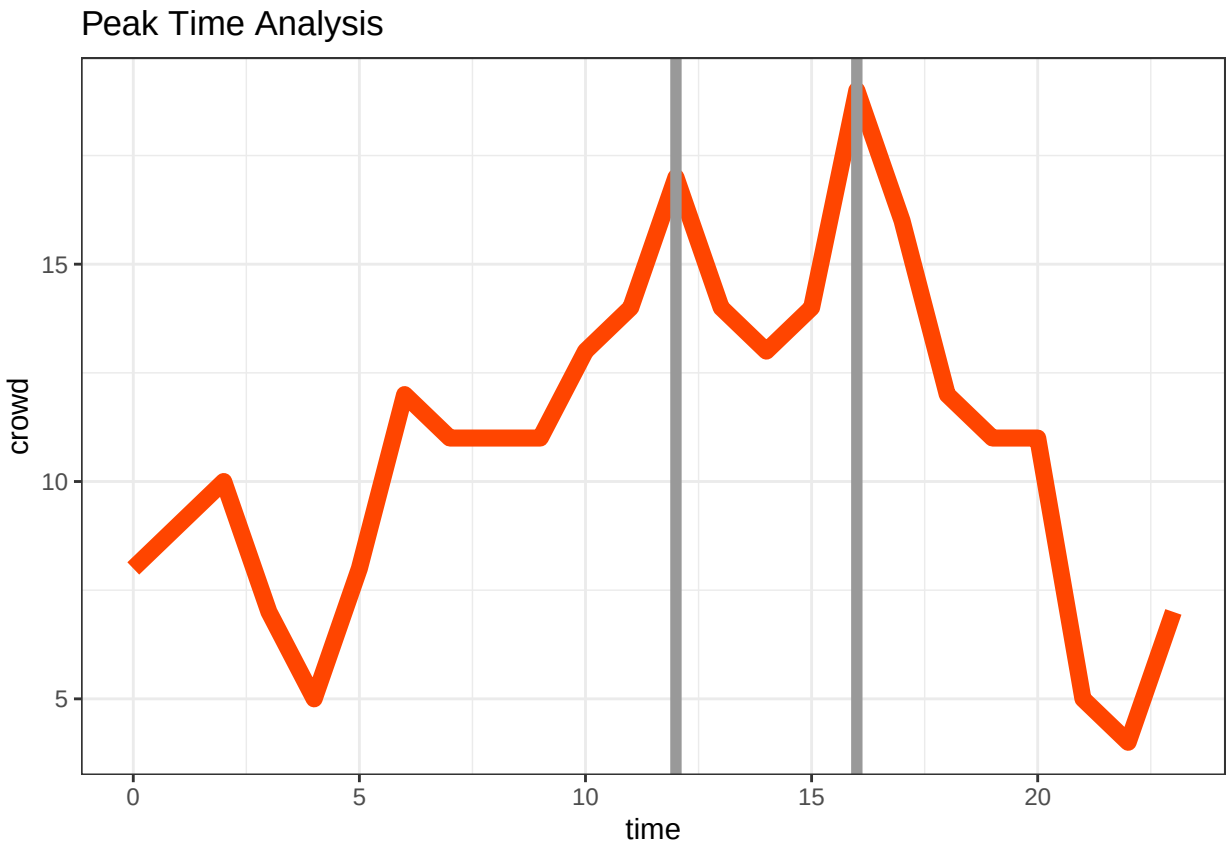

We can see that for route 1 the peak times are roughly around 9 am and 4 pm

```
g1 + geom_vline(xintercept =9,size = 2, col = "gray60") + geom_vline(xintercept =16, size = 2, col = "g
```

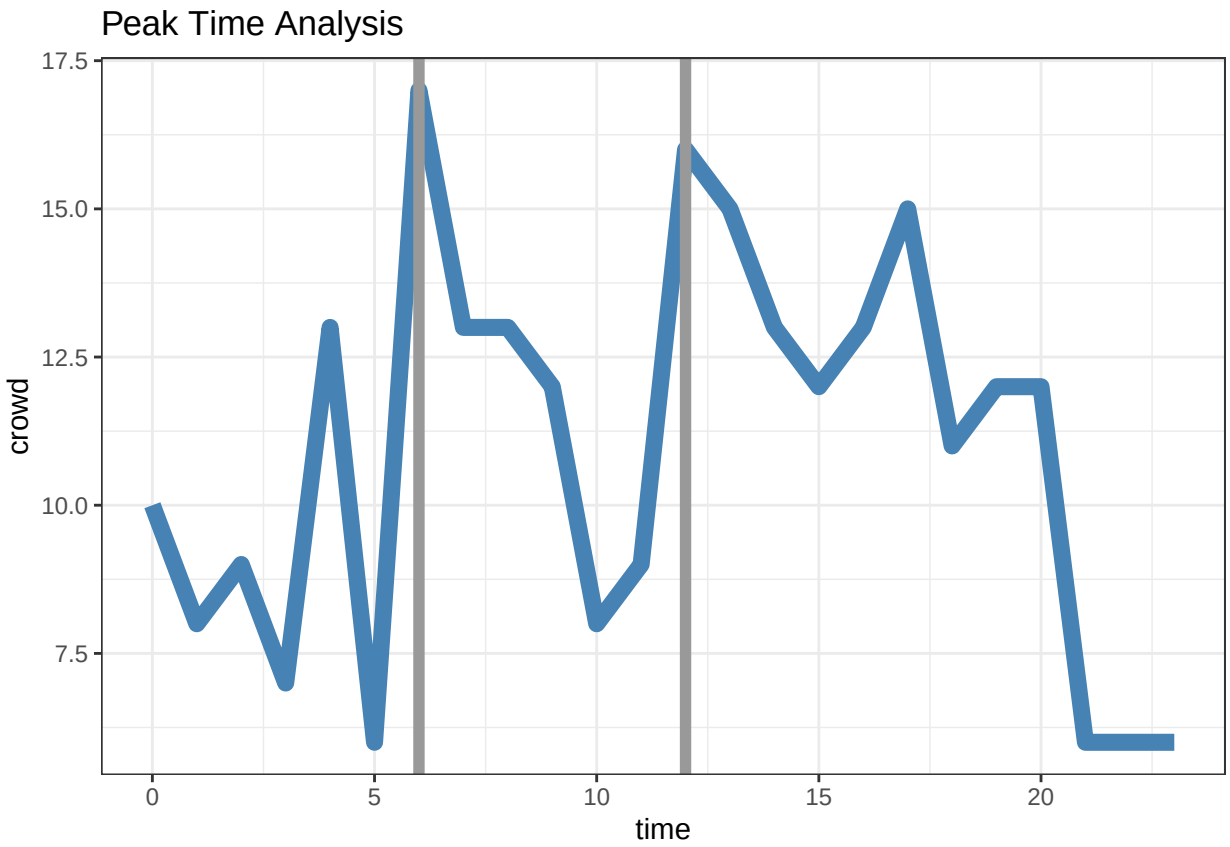



Similarly we have analytical data on other routes, here - route 2 and route 3, with their respective peak times.

```
g2 = ggplot(
  data_route_2,
      aes(
        x = time,
        y = crowd
      )
)
g2 = g2 + geom_line(color = "orangered", size = 3) + theme_bw() + ggtitle("Peak Time Analysis") + geom_
g2
```



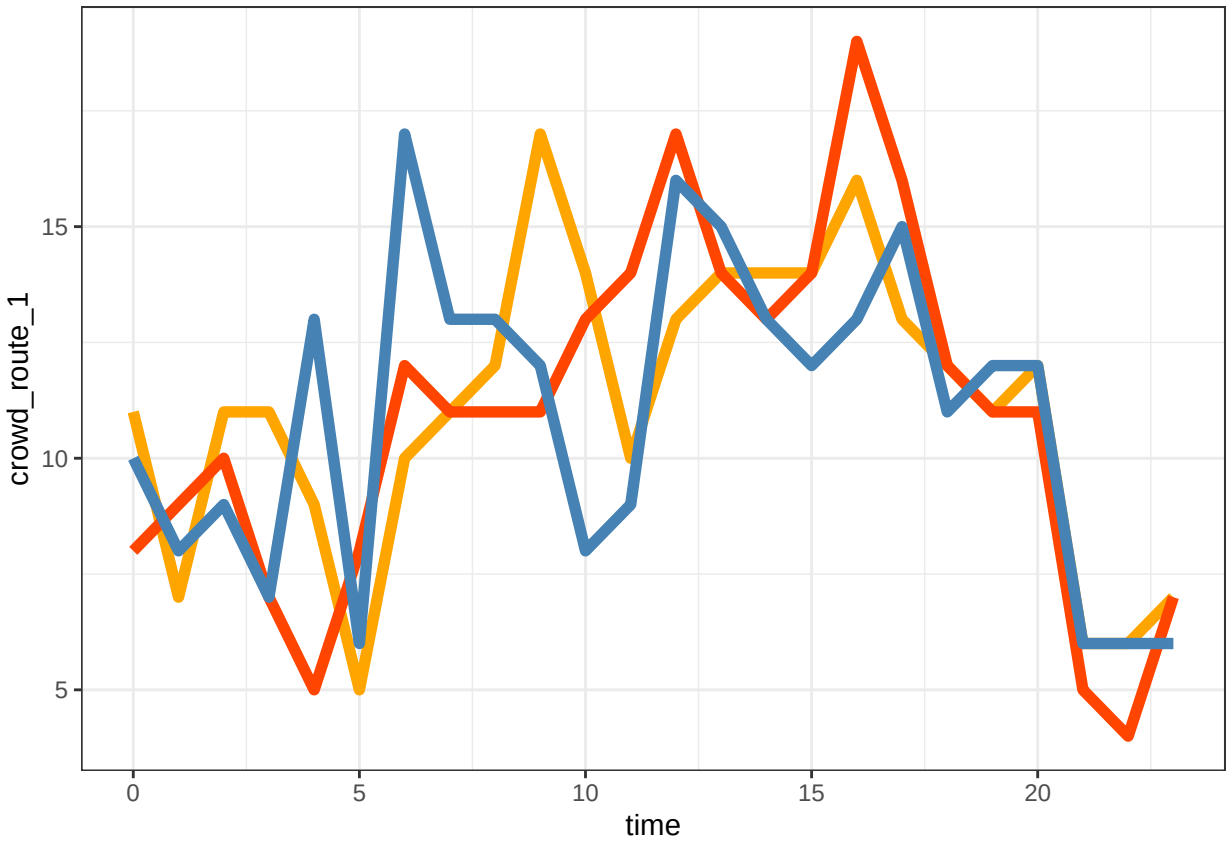

```
g2 = ggplot(
  data_route_3,
      aes(
        x = time,
        y = crowd
      )
)
g2 = g2 + geom_line(color = "steelblue", size = 3) + theme_bw() + ggtitle("Peak Time Analysis") + geom_
g2
```




We make a comparative study of the different peak times and schedules buses through various routes depending on the analytical data on those peak time.

```
data_all = data.frame(data_route_1$time,data_route_1$crowd,data_route_2$crowd,data_route_3$crowd)
names(data_all) = c("time","crowd_route_1","crowd_route_2","crowd_route_3")


g = ggplot(data_all, aes(x = time)) +
  geom_line(aes(y = crowd_route_1), color = "orange", size = 2) +
  geom_line(aes(y = crowd_route_2), color = "orangered", size = 2) +
  geom_line(aes(y = crowd_route_3), color = "steelblue", size = 2) +
  theme_bw()
g
```




An efficient system can be created by scheduling the buses to maintain adequate distance between them and when threshold of speed is encountered detected using statistical inference on analytical data, we deploy/redeploy buses, reroute and so on. which makes uses of resources at bare minimum and combats delays.

Monitoring the delays on a particular route and by using statistical inferencing on the analytical data we can optimize bus schedule through rerouting, deployment/undeployment, and so on.

```
set.seed(30)
bus_arrival_5 = data.frame(time=rep(17,365) + rnorm(365,0,5)/100)
q = as.numeric(quantile(bus_arrival_5$time,c(0.025,0.34,0.68,0.975)))
d <- density(bus_arrival_5$time)
data <- data.frame(x=d$x, y=d$y)
data = data %>% mutate(., col = factor(with(., case_when(
  (x<q[1])~1,
  (x>=q[1]&x<q[4])~2,
  (x>=q[4])~0
))))
#png(file="bus_norm.png")
g = ggplot(
  data,
  aes(x,y)
) + geom_line() +
  geom_ribbon(aes(ymin=0, ymax=y, fill=col)) +
  #scale_x_continuous(breaks=q) +
  #scale_fill_brewer(guide="none") +
  ggtitle("Distribution of arrival times around 5pm on a given day") +
```

```
  xlab("Time") +
  theme_bw()
#g
#dev.off()
#d = density(bus_arrival_5)
#plot(d, main = "Distribution of arrival times around 5pm on a given day", xlab = "Time")
#polygon(d, col="skyblue", border="violet")
#g = ggplot(
#  bus_arrival,
#  aes(
#    x=time
#  )
#) + geom_density(color="darkblue") +
#  geom_vline(xintercept =q,linetype = "longdash") +
#  theme_bw()
g
```