

When and where are bikes most likely to be reported as stolen in Toronto?

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Step 1

First, read in the data. Update the missing data identifiers to NA. Check for import issues (dimensions, headers, footers, variable names and variable types). Check for any data issues (import issues, missing values, data errors) particularly in the key variable we are analyzing. Make sure you write up a summary of all of your findings.

First, we will read in the data

```
# Read the data into bt  
bt <- data.table::fread("Bicycle_Thefts.csv")
```

Then, we will check the dimension and import issues.

```
# Check the dimension  
dim(bt)  
# Check the head of the data  
head(bt)  
# Check the tail of the data  
tail(bt)  
# Check variable name and type  
str(bt)
```

After, we will check any data issues (We will focus on city, Occurrence_Year, Occurrence_Month, Occurrence_DayOfMonth, Occurrence_DayOfWeek, Occurrence_Hour, Longitude, NeighbourhoodName, Premises_Type, Status, Bike_Type, Bike_Color).

```
# Look at summary of variables  
# Summary of City  
table(bt$City)  
# Summary of Year  
summary(bt$Occurrence_Year)  
# Summary of Month  
table(bt$Occurrence_Month)  
# Summary of DayOfMonth  
table(bt$Occurrence_DayOfMonth)  
# Summary of DayOfWeek  
table(bt$Occurrence_DayOfWeek)  
# Summary of Hour  
table(bt$Occurrence_Hour)  
# Summary of Longitude
```

```
summary(bt$Longitude)
# Summary of Latitude
summary(bt$Latitude)
# Summary of NeighbourhoodName
table(bt$NeighbourhoodName)
# Summary of Premises_Type
table(bt$Premises_Type)
# Summary of Status
table(bt$Status)
# Summary of Bike_Type
table(bt$Bike_Type)
# Summary of Bike_Color
table(bt$Bike_Colour)
```

We will now handle with data issue: replace all data identifier to NA.

```
# Update all missing value identifiers to NA
bt <- bt %>%
  mutate(Longitude = ifelse(Longitude >= 0, NA, Longitude)) %>%
  mutate(Latitude = ifelse(Latitude <= 0, NA, Latitude)) %>%
  mutate(City = ifelse(City == "NSA", NA, City)) %>%
  mutate(NeighbourhoodName = ifelse(NeighbourhoodName == "NSA", NA, NeighbourhoodName)) %>%
  mutate(Status = ifelse(Status == "UNKNOWN", NA, Status)) %>%
  mutate(Bike_Colour = ifelse(Bike_Colour == "NULL" | Bike_Colour == "18" |
    Bike_Colour == "", NA, Bike_Colour))
```

See if there exists more data issues.

```
# Summary of New Longitude and Latitude
summary(bt$Longitude)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.   NA's
## -79.82  -79.42  -79.39  -79.39  -79.37  -78.86    303
```

```
summary(bt$Latitude)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.   NA's
##  43.32  43.65  43.66  43.67  43.68  43.91    303
```

Summary of Step 1: At very beginning, we have read the Bicycle Thefts data and stored it into a data table *bt*. We found our data set contains 30154 observations of 35 variables. By looking at the head and tail of our data, all data points seems reasonable (with no importing issues). Moving closely to the summary of variables (we mainly focus on City, Occurrence_Year, Occurrence_Month, Occurrence_DayOfMonth, Occurrence_DayOfWeek, Occurrence_Hour, Longitude, NeighbourhoodName, Premises_Type, Status, Bike_Colour, Bike_Type), we found that the maximum of Longitude and minimum of Latitude is zero, which is not inside Toronto area. We believe these zero values are the missing data identifiers, therefore replace all of them with NA. We also found on the website that NSA is the missing data identifiers for City & NeighbourhoodName, and UNKNOWN is another missing data identifiers for Status. Therefore, we replace all of them with NA. After that, we did not notice any more data errors within our main variables, as there isn't any sign of single point being significantly varied from all other points.

Step 2

Clean the data – keep only necessary data columns and change the names of the key variables so that they are easier to identify. Change the type of key variables from string to factor as appropriate. Identify any outlier reports, and justify how you handle them.

We will keep rows without NA, report as STOLEN, within Toronto and only necessary columns

```
# Select Proper Rows and Columns
bt <- bt %>% select(OBJECTID, City, Occurrence_Year , Occurrence_Month ,
                  Occurrence_DayOfMonth , Occurrence_DayOfWeek ,
                  Occurrence_Hour , Longitude , Latitude, NeighbourhoodName
                  , Premises_Type, Bike_Colour, Bike_Type, Status) %>%
  drop_na() %>%
  filter(Status == "STOLEN") %>%
  filter(City == "Toronto")
```

We will rename some columns to make life easier

```
# Column Rename
bt <- bt %>% mutate(id = OBJECTID, year = Occurrence_Year,
                  month = Occurrence_Month,
                  dayofmonth = Occurrence_DayOfMonth,
                  dayofweek = Occurrence_DayOfWeek,
                  hour = Occurrence_Hour,
                  latitude = Latitude,
                  longitude = Longitude,
                  neighbourhood = NeighbourhoodName,
                  premises = Premises_Type,
                  color = Bike_Colour,
                  type = Bike_Type) %>%
  select(id, year, month, dayofmonth, dayofweek, hour, latitude,
         longitude, neighbourhood, premises, color, type)
```

Check which can apply string to factor change

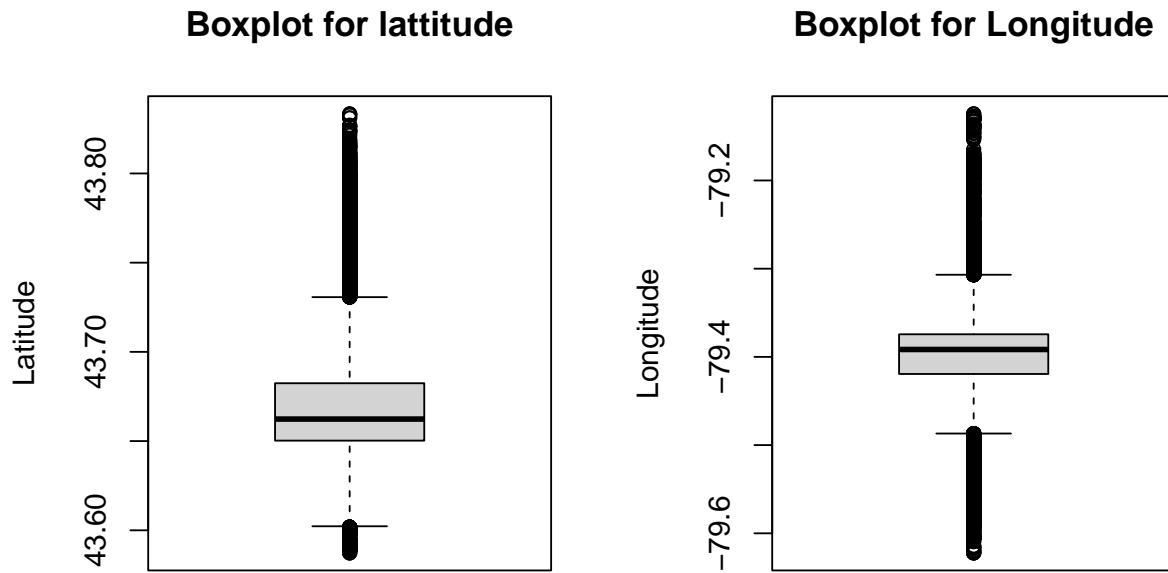
```
str(bt)
```

Apply Change

```
# Change string to factor
bt <- as.data.frame(unclass(bt), stringsAsFactors = TRUE)
```

Identify outliers

```
# Boxplot of Latitude and Longitude to identify outliers
par(mfrow= c(1, 2))
boxplot(bt$latitude, ylab = "Latitude", main = "Boxplot for latitude")
boxplot(bt$longitude, ylab = "Longitude", main = "Boxplot for Longitude")
```



Summary of Step 2: Initially, we select OBJECTID, City, Occurrence_Year, Occurrence_Month, Occurrence_DayOfMonth, Occurrence_DayOfWeek, Occurrence_Hour, Longitude, Latitude, Neighbourhood-Name, Premises_Type, Bike_Colour, Bike_Type, and Status as all necessary variables to solve the research question. Then, as required by the research question, we only select rows which are inside of (City=) Toronto and report as (Status=) STOLEN. And we remove any observations with NA in at least one of our necessary variables. Furthermore, we rename some of the key variables and convert all string to factor to obtain a clean and valid data set.

We plotted two boxplots of Latitude and Longitude to see if there exists outliers in our clean data set. It turns out that no observation is far away from the others. Therefore, we believe there is no more outliers in our clean dataset. In fact, all outliers are outside of Toronto, and they have already been filtered out from our clean data set.

Step 3

Explore the main question of interest. Calculate summary statistics for each season (e.g. means, medians, variances) and then conduct some basic analyses that enable you to compare across winter/spring/summer/fall (e.g. t-test, linear regression). Be sure to show the results and write up explanations of what you observe in these data.

Add a new variable season

```
bt <- bt %>% mutate(season = case_when(
  month %in% c("November", "December", "January") ~ "Winter",
  month %in% c("February", "March", "April") ~ "Spring",
  month %in% c("May", "June", "July") ~ "Summer", TRUE ~ "Fall"))
# Change string to factor
bt <- as.data.frame(unclass(bt), stringsAsFactors = TRUE)
```

We want to group our data by season, day and hour, that is, we want to know how many bike was stolen per hour for each season.

```
bt_season <- bt %>% group_by(season, dayofmonth, hour) %>% summarise(count = n())
```

```
## 'summarise()' has grouped output by 'season', 'dayofmonth'.
## You can override using the '.groups' argument.
```

We want to calculate the mean, median, sd amount of bike being stolen per hour in each month

```
bt_season %>% group_by(season) %>% summarise(mean = mean(count),
                                              median = median(count),
                                              sd = sd(count))
```

```
## # A tibble: 4 x 4
##   season mean median    sd
##   <fct> <dbl> <dbl> <dbl>
## 1 Fall    12.7     13  6.68
## 2 Spring   5.04      5  3.09
## 3 Summer  14.7     15  7.59
## 4 Winter   4.45      4  3.09
```

We build linear regression model to test whether bike stolen per hour depends on season

```
model <- lm(count~season, data = bt_season)
summary(model)
```

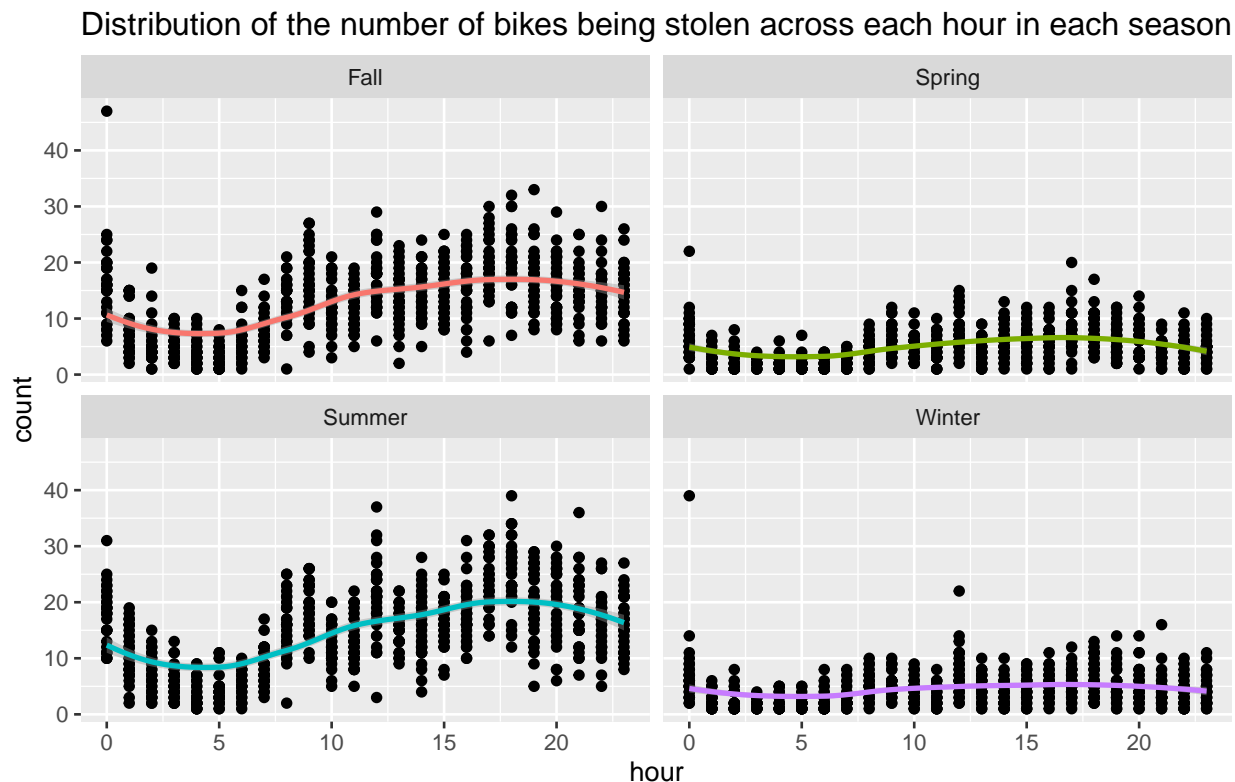
```
##
## Call:
## lm(formula = count ~ season, data = bt_season)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.697  -3.036  -0.455   3.272  34.545
##
```

```
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  12.7280    0.2057  61.885 < 2e-16 ***
## seasonSpring -7.6923    0.2979 -25.821 < 2e-16 ***
## seasonSummer  1.9690    0.2912  6.763 1.64e-11 ***
## seasonWinter -8.2733    0.2979 -27.771 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.591 on 2817 degrees of freedom
## Multiple R-squared:  0.3975, Adjusted R-squared:  0.3969
## F-statistic: 619.6 on 3 and 2817 DF,  p-value: < 2.2e-16
```

We will look deeper into amount bike stolen at each hour for each season

```
ggplot(bt_season, aes(y=count, x=hour)) + geom_point() + facet_wrap(~season) +
  geom_smooth(aes(color = season), show.legend = FALSE) +
  labs(title = "Distribution of the number of bikes being stolen across each hour in each season")
```

```
## 'geom_smooth()' using method = 'loess' and formula = 'y ~ x'
```



Summary of Step 3: To further investigate when bike is more likely to be stolen, we have break our data into four categories. We have group December, January, February into Winter; March, April, May into Spring; June, July, August into Summer; and September, October, November into Fall. For each season, we are interesting the amount of bike being stolen per hour to decide if bike stolen depends on the season. Therefore, we group our data by season and day+hour. As a summary, we found that the average number of bike being stolen per hour for winter, spring, summer, fall is 4.45, 5.03, 14.69, 12.72 receptively. By fitting a

linear regression model, we found that the p value for each coefficient is close to zero, which saying they are significantly different with each others. Looking more closely at the distribution of number of bikes being stolen across each hour in each season, we found that 17-19 pm is the peak. Therefore, we might say Bikes are more likely to be stolen in Fall/Summer at 17-19 pm.

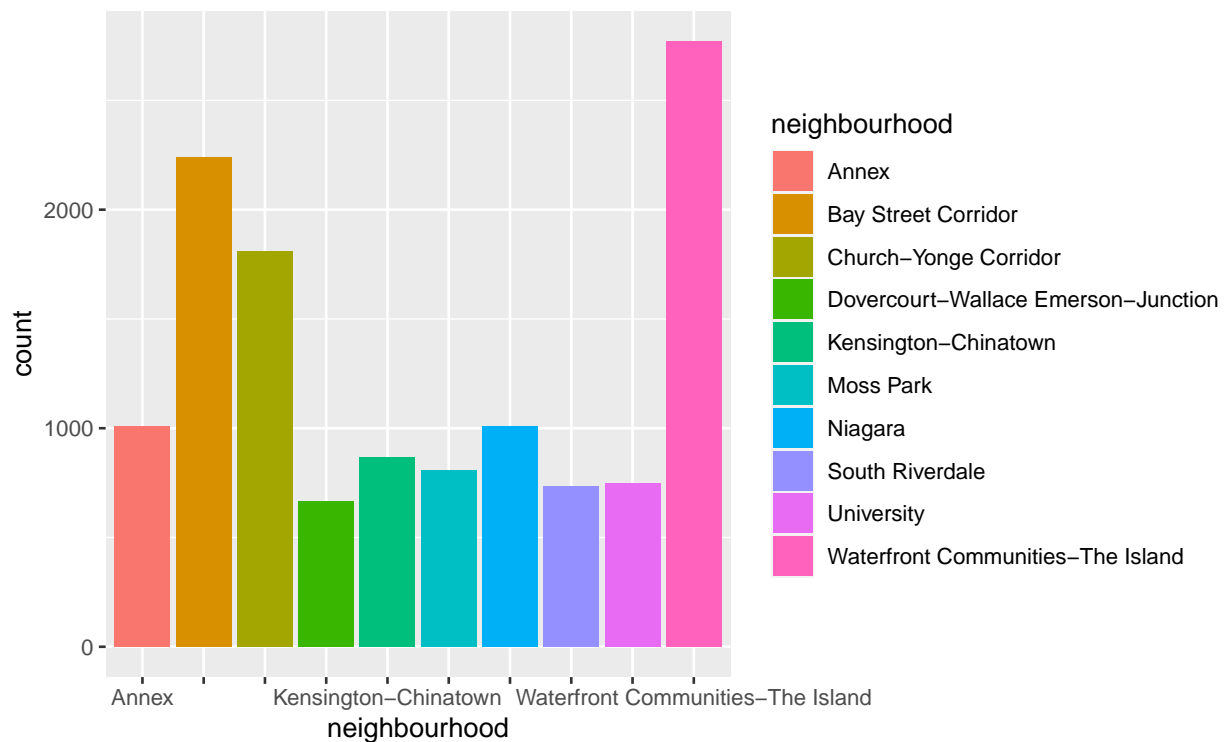
Step 4

Create exploratory plots (boxplots, histograms, time series) of which neighbourhoods and time of day bikes were reported stolen from.

As there are too many neighborhoods, we will firstly display the 10 neighbourhoods with Highest Number of Stolen Bike by barplot.

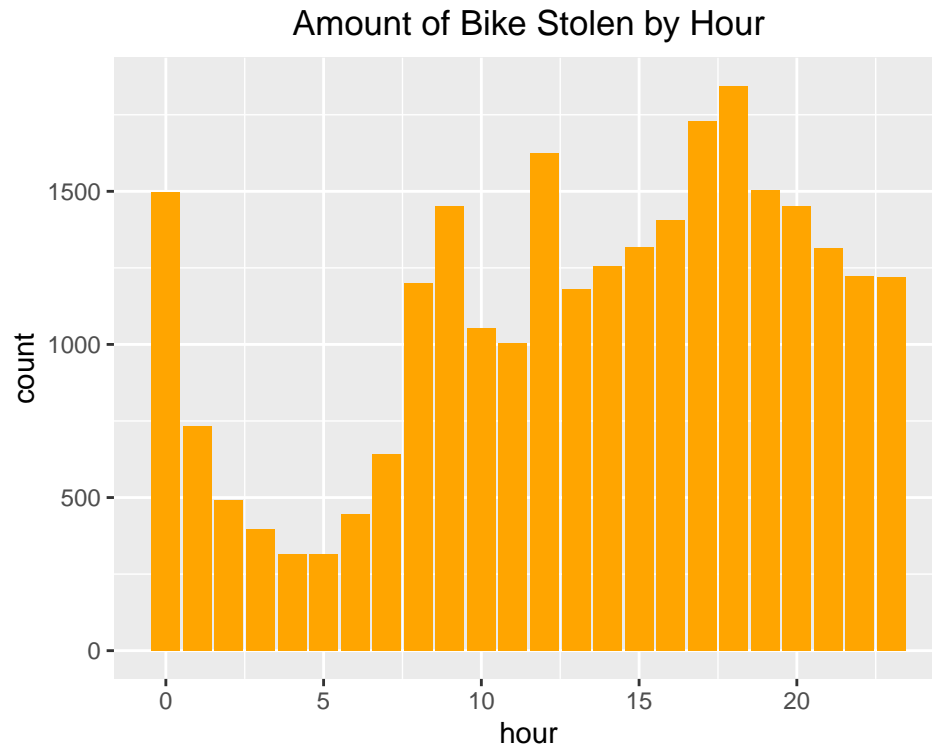
```
nb <- bt %>% group_by(neighbourhood) %>%
  summarise(count = n()) %>% arrange(desc(count))
ggplot(data = head(nb, 10), aes(x=neighbourhood, y = count,
                                fill=neighbourhood)) +
  geom_bar(stat="identity") +
  scale_x_discrete(guide = guide_axis(check.overlap = TRUE)) +
  labs(title = "10 Neighbourhoods with the Highest Number of Stolen Bike") +
  theme(plot.title = element_text(hjust = 0.5))
```

10 Neighbourhoods with the Highest Number of Stolen Bike



Since we are interesting in the amount of bike stolen by hour, we will visualize this distribution by making another barplot.

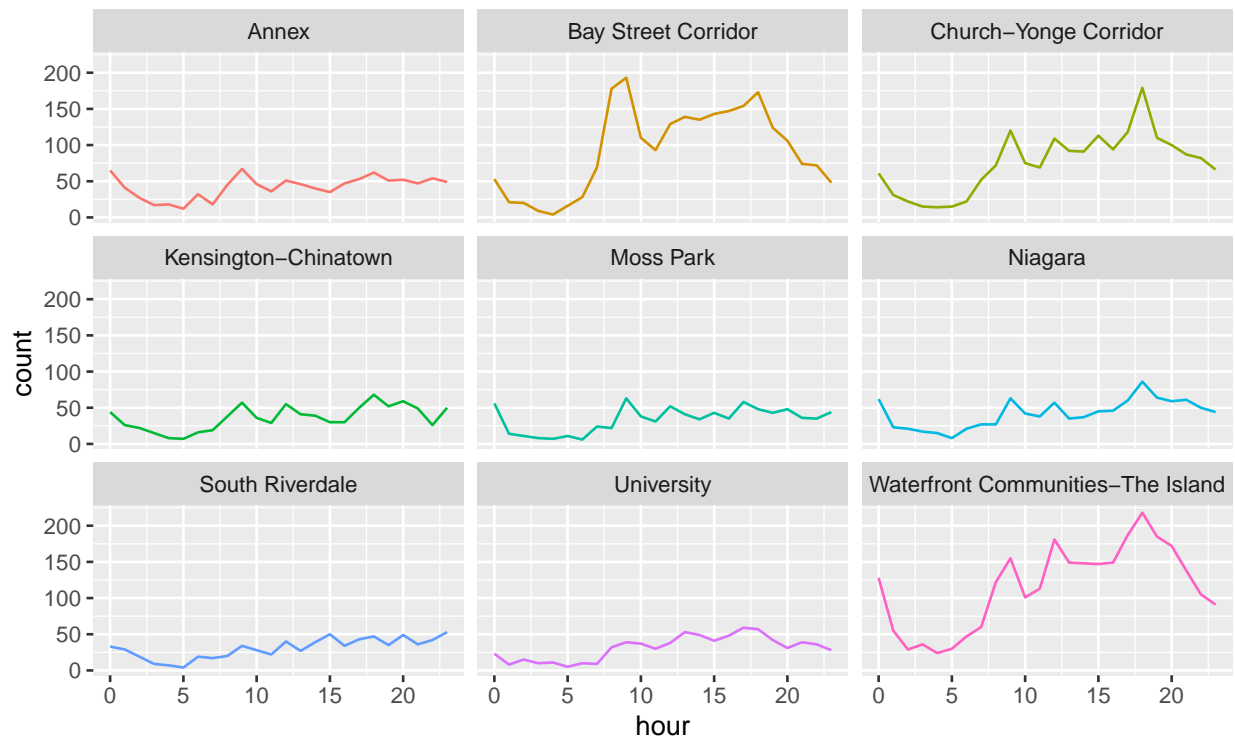
```
hr <- bt %>% group_by(hour) %>%
  summarise(count = n())
ggplot(data = hr, aes(x=hour, y = count)) +
  geom_bar(stat="identity", fill="orange") +
  labs(title="Amount of Bike Stolen by Hour") +
  theme(plot.title = element_text(hjust = 0.5))
```

Now, we will look at the time series of the number of stolen bike for each of those top neighbourhood

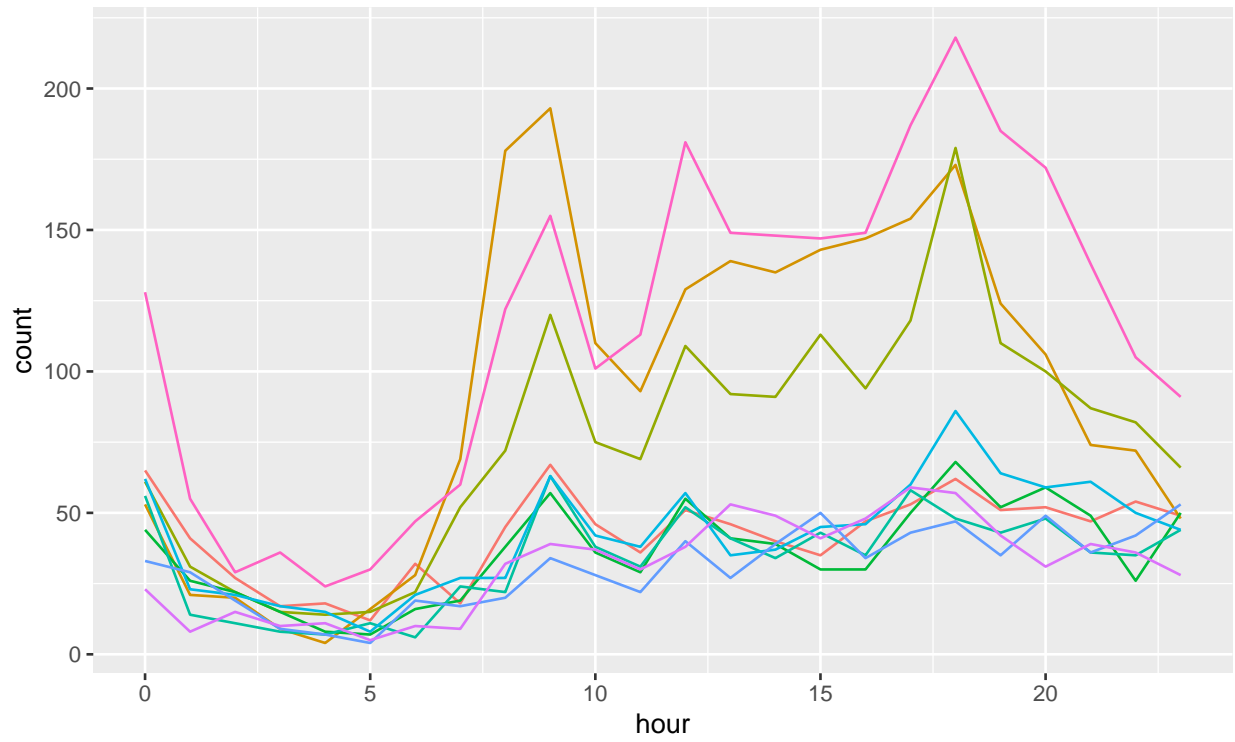
```
nb_h <- bt %>% filter(neighbourhood %in% head(nb, 9)$neighbourhood) %>%
  group_by(neighbourhood, hour) %>%
  summarise(count = n(), .groups = "keep")
ggplot(data = nb_h, aes(x=hour, y=count, color=neighbourhood)) +
  geom_line() + facet_wrap(~neighbourhood) +
  labs(title =
    "Time series of Number of Bike stolen at the Top 9 neighbourhood") +
  theme(plot.title = element_text(hjust = 0.5), legend.position = "none")
```

Time series of Number of Bike stolen at the Top 9 neighbourhood



```
ggplot(data=nb_h, aes(x = hour, y = count, color = neighbourhood)) +
  geom_line() +
  labs(title =
    "Time series of Number of Bike stolen at the Top 9 neighbourhood") +
  theme(plot.title = element_text(hjust = 0.5), legend.position = "none")
```

Time series of Number of Bike stolen at the Top 9 neighbourhood



Step 5

Create a basic map in `leaflet()` that shows the locations of all stolen unicycles (and their colours).

```
# Click the Markers to see their colours!
unbt <- bt %>% filter(type=="UN")
unbt <- unbt %>% mutate(colorc = case_when(
  color == 'RED' ~ "red",
  color == "GRY" ~ "grey",
  color == "BLK" ~ "black",
  color == "WHI" ~ "white",
  color == "GRN" ~ "green",
  TRUE ~ "brown"
))
leaflet(unbt) %>%
  addProviderTiles('OpenStreetMap') %>%
  addMarkers(lng = ~longitude, lat = ~latitude, popup = ~color ) %>%
  addCircles(lng = ~longitude, lat = ~latitude, fillColor = ~colorc, fillOpacity = 1, radius = 500)
```

PhantomJS not found. You can install it with `webshot::install_phantomjs()`. If it is installed, please