Developing A Tool to Uncover The Mysterious New York City Through Taxi Trip Records

---

A Thesis
Presented to
The Division of
Smith College

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Arts

Wencong (Priscilla) Li

May 2018

Approved for the Division
(Statistical and Data Sciences)

Benjamin Baumer

Jordan Crouser

Acknowledgements

Acknowledgements

I would love to thank my thesis advisor Benjamin Baumer, Assistant Professor of Statistical and Data Sciences at Smith College, for encouraging me to chanllenge myself and and guiding me through this project. I also want to thank all my friedns and my roommates for their love and support.

Table of Contents

List of Tables

List of Figures

Abstract

Abstract

The New York City Taxi Cabs are widely recognized as the icons of New York City. The New York City Taxi & Limousine Commission provide publicly accessible yellow and green taxi trip records for people to do research with. Each taxi trip record is like a little piece of a gigantic puzzle, and all together they draw a picture of what is happening in New York City every day. This thesis presents a more efficient and easy-to-use way for users to retrieve information of both New York City taxi trip record and trip records of other ridesharing services in New York City, such as Uber and Lyft. By focusing on New York City's iconic yellow taxi's trip records, we investigate social and taxi pricing questions. Additionally, this thesis illustrates a way for taxi drivers to better understand where the customers are and where the customers try to go.

Chapter 1

Introduction

1.1 Motivation

Working with medium data in R is not an easy task. Loading medium-sized data into R environment takes a long time and might crush an R session. Creating a user-friendly platform that allows R users to easily work with medium data is my motivation. There are a lot of interesting data that are needed to be explored. In my study, I focus on New York City taxicab data, because there is so much that could be learned from taxicab trip records.

New York City taxi drivers, passengers, and NYC Taxi & Limousine Commission are the three parties who are closely involved in the NYC taxi industry. Each party has its own needs. Better understanding the needs of the three parties and provide solutions to better satisfy their needs are what I am hooping to be the result of this thiesis.

1.2 Background

1.2.1 Yellow Taxi

The Yellow Cabs are widely recognized as the icons of New York City. NYC Taxicabs are operated by private firms and licensed by the New York City Taxi and Limousine Commission (TLC). TLC issues medallions to taxicabs, and every taxicab must have a medallion to operate. There were 13,437 yellow medallion taxicabs licenses in 2014, and taxi patronage has declined since 2011 because of the competition caused by rideshare services.

1.2.2 Green Taxi

The apple green taxicabs in New York City are called Boro taxis and they are allowed to only pick up passengers in outer boroughs and in Manhattan above East 96th and West 110th Streets. Historically, only the yellow medallion taxicabs were allowed to pick up passengers on the street. However, since 95% of yellow taxi pick-ups occurred in Manhattan to the South of 96th Street and at the two airports, Five Borough Taxi Plan was started to allow green taxis to fill in the gap in outer boroughs.

1.2.3 Uber

Uber Technologies Inc., famously known as Uber, is an American technology company that operates private cars worldwide. Uber drivers use their own cars, instead of corporate-owned vehicles, to drive with Uber. In NYC, Uber uses ‘upfront pricing”, meaning that riders are informed about the fares that they will pay before requesting a ride, and gratuity is not required. Riders are given the opportunity to compare different transportation fares before making their decisions on which one to choose. Uber NYC was launched in May 2011, and it only took 5 years to have its growth to plateau.

1.2.4 Lyft

Similar to Uber, Lyft is also an on-demand transportation company, and it operates the Lyft car transportation mobile app. Lyft is the main competitor of Uber, and it came into market in July 2014 in New York City.

1.3 Literature Review

1.4 Contribution

1.4.1 nyctaxi Package

nyctaxi is an etl-dependent R package that help users to easily get access to New York City Taxi, Uber and Lyft trip data through Extract, Transform, and Load functions (ETL). This package facilitates ETL to deal with medium data that are too big to store on a laptop. Users are given the option to choose specific years and months as the input parameters of the three ETL functions, and a populated SQL database will be returned as the output. Users do not need to learn SQL queries, since all user interaction is in R.

1.4.2 Social Impact of NYC Taxi

New York City taxi drivers, passengers, and NYC Taxi & Limousine Commission are the three parties who are closely involved in the NYC taxi industry. Each party has its own needs: taxi drivers want to maxmize their profit, and in order to do that, they need to maximize the revenue while minimizing the cost. Taxi passengers want the cheapest and most convenient way of transportantion. Since Uber and Lyft launched their services in New York City, many consumers started to demand the cheaper e-hail services. TLC wants to protect both taxi drivers and passengers, and it creates policies to make NYC taxi more accessible to consumers who really need this service. In this section, I think about what each party wants and try to find a way for them to be better-off.

1.4.3 Reproducible Research

Reproducible research and open sources are the very first things that Ben mentioned to me in the beginning of my honors project. As scholars place more emphasis on the reproducibility of research studies, it is essential for me to make my dat and code openly available for people to eith redo my analysis or test my result.

`Knitr` and Github are used in my project to make my study reproducible, ranging from the initial source to raw data to the package I wrote to utlize the raw data to the statistical data analysis. I used an Github Ripository called `thesisdown` to layout the basic structure of my paper, this tool allows students to create reproducible and dynamic techinical report in R Markdown. It also allows users to embed R code and interactive applicationis, and output into PDF, Word, ePub, or gitbook doocuments. `thesisdown` helps users to efficiently put together any paper with similar format.

Github is used to store the scripts for `nyctaxi` and this thesis. `nyctaxi` is available on CRAN for people to download and install, and the source code for data analysis in this thesis is available under the Github account of the author so that scholars can easyil access the information that thery are interested in. In terms of tables, figures, and anything included in the Appendix attached to this thesis, scripts that are used to generate them are included in the Github repository.

Chapter 2

Data and nyctaxi Package

2.1 Data and Storage

The `nyctaxi` R package allows users to download, clean, and load data into SQL databasses. There are four types of data that are available for users to get access to, and they are New York City yellow taxi trip data, NYC green taxi data, NYC uber trip data, and NYC lyft data. Here is a summary of data that are available to users from 2014 to 2016.

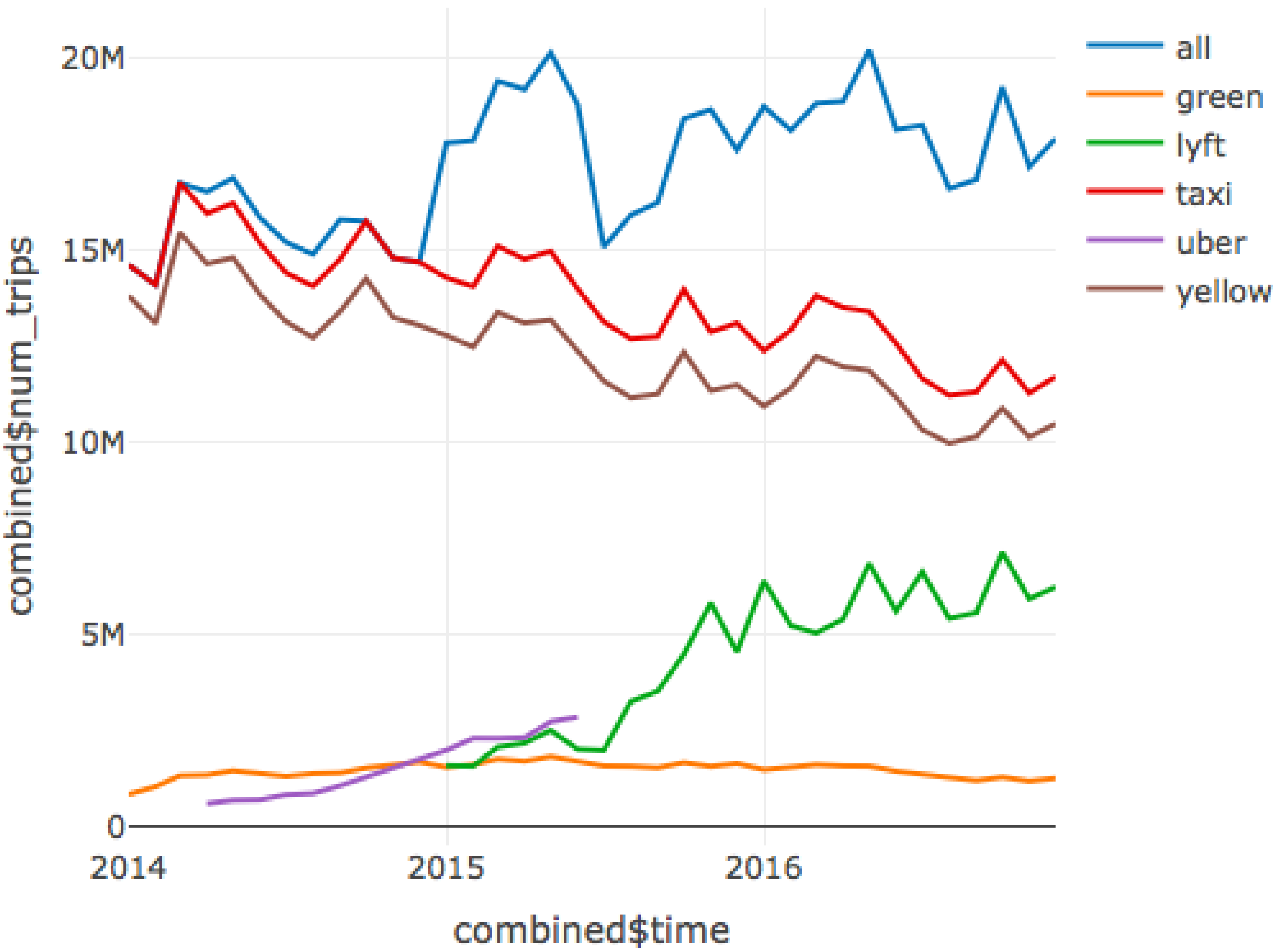


Figure 2.1

2.1.1 Yellow Taxi

The total size of all yellow taxi trip data `csv` files (from Jan 2010 to Dec 2016) is 191.38 GB, and NYC yellow taxi trip data from Jan 2009 to the most recent month can be found on NYC Taxi & Limousine Commission (TLC). The data were collected and provided to the NYC TLC by technology providers authorized under the Taxicab & Livery Passenger Enhancement Programs (TPEP/LPEP).

The yellow taxi trip records include the following fields: pick-up and drop-off dates/times, pick-up and drop-off locations, trip distances, itemized fares, rate types, payment types, and driver-reported passenger counts.

2.1.2 Green Taxi

The total size of green taxi trip data `csv` files (from Aug 2013 to Dec 2016) is 7.8 GB, and green taxi trip data from Aug 2013 to the most recent month can be downloaded from NYC Taxi & Limousine Commission (TLC). The data were collected and provided to the NYC TLC by technology providers authorized under the Taxicab & Livery Passenger Enhancement Programs (TPEP/LPEP).

The green taxi trip records include the following fields: pick-up and drop-off dates/times, pick-up and drop-off locations, trip distances, itemized fares, rate types, payment types, and driver-reported passenger counts.

2.1.3 Uber

The total size of Uber pick-up data (over 4.5 million from Apr to Sep 2014 and 14.3 million from Jan to June 2015) is 4.3 MB, and thanks to FiveThirtyEight who obtained the data from NYC TLC by submitting a Freedom of Information Law request on July 20, 2015, these data are now open to public.

The 2014 Uber data contains four variables: Data/Time (the date and time of the Uber pick-up), Lat (the latitude of the Uber pick-up), Lon (the longitude of the Uber pick-up), and Base (the TLC base company code affiliated with the Uber pickup).

The 2015 Uber data contains four variables: Dispatching_base_num (the TLC base company code of the base that dispatched the Uber), Pickup_date (the date of the Uber pick-up), Affiliated_base_num (the TLC base company code affiliated with the Uber pickup), and locationID (the pick-up location ID affiliated with the Uber pickup).

2.1.4 Lyft

The total size of weely-aggregated Lyft trip data (from Jan 2015 to Dec 2016) is 914.9 MB, and these data are open to public and weekly-aggregated Lyft data from 2015 to the most recent week can be found on NYC OpenData website.

2.1.5 Storage

The total size of all `csv` files of the four services is about 200 GB, and a laptop usually has memory less than or equal to 8GB. Limited memory constrains the amount of data that can be loaded by a personal computer. When users load data into R environment, R keeps them in memory; when the amount of data loaded into R environment gets close to the limit of a computer's memory, R becomes unresponsive or force quit the current session. Therefore, better ways to work with data that takes more space than

8 GB is needed. According to Weijia Zhang (2016), comparing to RAM, hard disk is often used to store medium-sized data, because it is affordable and are designed for storing large items permanently. However, retrieving data from hard drives usually takes about 1,000,000 times more time.

2.2 ETL nyctaxi Package

etl is the parent package of nyctaxi. etl package provides a CRAN-friendly framework that allows R users to work with medium data without any knowledge in SQL database. The end result is a populated SQL database, but the user interaction takes place solely within R. It has three operations -extract, transfer, and load- which bring real-time data into local or remote databases. etl-dependent packages make medium data - too big to store in memory on a laptop- more accessible to a wider audience. Additionally, etl-dependent packages use SQL translation supported by dyplr.

nyctaxi was initially designed to work with New York City taxi data, but later on Uber and Lyft data were added and the ETL functions are modified to be specialized in working with these data. This package compiled three major sources of hail service in New York City so that it is convenient for users to compare and contrast the performance of these three services.

This package inherits functions from many packages: etl, dplyr, DBI, rlang, and stringr. Since SQL databases are good tools for medium data analysis, ETL functions build connection to a SQL database at the back end and convert R code automatically into SQL queries and send them to the SQL database to get data tables containing data of each hail service. Thus, users do not need to have any knowledge of SQL queries and they can draw in any subsets of the data from the SQL database in R.

In general, extract.nyctaxi function download data of the four types of hail service data (yellow taxi, green taxi, uber, and lyft) from the corresponding sources. transform.nyctaxi uses different techniques to clean all four types of data to get then ready for the next step. extract.load loads the data user selected to a SQL database.

nyctaxi lives on the Comprehensive R Archive Network (CRAN), and Packages can be installed with the install.packages() function in R.

```
# install the package
install.packages("nyctaxi")

# load the package
library(nyctaxi)
```

Users need to create an etl object in order to apply the etl operations to it, and only the name of the SQL database, working directory, and type of SQL database need to be specified during initialization. If the type of SQL database is not specified, a local RSQLite database will be generated as default.

```
# initializing an etl object
db <- src_mysql("nyctaxi", user = "urname", host = "host", password = "pw")
taxi <- etl("nyctaxi", dir = "~/Desktop/nyctaxi", db)
```

In the example above, a folder called nyctaxi is created on the desktop and a connection to a MySQL database is generated. In the procession of initialization, a local folder contains two subfolders, `raw` and `load`, are also created under the directory the user specifies. `raw` folder stores data downloaded from online open sources, and `load` folder stores cleaned CSV data files that are ready to be loaded into SQL database. The ETL framework keeps data directly scraped from online data sources in their original forms. In this way, the original data is always available to users in case data corruption happens in later stages.

After an etl object is created (nyctaxi is the etl object in this case), four parameters are needed to specify the data that users want: (1) obj: an etl object (2) years: a numeric vector giving the years. The default is the most recent year. (3) months: a numeric vector giving the months. The default is January to December. (4) type: a character variable giving the type of data the user wants to download. There are four types: yellow, green, uber, and lyft. The default is yellow.

2.2.1 Taxi zone shapefile attached to nyctaxi R package

2.3 Extract

etl_extract.nyctaxi allows users to download New York City yellow taxi, green taxi, Uber, and Lyft data that are specific to their month of interest.

2.3.1 Yellow Taxi

2.3.2 Green Taxi

2.3.3 Uber

2.3.4 Lyft

2.4 Transform

etl_extract.nyctaxi allows users to transform New York City yellow taxi, green taxi, Uber, and Lyft data into forms that are meaningful to users.

2.4.1 Yellow Taxi

2.4.2 Green Taxi

2.4.3 Uber

2.4.4 Lyft

2.5 Load

etl_extract.nyctaxi allows users to load New York City yellow taxi, green taxi, Uber, and Lyft data into different data tables in a SQL database.

2.5.1 Yellow Taxi

2.5.2 Green Taxi

2.5.3 Uber

2.5.4 Lyft

2.6 SQL Database Initialization

2.6.1 Yellow Taxi

2.6.2 Green Taxi

2.6.3 Uber

2.6.4 Lyft

2.7 New Yoek City Hail Service Summary

2.8 Source Code

2.8.1 ETL Extract

```
etl_extract.etl_nyctaxi <- function(obj, years = as.numeric(format(Sys.Date(),
    "%Y")), months = 1:12, type = "yellow", ...) {
    # TAXI
    # YELLOW----------------------------------------------------------------------
    taxi_yellow <- function(obj, years, months, ...) {
        message("Extracting raw yellow taxi data...")
        remote <- etl::valid_year_month(years, months, begin = "2009-01-01") %>%
            mutate_(src = ~file.path("https://s3.amazonaws.com/nyc-tlc/trip+data",
                paste0("yellow", "_tripdata_", year, "-", stringr::str_pad(month,
                  2, "left", "0"), ".csv")))
        tryCatch(expr = etl::smart_download(obj, remote$src,
            ...), error = function(e) {
            warning(e)
        }, finally = warning("Only the following data are availabel on TLC:
                               Yellow taxi data: 2009 Jan - last month"))
```

```
}
# TAXI
# GREEN--------------------------------------------------------------------
taxi_green <- function(obj, years, months, ...) {
    message("Extracting raw green taxi data...")
    remote <- etl::valid_year_month(years, months, begin = "2013-08-01") %>%
        mutate_(src = ~file.path("https://s3.amazonaws.com/nyc-tlc/trip+data",
            paste0("green", "_tripdata_", year, "-", stringr::str_pad(month,
              2, "left", "0"), ".csv")))
    tryCatch(expr = etl::smart_download(obj, remote$src,
        ...), error = function(e) {
        warning(e)
    }, finally = warning("Only the following data are availabel on TLC:
                             Green taxi data: 2013 Aug - last month"))
}
# UBER--------------------------------------------------------------------
uber <- function(obj, years, months, ...) {
    message("Extracting raw uber data...")
    raw_month_2014 <- etl::valid_year_month(years = 2014,
        months = 4:9)
    raw_month_2015 <- etl::valid_year_month(years = 2015,
        months = 1:6)
    raw_month <- bind_rows(raw_month_2014, raw_month_2015)
    path = "https://raw.githubusercontent.com/fivethirtyeight/uber-tlc-foil-response
    remote <- etl::valid_year_month(years, months)
    remote_small <- intersect(raw_month, remote)
    if (2015 %in% remote_small$year && !(2014 %in% remote_small$year)) {
        # download 2015 data
        message("Downloading Uber 2015 data...")
        etl::smart_download(obj, "https://github.com/fivethirtyeight/uber-tlc-foil-r
            ...)
    } else if (2015 %in% remote_small$year && 2014 %in% remote_small$year) {
        # download 2015 data
        message("Downloading Uber 2015 data...")
        etl::smart_download(obj, "https://github.com/fivethirtyeight/uber-tlc-foil-r
            ...)
        # download 2014 data
        small <- remote_small %>% filter_(~year == 2014) %>%
            mutate_(month_abb = ~tolower(month.abb[month]),
              src = ~file.path(path, paste0("uber-raw-data-",
                month_abb, substr(year, 3, 4), ".csv")))
        message("Downloading Uber 2014 data...")
        etl::smart_download(obj, small$src, ...)
    } else if (2014 %in% remote_small$year && !(2015 %in% remote_small$year)) {
```

```
            message("Downloading Uber 2014 data...")
            # file paths
            small <- remote_small %>% mutate_(month_abb = ~tolower(month.abb[month
                src = ~file.path(path, paste0("uber-raw-data-",
                  month_abb, substr(year, 3, 4), ".csv")))
            etl::smart_download(obj, small$src, ...)
        } else {
            warning("The Uber data you requested are not currently available. Only
        }
    }
    # LYFT------------------------------------------------------------------------
    lyft <- function(obj, years, months, ...) {
        message("Extracting raw lyft data...")
        # check if the week is valid
        valid_months <- etl::valid_year_month(years, months,
            begin = "2015-01-01")
        base_url = "https://data.cityofnewyork.us/resource/edp9-qgv4.csv"
        valid_months <- valid_months %>% mutate_(new_filenames = ~paste0("lyft-",
            year, ".csv")) %>% mutate_(drop = TRUE)
        # only keep one data set per year
        year <- valid_months[1, 1]
        n <- nrow(valid_months)
        for (i in 2:n) {
            if (year == valid_months[i - 1, 1]) {
                valid_months[i, 6] <- FALSE
                year <- valid_months[i + 1, 1]
            } else {
                valid_months[i, 6] <- TRUE
                year <- valid_months[i + 1, 1]
            }
        }
        row_to_keep = valid_months$drop
        valid_months <- valid_months[row_to_keep, ]

        # download lyft files, try two different methods
        first_try <- tryCatch(download_nyc_data(obj, base_url,
            valid_months$year, n = 50000, names = valid_months$new_filenames),
            error = function(e) {
                warning(e)
            }, finally = "method = \"libcurl\" fails")
    }

    if (type == "yellow") {
        taxi_yellow(obj, years, months, ...)
```

```
    } else if (type == "green") {
        taxi_green(obj, years, months, ...)
    } else if (type == "uber") {
        uber(obj, years, months, ...)
    } else if (type == "lyft") {
        lyft(obj, years, months, ...)
    } else {
        message("The type you chose does not exit...")
    }

    invisible(obj)
}
```

2.8.2 ETL Transform

```
etl_transform.etl_nyctaxi <- function(obj, years = as.numeric(format(Sys.Date(),
    "%Y")), months = 1:12, type = "yellow", ...) {
    # TAXI
    # YELLOW-------------------------------------------------------------
    taxi_yellow <- function(obj, years, months) {
        message("Transforming yellow taxi data from raw to load directory...")
        # create a df of file path of the files that the user wants
        # to transform
        remote <- etl::valid_year_month(years, months, begin = "2009-01-01") %>%
            mutate_(src = ~file.path(attr(obj, "raw_dir"), paste0("yellow",
                "_tripdata_", year, "-", stringr::str_pad(month,
                  2, "left", "0"), ".csv")))
        # create a df of file path of the files that are in the raw
        # directory
        src <- list.files(attr(obj, "raw_dir"), "yellow", full.names = TRUE)
        src_small <- intersect(src, remote$src)
        # Move the files
        in_raw <- basename(src_small)
        in_load <- basename(list.files(attr(obj, "load_dir"),
            "yellow", full.names = TRUE))
        file_remian <- setdiff(in_raw, in_load)
        file.copy(file.path(attr(obj, "raw_dir"), file_remian),
            file.path(attr(obj, "load_dir"), file_remian))
    }
    # TAXI
    # GREEN-------------------------------------------------------------
    taxi_green <- function(obj, years, months) {
```

```
message("Transforming green taxi data from raw to load directory...")
# create a df of file path of the files that the user wants
# to transform
remote <- etl::valid_year_month(years, months, begin = "2013-08-01") %>%
    mutate_(src = ~file.path(attr(obj, "raw_dir"), paste0("green",
        "_tripdata_", year, "-", stringr::str_pad(month,
          2, "left", "0"), ".csv")))
# create a df of file path of the files that are in the raw
# directory
src <- list.files(attr(obj, "raw_dir"), "green", full.names = TRUE)
src_small <- intersect(src, remote$src)
# Clean the green taxi data files get rid of 2nd blank
# row-------------------------------------------------------
if (length(src_small) == 0) {
    message("The files you requested are not available in the raw director
} else {
    # a list of the ones that have a 2nd blank row
    remote_green_1 <- remote %>% filter_(~year != 2015)
    src_small_green_1 <- intersect(src, remote_green_1$src)
    # check that the sys support command line, and then remove
    # the blank 2nd row
    if (length(src_small_green_1) != 0) {
        if (.Platform$OS.type == "unix") {
          cmds_1 <- paste("sed -i -e '2d'", src_small_green_1)
          lapply(cmds_1, system)
        } else {
          message("Windows system does not currently support removing the
          in the green taxi datasets. This might affect loading data into
        }
    } else {
        "You did not request for any green taxi data, or all the green tax
    }
    # fix column
    # number-------------------------------------------------------------
    remote_green_2 <- remote %>% filter_(~year %in% c(2013,
        2014, 2015)) %>% mutate_(keep = ~ifelse(year %in%
        c(2013, 2014), 20, 21), new_file = ~paste0("green_tripdata_",
        year, "_", stringr::str_pad(month, 2, "left",
          "0"), ".csv"))
    src_small_green_2 <- intersect(src, remote_green_2$src)
    src_small_green_2_df <- data.frame(src_small_green_2)
    names(src_small_green_2_df) <- "src"
    src_small_green_2_df <- inner_join(src_small_green_2_df,
        remote_green_2, by = "src")
```

```
            src_small_green_2_df <- src_small_green_2_df %>%
                mutate(cmds_2 = paste("cut -d, -f1-", keep, " ",
                  src, " > ", attr(obj, "raw_dir"), "/green_tripdata_",
                  year, "_", stringr::str_pad(month, 2, "left",
                    "0"), ".csv", sep = ""))
            # remove the extra column
            if (length(src_small_green_2) != 0) {
                if (.Platform$OS.type == "unix") {
                  lapply(src_small_green_2_df$cmds_2, system)
                } else {
                  message("Windows system does not currently support removing the 2nd bl
                  in the green taxi datasets. This might affect loading data into SQL...
                }
            } else {
                "All the green taxi data you requested are in cleaned formats."
            }
            # Find the files paths of the files that need to be
            # transformed----------------------
            file.rename(file.path(dirname(src_small_green_2_df$src),
                src_small_green_2_df$new_file), file.path(attr(obj,
                "load_dir"), basename(src_small_green_2_df$src)))
            # Move the files
            in_raw <- basename(src_small)
            in_load <- basename(list.files(attr(obj, "load_dir"),
                "green", full.names = TRUE))
            file_remian <- setdiff(in_raw, in_load)
            file.copy(file.path(attr(obj, "raw_dir"), file_remian),
                file.path(attr(obj, "load_dir"), file_remian))
        }
    }
    # UBER------------------------------------------------------------------
    uber <- function(obj) {
        message("Transforming uber data from raw to load directory...")
        # creat a list of 2014 uber data file directory
        uber14_list <- list.files(path = attr(obj, "raw_dir"),
            pattern = "14.csv")
        uber14_list <- data.frame(uber14_list)
        uber14_list <- uber14_list %>% mutate_(file_path = ~file.path(attr(obj,
            "raw_dir"), uber14_list))
        uber14file <- lapply(uber14_list$file_path, readr::read_csv)
        n <- length(uber14file)
        if (n == 1) {
            uber14 <- data.frame(uber14file[1])
        } else if (n == 2) {
```

```
        uber14 <- bind_rows(uber14file[1], uber14file[2])
    } else if (n > 2) {
        uber14 <- bind_rows(uber14file[1], uber14file[2])
        for (i in 3:n) {
            uber14 <- bind_rows(uber14, uber14file[i])
        }
    }
    substrRight <- function(x, n) {
        substr(x, nchar(x) - n + 1, nchar(x))
    }
    uber14_datetime <- uber14 %>% mutate(date = gsub(" .*$",
        "", `Date/Time`), len_date = nchar(date), time = sub(".*\\ ",
        "", `Date/Time`))
    uber14_datetime <- uber14_datetime %>% mutate(month = substr(`Date/Time`,
        1, 1), day = ifelse(len_date == 8, substr(`Date/Time`,
        3, 3), substr(`Date/Time`, 3, 4)), pickup_date = lubridate::ymd_hms(pa
        month, "-", day, " ", time)))
    uber14_df <- uber14_datetime[-c(1, 5:9)]

    # 2015
    zipped_uberfileURL <- file.path(attr(obj, "raw_dir"),
        "uber-raw-data-janjune-15.csv.zip")
    raw_month_2015 <- etl::valid_year_month(years = 2015,
        months = 1:6)
    remote_2015 <- etl::valid_year_month(years, months)
    remote_small_2015 <- inner_join(raw_month_2015, remote_2015)
    if (file.exists(zipped_uberfileURL) && nrow(remote_small_2015) !=
        0) {
        utils::unzip(zipfile = zipped_uberfileURL, unzip = "internal",
            exdir = file.path(tempdir(), "uber-raw-data-janjune-15.csv.zip"))
        uber15 <- readr::read_csv(file.path(tempdir(), "uber-raw-data-janjune-
            "uber-raw-data-janjune-15.csv"))
    }

    names(uber14_df) <- c("lat", "lon", "affiliated_base_num",
        "pickup_date")
    names(uber15) <- tolower(names(uber15))
    uber <- bind_rows(uber14_df, uber15)
    utils::write.csv(uber, file.path(tempdir(), "uber.csv"))
    if (nrow(uber) != 0) {
        if (.Platform$OS.type == "unix") {
            cmds_3 <- paste("cut -d, -f2-7 ", file.path(tempdir(),
              "uber.csv"), " > ", file.path(attr(obj, "load_dir"),
              "uber.csv"))
```

```
                lapply(cmds_3, system)
            } else {
                message("Windows system does not currently support removing the 2nd blan
                in the green taxi datasets. This might affect loading data into SQL...")
            }
        } else {
            "You did not request for any green taxi data, or all the green taxi data you
        }
    }
    # LYFT------------------------------------------------------------------
    lyft <- function(obj, years, months) {
        valid_months <- etl::valid_year_month(years, months = 1,
            begin = "2015-01-01")
        message("Transforming lyft data from raw to load directory...")
        src <- list.files(attr(obj, "raw_dir"), "lyft", full.names = TRUE)
        src_year <- valid_months %>% distinct_(~year)
        remote <- data_frame(src)
        remote <- remote %>% mutate_(lcl = ~file.path(attr(obj,
            "load_dir"), basename(src)), basename = ~basename(src),
            year = ~substr(basename, 6, 9))
        class(remote$year) <- "numeric"
        remote <- inner_join(remote, src_year, by = "year")
        for (i in 1:nrow(remote)) {
            datafile <- readr::read_csv(remote$src[i])
            readr::write_delim(datafile, path = remote$lcl[i],
                delim = "|", na = "")
        }
    }

    # transform the data from raw to load
    if (type == "yellow") {
        taxi_yellow(obj, years, months)
    } else if (type == "green") {
        taxi_green(obj, years, months)
    } else if (type == "uber") {
        uber(obj)
    } else if (type == "lyft") {
        lyft(obj, years, months)
    } else {
        message("The type you chose does not exit...")
    }

    invisible(obj)
}
```

2.8.3 ETL Load

```
etl_load.etl_nyctaxi <- function(obj, years = as.numeric(format(Sys.Date(),
    "%Y")), months = 1:12, type = "yellow", ...) {
    # TAXI
    # YELLOW-----------------------------------------------------------------
    taxi_yellow <- function(obj, years, months, ...) {
        # create a df of file path of the files that are in the load
        # directory
        src <- list.files(attr(obj, "load_dir"), "yellow", full.names = TRUE)
        src <- data.frame(src)

        # files before 2016-07
        remote_old <- etl::valid_year_month(years, months, begin = "2009-01-01",
            end = "2016-06-30") %>% mutate_(src = ~file.path(attr(obj,
            "load_dir"), paste0("yellow", "_tripdata_", year,
            "-", stringr::str_pad(month, 2, "left", "0"), ".csv")))
        src_small_old <- inner_join(remote_old, src, by = "src")
        # files later then 2017-06
        remote_new <- etl::valid_year_month(years, months, begin = "2016-07-01") %
            mutate_(src = ~file.path(attr(obj, "load_dir"), paste0("yellow",
                "_tripdata_", year, "-", stringr::str_pad(month,
                 2, "left", "0"), ".csv")))
        src_small_new <- inner_join(remote_new, src, by = "src")
        # data earlier than 2016-07
        if (nrow(src_small_old) == 0) {
            message("The taxi files (earlier than 2016-07) you requested are not a
        } else {
            message("Loading taxi data from load directory to a sql database...")
            mapply(DBI::dbWriteTable, name = "yellow_old", value = src_small_old$s
                MoreArgs = list(conn = obj$con, append = TRUE))
        }

        # data later then 2016-06
        if (nrow(src_small_new) == 0) {
            message("The new taxi files (later than 2016-06) you requested are not
        } else {
            message("Loading taxi data from load directory to a sql database...")
            mapply(DBI::dbWriteTable, name = "yellow", value = src_small_new$src,
                MoreArgs = list(conn = obj$con, append = TRUE))
        }

    }
    # TAXI
```

```
# GREEN------------------------------------------------------------------
taxi_green <- function(obj, years, months, ...) {
    # create a list of file that the user wants to load
    remote <- etl::valid_year_month(years, months, begin = "2013-08-01") %>%
        mutate_(src = ~file.path(attr(obj, "load_dir"), paste0("green",
            "_tripdata_", year, "-", stringr::str_pad(month,
              2, "left", "0"), ".csv")))
    # create a df of file path of the files that are in the load
    # directory
    src <- list.files(attr(obj, "load_dir"), "tripdata",
        full.names = TRUE)
    src <- data.frame(src)
    # only keep the files thst the user wants to transform
    src_small <- inner_join(remote, src, by = "src")
    if (nrow(src_small) == 0) {
        message("The taxi files you requested are not available in the load director
    } else {
        message("Loading taxi data from load directory to a sql database...")
        mapply(DBI::dbWriteTable, name = "green", value = src_small$src,
            MoreArgs = list(conn = obj$con, append = TRUE,
              ... = ...))
    }
}
# UBER-------------------------------------------------------------------
uber <- function(obj, ...) {
    uberfileURL <- file.path(attr(obj, "load_dir"), "uber.csv")
    if (file.exists(uberfileURL)) {
        message("Loading uber data from load directory to a sql database...")
        DBI::dbWriteTable(conn = obj$con, name = "uber",
            value = uberfileURL, append = TRUE, ... = ...)
    } else {
        message("There is no uber data in the load directory...")
    }
}
# LYFT-------------------------------------------------------------------
lyft <- function(obj, years, months, ...) {
    message("Loading lyft data from load directory to a sql database...")
    # create a list of file that the user wants to load
    valid_months <- etl::valid_year_month(years, months,
        begin = "2015-01-01")
    src <- list.files(attr(obj, "load_dir"), "lyft", full.names = TRUE)
    src_year <- valid_months %>% distinct_(~year)
    remote <- data_frame(src)
    remote <- remote %>% mutate_(tablename = ~"lyft", year = ~substr(basename(src),
```

```
            6, 9))
        class(remote$year) <- "numeric"
        remote <- inner_join(remote, src_year, by = "year")
        if (nrow(remote) != 0) {
            write_data <- function(...) {
                lapply(remote$src, FUN = DBI::dbWriteTable, conn = obj$con,
                  name = "lyft", append = TRUE, sep = "|", ... = ...)
            }
            write_data(...)
        } else {
            message("The lyft files you requested are not available in the load di
        }
    }

    if (type == "yellow") {
        taxi_yellow(obj, years, months, ...)
    } else if (type == "green") {
        taxi_green(obj, years, months, ...)
    } else if (type == "uber") {
        uber(obj, ...)
    } else if (type == "lyft") {
        lyft(obj, years, months, ...)
    } else {
        message("The type you chose does not exit...")
    }

    invisible(obj)
}
```

2.8.4 utils

This utility function below was written to shortened the source code in ETL extract.

```
download_nyc_data <- function(obj, url, years, n, names, ...) {
    url <- paste0(url, "?years=", years, "&$limit=", n)
    lcl <- file.path(attr(obj, "raw"), names)
    downloader::download(url, destfile = lcl, ...)
    lcl
}
```

2.8.5 ETL Init

```
DROP TABLE IF EXISTS `yellow_old`;

CREATE TABLE `yellow_old` (
 `VendorID` tinyint DEFAULT NULL,
 `tpep_pickup_datetime` DATETIME NOT NULL,
 `tpep_dropoff_datetime` DATETIME NOT NULL,
 `passenger_count` tinyint DEFAULT NULL,
 `trip_distance` float(10,2) DEFAULT NULL,
 `pickup_longitude` double(7,5) DEFAULT NULL,
 `pickup_latitude` double(7,5) DEFAULT NULL,
 `RatecodeID` tinyint DEFAULT NULL,
 `store_and_fwd_flag` varchar(10) COLLATE latin1_general_ci DEFAULT NULL,
 `dropoff_longitude` double(7,5) DEFAULT NULL,
 `dropoff_latitude` double(7,5) DEFAULT NULL,
 `payment_type` tinyint DEFAULT NULL,
 `fare_amount` decimal(5,3) DEFAULT NULL,
 `extra` decimal(5,3) DEFAULT NULL,
 `mta_tax` decimal(5,3) DEFAULT NULL,
 `tip_amount` decimal(5,3) DEFAULT NULL,
 `tolls_amount` decimal(5,3) DEFAULT NULL,
 `improvement_surcharge` decimal(5,3) DEFAULT NULL,
 `total_amount` decimal(5,3) DEFAULT NULL,
 KEY `VendorID` (`VendorID`),
 KEY `pickup_datetime` (`tpep_pickup_datetime`),
 KEY `dropoff_datetime` (`tpep_dropoff_datetime`),
 KEY `pickup_longitude` (`pickup_longitude`),
 KEY `pickup_latitude` (`pickup_latitude`),
 KEY `dropoff_longitude` (`dropoff_longitude`),
 KEY `dropoff_latitude` (`dropoff_latitude`)
)
PARTITION BY RANGE( YEAR(tpep_pickup_datetime) ) (
  PARTITION p09 VALUES LESS THAN (2010),
  PARTITION p10 VALUES LESS THAN (2011),
  PARTITION p11 VALUES LESS THAN (2012),
  PARTITION p12 VALUES LESS THAN (2013),
  PARTITION p13 VALUES LESS THAN (2014),
  PARTITION p14 VALUES LESS THAN (2015),
  PARTITION p15 VALUES LESS THAN (2016),
  PARTITION p16 VALUES LESS THAN (2017)
);

DROP TABLE IF EXISTS `yellow`;
```

```
CREATE TABLE `yellow` (
 `VendorID` tinyint DEFAULT NULL,
 `tpep_pickup_datetime` DATETIME NOT NULL,
 `tpep_dropoff_datetime` DATETIME NOT NULL,
 `passenger_count` tinyint DEFAULT NULL,
 `trip_distance` float(10,2) DEFAULT NULL,
 `RatecodeID` tinyint DEFAULT NULL,
 `store_and_fwd_flag` varchar(10) COLLATE latin1_general_ci DEFAULT NULL,
 `PULocationID` tinyint DEFAULT NULL,
 `DOLocationID` tinyint DEFAULT NULL,
 `payment_type` tinyint DEFAULT NULL,
 `fare_amount` decimal(5,3) DEFAULT NULL,
 `extra` decimal(5,3) DEFAULT NULL,
 `mta_tax` decimal(5,3) DEFAULT NULL,
 `tip_amount` decimal(5,3) DEFAULT NULL,
 `tolls_amount` decimal(5,3) DEFAULT NULL,
 `improvement_surcharge` decimal(5,3) DEFAULT NULL,
 `total_amount` decimal(5,3) DEFAULT NULL,
 KEY `VendorID` (`VendorID`),
 KEY `pickup_datetime` (`tpep_pickup_datetime`),
 KEY `dropoff_datetime` (`tpep_dropoff_datetime`),
 KEY `PULocationID` (`PULocationID`),
 KEY `DOLocationID` (`DOLocationID`)
)
PARTITION BY RANGE( YEAR(tpep_pickup_datetime) ) (
  PARTITION p16 VALUES LESS THAN (2017),
  PARTITION p17 VALUES LESS THAN (2018)
);


DROP TABLE IF EXISTS `green`;

CREATE TABLE `green` (
 `VendorID` tinyint DEFAULT NULL,
 `lpep_pickup_datetime` DATETIME NOT NULL,
 `Lpep_dropoff_datetime` DATETIME NOT NULL,
 `Store_and_fwd_flag` varchar(10) COLLATE latin1_general_ci DEFAULT NULL,
 `RatecodeID` tinyint DEFAULT NULL,
 `Pickup_longitude` double(7,5) DEFAULT NULL,
 `Pickup_latitude` double(7,5) DEFAULT NULL,
 `Dropoff_longitude` double(7,5) DEFAULT NULL,
 `Dropoff_latitude` double(7,5) DEFAULT NULL,
 `Passenger_count` tinyint DEFAULT NULL,
 `Trip_distance` float(10,2) DEFAULT NULL,
```

```
 `Fare_amount` decimal(5,3) DEFAULT NULL,
 `Extra` decimal(5,3) DEFAULT NULL,
 `MTA_tax` decimal(5,3) DEFAULT NULL,
 `Tip_amount` decimal(5,3) DEFAULT NULL,
 `Tolls_amount` decimal(5,3) DEFAULT NULL,
 `improvement_surcharge` decimal(5,3) DEFAULT NULL,
 `Total_amount` decimal(5,3) DEFAULT NULL,
 `Payment_type` tinyint DEFAULT NULL,
 `Trip_type` tinyint DEFAULT NULL,
 KEY `VendorID` (`VendorID`),
 KEY `pickup_datetime` (`lpep_pickup_datetime`),
 KEY `dropoff_datetime` (`Lpep_dropoff_datetime`)
);


DROP TABLE IF EXISTS `lyft`;

CREATE TABLE `lyft` (
 `base_license_number` varchar(15) COLLATE latin1_general_ci DEFAULT NULL,
 `base_name` varchar(40) COLLATE latin1_general_ci DEFAULT NULL,
 `dba` varchar(40) COLLATE latin1_general_ci DEFAULT NULL,
 `pickup_end_date` DATE NOT NULL,
 `pickup_start_date` DATE NOT NULL,
 `total_dispatched_trips` smallint DEFAULT NULL,
 `unique_dispatched_vehicle` smallint DEFAULT NULL,
 `wave_number` tinyint DEFAULT NULL,
 `week_number` tinyint DEFAULT NULL,
 `years` smallint DEFAULT NULL,
 KEY `base_name` (`base_name`),
 KEY `pickup_end_date` (`pickup_end_date`),
 KEY `pickup_start_date` (`pickup_start_date`)
);


DROP TABLE IF EXISTS `uber`;

CREATE TABLE `uber` (
 `lat` double(7,5) DEFAULT NULL,
 `lon` double(7,5) DEFAULT NULL,
 `dispatching_base_num` varchar(15) COLLATE latin1_general_ci DEFAULT NULL,
 `pickup_date` DATETIME NOT NULL,
 `affiliated_base_num` varchar(15) COLLATE latin1_general_ci DEFAULT NULL,
 `locationid` tinyint DEFAULT NULL,
 KEY `pickup_date` (`pickup_date`),
 KEY `locationid` (`locationid`)
```

```
);

CREATE VIEW yellow_old_sum AS SELECT YEAR(tpep_pickup_datetime) as the_year, MONTH(t
  FROM yellow_old
  GROUP BY the_year, the_month;
);
```

Chapter 3

New York City Taxi Driver

3.0.1 Trip-level Tip Inofrmation

The income of Taxi drivers in New York City has two parts: taxi fare and tips. Taxi fare is usually calculated by the meters installed in the taxis, and the rate of fare cannot be changed by taxi drivers. Therefore, in order to make more profit, taxi drivers prefer to pick up passengers who offer big amount of tips. What are the regions that provide the most tips to yellow taxicab drivers?

In the following analysis, I will focus on trip data collected in August 2016. Taxi drivers usually does not correctly record the amount of tips paid by cash or check. Therefore, in order to find out the regions that offer the most tips, we need to filter out the trips that are not paid by credit or debit card.

```
library(dplyr)
library(readr)
yellow_2016.08_cleaned <- read_csv("~/Desktop/Honors Thesis/thesis/index/data/yell
yellow_2016.08_tip <- yellow_2016.08_cleaned %>% filter(fare_amount >
    0) %>% filter(tip_amount > 0) %>% filter(payment_type ==
    1) %>% filter(tip_amount < fare_amount)
```

Instead of the absolute amount of tips, we want to focus on the percentage of tips that passengers pay in addition to the total fare amount. Therefore, we use tip amount over fare amount to calculate the percent tip.

```
yellow_2016.08_tip <- yellow_2016.08_tip %>% mutate(tip_perct = tip_amount/fare_am
```

Let's visualize the distribution of percent tip of all trips occurred in August 2016:

```
library(ggplot2)
tip_individual <- ggplot(data = yellow_2016.08_tip, aes(x = tip_perct)) +
    xlab("Tips, percent") + geom_histogram(binwidth = 0.005) +
    geom_vline(xintercept = c(0.2), col = "red", linetype = "longdash") +
```

```
    geom_vline(xintercept = c(0.25), col = "green", linetype = "longdash") +
    geom_vline(xintercept = c(0.28), col = "yellow", linetype = "longdash")
tip_individual
```

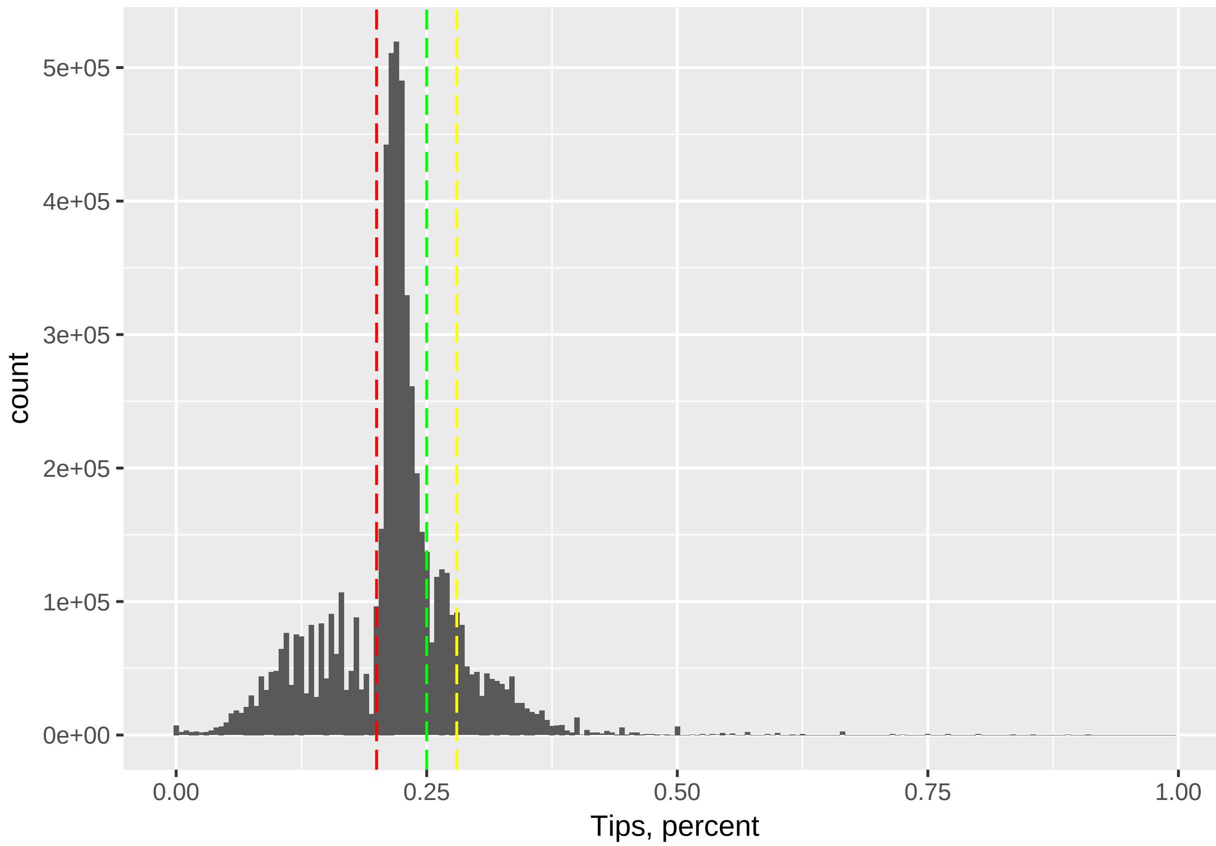


Figure 3.1: this is my caption

3.0.2 Aggregated Zone-level Tip Information

Instead of studying factors that affect individual trips' percent tip, it is more useful to study the aggregated effect of each zone on percent tip.

```
data(taxi_zone_lookup)
```

Taxi drivers are required to be indifferent to where passengers are going. Therefore, it makes sense to investigate the average amount of tips paid for each pick-up zone. What are the taxi pick-up zones that have the highest tip percents?

We first calculate the average percent tip paid for each pick-up zone. Here is a list of pick-up zones with more than 1000 trip per month along with their average percent tip:

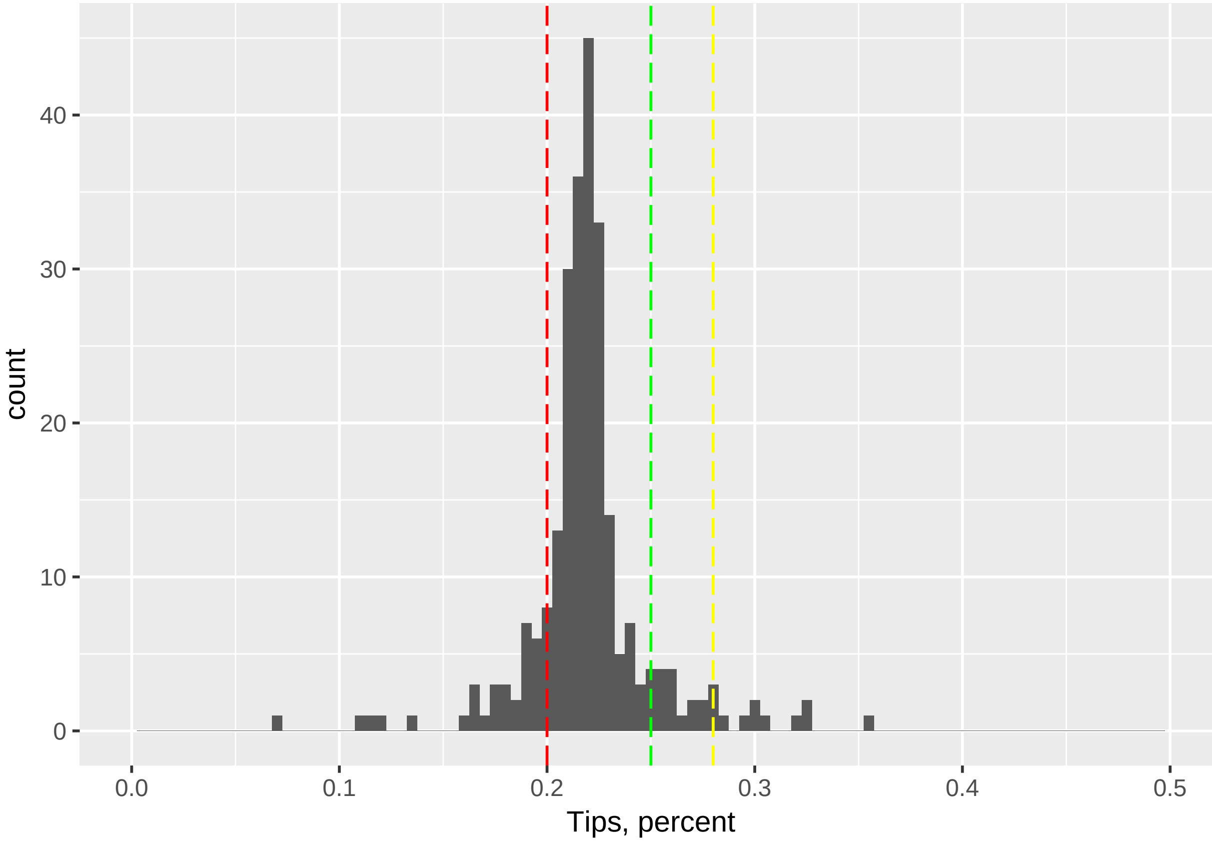
```
tip_pickup <- yellow_2016.08_tip %>% group_by(PULocationID) %>%
    summarise(avg_tip = mean(tip_perct), num_trips = n(), avg_dis = mean(trip_dist
    rename(LocationID = PULocationID) %>% left_join(taxi_zone_lookup,
    by = "LocationID") %>% arrange(desc(avg_tip)) %>% filter(Zone !=
    "Unknown")
tip_pickup %>% filter(num_trips > 1000) %>% head(10)
```

```
# A tibble: 10 x 6
   LocationID   avg_tip num_trips  avg_dis   Borough
        <int>     <dbl>     <int>    <dbl>    <fctr>
 1        106 0.2343283      1088 3.600248  Brooklyn
 2        223 0.2335789      3014 4.212296    Queens
 3         37 0.2318139      2309 3.251091  Brooklyn
 4         80 0.2290748      4547 3.212947  Brooklyn
 5        189 0.2286701      1842 3.361069  Brooklyn
 6        112 0.2278641      3709 3.335044  Brooklyn
 7          7 0.2277946      7277 3.397217    Queens
 8         40 0.2275125      3537 4.186876  Brooklyn
 9         36 0.2271561      1334 3.571627  Brooklyn
10        230 0.2267445    171017 3.044212 Manhattan
# ... with 1 more variables: Zone <fctr>
```

Below is a histogram of average percent tips paid for all pick-up zones. As show on the plot, the first peak is around 20%, which is the cheapest default option on the touch panel for passengers to chose.

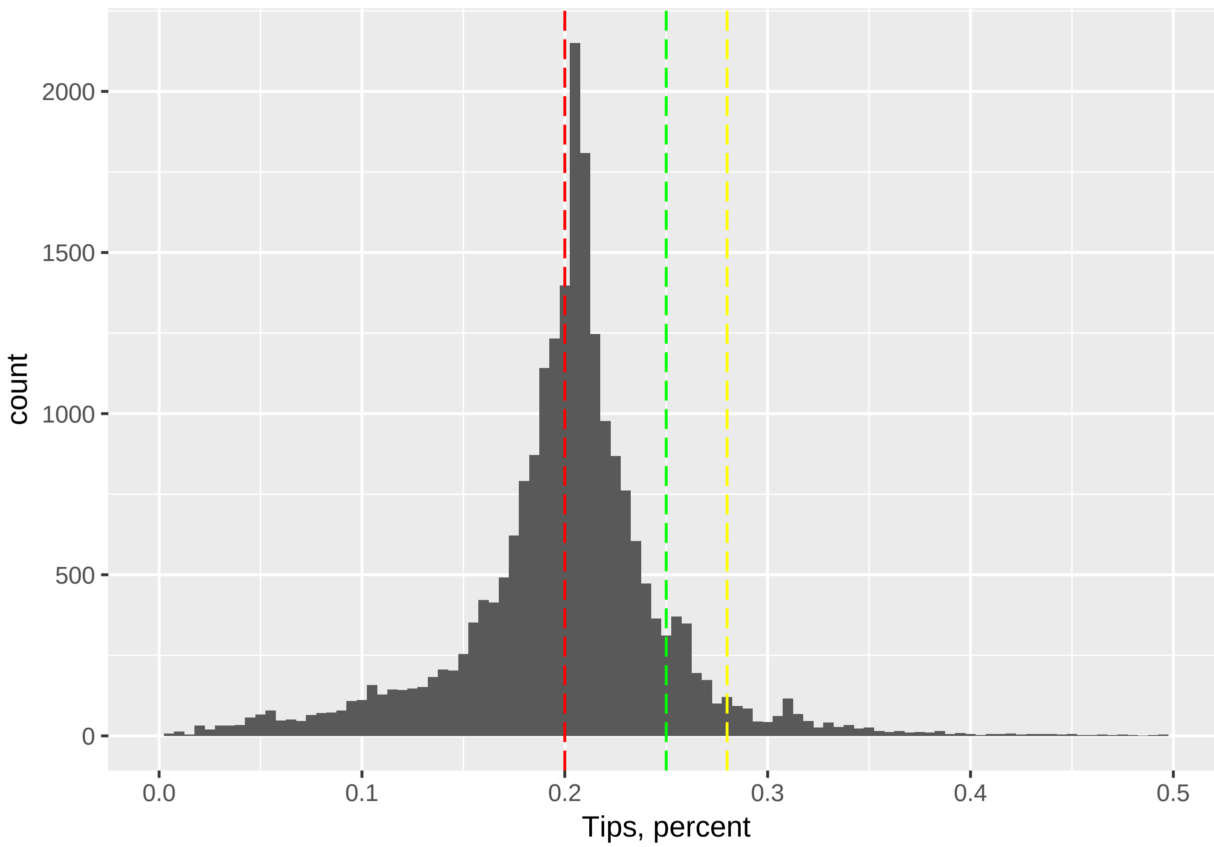
```
pickup_vis <- ggplot(data = tip_pickup, aes(x = avg_tip)) + xlab("Tips, percent")
    geom_histogram(binwidth = 0.005) + geom_vline(xintercept = c(0.2),
    col = "red", linetype = "longdash") + geom_vline(xintercept = c(0.25),
    col = "green", linetype = "longdash") + geom_vline(xintercept = c(0.28),
    col = "yellow", linetype = "longdash") + scale_x_continuous(limits = c(0,
    0.5))
pickup_vis
```

```
Warning: Removed 3 rows containing non-finite values (stat_bin).
```




```
tip_region <- yellow_2016.08_tip %>% group_by(PULocationID, DOLocationID) %>%
    summarise(avg_tip = mean(tip_perct), trips = n(), avg_dis = mean(trip_distance)) %>%
    # filter(trips > 10) %>%
arrange(desc(avg_tip)) %>% rename(LocationID = PULocationID) %>%
    left_join(taxi_zone_lookup, by = "LocationID")
# zone
region_vis <- pickup_vis %+% tip_region
region_vis
```

```
Warning: Removed 95 rows containing non-finite values (stat_bin).
```



The 20% peak is more clearly shown when we calculate the percent tips for each pick-up and drop-off locatins pair instead of pick-up location only.

Does trip distance increase the percent tips paid? One of the questions that I always wonder is whether longer trips result in higher tip percent. It takes taxi drivers more time to complete longer trips, so passengers might want to compensate taxi drivers more. I personally pay higher percent of tips for longer rides, so I believe trip distance has an impact on percentage of tips paid.

```
tip_distance <- lm(avg_tip ~ avg_dis + LocationID + DOLocationID,
    data = tip_region)
summary(tip_distance)$coef[1:2, ]
```

```
                 Estimate   Std. Error     t value  Pr(>|t|)
(Intercept)  2.025175e-01 1.140007e-03 177.6457606 0.0000000
avg_dis     -3.083442e-07 1.565416e-06  -0.1969727 0.8438507
```

Acoording to the simple linear regression result, trip distance does not have significant impact on the percent of tips paid, controlling for both pick-up and drop-off locations.

3.0.3 Which zones have the highest percent tip?

Let's fist take a look at which pick-up zones have the highest number of pickups. We create a heat map to visulizae the number of trip for each pick-up zones on a map of New York City Taxi Zones.

```
data("taxi_zones")
library(sp)
```

```
Warning: package 'sp' was built under R version 3.4.3
```

```
pick_up_zones <- merge(taxi_zones, tip_pickup, by.x = "LocationID",
    by.y = "LocationID")
```

```
library(leaflet)
reds = colorNumeric("Reds", domain = NULL)
# leaflet(data = pick_up_zones) %>% addTiles() %>%
# addPolygons(fillColor = ~reds(num_trips), fillOpacity =
# 0.6, weight = 1, opacity = 0.8) %>% setView(lat = 40.7128,
# lng = -74.0060, zoom = 10)
```

It's obbivous that Manhattan, La Guardia Airport, and JKF Airport have the most number of pick-ups.

Most yellow cab pick-ups occur in Manhattan. If we focus on the pick-up zones that have more than 900 trips per month or 30 trips per day, then we observe that many pick-up zones that have the highest percent tips are in Brooklyn.

```
# pick a threshold for the cutoff number of trips
pickup_zone_900 <- tip_pickup %>% filter(num_trips >= 900) %>%
    arrange(desc(avg_tip))

pickup_zone_900 %>% head(10)
```

```
# A tibble: 10 x 6
   LocationID   avg_tip num_trips  avg_dis   Borough
        <int>     <dbl>     <int>    <dbl>    <fctr>
 1        106 0.2343283      1088 3.600248  Brooklyn
 2        223 0.2335789      3014 4.212296    Queens
 3         37 0.2318139      2309 3.251091  Brooklyn
 4         80 0.2290748      4547 3.212947  Brooklyn
 5        189 0.2286701      1842 3.361069  Brooklyn
 6        112 0.2278641      3709 3.335044  Brooklyn
 7          7 0.2277946      7277 3.397217    Queens
 8         40 0.2275125      3537 4.186876  Brooklyn
 9         36 0.2271561      1334 3.571627  Brooklyn
10        230 0.2267445    171017 3.044212 Manhattan
# ... with 1 more variables: Zone <fctr>
```

```r
# library(knitr) kable(pickup_zone_1000[1:10,2:6], caption =
# 'Taxi zone with the highest tip percent, threshold = 1000')
```

People might think it is more reasonable to ses a list that is populated with Zones in Manhattan, since that's where all the wealthy people live. However, it turns out that passengers who get on taxis in Brooklyn pays more tips.

If we focus on the pick-up zones that have more than 90000 trips per month or 3000 trips per day, then we observe that all pick-up zones that have the highest percent tips are in Manhattan besides La Guardia Airport.

```r
# pick a threshold for the cutoff of number of trips
pickup_zone_90000 <- tip_pickup %>% filter(num_trips >= 90000) %>%
    arrange(desc(avg_tip))
pickup_zone_90000 %>% head(10)
```

```
# A tibble: 10 x 6
   LocationID   avg_tip num_trips   avg_dis   Borough
        <int>     <dbl>     <int>     <dbl>    <fctr>
 1        230 0.2267445    171017  3.044212 Manhattan
 2        186 0.2249650    213759  2.399181 Manhattan
 3        138 0.2249391    177262 10.084311    Queens
 4        161 0.2245180    230968  2.533839 Manhattan
 5        100 0.2245116    115242  2.467806 Manhattan
 6        162 0.2237261    224543  2.578228 Manhattan
 7        237 0.2226464    193035  1.942023 Manhattan
 8         48 0.2226313    180209  2.576908 Manhattan
 9        239 0.2224459    134925  2.454595 Manhattan
10        163 0.2218928    152459  2.556783 Manhattan
# ... with 1 more variables: Zone <fctr>
```

```r
# kable(pickup_zone_10000[1:10,2:5], caption = 'Taxi zone
# with the highest tip percent, threshold = 10000')
```

There are more than 100 times more yellow cab pick-ups that happen in Manhattan everyday than in Brooklyn, and that is why there are many dense red-shade polygons in the visulization above.

3.0.4 Do taxi drivers tend to go to zones that offer high tips?

So far, we have learned what pick-up zones offer the highest percent tip. Now, we want to dig into the relationships between percent tip and taxi-zone-specific variables.

It is not easy to find an available taxi on the street on New York City, because the demand for taxi trips is much higher than the supply. Does paying more tips help customers to more easily get taxis? If customers from certain regions keep paying higher tips, taxi drivers might be able to learn from their experiences in those regions, and be more willing to wonder around those regions more often and pick up passengers. Pick-up zones with higher tips should attract more taxi drivers with the control of taxi zones. Let's test it out and see whether it is true:

```
tip_region$LocationID <- as.character(tip_region$LocationID)
tip_pickup$LocationID <- as.character(tip_pickup$LocationID)
tip_and_trip_1 <- lm(trips ~ avg_tip + LocationID, data = tip_region)
# summary(tip_and_trip_1)
summary(tip_and_trip_1)$coef[1:2, ]
```

```
             Estimate Std. Error    t value     Pr(>|t|)
(Intercept) -188.5729   598.5170 -0.3150669 7.527139e-01
avg_tip     1447.2714   116.1562 12.4596964 1.629761e-35
```

Each one percent increase in average tips in pick-up zones is associated with 1447.2714 increase in the number of trips per month, controlling the pick-up zone.

```
9942263/31
```

```
[1] 320718.2
```

```
1447.2714/31
```

```
[1] 46.68617
```

In August 2016, yellow cabs made an average of 320,718 daily trips. Additionally, each one percent increase in average tips in pick-up zones is associated with 47 increase in the number of trips per day in a specific pick-up zone.

3.0.5 Which pick-up zone has the highest price per minute?

New York City Taxi Fare & Limousine Commission has information on how New York City taxi fare amount is calculated on their official website.

Metered Fare Information Onscreen rate is 'Rate #01 – Standard City Rate.' *The initial charge is $2.50.* Plus 50 cents per 1/5 mile or 50 cents per 60 seconds in slow traffic or when the vehicle is stopped. *In moving traffic on Manhattan streets, the meter should "click" approximately every four downtown blocks, or one block going cross-town (East-West).* There is a 50-cent MTA State Surcharge for all trips that end in New York City or Nassau, Suffolk, Westchester, Rockland, Dutchess, Orange or Putnam Counties. *There is a 30-cent Improvement Surcharge.* There is a daily 50-cent surcharge from 8pm to 6am. *There is a $1 surcharge from 4pm to 8pm on weekdays, excluding holidays.* Passengers must pay all bridge and tunnel tolls. *Your receipt will show your total fare including tolls. Please take your receipt.* The driver is not required to accept bills over $20. *Please tip your driver for safety and good service.* There are no charges for extra passengers or bags.

In taxi fare calculation, the only unknown variable is slow-trafice time, and all other variables were collected by the meters installed on each medallion taxi for each trip. It is reasonable to assume that for trips with the same pick-up and drop-off locations, the longer the total slow traffic time is, the longer the trip would take. Taxi drivers are compensated for both the normal-speed trip distance and the time spent in slow-traffice. According to the fare calculation algorithm, in moving traffic on Manhattan streets, the meter should "click" approximately every four downtown blocks, or one block going cross-town (East-West); in slow traffic, the meter should "click" every 60 seconds. Therefore, slow traffic reduces the fare per minute ratio.

New York CIty has the worst traffic jam, and it has overtaken Miami to be voted the U.S. city with the angriest and most aggressive drivers in 2009, according to a survey on road rage released on Tuesday. Bad traffic also cause slow-traffic, and taxi drivers tend to suck in traffic during rush hours. Does fare per minute ratio have an impact on the percent tip that passengers pay? Do passengers compensate taxi drivers more during rush hours? Are passengers sympathetic to taxi drivers for the time they spend in slow traffic?

`https://www.reuters.com/article/us-driving-roadrage-life/new-york-drivers-named-most-aggressive-angry-in-u-s-idUSTRE55F1J720090616`

```r
library(lubridate)
yellow_2016.08_time <- yellow_2016.08_tip %>% mutate(duration = round((tpep_dropof
    tpep_pickup_datetime)/60, 2)) %>% mutate(duration = as.numeric(duration)) %>%
    filter(duration > 0) %>% mutate(fare_per_min = fare_amount/duration)

# summary(yellow_2016.08_time$fare_per_min)
fare_min_ratio <- lm(tip_perct ~ fare_per_min, data = yellow_2016.08_time)
summary(fare_min_ratio)
```

```

Call:
lm(formula = tip_perct ~ fare_per_min, data = yellow_2016.08_time)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.21882 -0.01891  0.00242  0.02685  0.77849 

Coefficients:
               Estimate Std. Error t value Pr(>|t|)    
(Intercept)   2.189e-01  2.815e-05 7776.48   <2e-16 ***
fare_per_min -1.785e-05  6.984e-07  -25.56   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.06937 on 6088066 degrees of freedom
Multiple R-squared:  0.0001073, Adjusted R-squared:  0.0001071
F-statistic: 653.2 on 1 and 6088066 DF,  p-value: < 2.2e-16
```

As shown in the regression result, fare per minute ratio has a significant negative impact on percent tip. Since having more slow traffic time spent on the road reduces the fare per minute ratio, slow traffice does increase the impact on percent tip. Passengers do pay more tips to taxi drivers during rush hours.

Chapter 4

New York City Taxi Consumer

4.1 How long does it take for passengers to get to JFK, LaGuardia, and Newark Airports? When is the best time to travel?

```
library(dplyr)
library(readr)
yellow_2015.08_cleaned <- read_csv("~/Desktop/Honors Thesis/thesis/index/data/yell
yellow_2016.08_tip <- yellow_2015.08_cleaned %>% filter(fare_amount >
    0) %>% filter(tip_amount > 0) %>% filter(PULocationID !=
    DOLocationID)
```

```
dataset %>% group_by()
```

4.2 How does weather affect New York City taxi and Uber trips? How does snowfall affect taxi and Uber trips?

Chapter 5

New York City Taxi Fare & Limousine Commission

5.1 Should there be a flat rate between Manhattan and the JFK Airport?

5.1.1 People in Manhattan benefit from the $52 flat rate.

Why is there a flat rate to and from JFK airport and any location in Manhattan? Why is the flat rate $52? Does TLC make profit from the $52 flat rate? Does $52 reduce the cogestion on the road to JFK airport and make taking a train a more preferable choice?

If there is no flat rate between JFK and Manhattan,

```
jfk_trip <- yellow_2016.08_cleaned %>% filter(RatecodeID == 2) %>%
    filter(payment_type != 3) %>% filter(trip_distance > 0) %>%
    filter(fare_amount > 0) %>% filter(PULocationID != DOLocationID) %>%
    mutate(est_fare = 2.5 + 0.5 * trip_distance * 5 + extra +
        improvement_surcharge + mta_tax + tolls_amount, est_diff = est_fare -
        fare_amount)

to_jfk <- jfk_trip %>% filter(DOLocationID == 132)
```

```
to_jkf_zone <- to_jfk %>% group_by(PULocationID) %>% summarise(num_trips = n(),
    avg_dis = mean(trip_distance), avg_fare = mean(est_fare)) %>%
    rename(LocationID = PULocationID) %>% left_join(taxi_zone_lookup,
    by = "LocationID")

# to_jkf_fare <- merge(taxi_zones, to_jkf_zone, by.x =
# 'LocationID', by.y = 'PULocationID')
```

```
to_jkf_zone_above <- to_jkf_zone %>% filter(Borough == "Manhattan") %>%
    # filter(avg_fare >= 52) %>%
arrange(desc(avg_fare))

kable(to_jkf_zone_above[1:44, ], caption = "Pick-up Zones with avergae fare to JKF Airpo
```

Imagine it's your first time travelling to New York City, and you decided to live in a hotel in Manhattan Since you do not know much about the city, the $52 flat rate is nice for you, and it incentivizes you to take taxi to the JFK Airport. If there is no flat rate, there is uncertainty in how much someone needs to pay to take a taxi to JFK, and tourists might instead choose to take the train, even though taking a train would cost them more time and inconvenience.

Additionally, people who are native to Manhattan would have paid more than $52 to take a taxi to go to the JFK Airport. The higher the taxi fare is, the less the demand for taxi will be. Therefore, having a flat rate,helps taxi drivers to get more trips from Manhattan to JFK Airport.

5.2 However, are taxi drivers happy with the flat rate?

What the expected fare from JKF Airport to Manhattan?

```
from_jfk <- jfk_trip %>% filter(PULocationID == 132)

from_jkf_zone <- from_jfk %>% group_by(DOLocationID) %>% summarise(num_trips = n(),
    avg_dis = mean(trip_distance), avg_fare = mean(est_fare)) %>%
    rename(LocationID = DOLocationID) %>% left_join(taxi_zone_lookup,
    by = "LocationID")

from_jkf_fare <- merge(taxi_zones, from_jkf_zone, by.x = "LocationID",
    by.y = "LocationID")

# cols <- brewer.pal(n = 4, name = 'Greys')
lcols <- cut(from_jkf_fare$avg_fare, breaks = quantile(from_jkf_fare$avg_fare,
    na.rm = TRUE), labels = cols)
plot(from_jkf_fare, col = as.character(lcols))

from_jkf_zone_above <- from_jkf_zone %>% filter(Borough == "Manhattan") %>%
    # filter(avg_fare >= 52) %>%
arrange(desc(avg_fare))
kable(to_jkf_zone_above[1:67, ], caption = "Drop-off Zones with average fare amount from
```

Table 5.1: Pick-up Zones with avergae fare to JKF Airport

LocationID	num_trips	avg_dis	avg_fare	Borough	Zone
127	6	22.85833	65.06250	Manhattan	Inwood
243	8	21.54250	63.82125	Manhattan	Washington Heights North
13	1266	22.09787	62.44055	Manhattan	Battery Park City
244	74	20.42216	60.27892	Manhattan	Washington Heights South
239	1685	20.47249	60.11053	Manhattan	Upper West Side South
261	723	21.22151	59.59012	Manhattan	World Trade Center
143	655	20.53586	59.26524	Manhattan	Lincoln Square West
238	1233	19.93394	59.02019	Manhattan	Upper West Side North
12	41	20.62537	58.44146	Manhattan	Battery Park
88	362	20.30909	57.79963	Manhattan	Financial District South
151	637	19.39038	57.71180	Manhattan	Manhattan Valley
116	67	19.27463	57.54149	Manhattan	Hamilton Heights
158	751	19.68667	57.52564	Manhattan	Meatpacking/West Village West
24	248	19.21508	57.20560	Manhattan	Bloomingdale
152	67	19.12522	57.10769	Manhattan	Manhattanville
236	1574	18.94848	56.57681	Manhattan	Upper East Side North
166	447	18.88353	56.54928	Manhattan	Morningside Heights
140	1005	18.90681	56.04591	Manhattan	Lenox Hill East
262	1127	18.62596	55.91055	Manhattan	Yorkville East
50	628	18.90573	55.50548	Manhattan	Clinton West
263	1185	18.56361	55.47873	Manhattan	Yorkville West
87	1252	19.67124	55.39298	Manhattan	Financial District North
142	1832	19.19067	55.37192	Manhattan	Lincoln Square East
246	591	18.24122	54.95910	Manhattan	West Chelsea/Hudson Yards
42	92	18.05380	54.87038	Manhattan	Central Harlem North
43	826	18.74347	54.85187	Manhattan	Central Park
75	470	18.16949	54.77060	Manhattan	East Harlem South
41	238	18.02353	54.33887	Manhattan	Central Harlem
68	1623	17.91729	53.98436	Manhattan	East Chelsea
231	947	19.36168	53.91387	Manhattan	TriBeCa/Civic Center
249	866	18.50783	53.65980	Manhattan	West Village
237	1493	18.42390	53.65730	Manhattan	Upper East Side South
48	2780	17.99023	53.33922	Manhattan	Clinton East
141	1197	18.23483	53.16414	Manhattan	Lenox Hill West
90	1151	17.58740	53.09904	Manhattan	Flatiron
230	6585	17.78133	52.99621	Manhattan	Times Sq/Theatre District
74	257	17.28008	52.70712	Manhattan	East Harlem North
186	2236	17.30646	52.66024	Manhattan	Penn Station/Madison Sq West
113	947	17.94572	52.65996	Manhattan	Greenwich Village North
125	430	18.69965	52.63090	Manhattan	Hudson Sq
100	1742	17.24245	52.43794	Manhattan	Garment District
234	1803	17.20495	52.42949	Manhattan	Union Sq
105	1	17.31000	52.11500	Manhattan	Governor's Island/Ellis Island/Libe
224	315	17.46460	52.07268	Manhattan	Stuy Town/Peter Cooper Village

how much time it would take for a cb driver to do a round trip `https://ny.curbed.com/2017/1/17/14296892/yellow-taxi-nyc-uber-lyft-via-numbers`

Chapter 6

Conclusion

6.1 Future Research

For future study, I would love to investigate the sharp decline in the consumption of NYC yellow cab after e-hail services were introduced into the NYC ride-hail market. I also want to study what the impact of introducing new GPS and entertainment system is on the number of rides. The global product and marketing at Verifone, Jason Gross, said that, “I like to say that we provide what Uber says it provides.” With the raised expectation among rides caused by Uber and Lyft, yellow taxi industry need to respond quickly. How does the market react to the newly installed entertainment system? Has the market share of yellow cab rebounded since 2016? By looking into the patterns in market shares, it might be possible for me to predict the future market share distribution and find out what features of ride-hail transportation are the ones that affect market share distribution the most.

Appendix A

The First Appendix

This first appendix includes all of the R chunks of code that were hidden throughout the document (using the `include = FALSE` chunk tag) to help with readibility and/or setup.

In the main Rmd file

```
# This chunk ensures that the thesisdown package is installed
# and loaded. This thesisdown package includes the template
# files for the thesis.
if (!require(devtools)) install.packages("devtools", repos = "http://cran.rstudio.
if (!require(thesisdown)) devtools::install_github("ismayc/thesisdown")
library(thesisdown)
```

In Chapter ??:

Appendix B

The Second Appendix, for Fun

References

Angel, E. (2000). *Interactive computer graphics : A top-down approach with opengl*. Boston, MA: Addison Wesley Longman.

Angel, E. (2001a). *Batch-file computer graphics : A bottom-up approach with quicktime*. Boston, MA: Wesley Addison Longman.

Angel, E. (2001b). *Test second book by angel*. Boston, MA: Wesley Addison Longman.