

Tools for Understanding Taxicab and E-Hail Service Use in New York City

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Abstract

Yellow Taxi Cabs are widely recognized as the icons of New York City. The New York City Taxi & Limousine Commission (TLC) provides publicly accessible yellow and green taxi trip records. (“TLC Aggregated Reports,” 2009) Each taxi trip record is like a little piece of a gigantic puzzle, and all together they tell a story of what happens in New York City. This thesis presents a more efficient and easy-to-use way for users to retrieve trip records information of both New York City taxi and other ride-sharing services, such as Uber and Lyft, in New York City. By analyzing trip records of New York City’s iconic yellow taxi, we seek answers to questions that are commonly asked by taxi drivers, passengers, and TLC officials to help all three parties to improve their services or experiences.

Chapter 1

Introduction

1.1 Motivation

When is the best time during a day to travel to JFK Airport from Brooklyn? How much tip do passengers usually pay to the taxi drivers? Is the \$52 flat rate from Manhattan to JFK Airport appropriate? Questions about New York City taxicabs are frequently asked by people travelling in taxis in New York City. New York City Taxi and Limousine Commission (TLC) provides taxi trip data on their website for people to study and answer these questions. However, it is not easy to work with taxi trip data provided by TLC, because there are more than 250,000 taxi trips happenning everyday in New York City (Whitford, 2017), which implies the large size of the datasets.

Working with medium data, such as the taxi TLC trips records, in **R** is not an easy task. Loading medium-sized data into the **R** environment takes a long time and might crash an **R** session. Creating a user-friendly platform that allows **R** users to easily work with medium data is my motivation. In my study, I focus on New York City taxicab data because there are a lot of interesting questions about New York City

taxicabs that I want to explore.

New York City taxi drivers, passengers, and New York City TLC are the three parties who are closely involved in the New York City taxi industry. Each party has its own needs. Better understanding the needs of the three parties and providing solutions to satisfy their needs is the goal of this thesis.

This work contains two main components. The first component is building the tool to work with the TLC taxi trip data, and the second component is using the tool we build to understand the taxicab and e-hail service use in New York City.

1.2 Background

1.2.1 Yellow Taxi

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 (“Taxicabs of New York City,” 2018).

1.2.2 Green Taxi

The apple green taxicabs in New York City are called Boro taxis and they are only allowed to pick up passengers in the 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, the Five

Borough Taxi Plan was started to allow green taxis to fill in the gap in outer boroughs in the summer of 2013 (“Your guide to Boro Taxis,” 2009).

1.2.3 Uber

Uber Technologies Inc. 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 (“Uber Won New York,” 2015).

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 (“Uber Won New York,” 2015).

1.3 Literature Review

1.3.1 New York City Traffic and Taxi

New York City is one of the most popular cities in the United States, and New York City taxicabs represent the image of New York City. New York City’s traffic is a popular topic in journalism, and different aspects of it has been studied by journalists, such as Patricia Reaney. New York City’s traffic is a nightmare, and the

city officials have long been trying to solve the congestion problem. In 2009, New York City was voted to be the U.S. city with the “angriest and most aggressive drivers”. (Reaney, 2009) The bad temper of drivers are exacerbated by New York City’s severe cogestion.

How bad is the cogestion? In a journal published by New York Post in 2016, New York City was described as “the city that never moves”. (Danielle Furfaro & Fears, 2016) What has led to the congestion in the city? A journal from New York Post tried to find an answer to this question: According to a former top NYPD official, “The city streets are being engineered to create traffic congestion, to slow traffic down, to favor bikers and pedestrians” so that drivers will have the incentive to leave their cars at home and turn to mass transit or bicycles (Sugar, 2017).

No matter how miserable the driving experiences are, taxi drivers have no luxury to choose alternative transportation, and instead thay have to consistently drive their cabs, which are usually surrounded by bad traffic, in order to make a living.

1.3.2 Competition between New York City taxi and e-hail services

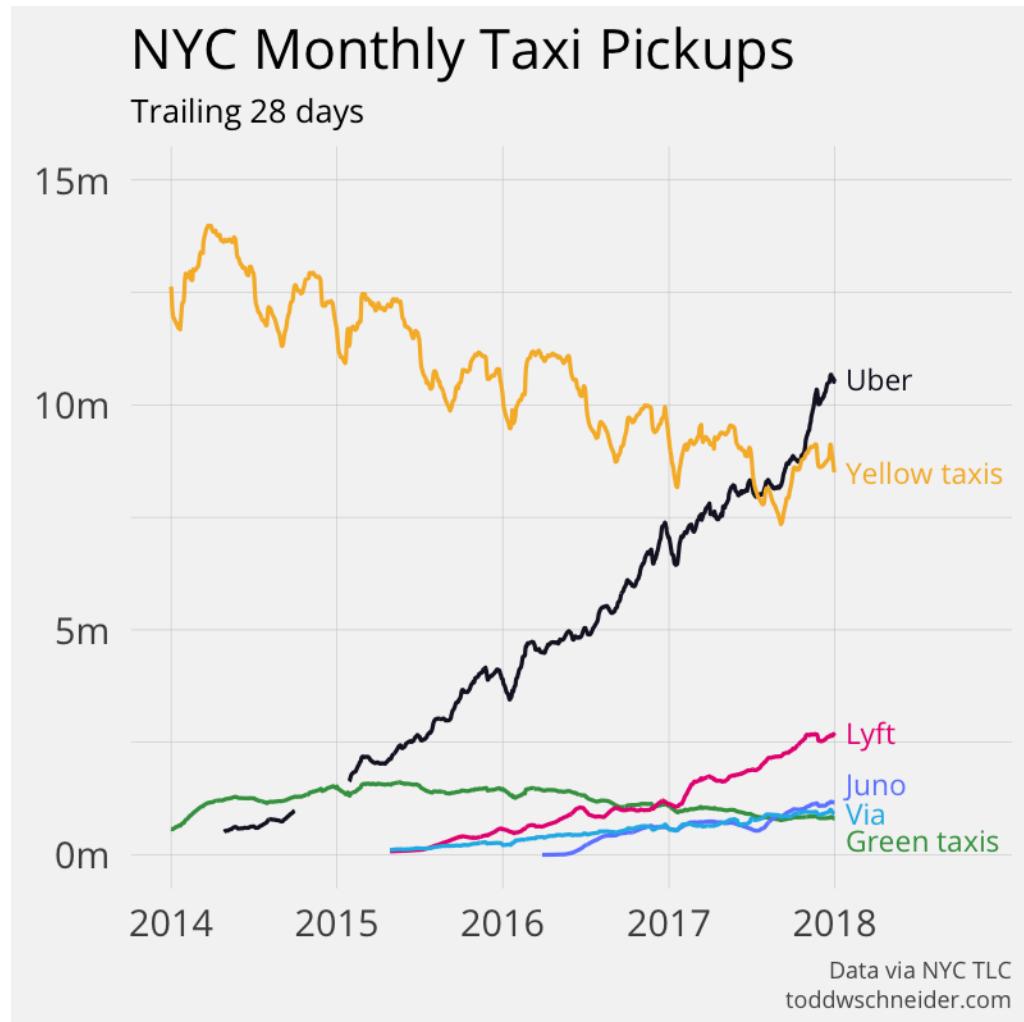


Figure 1.1: NYC Monthly Taxi Pickups

As shown in the visualization above (Schneider, 2015), the number of New York City yellow taxi trips has been consistently declining for about 4 years, and the numbers of Uber and Lyft trips keep increasing. In 2017, for the first time, the total number of monthly Uber trips exceeded the number of yellow taxi trips.

Some studies have shown how competitive Uber and Lyft are. In 2017, Uber and Lyft registered vehicles outnumbered NYC yellow cabs by 4 to 1. (Sugar, 2017) Even

though Yellow cab used to be the most popular street-hail transportation service in New York City, passengers nowadays tend to choose the more convenient options, ride-hailing apps.(Hu, 2017)

As reported in a journal from Forbes Tech, data scientists from the University of Cambridge in the UK and the University of Namur in Belgium found that yellow taxi rides are on average \$1.40 cheaper than Uber X, which is one type of economy ride service offered by Uber (HyreCar, 2018). Moreover, Uber appears more expensive for trips that are cheaper than \$35, and less expensive than yellow taxi ride for trips that are more expensive than \$35. Therefore, for short trips, taking a taxi is more affordable. (Guerrini, 2015)

Apps, such as Openstreetcab, that compares the price of Uber and taxi trips are designed to help customers to compare the fares of different transportations. (“Open-StreetCab,” 2015)

1.3.3 etl R package

In *R Markdown: Integrating A Reproducible Analysis Tool into Introductory Statistics*, the authors have presented experimental and statistical evidence that *R Markdown* replaced the antiquated and hard-to-reproduce *copy-and-paste workflow*, and makes creating fully-reproducible statistical analysis straight-forward (B. Baumer, Cetinkaya-Rundel, Bray, Loi, & Horton, 2014).

Work with taxi trip data is not an easy task, because of the large size of the taxi trip datasets (Whitford, 2017). Taxi trip datasets are classified as ‘medium data’. Loading medium-sized data into **R** environment takes a long time and might crush an **R** session. **etl R** package creates a user-friendly platform that allows **R** users to easily work with medium data with the extract, transform, load framework, which

is commonly known as ETL in computing (“Extract, transform, load,” 2018). The ETL process has been set up (B. S. Baumer, 2017) in **R** to facilitate etl operations for medium data, and it is designed to work with any general data set. Packages that are specific to particular data sets are needed to be written in order to better work with complex medium-sized data sets.

1.4 Contribution

1.4.1 ‘nyctaxi’ Package

nyctaxi is an **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). (B. S. Baumer, 2017) This package facilitates ETL to deal with medium data that are too big to store in memory 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 connection to 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**.

The screenshot shows the GitHub page for the nyctaxi package. At the top, there is a link to 'README.md'. Below it, the title 'New York City Taxi' is displayed in bold. Underneath the title, there are three status indicators: 'build failing', 'CRAN 0.0.1', and 'downloads 216/month'. The main content area is titled 'nyctaxi' in bold. It describes the package as an R package to download NYC's Taxi and Limousine Commission (TLC) Trip Data. It mentions that NYC's Taxi and Limousine Commission (TLC) Trip Data is a collection of green and yellow taxi trip records including fields capturing pick-up and drop-off locations, times, trip distances, fares, rate types, and driver-reported passenger counts. The data was collected and provided to the NYC TLC by technology providers under the Taxicab & Livery Passenger Enhancement Programs.

1.4.2 Social Impact of NYC Taxi

NYC Taxi drivers wants to make the most profit. 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 (Sugar, 2017). 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 these sections, we analyze what each party wants and try to find a way for them to be achieve their goals.

1.4.3 Reproducible Research

Reproducible research and open source are two main emphasis of this honors project. As scholars place more emphasis on the reproducibility of research studies, it is essential for us to make our data and code openly available for people to redo the analysis.

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 **R** package called **thesisdown** to typeset this paper, this tool allows authors to create reproducible and dynamic technical 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 (W. P. Li, Baumer, & Trang Le, 2017), and the source code for data analysis in this thesis is available under the Github account of the author so that scholars can easily 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 databases. There are four types of data that are available for users to get access to: trip level yellow taxi data from 2009 to the most recent month, trip level green taxi data from August 2013 to the most recent month, Uber pick-up data from April to September 2014 and from January to June 2015, and weekly-aggregated Lyft trip data from 2016 to the most recent week (W. P. Li et al., 2017).

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 the NYC Taxi & Limousine Commission (TLC) website (“TLC Trip Record Data,” 2009a). 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). (“TLC Trip Record Data,” 2009a) Green taxi trip records include the same variables as yellow taxi trip records.

2.1.3 TLC Summary Report

The New York City TLC publishes summary reports that include aggregate statistics about taxi, Uber, and Lyft usage. These are in addition to the trip-level data; although the summary reports contain much less detail, they’re updated more frequently, which provides a more current glimpse into the state of the cutthroat NYC taxi market. (“TLC Aggregated Reports,” 2009)

In addition, the trip level NYC Uber data only covers two periods, from April to September 2014 and from January to June 2015. However, the summary reports cover weekly-aggregated data from 2015 to the most recent week.

The screenshot shows the official website of the NYC Taxi & Limousine Commission. At the top, there's a navigation bar with links to 'NYC Resources', '311', and 'Office of the Mayor'. Below the header, the 'NYC Taxi & Limousine Commission' logo is displayed. A search bar is located at the top right. A horizontal menu bar includes 'Online Transactions (LARS)', 'Printer Friendly', 'Newsletter Sign-up', 'Translate This Page', and 'Text Size' options. On the left, a sidebar menu lists various categories such as Home, About TLC, TLC Rules and Local Laws, Licensing/Industry Information, Passenger Information, Frequently Asked Questions, TLC News, TLC Site Map, and Contact/Visit TLC. Below this is a social media sharing section with icons for Facebook, Twitter, YouTube, Instagram, LinkedIn, and NextDoor. The main content area features a yellow header titled 'Aggregated Reports'. Under this, there's a section about monthly aggregated reports, followed by links to 'Yellow Taxi Monthly Indicators' (CSV file format, Data Dictionary) and 'Street Hail Livery Monthly Indicators' (CSV file format, Data Dictionary). Both links lead to monthly metrics containing average daily trips and fare collected. There's also a link to the 'FHV Base Aggregate Weekly Report' (Dataset on Open Data, Data Dictionary), which is a monthly report containing weekly total dispatched trips and unique dispatched vehicles by base. To the right of the main content is a yellow sidebar titled 'Taxi News' with a message about new rules and pilot programs for FHV bases. At the bottom right of the main content area, there are navigation arrows and a page number '1/7'.

The data can be accessed by using the following commands:

- Yellow taxi data

```
download.file("http://www.nyc.gov/html/tlc/downloads/csv/data_reports_monthly_indi
```

*Uber and Lyft data

```
download.file("http://data.cityofnewyork.us/api/views/2v9c-2k7f/rows.csv?accessType
```

2.1.4 Uber

The total size of Uber pick-up data (from Apr to Sep 2014 and from Jan to June 2015) is 900 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. ("TLC Trip Record Data," 2009b)

The 2014 Uber data contains 4 variables: **Date/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 4 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).

NYC Open Data also provides weekly-aggregated Uber pick-up data from 2015 to the most recent month. (“Uber Trips NYC 2016,” 2015)

2.1.5 Lyft

The total size of weekly-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. (“LYFT Data,” 2015)

2.1.6 Data 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 8 GB. Limited memory constrains the amount of data that can be loaded by a personal computer at one time. 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 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 is about 1,000,000 times slower.

2.2 ETL *nyctaxi* Package

`etl` is the parent package of `nyctaxi`. `etl` provides a framework that allows **R** users to work with medium data without any knowledge in SQL database. Users can run SQL queries by using `dplyr` commands in **R** and choose to only return the final result, which could be a summary table, from SQL database into **R** Environment in order to avoid **R** from crashing. The user interaction takes place solely within **R**.

`etl` framework has three operations -Extract, Transfer, and Load- which bring real-time data into local or remote SQL databases. Users can specify which type of SQL database they prefer to connect to. `etl`-dependent packages, such as `nyctaxi`, make medium data more accessible to a wider audience. (B. Baumer et al., 2014)

`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 compiles 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. (W. P. Li et al., 2017)

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, `etl_extract.etl_nyctaxi()` function download data of the four types of hail service data (yellow taxi, green taxi, Uber, and Lyft) from the corresponding sources. `etl_transform.etl_nyctaxi()` uses different techniques to clean all four types of data to get then ready for the next step. `etl_load.etl_nyctaxi()` loads the data user selected to a SQL database.

The Comprehensive **R** Archive Network (CRAN) is a collection of sites that carry identical material, consisting of the **R** distributions, the contributed extensions, documentation for **R**, and binaries. (Studio, n.d.) `nyctaxi` **R** package lives on CRAN, and it can be installed with the `install.packages()` function in **R**.

```
install.packages("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.

```
db <- src_mysql("nyctaxi", user = "username", 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 process 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, and the default is the most recent year; (3) `months`: a numeric vector giving the months, and the default is `1:12`; (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

Two datasets are attached to `nyctaxi`. The first one is called `taxi_zone_lookup`, and this dataset contains information, such as taxi zone location IDs, location names, and corresponding boroughs for each ID. (“TLC Trip Record Data,” 2009a) A shapefile containing the boundaries for the taxi zones, `taxi_zones`, is also included in the package for users to do spatial analysis. Visualizations similar to one shown below can be generated with the shapefile.

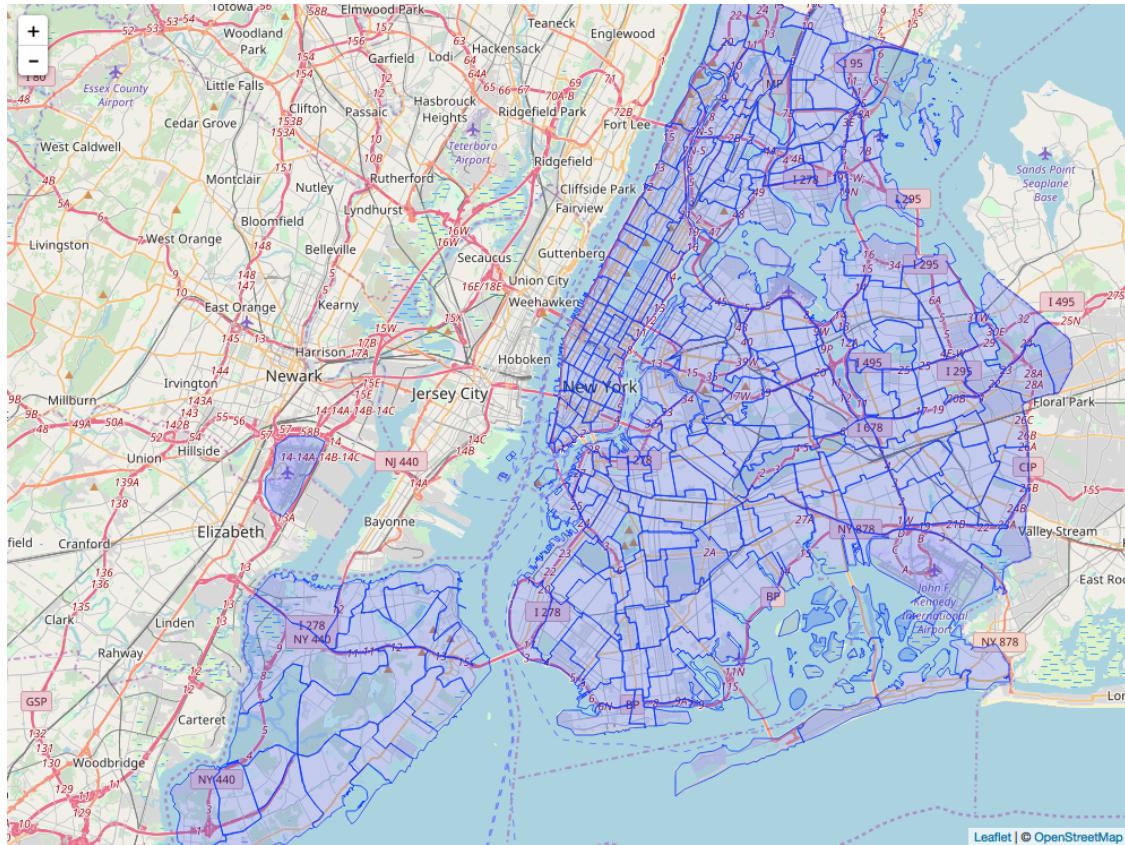


Figure 2.1: NYC Taxi Zone Map

2.3 Extract-Transform-Load

2.3.1 Extract

`etl_extract.etl_nyctaxi()` allows users to download New York City yellow taxi, green taxi, Uber, and Lyft data from the corresponding data sources. It takes the `years`, `months`, and `type` parameters and download the New York City taxi data specified by users. New York City Yellow and Green Taxi data are updated on NYC Taxi & Limousine Commission (TLC) website on a monthly basis.

```
taxi %>%  
  etl_extract(years = 2014:2016, months = 1:12, type = c("yellow", "green"))
```

Uber trip record data is static and small, so we decided to only give users the options to either download all data from April to Sepetember, 2014 or download all Uber trip records from Janaury to June, 2015 at onc. Users do not have the ability to download Uber data from a specific month.

```
taxi %>%  
  etl_extract(years = 2014:2016, months = 1:12, type = c("uber"))
```

Lyft data is updated on NYC Open Data webiste on a weekly basis. Since the weekly-aggregated data is tiny and only data later then 2014 is available, we decided to only allow users to download Lyft data by year.

```
taxi %>%  
  etl_extract(years = 2014:2016, months = 1:12, type = c("lyft"))
```

The default `years` is the current year, and the default `months` are the all twelve months. The default type of transportation is `yellow`. When an invalid month is entered, warning message will suggest users to reconsider their choice and select a new set of month.

2.3.2 Transform

`etl_transform.etl_nyctaxi()` allows users to transform New York City yellow taxi, green taxi, Uber, and Lyft data into cleaned formats, and it utlizes different data cleaning techniques when it transforms data for each transportation type. In general, it cleans the data and creates a new `csv` file in the `load` directory to store the cleaned data. It helps us to retain and protect raw data from being modified or destroyed.

Users are allowed to specify the month of interest in order to only transform the data that they are interested in. This functionality helps people to be more efficient with their use of time.

By default, it takes the current year Yellow taxi trip records data files, and save copies of them in the `load` directory. It skips the cleaning step, because the raw Yellow Taxi data downloaded from TLC is already in a desired format with all variables correctly labelled.

```
taxi %>%
  etl_transform(years = 2014:2016, months = 1:12, type = c("yellow", "green", "uber", "black"))
```

There are a few main transformations that are done by this function:

Green Taxi – Extra Blank Row and Column

Green Taxi monthly data from August 2013 to the most recent month besides 2015 all have a blank second row in the `csv` files. Similar to this problem, Green Taxi data from 2013, 2014, and 2015 all have an extra blank columns attached to the right-most column. These blank rows and columns cause problems in the later stage when users want to load data into SQL database. In order to get Green Taxi data ready for the `load` phase, we used the `system()` function in **R** to invoke the Terminal command specified to remove the blank rows and columns.

Uber Data – Reconciling Inconsistent Filenames

Uber only released over 4.5 million data records from April to September 2014 and 14.3 million records from January to June 2015. Information of different sets of variables are released for 2014 and 2015, and variables have different naming convention. When users want to download data from both years, variables are renamed so that data

from both years can be consolidated into one big dataset with consistent variable names.

Uber Data – Reconciling Inconsistent Data Formats

The data type of Date/Time variable in Uber datasets is originally encoded as character. In order to enable it to be recognized as timestamp by R, we use `ymd_hms` in `lubridate` (Grolemund & Wickham, 2011) to transform date time to `POSIXct` objects.

Optimizing I/O Process

Improving file input and output processes is an important part of `etl_transform`. `data.table` (Dowle & Srinivasan, 2017) only takes half of the time to read from and write into datasets comparing to `readr` (Wickham, Hester, & Francois, 2017). Therefore, `etl_transform` uses `fread()` and `fwrite()` from `data.table` instead of `read_csv` or `write_csv` from `readr` to reduce the data processing time (Zhang, 2017).

2.3.3 Load

`etl_load.etl_nyctaxi()` allows users to load New York City yellow taxi, green taxi, Uber, and Lyft data into different data tables in a SQL database. It populates a SQL database with data cleaned by `etl_transform`.

```
taxi %>%
  etl_load(years = 2014:2016, months = 1:12, type = c("yellow", "green", "uber",
```

2.3.4 SQL Database Initialization

`init.mysql()` is written under `nyctaxi` to help users to set up five basic table structures for MySQL database. `yellow_old` is created for Yellow Taxi data that are prior to August 2016, and `yellow` is created for data later than July 2016. `green`, `uber`, and `lyft` are also initiated for the three transportations.

`etl_init()` can be run after a database connection is built to process to process `init.mysql()` to initialize a MySQL database, and default columns with the correct variable names and typed defined will be automatically generated.

```
taxi %>%  
  etl_init()
```

In order to increase the query speed at the data analysis stage, KEYS are created for multiple variables for each transportation. Since there is no variable containing unique value for each observation, no primary variable is needed. Using KEYS in data analysis query can speed up the query process.

Due to the large size of Yellow Taxi datasets, `yellow_old` and `yellow` are partitioned into subgroups by `year`. When we need to run a query on data from a specific year, having partitions allows MySQL to directly find the data specified without filtering on every single row. It speeds up the query process. A VIEW called `yellow_old_sum` is also created to generate a summary table for the number of Yellow Taxi trips in each month.

```
CREATE
  ALGORITHM = UNDEFINED
  DEFINER = 'wiz7'@'%'
  SQL SECURITY DEFINER
VIEW nyctaxi`.`yellow_old_sum` AS
SELECT
  YEAR(`nyctaxi`.`yellow_old`.`tpep_pickup_datetime`) AS `the_year`,
  MONTH(`nyctaxi`.`yellow_old`.`tpep_pickup_datetime`) AS `the_month`,
  COUNT(1) AS `num_trips`
FROM
  `nyctaxi`.`yellow_old`
GROUP BY YEAR(`nyctaxi`.`yellow_old`.`tpep_pickup_datetime`), MONTH(`nyctaxi`.`yellow_old`.`tpep_pickup_datetime`)
```

The screenshot shows the MySQL Workbench interface. On the left, the schema browser displays the 'nyctaxi' database with tables like green, lyft, uber, yellow, and yellow.old, and a view named yellow.old_sum. The central pane shows the SQL code for creating the view. Below the code, the 'Object Info' tab is selected, showing the view's columns: the_year (int(4)), the_month (int(2)), and num_trips (bigint(21)). The bottom pane shows the query history with one entry: a SELECT * from nyctaxi.yellow.old_sum LIMIT 0, 100 query that returned 0 rows in 0.284 seconds.

Figure 2.2: MySQL View

2.4 New York City Taxicab and E-hail Services Summary

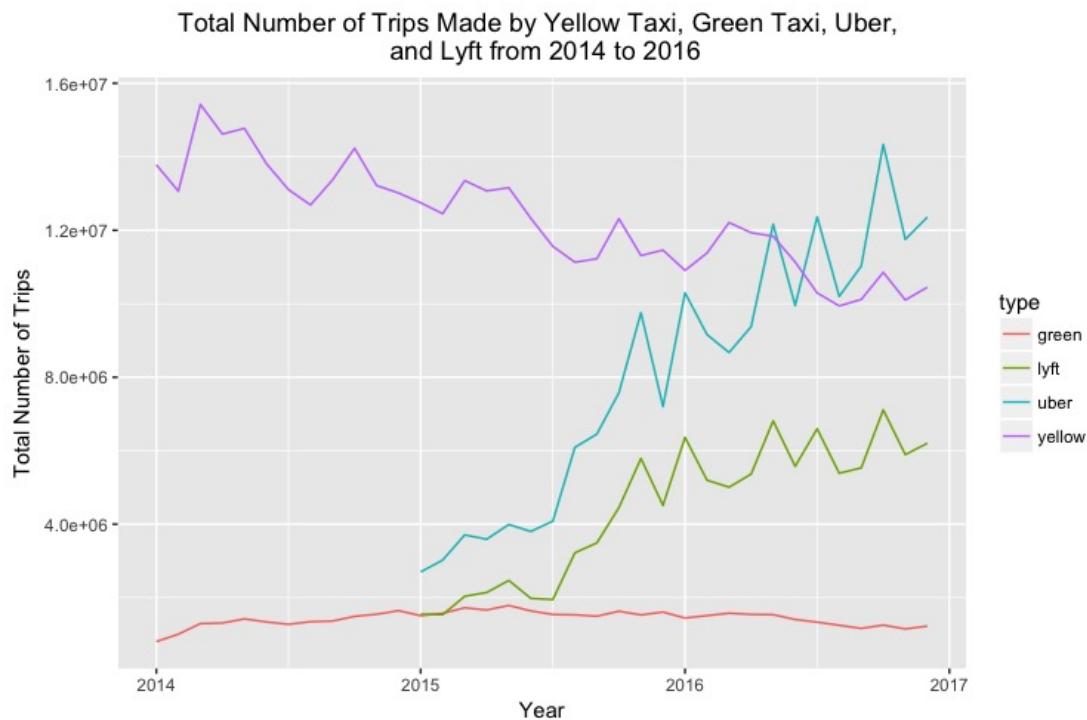


Figure 2.3: Summary of Number of trips Made by 4 Types of Transporations between 2014 and 2016 in NYC

Figure 2.3 is a summary of total number of trips made by all 4 types of transporations that are available to users from 2014 to 2016. In order to generate this summary, I combined trip-level yellow and green taxi data from TLC trip data website and weekly Uber and Lyft data from NYC OpenData. Data used in Figure 2.3 can be accessed by running the code below:

- Yellow taxi monthly data

```
download.file("http://www.nyc.gov/html/tlc/downloads/csv/data_reports_monthly_indicators
```

- Uber weekly data

```
download.file("https://data.cityofnewyork.us/resource/gt3n-7ri6.csv", destfile = "
```

- Lyft weekly data

```
download.file("https://data.cityofnewyork.us/resource/juxc-sutg.csv", destfile = "
```

2.5 Source Code

2.5.1 ETL Extract

```
etl_extract.etl_nytaxi <-
  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 available 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/master/uber-trip-data"
  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-foil-response/raw/master/
                                uber-trip-data/uber-raw-data-jan-june-15.csv.zip",...)}
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-foil-response/raw/master/uber-trip-data/
                                /uber-raw-data-jan-june-15.csv.zip",...)
  #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 data

from 2014/04-2014/09 and 2015/01-

2015/06 are available...")}

}

#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 exist...")}  
  
invisible(obj)  
}
```

2.5.2 ETL Transform

```
opts_chunk$set(tidy.opts=list(width.cutoff=60))

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 directory.")  
  
  } 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 2nd blank row
              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 requested are cleaned."}

#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 = ""))
```

```
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 blank row

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(paste0("2014-", 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-15.csv.zip",  
                                    "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 blank row
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 requested are cleaned."}

}

#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 exist...")}

invisible(obj)
}

```

2.5.3 ETL Load

```

opts_chunk$set(tidy.opts=list(width.cutoff=60))

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 available in
    the load directory...")
} else {
  message("Loading taxi data from
    load directory to a sql database...")
  mapply(DBI::dbWriteTable,
  name = "yellow_old", value = src_small_old$src,
  MoreArgs =
  list(conn = obj$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 available in the

    load directory...")

} 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 directory...")

} 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 directory...")}

}

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 exist...")}
```

```
    }

invisible(obj)
}
```

2.5.4 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(tpipep_pickup_datetime) as the_year, MONTH(tpipep_pickup_datetime) as the_month  
FROM yellow_old  
GROUP BY the_year, the_month;  
);
```


Chapter 3

New York City Taxi Driver

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, we will focus on trip data collected in 2017. Taxi drivers usually do not correctly record the amount of tips paid by cash or check (W. Li, 2018). 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.

As mentioned in the previous chapter, that we can utilize the connection to a MySQL database to run data analysis in MySQL for medium-sized data. Since we are using all 12 month data from 2017 in this analysis, it is impractical to load all data needed into **R** environment. Instead, we want to only load a fraction of the 2017 Yellow Taxi data from MySQL database.

In this section, we only want to load trip records with payment type equals to 1, which represents credit card. Only trip records with payment type credit card have accurate

information on tip amount. Let's load the 2017 trip record into **R** environment by using the MySQL connection we just generated, `taxi`.

```
yellow_2017 <- taxi %>%
 tbl("yellow") %>%
  filter(payment_type == 1) %>%
  collect(n = Inf)
```

3.1 Aggregated Zone-level Tip Information

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. We then calculated the mean percent tip, mean distances travelled, mean number of minutes spent travelling, and total number of trips of each pick-up and drop-off pair in 2017 to get the aggregated zone-level information in order to compare the percent tip passengers pay in each zone.

```
yellow_2017_summary <- yellow_2017 %>%
  mutate(year = year(tpep_pickup_datetime),
         month = month(tpep_pickup_datetime),
         tip_perct = tip_amount/fare_amount) %>%
  group_by(year, month, PULocationID, DOLocationID) %>%
  summarise(avg_tip = mean(tip_perct),
            trips = n(),
            avg_dis = mean(trip_distance),
            avg_duration = mean(duration))
```

Each taxi trip has pick-up and drop-off locations associated with it, and there are 263 known taxi zones.

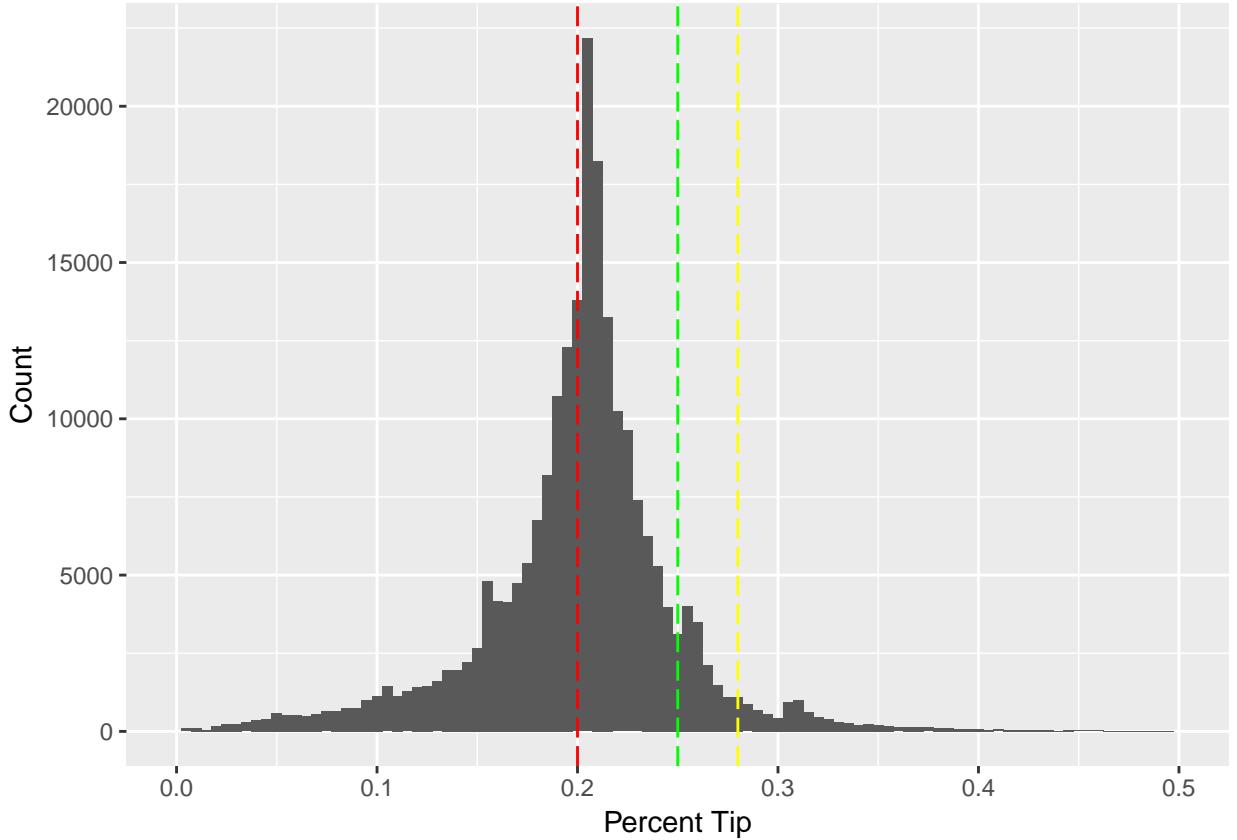


Figure ?? is a histogram of mean tip percents for all known pick-up and drop-off zone pairs.

3.1.1 Pick-up Zone Tip Information

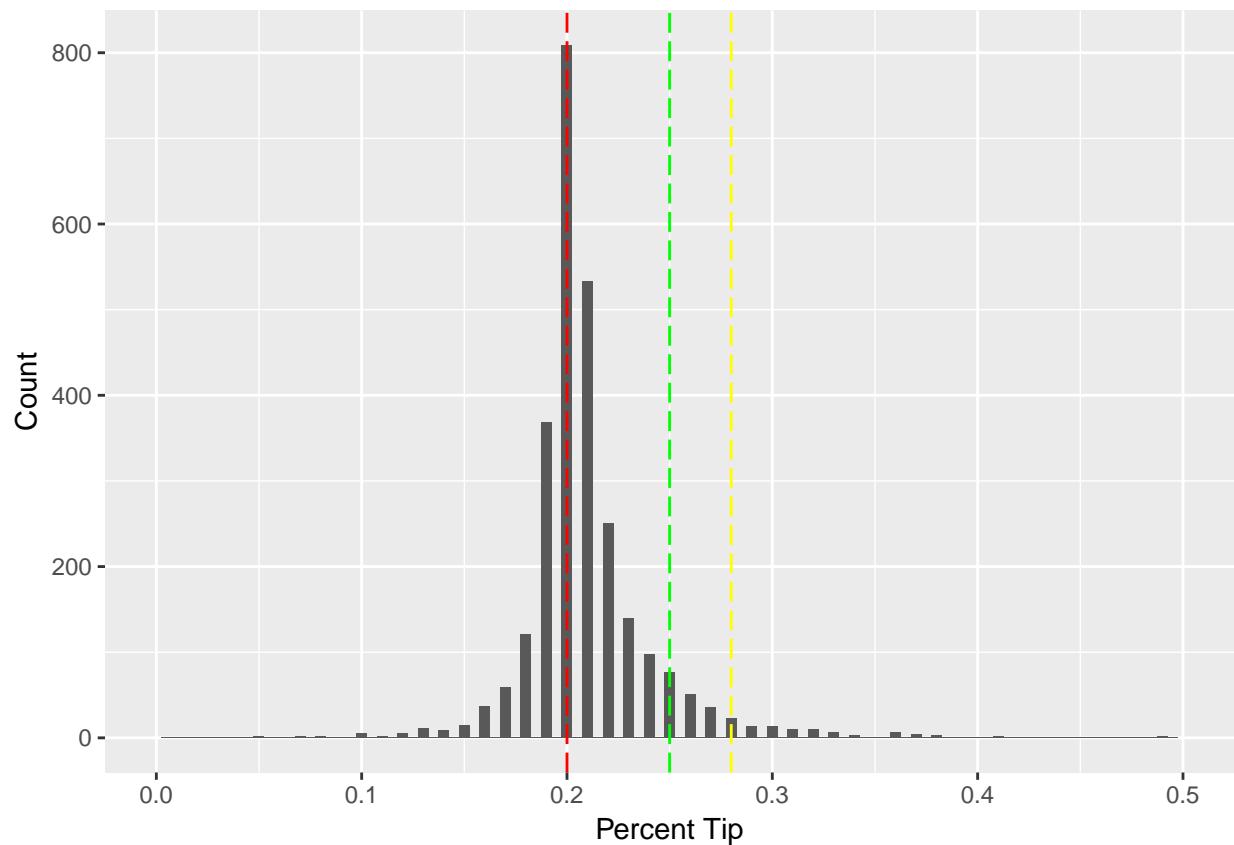
Taxi drivers are required to be indifferent to where passengers are going. Therefore, it makes sense to investigate the average amount of tips paid for each pick-up zone. What are the taxi pick-up zones that have the highest tip percents?

We first calculate the average percent tip paid for each pick-up zone. Table @ref(tab:tip_pickup_1) is a list of pick-up zones with their average percent tip.

We created a histogram to visualize the distribution of average percent tips paid for all

Table 3.1: Ten taxi pick-up zones with the highest average tip in January, 2017

avg_tip	num_trips	avg_dis	avg_duration	Borough	Zone
0.29	11	7.37	15.74	Queens	Douglaston
0.29	25	7.05	20.78	Bronx	East Tremont
0.29	12	10.40	17.87	Queens	Oakland Gardens
0.28	19	7.97	22.29	Queens	Glendale
0.28	33	8.33	25.23	Queens	Saint Michaels Cemetery/Woodside
0.27	34	7.60	19.70	Queens	Bayside
0.27	56	9.56	24.35	Brooklyn	Coney Island
0.27	29	10.63	25.94	Queens	Howard Beach
0.27	20	11.20	23.28	Brooklyn	Marine Park/Mill Basin
0.26	21	6.22	18.80	Bronx	Norwood



pick-up zones.

As shown in Figure ??, the first peak is around 20%, which is the cheapest default option on the touch panel for passengers to choose.

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.

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.211325482	3.733048e-04	566.09360	0
avg_dis	-0.001052903	2.105014e-05	-50.01881	0

According to the simple linear regression result, trip distance does have a negative significant impact on the percent of tips paid, controlling for both pick-up and drop-off locations. This could be caused by a psychological reason. Long trips cost more than short trips. For a constant tip percent, the absolute value of tip amount cost more for longer trips. For example, for a \$100 trip, 20% tip costs \$20; for a \$50 trip, 20% tip costs \$10. Even though consumers are paying the same percent amount of tips, \$20 is more expensive than \$10. Therefore, consumers might decide to pay less percent tip for longer trips.

3.1.2 Which taxi zones have the highest number of pick-ups?

Let's fist take a look at which pick-up zones have the highest number of pick-ups.

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

We can create a heat map to visulizae the number of trip for each pick-up zones on a map of New York City Taxi Zones.

Table 3.2: Ten taxi zones with the highest number of pick-ups

avg_tip	num_trips	avg_dis	avg_duration	Borough	Zone
0.20	2519900	9.21	33.32	Manhattan	Upper East Side South
0.21	2461602	10.04	34.48	Manhattan	Midtown Center
0.20	2382970	9.63	33.22	Manhattan	Union Sq
0.20	2372509	9.21	31.94	Manhattan	Upper East Side North
0.21	2349386	9.70	32.83	Manhattan	Midtown East
0.21	2231723	9.66	31.90	Manhattan	Murray Hill
0.21	2193036	9.99	36.77	Manhattan	Penn Station/Madison Sq West
0.20	2097416	9.48	30.39	Manhattan	East Village
0.21	2059444	11.90	36.10	Queens	LaGuardia Airport
0.20	1972303	10.32	35.97	Manhattan	Times Sq/Theatre District

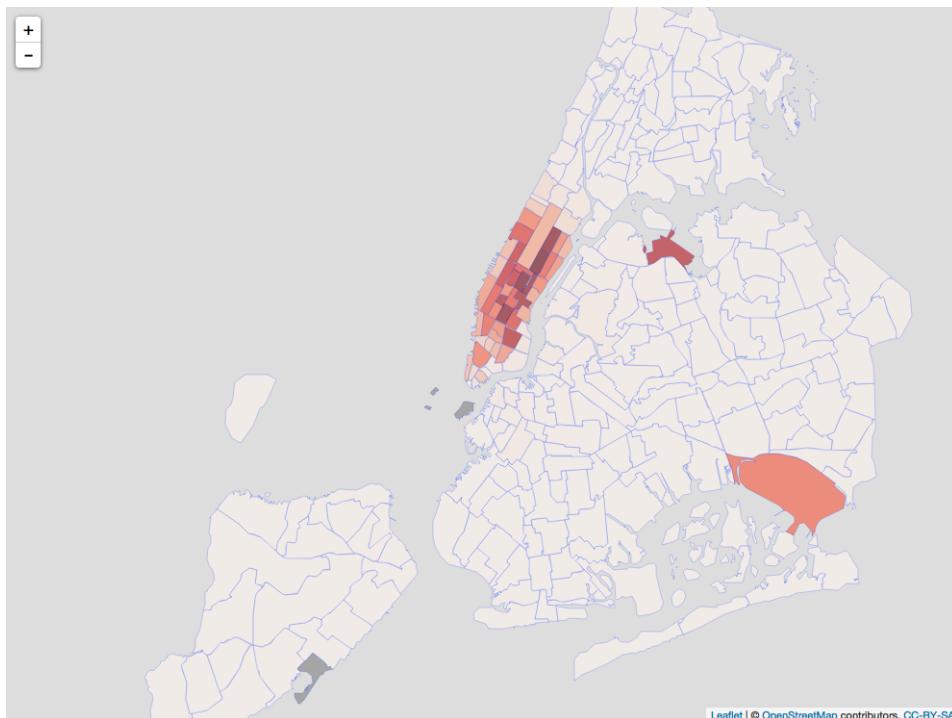


Figure 3.1: Number of Pick-ups in Each Taxi Zone

According to Figure 3.1, It's obvious that Upper East Side Manhattan, Midtown Manhattan, and La Guardia Airport are the most popular location for pick-ups. Table @ref(tab:tip_pickup_zone) gives you a better idea of which taxi zones have the highest number of pick-ups.

Table 3.3: Ten taxi pick-up zones with the highest percent tip (taxi zones has at least 30 pick-up per day)

avg_tip	num_trips	avg_dis	avg_duration	Borough	Zone
0.22	13329	14.27	42.94	Queens	Baisley Park
0.21	2461602	10.04	34.48	Manhattan	Midtown Center
0.21	2349386	9.70	32.83	Manhattan	Midtown East
0.21	2231723	9.66	31.90	Manhattan	Murray Hill
0.21	2193036	9.99	36.77	Manhattan	Penn Station/Madison Sq West
0.21	2059444	11.90	36.10	Queens	LaGuardia Airport
0.21	704925	10.22	32.82	Manhattan	Battery Park City
0.21	363915	10.02	33.07	Manhattan	World Trade Center
0.21	268535	10.26	33.44	Manhattan	Financial District South
0.21	72911	7.33	26.85	Brooklyn	Brooklyn Heights

3.1.3 Which taxi zones have the highest percent tips?

Most yellow cab pick-ups occur in Manhattan. If we focus on the pick-up zones that have at least 30 trips per day or 10950 per year, we will observe that many taxi pick-up zones with highest percent tips are not necessarily the ones with the highest number of pick-ups.

```
#pick a threshold for the cutoff number of trips
pickup_zone_30 <- tip_pickup_zone %>%
  filter(num_trips >= (30*365)) %>%
  arrange(desc(avg_tip))
```

People might think it is more reasonable to see a list that is populated with Zones in Manhattan, since that's where all the wealthy people live. However, Table @ref(tab:pickup_zone_30) shows that passengers who get on taxis from certain zones in Brooklyn and Queens also pay a lot of tips. Taxi drivers who would love to get more tips compensation can drive to the zones listed above to pick-up passengers.

If we focus on the pick-up zones that have more than 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.

```
pickup_zone_3000 <- tip_pickup_zone %>%
  filter(num_trips >= (365*3000)) %>%
  arrange(desc(avg_tip))
```

avg_tip	num_trips	avg_dis	avg_duration	Borough	Zone
0.21	2461602	10.04	34.48	Manhattan	Midtown Center
0.21	2349386	9.70	32.83	Manhattan	Midtown East
0.21	2231723	9.66	31.90	Manhattan	Murray Hill
0.21	2193036	9.99	36.77	Manhattan	Penn Station/Madison Sq West
0.21	2059444	11.90	36.10	Queens	LaGuardia Airport
0.20	2519900	9.21	33.32	Manhattan	Upper East Side South
0.20	2382970	9.63	33.22	Manhattan	Union Sq
0.20	2372509	9.21	31.94	Manhattan	Upper East Side North
0.20	2097416	9.48	30.39	Manhattan	East Village
0.20	1972303	10.32	35.97	Manhattan	Times Sq/Theatre District

There are more than 100 times more yellow cab pick-ups that happen in Manhattan

everyday than in Brooklyn. By comparing the average tip percent in Table @ref(tab:pickup_zone_30) and Table @ref(tab:pickup_zone_3000), we can observe that percent tips paid in taxi zones with low pick-up numbers seem to be higher than percent tips paid in taxi zones with high pick-up numbers.

3.2 What features of taxi trips are attractive to taxi drivers?

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.

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

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 high percent tips help customers to attract more 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 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. However, conflicting to what I assumed, Table @ref(tab:pickup_zone_30) and Table @ref(tab:pickup_zone_3000) show that percent tips seem to have a inverse relationship with number of pick-ups.

Let's test the relationship between number of trips and average percent tips in each pick-up zone:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	61203.5	6818.591	8.975975	5.106658e-19
avg_tip	-166807.7	27124.605	-6.149682	8.900927e-10

Each one percent increase in average tips in pick-up zones is associated with a significant decline in the number of trips per month. Therefore, increase in average percent tips in pick-up zones does not make pick-up zones more attractive. Taxi drivers are not attracted to taxi zones with high percent tips. This is why we observe high percent tips in Baisley Park, Queens in Table @ref(tab:pickup_zone_30).

3.2.2 Do passengers pay more tips during rush hours?

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-traffic 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-traffic. 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 increase the minute per mile 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.(Reaney, 2009) Does minute per mile 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?

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.193453599	1.870711e-04	1034.1180	0
min_per_mile	0.002841351	3.134322e-05	90.6528	0

As shown in the regression result, fare per minute ratio has a significant positive impact on percent tip. `min_per_mile` ratio does have an positive impact on percent tips. Since trips with slow traffic can be depicted by high minute per mile ratio, passengers do pay more tips during rush hours.

Chapter 4

New York City Taxi Passengers

4.1 How long does it take to get to JFK, La Guardia, and Newark Airports? When is the best time to depart?

We want to calculate the average number of minutes it takes to go to all three airport from a specific taxi zone at every hour. First, we want to focus on trips going to any of the three airports, JFK, LaGuardia, or Newark Airport. We need to load trip records with destination as one of the three airports from the MySQL connection we built.

```
to_jfk_trip <- taxi %>%  
 tbl("yellow") %>%  
  filter(DOLocationID == 132) %>%  
  collect(n = Inf)  
  
to_lg_trip <- taxi %>%
```

Table 4.1: Average number of minutes it takes from Alphabet City, Manhattan to JFK Airport during different hours

	PULocationID	hour	avg_min	airport
10	4	0	45.37000	JFK
11	4	1	36.77500	JFK
12	4	2	28.66000	JFK
13	4	3	27.83350	JFK
14	4	4	27.19490	JFK
15	4	5	28.68889	JFK
16	4	6	34.25271	JFK
17	4	7	38.13817	JFK
18	4	8	41.59687	JFK
19	4	9	35.39226	JFK
20	4	10	36.22867	JFK

```

tbl("yellow") %>%
  filter(DOLocationID == 138) %>%
  collect(n = Inf)

to_newark_trip <- taxi %>%
  tbl("yellow") %>%
  filter(DOLocationID == 1) %>%
  collect(n = Inf)

```

Now we want to calculate the average amount of time it take from each zone to one of the three airports during each hour.

So far, we have created three tables summarising the average number of minutes it takes to go to all three airports for every hour from different taxi zones.

It would be easier if we combine all three tables and put information related to trip duration to all three airports in the same table. Table @ref(tab:three_air) displays the average number of minutes it takes from Alphabet City, Manhattan to JFK Airport during different hours.

4.1.1 Case Study: From Alphabet City, Manhattan to all three airport

Alphabet City, Manhattan has pick-up zone ID number 4. Let's take a look at how much time is needed to travel to all three airports from taxi zone No.4.

```
alphabet <- three_air%>%
  filter(PULocationID ==4)
```

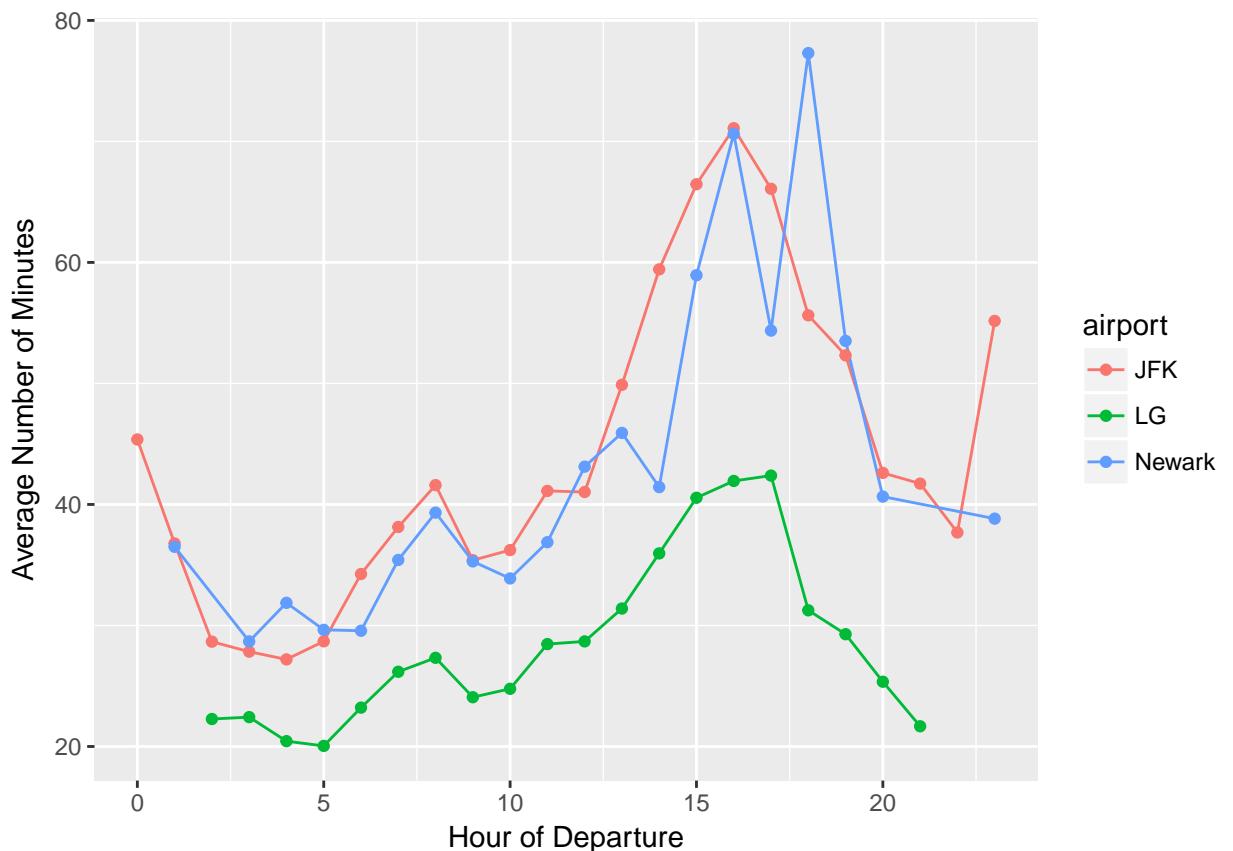


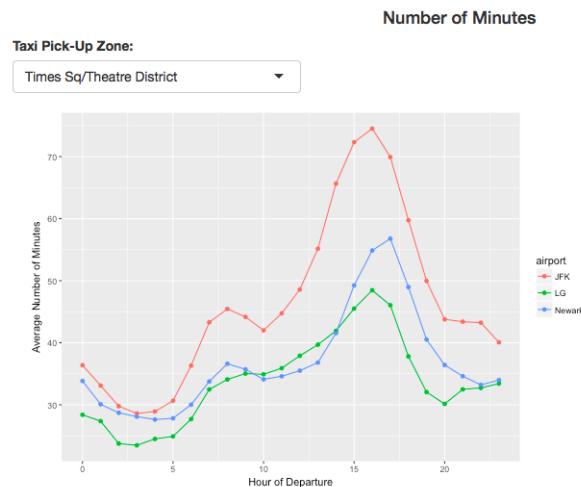
Figure 4.1: Average number of minutes it takes from Alphabet City, Manhattan to all three airports during different hours

According to the red line Figure 4.1, it takes the least time, less than 30 minutes, to travel from Alphabet City, Manhattan to JFK Airport around 4 AM in the morning, and it takes the most time, about 70 minutes, around 4 PM in the afternoon.

According to the green line, it takes the least time, about 20 minutes, to travel to JFK Airport around 5 AM in the morning, and it takes the most time, more than 40 minutes, around 5 PM in the afternoon.

As shown by the blue line, it takes the least time, a little less than 30 minutes, to travel to Newark Airport at 2 AM at midnight, and it takes the most time, a little less than 80 minutes, around 6 PM in the evening.

4.1.2 A Shiny App: allowing users to choose a pick up zone of their interest, and output the best time to travel from that zone to all three airports in New York



This Shiny App helps passengers to estimate the amount of time that is needed for them to travel to any one of the these three airports from any New York City taxi zones.

Table 4.2: Uber 2017 Weekly Total Dispatched Trips

Pickup Start Date	Pickup End Date	Total Dispatched Trips
01/01/2017	01/07/2017	2866569
01/08/2017	01/14/2017	3114792
01/15/2017	01/21/2017	3089595
01/22/2017	01/28/2017	3299763
01/29/2017	02/04/2017	3224451
02/05/2017	02/11/2017	3310481
02/12/2017	02/18/2017	3456042
02/19/2017	02/25/2017	3194805
02/26/2017	03/04/2017	3533347
03/05/2017	03/11/2017	3614559

4.2 How does weather affect the number of taxi and Lyft trips?

On a snowy or rainy day, it is hard for passengers to find a yellow cab on the street. Taxi drivers get paid at the same rate no matter how bad the weather gets, so they tend to stay at home instead of going out to work when the weather is bad. Uber drivers, however, get paid more on a snowy or rainy day, since Uber uses a pricing model that takes the number of Uber vehicles available on the street into account. When weather is bad, less Uber vehicles are available on the street, so Uber fare rate increases. Uber's pricing model gives Uber drivers an incentive to keep working on ugly days. Lyft has a similar pricing model to the one that Uber uses.

In this section, we want to study the number of pickups of yellow cab, Uber, and Lyft. We compare number of pick-ups in each taxi zone in the weeks of bad weather with previous weeks' total number of pick-ups to see whether Uber drivers have an incentive to drive around the city more when weather gets bad.

Uber Weekly Data **Yellow Cab Weekly Data** In this section, we use New York City Yellow Taxi and Uber data to calculate the number of trips occurred in each

Table 4.3: Yellow Taxi 2017 Weekly Total Dispatched Trips

Pickup Start Date	Total Dispatched Trips
2017-01-01	2044643
2017-01-08	2230950
2017-01-15	2219214
2017-01-22	2307122
2017-01-29	2331749
2017-02-05	2181622
2017-02-12	2387399
2017-02-19	2225850
2017-02-26	2464800
2017-03-05	2456285

week.

4.2.1 Case Study: March 14th, 2017 Snow Storm

There are two commonly known bad weather conditions, rainy and snowy day. Let's first focus on snowstorm. I downloaded daily Central Park weather data from the National Climatic Data Center, and joined it to the taxi data to see if we could learn anything else about the relationship between weather and taxi rides.

On March 14th, 2017, a snow storm brought seven inches of snow to New York City.

Yellow Taxi

Pickup Start Date Total Dispatched Trips

1	2017-03-05	2456285
2	2017-03-12	2066285

(2066285 - 2456285) / 2456285

[1] -0.1587764

Uber

A tibble: 2 x 3

```
# Groups:  Pickup Start Date [2]
`Pickup Start Date` `Pickup End Date` `Total Dispatched Trips`
<chr>           <chr>           <int>
1      03/05/2017    03/11/2017     3614559
2      03/12/2017    03/18/2017     3430189
(3430189 - 3614559) / 3614559
```

```
[1] -0.05100761
```

In this case, we observe that the percent decline in Uber's total number of pick-ups is 10% less than the percent decline in Yellow Taxi's total number of drop-off. Even though the total number of Uber pick-ups did not increase, Uber's pricing model definitely was able to keep more drivers in the market on a snowy day.

More analysis is needed here

Chapter 5

New York City Taxi Fare & Limousine Commission

5.1 Should there be a flat rate between Manhattan and John F. Kennedy International Airport?

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 congestion on the road to JFK airport and make taking a train a more preferable choice? The New York City taxi trip records can reveal the answers to these questions.

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.

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

If there is no flat rate between JFK and Manhattan, how much would passengers pay for the distance they travelled between JFK Airport AND Manhattan? And how much more or less should they have paid comparing to the \$52 flat rate?

In this study, we are only interested in yellow taxi trip between Manhattan and JFK Airport.

```
to_jkf <- taxi %>%
 tbl("yellow") %>%
  filter(DOLocationID == 132) %>%
  collect(n = Inf)

from_jfk <- taxi %>%
 tbl("yellow") %>%
  filter(PULocationID == 132) %>%
  collect(n = Inf)
```

Read 54.1% of 998023 rows

Read 69.1% of 998023 rows

```
Read 99.2% of 998023 rows
```

```
Read 998023 rows and 17 (of 17) columns from 0.083 GB file in 00:00:05
```

```
Read 3.7% of 2726868 rows
```

```
Read 18.3% of 2726868 rows
```

```
Read 40.0% of 2726868 rows
```

```
Read 60.5% of 2726868 rows
```

```
Read 80.3% of 2726868 rows
```

```
Read 84.0% of 2726868 rows
```

```
Read 92.0% of 2726868 rows
```

```
Read 2726868 rows and 17 (of 17) columns from 0.227 GB file in 00:00:12
```

```
Warning in as.POSIXlt.POSIXct(x, tz): unknown timezone 'zone/tz/2018c.1.0/zoneinfo/America/New_York'
```

```
Warning in as.POSIXlt.POSIXct(x): unknown timezone 'zone/tz/2018c.1.0/zoneinfo/America/New_York'
```

```
Warning in as.POSIXlt.POSIXct(x, tz = tz(x)): unknown timezone 'zone/tz/2018c.1.0/zoneinfo/America/New_York'
```

```
Warning in as.POSIXlt.POSIXct(x): unknown timezone 'zone/tz/2018c.1.0/zoneinfo/America/New_York'
```

```
Warning in as.POSIXlt.POSIXct(x, tz = tz(x)): unknown timezone 'zone/tz/2018c.1.0/zoneinfo/America/New_York'
```

Trips from Manhattan to JFK Airport

We first focus on all the trips that departed in Manhattan and went to JFK Airport, and then we calculate the estimated fare amount that the passengers should have paid

based on the distance travelled from each pick-up point to JFK Airport based on the fare rate suggested by TLC for each pick-up zone.

Here is a map of estimated fare amount calculated by taking the average of all estimated fare amounts from the same pick-up zone to JFK Airport based on the fare rate suggested by TLC for each pick-up zone.

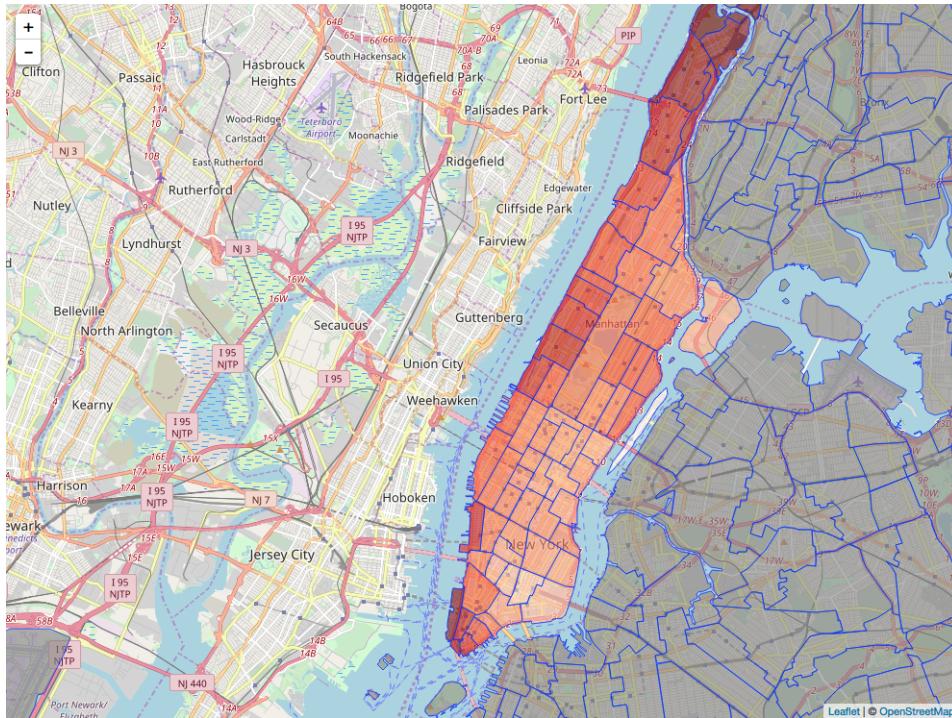


Figure 5.1: Estimated fare amount from each pick-up zone to JFK Airport

According to the map, trips from Midtown on average cost less than trips from other taxi zones in Manhattan.

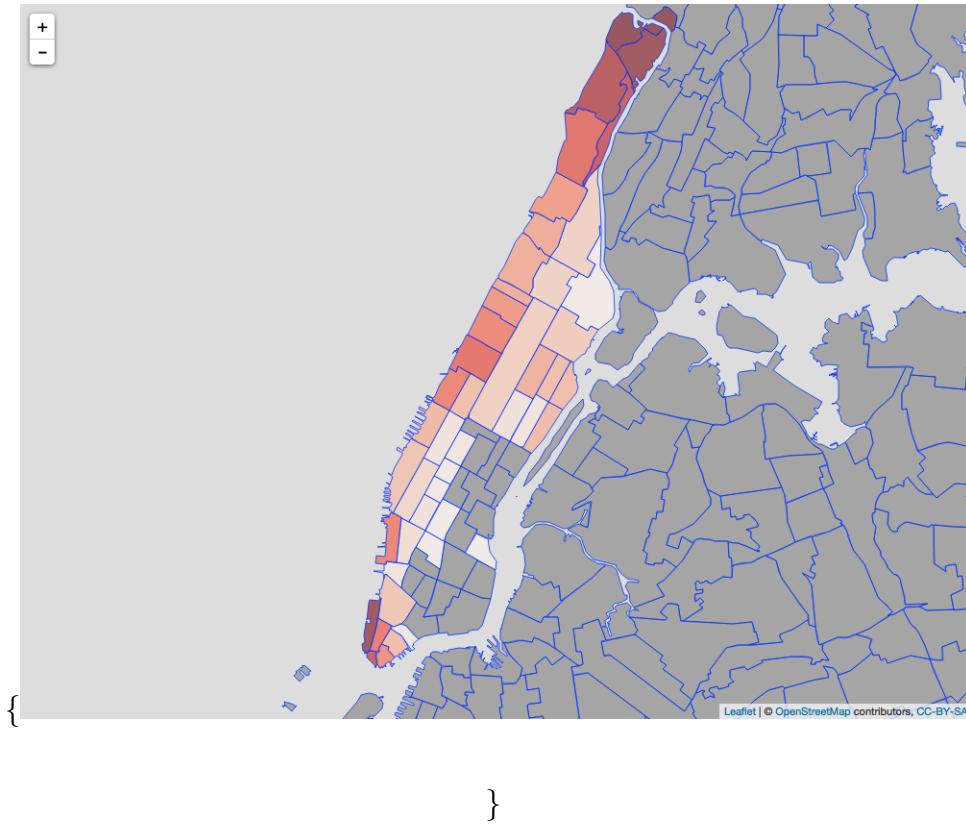
5.1.2 Taxi zones pays on average more than \$52

Let's visualize the taxi zones that would have costed more than the \$52 flat rate.

\begin{figure}

Table 5.1: Ten pick-up zones with the highest average fare from Manhattan to JFK Airport

LocationID	num_trips	avg_est_fare	avg_est_diff	Borough	Zone
105	3	66.38167	14.381667	Manhattan	Governor's Island/Ellis Isl
128	3	64.53667	12.536667	Manhattan	Inwood Hill Park
153	1	64.51000	12.510000	Manhattan	Marble Hill
13	10327	64.03150	11.844558	Manhattan	Battery Park City
127	41	63.98256	9.970366	Manhattan	Inwood
243	127	62.97567	10.892992	Manhattan	Washington Heights North
12	275	61.99327	9.889636	Manhattan	Battery Park
120	8	61.45063	8.700625	Manhattan	Highbridge Park
244	542	60.49388	8.278941	Manhattan	Washington Heights South
239	12601	60.18006	8.107309	Manhattan	Upper West Side South



\caption{Zones that cost more than the \\$52 flat rate} \end{figure}

Therefore, passengers from places in Manhattan besides Midtown, East Village, and some parts of Lower Manhattan benefit from the \\$52 flat rate. However, people living in Midtown, East Village, and some parts of Lower Manhattan might be relatively

more indifferent to the price of taxi. Instead, they probably put more emphasis on convenience and time.

```
mean(to_jkf_zone$avg_est_diff)
```

```
[1] 2.825257
```

On average people travel from Manhattan pay \$2.14 less with the \$52 flat rate policy. Therefore, passengers overall benefit from the \$52 flat rate policy.

5.2 However, are taxi drivers happy when their passengers are going to JFK Airport from Manhattan?

Everytime I travel to New York City, I always take Yellow cabs to go around the city. It seemed to me that the cab drivers were always happy whenever they heard me telling them that I need to go to the JFK Airport from Manhattan. Are taxi drivers happy when their passengers are going to JFK Airport from Manhattan? How much on average would taxi driver make on their way bavk to the city from Manhattan?

```
from_jfk <- from_jfk %>%
  mutate(est_fare = 2.5 + 0.5 * trip_distance * 5 + extra + improvement_surcharge + mta_
  mutate(est_diff = est_fare - fare_amount) %>%
  rename(LocationID = DOLocationID) %>%
  left_join(taxi_zone_lookup , by = "LocationID")
```

Since a taxi driver coming from Manhattan to JFK Airport could be directed back to anywhere in the city. We can calculate the average taxi fare amount that the taxi drivers would get paid for a random trip from JFK Airport to any part of the city.

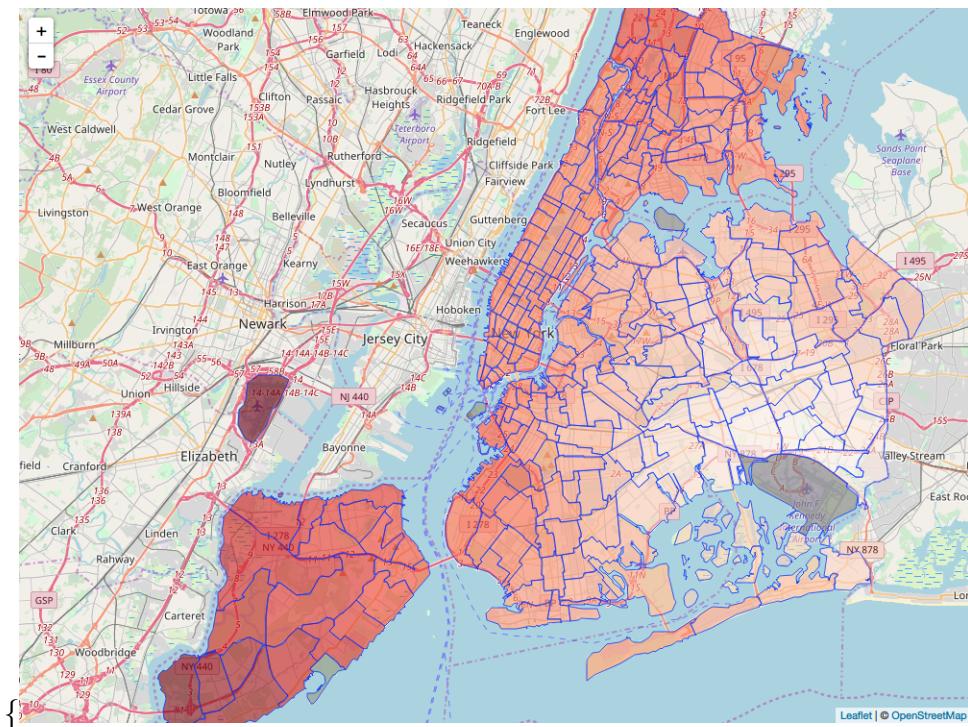
```
mean(from_jfk$est_fare)
```

```
[1] 50.1774
```

On average, taxi drivers would get paid for \$50.18 for a trip from the JFK Airport to any taxi zone in New York City. What are the most popular drop-off zones for yellow taxis from JFK Airport? Table @ref(tab:from_jkf_zone) shows that Times Square is the most popular destination for passengers coming from the JFK Airport in 2017!

What's the average fare to each drop-off zone from JFK Airport?

\begin{figure}



}

\caption{Zones that cost more than the \$52 flat rate} \end{figure}

As we expected, the red shades are smoothly distributed, since taxi zones that are further away should cost more to get there.

By comparing the distribution of the true average fare and estimated average fare

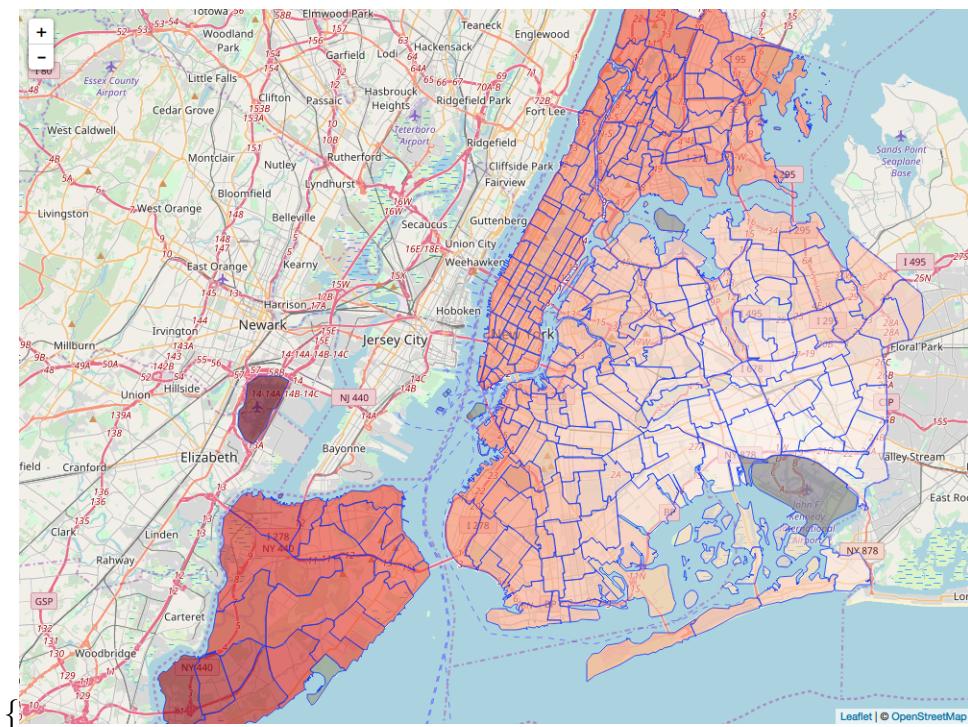
Table 5.2: Ten most popular destinations in Manhattan

avg_fare	avg_est_fare	avg_est_diff	Borough	Zone
52.04228	55.66633	3.6240464	Manhattan	Times Sq/Theatre District
52.02081	53.52208	1.5012669	Manhattan	Midtown East
52.02929	52.63605	0.6067620	Manhattan	Murray Hill
52.03004	53.80791	1.7778762	Manhattan	Midtown South
52.02521	54.58522	2.5600104	Manhattan	Midtown Center
52.05343	55.98649	3.9330603	Manhattan	Clinton East
52.03455	54.83727	2.8027265	Manhattan	Midtown North
50.00658	44.76501	-5.2415700	Brooklyn	Park Slope
52.02256	53.21899	1.1964270	Manhattan	East Village
52.03064	61.17181	9.1411702	Manhattan	Upper West Side South
52.01959	54.14923	2.1296414	Manhattan	Gramercy
52.01070	57.84099	5.8302851	Manhattan	Lincoln Square East
47.63555	44.90296	-2.7325867	Brooklyn	Williamsburg (North Side)
52.03112	56.25001	4.2188859	Manhattan	East Chelsea
52.03906	60.29511	8.2560483	Manhattan	Upper West Side North
52.02476	52.97979	0.9550299	Manhattan	UN/Turtle Bay South
51.99849	57.81879	5.8203015	Manhattan	Upper East Side North
51.99713	54.47645	2.4793268	Manhattan	Lenox Hill West
52.00822	57.15378	5.1455658	Manhattan	Yorkville West
52.02406	54.81988	2.7958225	Manhattan	Union Sq
52.07553	56.69429	4.6187540	Manhattan	TriBeCa/Civic Center
52.01202	52.43096	0.4189478	Manhattan	Sutton Place/Turtle Bay North
52.05171	54.83581	2.7840969	Manhattan	Penn Station/Madison Sq West
52.06783	58.98586	6.9180264	Manhattan	Financial District North
52.03343	55.09034	3.0569088	Manhattan	Upper East Side South
52.03268	57.17143	5.1387500	Manhattan	Yorkville East
52.03140	55.81486	3.7834609	Manhattan	Flatiron
46.04130	43.71681	-2.3244880	Brooklyn	Greenpoint
33.85242	33.24060	-0.6118174	Queens	LaGuardia Airport
36.97857	33.03031	-3.9482525	Brooklyn	Crown Heights North
52.06251	51.01663	-1.0458781	Manhattan	Lower East Side
52.02719	55.27376	3.2465709	Manhattan	Greenwich Village North
52.04350	55.88538	3.8418807	Manhattan	West Village
52.03693	54.29060	2.2536722	Manhattan	Garment District
52.01163	56.00767	3.9960410	Manhattan	Lenox Hill East
46.25439	43.92609	-2.3282967	Queens	Long Island City/Hunters Point
41.90473	40.38467	-1.5200572	Queens	Astoria
43.36798	39.15502	-4.2129655	Brooklyn	Clinton Hill
52.07690	64.38598	12.3090860	Manhattan	Battery Park City
54.41380	50.55337	-3.8604301	Brooklyn	Brooklyn Heights
45.65715	43.06496	-2.5921825	Brooklyn	East Williamsburg
52.05255	51.83931	-0.2132436	Manhattan	Little Italy/NoLiTa
48.20942	45.35472	-2.8546965	Brooklyn	Williamsburg (South Side)
25.38152	24.34936	-1.0321571	Queens	Forest Hills
50.59733	45.43951	-5.1578123	Brooklyn	Boerum Hill

calculated by distance travelled,

***** add sentences *****

\begin{figure}

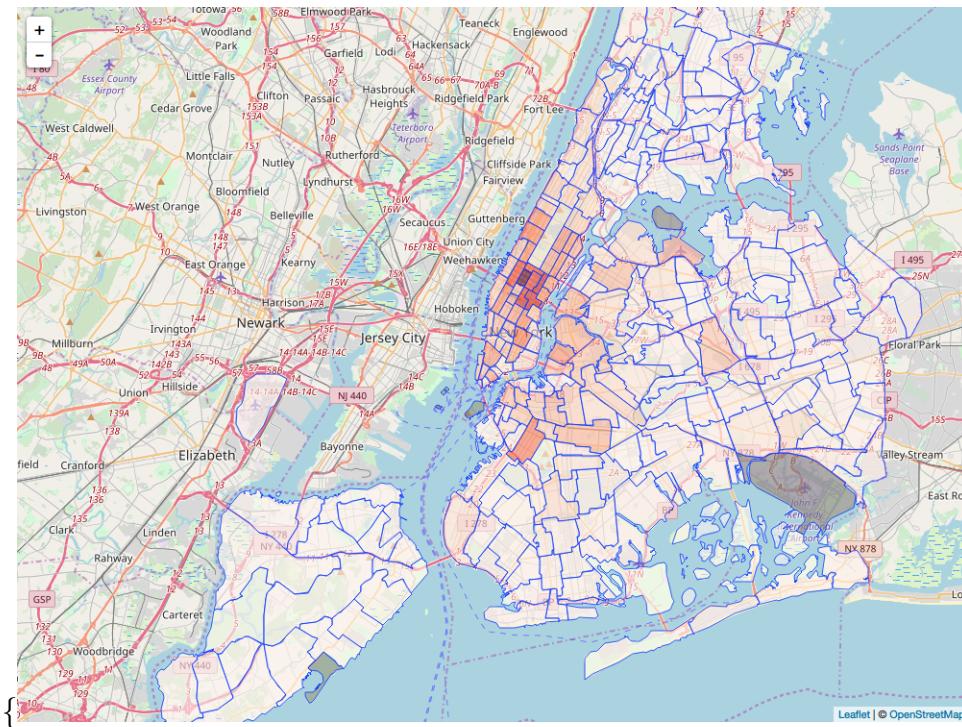


}

\caption{Zones that cost more than the \\$52 flat rate} \end{figure}

What's the most popular drop-off locations for passengers from JFK Airport?

\begin{figure}



}

\caption{Zones that cost more than the \\$52 flat rate} \end{figure}

According to the map above, Manhattan is still the most popular destination for passengers departing from the JFK Airport.

```
# A tibble: 2 x 2
```

```
Manhattan all_trips
```

```
<dbl> <int>
```

1	0	521476
2	1	970366

```
from_jkf_zone[2,2] / (from_jkf_zone[1,2] + from_jkf_zone[2,2])
```

```
num_trips
```

```
1 0.4054057
```

According to the summary, the total amount of trips from JFK Airport to Manhattan

is about 65.05% of the total number of trips travelling from JFK Airport to all other Borough. Therefore, it is very likely for taxi drivers to get passengers who want to go to Manhattan with a flat rate of \$52. In this case, a round trip to and from JFK Airport is worthy. Therefore, taxi drivers should be pretty happy when their passengers are going to JFK Airport from Manhattan.

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

Appendix A

A.1 utility function

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

etl_extract.etl_nyctaxi() function.

```
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  
}
```


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