

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

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Wencong (Priscilla) Li

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Benjamin Baumer

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Table of Contents

Chapter 1: Introduction	1
1.1 Background	2
1.1.1 Yellow Taxi	2
1.1.2 Green Taxi	3
1.1.3 Uber	3
1.1.4 Lyft	4
1.2 Literature Review	4
1.2.1 New York City Traffic and Taxi	4
1.2.2 Competition between New York City taxi and e-hail services	5
1.2.3 <code>etl</code> R package	6
1.3 Contribution	7
1.3.1 ‘nyctaxi’ Package	7
1.3.2 Reproducible Research	8
1.3.3 Recommendations for taxi drivers, passengers, and TLC officials	9
Chapter 2: Data and <code>nyctaxi</code> Package	11
2.1 Data and Storage	11
2.1.1 Yellow Taxi	11
2.1.2 Green Taxi	12
2.1.3 TLC Summary Report	12

2.1.4	Uber	14
2.1.5	Lyft	14
2.1.6	Data Storage	15
2.2	<code>ettl</code> and <code>nyctaxi</code> Packages	15
2.2.1	Taxi zone shapefile attached to <code>nyctaxi</code> R package	18
2.3	Extract-Transform-Load	19
2.3.1	Extract	19
2.3.2	Transform	21
2.3.3	Load	23
2.3.4	SQL Database Initialization	23
2.4	New York City Taxicab and E-hail Services Summary	25
2.5	Source Code	26
2.5.1	ETL Extract	26
2.5.2	ETL Transform	31
2.5.3	ETL Load	38
2.5.4	ETL Init	43
Chapter 3:	New York City Taxi Drivers	49
3.1	Aggregated Zone-level Tip Amount	50
3.1.1	Pick-up Zone Percent Tips Amount	52
3.1.2	Which taxi zones are the most popular ones for pick-ups? . . .	53
3.1.3	Which pick-up zones have the highest percent tips?	54
3.2	What features of taxi trips increase the percent tip amount that passengers pay?	56
3.2.1	Does trip distance increase the percent tips paid by passengers? .	57
3.2.2	Do passengers pay more tips during rush hours?	57
3.3	Recommendations to Taxi Drivers	59

Chapter 4: New York City Taxi Passengers	61
4.1 How long does it take passengers to get to JFK, La Guardia, and Newark Airports from anywhere in New York City?	61
4.1.1 Case Study: From Central Park, Manhattan to all three airports	62
4.1.2 A Shiny App: When is the best time to travel to JFK Airport?	65
4.2 How does weather affect the number of taxi and Uber trips?	66
4.2.1 Case Study: March 14th, 2017 Snow Storm	67
4.2.2 Case Study: Impact of Precipitation on Taxi Rides	68
4.3 Recommendations to Taxi Passengers	72
Chapter 5: New York City Taxi & Limousine Commission	73
5.1 Should there be a flat rate between Manhattan and John F. Kennedy International Airport?	73
5.2 Passengers departing from Manhattan benefit from the \$52 flat rate .	74
5.2.1 Trips from Manhattan to JFK Airport	75
5.2.2 Which taxi zones would pay more than \$52 without the flat rate?	76
5.3 Are taxi drivers happy when a passenger wants to go to JFK Airport from Manhattan?	78
5.3.1 How much on average would taxi driver make on their way back from JFK Airport?	78
5.4 Recommendations to New York City Taxi Fare & Limousine Commission	82
Chapter 6: Conclusion	85
6.1 Future Research	86
Appendix A: Utility Function	87
Appendix B: Data Dictionary – Yellow Taxi	89
Appendix C: Freedom of Information Law Request	91

Appendix D: NOAA Climate Data Request 93

References 97

List of Tables

3.1	Ten taxi pick-up zones with the highest average tip in January, 2017	53
3.2	Ten taxi zones with the highest number of pick-ups	55
3.3	Ten taxi pick-up zones with the highest percent tip (taxi zones has at least 1 pick-up per hour)	55
3.4	Ten taxi pick-up zones with the highest percent tip (taxi zones has at least 1 pick-up per minute)	56
4.1	Average number of minutes it takes from Alphabet City, Manhattan to JFK Airport during different hours	63
4.2	Uber 2017 Weekly Total Dispatched Trips	66
4.3	Yellow Taxi 2017 Weekly Total Dispatched Trips	67
4.4	Yellow Taxi Total Dispatched Trips	67
4.5	Uber Total Dispatched Trips	68
4.6	10 weeks that have the most rainfall in 2017	69
4.7	10 weeks that have the most rainfall in 2017 and the total number of dispatched yellow taxi trips in those weeks	69
4.8	10 weeks that have the most rainfall in 2017 and the total number of dispatched Uber trips in those weeks	70
4.9	The percentage change in total number of dispatched trips comparing to the previous weeks of yellow taxi and Uber	71

5.1	Ten pick-up zones with the highest average fare from Manhattan to JFK Airport	76
5.2	5 most popular destinations in Manhattan	79
5.3	Number of Trips going to Manhattan or other boroughs from JFK Airport	80
5.4	10 most popular taxi drop-off zones from JFK Airport with the corre- sponding average fare amount	80

List of Figures

1.1	NYC Monthly Taxi Pickups	5
2.1	NYC Taxi and Limousine Commission Aggregated Reports	13
2.2	‘nyctaxi’ package GitHub Repository	17
2.3	NYC Taxi Zone Map	19
2.4	MySQL View	24
2.5	Summary of Number of trips Made by 4 Types of Transportations between 2014 and 2016 in NYC	25
3.1	Percent Tip Paid by Passengers in Each Pick-up And Drop-off Pair in NYC	51
3.2	Tip Payment Page on New York City Touch Panel	52
3.3	Number of Pick-ups in Each Taxi Zone	54
4.1	Average number of minutes it takes from Central Park, Manhattan to all three airports during different hours	63
5.1	Estimated fare amount from the each pick-up zone to JFK Airport . .	75
5.2	Pick-up Zones that cost more than the 52 US Dollar flat rate	77
5.3	Number of trips from JFK Airport to any Taxi Zones	79
5.4	Zones that cost more than the 52 US Dollar flat rate	81
B.1	Data Dictionary – Yellow Taxi Trips Records	90

C.1	Freedom of Information Law Request	92
D.1	NOAA Climate Data Request	94
D.2	NOAA Climate Data Order Compeletion	95

Abstract

Yellow Taxi Cab is widely recognized as an important part of New York City. 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 everyday. Since New York City taxi data is too big to be used for data analysis in R, we need a tool that helps users to answer questions of NYC Street-Hail Services in R. This thesis presents an efficient and easy-to-use way to retrieve trip information of both taxi and other ride-sharing services, such as Uber and Lyft, in New York City. By analyzing trip records of New York City's yellow cab, we answer questions that are commonly asked by taxi drivers, passengers, and New York City Taxi & Limousine Commission (TLC) officials to help all three parties to improve their services or experiences.

Chapter 1

Introduction

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 publicly accessible yellow and green taxi trip records on their website for people to investigate 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 happening everyday in New York City (Whitford, 2017), resulting in large size of the datasets. The size of 2017 yellow taxi trip data CSV file is about 10 GB, and this dataset is too big to be processed in an **R** session. We call data that is too big to be loaded into R environment but not too big to be saved on a hard drive *medium data*.

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 New York City taxi and ride-sharing services is our motivation. In our

study, we focus on New York City taxicab data because there are a lot of interesting questions about New York City taxicabs that we 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. By using a tool that allows users to answer questions of NYC Street-Hail Services in R, we can provide solutions to satisfy their needs.

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.

1.1 Background

New York City has many public transportations, and the most commonly used ones are subway, bus, and taxi. Subways and buses cover a lot of regions in New York City, but they are not the most comfortable and convenient way to get around the city. New York City taxi is a faster and more comfortable of transportation, but it is much more expensive than subway and bus. Because of the high rate of fare of taxi and limited number of taxi vehicles available, consumer in New York City demand a cheaper option of rides. E-hail service companies, such as Uber and Lyft, started to be popular by offering cheaper ride options. After Uber and Lyft were introduced in New York City, taxi's popularity started to decline.

1.1.1 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 (N. T. Staff, 2018).

1.1.2 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 (N. T. Staff, 2009d).

1.1.3 Uber

Uber Technologies Inc. is an American technology company that operates transportation network platforms worldwide. Uber drivers use their own cars, instead of corporate-owned vehicles, to pick up passengers (U. Staff, 2009). Uber NYC was launched in May 2011. 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 transportations’ fares before making their decisions on which one to choose (“Uber Moves New York City,” 2015).

1.1.4 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 Moves New York City,” 2015).

1.2 Literature Review

1.2.1 New York City Traffic and Taxi

New York City is one of the most popular cities in the United States. New York City’s traffic is a popular topic in journalism, and different aspects of it has been studied by journalists. 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”, and the bad temper of drivers are exacerbated by New York City’s severe congestion (Reaney, 2009).

How bad is the cogestion? In “NYC is already tired of Christmas and Donald Trump”, New York City has been described as “the city that never moves” (Furfaro, Cohen, & Fears, 2016). What has led to the congestion in the city? According to “Uber and Lyft cars now outnumber yellow cabs in NYC 4 to 1”, “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.

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

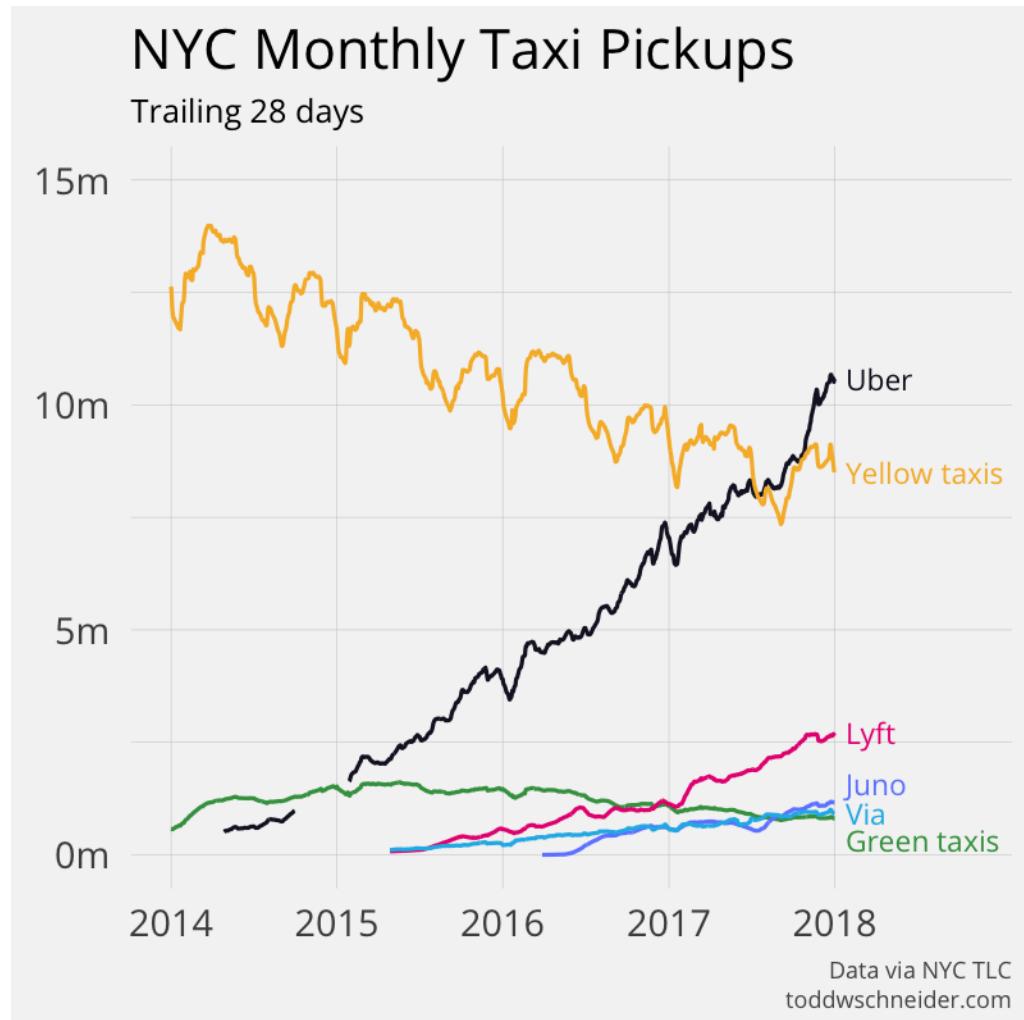


Figure 1.1: NYC Monthly Taxi Pickups

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 number 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 cabs 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).

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 (H. Staff, 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 (Vsevolod Salnikov, 2015).

Apps, such as Openstreetcab, that compare the price of Uber and taxi trips are designed to help customers to compare the fares of different transportations (Vsevolod Salnikov, 2015).

1.2.3 **etl** R package

Working with taxi trip data is not an easy task, because of the large size of the taxi trip datasets (Whitford, 2017). Loading these datasets into **R** environment takes a long time and might crush an **R** session. Taxi trip datasets are classified as medium data, because they are too big to be processed in an R session but not too big to be saved on a hard drive.

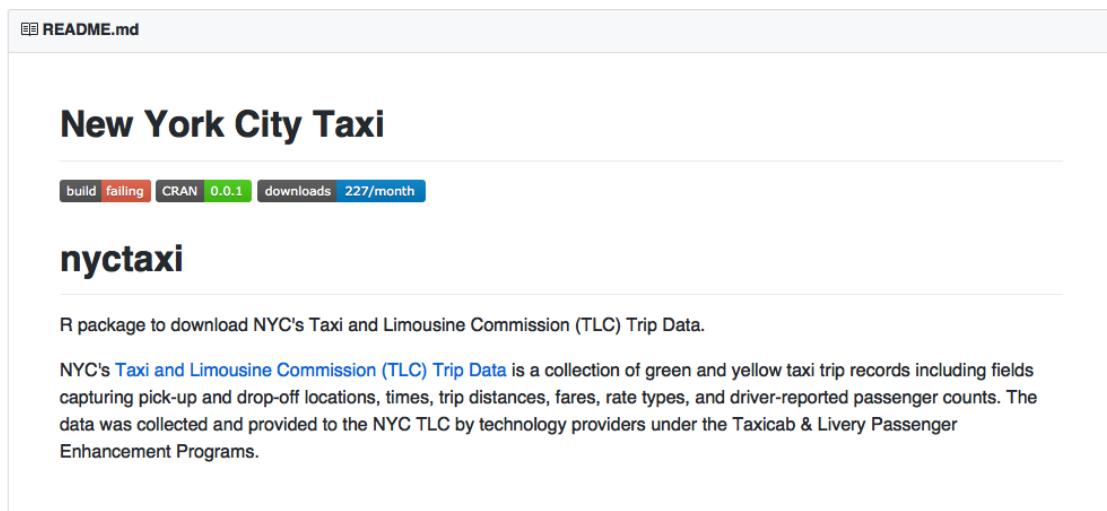
The **etl** **R** package creates a user-friendly platform that allows **R** users to easily work with medium data with the *extract, transform, load* framework, which is commonly known as ETL in computing. The ETL process has been set up (B. S. Baumer, 2017) in **R** to facilitate **etl** operations 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.

1.3 Contribution

This thesis has two main components: the `nyctaxi` **R** package, which helps users to analyze the New York City street-hail services' data in **R**, and recommendations for taxi drivers, passengers, and TLC officials. In addition to the two main parts, we focus on making all analysis and visualizations in this study reproducible.

1.3.1 ‘nyctaxi’ Package

`nyctaxi` is an **R** package that help users to easily get access to New York City Taxi, Uber and Lyft trip data(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**.



1.3.2 Reproducible Research

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).

Reproducible research and open source are two main points of emphasis in 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 (Xie, 2018) and Github are used in this project to make the study reproducible, ranging from the initial data source to the **nyctaxi** package to the statistical data analysis. We 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 documents. **thesisdown** helps users to efficiently put together any paper with similar format (Solomon, n.d.).

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 they 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.

1.3.3 Recommendations for taxi drivers, passengers, and TLC officials

In Chapters 3 to 5, we analyze what taxi drivers, passengers, and TLC officials want and we try to find ways for them to achieve their goals.

NYC Taxi drivers want to make the profit. Our analysis has suggested that taxi passengers are sympathetic with the drivers who have to suffer the congestion in New York City, and pay more tips during rush hours.

Taxi passengers want the cheapest and most convenient way of transportation. We created a Shiny App for passengers to choose a pick up zone of their interest and then decide when is the most favorable time for them to travel from that zone to any of the three airports in New York.

TLC wants to protect both taxi drivers and passengers, and it creates policies to make NYC taxi more accessible to consumers and taxi drivers enjoy their work. We suggest New York City TLC to modify the fare on rainy or snowy days to incentive taxicab drivers to pick up more trips in order to make taking a street hail vehicle on average more affordable on rainy days for passengers.

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 (N. T. Staff, 2009b). 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). (N. T. Staff, 2009b) 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. (N. T. Staff, 2009a)

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 (N. T. Staff, 2009c).

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. The main content area has a yellow header titled 'Aggregated Reports'. Under this, there's a section about monthly aggregated reports, local law reports, and other statistical findings. It includes links for 'Yellow Taxi Monthly Indicators' (CSV file format, Data Dictionary) and 'Street Hail Livery Monthly Indicators' (CSV file format, Data Dictionary). Below these are sections for 'FHV Base Aggregate Weekly Report' (Dataset on Open Data, Data Dictionary) and 'Local Law Reports' (Local Law 32, Local Law 28, Local Law 31, Local Law 07). On the right side, there's a 'Taxi News' box with a message about new rules and pilot programs for FHV bases. The footer contains social media links and a 'Contact/Visit TLC' link.

Figure 2.1: NYC Taxi and Limousine Commission Aggregated Reports

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_indicators_yellow.csv",
destfile = "~/Desktop/yellow_monthly_data.csv")
```

- Uber and Lyft data

```
download.file("http://data.cityofnewyork.us/api/views/2v9c-2k7f/rows.csv
?accessType=DOWNLOAD",
destfile = "~/Desktop/fhv_weekly_data.csv")
```

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 (FiveThirtyEight, 2015) who obtained the data from NYC TLC by submitting a Freedom of Information Law (FOIL) request on July 20, 2015, these data are now open to public.

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 (N. O. Staff, 2015b).

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 (N. O. Staff, 2015a).

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 8 GB of physical memory. 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. 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(Zhnag, 2017).

2.2 **ettl** and *nyctaxi* Packages

`ettl` is the parent package of *nyctaxi*. `ettl` 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**.

`ettl` 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. `ettl`-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`(B. S. Baumer, 2017)
- `dplyr` (Wickham, Francois, Henry, & Müller, 2017)
- `DBI` (R Special Interest Group on Databases (R-SIG-DB), Wickham, & Müller, 2018)
- `rlang` (Henry & Wickham, 2018)
- `lubridate` (Grolemund & Wickham, 2011)
- `leaflet` (Cheng, Karambelkar, & Xie, 2017)
- `stringr` (Wickham, 2018)

SQL database can store medium data and it takes less time to retrieve data from a SQL database than from a hard disk. 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**.

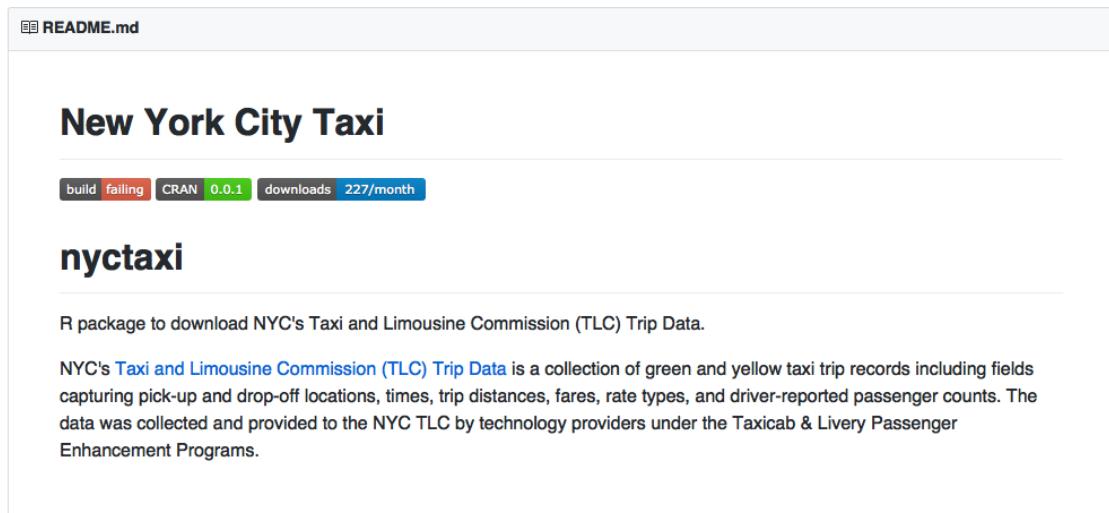


Figure 2.2: ‘nyctaxi’ package GitHub Repository

In general, `ettl_extract.ettl_nyctaxi()` function downloads data of the four types of hail service data (yellow taxi, green taxi, Uber, and Lyft) from the corresponding sources. `ettl_transform.ettl_nyctaxi()` uses different techniques to clean all four types of data to get them ready for the next step. `ettl_load.ettl_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 (C. Staff, n.d.). `nyctaxi` **R** package lives on CRAN, and it can be installed as follows:

```
install.packages("nyctaxi")
```

Users need to create an `ettl` 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 procession of initialization, two subfolders, `raw` and `load`, are also created under the directory the user specifies. The `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 (`taxi` 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 correspondinng to four street-hail services: `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 (N. T. Staff, 2009b). A shapefile containing the boundaries for the taxi zones, `taxi_zones`, is also included in the package for users to do spatial analysis. This shapefile is publicly accessible on NYC TLC's website (N.

T. Staff, 2009b).

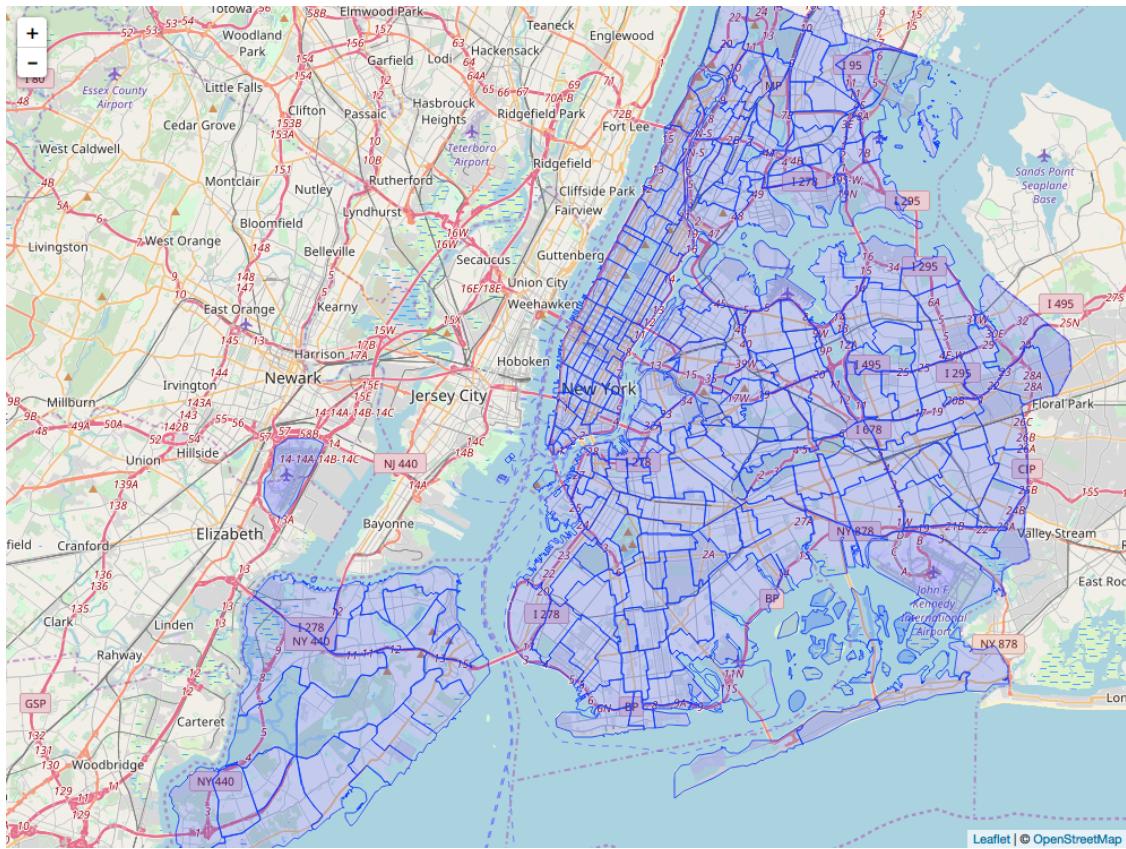


Figure 2.3: NYC Taxi Zone Map

Visualizations similar to Figure 2.3 can be generated with the shapefile.

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 download either all data from April to Sepetember, 2014 or all Uber trip records from Janaury to June, 2015 at once. We do not give users the option to download Uber data by month, since the total size of all trip-level data from 2014 and 2015 are small.

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

Lyft data is updated on NYC Open Data website on a weekly basis. Since the weekly-aggregated data is tiny and only data later than 2014 is available, we decided to only allow users to download Lyft data by year. We do not give users the option to download Lyft data by month, since trip records are weekly-aggregated.

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

The default `years` is the current year, and the default `months` are 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.

An utility function, `download_nyc_data()`, was written to be used in `etl_extract.etl_nyctaxi()` to make this function more concise (Appendix A).

2.3.2 Transform

`etl_transform.etl_nyctaxi()` allows users to transform the data into cleaned formats, and it utilizes 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 data from certain months. This functionality helps people to be more efficient with their use of time by only transforming months of data that are needed in later steps.

By default, it takes the current year yellow taxi trip records data files, and saves 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", "lyft"))
```

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 `cut`

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", "lyft"))
```

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 July 2016, and `yellow` is created for data later than June 2016. There are two tables created for yellow taxi data because NYC TLC changed the variables included in yellow taxi datasets in 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 types 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.

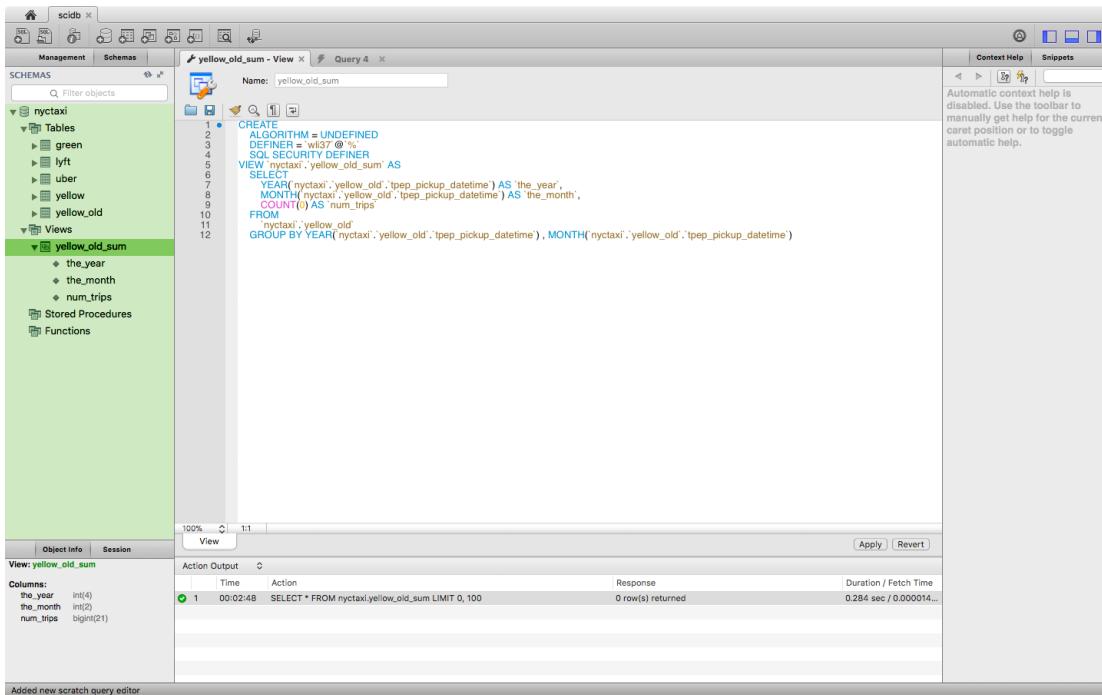


Figure 2.4: MySQL View

A VIEW called `yellow_old_sum` is also created to generate a summary table for the number of Yellow Taxi trips in each month.

2.4 New York City Taxicab and E-hail Services Summary

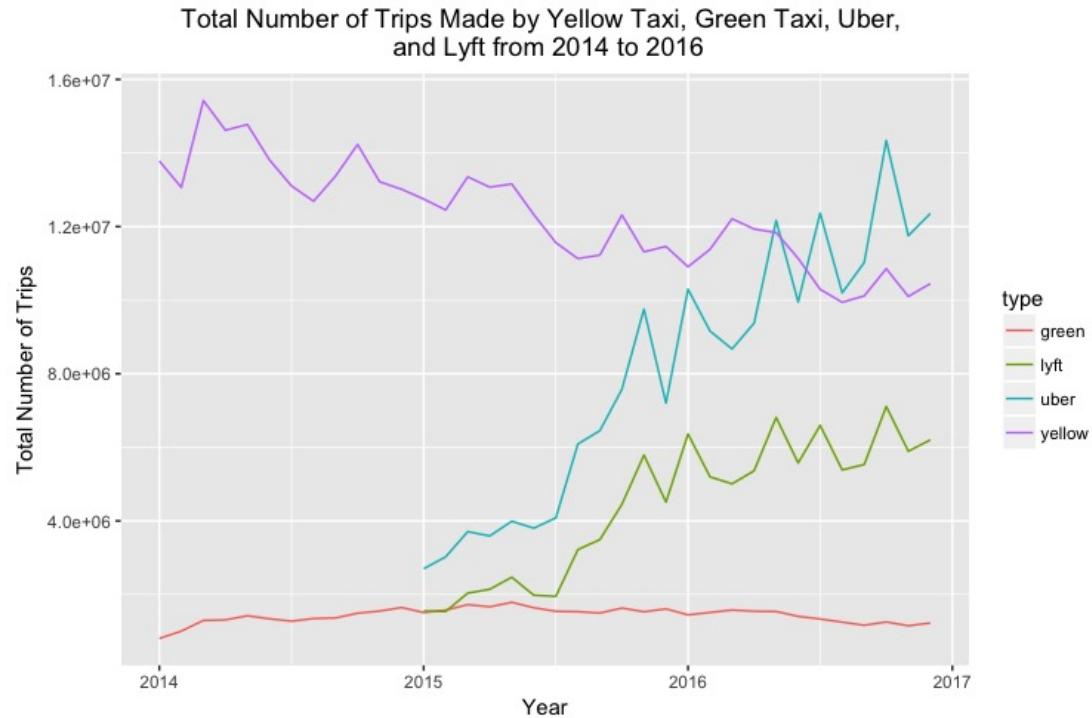


Figure 2.5: Summary of Number of trips Made by 4 Types of Transporations between 2014 and 2016 in NYC

Figure 2.5 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 website (N. T. Staff, 2009b) and weekly Uber (N. O. Staff, 2015b) and Lyft data from NYC OpenData (N. O. Staff, 2015a). Trip-level Uber data that can be accessed by using the `nyctaxi` package is not used in the creation of Figure 2.5 because of the limited ranges of dates where the Uber trip-level data is available.

Data used in Figure 2.5 can be accessed by running the code below:

- Yellow and green taxi trip data

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

- Uber weekly data

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

- Lyft weekly data

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

2.5 Source Code

2.5.1 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 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 available 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-tlc-foil-response/raw/master/
    uber-trip-data/uber-raw-data-janjune-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-tlc-foil-response/raw/master/uber-trip-data
    /uber-raw-data-janjune-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 = ""))

#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 than 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(tpep_pickup_datetime) as the_year, MONTH(tpep_pickup_datetime) AS the_month,
       FROM yellow_old
      GROUP BY the_year, the_month;
);
```

In the second part of the thesis, we give examples of how to answer New York City street-hail service related questions that used to be impossible to be answered by using R on a standard laptop.

Chapter 3

New York City Taxi Drivers

The income of Taxi drivers in New York City comes from two sources: 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 this analysis, we will focus on trip data collected in 2017. Descriptions of variables mentioned in the following chapters can be found in Appendix B.

In order to answer questions regarding to taxi trips' tips, we filter out trips that are not paid by credit or debit card, because taxi drivers usually do not correctly record the amount of tips paid by cash or check (W. Li, 2018).

As mentioned in the previous chapter, 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, **taxis**.

```
# extract yellow taxi trip records that have payment type equals to credit card
# from MySQL database
yellow_2017 <- taxi %>%
 tbl("yellow") %>%
  filter(payment_type == 1)
```

3.1 Aggregated Zone-level Tip Amount

Instead of the nominal 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. Taxi meters sometimes do not function properly, so the information recorded is not always accurate. When taxi meters dysfunction, taxi pick-up and drop-off locations are labelled as “Unknown”. We only want to include trips coming from and going to known taxi zones in this analysis.

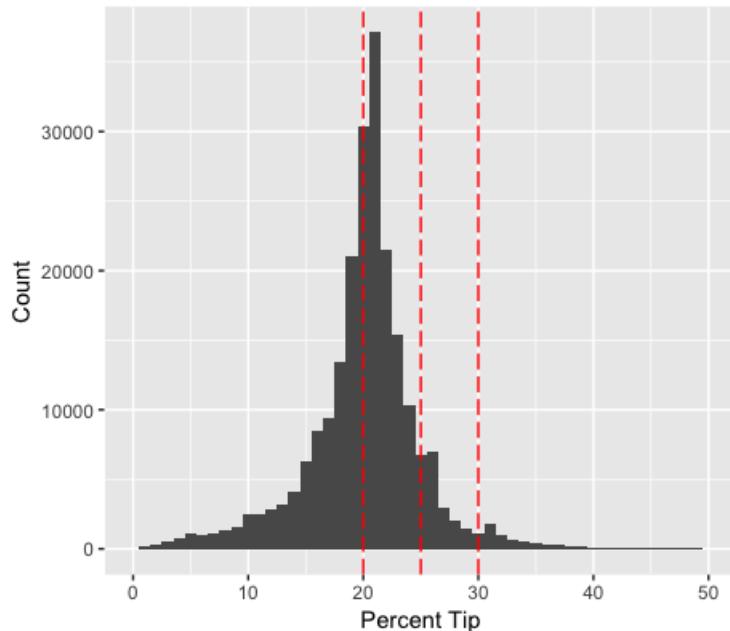


Figure 3.1: Percent Tip Paid by Passengers in Each Pick-up And Drop-off Pair in NYC

Figure 3.1 is a histogram of mean tip percents for all known pick-up and drop-off zone pairs. The red dash lines are drawn at 20%, 25%, and 30%, which are the default percentage of tips that are shown on the touch panel for credit and debit car payments (see Figure 3.2), and passengers tend to pick the the lowest default percent tip.

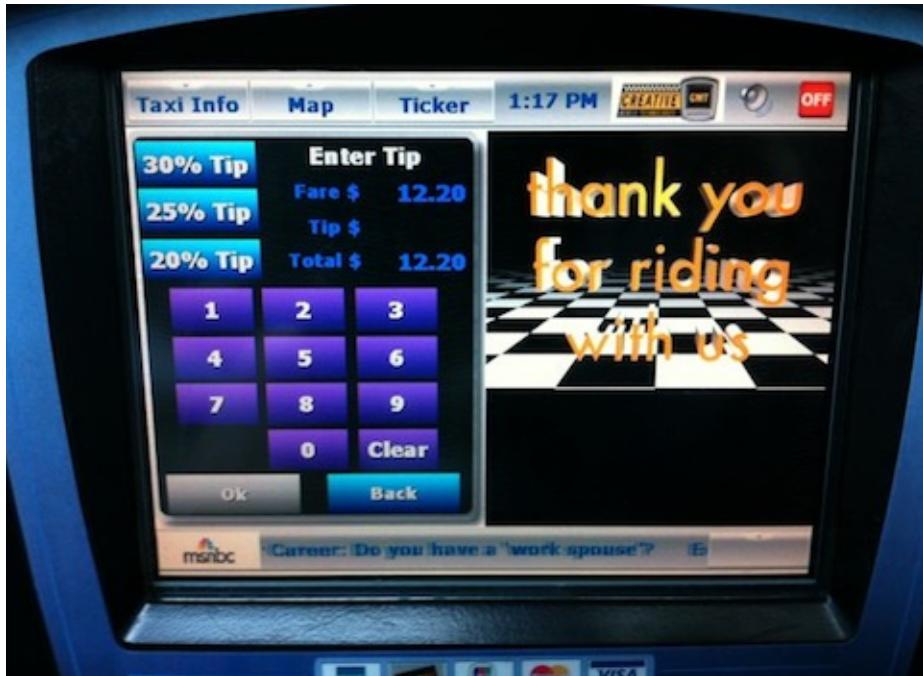


Figure 3.2: Tip Payment Page on New York City Touch Panel

3.1.1 Pick-up Zone Percent Tips Amount

Taxi drivers are required to be indifferent to where passengers are going. It is illegal for New York city taxi drivers to refuse service because of passengers' race, ethnicity, cultural background, disability, gender, or destination (N. T. Staff, 2018). Taxi drivers cannot choose where the passengers want to go, and instead they can only choose which pick-up zone they would prefer to drive around to get hailed. Therefore, it makes sense to investigate the average amount of tips paid by passengers departed from each pick-up zone. What are the taxi pick-up zones that have the highest percent tips paid by passengers? We calculated the average percent tip paid for each pick-up zone as shown in Table 3.1. According to Table 3.1, 6 out of 10 taxi zones with the highest average percent tips are in Queens. At a first glance, Queens seems to be a good place for taxi drivers to go and pick up passengers to make more money.

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

Borough	Zone	Average % Tips
Queens	Douglasston	29
Bronx	East Tremont	29
Queens	Oakland Gardens	29
Queens	Glendale	28
Queens	Saint Michaels Cemetery/Woodside	28
Queens	Bayside	27
Brooklyn	Coney Island	27
Queens	Howard Beach	27
Brooklyn	Marine Park/Mill Basin	27
Bronx	Norwood	26

3.1.2 Which taxi zones are the most popular ones for pick-ups?

Which pick-up zones have the highest number of taxi trip pick-ups? We can create a heat map to visualize the number of trips for each pick-up zones on a map of New York City Taxi Zones.

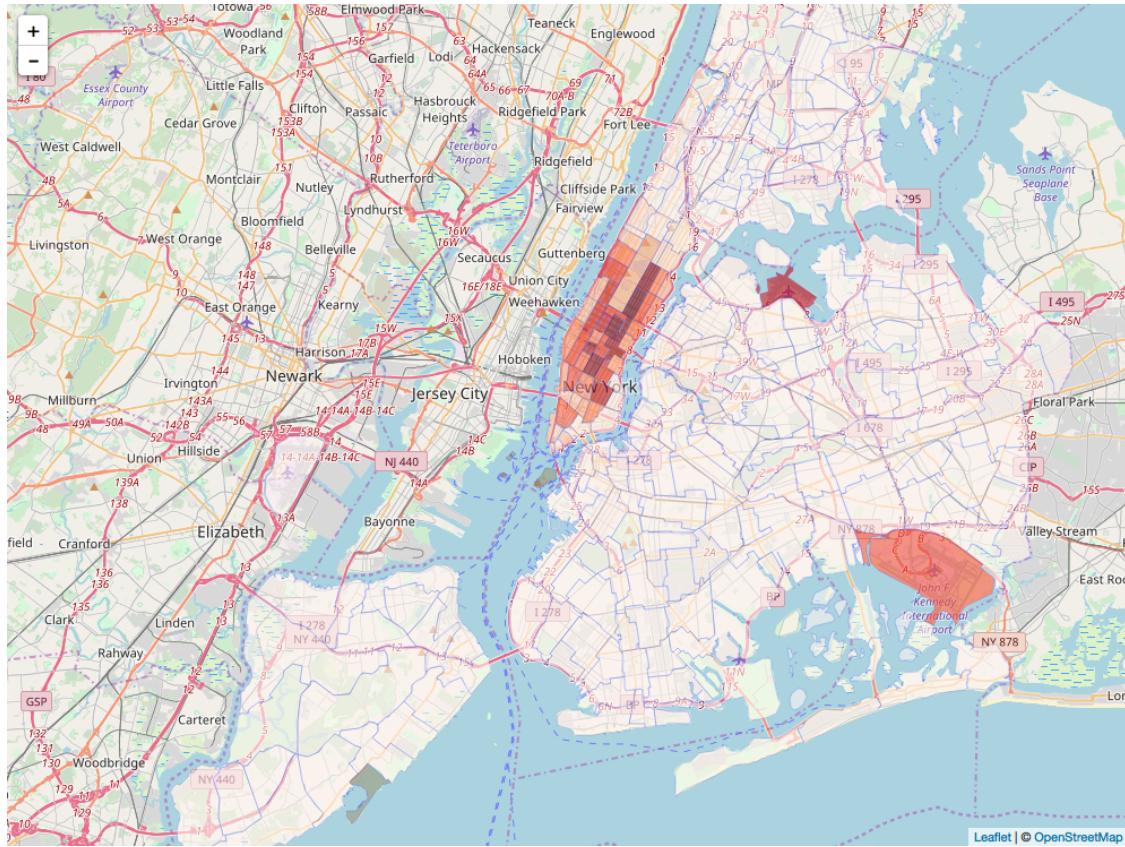


Figure 3.3: Number of Pick-ups in Each Taxi Zone

In Figure 3.3, taxi zones with more number of pick-ups are colored by darker shades of orange, and it is obvious that Manhattan and La Guardia Airport are the most popular locations for taxi pick-ups. Table 3.2 tells which specific taxi zones have the highest number of pick-ups, and 9 out of the top 10 taxi zones that have the most number of pick-ups are located in Manhattan. There are about 6000 yellow taxi pick-ups in the top 10 taxi zones everyday in 2017.

3.1.3 Which pick-up 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 1 trip per hour (or 24 trips per day), we will observe that many taxi pick-up zones with the highest percent tips are not necessarily the ones with the

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

Borough	Zone	Number of Trips
Manhattan	Upper East Side South	2519900
Manhattan	Midtown Center	2461602
Manhattan	Union Sq	2382970
Manhattan	Upper East Side North	2372509
Manhattan	Midtown East	2349386
Manhattan	Murray Hill	2231723
Manhattan	Penn Station/Madison Sq West	2193036
Manhattan	East Village	2097416
Queens	LaGuardia Airport	2059444
Manhattan	Times Sq/Theatre District	1972303

Table 3.3: Ten taxi pick-up zones with the highest percent tip (taxi zones has at least 1 pick-up per hour)

Borough	Zone	Average % Tips
Queens	Baisley Park	21.55
Brooklyn	Gowanus	21.45
Queens	Steinway	21.36
Brooklyn	Carroll Gardens	21.18
Queens	LaGuardia Airport	21.00
Brooklyn	Greenpoint	21.00
Brooklyn	Prospect Heights	21.00
Manhattan	Midtown Center	20.82
Brooklyn	Cobble Hill	20.82
Brooklyn	East Williamsburg	20.82

highest number of pick-ups. People might think it is more reasonable to see a list that is populated with zones in Manhattan, since that's where most of the wealthy people live. However, Table 3.3 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 higher percent tips can drive to the zones listed above to pick-up passengers.

If we focus on the pick-up zones that have more than 1 trip per minute (or 60 trips per hour), then we observe that all pick-up zones that have the highest percent tips are in Manhattan besides La Guardia Airport. There are more than 100 times more yellow

Table 3.4: Ten taxi pick-up zones with the highest percent tip (taxi zones has at least 1 pick-up per minute)

Borough	Zone	Average % Tips
Queens	LaGuardia Airport	21.00
Manhattan	Midtown Center	20.82
Manhattan	Battery Park City	20.73
Manhattan	Midtown East	20.55
Manhattan	Murray Hill	20.55
Manhattan	Penn Station/Madison Sq West	20.55
Manhattan	UN/Turtle Bay South	20.45
Manhattan	Times Sq/Theatre District	20.36
Manhattan	Union Sq	20.18
Manhattan	Midtown North	20.18

cab pick-ups that happen in Manhattan everyday than in Brooklyn. By comparing the average tip percent in Table 3.3 and Table 3.4, we observe that 8 out of 10 average percent tips in taxi zones with high pick-up numbers in Table 3.4 are lower than average percent tips in taxi zones with low pick-up numbers in Table 3.3. Therefore, there could be a correlation between number of trips and average percent tips that passengers pay, and this can be futher studied with more taxi-zone-specific data, such as median household income, provided.

3.2 What features of taxi trips increase the percent tip amount that passengers pay?

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 Does trip distance increase the percent tips paid by passengers?

Do 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.

```
tip_distance <- lm(avg_tip ~ avg_dis + PULocationID + DOLocationID, data = tip_reg)
```

	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 small negative impact on the percent of tips paid, controlling for both pick-up and drop-off locations. Since the number of observations in this regression model is big, the p-value quickly goes to zero. Therefore, in this regression, p-value does not matter so much. What is important in this result is the negative correlation between average percent tips and average distance that a taxi travels.

The negative correlation could be caused by a psychological reason. Long trips cost more than short trips. For a constant tip percent, the nominal 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.

3.2.2 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.

The metered fare rate information is collected from TLC rate of fare webpage (N. T. Staff, n.d.).

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 increases the minute per mile ratio.

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?

```
min_mile_ratio <- lm(avg_tip ~ min_per_mile, data = yellow_2017_summary_small)
```

	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, `min_per_mile` ratio does have a small 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.

3.3 Recommendations to Taxi Drivers

Our analysis has suggested that taxi passengers are sympathetic with the drivers who have to suffer the cogestion in New York City, so we hope that taxi drivers would feel better during rush hours by knowing that passengers do pay for tips to compensate the negative feelings that drivers carry in congestion.

Chapter 4

New York City Taxi Passengers

4.1 How long does it take passengers to get to JFK, La Guardia, and Newark Airports from anywhere in New York City?

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.

```
# extract data of trips going to JFK Airport  
# from MySQL database  
to_jfk_trip <- taxi %>%  
 tbl("yellow") %>%  
  filter(DOLocationID == 132)
```

```
# extract data of trips going to La Guardia Airport
# from MySQL database
to_lg_trip <- taxi %>%
 tbl("yellow") %>%
  filter(DOLocationID == 138)

# extract data of trips going to Newark Airport
# from MySQL database
to_newark_trip <- taxi %>%
 tbl("yellow") %>%
  filter(DOLocationID == 1)
```

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 summarizing 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 4.1 displays the average number of minutes it takes from Alphabet City, Manhattan to JFK Airport during different hours.

4.1.1 Case Study: From Central Park, Manhattan to all three airports

Central Park, Manhattan has pick-up zone ID number 43. Let's take a look at how much time is needed to travel to all three airports from taxi zone No.4.

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

Borough	Zone	Hour of Departure	Average Number of Minutes	
10	Manhattan	Alphabet City	0	45.37000
11	Manhattan	Alphabet City	1	36.77500
12	Manhattan	Alphabet City	2	28.66000
13	Manhattan	Alphabet City	3	27.83350
14	Manhattan	Alphabet City	4	27.19490
15	Manhattan	Alphabet City	5	28.68889
16	Manhattan	Alphabet City	6	34.25271
17	Manhattan	Alphabet City	7	38.13817
18	Manhattan	Alphabet City	8	41.59687
19	Manhattan	Alphabet City	9	35.39226
20	Manhattan	Alphabet City	10	36.22867
21	Manhattan	Alphabet City	11	41.12000
22	Manhattan	Alphabet City	12	41.02800

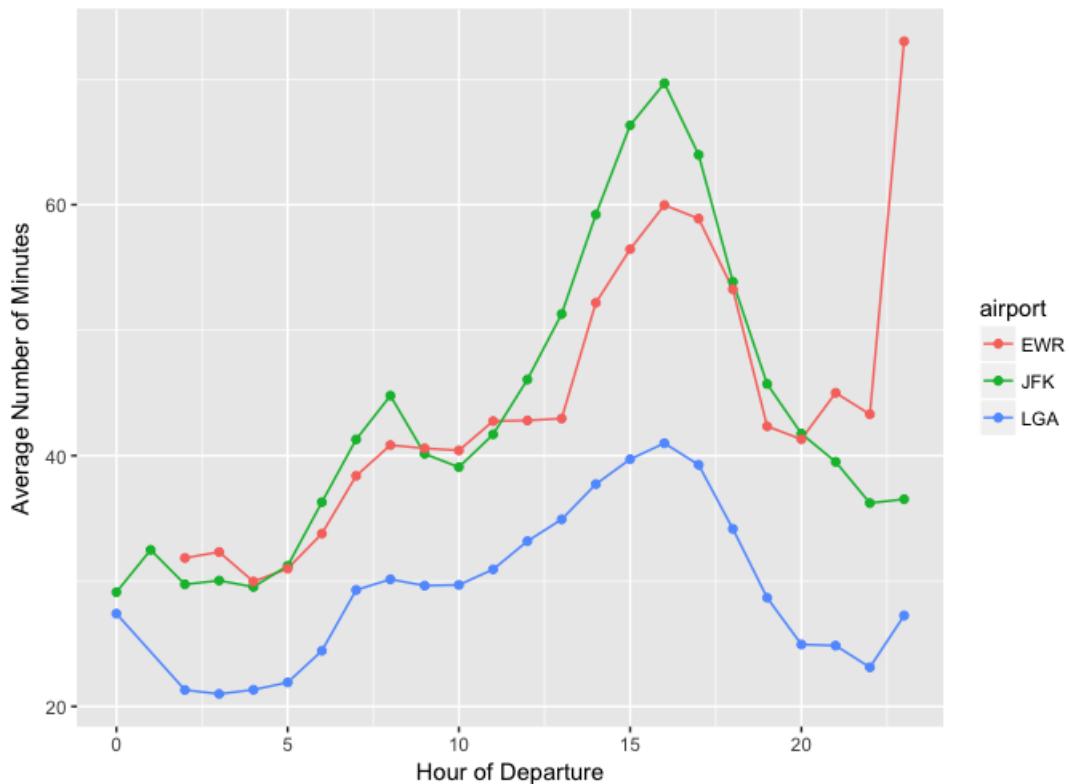


Figure 4.1: Average number of minutes it takes from Central Park, Manhattan to all three airports during different hours

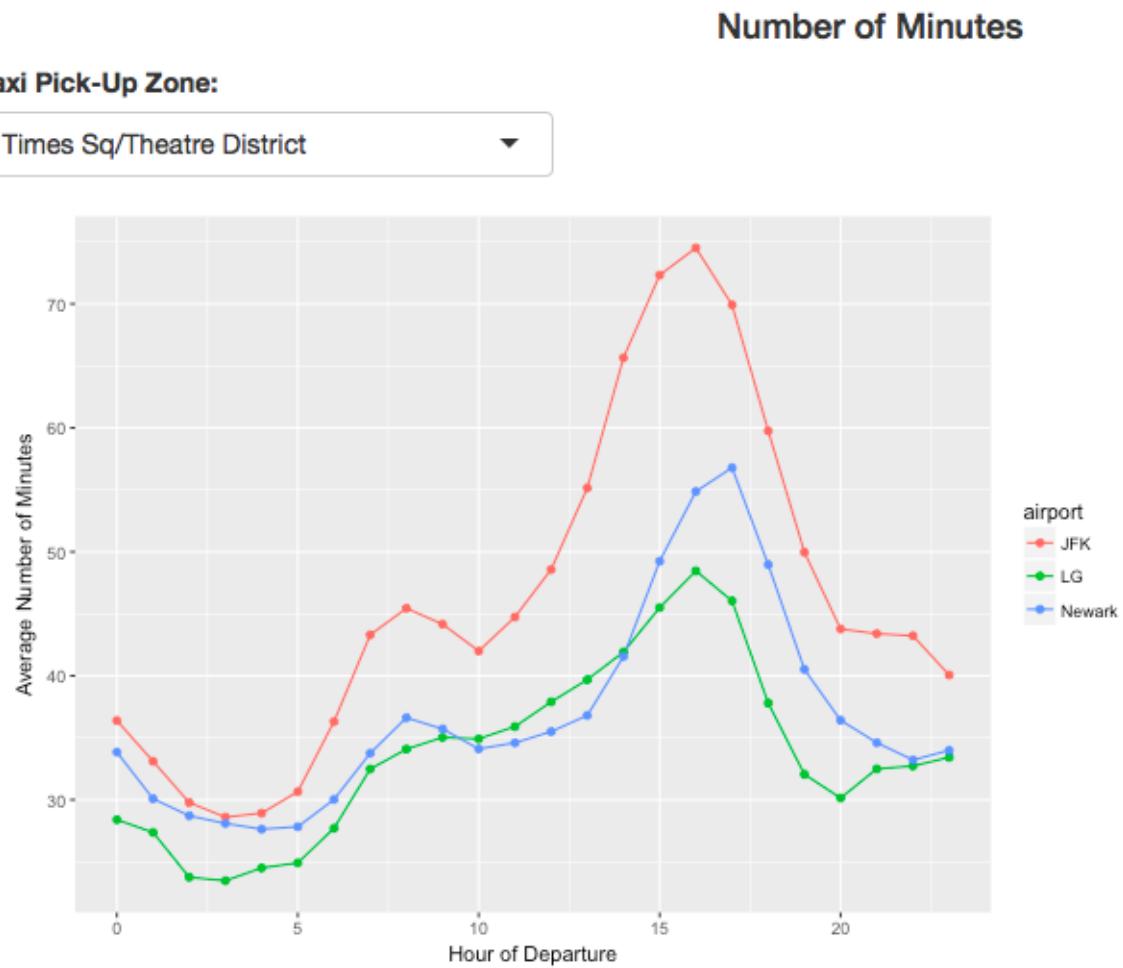
According to the red line Figure 4.1, it takes the least time, less than 30 minutes, to travel from Central Park, Manhattan to Newark Airport around 4 AM in the morning and it takes more than 70 minutes around 11 PM at night.

According to the green line, it only takes about 30 minutes to travel to JFK Airport around 4 AM in the morning, and it takes the most time, about 70 minutes, around 4 PM in the afternoon.

As shown by the blue line, it takes the least time, about 20 minutes, to travel to La Guardia Airport at 2 AM at midnight, and it takes a little more than 40 minutes around 4 PM in the evening.

Being able to know the average time it takes to go to one of the airports ahead, passengers can buy their flight tickets accordingly. For example, a mum who wants to visit Disney World with her kids can use this visualization to estimate the amount of time needed for her and her families to catch their flight. If this mum wants to catch a flight that departs at 10 AM from JFK Airport, then when she should depart from Central Park in order to get to the airport on time? According to Figure 4.1, she can depart at 7 AM, and it will take a little bit more than 40 minutes for her to get to JFK Airport to catch her 10 AM flight.

4.1.2 A Shiny App: When is the best time to travel to JFK Airport?



According to ??, a person travelling from Times Square to JFK Airport to catch a 11AM flight need to depart around 8:30 AM in order to arrive at the airport 2 hours before the flight departs.

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

4.2 How does weather affect the number of taxi and Uber 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 supply and demand into account. When weather is bad, demand for rides is higher, so Uber fare rate increases. Uber's pricing model gives Uber drivers an incentive to work extra hard on ugly days.

In this section, we study the number of pickups of yellow cab and Uber. 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 We first calculated the number of total dispatched trips of Uber by using weekly-aggregated Uber pick-up data available on NYC OpenData (N. O. Staff, 2015b), and summary is shown in Table 4.2.

Table 4.3: Yellow Taxi 2017 Weekly Total Dispatched Trips

Pickup Start Date	Pickup End Date	Yellow Total Dispatched Trips
2017-01-01	2017-01-07	2044643
2017-01-08	2017-01-14	2230950
2017-01-15	2017-01-21	2219214
2017-01-22	2017-01-28	2307122
2017-01-29	2017-02-04	2331749
2017-02-05	2017-02-11	2181622
2017-02-12	2017-02-18	2387399
2017-02-19	2017-02-25	2225850
2017-02-26	2017-03-04	2464800
2017-03-05	2017-03-11	2456285

Table 4.4: Yellow Taxi Total Dispatched Trips

Pickup Start Date	Pickup End Date	Yellow Total Dispatched Trips
2017-03-05	2017-03-11	2456285
2017-03-12	2017-03-18	2066285

Yellow Cab Weekly Data

We also calculated the number of total dispatched trips of New York City yellow cabs by using `nyctaxi` package to retrieve yellow taxi data from 2017, and the summary is shown in Table 4.3.

4.2.1 Case Study: March 14th, 2017 Snow Storm

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

Yellow Taxi

(2066285–2456285) / 2456285

[1] -0.1587764

Table 4.5: Uber Total Dispatched Trips

Pickup Start Date	Pickup End Date	Uber Total Dispatched Trips
2017-03-05	2017-03-11	3614559
2017-03-12	2017-03-18	3430189

Yellow taxi's number of total dispatched trips declined by 15% (see Table 4.4).

Uber

```
(3430189 - 3614559) / 3614559
```

```
[1] -0.05100761
```

Uber's number of total dispatched trips declined by 5% (see Table 4.5).

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 may keep more drivers in the market on a snowy day.

4.2.2 Case Study: Impact of Precipitation on Taxi Rides

People living in New York might have noticed that it is hard to find a taxi on the street when it rains. Economists have studied this phenomena for a long time, and an analysis that studied the correlation between taxi movement and hourly rainfall data in Central Park from 2009 to 2013 found that there is no significant correlation between a driver's hourly wage and precipitation in the city, which implies that drivers don't earn more or less when it rains (Jaffe, 2014).

We got access to the 2017 daily Central Park weather data from the National Climatic Data Center by submitting a Climate Data Online request (Appendix D) to National Centers for Environmental Information (Environmental Information Staff,

Table 4.6: 10 weeks that have the most rainfall in 2017

Pickup Start Date	Pickup End Date	Weekly Rainfall
2017-06-18	2017-06-25	7.00
2017-04-30	2017-05-07	6.71
2017-10-29	2017-11-05	6.16
2017-07-02	2017-07-09	5.56
2017-03-26	2017-04-02	5.11
2017-01-22	2017-01-29	3.99
2017-08-13	2017-08-20	3.95
2017-06-11	2017-06-18	3.91
2017-04-02	2017-04-09	3.17
2017-04-23	2017-04-30	2.88

Table 4.7: 10 weeks that have the most rainfall in 2017 and the total number of dispatched yellow taxi trips in those weeks

Pickup Date	Dispatched Trips	Last Week Date	Last Week Trips	% Change Trips
2017-06-18	2231205	2017-06-11	2285958	-2.40
2017-04-30	2386559	2017-04-23	2394329	-0.32
2017-10-29	2266196	2017-10-22	2267693	-0.07
2017-07-02	1664159	2017-06-25	2038406	-18.36
2017-03-26	2341096	2017-03-19	2272369	3.02
2017-01-22	2307122	2017-01-15	2219214	3.96
2017-08-13	1871668	2017-08-06	1929860	-3.02
2017-06-11	2285958	2017-06-04	2313236	-1.18
2017-04-02	2414700	2017-03-26	2341096	3.14
2017-04-23	2394329	2017-04-16	2337161	2.45

n.d.), and joined it to the 2017 taxi data to study relationship between rainfall and taxi rides.

First, we generate a list of total amount of daily rainfall in New York City and we pick the 10 weeks that have the most rainfall in 2017 (see Table 4.6). We then find the weekly total number of dispatched yellow taxi trips of the 10 weeks with the most rainfall (see Table 4.7). We also need to add the weekly total number of dispatched Uber trips of the 10 weeks with the most rainfall (see Table 4.8). We combine the percentage change in total number of dispatched trips of yellow taxi and Uber, and

Table 4.8: 10 weeks that have the most rainfall in 2017 and the total number of dispatched Uber trips in those weeks

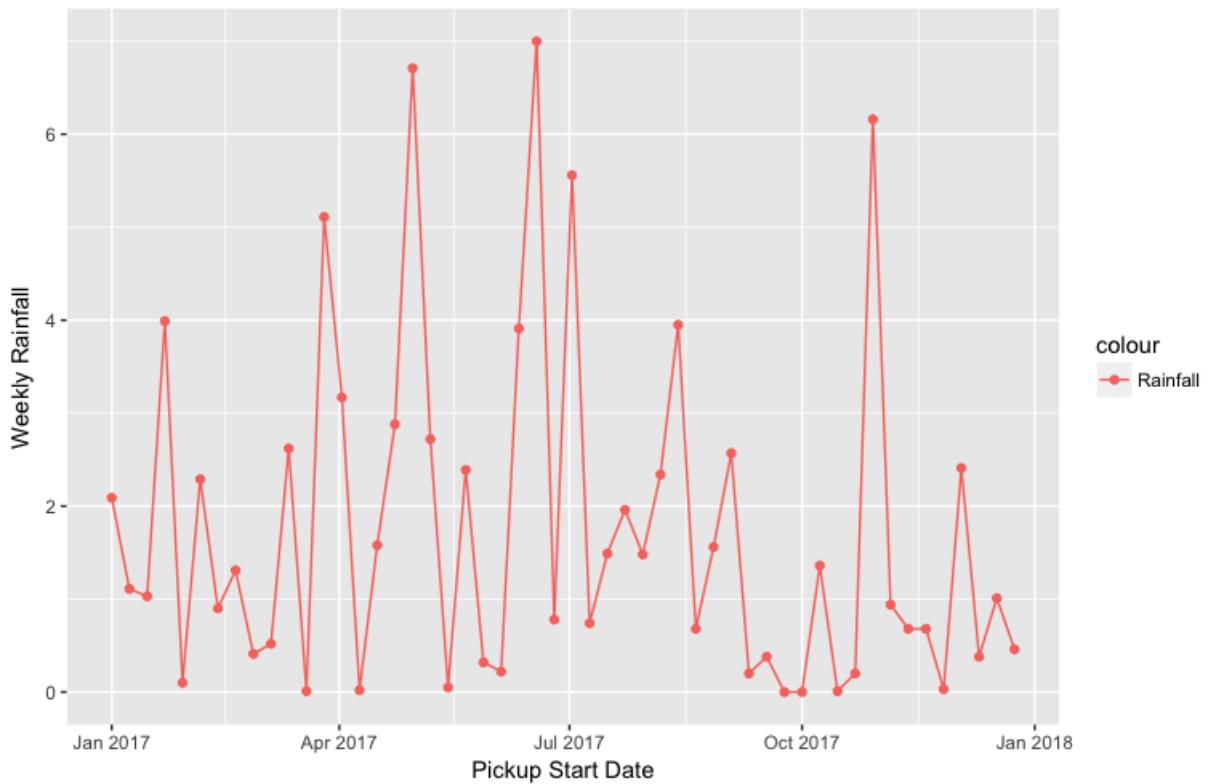
Pickup Date	Dispatched Trips	Last Week Date	Last Week Trips	% Change Trips
2017-06-18	3654932	2017-06-11	3658220	-0.09
2017-04-30	3546893	2017-04-23	3606408	-1.65
2017-10-29	4317572	2017-10-22	4193611	2.96
2017-07-02	3212582	2017-06-25	3406814	-5.70
2017-03-26	3541624	2017-03-19	3425475	3.39
2017-01-22	3299763	2017-01-15	3089595	6.80
2017-08-13	3599772	2017-08-06	3584023	0.44
2017-06-11	3658220	2017-06-04	3622252	0.99
2017-04-02	3443444	2017-03-26	3541624	-2.77
2017-04-23	3606408	2017-04-16	3427564	5.22

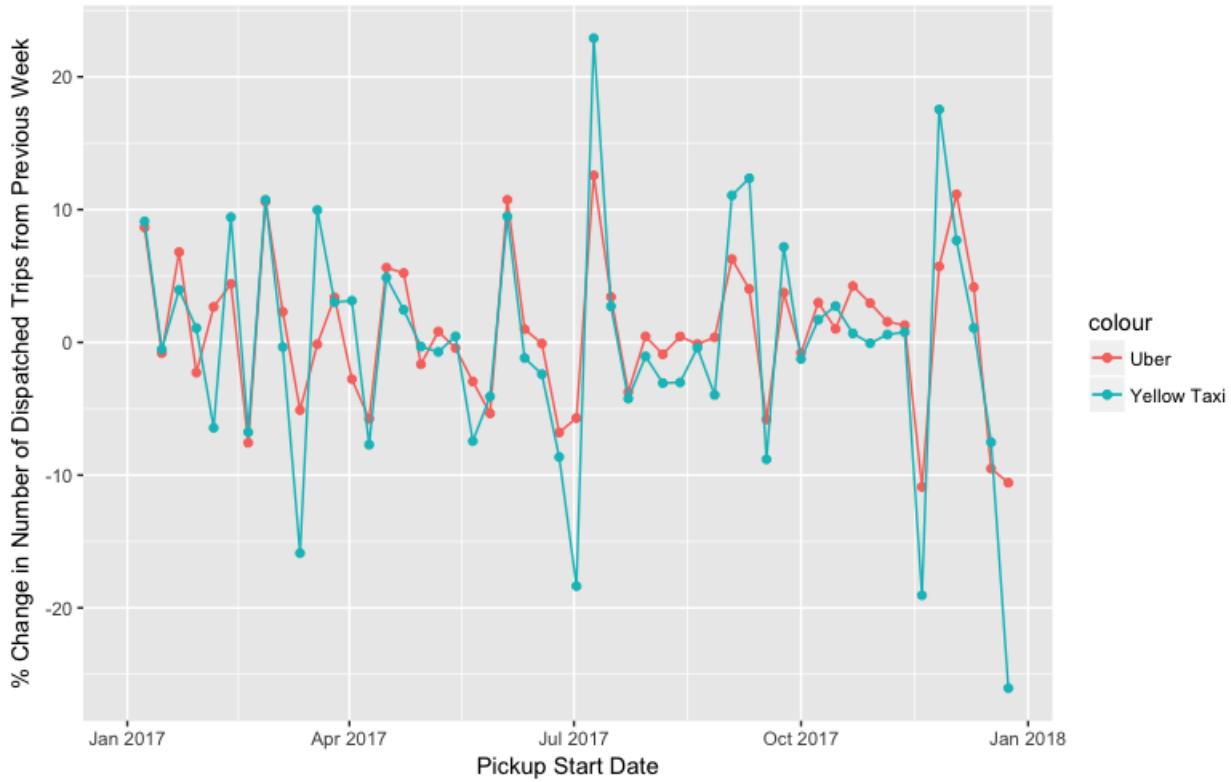
we compare the result (see Table 4.9). Besides the week of April 30th, 2017, all other weeks have higher increases in the number of total dispatched trips of Uber or lower declines in the number of weekly Uber trips. Therefore, on rainy days, Uber drivers tend to increase the number of trips they drive at a higher rate.

We then plot the weekly rainfall and Yellow Taxi and Uber's percent Change in Number of Dispatched Trips from Previous Week.

Table 4.9: The percentage change in total number of dispatched trips comparing to the previous weeks of yellow taxi and Uber

Pickup Start Date	Weekly Rainfall	Last Week Date	Uber	Yellow
2017-06-18	7.00	2017-06-11	-0.09	-2.40
2017-04-30	6.71	2017-04-23	-1.65	-0.32
2017-10-29	6.16	2017-10-22	2.96	-0.07
2017-07-02	5.56	2017-06-25	-5.70	-18.36
2017-03-26	5.11	2017-03-19	3.39	3.02
2017-01-22	3.99	2017-01-15	6.80	3.96
2017-08-13	3.95	2017-08-06	0.44	-3.02
2017-06-11	3.91	2017-06-04	0.99	-1.18
2017-04-02	3.17	2017-03-26	-2.77	3.14
2017-04-23	2.88	2017-04-16	5.22	2.45





According to Figure @ref(fig:rainfall_vis) and Figure @ref(fig:weather_vis), when weekly rainfall is high, Uber usually have less percent decline in total number of dispatched trips comparing to the total number of trips from previous week than yellow cab does. Uber passengers pay higher fare on rainy days because of Uber's pricing model. Since taxi drivers do not get paid more on rainy days, they tend to work less than Uber drivers, which limits the options for passengers. Passengers sometimes have to choose the more costly Uber instead (Jaffe, 2014).

4.3 Recommendations to Taxi Passengers

We suggest passengers to use our Shiny App to choose a pick up zone of their interest and then decide when is the most favorable time for them to travel from that zone to any of the three airports in New York.

Chapter 5

New York City Taxi & 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 stay in a hotel in Manhattan. Since you might not know much about the city, the fixed \$52 flat rate provides cost certainty for you, and it incentivizes you to take taxi to 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, anxiety, and inconvenience.

Additionally, people living in most parts of 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 might help taxi drivers to get more trips from Manhattan to JFK Airport.

5.2 Passengers departing from 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. Since JFK Airport's Location ID is 132, we only retrieve trip records with either pick-up or drop-off location ID as 132 from the database.

```
# extract yellow records of trips going to JFK Airport
# from a SQL database
to_jfk <- taxi %>%
 tbl("yellow") %>%
  filter(DOLocationID == 132)

# extract yellow records of trips coming from JFK Airport
# from a SQL database
from_jfk <- taxi %>%
```

```
tbl("yellow") %>%
  filter(PULocationID == 132)
```

5.2.1 Trips from Manhattan to JFK Airport

We first focus on all the trips that departed from 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.

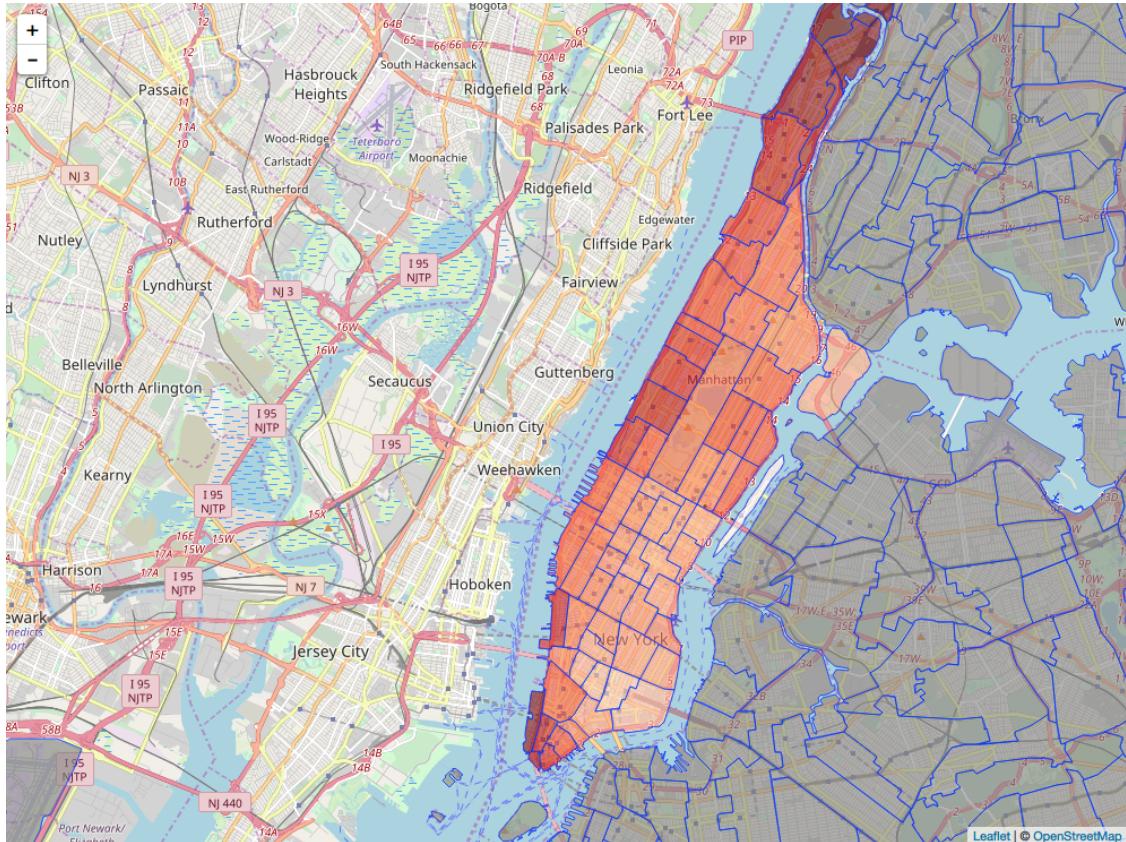


Figure 5.1: Estimated fare amount from each pick-up zone to JFK Airport

Figure 5.1 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

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

avg_est_fare	avg_est_diff	Borough	Zone
64.03150	11.844558	Manhattan	Battery Park City
63.98256	9.970366	Manhattan	Inwood
62.97567	10.892992	Manhattan	Washington Heights North
61.99327	9.889636	Manhattan	Battery Park
60.49388	8.278941	Manhattan	Washington Heights South
60.18006	8.107309	Manhattan	Upper West Side South
59.74384	7.511991	Manhattan	World Trade Center
59.31411	7.058534	Manhattan	Meatpacking/West Village West
59.24692	7.200516	Manhattan	Lincoln Square West
59.13439	7.083517	Manhattan	Upper West Side North

fare rate suggested by TLC for each pick-up zone. According to the map, trips from Midtown on average cost less than trips from other taxi zones in Manhattan.

5.2.2 Which taxi zones would pay more than \$52 without the flat rate?

We computed the average fare paid by passengers for trips going from each taxi zone in Manhattan to JFK Airport in Table 5.1.

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

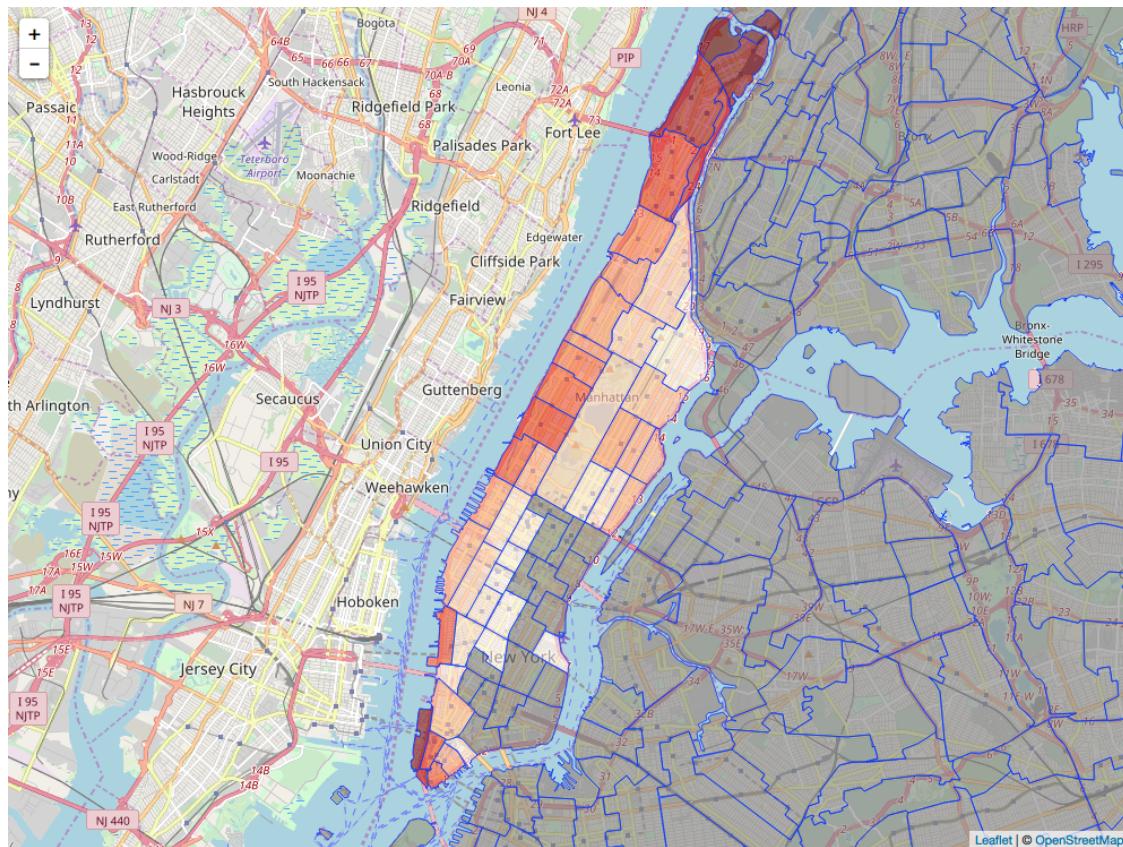


Figure 5.2: Pick-up Zones that cost more than the 52 US Dollar flat rate

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, since they would pay less than \$52 without the flat rate. Instead, they probably put more emphasis on convenience and time.

On average people travel from Manhattan pay \$2.83 less with the \$52 flat rate policy. Therefore, passengers overall benefit from the \$52 flat rate policy.

5.3 Are taxi drivers happy when a passenger wants to go to JFK Airport from Manhattan?

Are taxi drivers happy when their passengers want to go to JFK Airport from Manhattan? In this section, we study the hourly wage of taxi drivers for different trips they completed, and we investigate whether taxi driver hourly wage from Manhattan to JFK Airport is higher than other trips.

[1] 63.29

The average hourly wage of taxi drivers calculated by using all trips excluding the ones going from Manhattan to JFK Airport is \$63.29.

[1] 69.05

The average hourly wage of taxi drivers calculated by using trips going from Manhattan to JFK Airport is \$69.05, slightly higher than \$63.29 dollar per hour, which means that on average taxi drivers driving from Manhattan to JFK Airport have an hourly wage that is about \$6 higher than the hourly wage of taxi drivers doing other trips.

5.3.1 How much on average would taxi driver make on their way back from JFK Airport?

A taxi driver waiting in line to pickup passengers at JFK Airport could be directed back to anywhere in the city. Therefore, the estimated fare that a taxi driver would make on the way back from JFK is unknown. We calculate the average taxi fare amount that a taxi driver would get paid for a trip from JFK Airport to any part of the city.

Table 5.2: 5 most popular destinations in Manhattan

Borough	Zone	num_trips	avg_fare	avg_duration
Manhattan	Times Sq/Theatre District	59419	69.80599	55.92389
Manhattan	Midtown East	40513	69.40195	47.42096
Manhattan	Murray Hill	40071	69.91174	43.66998
Manhattan	Midtown South	38890	70.11065	48.34342
Manhattan	Midtown Center	36405	69.64272	52.62410

What are the most popular drop-off locations for passengers departing from JFK Airport?

Table 5.2 shows that Times Square is the most popular destination for passengers coming from the JFK Airport in 2017.

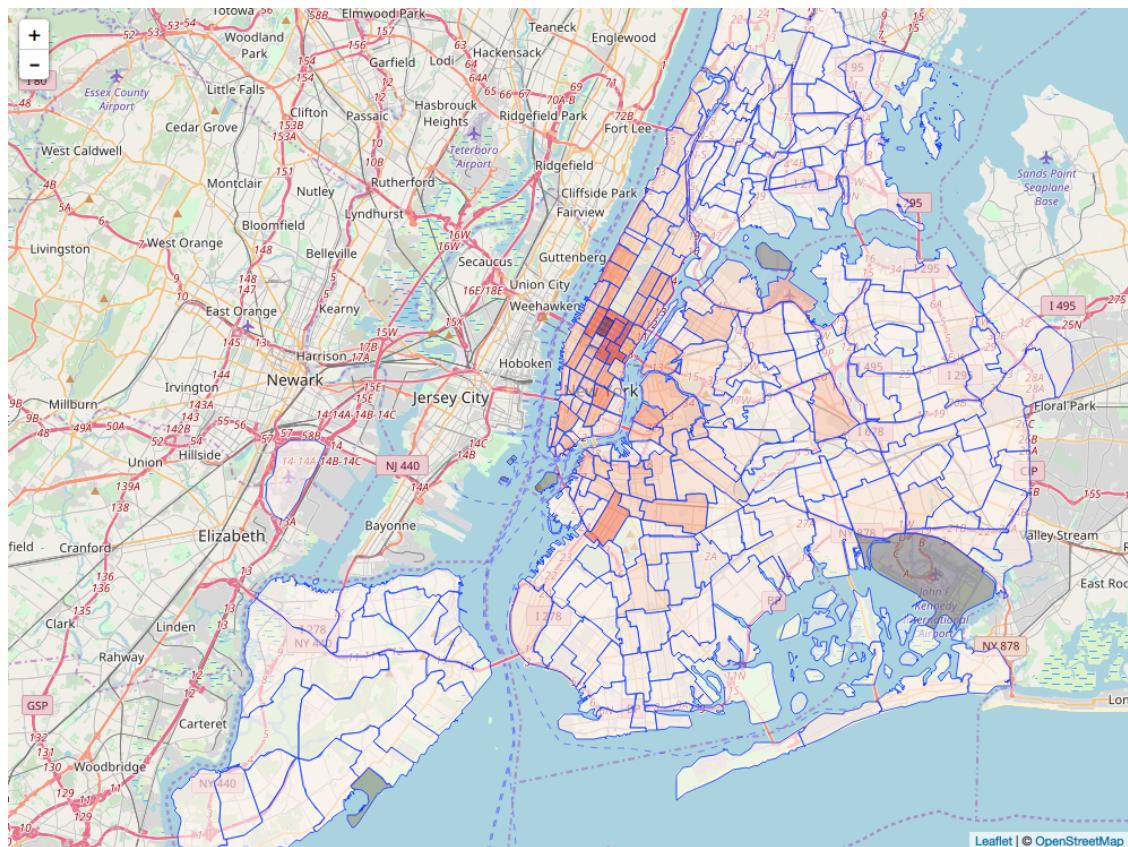


Figure 5.3: Number of trips from JFK Airport to any Taxi Zones

According to the Figure @??fig:from-jfk-num-trips), Manhattan is the most popular

Table 5.3: Number of Trips going to Manhattan or other boroughs from JFK Airport

Going to Manhattan	Number of Trips
0	521476
1	970366

Table 5.4: 10 most popular taxi drop-off zones from JFK Airport with the corresponding average fare amount

Borough	Zone	# of Trips	Average Fare	Average Duration
Manhattan	Times Sq/Theatre District	59419	69.81	55.92389
Manhattan	Midtown East	40513	69.40	47.42096
Manhattan	Murray Hill	40071	69.91	43.66998
Manhattan	Midtown South	38890	70.11	48.34342
Manhattan	Midtown Center	36405	69.64	52.62410
Manhattan	Clinton East	35297	69.20	55.78806
Manhattan	Midtown North	34538	68.30	55.80455
Brooklyn	Park Slope	27219	60.96	45.75234
Manhattan	East Village	26595	66.98	45.45684
Manhattan	Upper West Side South	24723	69.95	50.87777

destination for passengers departing from JFK Airport. According to the summary, the total amount of trips from JFK Airport to Manhattan is about 65.04% 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.

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

We can use a map to visualize the distribution of average fare amount needed to travel from JFK Airport to any taxi zone in New York City.

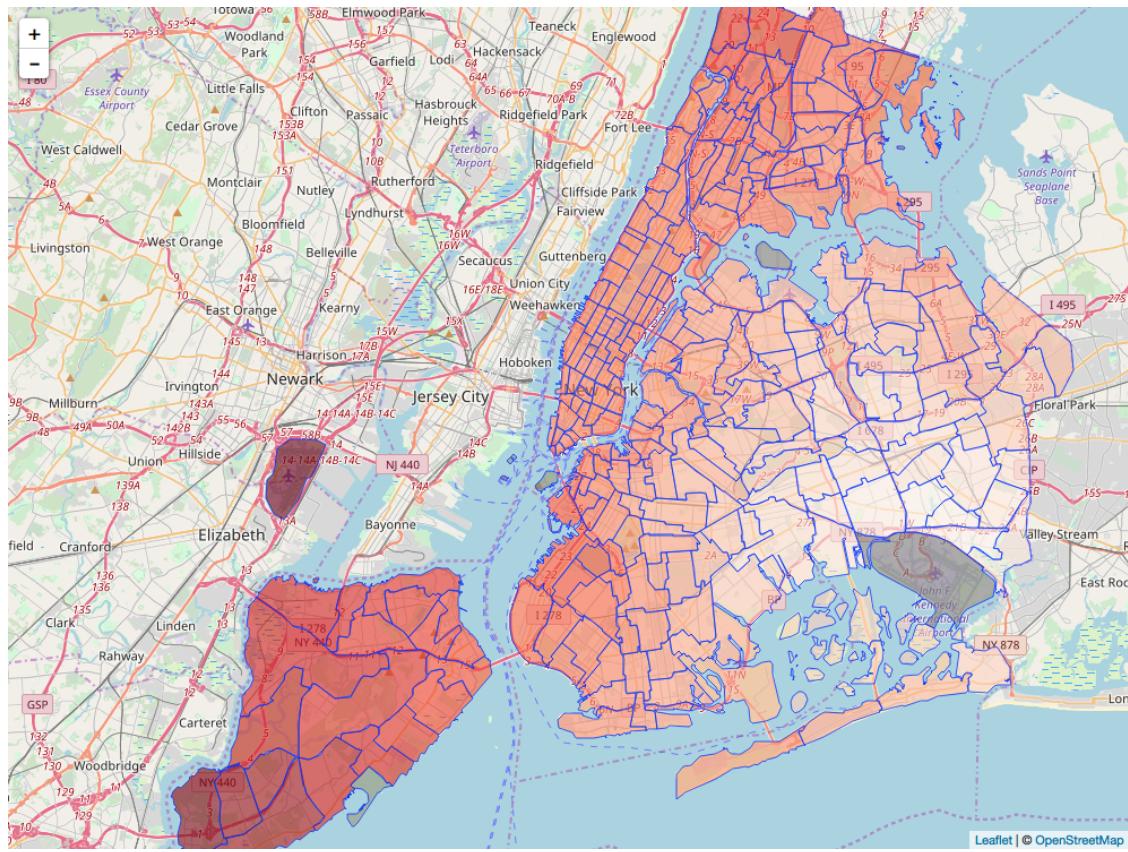


Figure 5.4: Zones that cost more than the 52 US Dollar flat rate

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

How much on average would taxi driver make on their way back from JFK Airport?

[1] 62.7

On average, taxi drivers would get paid for on average \$62.7 for a trip from the JFK Airport to any taxi zone in New York City, and on average trips from JFK Airport last 44 minutes.

[1] 63.15

The average hourly wage of taxi drivers calculated by using all trips excluding the ones departing from JFK Airport is 63.15 dollar per hour.

[1] 94.65

The average hourly wage of taxi drivers calculated by using trips departing from JFK Airport is \$94.65 per hour, which means that on average taxi drivers going from JFK Airport to any taxi zones in New York City have an hourly wage that is more than \$30 higher than the hourly wage of taxi drivers doing other trips.

How much more do taxi drivers make on average for a round trip to and from JFK Airport, comparing to any other trips?

On average taxi drivers driving from Manhattan to JFK Airport make \$6 more every hour than taxi drivers doing other trips. On average taxi drivers going from JFK Airport to any taxi zones in New York City make \$30 more every hour than taxi drivers doing other trips. Overall, a taxi driver doing a round trip to and from JFK Airport make \$36 more every hour, comparing to a taxi driver doing any other trips. In this case, a round trip to and from JFK Airport is worthwhile, and that's why taxi drivers should feel happy when pick up a passenger in Manhattan and is told that he or she wants to go to JFK Airport.

5.4 Recommendations to New York City Taxi Fare & Limousine Commission

In this chapter, we have found the reason why taxicab drivers feel happy when they pick up passengers who want to go to JFK Airport in Manhattan. Even though \$52 is lower than the average amount of fare that taxi drivers would have made without the

flat rate, it still induces an higher than average hourly wage, so it does not disincentive drivers to go to JFK Airport from Manhattan. Therefore, we suggest the TLC to keep this flat rate so that passengers do not have any uncertainty in cost and they are more willing to take a taxi to travel to JFK Airport from Manhattan.

Chapter 6

Conclusion

In this Honors thesis, we present a more efficient and user-friendly way for **R** users to retrieve trip record of both taxi and other ride-sharing services, such as Uber and Lyft, in New York City.

By analyzing trip records of New York City's yellow taxi, we found answers to questions that are of interest to taxi drivers, passengers, and TLC officials:

- We found which taxi zones have passengers who offer the highest percent of tips, and we showed that taxi drivers do get compensated more during rush hours.
- We helped passengers to know the average time it takes to go to one of the three airports in New York City so that passengers can plan their trips accordingly.
- We also found that the \$52 flat rate between Manhattan and JFK Airport is beneficial for the passengers, because it is cheaper than the average amount of fare that passenger would need to pay without the flat rate.
- We have also shown that the flat rate does not discourage drivers, even though taxi drivers would have been paid more without the flat rate.

We suggest passengers to use our Shiny App to choose a pick up zone of their interest

and then decide when is the most favorable time for them to travel to any airport in New York. We recommend New York City TLC to modify the fare on rainy or snowy days to incentive taxicab drivers to pick up more trips in order to make street-hail service more affordable on rainy days for passengers. We also suggest the TLC to keep the \$52 flat rate between Manhattan and JFK Airport so that passengers do not have any uncertainty in cost and they are more willing to take a taxi to travel to JFK Airport from Manhattan.

6.1 Future Research

Using `nyctaxi` R package, we can answer more street-hail services related questions. We 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. By looking into the patterns in market shares, it might be possible to predict the future market share distribution and find out what features of ride-hail transportation are the ones that affect market share the most.

As mentioned in Chapter 3, we also want to study the correlation between number of trips and average percent tips in each taxi zone. If more taxi-zone-specific data is provided, we could find out the true correlation between the two variables.

we could also use `nyctaxi` R package to study the impact of the newly-installed GPS and entertainment system in taxicabs on the number of taxi rides. With the raised expectation among ride experience caused by Uber and Lyft, yellow taxi industry need to respond quickly (Hawkins, 2016). TLC decided to install GPS and entertainment system in order to attract more passengers to take taxis. How does the market react to the newly installed entertainment system? Has the market share of yellow cab rebounded since the installation of the entertainment system in 2016?

Appendix A

Utility Function

This utility function was written to shorten the source code in ETL `etl_extract.etl_nyctaxi()` function. It takes in ‘url’, `year`, `n` (number of observations), and `names` (which are the names CSV data files), and create a list of raw data directories.

```
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  
}
```


Appendix B

Data Dictionary – Yellow Taxi

All variables used in data analysis of yellow taxi data are listed in this data dictionary.

Data Dictionary – Yellow Taxi Trip Records

September 28, 2015

Page 1 of 1

This data dictionary describes yellow taxi trip data. For dictionaries describing green taxi and FHV data, please visit http://www.nyc.gov/html/tlc/html/about/trip_record_data.shtml.

Field Name	Description
VendorID	A code indicating the TPEP provider that provided the record. 1= Creative Mobile Technologies, LLC; 2= VeriFone Inc.
tpep_pickup_datetime	The date and time when the meter was engaged.
tpep_dropoff_datetime	The date and time when the meter was disengaged.
Passenger_count	The number of passengers in the vehicle. This is a driver-entered value.
Trip_distance	The elapsed trip distance in miles reported by the taximeter.
Pickup_longitude	Longitude where the meter was engaged.
Pickup_latitude	Latitude where the meter was engaged.
RateCodeID	The final rate code in effect at the end of the trip. 1= Standard rate 2=JFK 3=Newark 4=Nassau or Westchester 5=Negotiated fare 6=Group ride
Store_and_fwd_flag	This flag indicates whether the trip record was held in vehicle memory before sending to the vendor, aka “store and forward,” because the vehicle did not have a connection to the server. Y= store and forward trip N= not a store and forward trip
Dropoff_longitude	Longitude where the meter was disengaged.
Dropoff_latitude	Latitude where the meter was disengaged.
Payment_type	A numeric code signifying how the passenger paid for the trip. 1= Credit card 2= Cash 3= No charge 4= Dispute 5= Unknown 6= Voided trip
Fare_amount	The time-and-distance fare calculated by the meter.
Extra	Miscellaneous extras and surcharges. Currently, this only includes the \$0.50 and \$1 rush hour and overnight charges.
MTA_tax	\$0.50 MTA tax that is automatically triggered based on the metered rate in use.
Improvement_surcharge	\$0.30 improvement surcharge assessed trips at the flag drop. The improvement surcharge began being levied in 2015.
Tip_amount	Tip amount – This field is automatically populated for credit card tips. Cash tips are not included.
Tolls_amount	Total amount of all tolls paid in trip.
Total_amount	The total amount charged to passengers. Does not include cash tips.

Figure B.1: Data Dictionary – Yellow Taxi Trips Records

Appendix C

Freedom of Information Law Request

We submitted this FOIL Request to seek answers of the questions listed below to better analyze the yellow taxi data.



Meera Joshi
Commissioner

Christopher Wilson
Deputy Commissioner/General Counsel
Office of Legal Affairs
33 Beaver Street, 22nd Floor
New York, NY 10004

+1 212 676 1102 fax

FOIL REQUEST FORM

Taxi and Limousine Commission
Office of Legal Affairs
33 Beaver Street, 22nd Floor
New York, New York 10004
Attn: Records Access Officer

FROM: (Please print your name, address, telephone # and email address)

Your email address: wli37@smith.edu

**I request the following record(s) under the Freedom of Information Law:
Please reasonably describe the record(s) you are requesting to allow us to identify any responsive document(s).**

I have a few questions about some of the variables, and could you please help me to answer them:

1. negative fare amount: I saw some negative fare amounts. Could you please tell me what situations lead to negative fare amount data entries? Broken meters?
2. zero fare amount: Some trips have zero fare amounts. Does it mean that the taxi driver cancelled the trip? Or does it mean that the passengers refused to pay the taxi fare?

3. negative tip amount: I saw some negative tip amounts. Could you please tell me what situations lead to negative tip amount data entries? Broken meters?

4. huge tolls amount: I saw some huge tolls amount. Do you know what might have caused that? One of the trips has a toll amount that is more than \$450.

5. passenger count: Did taxi drivers manually enter this data?

6. Do smaller taxi (5 seats) and bigger taxis (6 or 7 seats) have the same rate of fare?

7. Do green taxi and yellow taxis have the same rate of fare?

Please state the reason for your request: (optional)

I am Wencong Li (Priscilla), a senior at Smith College, MA. I am currently working on my thesis and I am using the TLC taxi data to do data analysis.

WENCONG LI

Signature

02/06/18

Date

This is a Freedom of Information Law ("FOIL") request. As such, your request will be considered under the Public Officer's Law, Article 6, Section 84 et seq. Subject to the provisions of this article, the Taxi and Limousine Commission, within five business days of the receipt of a written request for a record reasonably described, shall furnish a written acknowledgement of the receipt of such request.

Figure C.1: Freedom of Information Law Request

Appendix D

NOAA Climate Data Request

We submitted the NOAA Climate Data Request to get access to 2017 New York City weather data.

Smith College Mail - Climate Data Online request 1313559 submitted.

4/14/18, 11:21 PM



Wencong Li <wli37@smith.edu>

Climate Data Online request 1313559 submitted.

1 message

NCDC CDO <noreply@noaa.gov>
To: wli37@smith.edu

Sat, Apr 14, 2018 at 11:00 PM



Order submitted

Getting started

Thank you for using the NCEI data ordering services. Your order has been successfully submitted and will begin processing shortly. This is the first step of getting your data order processed. Once the data is added to the processing queue it will be processed as soon as possible and then an email will be sent when processing is complete.

Order details

Order #1313559 (LCD CSV)

Order #	1313559
Date Submitted	2018-04-14 11:00
Order Summary	View Summary
Documentation	View Documentation

What's next?

Most orders only take a very short while to process, but larger orders do take more time and are affected by the number of orders in the data request queue.

While you are waiting for your order to complete, you may find it helpful to find out more about the dataset from which you ordered the data or certification.

Other questions you may have may also be answered in our Help/Frequently Asked Questions section. Use the links below to find this information.

If you still have questions, use the Contact Us link below to contact one of our Customer Service representatives for further assistance.

Want to manage your order online?

https://mail.google.com/mail/u/0/?ui=2&ik=b9ce5d19c1&jsver=z8_jB6....&view=pt&search=inbox&th=162c73f4ed5ab6c0&siml=162c73f4ed5ab6c0 Page 1 of 2

Figure D.1: NOAA Climate Data Request

The NOAA Climate Data Order Completion Notification grants me rights to access to 2017 New York City weather data.

Smith College Mail - Climate Data Online request 1313559 complete

4/14/18, 11:23 PM



Wencong Li <wli37@smith.edu>

Climate Data Online request 1313559 complete

1 message

NCDC CDO <noreply@noaa.gov>
To: wli37@smith.edu

Sat, Apr 14, 2018 at 11:03 PM



Order Complete

Your order has been processed and is ready for download. Use the links below to download the individual orders.

If any part of your order has certifiable data, a link will be supplied that will help you with the certification process.

Documentation for each dataset is linked from within the order for your convenience.

Order Details

Order #1313559 (LCD CSV)

File [Download](#) (Available until 2018-Apr-21)

Order ID [1313559](#)

Date Submitted 2018-04-14 11:00

Order Summary [View Summary](#)

Documentation [View Documentation](#)

Want to manage your previous orders online?

If you want to check or resubmit an older order, please visit our [order status page](#).



[Order Certification](#)



[Help](#)



[Contact Us](#)

Figure D.2: NOAA Climate Data Order Completion

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