Balancing of a bicycle loan system with fixed stations

David E. Castillo Rodríguez, Luis A. Moncayo Martínez

Instituto Tecnológico Autónomo de México

November 29, 2023

Outline

1. Bike systems through the time
   - Research areas
2. Bike sharing System in Mexico City
   - Available data
   - Identified problems
3. Balancing
   - Station Identification
   - Status of each station at time t
   - Balancing exercise
4. Conclusions

Bike systems through the time

According to [hs04], we can classify a bike system as:

- **First generation:** White bike program at Amsterdam, 1964. You could pick a bike and leave it in any place.
- **Second generation:** City Bikes program at Copenhagen, 1995. You could pick up and deliver a bike from specific places by a coin deposit.
- **Third generation:** Bikeabout program at Portsmouth University, England 1996. You could pick up a bike using a magnetic card.
- **Fourth generation:** Call a Bike program at Germany, 2000. You need a digital authentication to lock or unlock a bike.

Research areas

- **Balancing Methods:** Balancing operations to ensure the system sustainability, [Fis16]-[SHv17].
- **Underused systems:** Research why people decided to don´t use the service, [Fis16].
- **Interaction between car drivers and bike users:** Research the behavior of car drivers towards bike users to implement security measures, [Fis16].

Research areas

- **Quantitative metrics:** Research and development of quantitative metrics to measure the impact of the bike sharing systems in terms of vehicular transit and environment pollution, [Fis16].

- **Demand prediction:** It is necessary to know the demand of the system to maintain the system. The prediction of the demand is an input to other type of analysis, [SHv17].

Bike sharing System in Mexico City

The bike sharing system of the Mexico city, called Ecobici, started operations in February of 2010, [htt10].

- This is a 3rd generation system.
- It consists of 480 bike-stations spread around the Mexico city.
- By paying a membership, any user can take a bike for 45 minutes on a schedule between the 05:00 and 00:30 hrs of the next day.

Available data

The information is public and can be consulted in the web page of the service. The captured information by the system is the following:

- Genero_Usuario
- Edad_Usuario
- Bici
- Ciclo_Estacion_Retiro
- Ciclo_Estacion_Arribo
- Fecha_Retiro
- Fecha_Arribo
- Hora_Retiro
- Hora_Arribo

Identified problems with the data

1. The information is reported at service level, i.e, we never know how many bikes are in each station at any moment.

2. The information is reported at the end of each month in the web site.

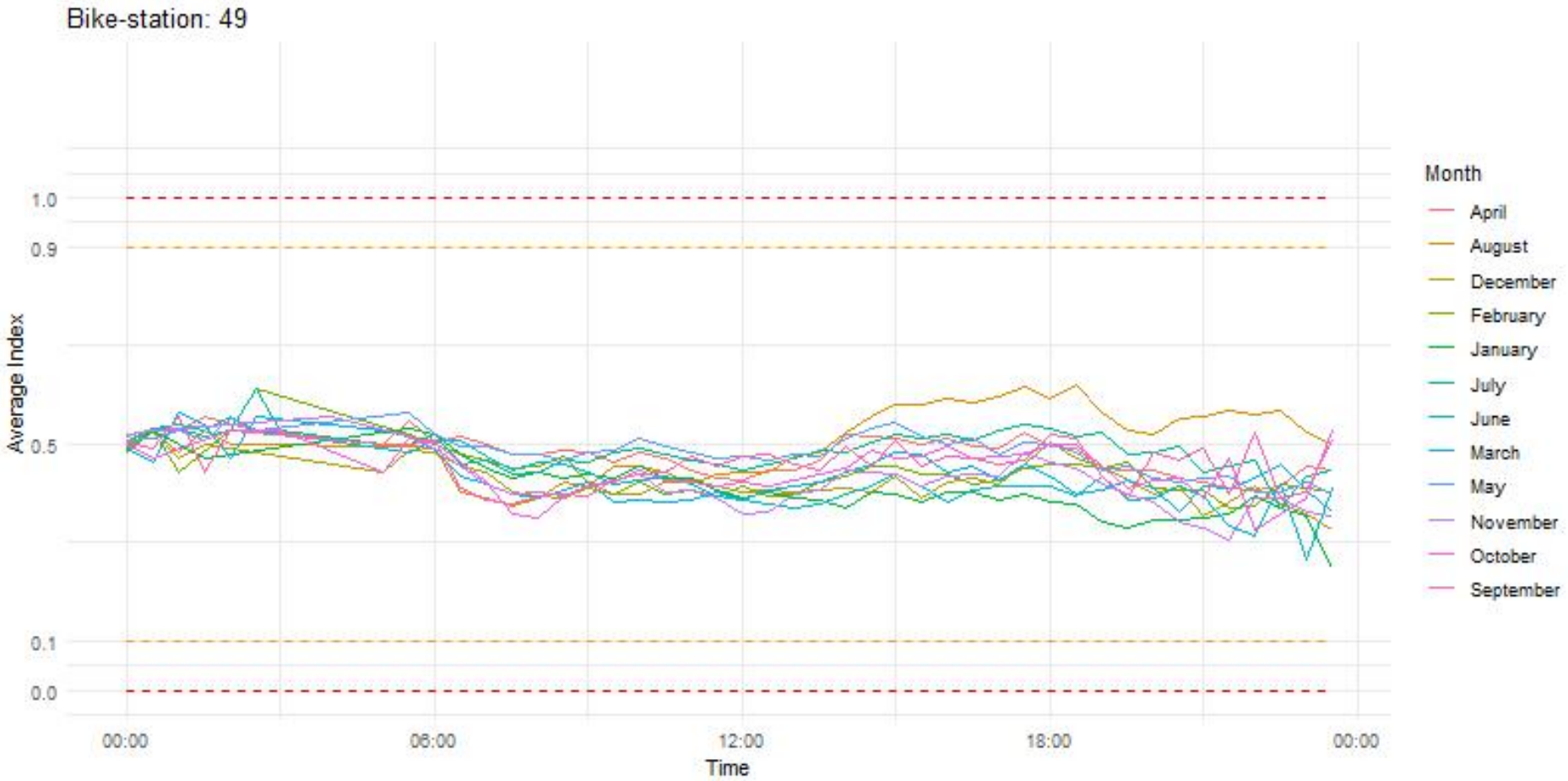
Balancing

To face the problem that the information is reported at the end of each month, we analyzed the historical data to identify certain patterns. For each station c, We analyzed the flow of arrivals minus withdrawals of bikes divided by the total capacity of the station, k, as following:

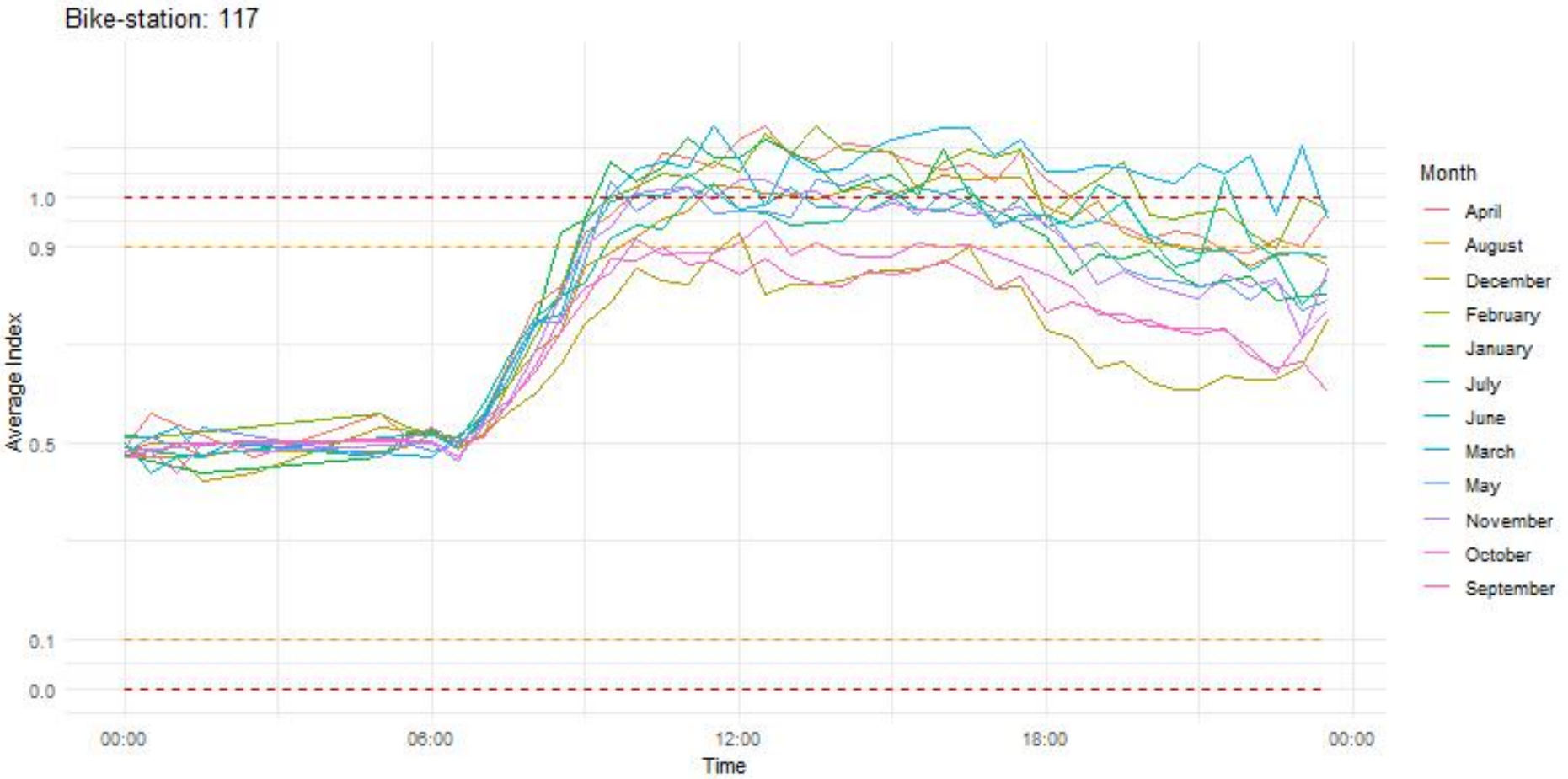
$$I_t^c = \frac{A_t - R_t}{k} + C_0, \tag{1}$$

- A_t are the bike arrivals until time t.
- R_t are the bike withdrawals until time t.
- C_0 is a constant between 0 and 1.

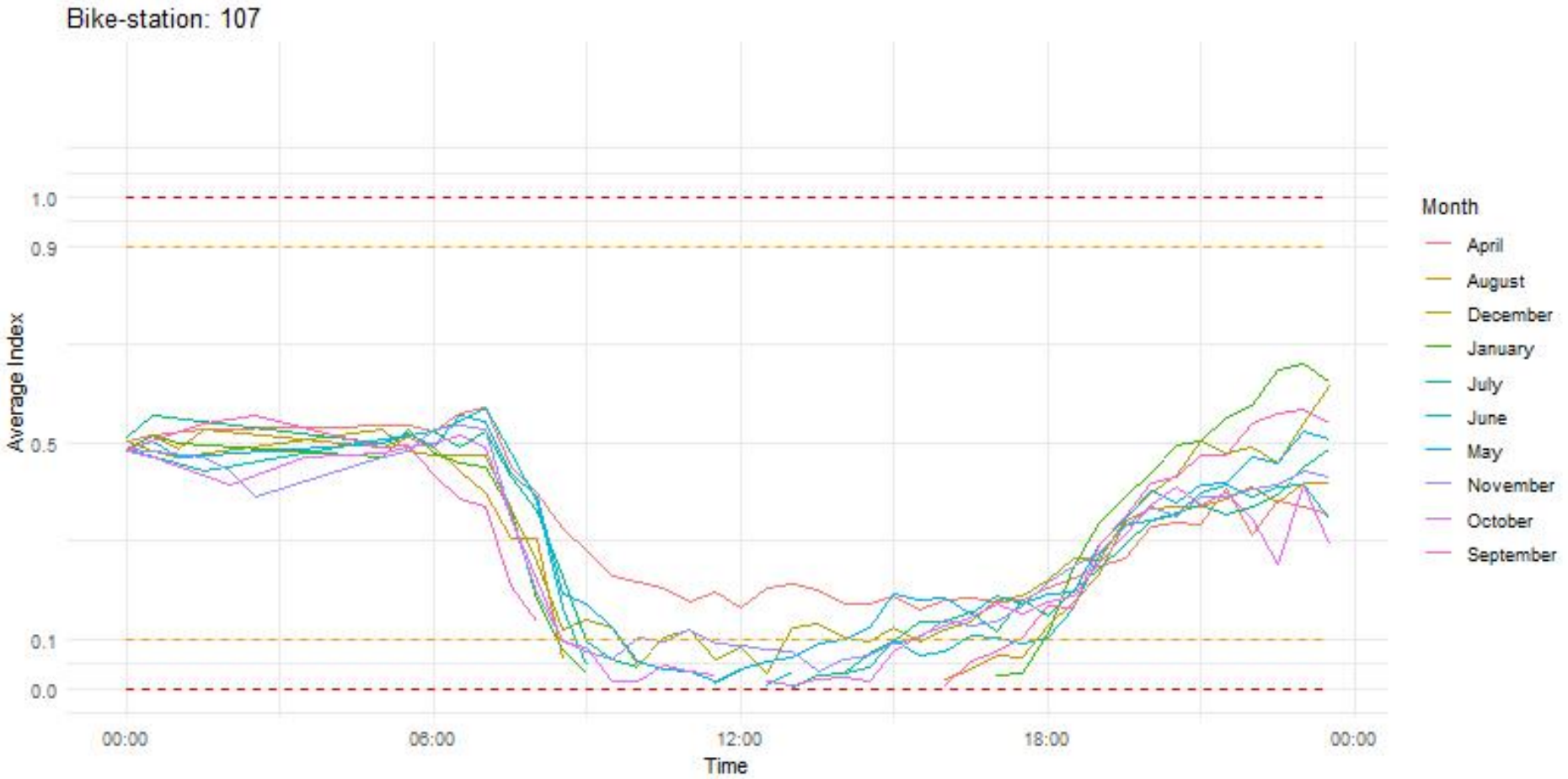
Station Identification // Equilibrium Station



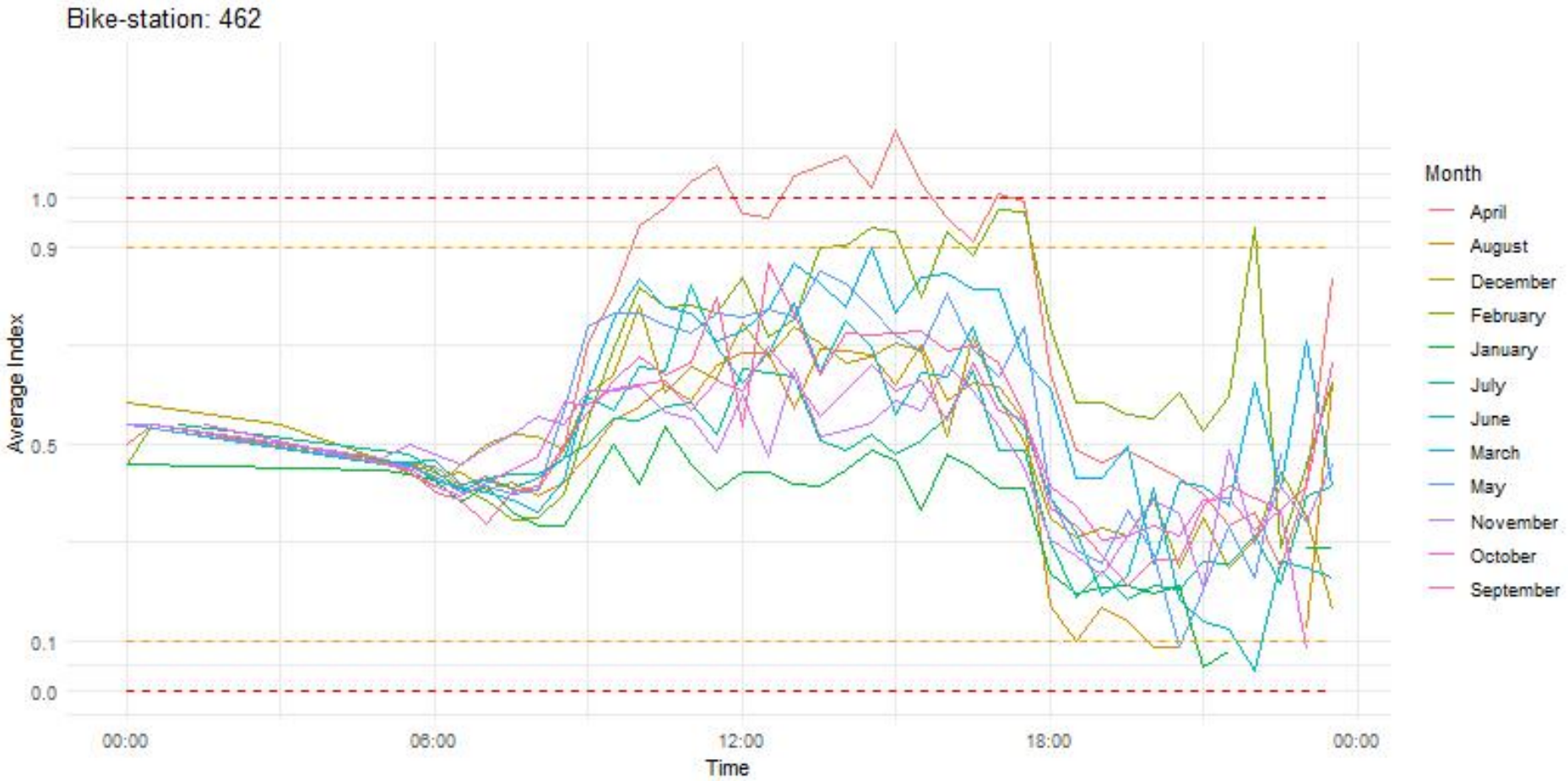
Station Identification // Saturate Station



Station Identification // Empty Station

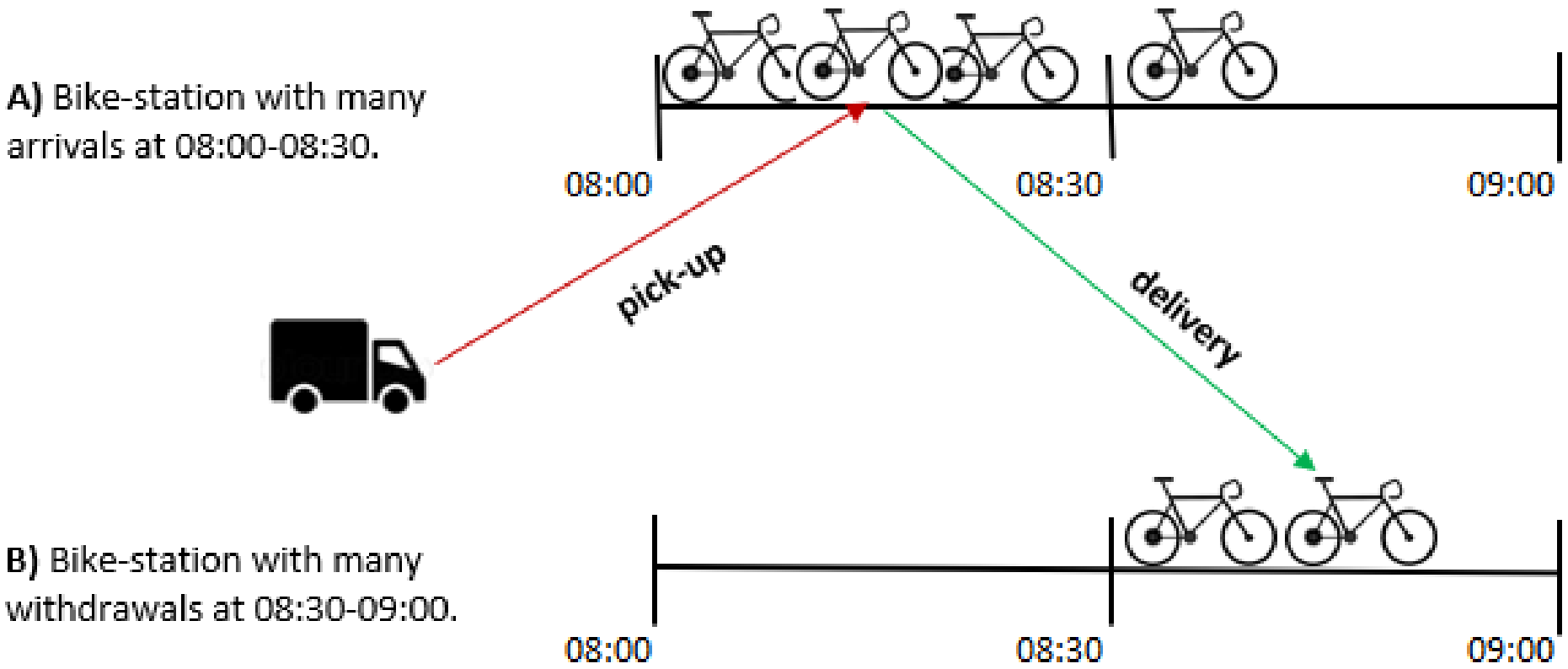


Station Identification // Not a clear pattern

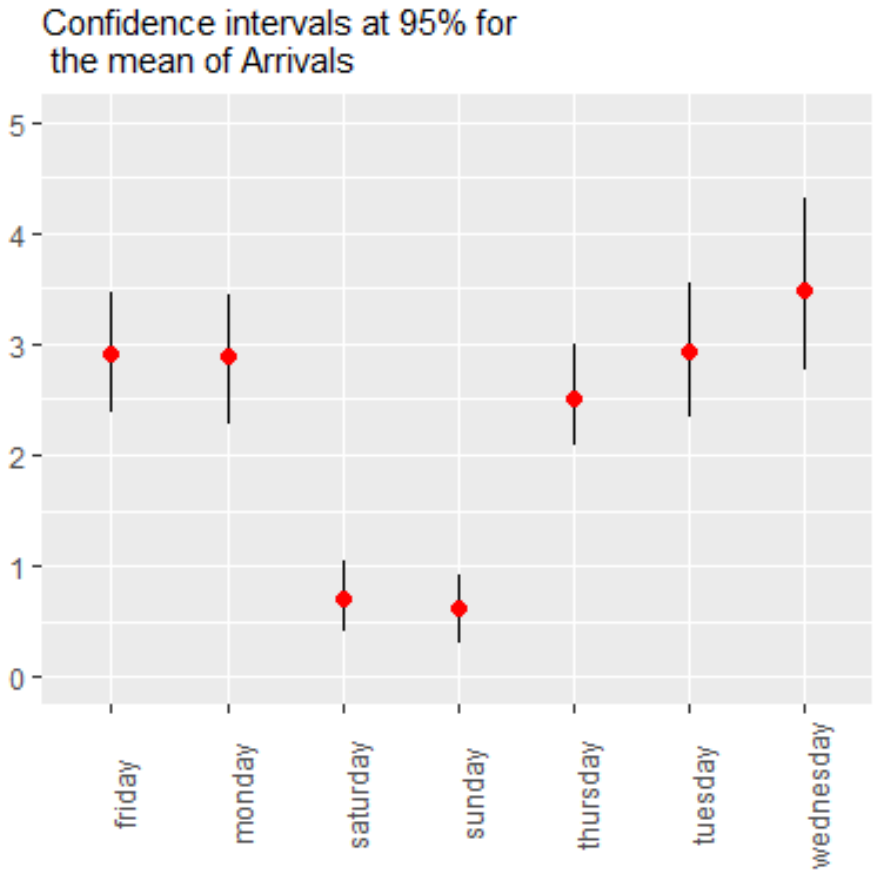


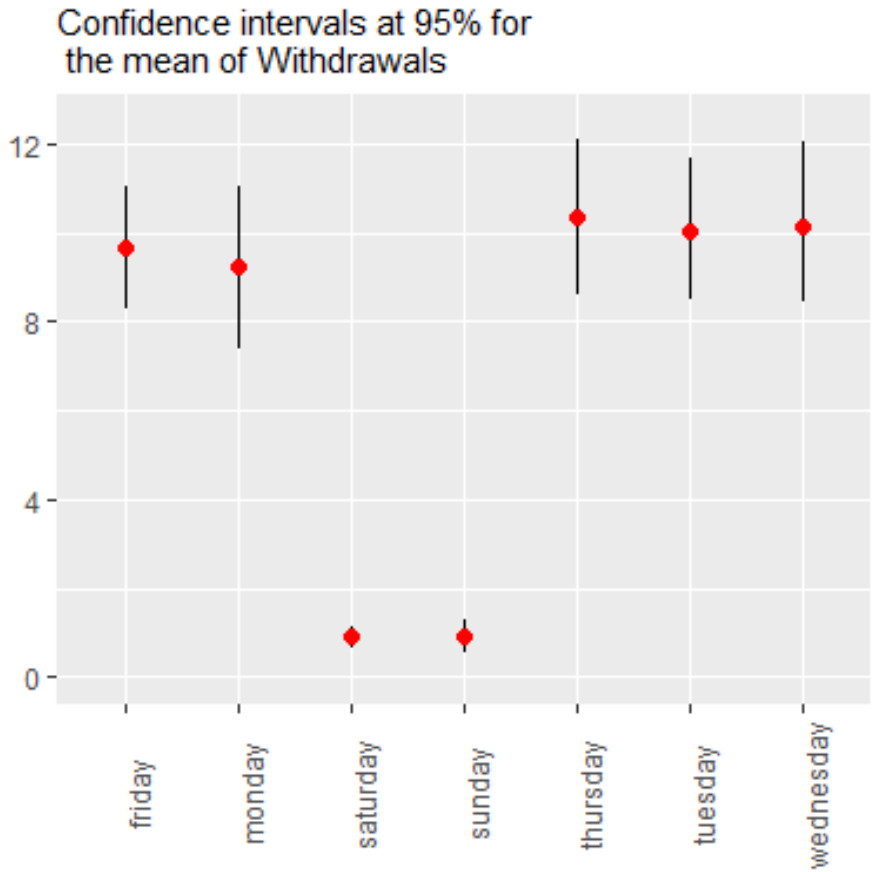
Demand and Supply estimates

We took the average arrivals and withdrawals over a time window of thirty minutes as the estimates of the supply and demand, respectively.

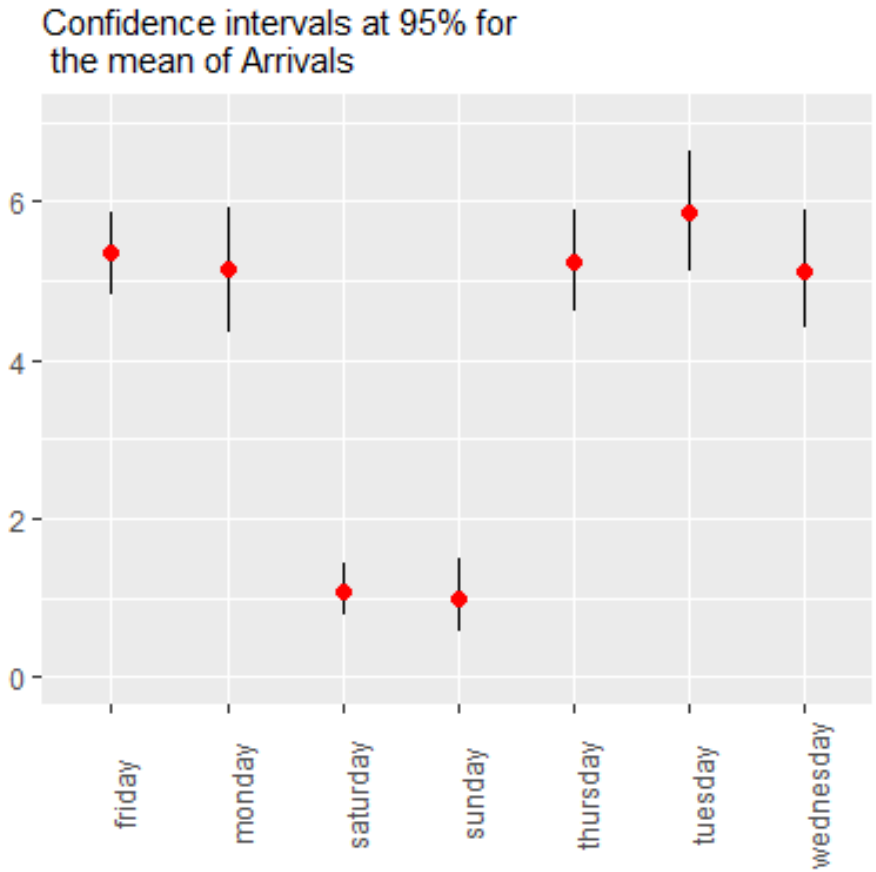


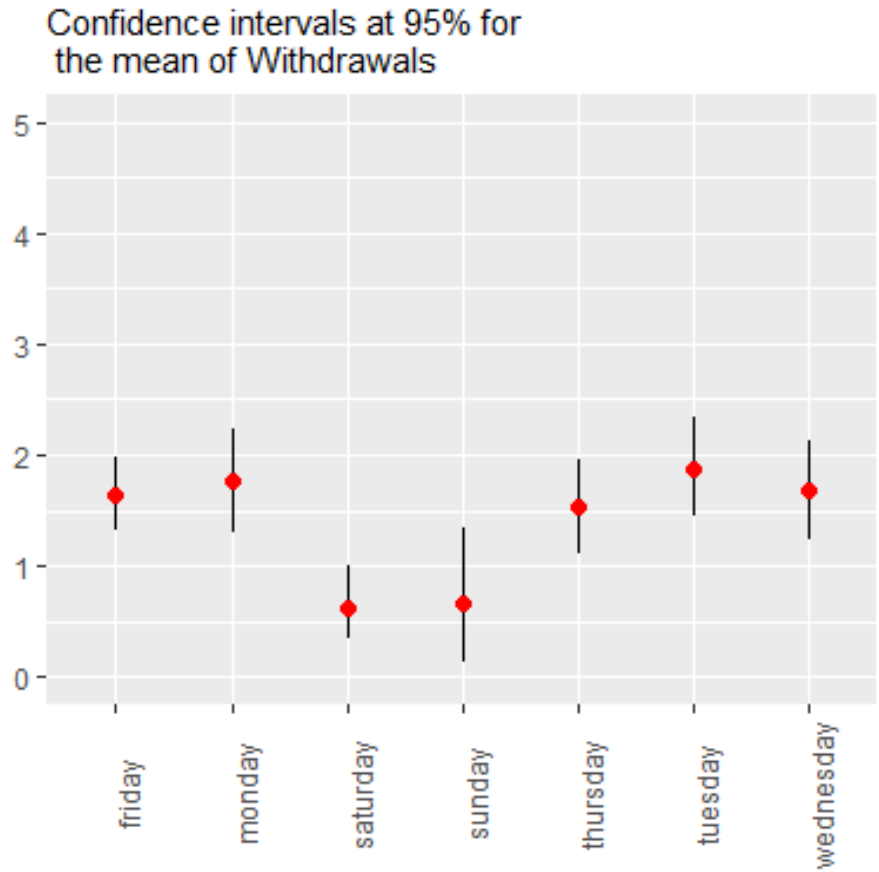
Bootstrap Intervals for station 107





Bootstrap Intervals for station 117





Traveling Salesman Problem

This problem consists of visiting each vertex of a complete graph just once and with the lowest total cost, where the total cost is the sum of the individual costs along the edges of the tour [CLRS09].

$$
\begin{aligned}
TSP = \{&\langle G, c, k\rangle : G = (V, E) \text{ is a complete graph,} \\
&c \text{ is a function from } V \times V \to Z, \\
&k \in Z, \\
&G \text{ has a traveling-salesman tour with cost at most } k\}
\end{aligned}
$$

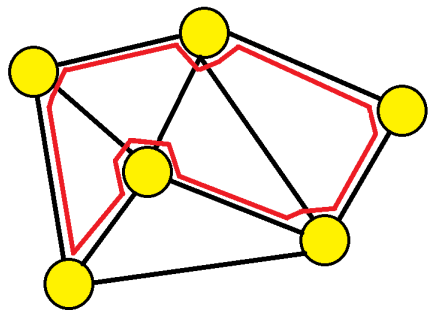
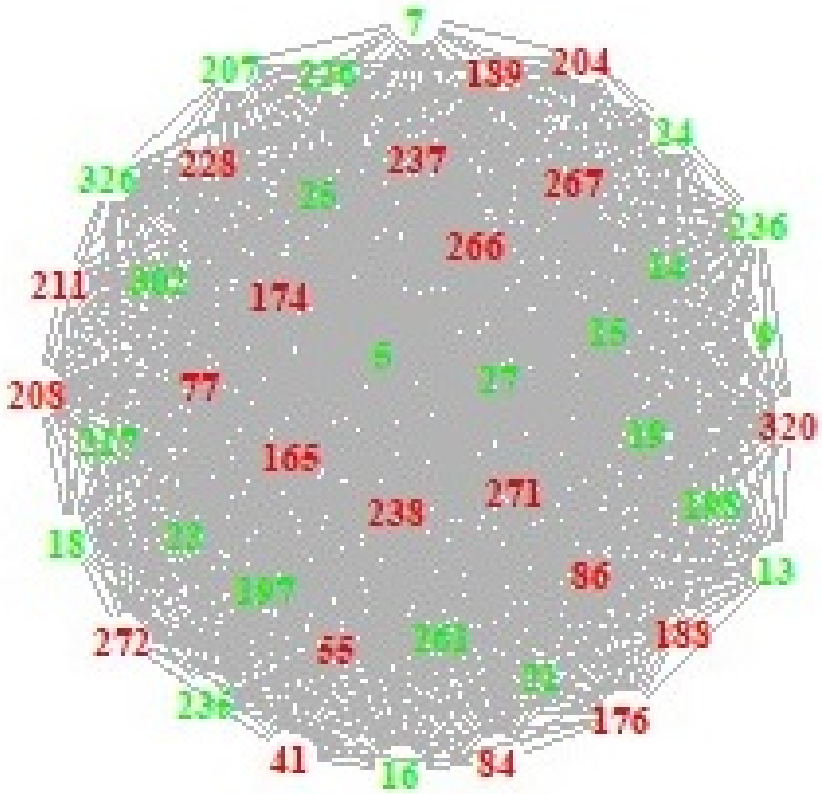
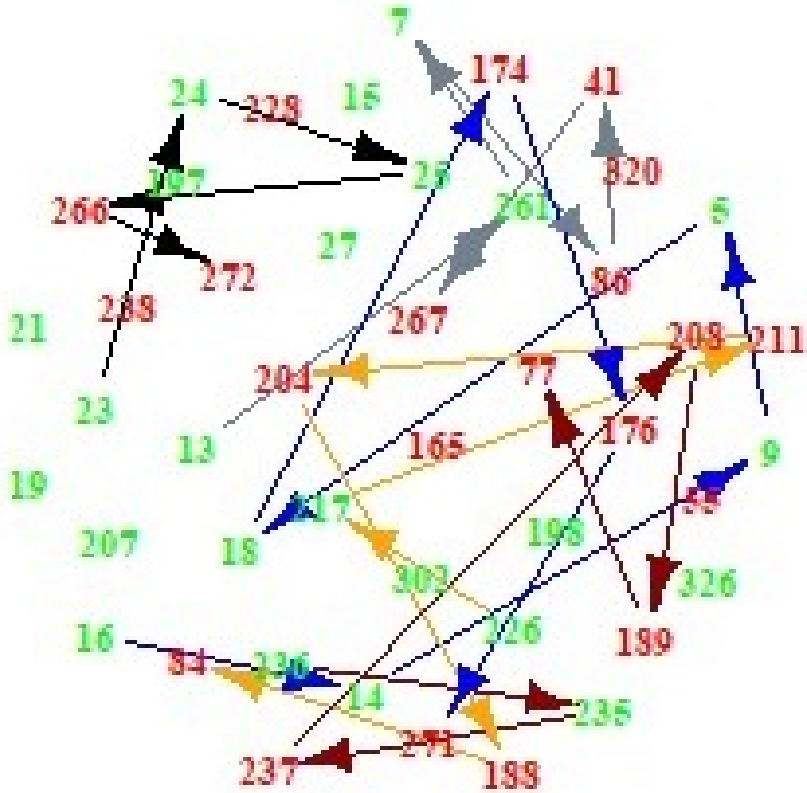


Figure: Source-wikipedia

Balancing exercise at 08:00-09:00





Results 08:00-09:00

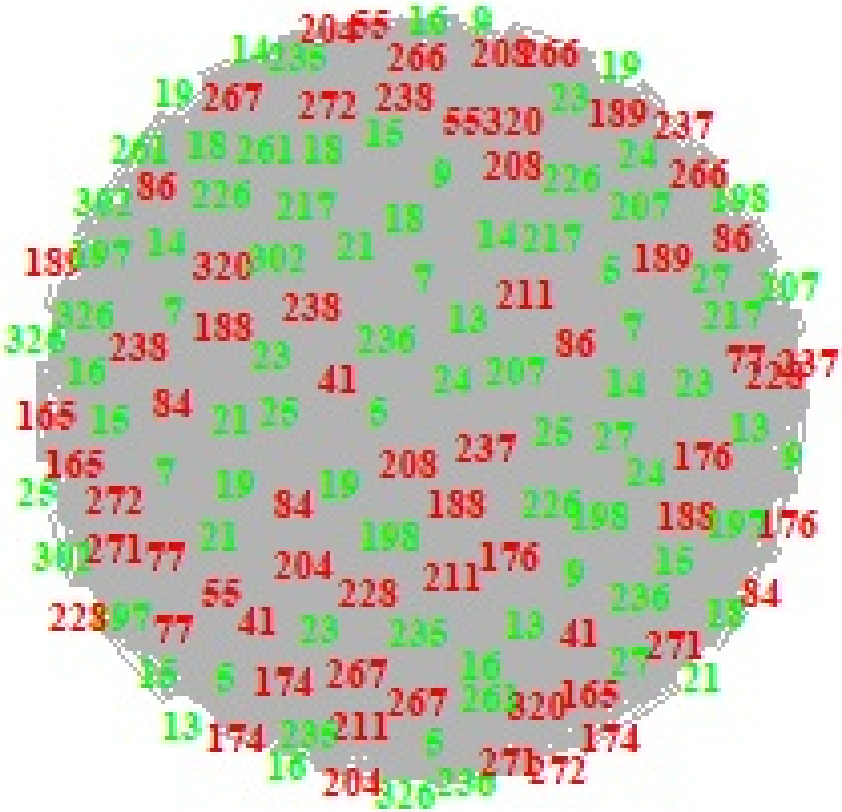
Time	DR	DA	%DA
08:30:00	151	136	90%

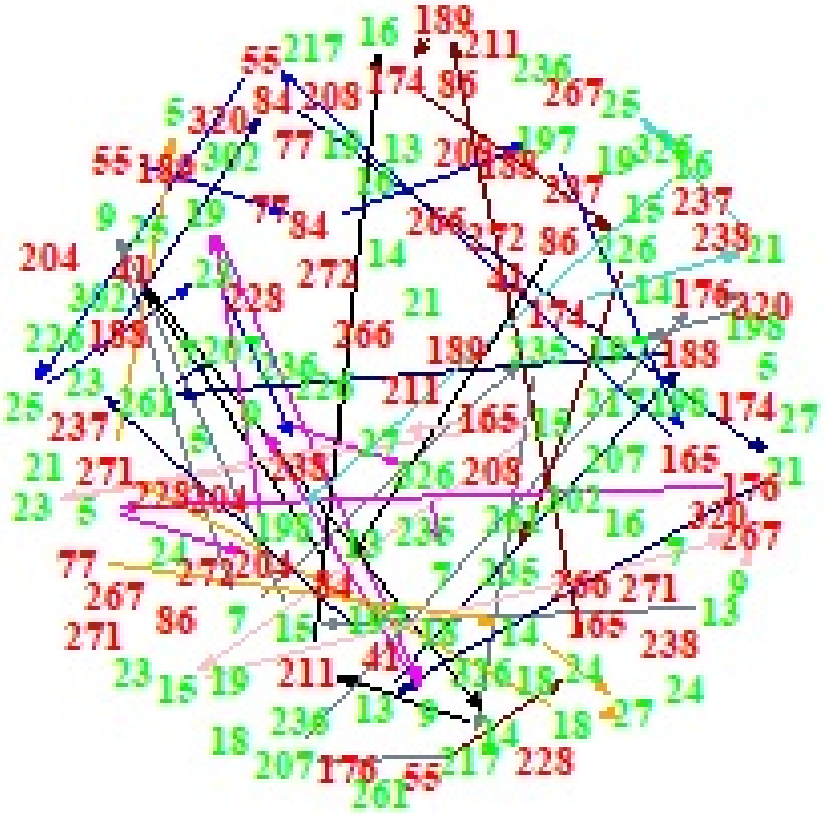
Table: Attended demand

Time	KM	T
$08:00 - 09:00$	6.1	36.6

Table: Average distance and time

Balancing exercise at 18:00-19:00





Results 18:00-19:00

Time	DR	DA	%DA
18:30:00	191	145	75%

Table: Attended demand

Time	KM	T
$18:00 - 19:00$	9.2	55.4

Table: Average distance and time

Conclusions

- The bike systems have generated complex data sets.
- Many areas of interest requires the estimation of the demand and supply of bikes, so is of interest having accurate methods to estimate these quantities.
- The velocity at which a vehicle can move through the city is of interest.

References I

- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, *Introduction to algorithms, third edition*, 3rd ed., The MIT Press, 2009.
- Elliot Fishman, *Bikeshare: A review of recent literature*, Transport Reviews **36** (2016), no. 1, 92–113.
- http://bike sharing.blogspot.com/, *The bike-sharing blog*, 2004.
- https://www.ecobici.cdmx.gob.mx/, *Ecobici*, 2010.
- J. Schuijbroek, R.C. Hampshire, and W.-J. van Hoeve, *Inventory rebalancing and vehicle routing in bike sharing systems*, European Journal of Operational Research **257** (2017), no. 3, 992–1004.

Questions?