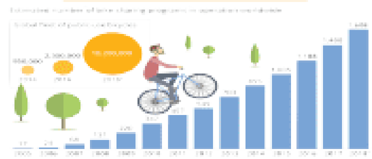
2018-2019 Academic Year

INVENTORY BALANCING AND VEHICLE ROUTING IN BIKE SHARING SYSTEMS

Students: Hasan Hüseyin BİRİNCİ // İbrahim Tümay GÜLBAHAR // Halit YALÇIN
Academic Supervisor: Asst. Prof. Dr. Selçuk GÖREN // Company Supervisor: Muhammed Şafak PINAR
ABDULLAH GÜL UNIVERSITY
DEPARTMENT OF INDUSTRIAL ENGINEERING

MOTIVATION

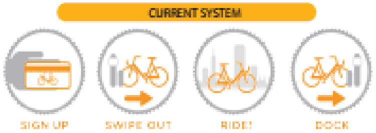


One of the reasons for avoiding the use of public transport in urban transport is the size of the distance between the point of departure and the destination. Services such as buses and trams cannot provide transportation to every corner of the city. This is called the last-mile problem in the literature. In order to solve the problem of the last mile, various projects were implemented in the world. One of these projects is bicycle sharing systems.

Bike sharing systems are becoming more and more widespread in many regions. This system offers cheap and environmentally friendly transportation options for short distances to people. According to citylab.com, the number of bike share bicycles hits an estimated 1,000,000 globally. With nearly 900 bike sharing systems in operation worldwide now, and also usage and performance of bike sharing system is becoming more widely available.

KayBis, is Turkey's first domestic bicycle sharing system that Kayseri Transport Parking and Bike Directorate carried out its activities. Although it does not have a high profit yield, Kayseri Transportation Inc. has provided the KayBis system to the urban people in line with the above-mentioned objectives and is in the process of various improvement and renovation to guarantee the continuity of the system. In this respect, the individuals who want to use the system are identified with a reasonable usage fee and the members can use this special bicycle card to get a bicycle from any station and leave them to any station again after using it in city transportation. After the usage, the person is charged in proportion to the time he/she rented a bike.

CURRENT SYSTEM



51 different stations

More than 400 bicycles

19 hours daily for 8 months

A random relocation

One relocation vehicle with capacity of 20 bikes

PROBLEM DEFINITION

A RANDOM ROUTE with the INITIATIVE

LOSS of USER SATISFACTION

LOSS of TIME

TRANSPORTATION COST

OUT of SERVICE

DATA PREPROCESSING

SEASONAL COSTOMER USAGE NET FLOW MATRIX
51x240(20 hours by 5 min)

51x51
DISTANCE MATRIX

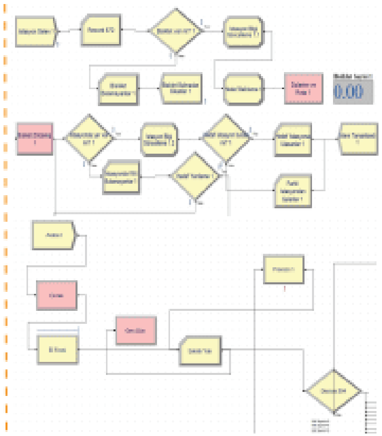
18 MILLION ROWS

8 MONTHS SYSTEM DATA of 2018

102 STATISTICAL DISTRIBUTION

MATLAB, Excel, MS SQL, PYTHON
and ARENA Simulation

SIMULATION MODEL



A Comparison of three safety limits.

Bicycle Number	Safety Number	Number In	Customers Couldn't Find Bicycle	Customers Couldn't Find Bicycle/Number Out
400	[illegible]	[illegible]	[illegible]	[illegible]
400	[illegible]	[illegible]	[illegible]	[illegible]
400	[illegible]	[illegible]	[illegible]	[illegible]

B Bicycle numbers are changed to 300, 480 and 600 with equal safety limits.

Bicycle Number	Safety Number	Number In	Customers Couldn't Find Bicycle	Customers Couldn't Find Empty Slot	Customers Couldn't Find Bicycle/Number Out
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

C Relocating team carries 6 bikes in one run and 8 bikes in one run.

Bicycle Number	Safety Number	Number In	Customers Couldn't Find Bicycle	Customers Couldn't Find Bicycle/Number Out
400	[illegible]	[illegible]	[illegible]	[illegible]
400	[illegible]	[illegible]	[illegible]	[illegible]

Location of 51 stations around the city are seen below.

SYSTEM-ON MATHEMATICAL MODELLING

Sets

S	station;	$S = \{1, 2, 3 \ldots 49, 50, 51\}$ $i, j \in S$
T	time period;	$t = \{1, 2, 3 \ldots 238, 239, 240\}$ $t, v \in T$

Data

C_{ij} Distance between station 'i' and station 'j' (meter)

RT_{ij} Required time in order to travel from station 'i' to station 'j' (Time Period, t)

DS_{it} The difference between the coming and leaving number of bikes on station 'i' at time 't', station NetFlow (Bicycles)

Cap_i Bike capacity of station 'i'

Decision Variables

L_t Load on vehicle at time period 't'

P_{jit} Number of bikes leaved from station 'j' to station 'i' at time period 't'

R_{ijt} Number of bikes taken from station 'i' to station 'j' at time period 't'

S_{it} Load on station at time period 't'

X_{ijt} $\begin{cases} 1, \text{ if vehicle has left the station '}i\text{' at time '}t\text{' in order to arrive at station '}j\text{'} \\ 0, \text{ otherwise} \end{cases}$

Y_{ijv} $\begin{cases} 1, \text{ if vehicle that has left from station '}i\text{' entered the station '}j\text{' at time '}v\text{'} \\ 0, \text{ otherwise} \end{cases}$

Formulation

$$Minimize\ z = \sum_i \sum_j \sum_t (X_{ijt} C_{ij}) - \sum_i \sum_j \sum_t (X_{ijt} DS_{it} - X_{ij(t+RT_{ij})} DS_{i(t+RT_{ij})})$$

The objective function tries to lower the transportation cost of the vehicle while trying to maximize the number of bicycles taken and left at each trip

Subject to;

Constraint -1 $\sum_i \sum_j X_{ijt} \leq 1$ $\forall t$

This constraint ensures that maximum 1 travel order can be placed at a time period t

Constraint -2 $X_{ijt} = Y_{ij(t+RT_{ij})}$ $\forall i, j, t$

This constraint provides that the vehicle that has left donor station will enter to the destination station after a certain amount of time

Constraint -3 $\sum_i \sum_j Y_{ijt} \leq 1$ $\forall t$

This constraint ensures that maximum one vehicle can be received at a time period t

Constraint -4 $X_{iit} = 0$ $\forall i, t$

This constraint eliminates for the station to be donor and receiver at the same time

Constraint -5 $\sum_j X_{ijt} = \sum_j Y_{jit}$ $\forall i, t$

This constraint ensures that if the vehicle has entered a station j at time t, there will be an outgoing trip from station j at time t

Constraint -6 $R_{ijt} \leq 20X_{ijt}$ $\forall i, j, t$

This constraint ensures that the vehicle can take at most 20 bikes for relocation from station i to station j at time t

Constraint -7 $P_{jit} \leq 20Y_{jit}$ $\forall i, j, t$

This constraint ensures that the vehicle can leave at most 20 bikes for relocation from station j to station i at time t

Constraint -8 $R_{ijt} \geq 0$ $\forall i, j, t$

This constraint ensures that the taken value by vehicle cannot be negative station i to station j at time t

Constraint -9 $P_{jit} \geq 0$ $\forall i, j, t$

This constraint ensures that the left value by vehicle cannot be negative station j to station i at time t

Constraint -10 $L_1 = R_{ij1} - P_{ji1}$ $\forall i, j$

This constraint ensures that the number of bikes on the vehicle at the first time period must be equal to difference between taken and left bikes

Constraint -11 $\sum_i S_{i1} = 400$

This constraint ensures that the number of bikes on all stations at the first time is equal to 400

Constraint -12 $S_{it} \geq 0$ $\forall i, t$

This constraint ensures that the number of bikes at station i cannot be negative at any time

Constraint -13 $S_{it} \leq Cap_i$ $\forall i, t$

This constraint ensures that the number of bikes at station i cannot be more than capacity of station i

Constraint -14 $L_t = L_{(t-1)} - \sum_i \sum_j P_{jit} + \sum_i \sum_j R_{ijt}$ $\forall t \in T/\{1\}$

This constraint ensures that the number of bikes on the vehicle at time t must be equal to number of bikes on the vehicle at time t-1, difference between taken and left bikes at time t

Constraint -15 $S_{it} = S_{i,t-1} + DS_{i,t} + \sum_i \sum_j P_{jit} - \sum_i \sum_j R_{ijt}$ $\forall i, t \in T/\{1\}$

This constraint ensures that the number of bikes at station i at time t equals to number of bikes at station i at time t-1, difference between taken and left bikes at time t, and NetFlow at time t

Constraint -16 $\sum_i \sum_j X_{ij1} = 1$

This constraint ensures that at the first time period relocation operation starts

Constraint -17 $\sum_i \sum_j Y_{ij240} = 1$

This constraint ensures that at the last time period relocation operation finishes

RESULTS and CONCLUSION

Stations \ Time Periods	1	3	7	15	30	42	56	60	67	81	98	11	124	131	137	151	165	181	197	211	224	240
2																						
4																						
6																						
7																						
14																						
15																						
19																						
20																						
21																						
22																						
43																						
47																						
48																						
50																						
Load	5	8	13	15	13	14	15	13	11	13	12	10	15	14	13	10	12	14	15	16	13	11

It is indicated by the arrows above the movement of the relocation vehicle route. There are stations in the lines and time intervals in the columns. The table shows the current cycling numbers, station and time intervals. As can be seen from the results, some stations are experiencing density. During ARENA simulation, stations with customers who can't find bicycles match the results of the optimization work. It will be suggested that Kayseri Ulasim AS would increase the number of lockouts at the stations where there is density as project output.

INDUSTRIAL ENGINEERING
KAYSERI ULAŞIM
YAEM 2019
TÜBİTAK