Strategic Planning for Shared Mobility Systems

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Overview

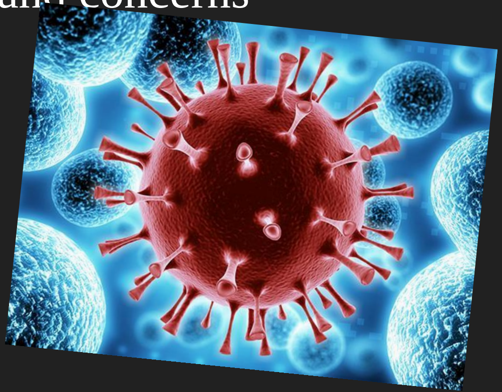
- ❖ Introduction
- ❖ Aim and Objective
- ❖ Problem description
- ❖ Literature review
- ❖ Model formulation
- ❖ Illustrative example
- ❖ Result analysis
- ❖ Limitations
- ❖ Conclusion

Introduction

❖ History

❖ Current situation and Bike-Sharing System

❖ Necessity and concerns



Aim

- ❖ Increase the modal share of cycling as a relevant mode of everyday transport
- ❖ Minimizing cost
- ❖ Efficient facility design depending on access to the stations

Objective

- ❖ Minimizing users total travel time
- ❖ Investment budget constraints
- ❖ Service access
- ❖ Avoiding costly redistribution

Problem Description

- ❖ Minimizing the total travel time of all users
- ❖ Providing sufficient service access
- ❖ Investmentment budget
- ❖ Constructing bike stations in urban areas
- ❖ User’s travel time deconstruction

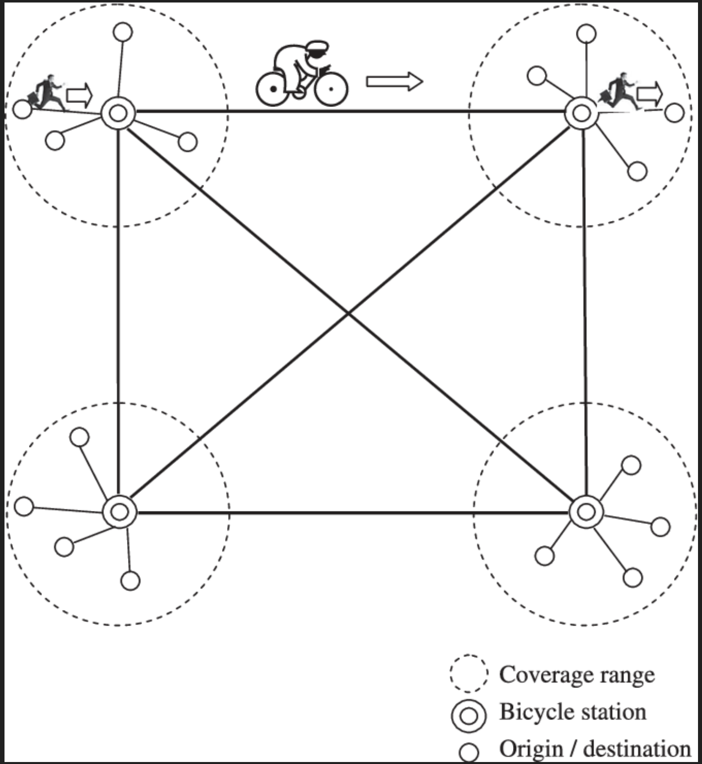
Literature Review

1. Hub location model with performance constraints (Lin and Yang, 2011)
2. Bike fleet size which minimizes simultaneously unmet demand (Sayarshad et al., 2012)
3. User demand, investment and different schemes (Martinez et al., 2012)
4. Minimization of total travel time or the total length of the journey (Chen and Sun, 2015)
5. Cluster concept and greedy heuristic (Guo et al., 2014)
6. Maximizing the coverage of user demand or minimizing the unmet demand (García-Palomares et al., 2012)

Model Formulation Design

Related assumptions:

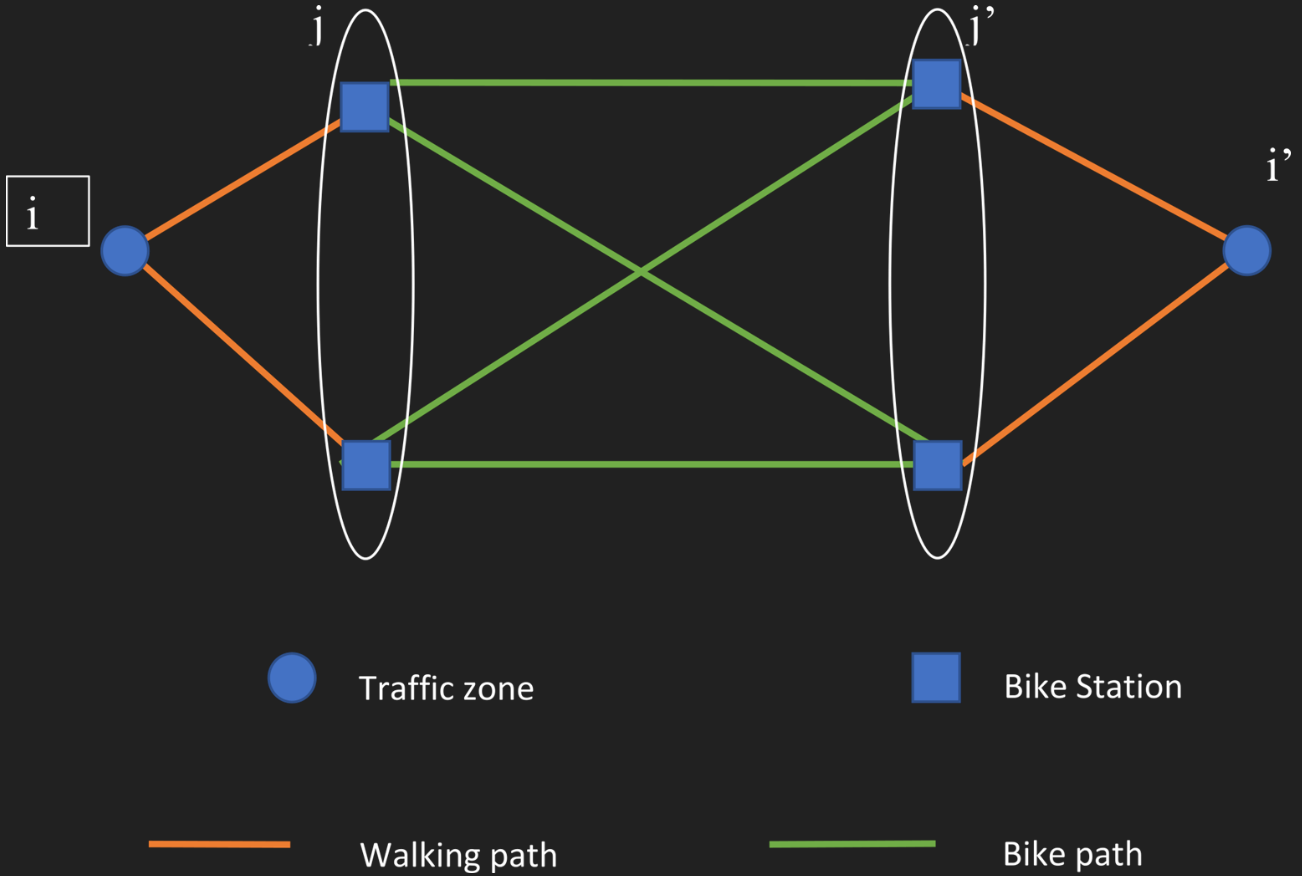
- User knows the distance and inventory of the nearest bike station
- Bike traffic is within a day's rush hours
- Replenishment once a day before morning peak
- Users use shortest path



Layout Design

Bicycles are secured at the Stations

Model Formulation



Model Formulation

Objective function:

$$m\varphi = \sum_{k \in k} \sum_{i \in I} \sum_{i' \in I} \left(\frac{\sum_{j \epsilon J} B_{i,j,i',k} \cdot d_{i,j}}{u_2} + \frac{\sum_{j \epsilon J} \sum_{j' \epsilon J} E_{i,j,j',k} \cdot d_{j,j'}}{u_2} + \frac{\sum_{j' \epsilon J} R_{i,j',k} \cdot d_{i',j}}{u_1} \right) = 199{,}517$$

Model Formulation

s.t

$$a_{i,j} = \begin{cases} 1, d_{i,j} \leq C \\ 0, d_{i,j} \leq C \end{cases} \forall i \in I, \forall j \in J \tag{1}$$

Defines a 0–1 matrix, which ensures that a given traffic zone can only be served by bike stations within the maximum walking distance

2

$$\sum_{j \in J} g_j y_j + f_1 \sum_{j \in J} Z_j y_j + f_2 \sum_{j \in J} T_j y_j \leq H$$

Ensures that the sum of fixed costs of bike stations, purchasing costs of bikes, and installment costs of parking lockers does not exceed the total investment budget.

Model Formulation

s.t

$$P_{j,k} = V_{j,k} + \sum_{i \in I} \sum_{i' \in I} R_{i',j,i,k} \quad \forall j \in J, \forall k \in K \qquad 3$$

Number of bikes that bike station j can provide during period k , and equals the number of bikes present at bike station j at the beginning of period k plus the number of bikes returned to this station j during this period k .

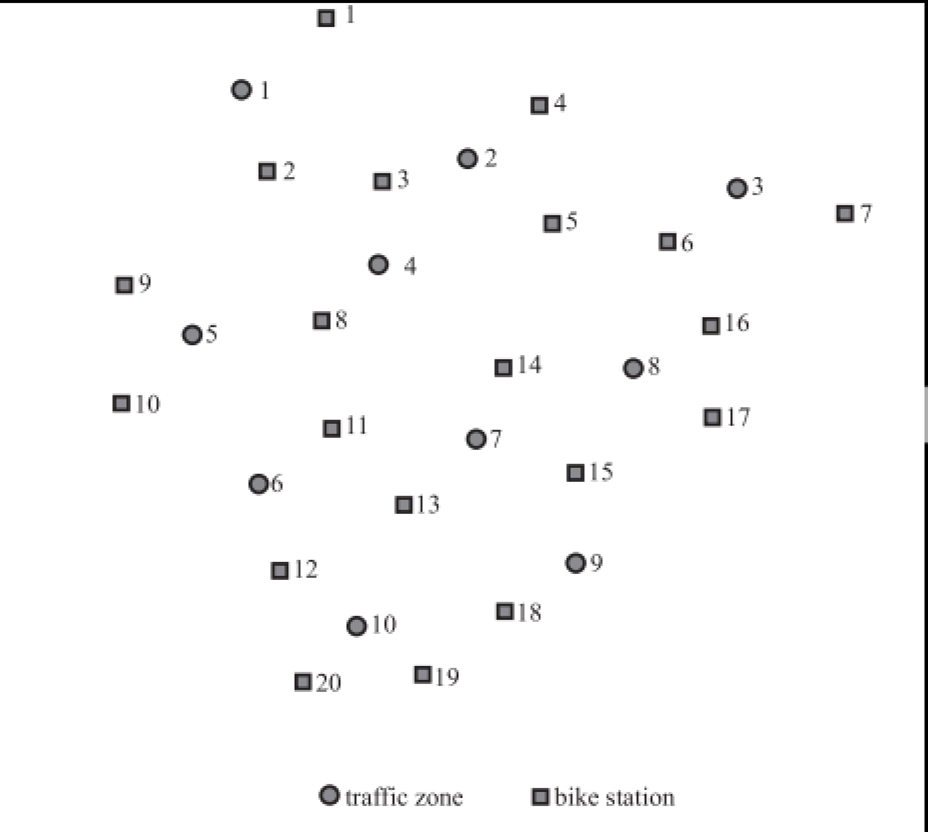
$$Z_j \geq \alpha \cdot y_j \qquad \forall j \in J \qquad 4$$

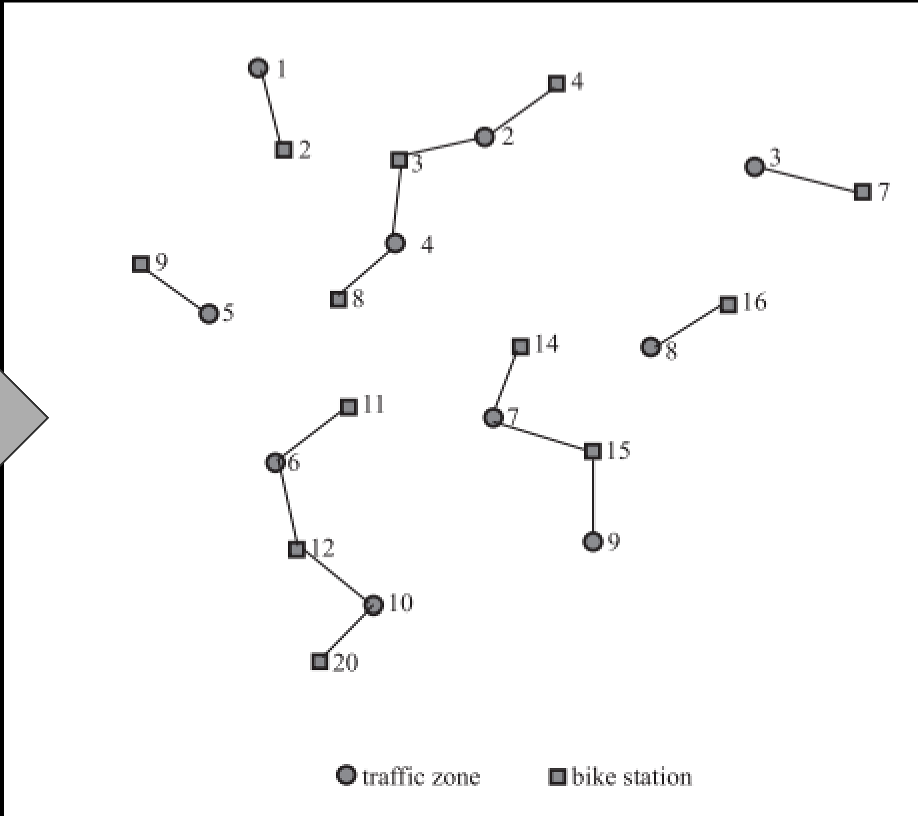
Places a limit on the minimum number of bikes present at each selected bike station at the beginning of operation periods K.

Result

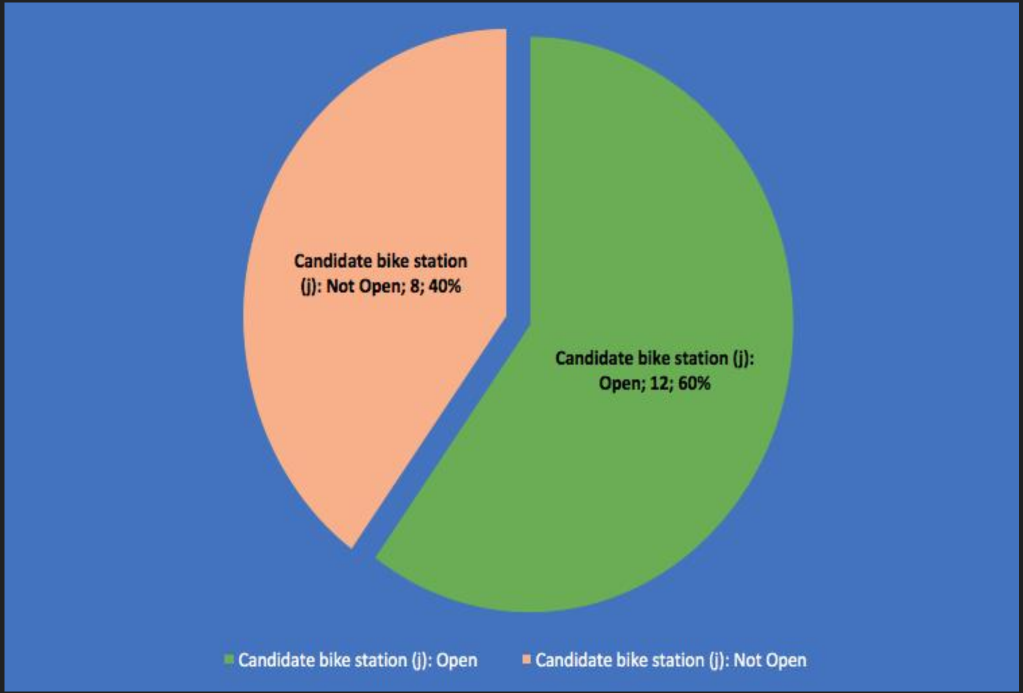
- Based on candidate bike station and traffic zone (distance) and maximum walking distance(C)
- Twelve bike stations selected out of Twenty candidate bike station by using LINGO solver.

Selected bike stations





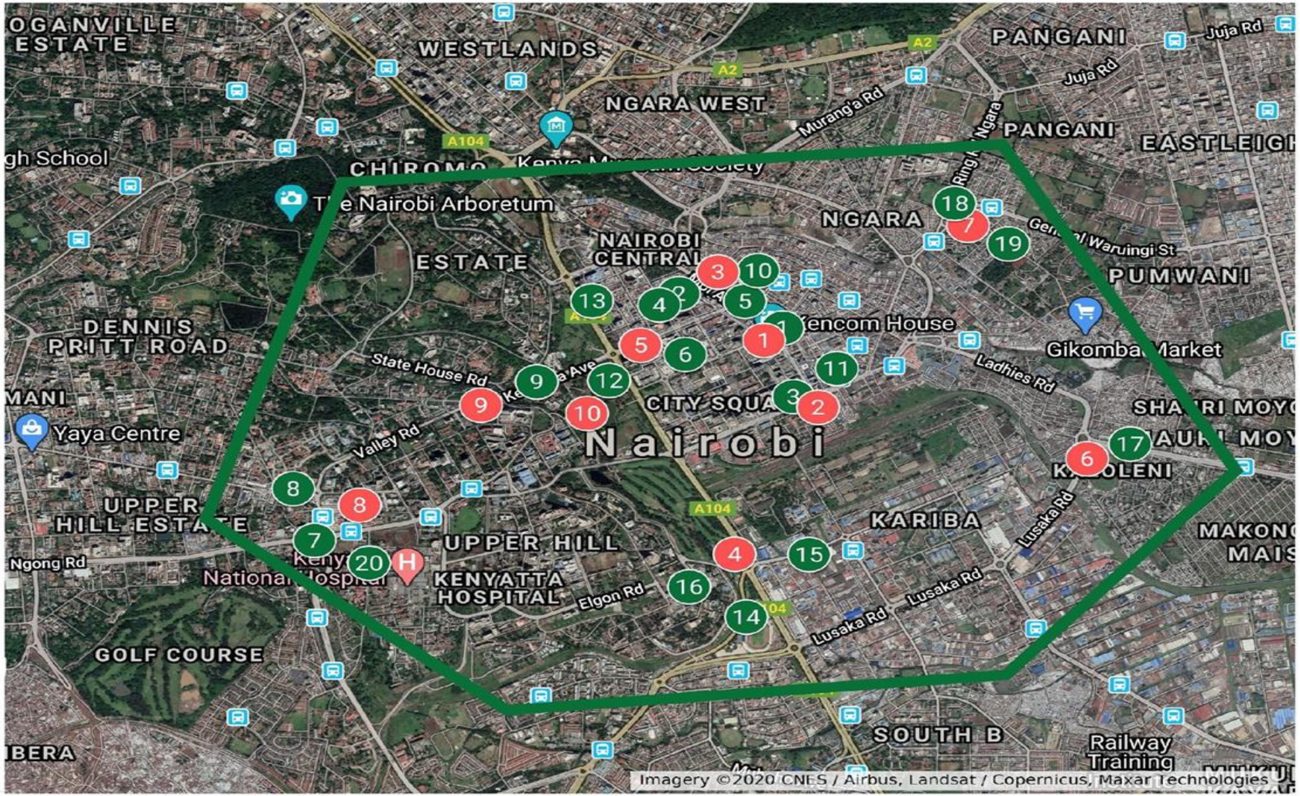
Bike station location decision



BSS

Bike stations

1 Kenya National Archives
2 Jamia mall
3 Cooperative House
4 City Market
5 Imenti House
6 City Hall Annex
7 city Mortuary
8 Hurlingham
9 Serena
10 River rd.
11 Bus Station
12 Uhuru park
13 University
14 Nyayo
15 Baricho rd
16 NTSA
17 City stadium
18 Kariokor Market
19 Pumwani
20 KNH
Border



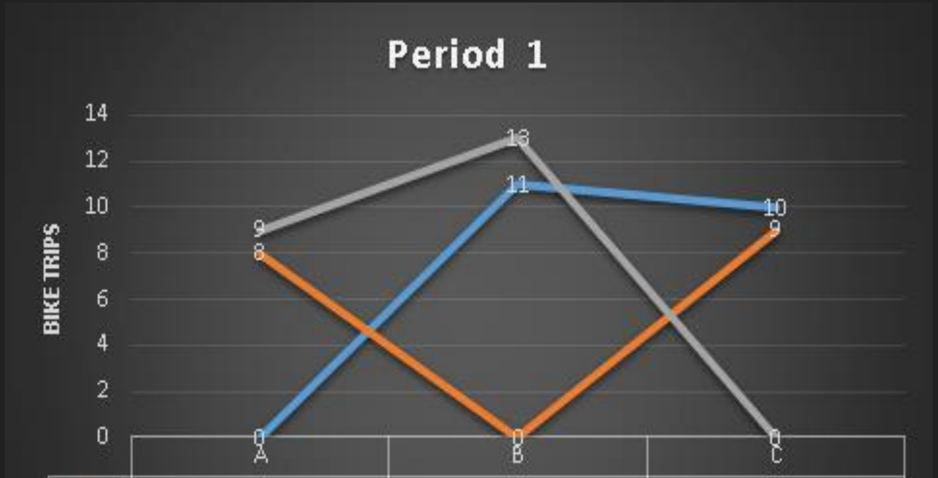
Traffic Zones

1 Kencom/Ambassadeur

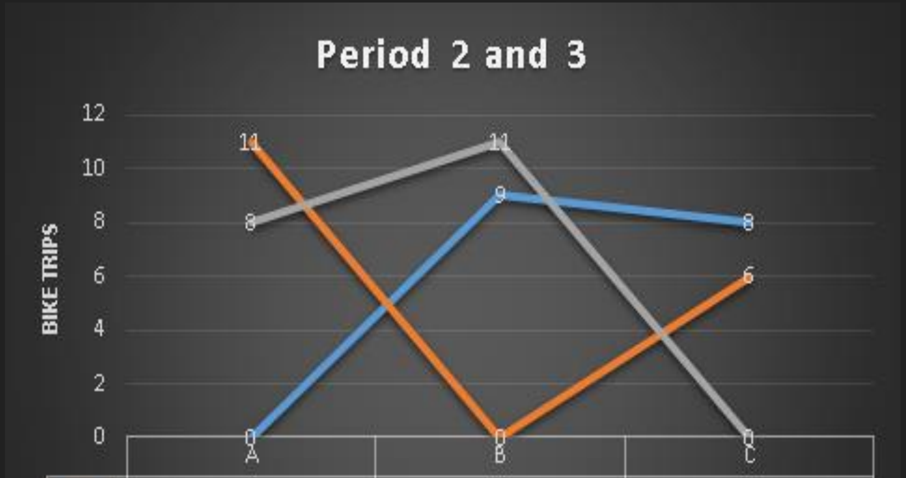
Illustrative Example (AMPL Experiment)

Input Parameters	Values
C	400m
gj	$70 000
f1	$700
u1	1.4m/s
M	10 000
$\boldsymbol{\alpha}$	15
f2	$4000
u2	5 m/s
H	$2 000 000

Illustrative Example(AMPL Experiment)

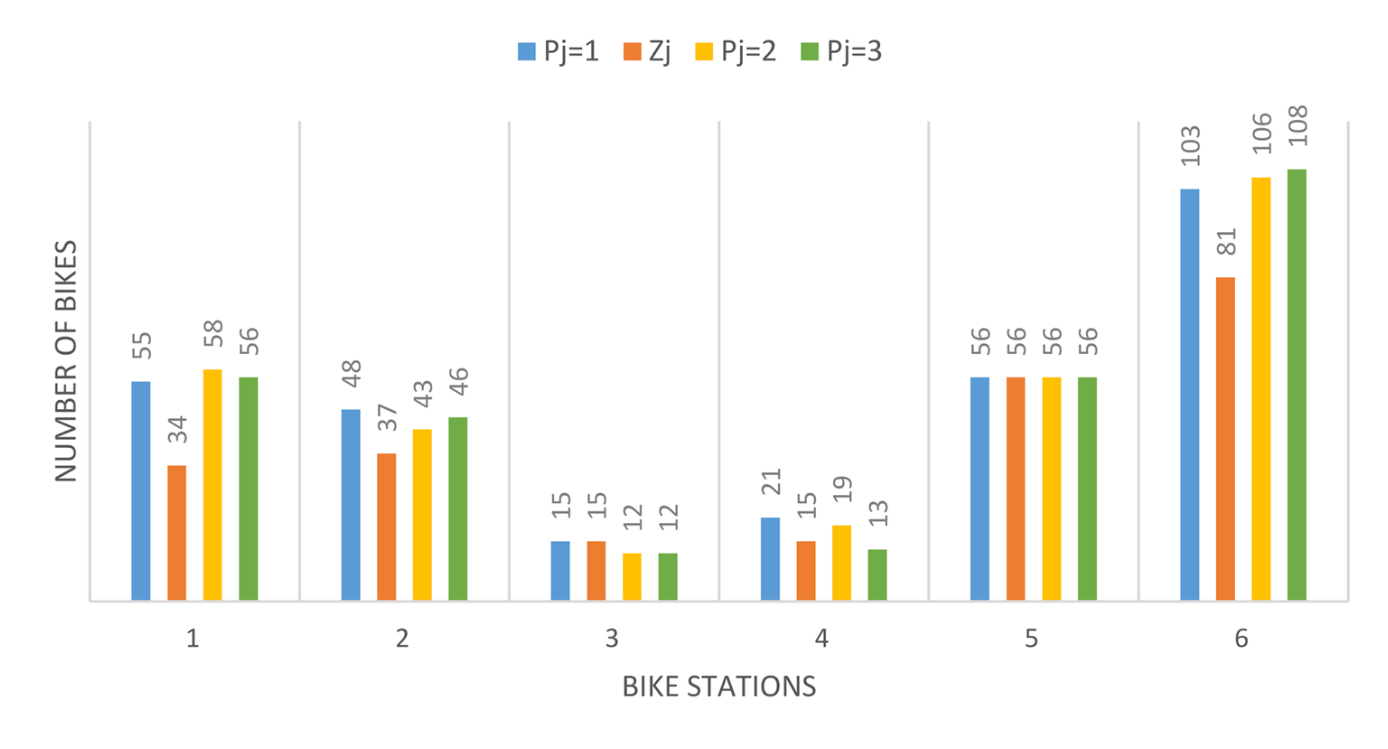


	A	B	C
A	0	11	10
B	8	0	9
C	9	13	0



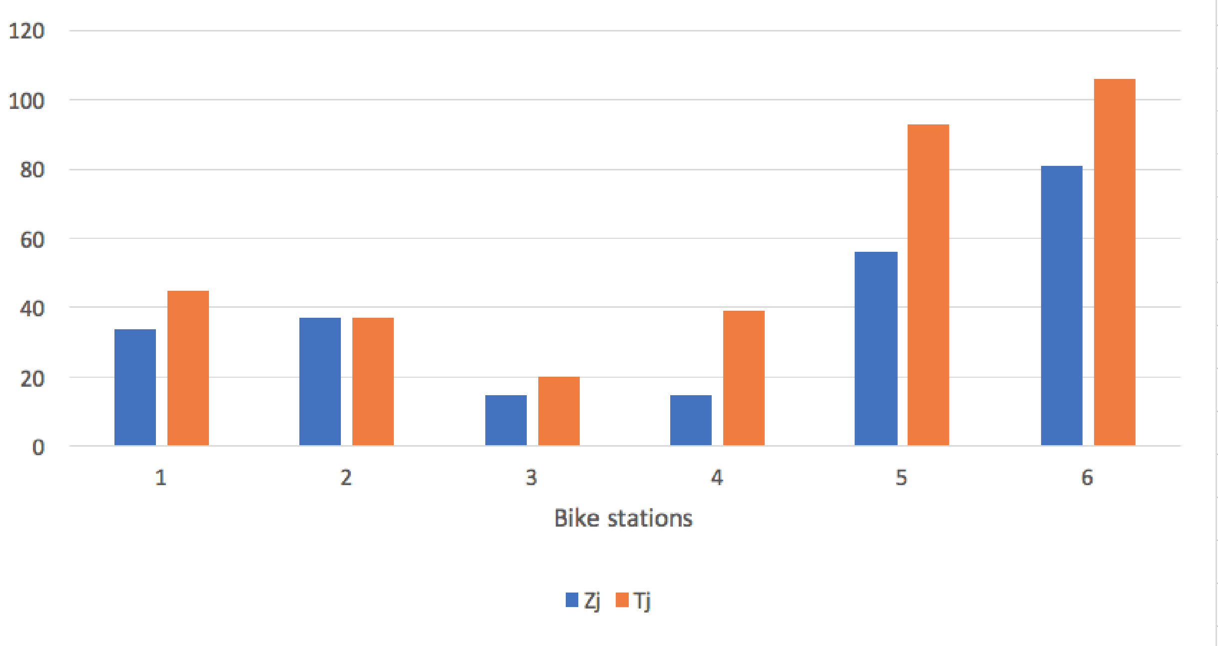
	A	B	C
A	0	9	8
B	11	0	6
C	8	11	0

Illustrative Example (AMPL Experiment)



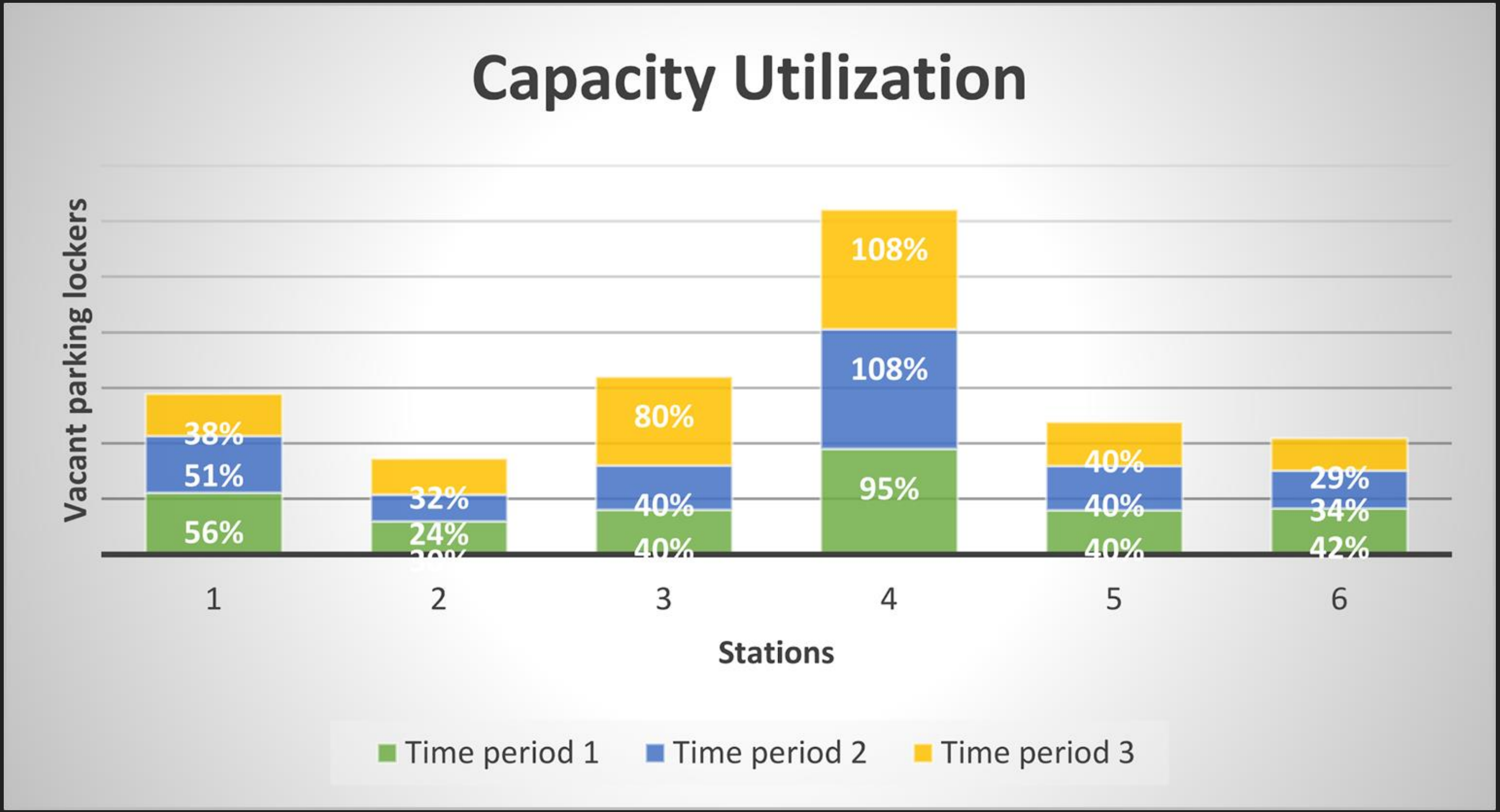
Number of bikes that a bikes a station can provide compared to the number of bikes and lockers of a station at the beginning of operation

Illustrative Example (AMPL Experiment)



The number of bikes present at the beginning of operation periods and the number of parking lockers equipped at each bike station.

Illustrative Example(AMPL Experiment)



Illustrative Example (Experiment)

Origin Zone A	Origin Zone B	Origin Zone C
$E_{A,1,2,B,1} = 2$	$E_{B,2,1,A,1} = 11$	$E_{C,6,1,A.1} = 10$
$E_{A,1,4,B,1} = 6$	$E_{B,2,1,A,2} = 9$	$E_{C,6,1,A.2} = 8$
$E_{A,1,4,B,2} = 11$	$E_{B,2,1,A,3} = 9$	$E_{C,6,1,A.3} = 8$
$E_{A,1,2,B,3} = 6$	$E_{B,4,6,C,1} = 13$	$E_{C,6,2,B,1} = 9$
$E_{A1,4,B,3} = 5$	$E_{B,4,6,C,2} = 11$	$E_{C,6,2,B,2} = 6$
$E_{A,1,6,C,1} = 6$	$E_{B,4,6,C,3} = 11$	$E_{C,6,2,B,3} = 6$
$E_{A,3,6,C,1} = 3$		
$E_{A,1,6,C,2} = 8$		
$E_{A,3,6,C,3} = 8$		

Table VII.Choices for Rental stations and travel routes of users

AMPLE CODE

AMPL IDE

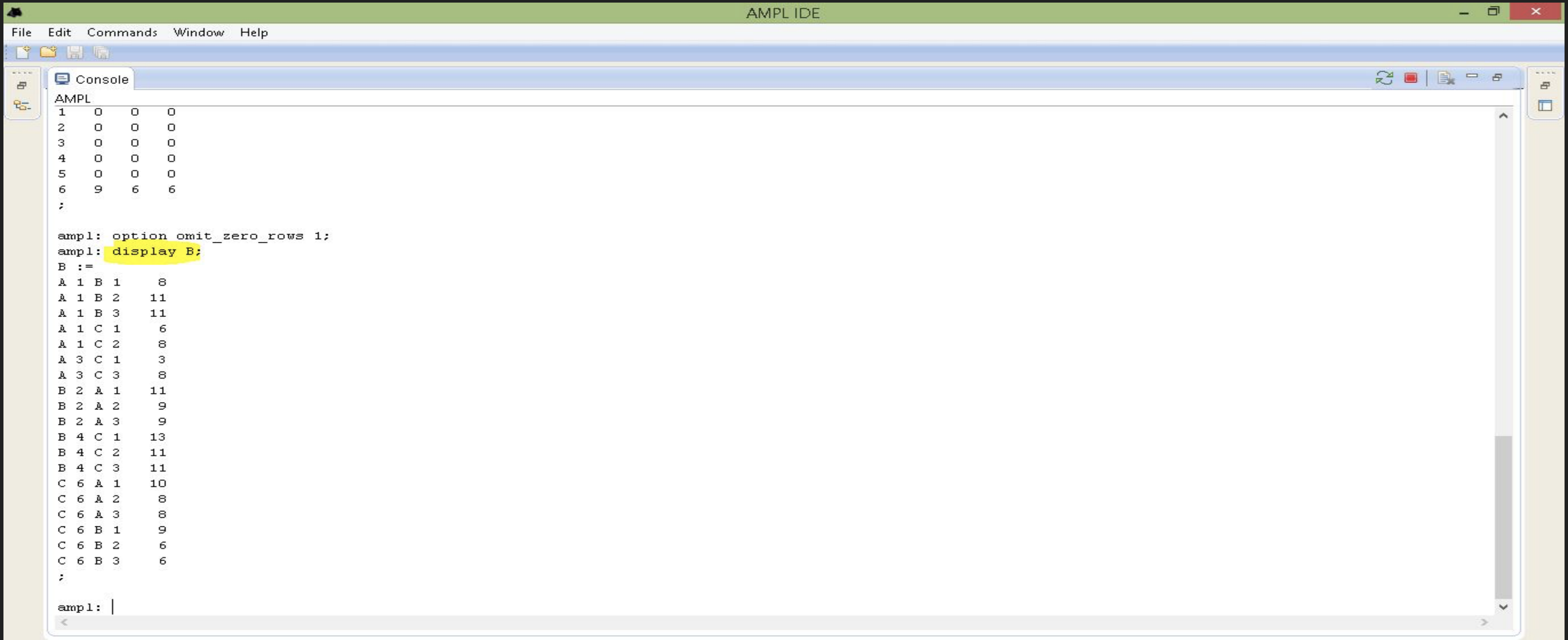
File Edit Commands Window Help

Console

AMPL

```
ampl: reset;
ampl: model 'C:\Users\Toshiba\Downloads\Softwares\ampl_mswin64\Test\BSS\test.mod';
ampl: data 'C:\Users\Toshiba\Downloads\Softwares\ampl_mswin64\Test\BSS\bssNairobi.dat';
ampl: option solver cplex;
ampl: solve;
CPLEX 12.10.0.0: optimal solution; objective 199517.1429
42 dual simplex iterations (0 in phase I)
ampl: display sum {j in J} g[j]*y[j] + f1*(sum {j in J} (Z[j]*y[j])) + f2*(sum {j in J} T[j]*y[j]);
sum{j in J} g[j]*y[j] + f1*(sum{j in J} Z[j]*y[j]) + f2*(sum{j in J} T[j]*y[j]
  ) = 1946600
```

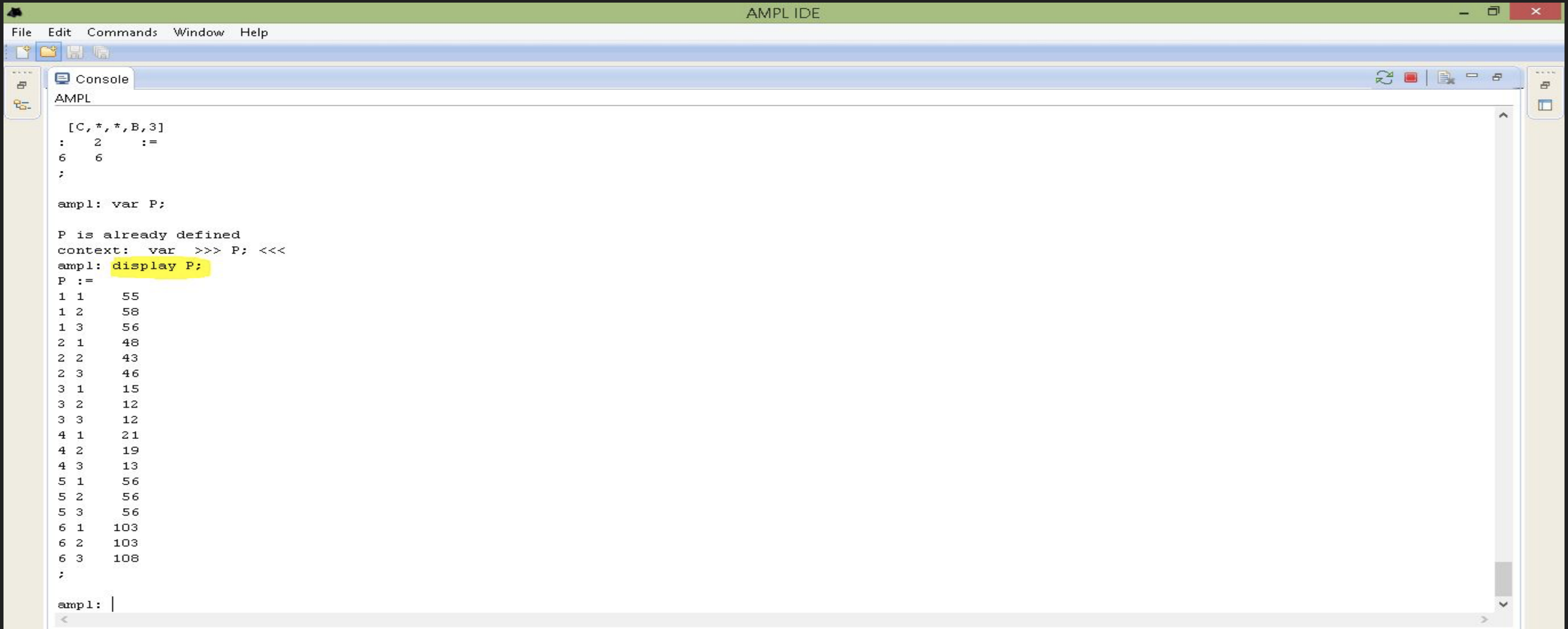
AMPLE CODE


AMPL IDE
File Edit Commands Window Help
Console
AMPL
1 0 0 0
2 0 0 0
3 0 0 0
4 0 0 0
5 0 0 0
6 9 6 6
;
ampl: option omit_zero_rows 1;
ampl: display B;
B :=
A 1 B 1 8
A 1 B 2 11
A 1 B 3 11
A 1 C 1 6
A 1 C 2 8
A 3 C 1 3
A 3 C 3 8
B 2 A 1 11
B 2 A 2 9
B 2 A 3 9
B 4 C 1 13
B 4 C 2 11
B 4 C 3 11
C 6 A 1 10
C 6 A 2 8
C 6 A 3 8
C 6 B 1 9
C 6 B 2 6
C 6 B 3 6
;
ampl:

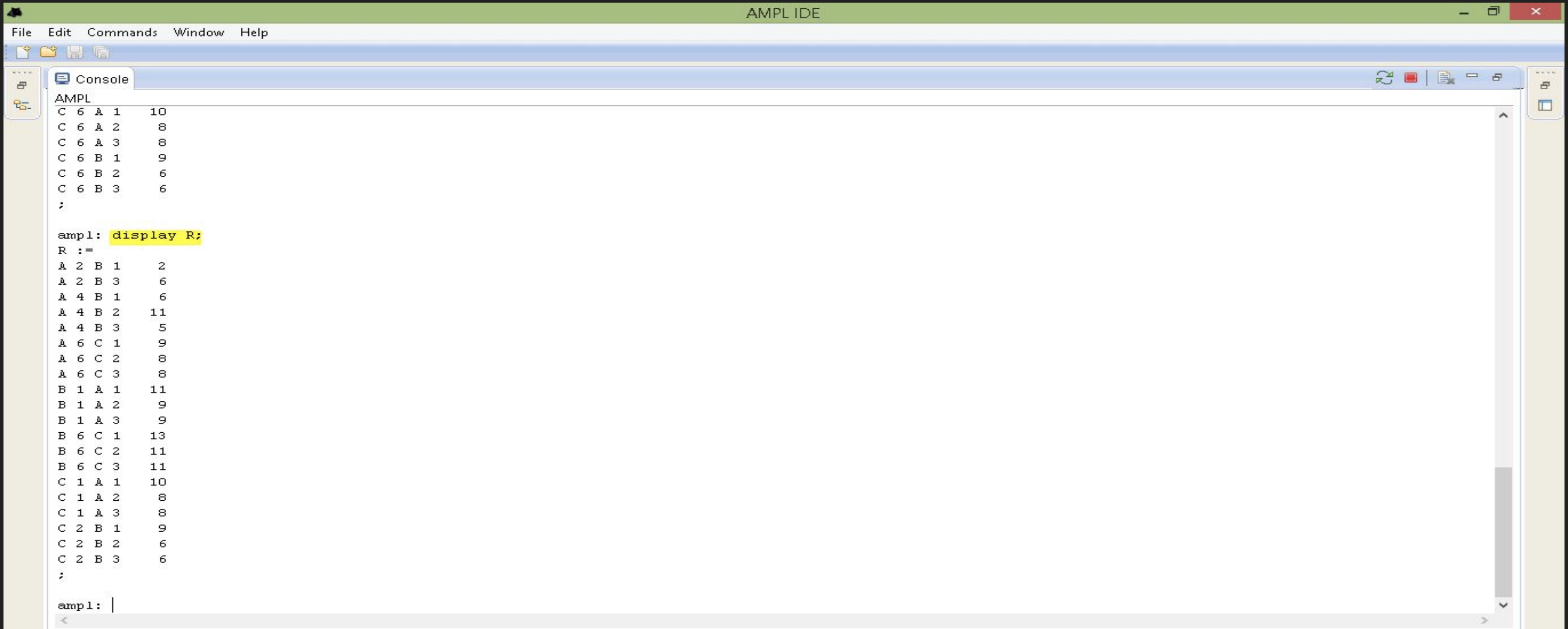
Ample CODE

```
ampl: option omit_zero_cols 1;
ampl: display E;
E [A,*,*,B,1]
:    2    4     :=
1    2    6

 [A,*,*,B,2]
:    4      :=
1    11

 [A,*,*,B,3]
:    2    4     :=
1    6    5

 [A,*,*,C,1]
:    6     :=
1    6
3    3

 [A,*,*,C,2]
:    6     :=
1    8

 [A,*,*,C,3]
:    6     :=
3    8

 [B,*,*,A,1]
:    1      :=
2    11

 [B,*,*,A,2]
```

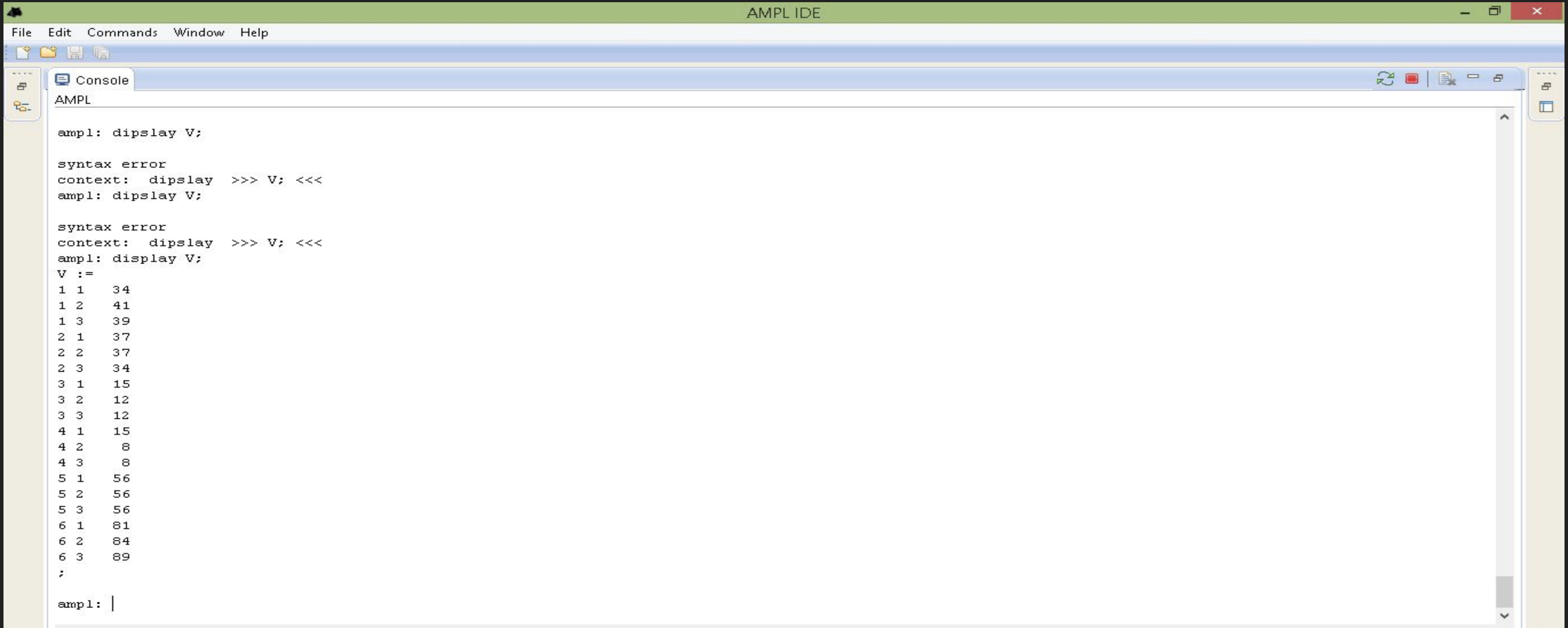
AMPLE CODE


AMPL IDE
File Edit Commands Window Help
Console
AMPL
[C,*,*,B,3]
: 2 :=
6 6
;
ampl: var P;
P is already defined
context: var >>> P; <<<
ampl: display P;
P :=
1 1 55
1 2 58
1 3 56
2 1 48
2 2 43
2 3 46
3 1 15
3 2 12
3 3 12
4 1 21
4 2 19
4 3 13
5 1 56
5 2 56
5 3 56
6 1 103
6 2 103
6 3 108
;
ampl:

AMPLE CODE


AMPL IDE
File Edit Commands Window Help
Console
AMPL
C 6 A 1 10
C 6 A 2 8
C 6 A 3 8
C 6 B 1 9
C 6 B 2 6
C 6 B 3 6
;
ampl: display R;
R :=
A 2 B 1 2
A 2 B 3 6
A 4 B 1 6
A 4 B 2 11
A 4 B 3 5
A 6 C 1 9
A 6 C 2 8
A 6 C 3 8
B 1 A 1 11
B 1 A 2 9
B 1 A 3 9
B 6 C 1 13
B 6 C 2 11
B 6 C 3 11
C 1 A 1 10
C 1 A 2 8
C 1 A 3 8
C 2 B 1 9
C 2 B 2 6
C 2 B 3 6
;
ampl:

AMPLE CODE


AMPL IDE
File Edit Commands Window Help
Console
AMPL
ampl: dipslay V;

syntax error
context: dipslay >>> V; <<<
ampl: dipslay V;

syntax error
context: dipslay >>> V; <<<
ampl: display V;
V :=
1 1   34
1 2   41
1 3   39
2 1   37
2 2   37
2 3   34
3 1   15
3 2   12
3 3   12
4 1   15
4 2   8
4 3   8
5 1   56
5 2   56
5 3   56
6 1   81
6 2   84
6 3   89
;

ampl:

BSS

Bike stations

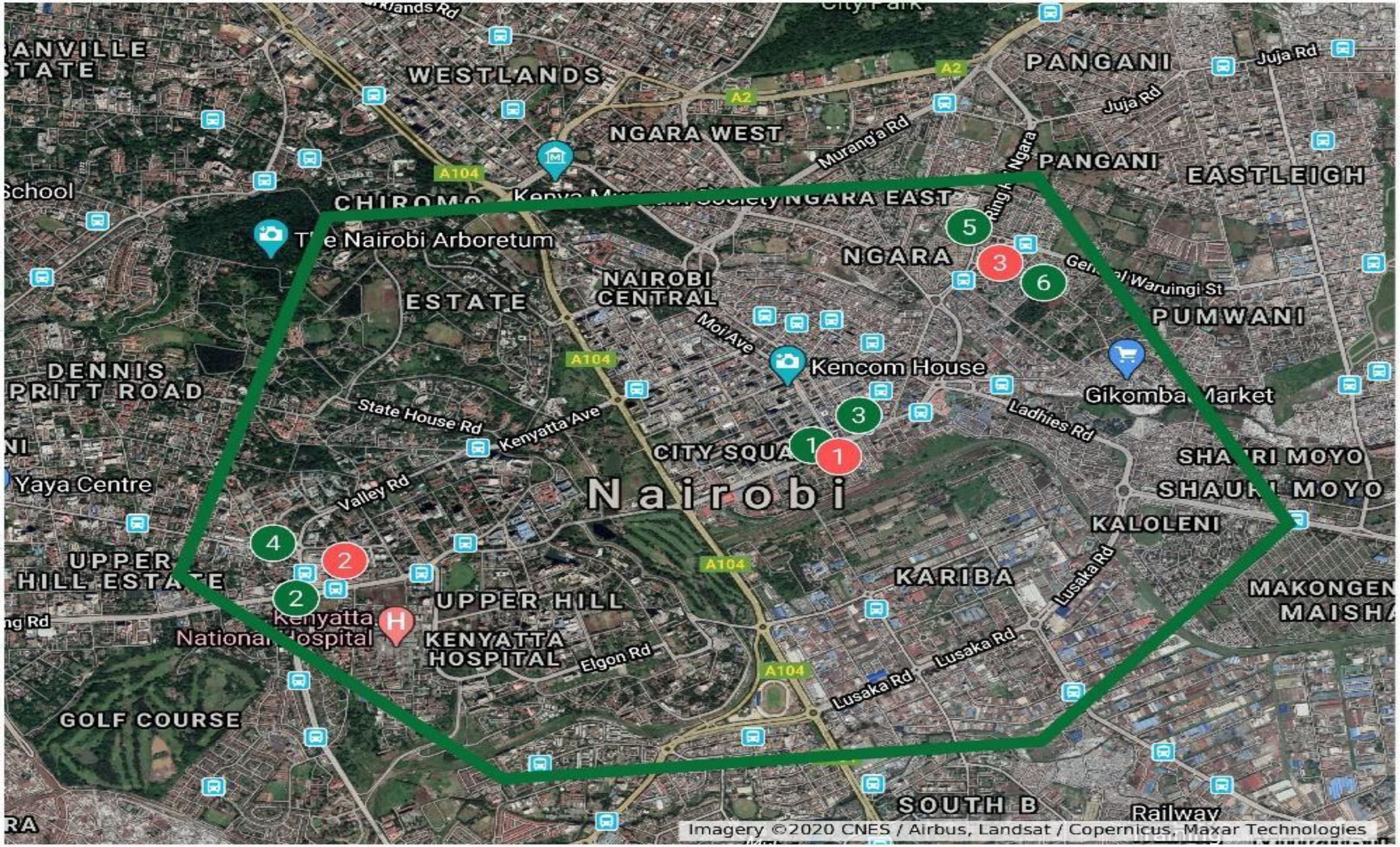
1 Cooperative House
2 city Mortuary
3 Bus Station
Border
4 Hurlingham
5 Kariakor Market
6 Pumwani

Traffic Zones

1

Railways Bus stop /bus Stage

2 Ngong road
3 Ngara



Model Formulation

Objective function:

$$m\varphi = \sum_{k \in k} \sum_{i \in I} \sum_{i' \in I} \left(\frac{\sum_{j \epsilon J} B_{i,j,i',k} \cdot d_{i,j}}{u_2} + \frac{\sum_{j \epsilon J} \sum_{j' \epsilon J} E_{i,j,j',k} \cdot d_{j,j'}}{u_2} + \frac{\sum_{j' \epsilon J} R_{i,j',k} \cdot d_{i',j}}{u_1} \right) = 199{,}517$$

Model Formulation

s.t

$$a_{i,j} = \begin{cases} 1, d_{i,j} \leq C \\ 0, d_{i,j} \leq C \end{cases} \forall i \in I, \forall j \in J \qquad 1$$

Defines a 0–1 matrix, which ensures that a given traffic zone can only be served by bike stations within the maximum walking distance

$$\sum_{j \in J} g_j y_j + f_1 \sum_{j \in J} Z_j y_j + f_2 \sum_{j \in J} T_j y_j \leq H \qquad 2$$

$$1{,}946{,}600 \leq 2{,}000{,}000$$

Ensures that the sum of fixed costs of bike stations, purchasing costs of bikes, and installment costs of parking lockers does not exceed the total investment budget.

Limitation

- Initial Model prediction heavily relies on data collection
- Replenishment (operational problem) should be handled by another model
- Setting up the Information System (Apps) is not integrated in the model
- Road and bike lanes should be considered rigorously for better service

Conclusion

- Designing efficient layout for the bike sharing system
- Selecting number of parking stations for construction and parking lockers, also picking and dropping off bike at each period was challenging
- Each traffic zone can be served by at least one bike with maximum walking distance
- Ensure trip between traffic zones and two bike station

References

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6. Guo T, Zhang P, Shao F, et al. Allocation optimization of bicycle-sharing stations at . scenic spots. Allocation optimization of bicycle-sharing stations at scenic spots. 2014; 21(8): 3396-3403.

Thanks for your time. Any Questions?