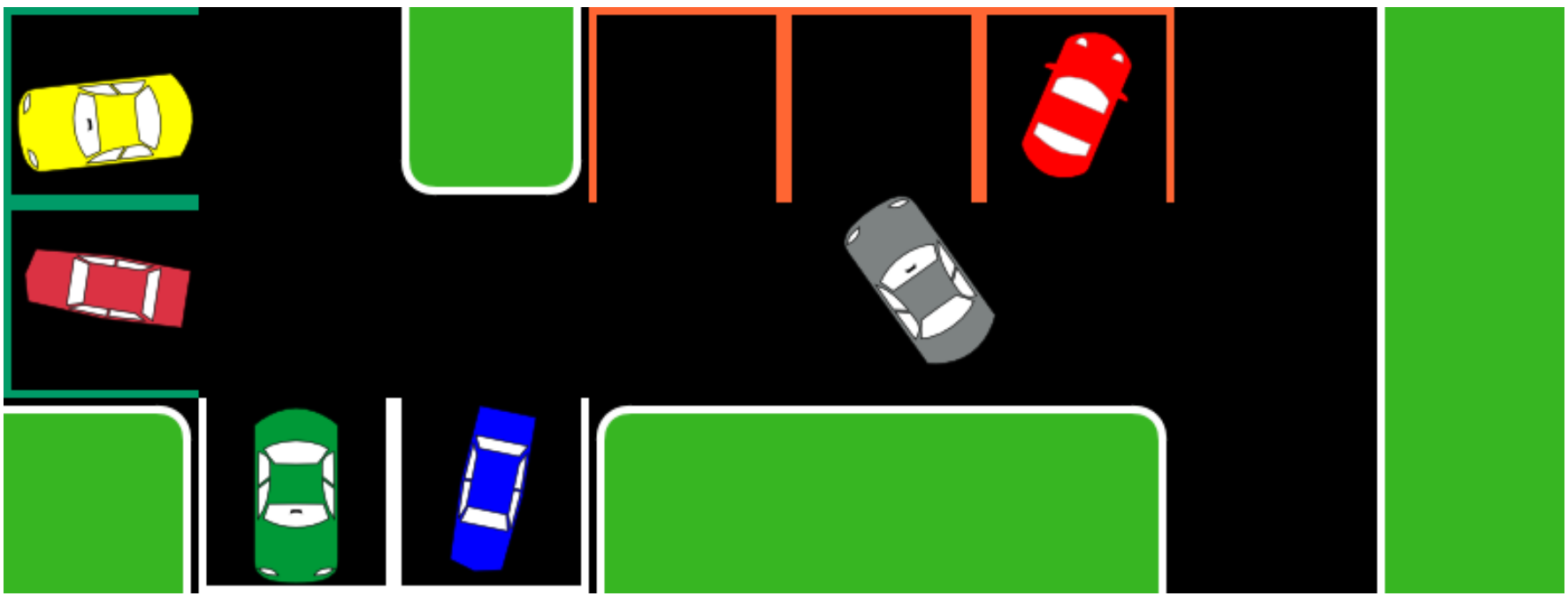
Parking Project

Nate Black and Janine Janoski

Clemson University

MthSc 985

April 27, 2010



Introduction

- Our goal was to model the parking on Clemson's campus.
- Others that have studied parking:
  - An Agent-based Model for Simulating Parking Search-Dieusaert, Aerts, Steenberghen, Maerivoet, Spitaels
  - Geosimulation of Parking in the City- Benenson, Martens
- We choose to use a cellular automaton

Introduction

- Our goal was to model the parking on Clemson's campus.
- Others that have studied parking:
  - An Agent-based Model for Simulating Parking Search-Dieusaert, Aerts, Steenberghen, Maerivoet, Spitaels
  - Geosimulation of Parking in the City- Benenson, Martens
- We choose to use a cellular automaton

Introduction

- Our goal was to model the parking on Clemson's campus.
- Others that have studied parking:
  - An Agent-based Model for Simulating Parking Search-Dieusaert, Aerts, Steenberghen, Maerivoet, Spitaels
  - Geosimulation of Parking in the City- Benenson, Martens
- We choose to use a cellular automaton

Introduction

- Our goal was to model the parking on Clemson's campus.
- Others that have studied parking:
  - An Agent-based Model for Simulating Parking Search-Dieusaert, Aerts, Steenberghen, Maerivoet, Spitaels
  - Geosimulation of Parking in the City- Benenson, Martens
- We choose to use a cellular automaton

Introduction

- Our goal was to model the parking on Clemson's campus.
- Others that have studied parking:
  - An Agent-based Model for Simulating Parking Search-Dieusaert, Aerts, Steenberghen, Maerivoet, Spitaels
  - Geosimulation of Parking in the City- Benenson, Martens
- We choose to use a cellular automaton

Assumptions

Assumptions

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Assumptions about people

- People arrive and leave at the same time daily
- People "know" which parking lots they were able to find a spot in for all previous days
- People know an ordered list of parking lots which will minimize their time from the arrival location to the building cluster
- People arrive on campus in a fixed interval
- People never leave campus and come back later
- People park for at least 30 minutes
- If a person cannot find a parking spot after searching their list of lots, they leave for the day

Parking lot assumptions

- On street parking modeled like a parking lot or disregarded
- No illegal parking
- If you arrive at a parking lot and there are spots available you get a spot instantaneously
- Multiple people can enter the parking lot at the same time
- Parking lots do not change type after 4:30

Parking lot assumptions

- On street parking modeled like a parking lot or disregarded
- No illegal parking
- If you arrive at a parking lot and there are spots available you get a spot instantaneously
- Multiple people can enter the parking lot at the same time
- Parking lots do not change type after 4:30

Parking lot assumptions

- On street parking modeled like a parking lot or disregarded
- No illegal parking
- If you arrive at a parking lot and there are spots available you get a spot instantaneously
- Multiple people can enter the parking lot at the same time
- Parking lots do not change type after 4:30

Parking lot assumptions

- On street parking modeled like a parking lot or disregarded
- No illegal parking
- If you arrive at a parking lot and there are spots available you get a spot instantaneously
- Multiple people can enter the parking lot at the same time
- Parking lots do not change type after 4:30

Parking lot assumptions

- On street parking modeled like a parking lot or disregarded
- No illegal parking
- If you arrive at a parking lot and there are spots available you get a spot instantaneously
- Multiple people can enter the parking lot at the same time
- Parking lots do not change type after 4:30

Data assumptions

- No CAT bus
- Roads are all same speed limit, there is no traffic, there are no traffic lights
- Times from parking lots to buildings were determined by straight line distance
- Middle of the building cluster is used to determine distances
- The total number of people who have purchased a permit do not drive to campus everyday

Data assumptions

- No CAT bus
- Roads are all same speed limit, there is no traffic, there are no traffic lights
- Times from parking lots to buildings were determined by straight line distance
- Middle of the building cluster is used to determine distances
- The total number of people who have purchased a permit do not drive to campus everyday

Data assumptions

- No CAT bus
- Roads are all same speed limit, there is no traffic, there are no traffic lights
- Times from parking lots to buildings were determined by straight line distance
- Middle of the building cluster is used to determine distances
- The total number of people who have purchased a permit do not drive to campus everyday

Data assumptions

- No CAT bus
- Roads are all same speed limit, there is no traffic, there are no traffic lights
- Times from parking lots to buildings were determined by straight line distance
- Middle of the building cluster is used to determine distances
- The total number of people who have purchased a permit do not drive to campus everyday

Data assumptions

- No CAT bus
- Roads are all same speed limit, there is no traffic, there are no traffic lights
- Times from parking lots to buildings were determined by straight line distance
- Middle of the building cluster is used to determine distances
- The total number of people who have purchased a permit do not drive to campus everyday

Data

Data

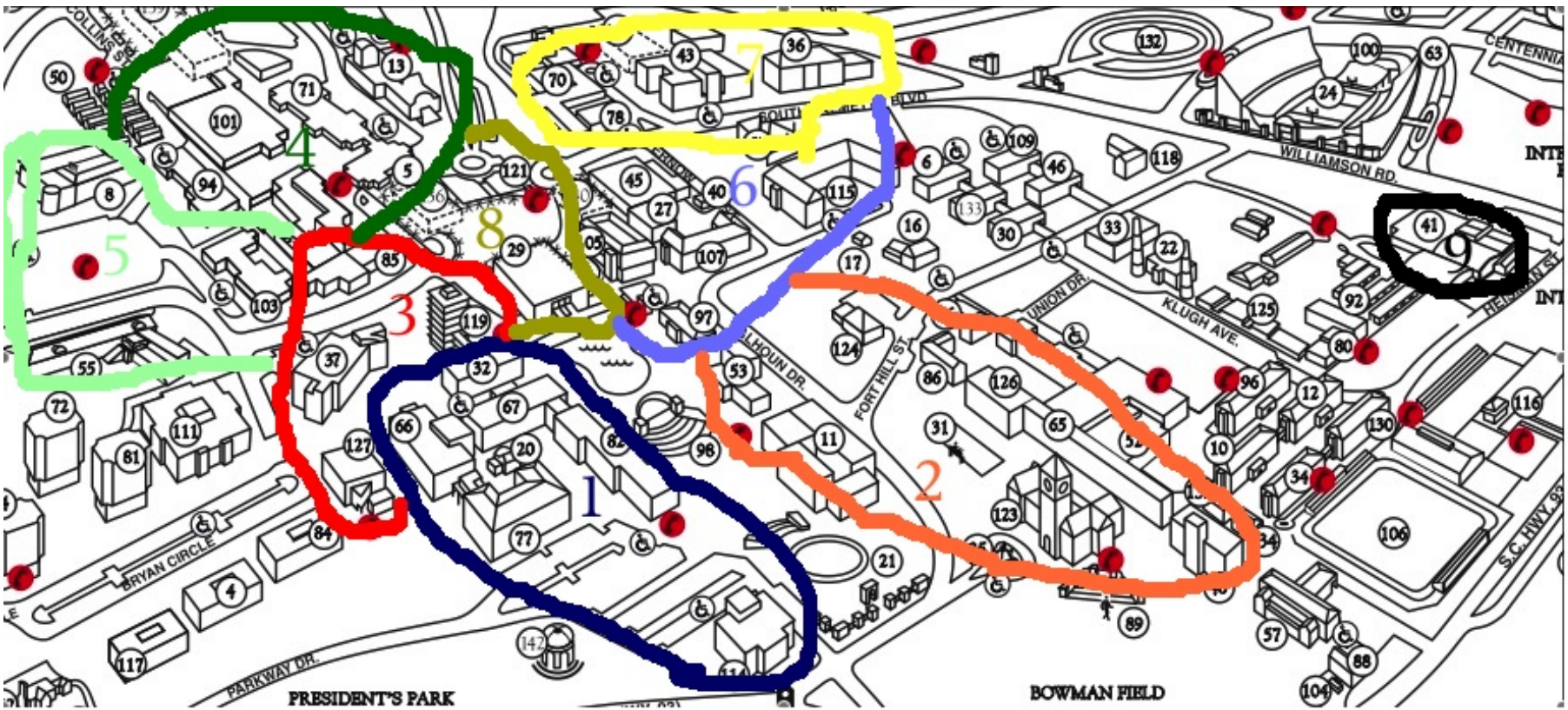
Building clusters

1. Martin Hall Cluster- Martin, Sikes, Long, Daniel, Kinard, Jordan
2. Bracket Cluster- Bracket, Tillman, Hardin, Holtzondorff, University Union
3. McAdams Cluster- McAdams, Strode Towers, Edwards, Vickery
4. Brooks Cluster- Brooks, Barre, Lehotsky, P&A, Newman, Life Sciences
5. Hendrix Cluster- Hendrix, Redfern, Biosystems Research Complex
6. Riggs Cluster- Freeman, Riggs, Rhodes, Oline, Sirrine
7. Lee Cluster- Lee, Flour Daniel, Smith, Earle, Lowry, Hunter
8. Library- Library, Thurmond Institute
9. Fike

Building clusters

1. Martin Hall Cluster- Martin, Sikes, Long, Daniel, Kinard, Jordan
2. Bracket Cluster- Bracket, Tillman, Hardin, Holtzondorff, University Union
3. McAdams Cluster- McAdams, Strode Towers, Edwards, Vickery
4. Brooks Cluster- Brooks, Barre, Lehotsky, P&A, Newman, Life Sciences
5. Hendrix Cluster- Hendrix, Redfern, Biosystems Research Complex
6. Riggs Cluster- Freeman, Riggs, Rhodes, Oline, Sirrine
7. Lee Cluster- Lee, Flour Daniel, Smith, Earle, Lowry, Hunter
8. Library- Library, Thurmond Institute
9. Fike

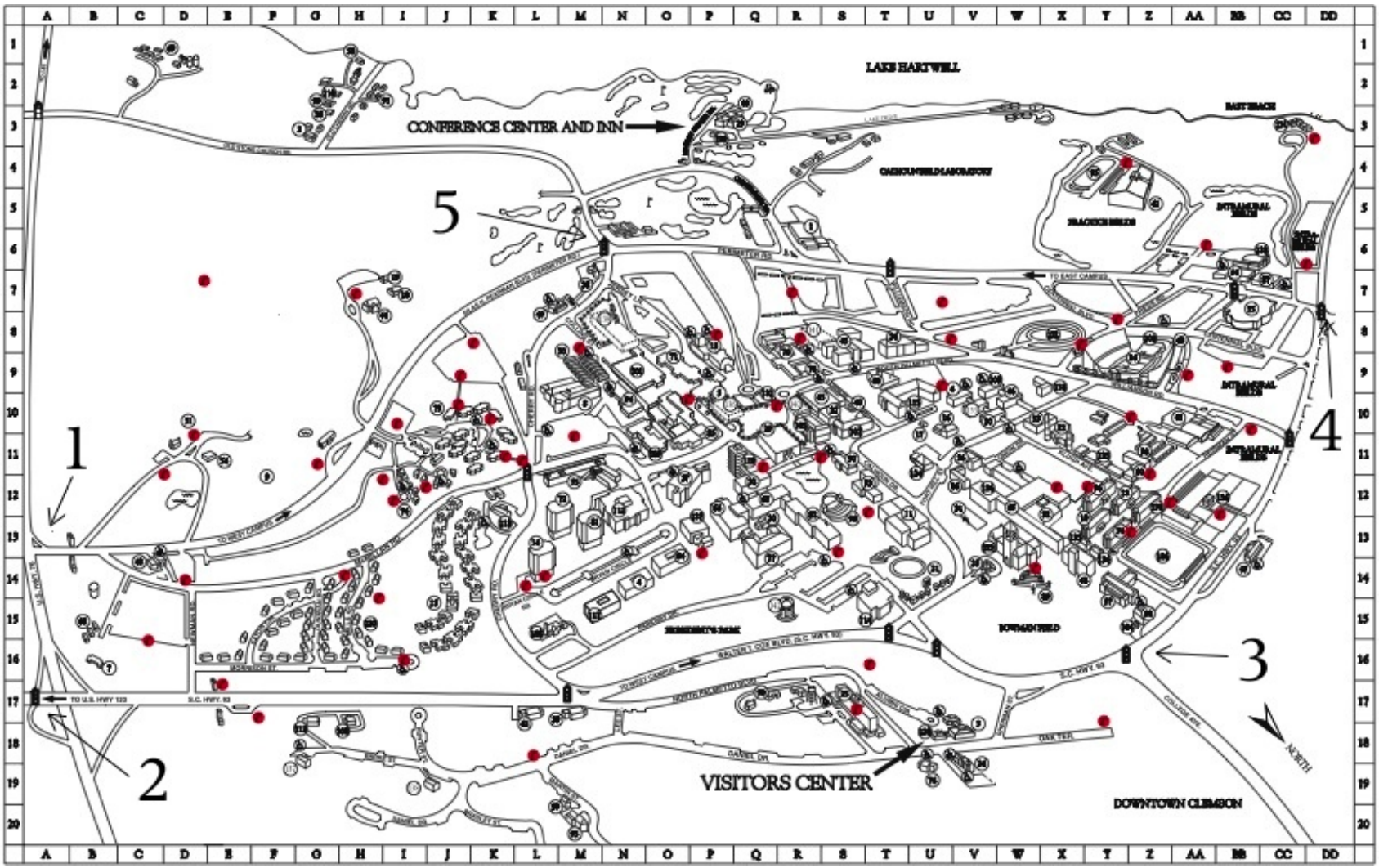
Building clusters



Arrival locations

1. 76 to Perimeter
2. 93 from Central
3. College Ave to 93
4. 93 from Seneca
5. Light by Brooks

Arrival locations



Commuter Lots

Lot Number	Location	Number of Parking Spaces
C1	Firehouse	174
R1		287
C11	Brooks	364
C4	Lee	268
C5	Lee	238
C12	Earle	220
C7	Fike Commuter Street	281
C2	Far Stadium	294
C6	Fike Commuter	55
C9	Intramural	93
Total		2174

Employee Lots

Lot Number	Location	Number of Parking Spaces
E1	Hendrix	231
E2	Brooks	132
E3	Lee	62
E6	Martin	97
E5	Fike Main	163
E4	Earle	260
C6	Fike	88
E15	Library	49
E14	Fike Small	33
E7	Fike Street	140
E10	Clemson House	267
Total		1522

Other Lots

Any lots:

Lot Number	Location	Number of Parking Spaces
P1	Kite Hill	465 spaces
P3	Stadium	691 spaces
C11	Brooks	254 spaces
Total		1410

Extra Lots:

Lot Number	Location	Number of Parking Spaces
Commuter	Gravel Lot	181
C2	Life Sciences	364
Total		545

Other Lots

Any lots:

Lot Number	Location	Number of Parking Spaces
P1	Kite Hill	465 spaces
P3	Stadium	691 spaces
C11	Brooks	254 spaces
Total		1410

Extra Lots:

Lot Number	Location	Number of Parking Spaces
Commuter	Gravel Lot	181
C2	Life Sciences	364
Total		545

Number of permits

Type of lot	Parking spaces in model	Actual parking spaces
Commuter	2174	2865
Employee	1522	2495
Any	1410	1742

Type of permit	Permits used in model	Permits ordered 2009-2010
Commuter	6270	9552
Employee	3401	3840
Total	9671	13392

Number of permits

Type of lot	Parking spaces in model	Actual parking spaces
Commuter	2174	2865
Employee	1522	2495
Any	1410	1742

Type of permit	Permits used in model	Permits ordered 2009-2010
Commuter	6270	9552
Employee	3401	3840
Total	9671	13392

Number of permits

Let:

x = the number of employee permits
y = the number of commuter permits
E = the number of employee parking spots
C = the number of commuter parking spots
A = the number of any parking spots

Then we solve the following system for x_n and y_n

$$\frac{E_n + A_n + C_n}{E_o + A_o + C_o} = \frac{x_n + x_y}{x_0 + y_0}$$

$$\frac{C_n + 0.8A_n}{E_n + 0.2A_n} = \frac{y_n}{x_n}$$

Number of permits

Let:

x = the number of employee permits
y = the number of commuter permits
E = the number of employee parking spots
C = the number of commuter parking spots
A = the number of any parking spots

Then we solve the following system for x_n and y_n

$$\frac{E_n + A_n + C_n}{E_o + A_o + C_o} = \frac{x_n + x_y}{x_0 + y_0}$$

$$\frac{C_n + 0.8A_n}{E_n + 0.2A_n} = \frac{y_n}{x_n}$$

Number of permits

Let:

x = the number of employee permits
y = the number of commuter permits
E = the number of employee parking spots
C = the number of commuter parking spots
A = the number of any parking spots

Then we solve the following system for x_n and y_n

$$\frac{E_n + A_n + C_n}{E_o + A_o + C_o} = \frac{x_n + x_y}{x_0 + y_0}$$

$$\frac{C_n + 0.8A_n}{E_n + 0.2A_n} = \frac{y_n}{x_n}$$

Implementation

Implementation

Data Generation

Each person is assigned the following attributes:

- arrival location
- arrival time
- departure time
- target building
- status: Employee or Commuter

Data Generation

Each person is assigned the following attributes:

- arrival location
- arrival time
- departure time
- target building
- status: Employee or Commuter

Data Generation

Each person is assigned the following attributes:

- arrival location
- arrival time
- departure time
- target building
- status: Employee or Commuter

Data Generation

Each person is assigned the following attributes:

- arrival location
- arrival time
- departure time
- target building
- status: Employee or Commuter

Data Generation

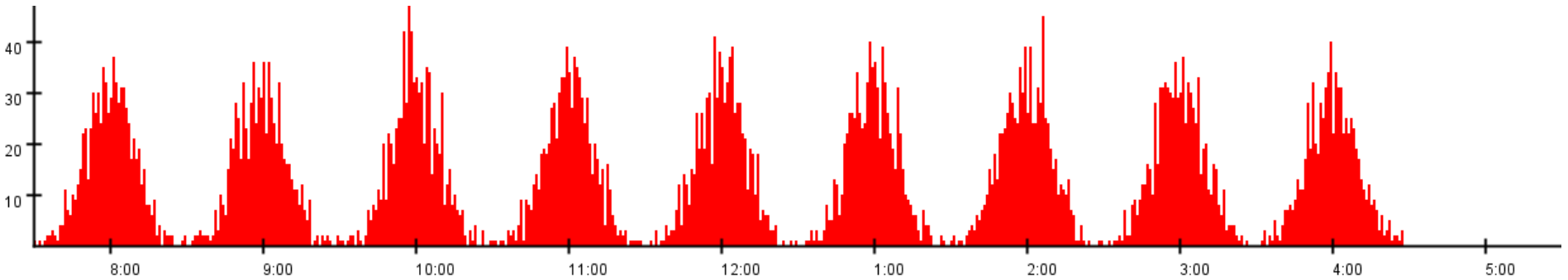
Each person is assigned the following attributes:

- arrival location
- arrival time
- departure time
- target building
- status: Employee or Commuter

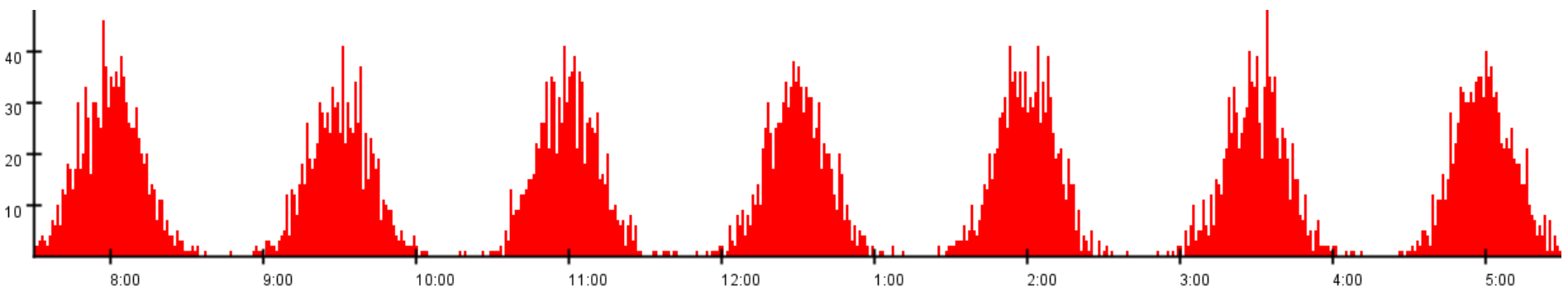
Arrival Times

Clustered around class times

- MWF: 8:00-4:00 every hour



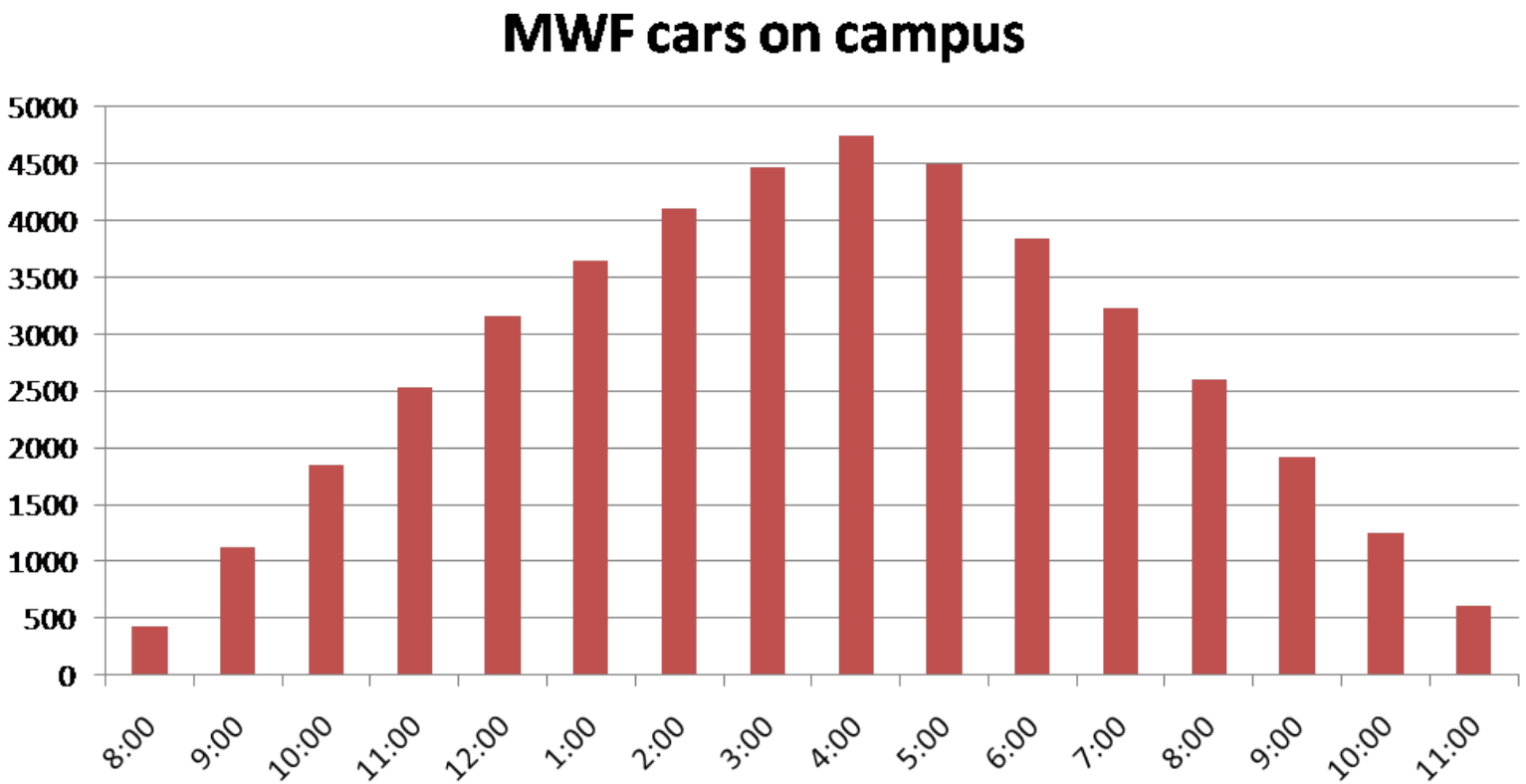
- TTH: 8:00-5:00 every hour and a half



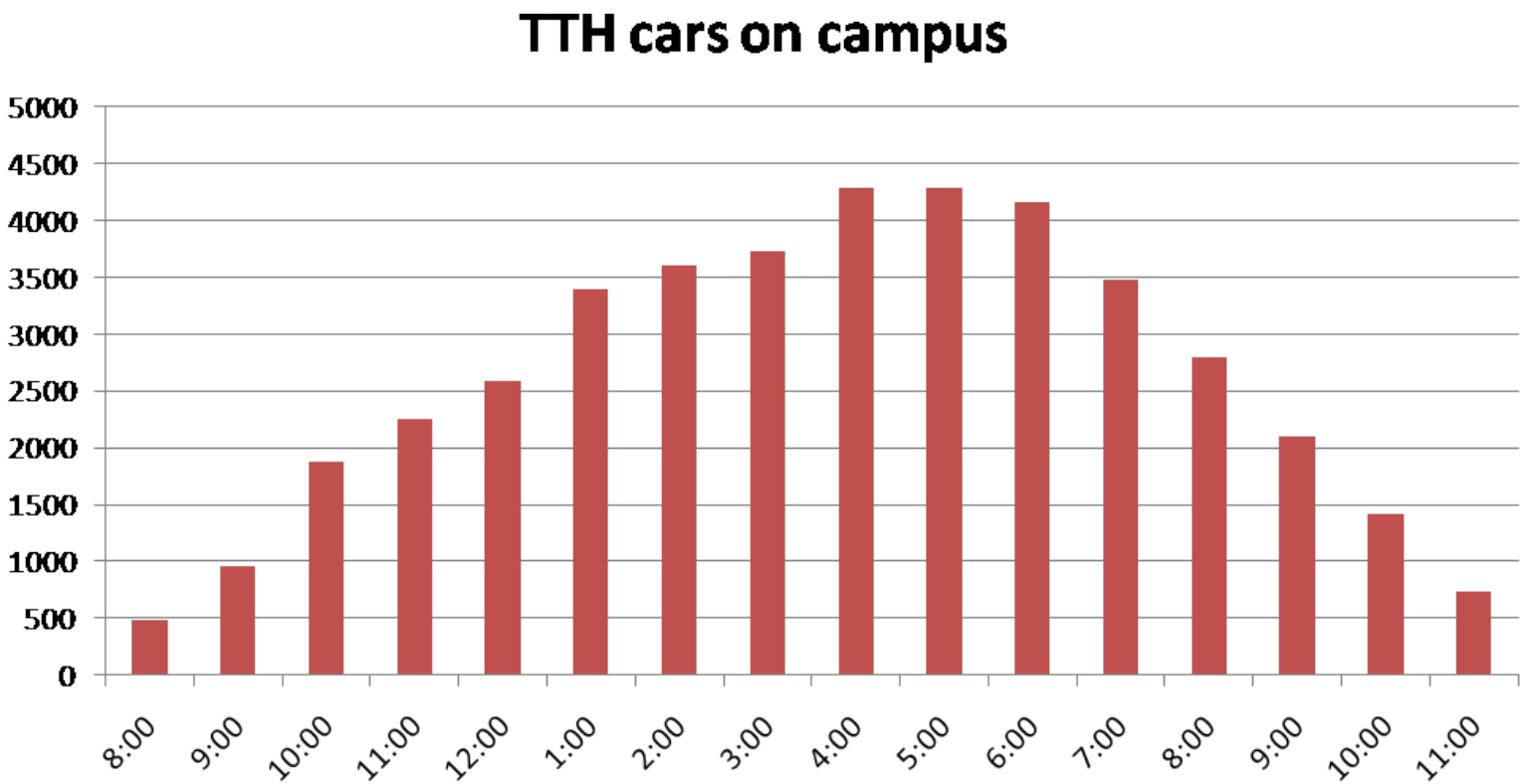
Other Parameters

- **Departure times:**
  uniformly picked between arrival time and the end of the day
- **Arrival location:**
  uniformly picked from the 5 arrival locations
- **Target building:**
  uniformly picked from the 9 building clusters
- **Status:**
  picked based on the ratio of Employee permits (x_n) to Commuter permits (y_n)

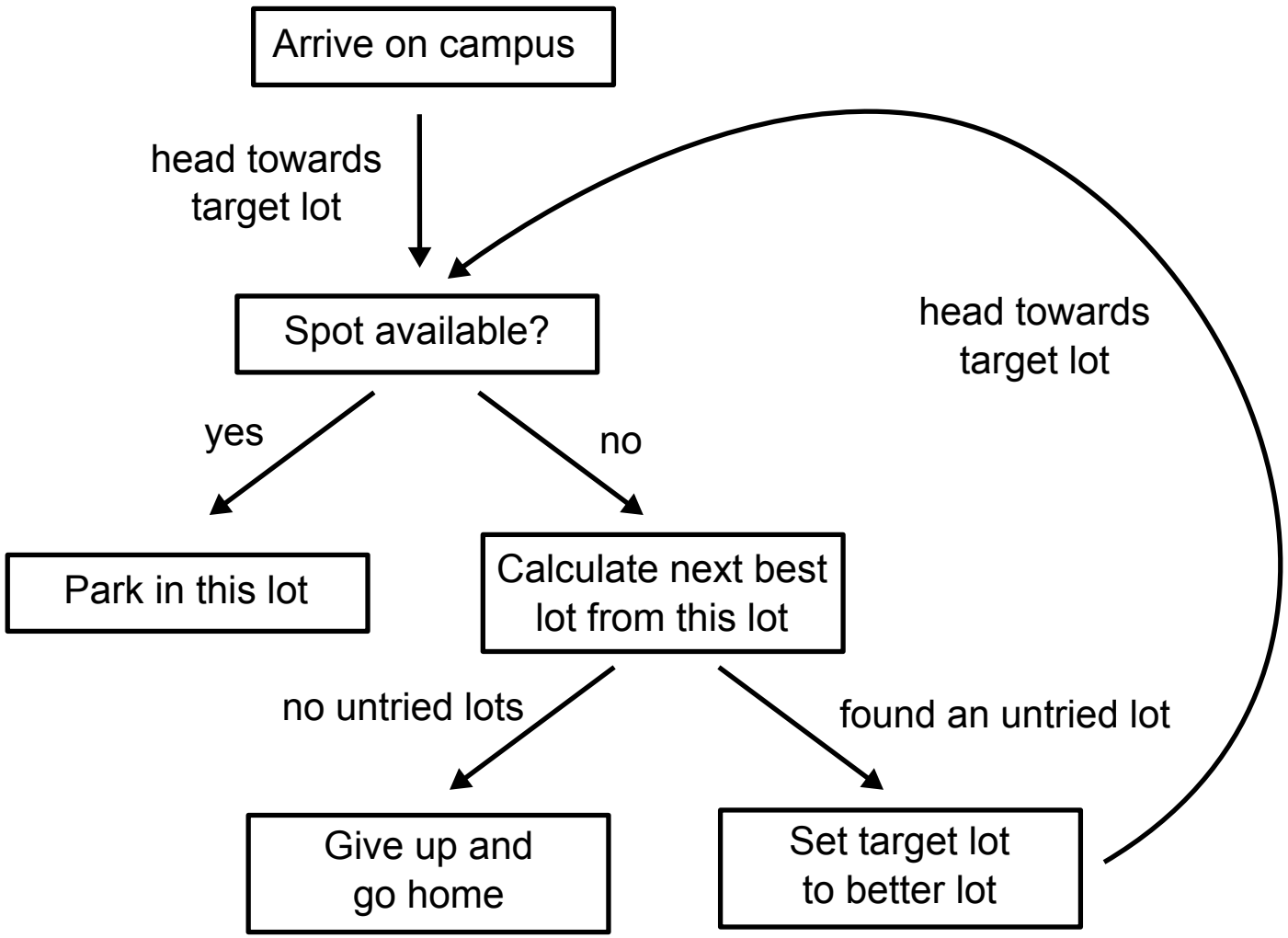
MWF cars on campus



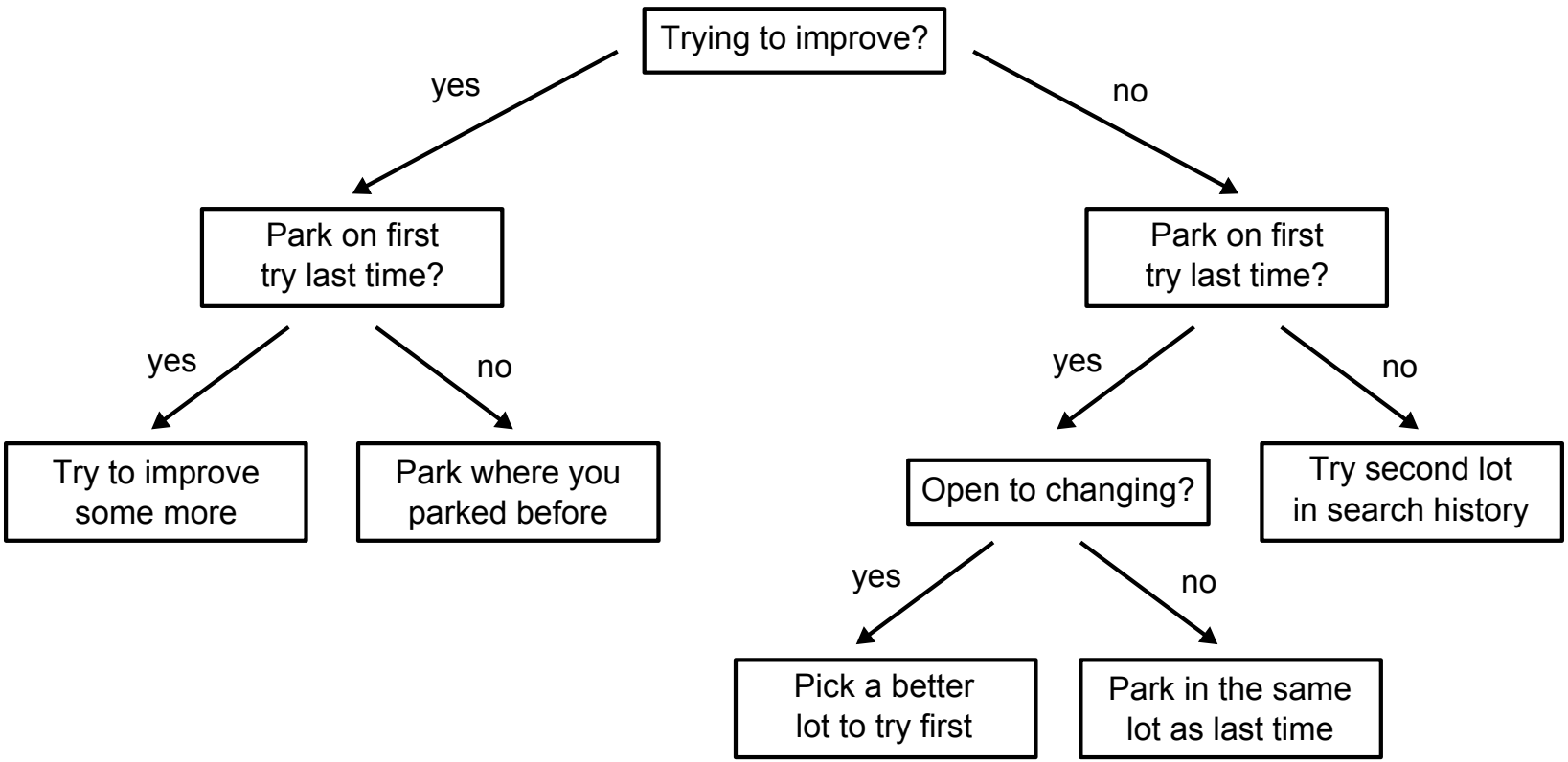
TTH cars on campus



Daily Algorithm



Global Algorithm

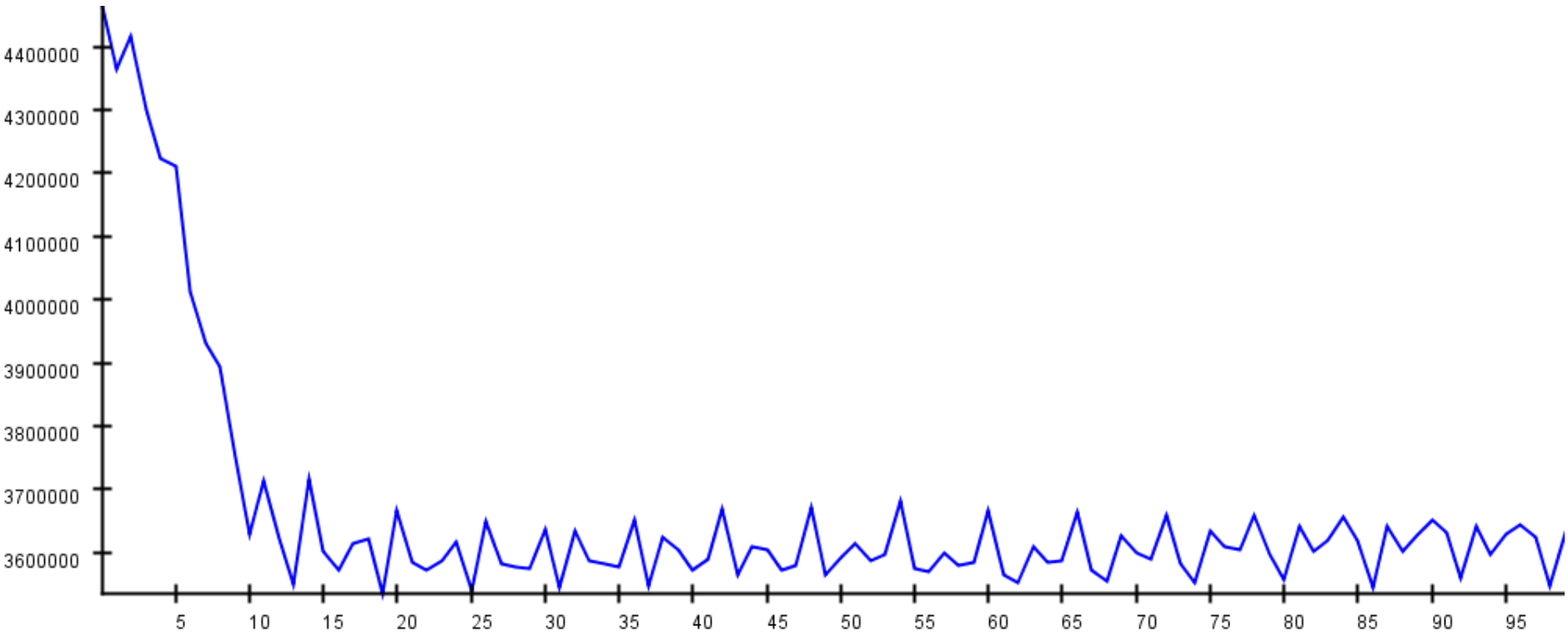


Results

Results

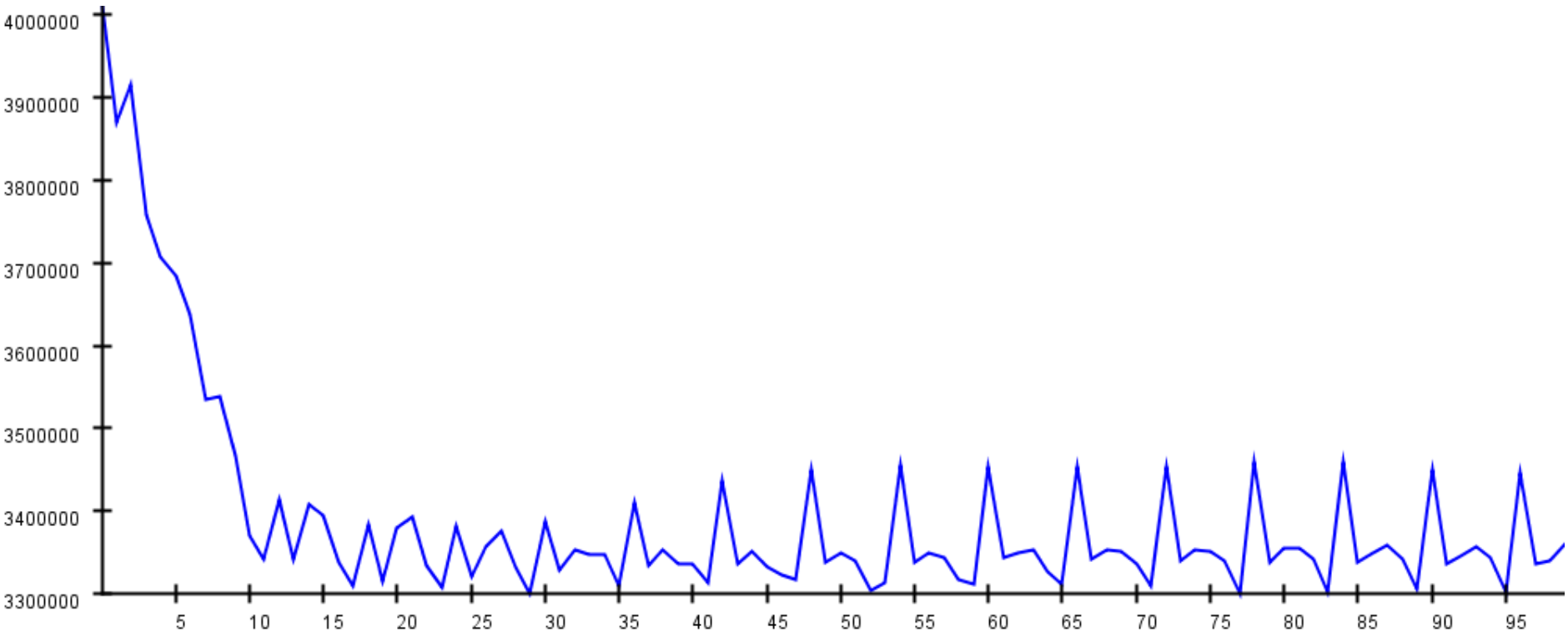
Total Parking Time

- MWF: number of days vs. total parking time (seconds)



Total Parking Time

- TTH: number of days vs. total parking time (seconds)



Metrics

- Steady state is defined to be when most people are parking on their first try
- How long does is take to reach the steady state
- What happens if we change some of the parameters
  1. Arrival times
  2. Size of lots
  3. Lot types

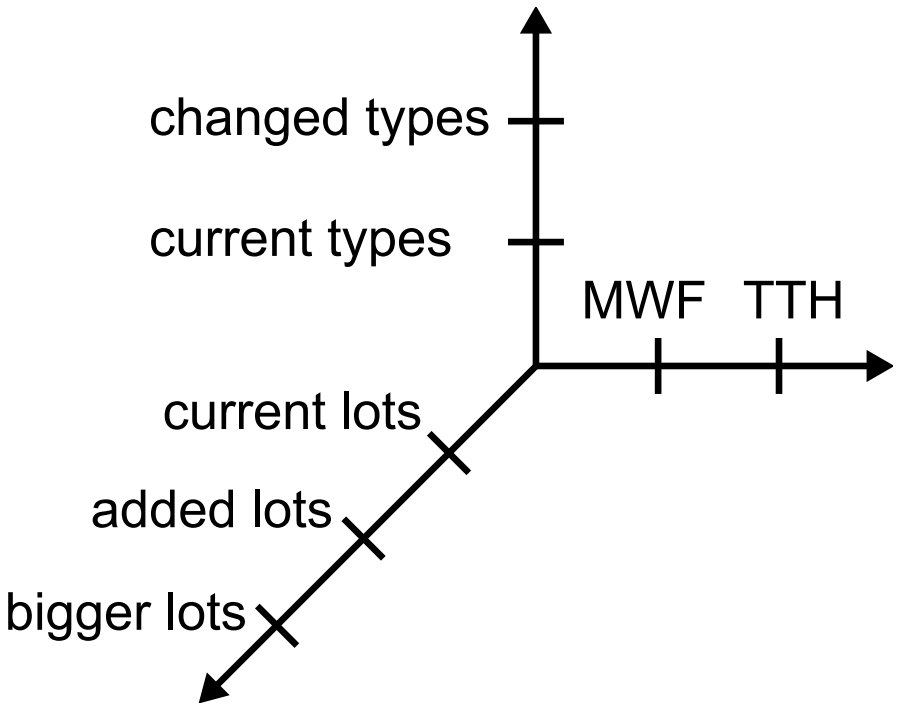
Metrics

- Steady state is defined to be when most people are parking on their first try
- How long does is take to reach the steady state
- What happens if we change some of the parameters
  1. Arrival times
  2. Size of lots
  3. Lot types

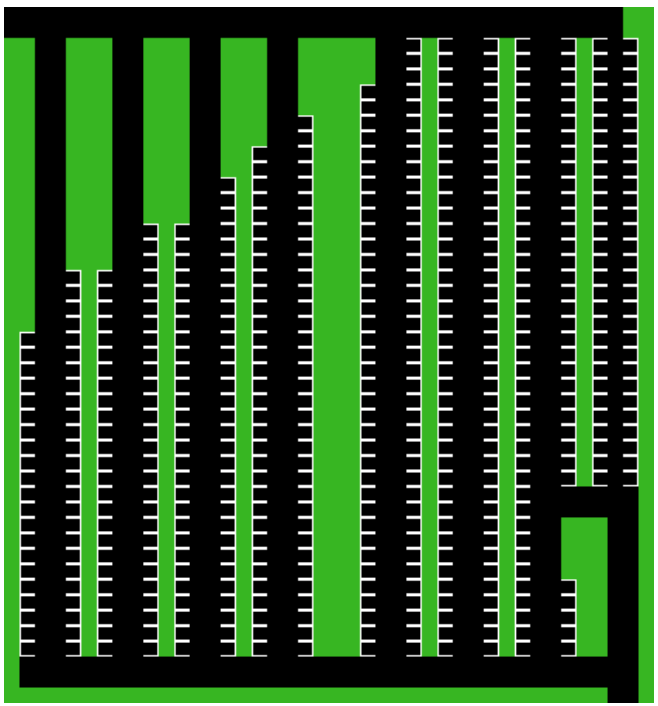
Metrics

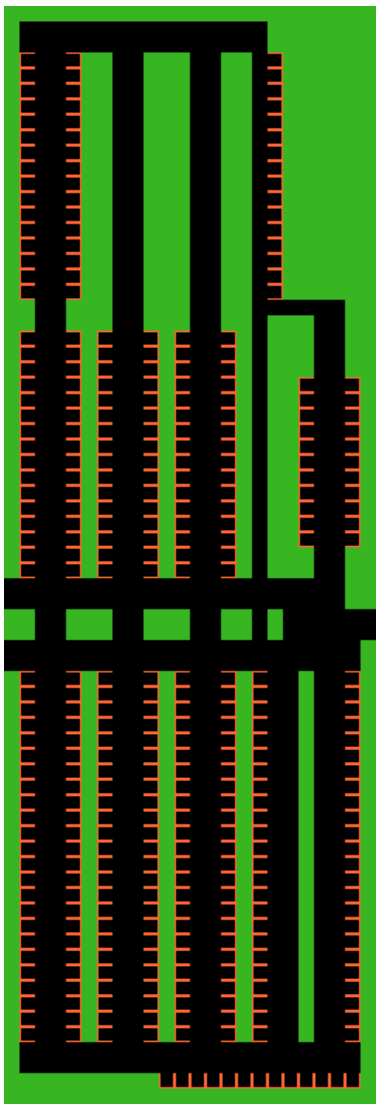
- Steady state is defined to be when most people are parking on their first try
- How long does is take to reach the steady state
- What happens if we change some of the parameters
  1. Arrival times
  2. Size of lots
  3. Lot types

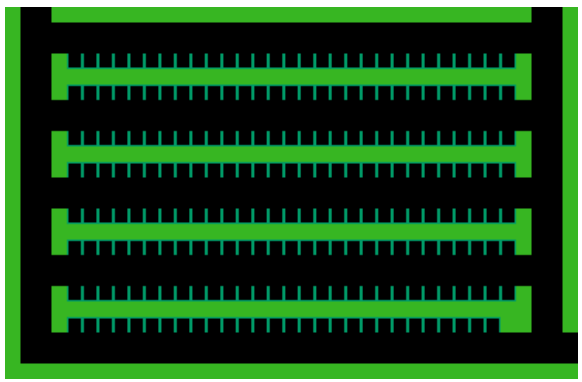
Simulation Configurations



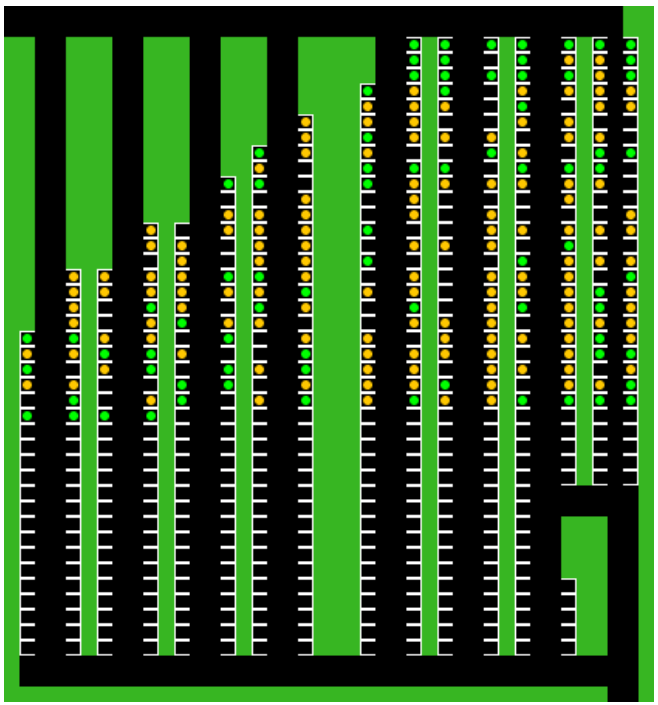
Simulation Visualizer

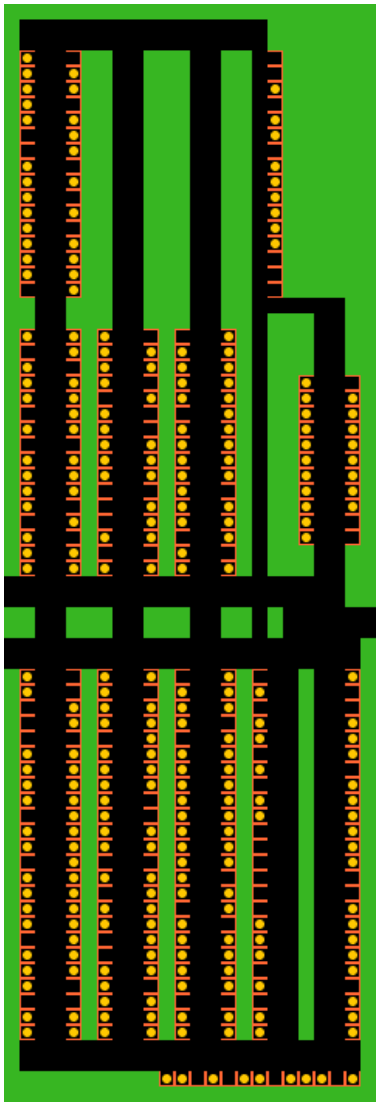


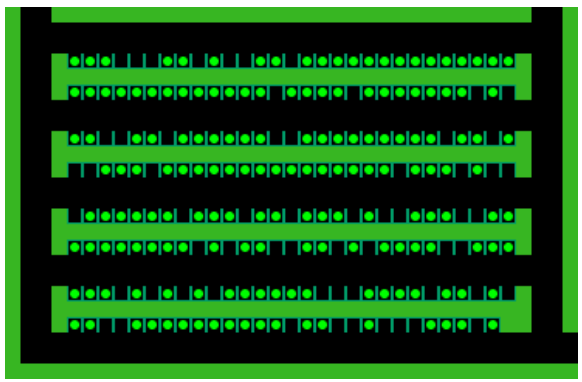




Simulation Visualizer



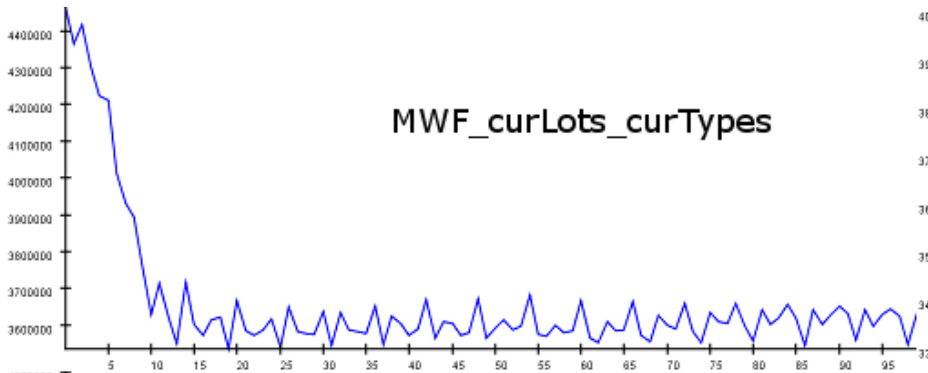


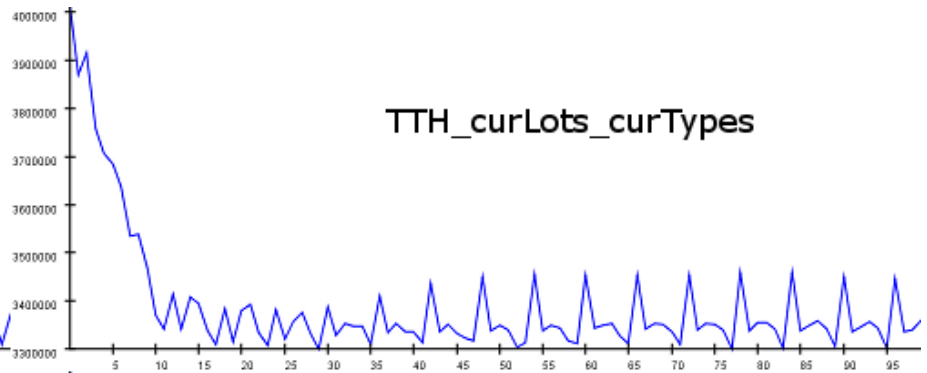


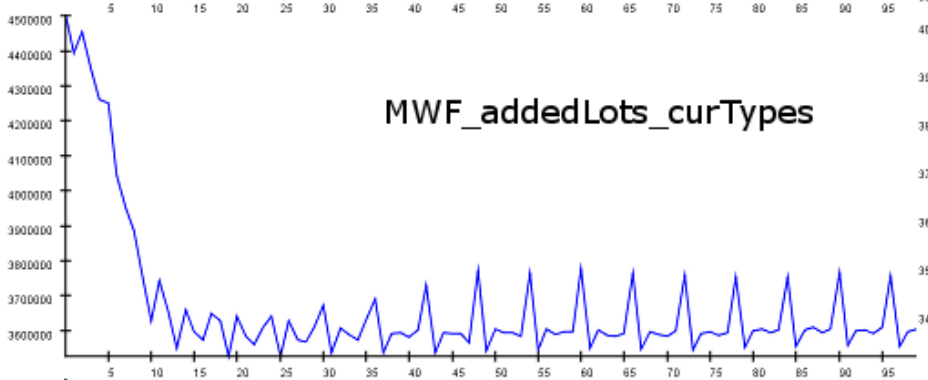
Simulation Visualizer

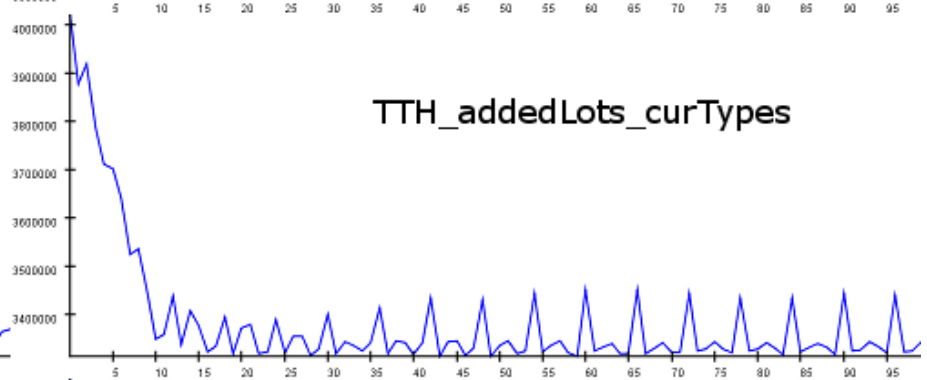
Fast motion video of an entire day of a MWF simulation using the current lots and the current types

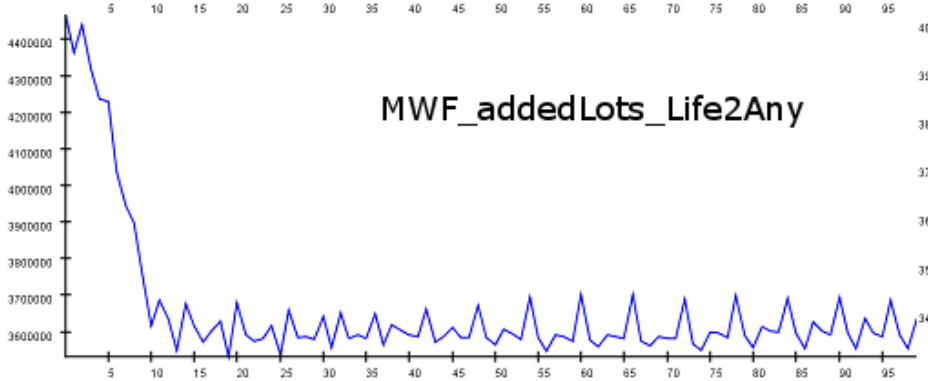
Results Summary

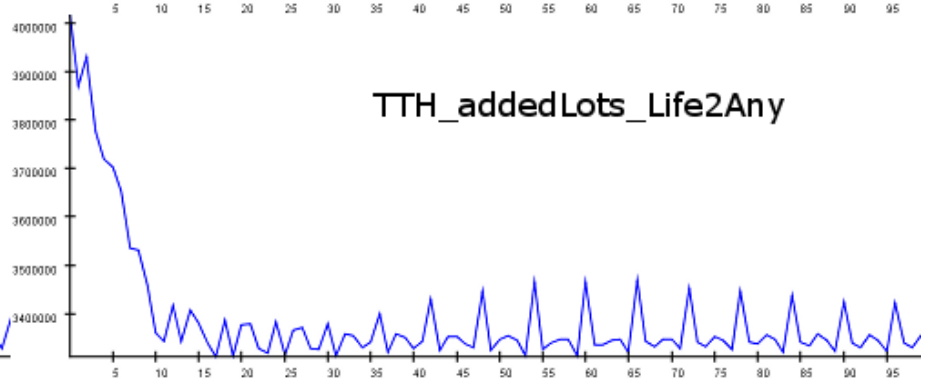












Improvements

Improvements

Data Collection

- Parking Services Surveys (2006 and 2008)
  1. checked lots at peak times
  2. counted number of occupied spots
- These surveys do not provide information for generating arrival times
- Collect data by counting the number of cars that arrive and when they arrive

Data Collection

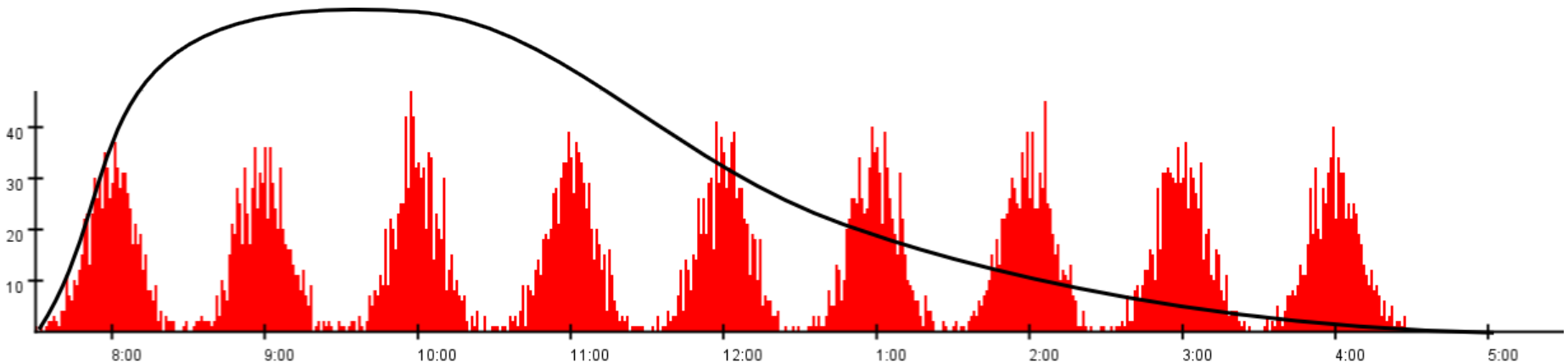
- Parking Services Surveys (2006 and 2008)
  1. checked lots at peak times
  2. counted number of occupied spots
- These surveys do not provide information for generating arrival times
- Collect data by counting the number of cars that arrive and when they arrive

Data Collection

- Parking Services Surveys (2006 and 2008)
  1. checked lots at peak times
  2. counted number of occupied spots
- These surveys do not provide information for generating arrival times
- Collect data by counting the number of cars that arrive and when they arrive

People Generation

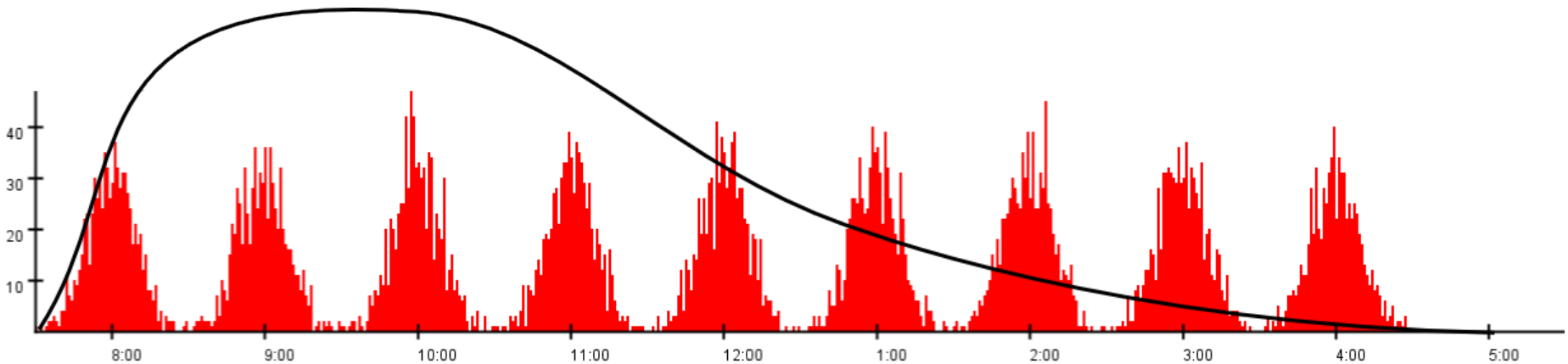
- Arrival times should follow a daily distribution



- Arrival times should differ for Employees and Commuters
- Building targets should be based on how many people actually work/attend class in each building

People Generation

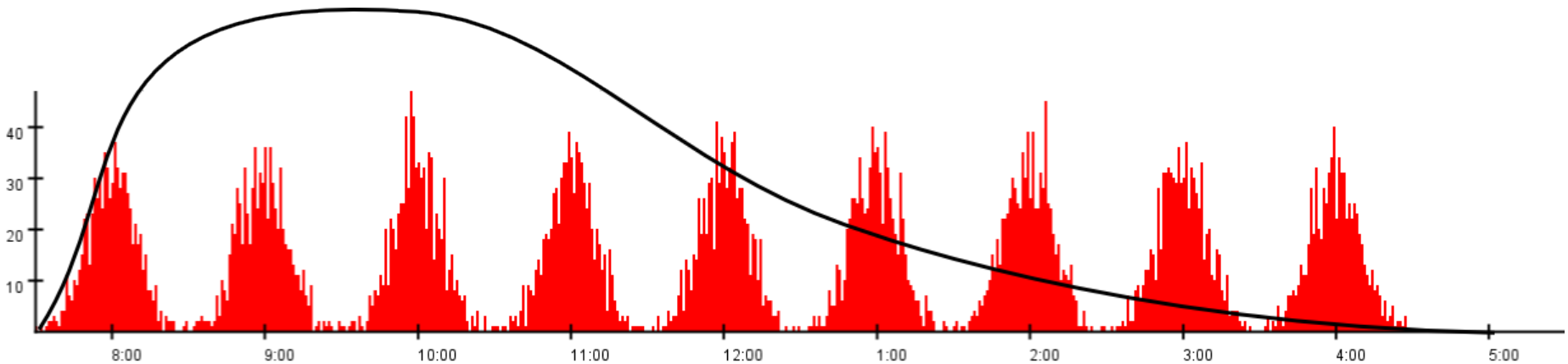
- Arrival times should follow a daily distribution



- Arrival times should differ for Employees and Commuters
- Building targets should be based on how many people actually work/attend class in each building

People Generation

- Arrival times should follow a daily distribution



- Arrival times should differ for Employees and Commuters
- Building targets should be based on how many people actually work/attend class in each building

Simulation

- Loop back if no spots are available on you first tour of all the lots
- Simulate searching for a spot in a given lot
- People should be able to leave campus and then try to return

Simulation

- Loop back if no spots are available on you first tour of all the lots
- Simulate searching for a spot in a given lot
- People should be able to leave campus and then try to return

Simulation

- Loop back if no spots are available on you first tour of all the lots
- Simulate searching for a spot in a given lot
- People should be able to leave campus and then try to return

Conclusion

Thanks to the following people:

- Parking Services for data
- Robert Lund and Ellen Breazel for statistical consultation
- And thank you for your attention

Conclusion

Thanks to the following people:

- Parking Services for data
- Robert Lund and Ellen Breazel for statistical consultation
- And thank you for your attention

Conclusion

Thanks to the following people:

- Parking Services for data
- Robert Lund and Ellen Breazel for statistical consultation
- And thank you for your attention