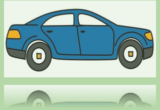
# Parking lot simulation

## -modeling parking time-


Modeling seminar
Faculty of Sciences
University of Novi Sad

January, 2023


Banjanin Nađa 

Doknić Ilija 

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Pavićević Maša 

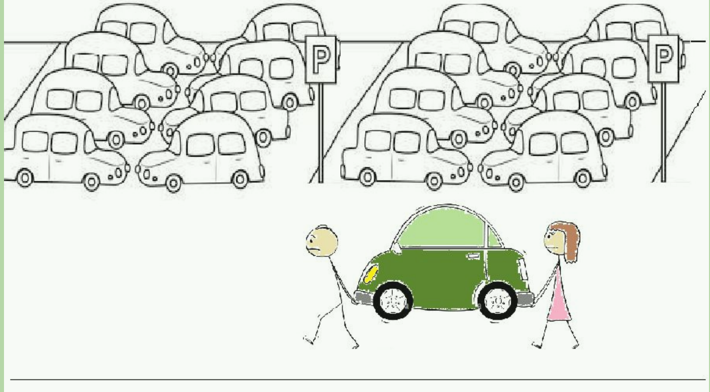

SUPERMARKET

# About the project

- We present two models which provide the expected parking time
- the observed parking lot has the established set of properties and assumption
- The main data used for developing Model 1 and Model 2 is the attendance data for the local 'Lidl' supermarket, available on Google
- Model 1 was our first solution, but we improveD it with Model 2
- The final results are obtained by using the Monte Carlo simulations

# INTRODUCTION

- MANY FACTORS, FOR EXAMPLE BETTER SALARY OR MORE OPPORTUNITIES FOR JOBS , BRING PEOPLE TO CITY
- HALF OF THE GLOBAL POPULATION LIVES IN CITY
- RAPID INCREASE OF CARS LEADS TO THE SHORTAGE OF PARKING SPOTS
- STUDIES SHOW THAT SOME DRIVERS SPEND 67 HOURS EVERY YEAR IN ORDER TO FIND AVAILABLE PARKING PLACE

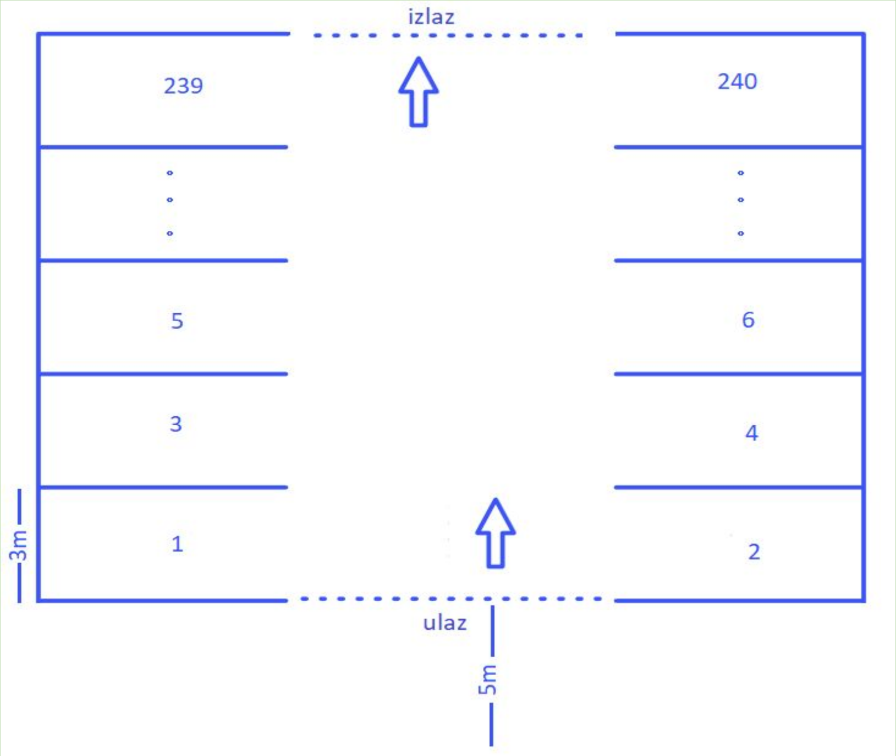


# Parking properties and assumptions

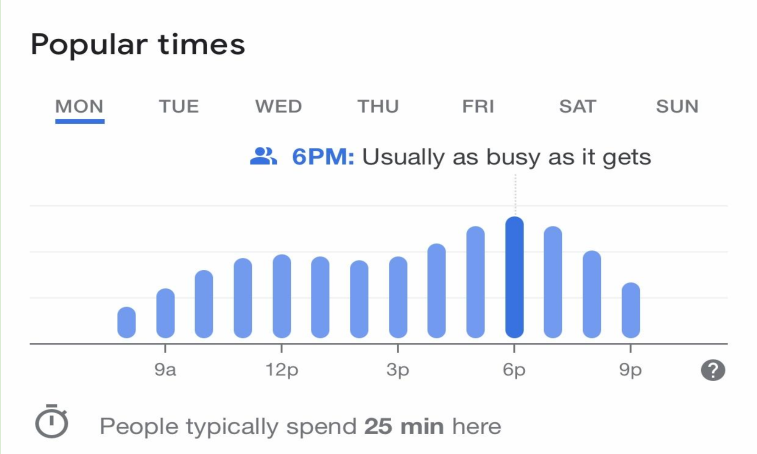
- Parking lot belongs to a supermarket on the outskirts of the city,so the vast majority of customers arrive by car
- Using this assumption, we can identify the attendance data with the number of cars that will need to be parked
- Drivers move uniformly from the ramp to their parking space, with the average speed of 10km/h (2.78m/s)
- time which takes each driver to park in and adjust the car is neglected

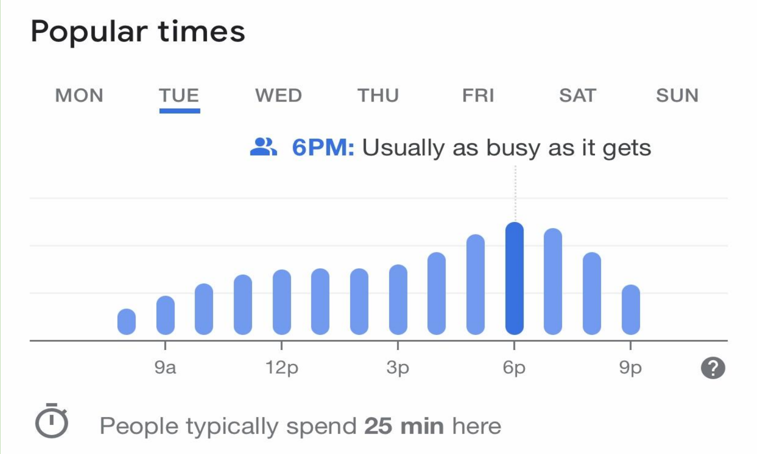
# Parking properties and assumptions

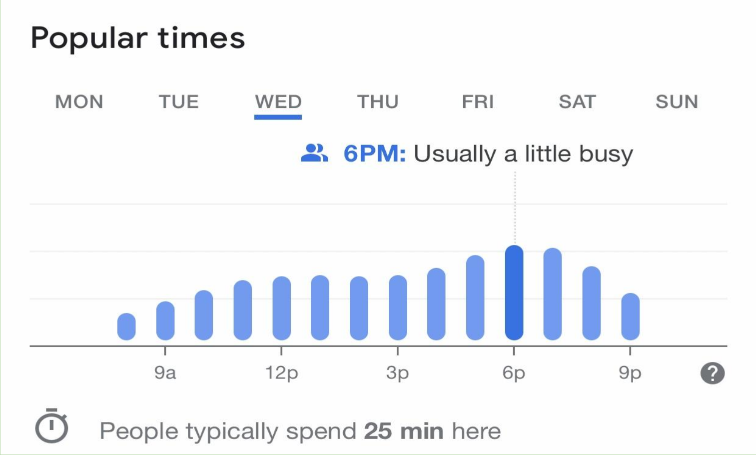
- The capacity is 240 spaces: two columns with a passage between them
- Only one entrance and one exit
- There is a ramp at the entrance and it is lowered only when the capacity is full
- 5m - The distance from the ramp to the first two parking spaces
- Parking spaces are perpendicular to the passage; they're 3m wide

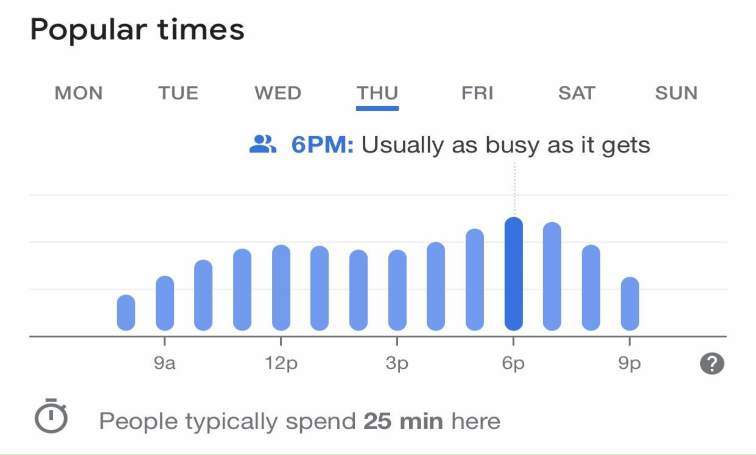


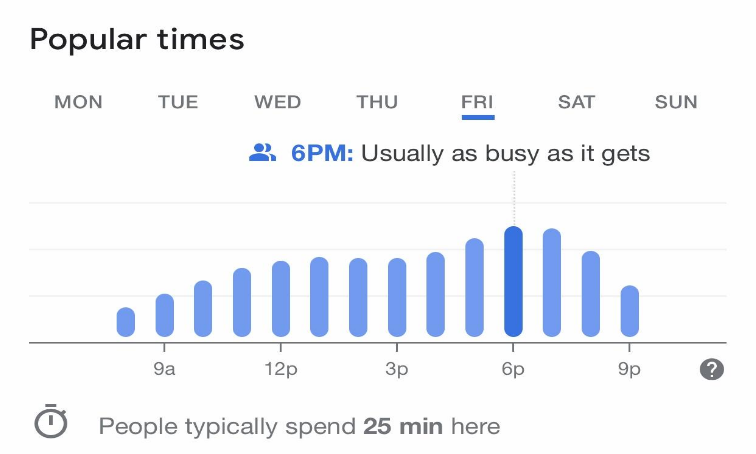
- In accordance with assumptions, we used the information about 'popular times' for the local 'Lidl' supermarket (Bulevar vojvode Stepe 2, Novi Sad),
- found on Google
- attendance graphs for each day (Monday - Sunday, 8am-10pm):




Popular times
MON TUE WED THU FRI SAT SUN
6PM: Usually a little busy
9a 12p 3p 6p 9p
People typically spend 25 min here


Popular times
MON TUE WED THU FRI SAT SUN
6PM: Usually as busy as it gets
9a 12p 3p 6p 9p
People typically spend 25 min here


Popular times
MON TUE WED THU FRI SAT SUN
6PM: Usually as busy as it gets
9a 12p 3p 6p 9p
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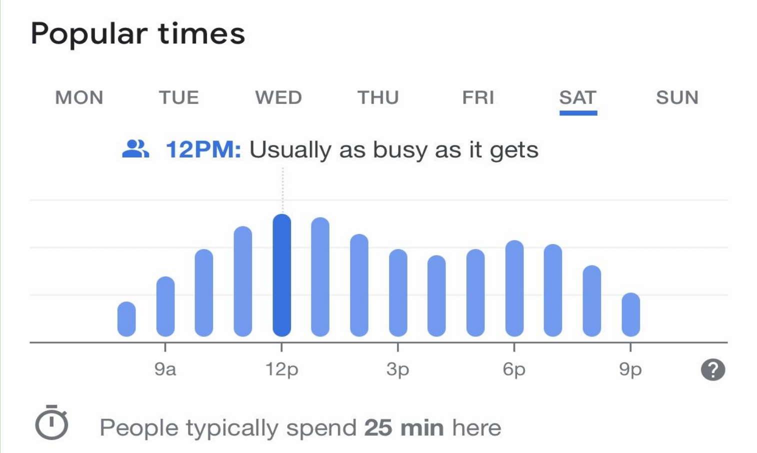
Popular times
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12PM: Usually as busy as it gets
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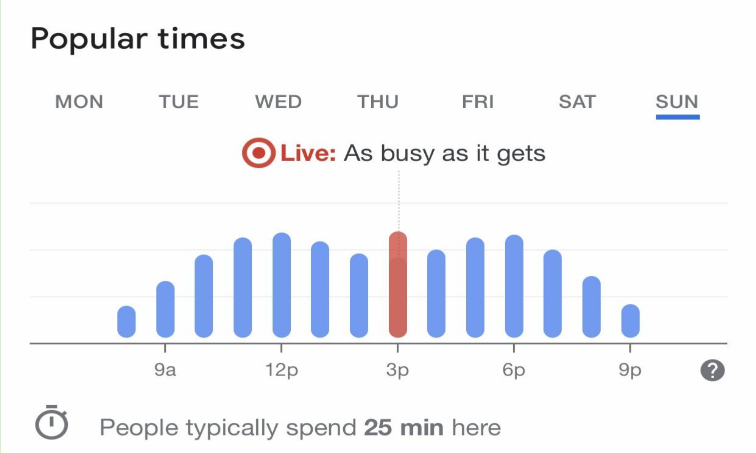
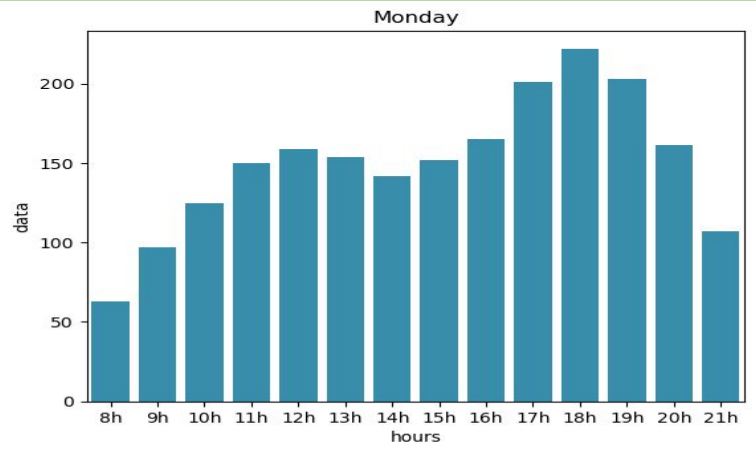
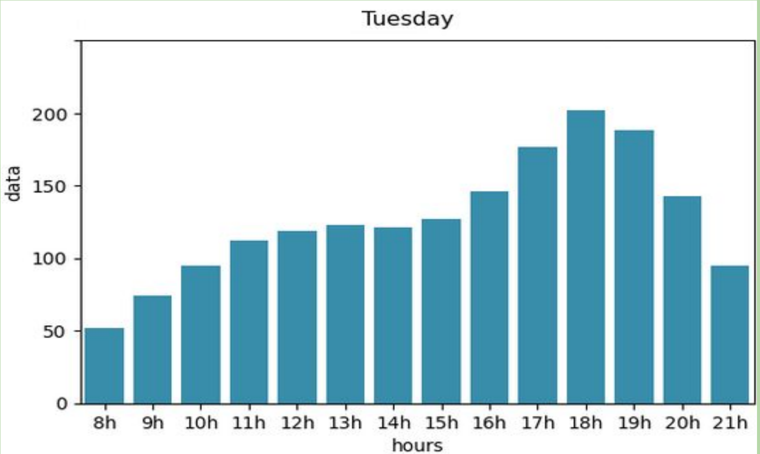
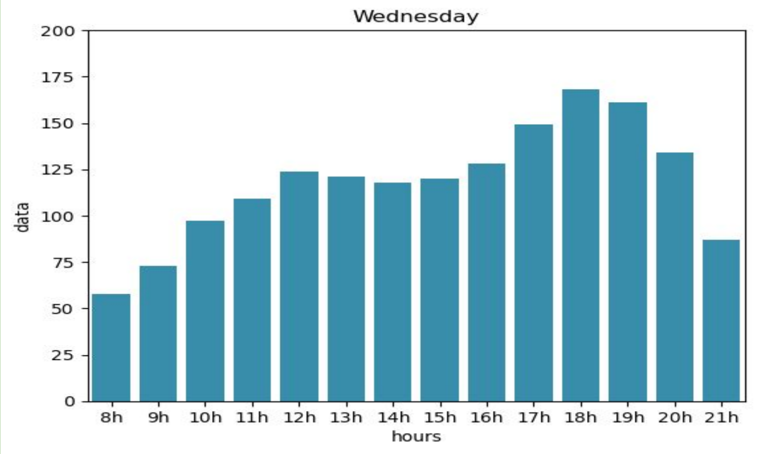
6p
9p
People typically spend 25 min here

Popular times
MON
TUE
WED
THU
FRI
SAT
SUN
Live: As busy as it gets
9a
12p
3p
6p
9p
People typically spend 25 min here

- The available data is only providing information about popular times throughout the day
- we added values for the number of people arriving (vertical axis) at each hour (horizontal axis), so that they correspond to the initial graphs:




Wednesday
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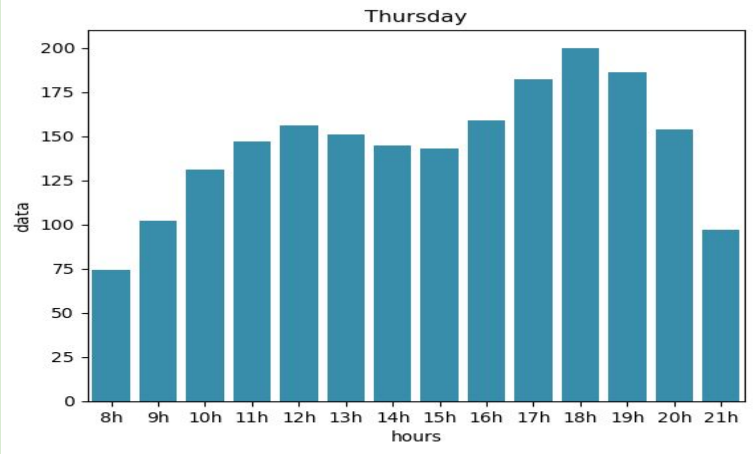
hours


Thursday
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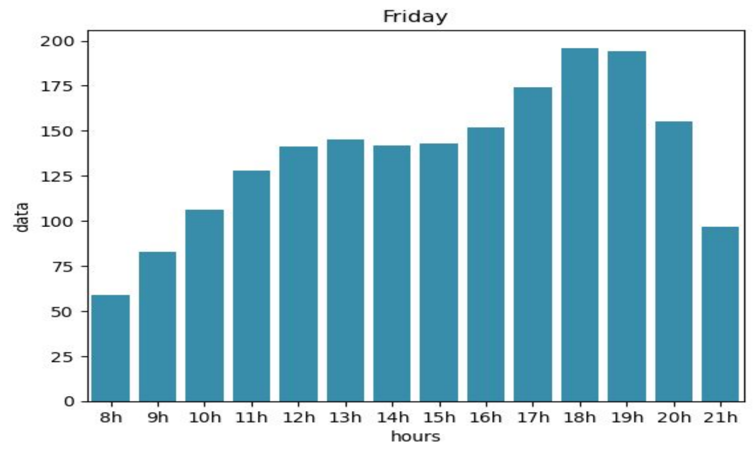
hours


Friday
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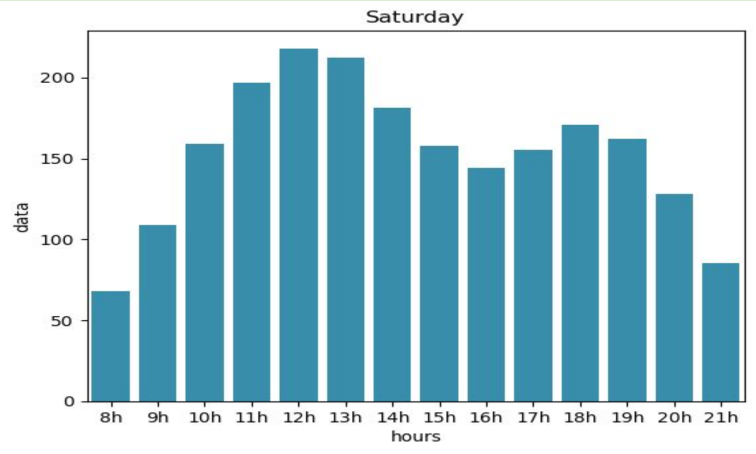
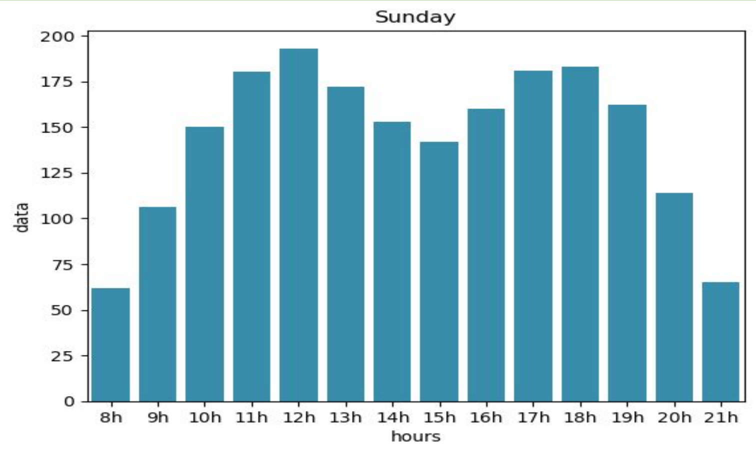



- The attendance data in a particular working hour = the average number of cars that will arrive throughout that hour, $\lambda_i$ , where $i \in \{1,\ldots,14\}$

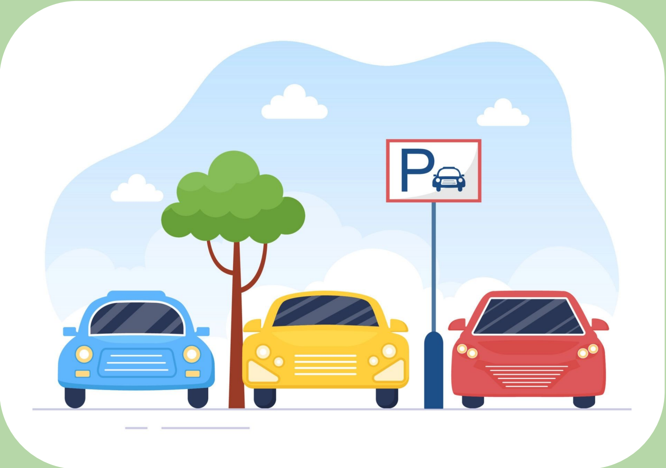
# Model 1

1. The first thing was getting the number of arrivals during the observed hour using the Poisson's distribution with the parameter $\lambda$

2. We divide that number of people by 3 (for the 3 arrivals inside that hour)

3. We assign the first available parking place to every driver(nearest row, priority-left side)

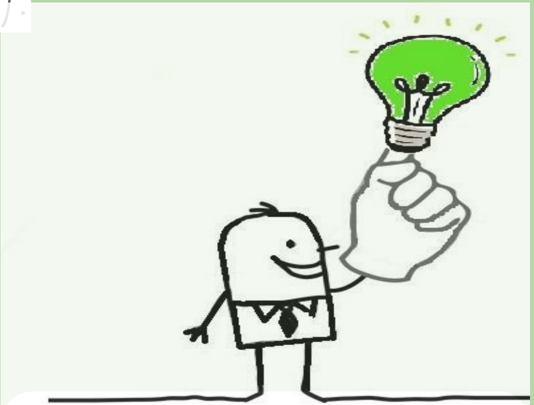
The parameter $\lambda$ is different for every working hour $i$ ($i \in \{1, \ldots, 14\}$) and is equal to the attendance in that hour.



- People arrive every 20 minutes. People come at 8:00, 8:20, 8:40, 9:00, and so on.
- Every car stays in the parking lot for exactly 40 minutes.
- In the last hour, people who arrive at 21:40h have to leave the supermarket and parking lot until 22:00h.


People who arrive at 8:00, leave at 8:40.

The time required to park depends on the distance of the parking place and the average moving speed (2.78m/s):



$$t = \frac{5m+(x-1)^{*}3m}{2.78m/s}$$

x is the number of parking rows,from 1 to 120.

Example: If we want to park the car in the second place in the parking lot, we only need to pass 5m+the first place.

# Description Of Algorithm in python

1. Our input parameter is array of 14 elements, each representing arrivals from 8am to 21pm by day.

2. Based on it, we generate 1000 arrays for a day, using Poisson's distribution with the parameter λ

3.We initialize PARKING variable to be array of two arrays containing 120 elements each one. In other words, it's matrix 2 x 120.

4. Next, we divide that number of ARRIVALS IN ONE HOUR by 3, getting a new array or arrivals, each one representinh arrivals in 20 minutes

5. For each arrival in 20 min, we keep information in parking matrix in list with three elements, using function pickPlace(parking, arrivalTime):

- first can have value 0 or 1 (0 free, 1 occupied)
- arrival time
- time spent in finding place

# Description Of Algorithm in python

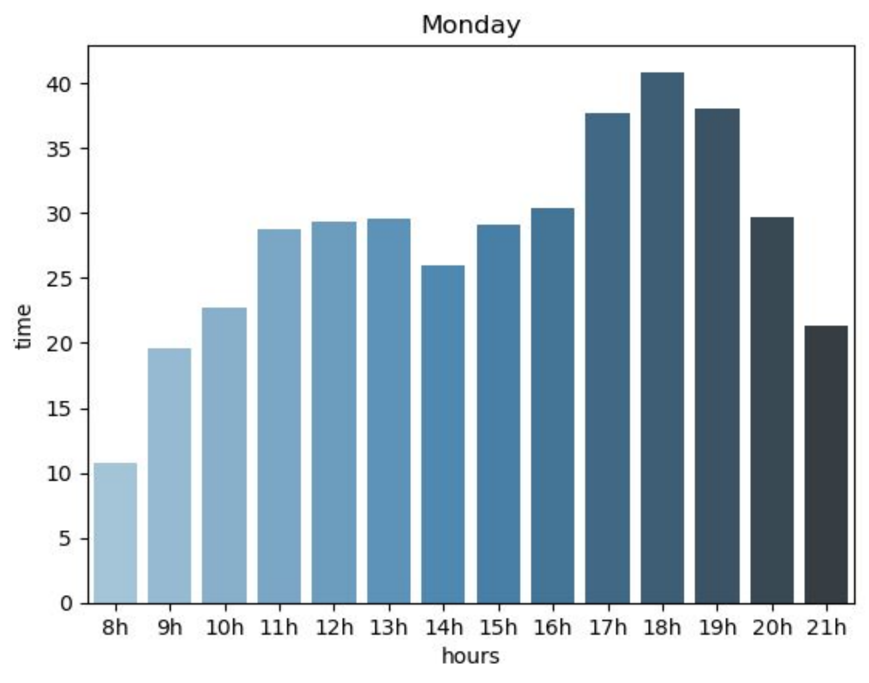
6. Before placing new arrivals in the matrix, we remove those who came 40 minutes ago.

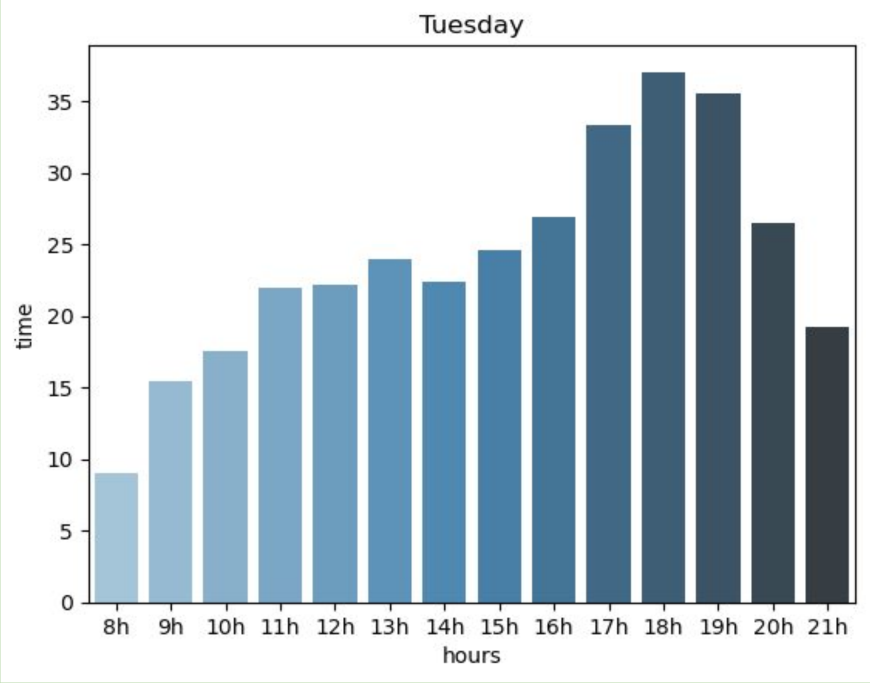
7. The output of this function is avarage time spent in finding free parking place for each hour - array of 14 elements

8. we repeat this procedure 1000 times for one day. Using the Monte Carlo method we get more precise time.

9. Result: The horizontal axis represents the working hours and the vertical axis represents the expected parking time in seconds. The following graphs are results for Monday-Sunday:

# Results from Model 1



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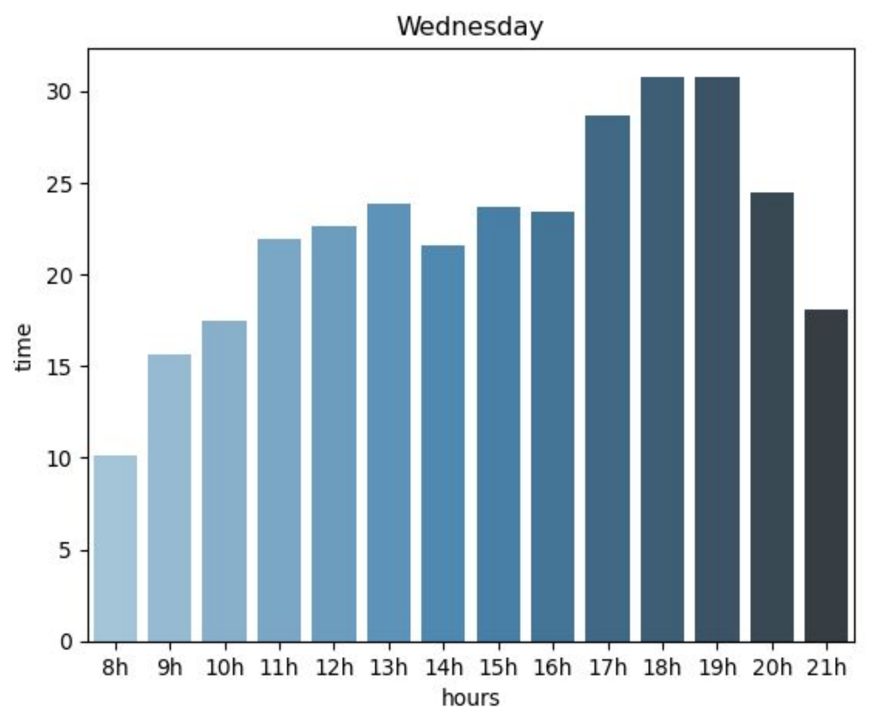


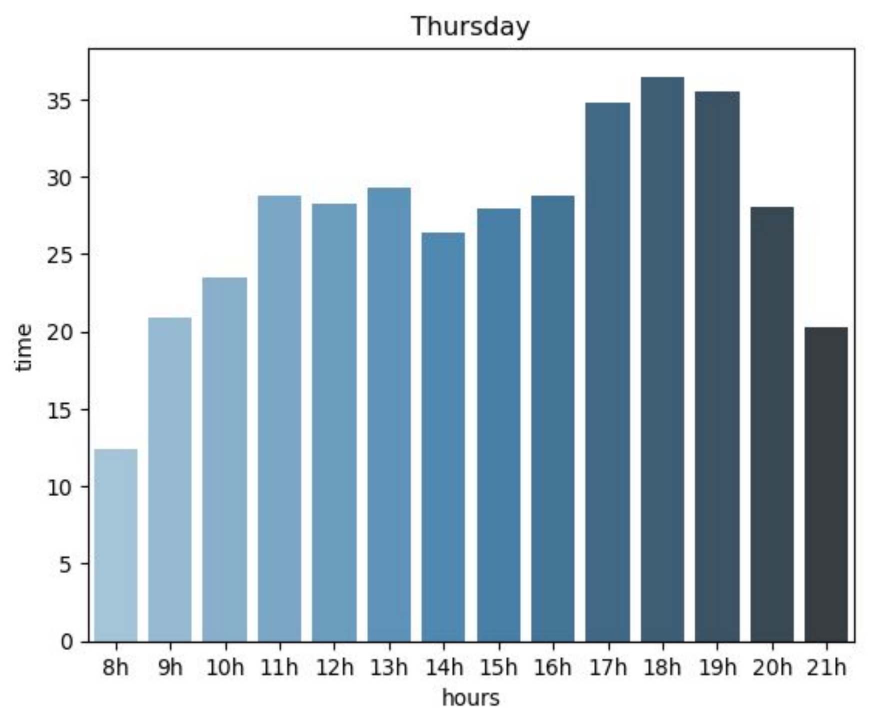

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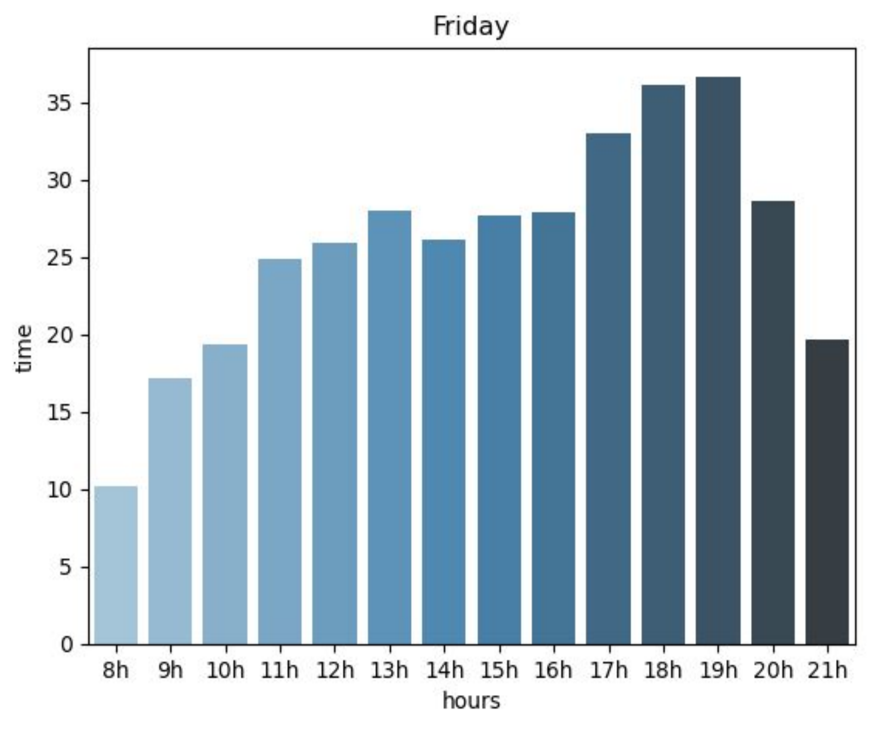
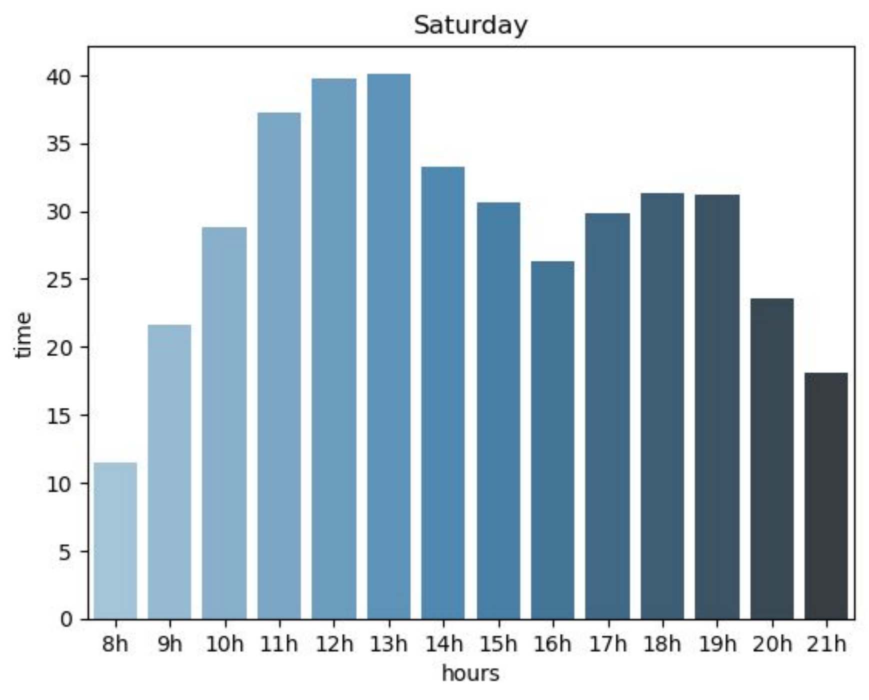
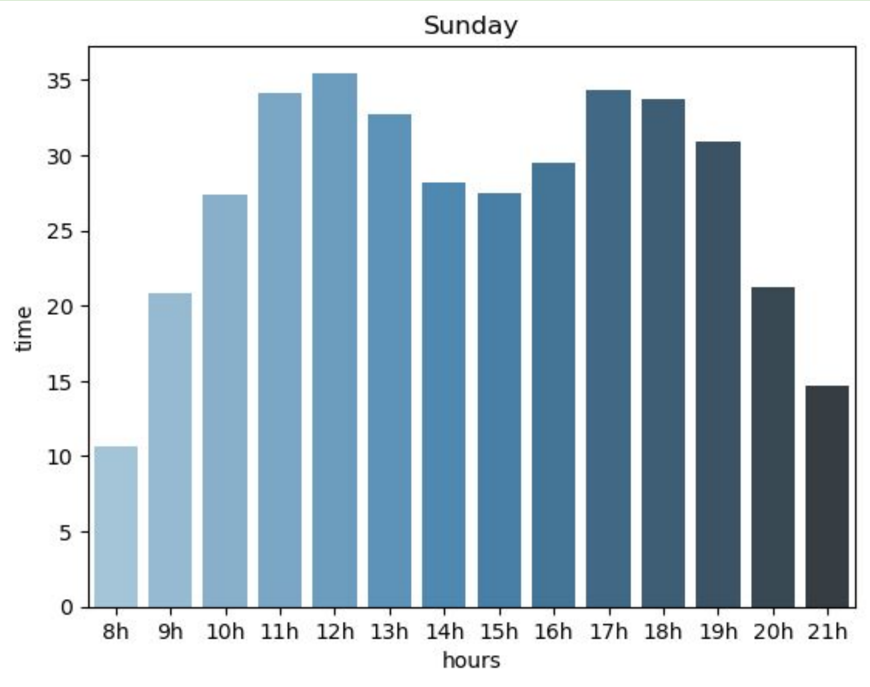


# Results from model 1



**Average time needed to park a car throughout the day**

| | Average |
|---|---|
| **8:00-9:00** | 10.66 |
| **9:00-10:00** | 18.76 |
| **10:00-11:00** | 22.47 |
| **11:00-12:00** | 28.26 |
| **12:00-13:00** | 29.09 |
| **13:00-14:00** | 29.67 |
| **14:00-15:00** | 26.28 |
| **15:00-16:00** | 27.32 |
| **16:00-17:00** | 27.57 |
| **17:00-18:00** | 33.09 |
| **18:00-19:00** | 35.16 |
| **19:00-20:00** | 34.04 |
| **20:00-21:00** | 26.05 |
| **21:00-22:00** | 18.78 |

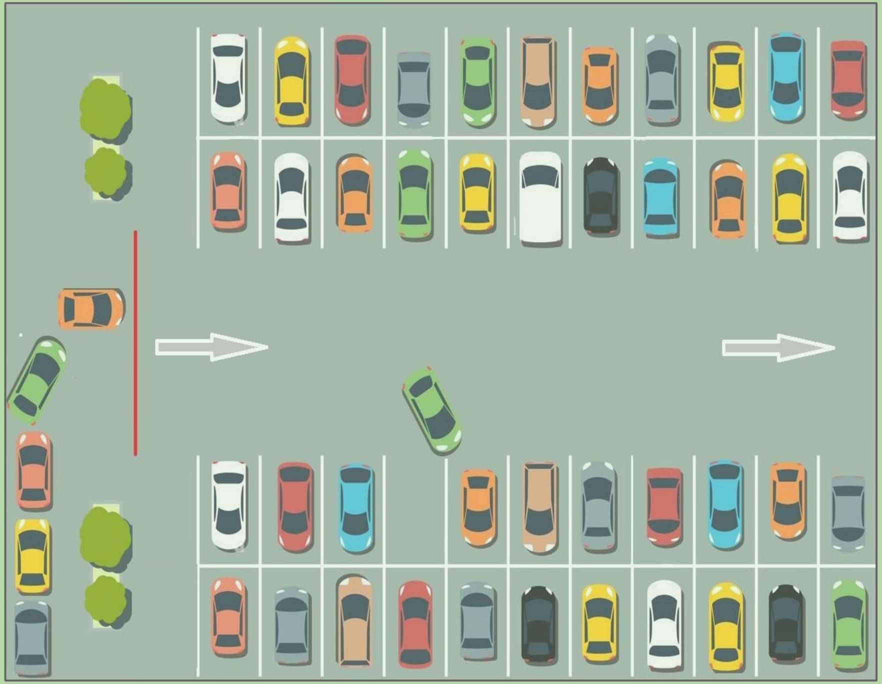
The least amount of time for parking is needed from 8 to 9am.

The most amount of time for parking is needed from 6 to 7pm.

# A special case of model 1

- One special case that is interesting because of the possible impact on the final result is when the parking capacity is full, that is, when we do not have a single parking space available.

- We will limit the maximum number of cars waiting for an available parking space in front of the ramp to 5.



# The assumptions are as follows:

- The number of cars waiting to enter the parking lot can be 1, 2, 3, 4 or 5.
- Cars arrive at the parking lot independently of each other at random times and stay for exactly 40 minutes.
- The first car parked at the parking lot out of all 240 cars after this period leaves the parking lot, making room for the next vehicle.

For the first waiting vehicle, the expected time for which the parking space will be freed is found using the formula:

The expression in parentheses tells us how long the first parked car has been in the parking lot, and when we subtract from the expected holding time, we get the expected departure time of that car. The expected time that will pass until finding an available parking lot space is that time plus the time required to reach an available parking space.


40min-(current time-minimum parking time)

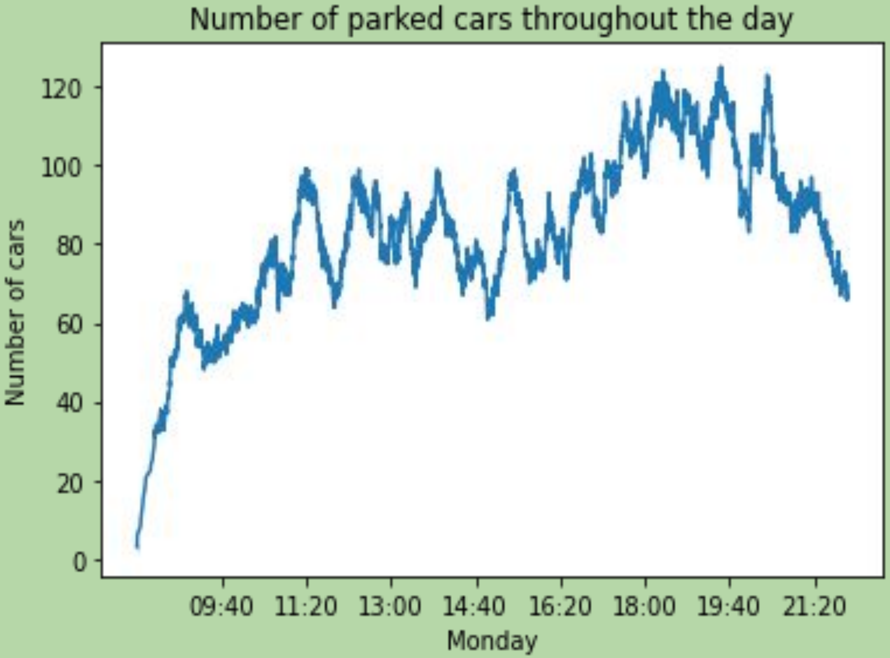
If the second car is waiting for the parking space to become free, its waiting time will be the time it took the first car to park + the waiting time for the next car to leave the parking lot

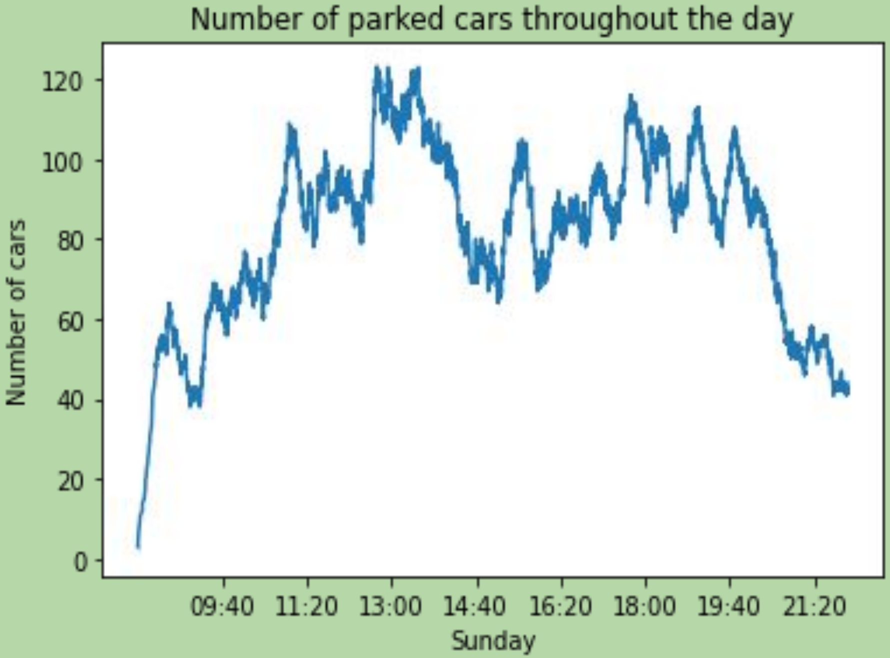
. . .

# Before building a parking lot for supermarket or shopping center...

...VARIOUS FACTORS ARE TAKEN INTO ACCOUNT, DISTANCE FROM THE CITY, PROXIMITY TO BUS STOPS, SIZE OF THE RESIDENTIAL AREA, I.E. THE EXPECTED NUMBER OF PEOPLE FOR WHOM THAT STORE WOULD BE THE FIRST CHOICE FOR SHOPPING, ETC.

LET'S SEE HOW THE OCCUPANCY OF THE PARKING LOT MOVED ON CERTAIN DAYS.


Number of parked cars throughout the day
Number of cars
0
20
40
60
80
100
120
09:40
11:20
13:00
14:40
16:20
18:00
19:40
21:20
Monday


Number of parked cars throughout the day
Number of cars
0
20
40
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80
100
120
09:40
11:20
13:00
14:40
16:20
18:00
19:40
21:20
Sunday

The previous graphs show the expected occupancy of the parking lot at a given time, expected
number of visitors in a rush hour and the average length of their stay.

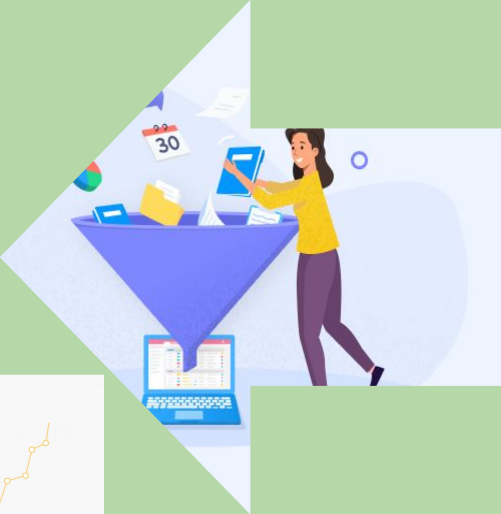
As we can see, the occupancy of the parking lot in peak hours during the day is approximately 50%.

# Model 2

- We observe a parking lot with the same structure as in the first model.
- Also, we use the same input data.
- We want to compare the results we can get as outputs of both models.
- We assume that vehicles in the parking lot will not enter after 9:45 p.m. because the working hours are until 10 p.m., and customers in the big supermarket come to make larger purchases.

# Input data:

- Graph showing 14 x $\lambda$ change during a day
- The average retention time is 25min = 1500 seconds
- Standard deviation is 3min = 180 seconds
- Average speed of 2.78m/s
- Distance from the ramp to the first parking space is 5m
- Parking spare width is 3m
- Parking lot capacity: 240
- Parking lot is  never completely full



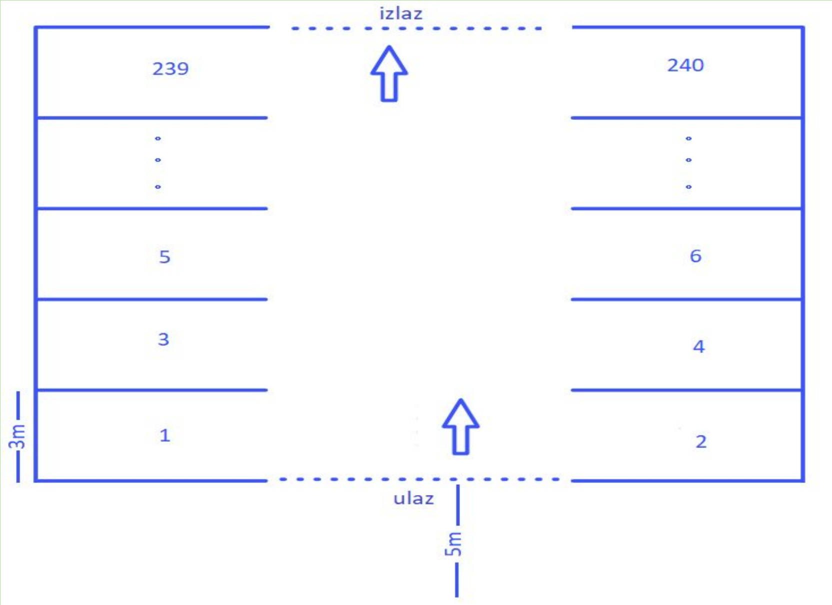

PARKING STRATEGY:

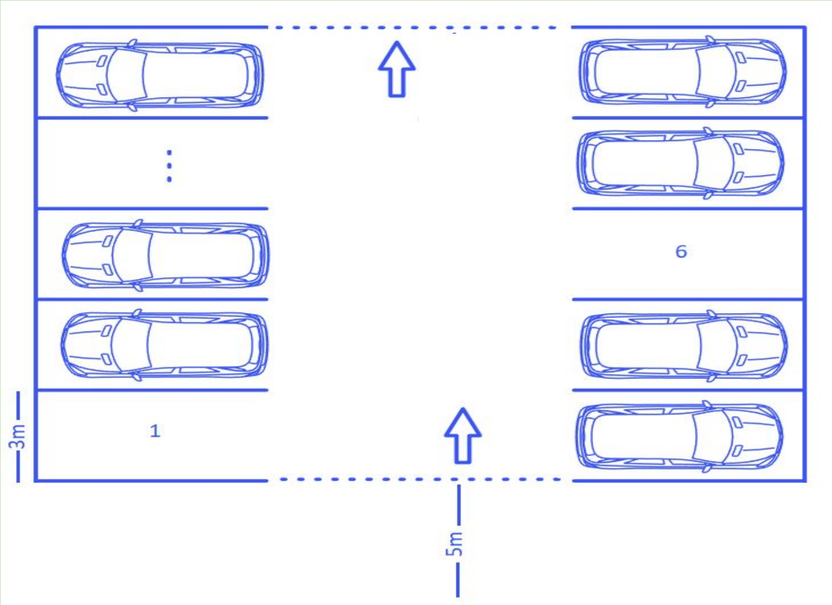
PEOPLE ALWAYS PARK IN THE FIRST AVAILABLE CLOSEST PARKING SPOT.

THE PRIORITY IS ON THE LEFT SIDE (IF THE PARKING SPOTS ARE IN THE SAME ROW).


# Differences from Model 1

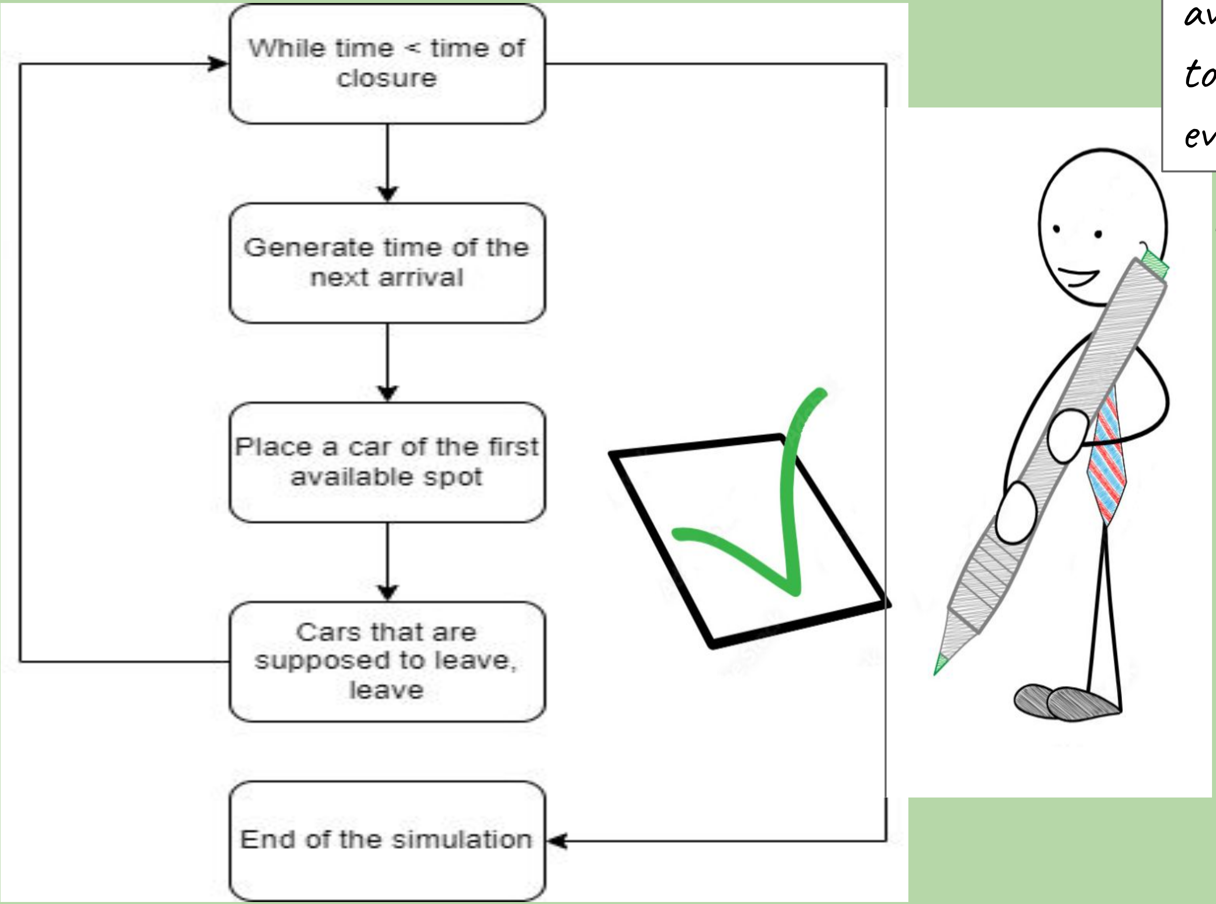
- The numbering of the parking spaces is also slightly different.
- Also, they come and leave the supermarket whenever they want.
- The improvement we introduced in this model is that we do not limit customers to spend 40 minutes in the parking lot. The time spent in the parking lot is obtained from a normal distribution with parameter 1500 s (25 min) and standard deviation 180 s (3 min).
- We use $\varepsilon(1/\lambda)$-Exponential distribution-represents the time until the next car comes to the parking lot where parameter $\lambda$ is arrival rate $\lambda$ = *number of cars/3600s*



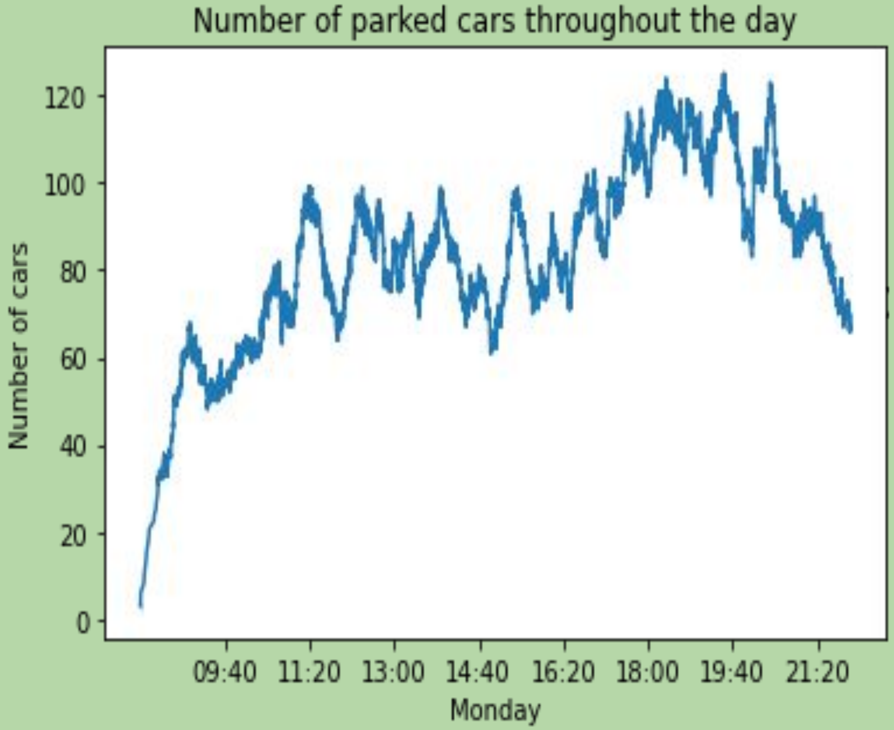




WE ASSIGN A PARKING SPOT AND TIME OF STAY IN THE PARKING LOT TO EACH CAR, AND AT THE SAME TIME WE GET THE TIME OF DEPARTURE FROM THE PARKING LOT. CARS LEAVE THE PARKING LOT REGARDLESS OF WHICH ONE ARRIVED FIRST AND THEIR PARKING SPOT BECOMES AVAILABLE.

# How the simulation works?




*Output data is the average time required to find parking for every hour.*


Number of parked cars throughout the day
Number of cars
0
20
40
60
80
100
120
09:40
11:20
13:00
14:40
16:20
18:00
19:40
21:20
Monday


Expected time need to park throughout the day
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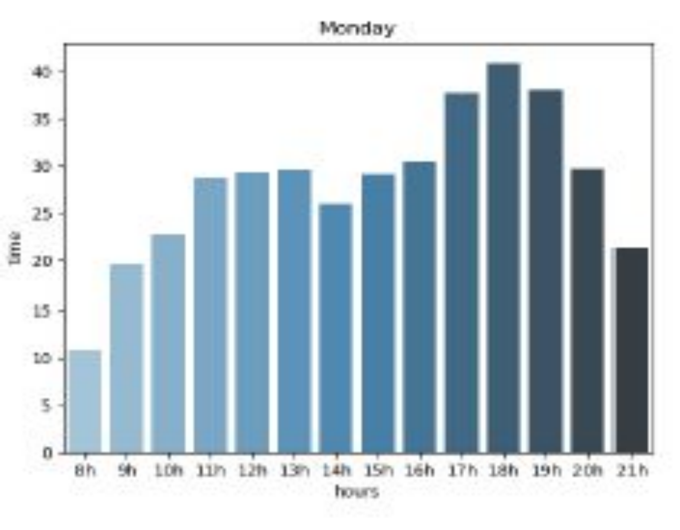
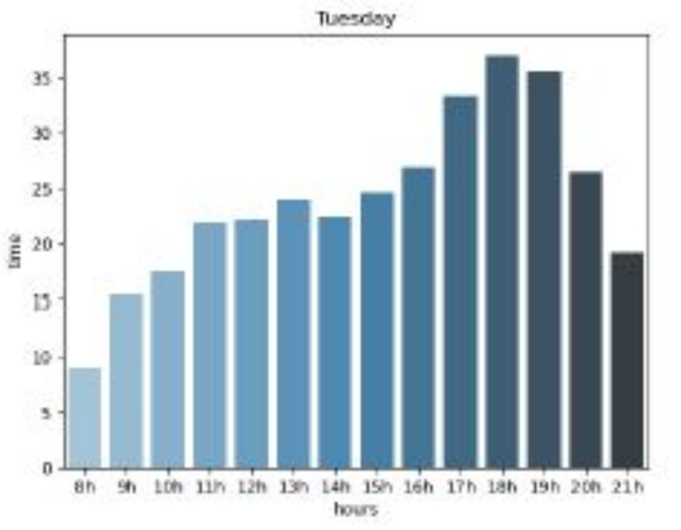
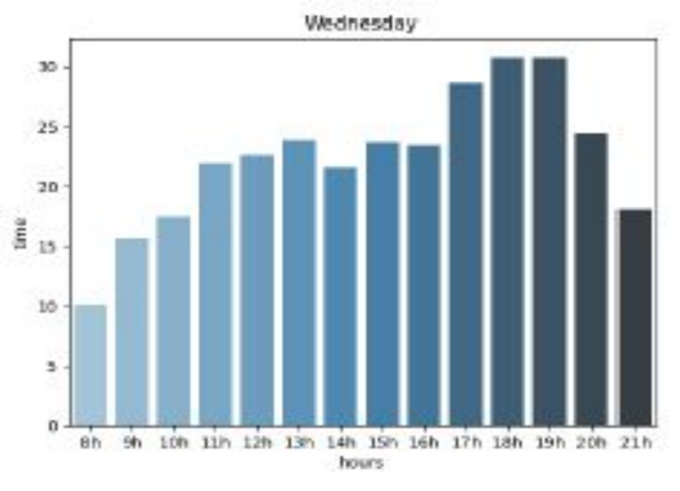
21:00
Monday

# Results from Model 2





Wednesday
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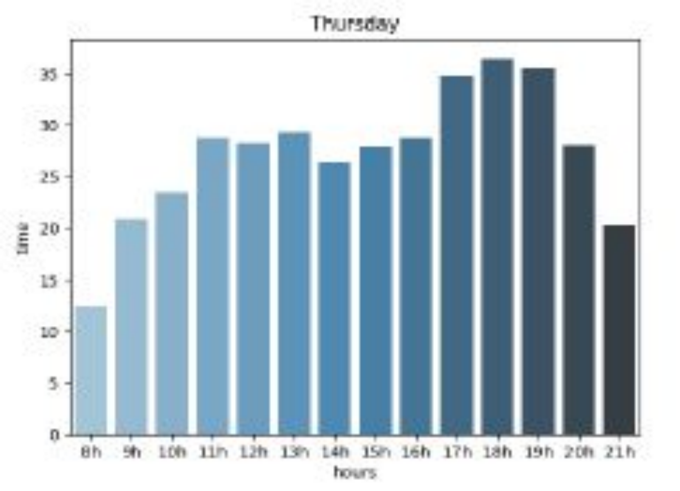
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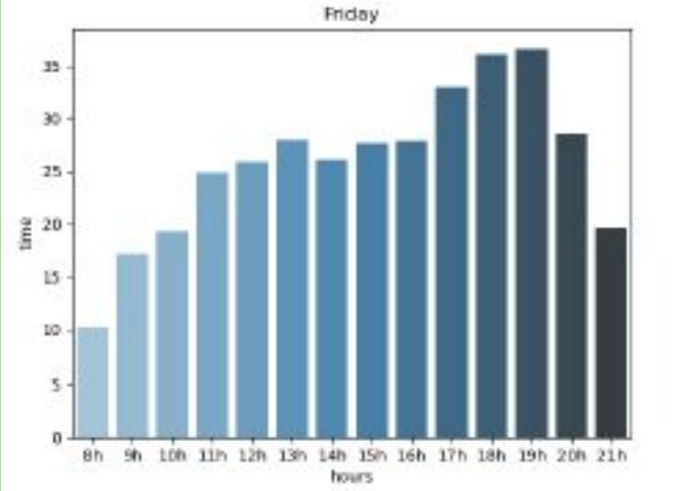
Friday
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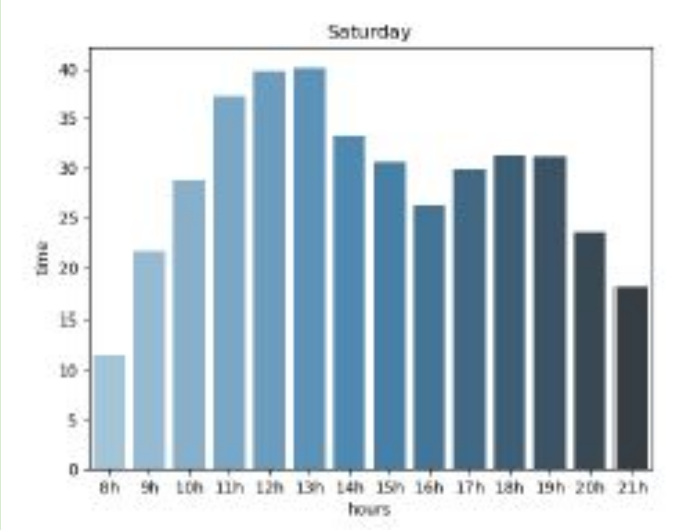
Saturday
time
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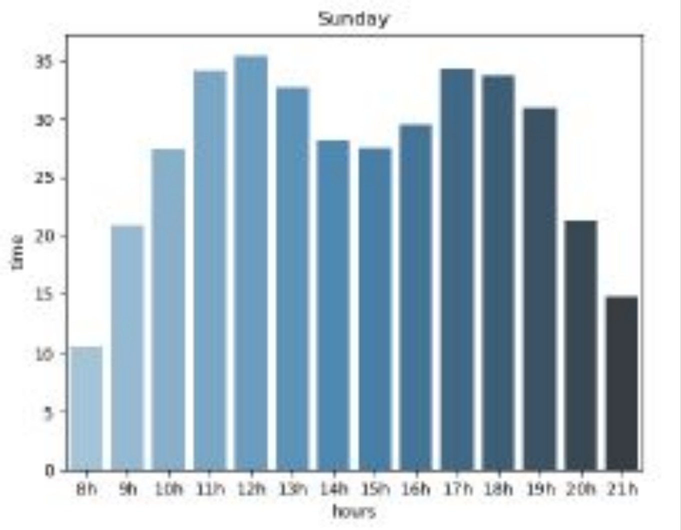
Sunday
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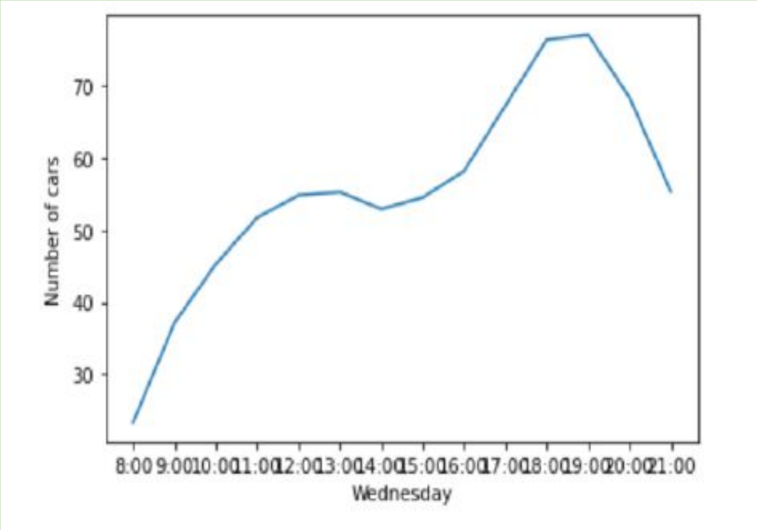
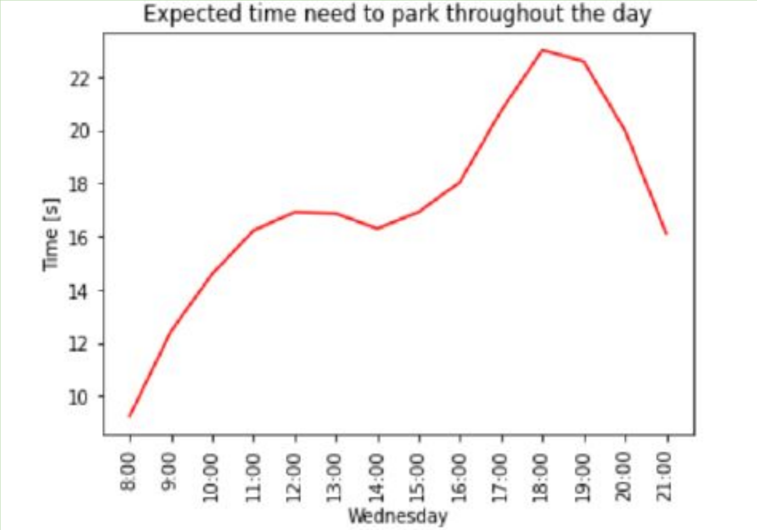
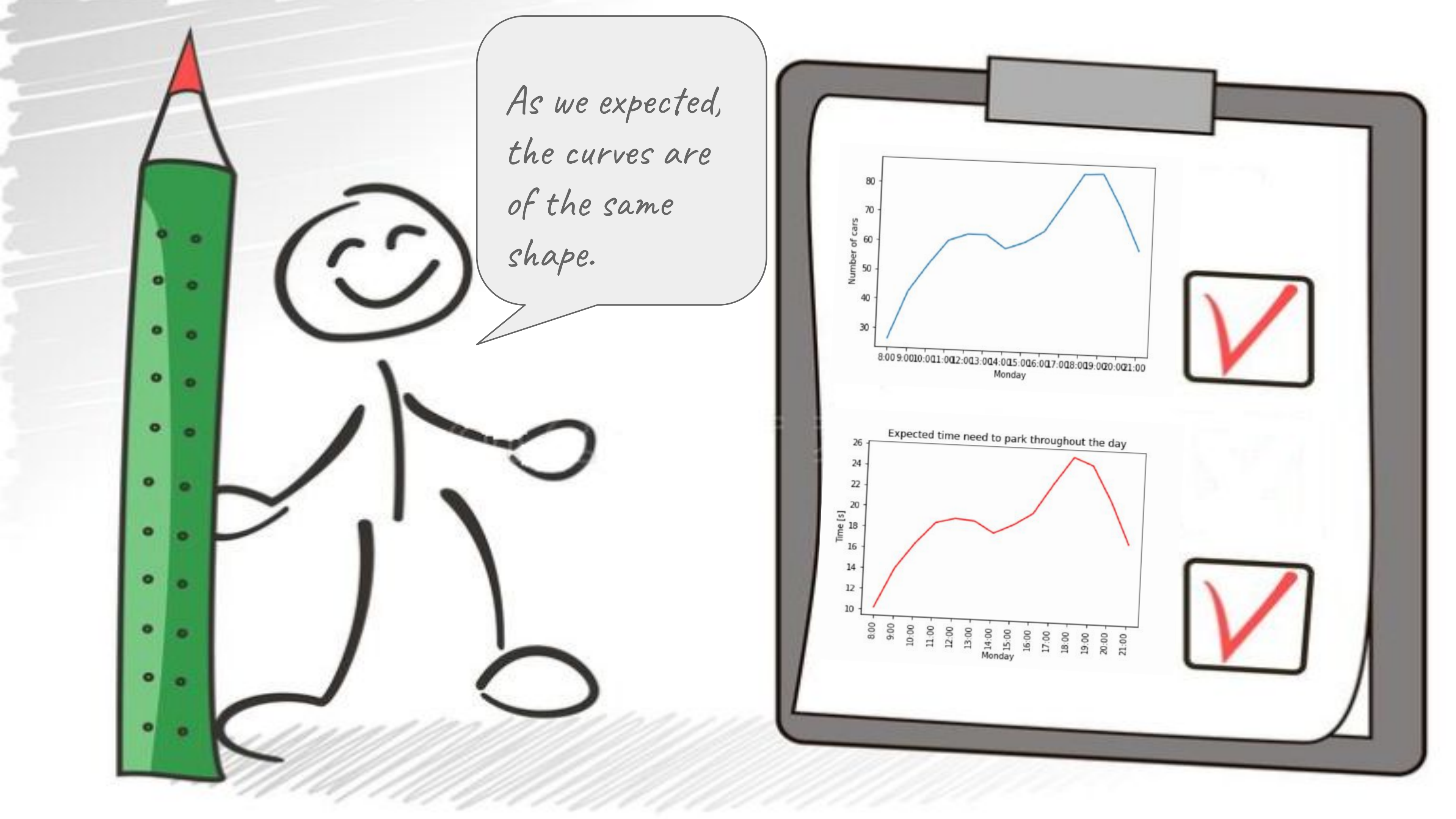
18h
19h
20h
21h




THE BLUE CURVE REPRESENTS THE NUMBER OF CARS AND THE RED CURVE REPRESENTS THE AVERAGE TIME NEEDED TO FIND AN AVAILABLE ONE PARKING SPACE.


As we expected, the curves are of the same shape.
Number of cars
Monday
Expected time need to park throughout the day
Time [s]
Monday

## Average per hours

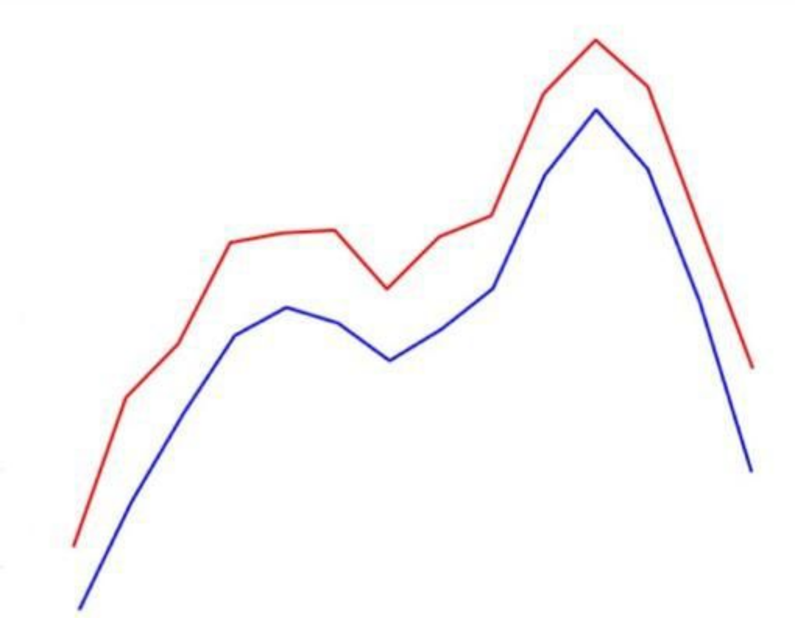
| | Average |
|---|---|
| 8:00-9:00 | 9.85 |
| 9:00-10:00 | 13.25 |
| 10:00-11:00 | 15.75 |
| 11:00-12:00 | 17.54 |
| 12:00-13:00 | 18.30 |
| 13:00-14:00 | 18.02 |
| 14:00-15:00 | 17.27 |
| 15:00-16:00 | 17.72 |
| 16:00-17:00 | 18.83 |
| 17:00-18:00 | 21.15 |
| 18:00-19:00 | 23.39 |
| 19:00-20:00 | 23.17 |
| 20:00-21:00 | 20.32 |
| 21:00-22:00 | 16.55 |

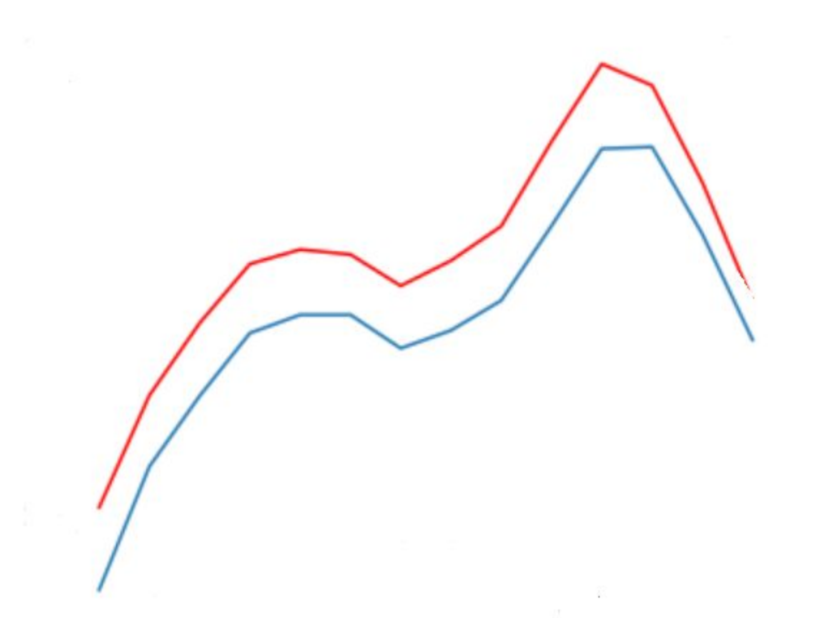
The least amount of time for parking is needed from 8 to 9am.

The most amount of time for parking is needed from 6 to 7pm.

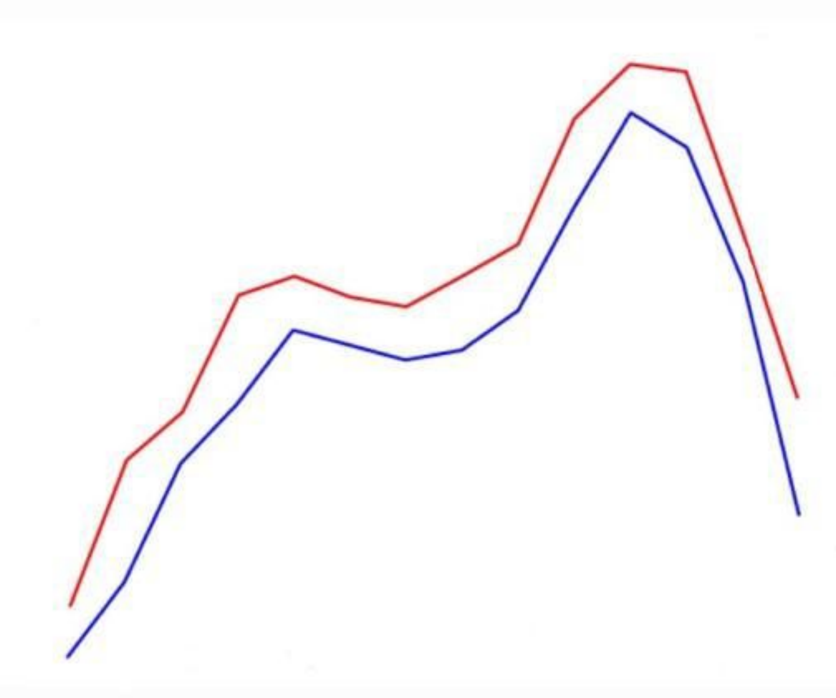
# Comparing

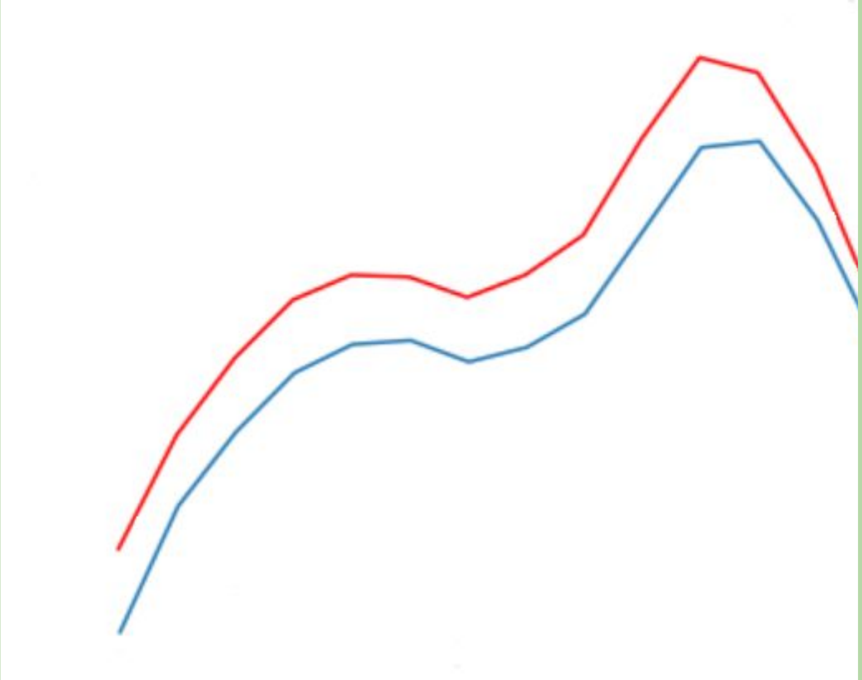
RESULTS FROM MONDAY:



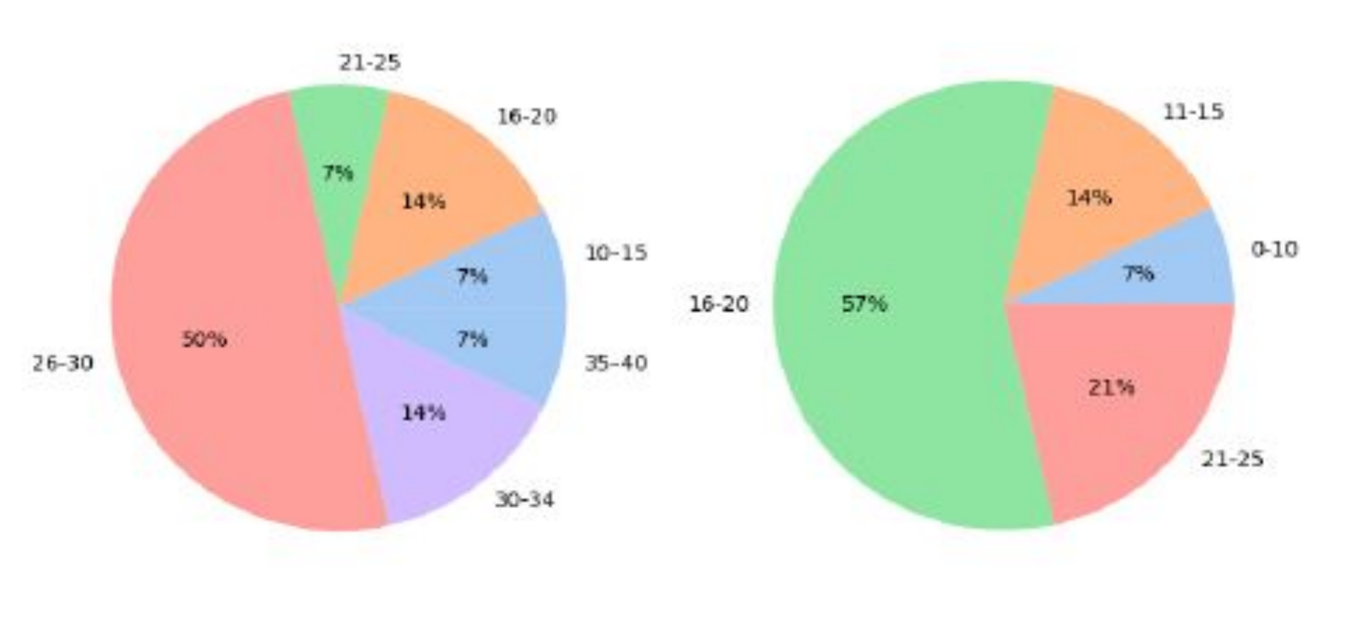


# RESULTS FROM WEDNESDAY:





The time shown on the diagrams is in seconds and it is marked what percentage of parking is done for such a period of time.



We can see that the data obtained in both models do not differ too much, the curves have the same shape, and both models follow the attendance graph as we expected. If we compare the average time required for parking, we will see that the results obtained in the first and second models are different.
They are different because in the first model, it was assumed that cars stay in the parking lot for 40 minutes, while in the second, the average retention is 25 minutes.

# EXAMPLE:

ASSUME THAT WE HAVE 120 CARS IN PARKING AREA. IN BOTH MODELS CAR IS GOING TO TAKE FIRST AVAILABLE SPOT, PRIORITY IS LEFT SIDE.

FIRST MODEL:

40 CARS ARRIVE EVERY 20 MINUTES AND TAKE THE FIRST AVAILABLE PARKING SPOTS. THEY STAY FOR 40 MINUTES.

SECOND MODEL:

120 CARS ARRIVE IN 1 HOUR, APPROXIMATELY 2 CARS EVERY MINUTE. THEY STAY FOR ABOUT 25 MINUTES, WITH ST.DEVIATION OF 3 MINUTES.

IN SECOND MODEL CARS LEAVE PARKING SPOT EARLIER THAN IN THE FIRST MODEL, WHICH MEANS THAT THERE IS A POSSIBILITY TO FIND AVAILABLE PARKING SPOT IN THOSE FIRST 40 SPOTS. WE DONT HAVE THIS OPTIONS IN THE FIRST MODEL, BECAUSE THE FIRST 40 PLACES ARE TAKEN ALL 40 MINUTES.

# How to improve model?

Other factors that affect parking time can also be examined, such as what would happen if

- the driver's preference to park in the closest spot was turned off, instead of considering that customers want to park close to the entrance of the market
- We don't have a ramp and cars drive through the parking lot while waiting for a spot to open up. If they notice someone leaving, they wait for them to exit and park in their spot, instead of parking in a spot close to the market entrance....