**CENG 4513 Modeling and Simulation Project Report**

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**Project Name**: Traffic Simulation Models

## 1. Introduction

The traffic problem I experienced in the city building game Cities: Skylines inspired me. In my project, I simulated 3 different road patterns with paid passages with 3 different models. I have observed the performance of the queue in the passages and the difference between the number of cars entering and leaving according to the arrangement of the roads.

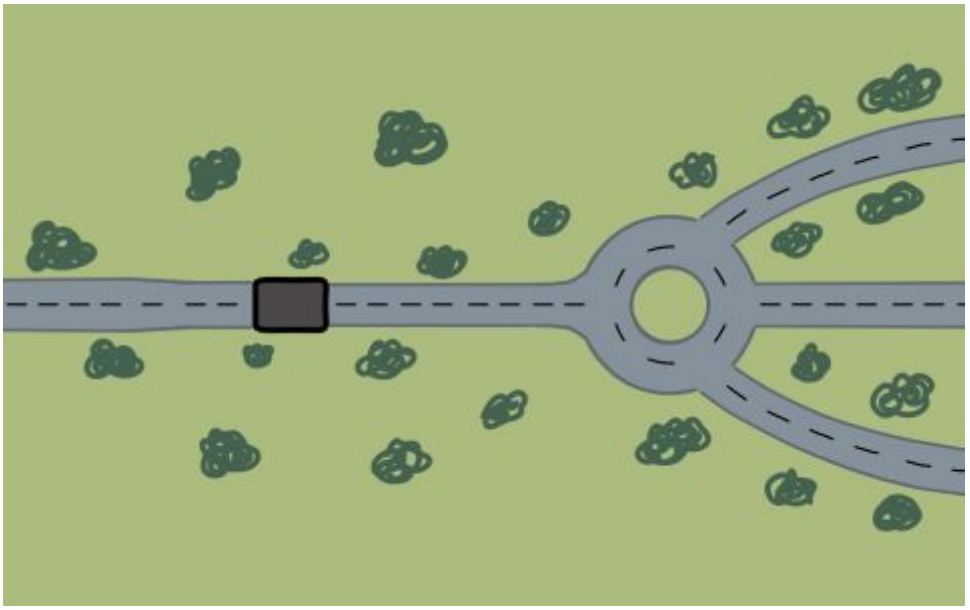
## 2. Modeling Part

As I mentioned in the Introduction section, I use 3 different models with different road patterns with paid passages. There are 3 reasons why I work with 3 models instead of a single model:

a. Inclusion of the lengths of the roads in the model
b. To examine the effects of passages by increasing the number of passes and thus the number of queues, not the performance of a single paid passage with a single queue by increasing the number of resources
c. To extend the scope of the project

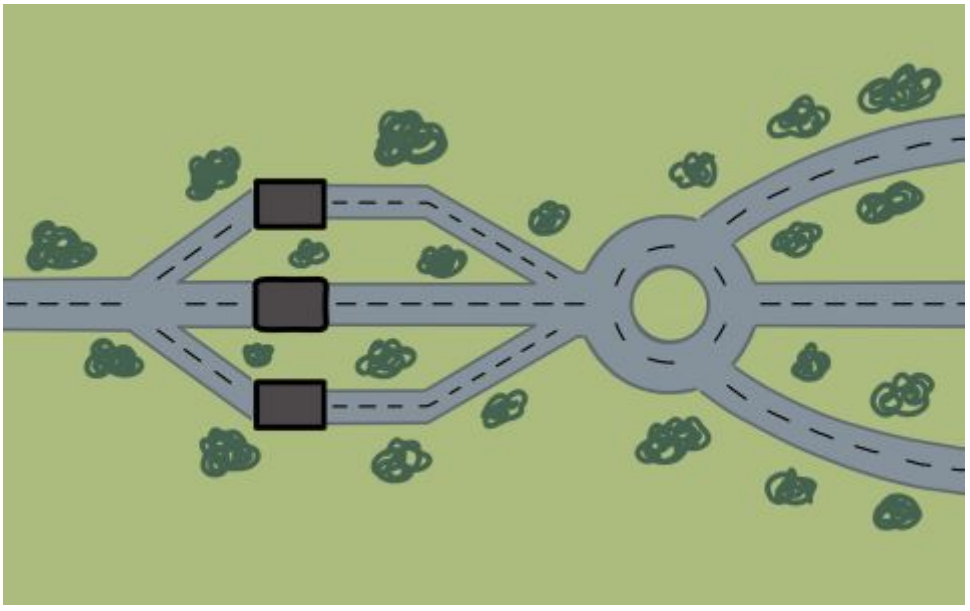
Before we get into details, if we look at the simulation layouts of all 3 models:

**Figure 1:** 1-1 Model



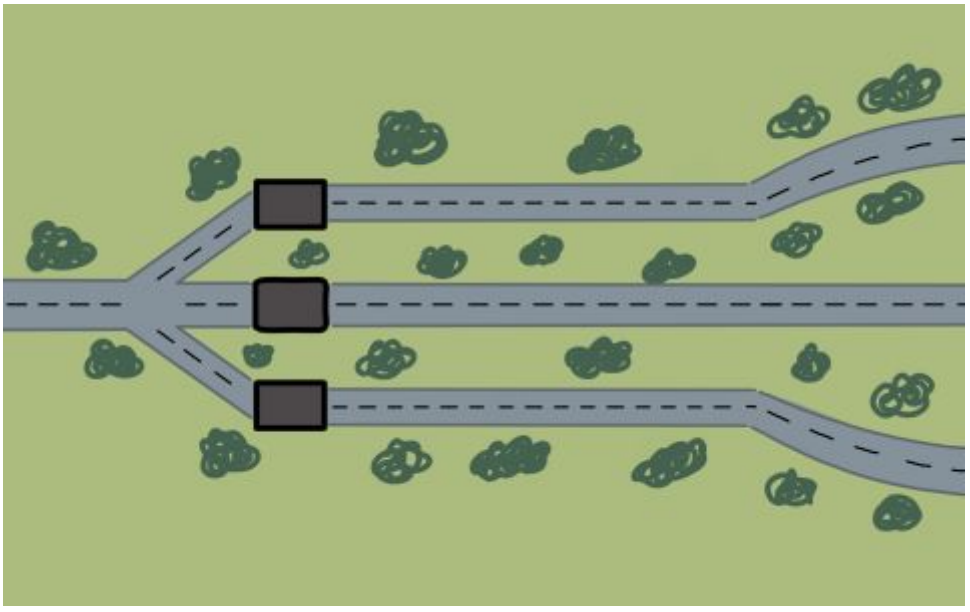
This model has a single paid passage and an intersection used to get to the exit.

**Figure 2:** 3-1 Model



This model has 3 paid passages and an intersection used to get to the exit.

**Figure 3:** 3-3 Model



This model has 3 paid passages and 3 paths that connect directly to the exit from paid passages.

Inputs and values for all models are given in the table below.

**Table 1:** Inputs and Values for Models

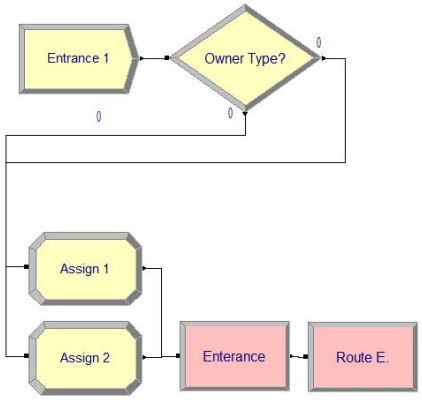
| INPUT | VALUE | |
|---|---|---|
| **Time Between Arrivals of Cars** | Exponential | 5 min |
| **Time Between Entrance and Crossroad** | 1,5 min | |

| | | |
|---|---|---|
| **Time Between Crossroad and Paid Passages** | *(Passage No)* | *(Time)* |
| | 1 | 2 min |
| | 2 | 3 min |
| | 3 | 3 min |
| **Duration of Payment Process** | *(for all Payment Processes)* | |
| | *Delay Type: Normal* | |
| | *Mean: 3 min* | *Std: .2 min* |
| **Time Between Payment Process and Intersection** | *(for 1-1 Model)* | |
| | *(Payment No)* | *(Time)* |
| | 1 | 5 min |
| | *(for 3-1 Model)* | |
| | *(Payment No)* | *(Time)* |
| | 1 | 5 min |
| | 2 | 7 min |
| | 3 | 7 min |
| **Time Between Payment Process and Exit** | *(for 3-3 Model)* | |
| | *(Passage No)* | *(Time)* |
| | 1 | 8 min |
| | 2 | 9 min |
| | 3 | 9 min |
| **Time Between Intersection's Start and Point of Separation** | *(for 1-1 and 3-1 Models)* | |
| | 2 min | |
| **Time Between Point of Separation and Exit** | *(for 1-1 and 3-1 Models)* | |
| | *(Exit Name)* | *(Time)* |
| | Bloomsbury | 7 min |
| | Smithfield | 5 min |
| | Marylebone | 5 min |
| **RATES** | | |
| **Vehicle Owner's Type Ratios** | 75% | civilian |
| | 25% | tourist |
| **Paid Passage Selection Condition** | *(for 3-1 and 3-3 Models)* | |
| | *(Passage No)* | *(Expression)* |

| | | |
|---|---|---|
| | 1 | The total number of cars entering Payment 1 is less than others OR equal to the total number of vehicles entering Payment 2 |
| | 2 | The total number of cars entering Payment 2 is less than others OR equal to the total number of vehicles entering Payment 3 |
| | 3 | The total number of cars entering Payment 3 is less than others OR equal to the total number of vehicles entering Payment 1 |
| **Ratios of Choosing Which District to Use for Exit** | *(for 1-1 and 3-1 Models)* | |
| | 34% | Bloomsbury |
| | 33% | Smithfield |
| | 33% | Marylebone |
| **RESOURCES** | | |
| **Number of Officers** | *(for all models and for each payment process)* | |
| | 1 | |

All values are going to be more meaningful with the sections below.

### 2.1. Entrance Diagram

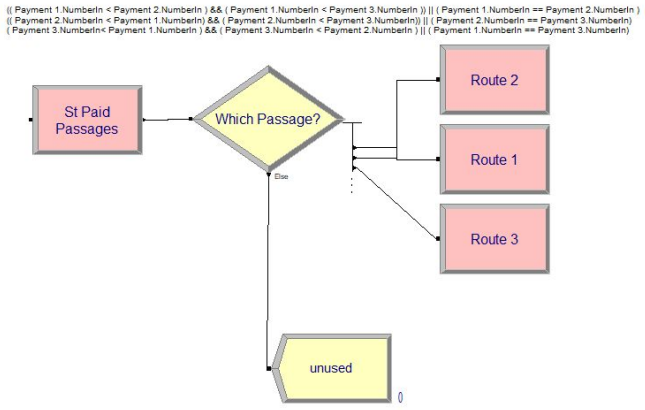



This part is common for all models.

- The car enters from “Entrance 1”.
- The vehicle that comes to the decision stage, "Owner Type?", selects one of the paths according to the rates in the Table 1.

- “Assign 1” assigns the car an attribute named "Owner.type" and value "citizen".
- “Assign 2” assigns the car an attribute named "Owner.type" and value "tourist".
- There is a station called "Entrance" for simulation.
- "Route E" leads the car to "St Paid Passage", the first station of the next section.

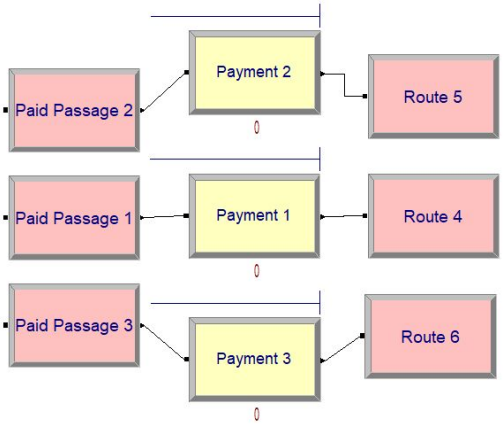
## 2.2. Crossroad Diagram




This part is common for 3-1 and 3-3 models. In the 1-1 model, there is no “Which Passage?” part, “St Paid Passage” links “Route 1” directly.

- The car arriving at "St Paid Passage" station comes to the decision stage, "Which Passage?", and chooses the path to go according to the conditions in Table 1.
- The "unused" exit is not used because there is never a situation where conditions are not met at the decision stage.
- “Route x” leads the car to “Paid Passage x” station in the next section.

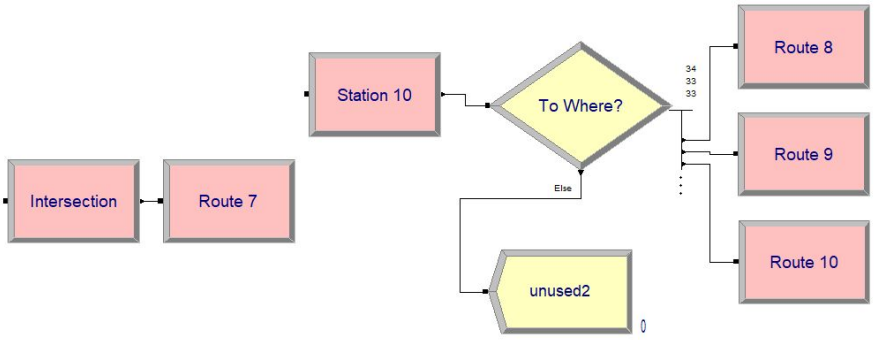
## 2.3. Paid Passages Diagram




This part is common for all models.
In the 1-1 model, there are no parts for Paid Passage 2 and 3.
In the 3-3 model, Routes 4, 5 and 6 lead the car to exit stations in the exit section.

- The car arriving at “Paid Passage x” station comes to the “Payment x” process.
- “Route x” leads the car to “Intersection” station in the next section.

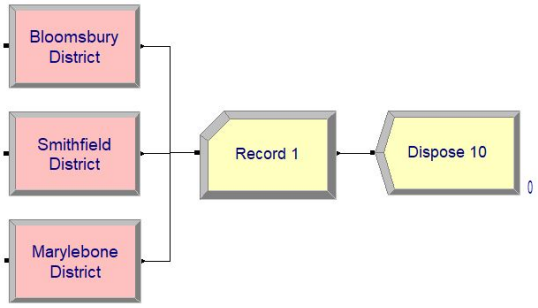
## 2.4. Intersection Diagram




This part is common for 3-1 and 3-3 models. 1-1 model, does not have this part.

- The car arriving at “Intersection” station comes to the “Route 7”.
- “Route 7” leads the car to “Station 10” station.
- The car arriving at "Station 10" station comes to the decision stage, "To Where?", and chooses the path to go according to the rates in Table 1.
- The "unused2" exit is not used because there is never a situation where conditions are not met at the decision stage.
- “Route 8” leads the car to “Bloomsbury District” station in the next section.
- “Route 9” leads the car to “Smithfield District” station in the next section.
- “Route 10” leads the car to “Marylebone District” station in the next section.

## 2.5. Exit Diagram

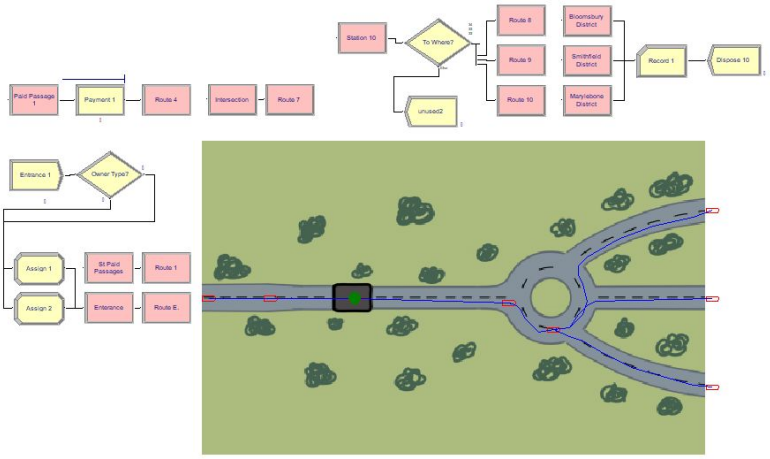



This part is common for all models.

- The car arriving at “Bloomsbury District” station comes to the “Record 1” to keep statistics of the number of cars according to the owners' types.
- The car arriving at “Smithfield District” station comes to the “Record 1” to keep statistics of the number of cars according to the owners' types.
- The car arriving at “Marylebone District” station comes to the “Record 1” to keep statistics of the number of cars according to the owners' types.
- The car passing through "Record 1" comes to the "Dispose 10" exit and completes the simulation.

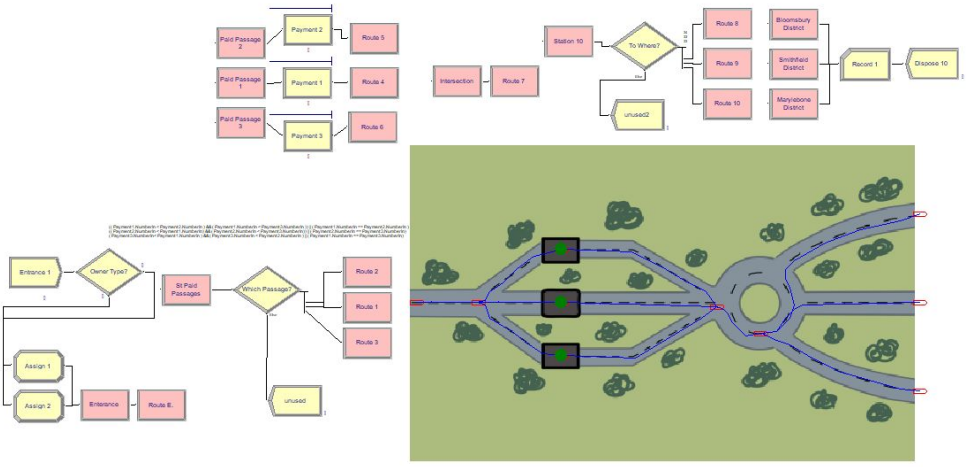
## 2.6. All Simulation Models with Diagrams

**Figure 4:** 1-1 Simulation Models with Diagram



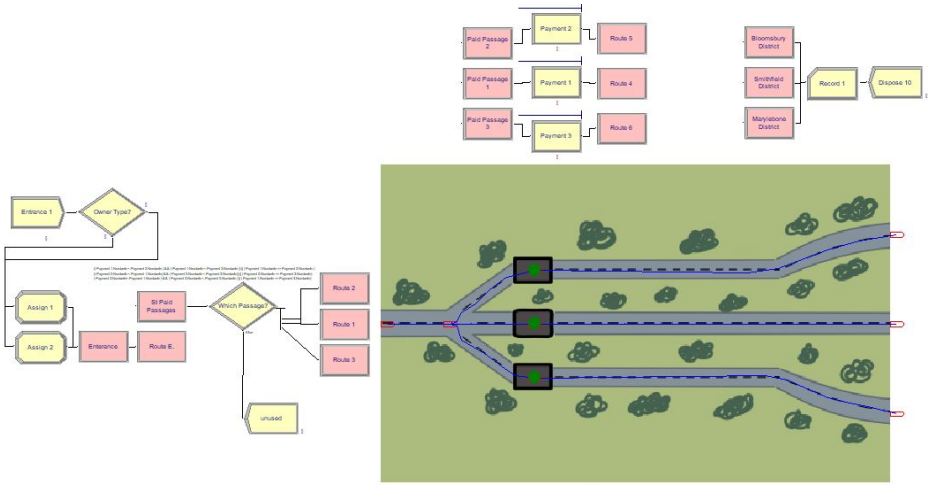

Youtube video link for screen recording of the simulation running:
https://youtu.be/2_W1o-sR3UQ

**Figure 5:** 3-1 Simulation Models with Diagram




Youtube video link for screen recording of the simulation running:
https://youtu.be/ByQpTAzlGvc

**Figure 6:** 3-3 Simulation Models with Diagram



Youtube video link for screen recording of the simulation running:
https://youtu.be/nuv7Wbk3AJc

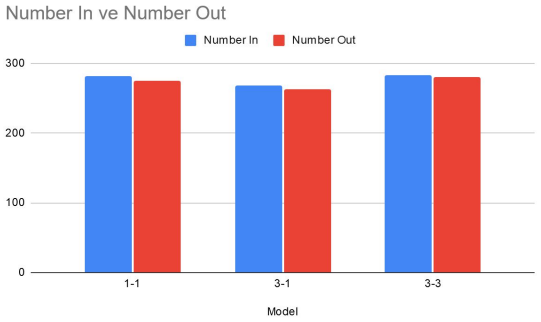
## 3. Results of The Model

I ran the model for a 24 hour period and noted the values on the report. Below are the values and evaluations.

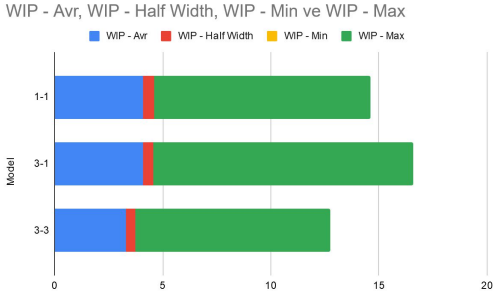
**Table 2:** Entity Results

| Model | Number In | Number Out | WIP (Work In Process) | | | |
|---|---|---|---|---|---|---|
| | | | Avr | Half Width | Min | Max |
| 1-1 | 281 | 275 | 4,1 | 0,49 | 0 | 10 |
| 3-1 | 268 | 263 | 4,08 | 0,49 | 0 | 12 |
| 3-3 | 283 | 280 | 3,28 | 0,47 | 0 | 9 |

**Graph 1:**




**Graph 2:**




If we look at Table 2 and graphs above:

- When we look at the number in, we see that the differences do not vary according to the models. This does not surprise us, because all models have a Create method and the time between arrivals of cars values are the same.
- When we look at how many cars entering could not exit for each model, we see that 6 for Model 1-1, 5 for Model 3-1 and 3 cars for Model 3-3 could not complete the model.

The reasons for this number to decrease gradually:

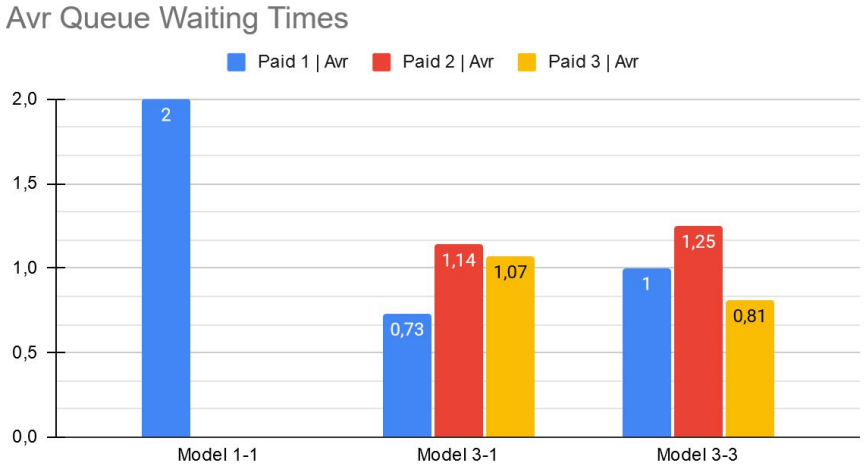
* increased number of paid passages for the 1-1 and 3-1 models,
* for the 3-1 and 3-3 models, the 3-3 model has direct routes to the exit, while the 3-1 model has to pass through the intersection before the exits and this causes losing time

- When we look at the Work In Process values, we see that the average is gradually decreasing. The reason for this can be attributed to the decrease in the density of the queues with the increase of paid passages.

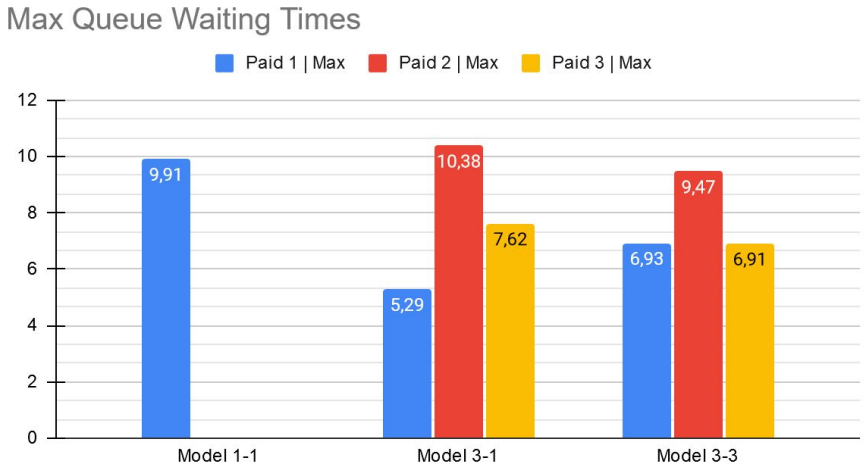
**Table 3:** Queue Results 1

| Model | Waiting Time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Paid 1.Queue | | | Paid 2.Queue | | | Paid 3.Queue | | |
| | Avr | Min | Max | Avr | Min | Max | Avr | Min | Max |
| 1-1 | 2 | 0 | 9,91 | - | - | - | - | - | - |
| 3-1 | 0,73 | 0 | 5,29 | 1,14 | 0 | 10,38 | 1,07 | 0 | 7,62 |
| 3-3 | 1 | 0 | 6,93 | 1,25 | 0 | 9,47 | 0,81 | 0 | 6,91 |

**Graph 3:**




**Graph 4:**



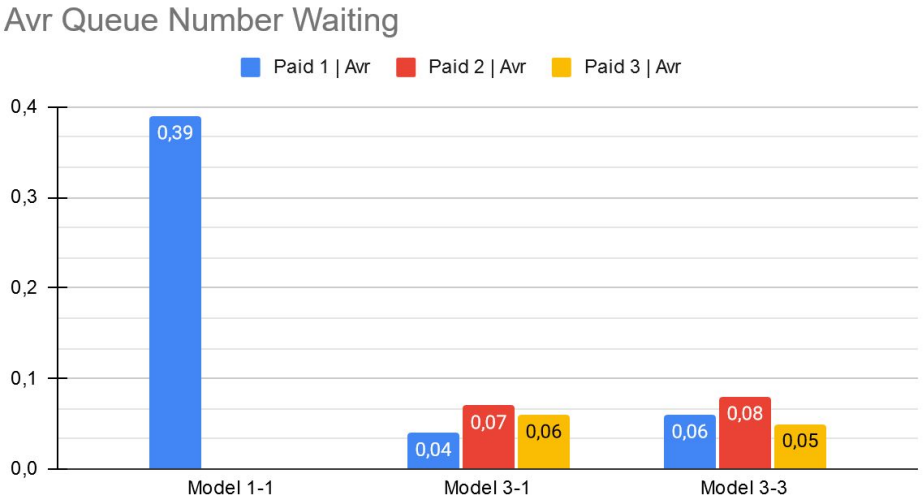

If we look at Table 3 and graphs above:

- When we look at the average waiting times, we see that model 1-1 is almost 2 times the others. We can attribute this to the fact that they have to wait in a single queue, as there is only one paid passage in model 1-1.
- When we look at the maximum waiting times, we see that the values are very close to each other. As we said, however, the reason for the high maximum value in model 1-1 is that more cars wait with values close to the maximum value because it is a single queue.

**Table 4:** Queue Results 2

| Model | Number Waiting | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Paid 1.Queue | | | Paid 2.Queue | | | Paid 3.Queue | | |
| | Avr | Min | Max | Avr | Min | Max | Avr | Min | Max |
| 1-1 | 0,39 | 0 | 4 | - | - | - | - | - | - |
| 3-1 | 0,04 | 0 | 2 | 0,07 | 0 | 4 | 0,06 | 0 | 3 |
| 3-3 | 0,06 | 0 | 3 | 0,08 | 0 | 3 | 0,05 | 0 | 3 |

**Graph 5:**

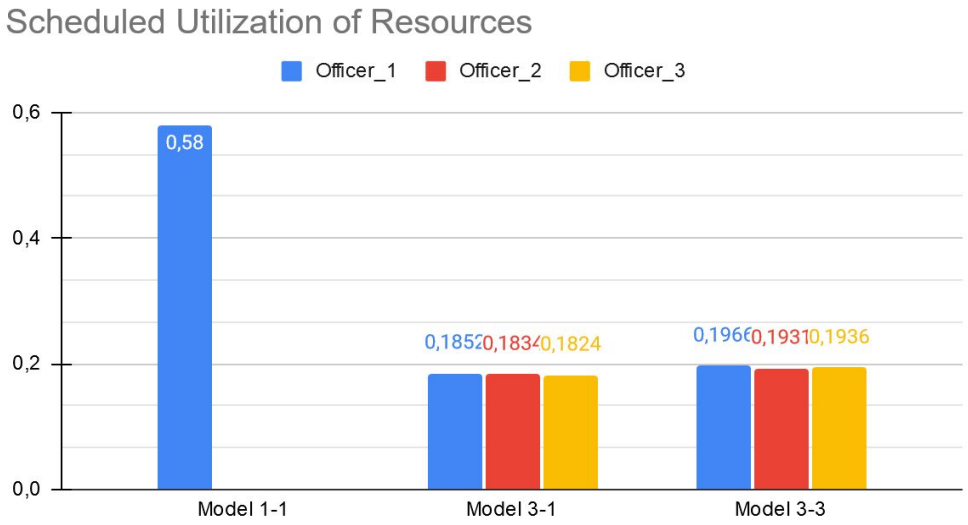



If we look at Table 4 and the graph:
- When we look at the average waiting times, we see that model 1-1 is almost 10 times the others. We can attribute this to the fact that they have to wait in a single queue, as there is only one paid passage in model 1-1.

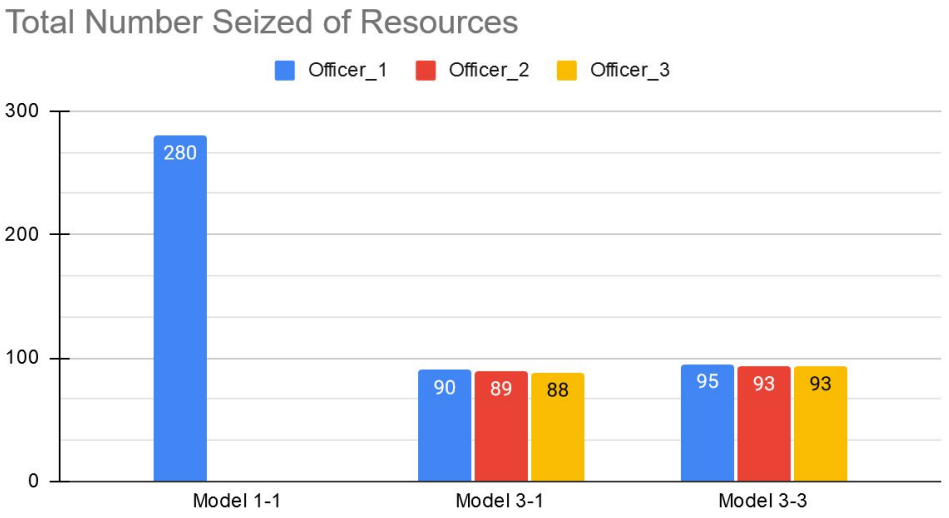
**Table 5:** Resource Results

| Model | Scheduled Utilization | | | Total Number Seized | | |
|---|---|---|---|---|---|---|
| | Officer_1 | Officer_2 | Officer_3 | Officer_1 | Officer_2 | Officer_3 |
| 1-1 | 0,58 | - | - | 280 | - | - |
| 3-1 | 0,1852 | 0,1834 | 0,1824 | 90 | 89 | 88 |
| 3-3 | 0,1966 | 0,1931 | 0,1936 | 95 | 93 | 93 |

**Graph 6:**




**Graph 7:**



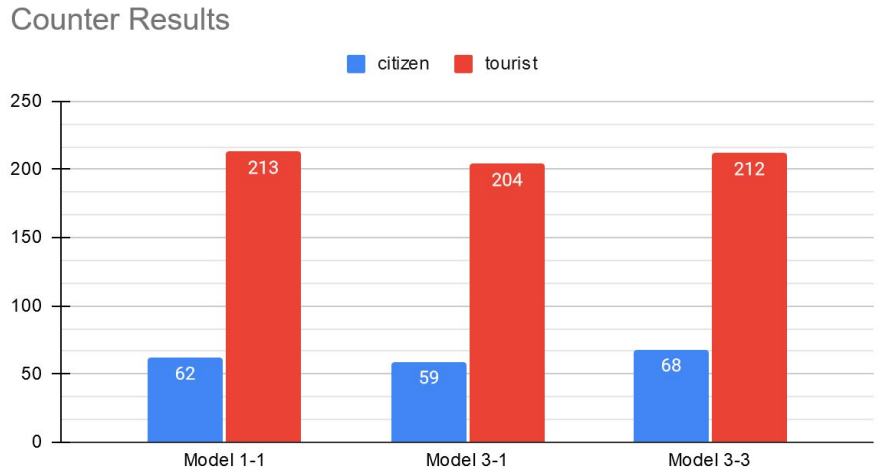

If we look at Table 5 and graphs above:

- We see that the Model 1-1's utilization is 3 times more than the others. This is because there is only one paid passage in the 1-1 model.
- The reason that the values of the officers' utilizations in Model 3-1 and Model 3-3 are very close to each other is that due to the condition in which cars chose the paid passages, each gate serves almost equal number of cars in the end as we can see in the Table 5 "**Total Number Seized**".

**Table 6:** Counter Results

| **Model** | **Car Type Counter** | |
|---|---|---|
| | **civilian** | **tourist** |
| 1-1 | 62 | 213 |
| 3-1 | 59 | 204 |
| 3-3 | 68 | 212 |

**Graph 8:**



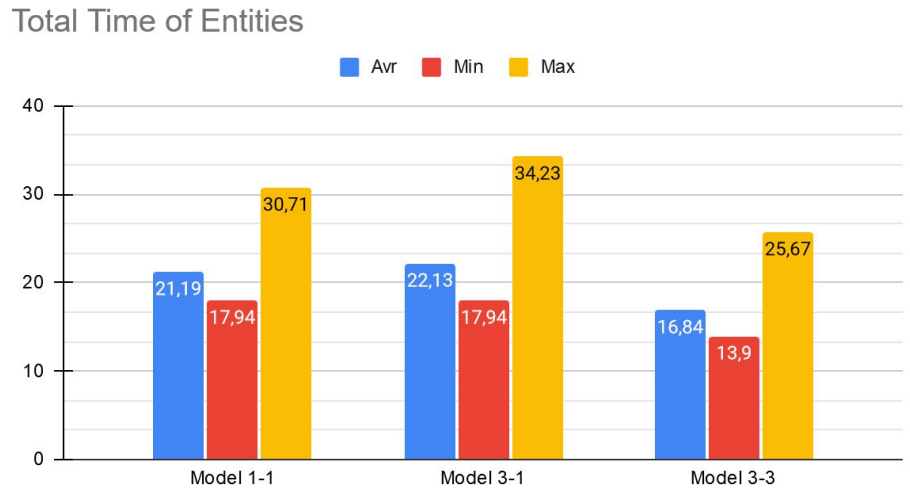

If we look at Table 6 and the graph above, where I obtained the statistics and took notes by using the Assign and Record modules I added:

- Although the "citizen" selection rate in the decision stage conditions to choose assign module is higher than the "tourist" rate, we see that the "Owner.Type" attribute is assigned to the cars entering the city in all models with a "tourist" value more than the number of the "citizen".

**Table 7:** Total Time of Entity

| Model | Total Time | | |
|---|---|---|---|
| | Avr | Min | Max |
| 1-1 | 21,19 | 17,94 | 30,71 |
| 3-1 | 22,13 | 17,94 | 34,23 |
| 3-3 | 16,84 | 13,9 | 25,67 |

**Graph 9:**



If we look at Table 7 and the graph above:

- Since we know that the longest path is in model 3-1 and the shortest path is in model 3-3, we can say that the total time in the system depends on the path length, in other words route times.

## 4. Conclusion

If we have to compare 3 models:

- **Model 1-1** has a single paid passage and thus a single queue, so the queue **performance is lowest** compared to the others.
- Due to the road difference (route times) between Model 3-1 and Model 3-3, the **Model 3-3** was able to **out more of the cars** than the others.

In general, we can say that the **queue performance** depends on the **number of passages**, that is, the increase in the number of passages decreases the number and duration of those waiting in the queue.

Considering the above, we can say that the best model is Model 3-3. Because the best number in/out rate, the best average number of work in process, the best average waiting time of queues, the best average number waiting and best average total time belong to the Model 3-3.