University of Victoria

CSC446 Project

The Optimal Queuing Strategy for Airport Taxis

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Contents

1 Project Description

Recently, passengers and members of the general public have been debating the efficiency of airport taxi services as a subject of conversation. The first problem is that there is a very long line of people waiting to be served. Because there is a high volume of foot traffic at the airport, passengers sometimes need to wait in line for very extended periods of time, which is difficult for them. The second issue is improper vehicle scheduling. As a consequence of improper vehicle scheduling or late drivers picking up customers, a number of taxis are forced to wait in line for an extremely extended period of time, and a number of passengers are unable to hail taxis at the appropriate times.
This project's objective is to provide the most efficient and convenient airport taxi line system that is humanly feasible. Customers may have shorter wait times as a result of the optimization of the queuing system, which may also increase taxi drivers' total efficiency and improve the experience for everyone involved.

2 Simulation Model

First, a dual-queue model and system simulation are used in this research. Both customers and taxis must line up before receiving service from airport taxis. The service can only begin when both the passenger and the taxi arrive since their relationship is a two-way queuing one. But in our project, we only consider the situation where there are enough taxis and passengers.
The many strategies we simulated involve determining the number of pick-up points, number of lanes, number of taxis in each lane, and lane configuration. In Figure 1, the taxi boarding area on the right is the pick-up area, and the taxi pool on the left is the taxis' arrival area. Near the pickup location, passengers form a line. Figure 1 depicts how many pick-up spots there are, how many lanes there are, and how many automobiles there are in each lane.

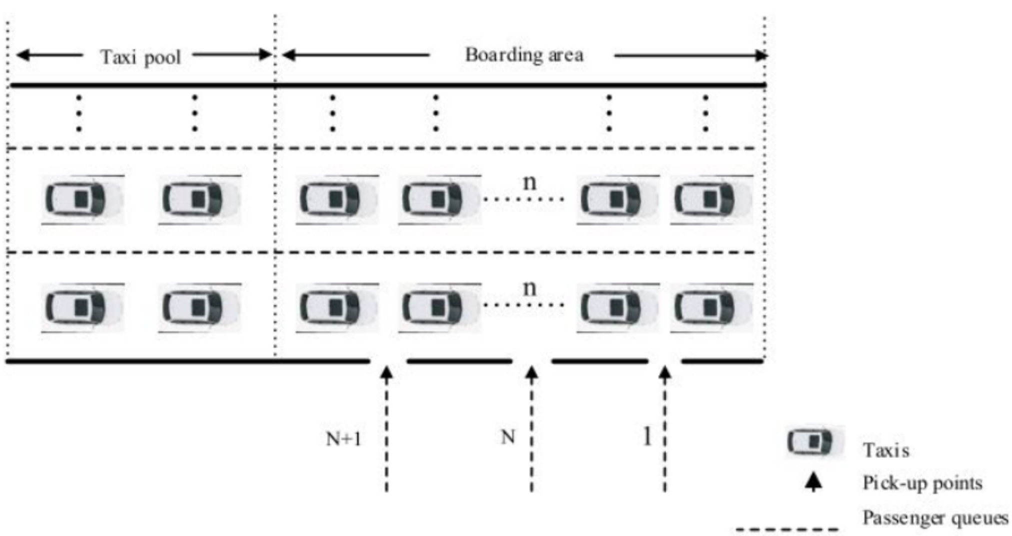

Figure 1: Strategy for airport taxi-taking with multiple pick-up points and multiple lanes.[1]

By simulations and quantifying the average time that taxis spend in line under various strategies, we are able to determine the best taxi queuing strategies. Our findings not only help determine the best taxi queue strategies but also serve as a crucial benchmark for improving airport lanes.

3 Simulation Parameters

We must first decide where the pick-up points and the taxi parking space will be. As seen in Figure 2, there is a batch of taxis in the boarding area. We assume that only after each batch of taxis has finished picking up passengers and departing the boarding area can the arrival of the subsequent batch of taxis be planned. Additionally, the distance between the two cars is almost the same. Therefore, the pick-up location must be in the middle of the taxi line.

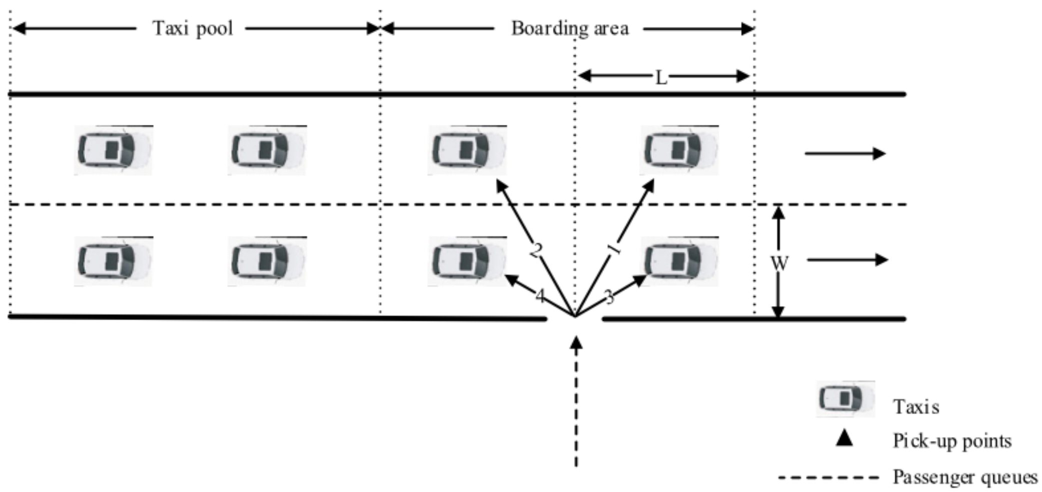

Figure 2: Strategy for airport taxi-taking with single pick-up points and multiple lanes.[1]

Some of the following simulation parameters follows the conclusions obtained by Wang et al.[1] after field investigation.

L: The average front-and-back distance between taxis parked in the taxi pick-up areas, its value takes 5.3m.

W: The average left-and-right distance between taxis parked in the taxi pick-up areas, its value takes 2.5m.

R: the number of passengers in the taxi.

Δt : The departure time interval of passengers at the pick- up point, the unit is seconds (s).

T: The departure time,the unit is seconds (s).

V: The walking speed of passengers from the pick-up points to the taxis, its unit is meter/second (m/s).

T_f : The time it takes for passengers to place their personal belongings and get on the taxis, the unit is seconds (s).

T_L : The time it takes for the last passenger getting on the taxi.

T(n) : The time it takes for taxis to move n units of car length distance from the taxi pool to the boarding area,the unit is seconds (s).
In this paper, we assume that the queuing of taxis and passengers follows the rule of first-come-first-served. The number of passengers in a taxi obeys a Poisson distribution, and the movement of passengers and taxis roughly obeys a normal distribution. The time interval between passengers queuing and the time for passengers to put their luggage and board a taxi approximately obeys the negative exponential distribution.

We assume that each batch of taxis has k lanes, and there are n cars in each lane.In this way, we can regard each batch of taxis as a matrix of size k×n.So the distance from pick-up points to the taxis is $\left|\frac{n+1}{2} - column\right| \times L + (k - row) \times W$.
The time for each passenger to get on the taxis can be calculated as:

$$T + \left(\left|\frac{n+1}{2} - column\right| \times L + (k - row) \times W\right)/V + T_f$$

4 Methodology

4.1 Main Flow

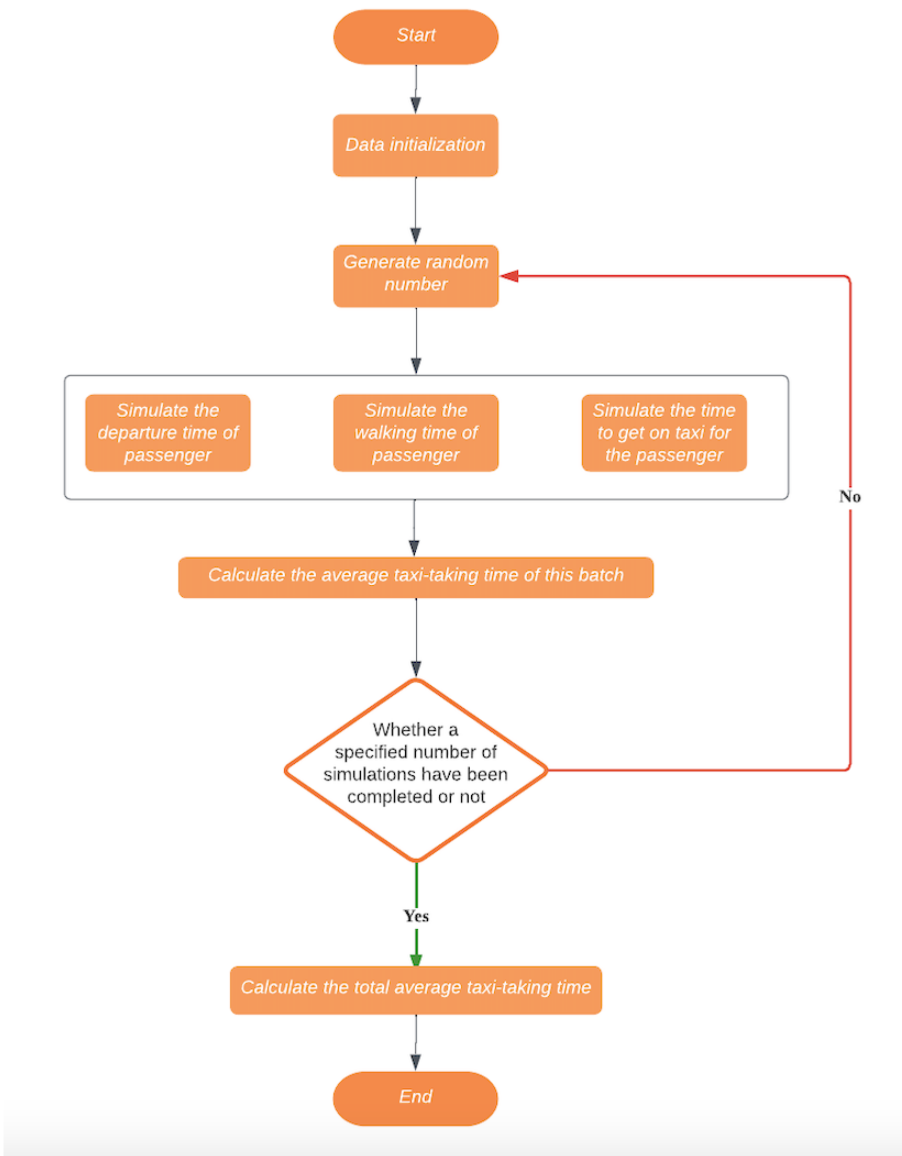

Figure 3: Main flow of the simulation

4.2 Specific steps for the simulation

Step1: Data initialization.Such as:
Number of pick-up points m
Number of lanes k
Number of taxis in each lane n
The average front-and-back distance between taxis L
The average left-and-right distance between taxis W
Number of simulations
Average speed of movement of the taxi
Average speed of movement of the passenger
Average number of passengers on the taxi
Average departure time interval of passengers at the pick- up point
Average time it takes for passengers to place their personal belongings and get on the taxis

Step2: Use numpy.random.*() to generate the random number.Such as:
Speed of movement of the taxi
Speed of movement of the passenger
Number of passengers on the taxi
Inter-departure time of passengers
Time it takes for passengers to place their personal belongings and get on the taxis

Step3: Use the random number above to calculate the departure time for each passenger and then calculate the get on taxis time for each passenger.Find the time it takes for the last passenger getting on the taxi, then the average taxi-taking time of this batch is $\frac{T_l}{m \times n \times k}$.

Step4: Go back to step 2 and continue the simulation until the set number of simulations is reached

Step5: Calculate the total average taxi-taking time in the test, then the simulation ends.

4.3 Collect the stats

In our simulation, we mainly have three scenarios.Single pick-up point with one lane, single pick-up point with two lanes, and single pick-up point with three lanes are the three scenarios. We will adjust the number of cabs in each lane in each scenario from 2 to 10. Each batch of taxis will be recorded and saved as a simulation table. Each average taxi queuing time and average passenger queuing time were recorded.

5 Analysis

The average queuing time for taxis in various conditions is shown in Tables 1, Table 2, and Table 3, accordingly. We conducted five simulations of each situation using various random seeds to get the average.

Table 1: Average taxi queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and single lane.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	12.49629	12.64762	12.57135	12.61485	12.41356	12.54873
3	11.66633	11.68795	11.69101	11.77714	11.4307	11.65063
4	11.17681	11.21444	11.25331	11.34519	11.08856	11.21566
5	10.82948	10.96301	10.98752	11.07851	10.87942	10.94759
6	10.7207	10.9411	10.79544	10.81472	10.76687	10.80777
7	10.62198	10.70239	10.67507	10.70074	10.53364	10.64676
8	10.53347	10.67127	10.57875	10.67824	10.64311	10.62097
9	10.5426	10.59748	10.51561	10.544	10.54359	10.54866
10	10.5847	10.58375	10.51199	10.57024	10.54037	10.55821

Table 2: Average taxi queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and two lanes.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	9.61829	9.68261	9.67947	9.77322	9.53584	9.65789
3	8.91779	9.13638	8.99436	9.02623	8.97872	9.0107
4	8.6814	8.8185	8.70956	8.81769	8.76078	8.75759
5	8.67429	8.67232	8.58941	8.67219	8.62614	8.64687
6	8.54472	8.59192	8.5342	8.53232	8.54097	8.54883
7	8.52296	8.58299	8.51959	8.54631	8.47628	8.52963
8	8.48335	8.52452	8.46497	8.48459	8.39546	8.47058
9	8.46478	8.48421	8.41462	8.45682	8.37401	8.43889
10	8.42856	8.46678	8.42037	8.46436	8.40735	8.43748

The average queuing time for passenger in various conditions is shown in Tables 4, Table 5, and Table 6, accordingly. We conducted five simulations of each situation using various random seeds to get the average.

Table 3: Average taxi queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and three lanes.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	8.47673	8.67974	8.53962	8.57434	8.51518	8.55712
3	8.08115	8.13969	8.05822	8.09654	8.07143	8.08941
4	7.93168	7.97965	7.92479	7.93183	7.93245	7.94008
5	7.84879	7.93076	7.84173	7.87048	7.86227	7.87081
6	7.82448	7.84406	7.77883	7.82028	7.73687	7.8009
7	7.78295	7.86669	7.763	7.77997	7.73374	7.78527
8	7.76421	7.80812	7.75805	7.7839	7.71634	7.76612
9	7.80329	7.7933	7.71269	7.76506	7.70732	7.75633
10	7.75805	7.75297	7.72603	7.76737	7.70552	7.74199

Table 4: Average passenger queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and single lanes.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	4.32847	4.2192	4.20364	4.29936	4.27273	4.26468
3	3.84408	3.86032	3.82842	3.82959	3.81059	3.8346
4	3.64856	3.67948	3.68739	3.66109	3.64147	3.6636
5	3.54741	3.56355	3.50891	3.60783	3.55265	3.55607
6	3.48283	3.50774	3.47854	3.51978	3.516	3.50098
7	3.45447	3.45742	3.41385	3.43603	3.40806	3.43397
8	3.41239	3.45491	3.39199	3.4284	3.41224	3.41999
9	3.40347	3.41276	3.37542	3.38555	3.40714	3.39687
10	3.39654	3.39303	3.37383	3.38744	3.38644	3.38746

Table 5: Average passenger queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and two lanes.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	3.12647	3.16155	3.16041	3.13967	3.11437	3.14049
3	2.88583	2.91717	2.88538	2.92638	2.9184	2.90663
4	2.80119	2.84337	2.78251	2.82088	2.79719	2.80903
5	2.77361	2.77048	2.74722	2.77148	2.76161	2.76488
6	2.73404	2.73186	2.741	2.7268	2.71609	2.72996
7	2.72184	2.72304	2.71805	2.71718	2.70269	2.71656
8	2.70713	2.70314	2.70063	2.69915	2.68687	2.69938
9	2.6987	2.69082	2.67945	2.70072	2.67393	2.68872
10	2.67718	2.6777	2.67857	2.68154	2.67794	2.67859

Table 6: Average passenger queuing time under the condition of different numbers of taxis in the boarding area for single pick-up point and three lanes.

Number of taxis	Run 1	Run 2	Run 3	Run 4	Run 5	Average
2	2.7413	2.76931	2.73736	2.77656	2.76455	2.75782
3	2.59497	2.61023	2.57401	2.5882	2.59398	2.59228
4	2.5346	2.53466	2.54266	2.53306	2.51946	2.53289
5	2.48422	2.52445	2.49343	2.50539	2.48736	2.49897
6	2.49216	2.48573	2.4748	2.4952	2.46817	2.48321
7	2.47574	2.48324	2.46879	2.48523	2.46884	2.47637
8	2.46803	2.4745	2.46041	2.46819	2.45543	2.46531
9	2.46539	2.47342	2.45203	2.46029	2.44942	2.46011
10	2.45628	2.45938	2.44294	2.45307	2.44394	2.45112

6 Conclusion

Figure 4 is constructed based on the number of taxis and the value of average in Table 1, Table 2 and Table 3,it makes it quite evident that the average wait time for taxis decreases as the number of lanes grows. However, there isn't much of a time difference between two and three lanes. Additionally, the average time spent in a taxi line gets shorter as the number of lanes per taxi increases. When there are 2 to 5 taxis on each lane for varied numbers of lanes, the average wait time will be greatly reduced. When the number of taxis exceeds 6, the average queuing time decreases very little.

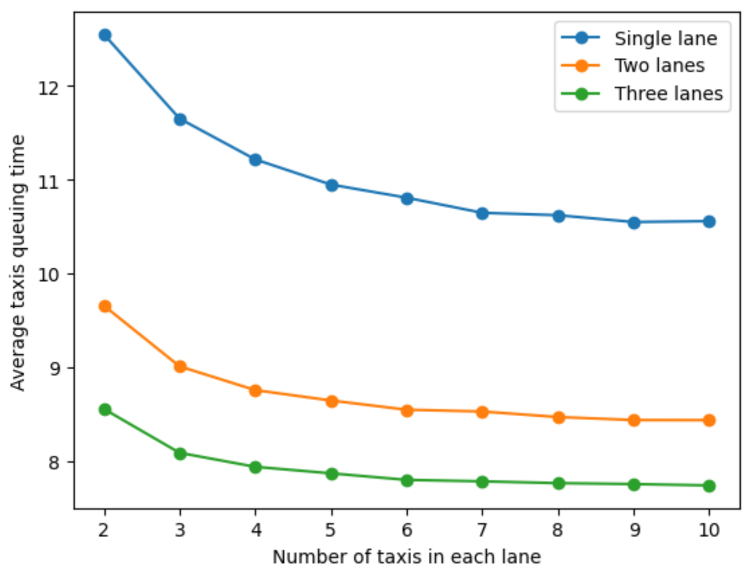

Figure 4: The average taxis queuing time under different strategies

Figure 5 is constructed based on the number of taxis and the value of average in Table 4, Table 5 and Table 6, this figure's trend closely resembles that of figure 4's. The time that customers must wait in line is getting shorter as both the number of lanes and the number of taxis rise. Additionally, the rate of decline is quite rapid before climbing to the sixth taxis. The drop is barely noticeable with the addition of the sixth taxis. This graph's trend closely resembles that of figure 4's. The time that customers must wait in line is getting shorter as both the number of lanes and the number of taxis rise. Additionally, the rate of decline is quite rapid before climbing to the sixth taxis. The drop is barely noticeable with the addition of the sixth taxis.

As a result, based on reality and takeing into consideration the airport's development costs. The

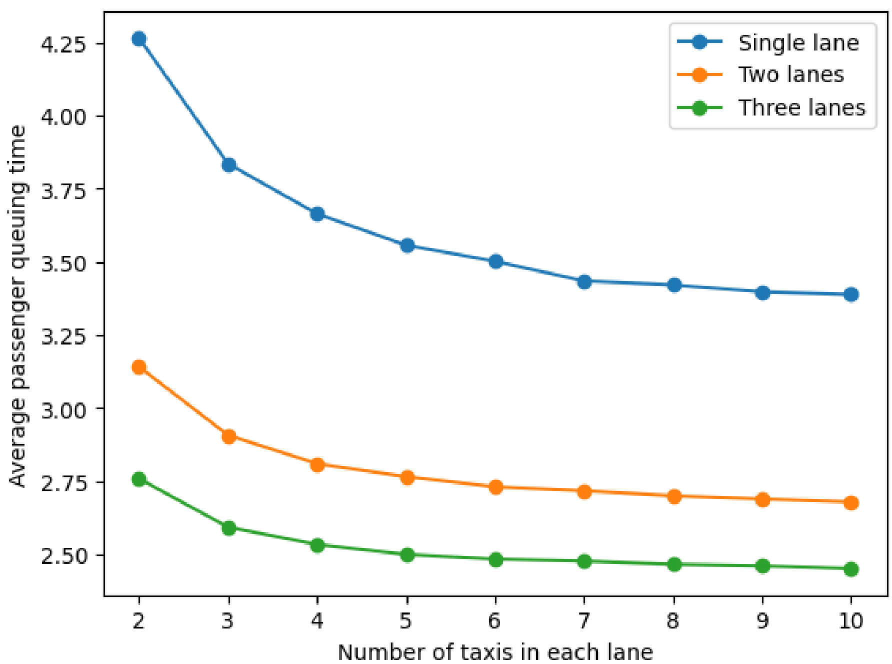

Figure 5: The average passenger queuing time under different strategies

optimal strategies consists of two lanes with five vehicles each.

Compared with the data and conclusions obtained by Wang et al[1]. First of all, the data we get is different. This is because for the average speed of movement of the taxi, the average speed of movement of the passenger, the average number of passengers on the taxi, the average departure time interval of passengers at the Pick-up point, the average time it takes for passengers to place their personal belongings and get on the taxi, our values are different. However, the data's depiction of a changing trend and the conclusion we reached at the end are almost the same. The average waiting time is getting shorter as both the number of lanes and the number of taxis rise.

Based on queuing theory, this project constructs a queuing model for airport taxis and simulates the situation in different strategies.By adjusting the quantity of lanes and the amount of taxis each lane, the optimal strategies for scheduling airport taxis is discovered. Additionally, this project serves as a crucial point of reference for the design and constructed of airport taxi queue area. The accuracy of the data in this project is not especially high, though. To get enough data, a lot of labour is needed in the beginning.The model used in this project only accounts for a small portion of the various other factors that must be considered while the actual airport taxi queueing process is taking place. Later, more factors will need to be taken into account to increase the precision of models and simulations,e.g. Airport passenger traffic in different seasons and local airport traffic equipment to add to the authenticity of the numbers.

7 References

[1] Xiu-Li Wang; Qiang Wen; Zhao-Jun Zhang; Mu Ren."The Optimal Queuing Strategy for Airport Taxis | IEEE"`https://ieeexplore.ieee.org/document/9260182`. Accessed April 2023.

[2] "Pyplot tutorial — Matplotlib 3.7.1 documentation." `https://matplotlib.org/stable/tutorials/introductory/pyplot.html`. Accessed April 2023.