Airport Traffic Simulation

CSE 6730 – Spring 2017 Project 1

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***Abstract*—Discrete event models the operation of a system as a discrete sequence of events in time. Airline traffic within and between airports is one of the application of discrete event model. This report uses 5 airports and xxx airplanes for the simulation.**

Keywords—Discrete Event, Airport Traffic, Queuing System

I. Introduction

This report is designed to show the development of a discrete event (as opposed to a time-stepped) simulation that models a simple manufacturing system. This simulation is known as a queueing model in the literature. Queueing models are widely studied and used to model systems such as customers using a facility (e.g., a department store or restaurant), air and road transportation systems, computer networks and computer systems, and manufacturing systems, to men- tion a few. All of these systems involve customers (e.g., people, aircraft, vehicles, data packets, computer jobs, parts) that must travel from one station to another and receive service or processing at each station. Each station can only process one of these entities (e.g., a customer) at a time. Customers wanting to use a facility that is busy handling another customer must wait in a queue until the station is ready to process the next customer.

The airport simulation model is one of the application for discrete event systems. Usually the landing and departing processes are monitored by air traffic controllers. The situation is more complex in real world. In the simulation of this report, the model is simplied as one runway per airport. The idea behind the system is the same as what happens in real life and the simplied model can give a good view of how this system works.

II. Model Descriptions

Specifically, the system of interest is airport model with one runway. An airplane leaving one airport move flies to another airport. The runway of an airport can be either busy or free. If the runway is idle when the airplane arrives, it begins landing process. If the runway is busy, the airplane is placed in a queue where it will wait until the runway is free. Airplanes are removed from the queue in first-in-first-out (FIFO) order.

An airtraffic "controller", which is the simulator in the simulation model, is created to help schedule and maintain the future event list. The events of an airplane are scheduled based on runway condition and its current event type. This is controller by the simulator.

The simulation computes the total amount of circling time for each airport, which is the time where an airplane is ready to land but is waiting for an opening. The number of passengers arriving and departing each airport is provided as well. The simulator requires user-defined number of aircrafts, length of simulation in minutes and some random seeds. Other factors such as the aircraft speed and capacity can also be changed to user-defined, but for the sake of simplicity of this simulation, I keep these variables uniformed distributed and more detailed discussions can be found in next section.

III. Model Design

This simulation models 5 airports. The 5 chosen airports are Hartsfield–Jackson Atlanta International Airport (ATL), John F. Kennedy International Airport (JFK), Los Angeles International Airport (LAX), San Francisco International Airport (SFO), and Seattle–Tacoma International Airport (SEA). The distance metrics of these airports are calculated using the shortest distance between their geo locations.

TABLE I. Airport Geo Locations

Airport	***Latitude***	***Longitude***
ATL	33.6366997	-84.4281006
JFK	40.639801	-73.7789002
LAX	33.9425011	-118.4079971
SFO	37.6189995	-122.375
SEA	47.4490013	-122.3089981

Using the geo locations above, I can use the Haversine formula to calculate the great-circle distance between two points – that is, the shortest distance over the earth's surface.

A. Airport Model

The model assumes that the on-ground time is the sum of taxi out time and departure delay. They are 35 mins for ATL, 45 mins for JFK, 40 mins for LAX, 30 mins for SFO, and 25 mins for SEA. Both taking off and landing use the runway. To make it simple, I assume the time for landing and taking off hold the same. The takeoff/land time takes 20 mins for ATL, 25 mins for JFK, 20 mins for LAX, 15 mins for SFO and 15 mins for SEA.

B. Aircraft Model

Once an airport is generated, the maximum speed and maximum capacity of the aircraft is set. For the maximum speed of each plane, it is set as the cruise speed, ranging from 400-600 mph uniformly distributed. The maximum capacity of each airplane is uniformly distributed from 100 to 360 persons. Load capacity is set 50% to 100% uniformly for each aircraft once it starts a new departure. The initial state of the simulation model is randomly assigned based on the user-defined number of aircrafts during the simulation. The planes with different speed and capacity is randomly assigned to each airport at the first 100 minutes of the simulation.

The modeling of an airport traffic flow consists of four states in my simulation. They are arrival, landed, depart, and left.

1) Arrival State

The arrival state of an airplane means there is a new aircrafe arrives at the region of an airport. If the runway is free, it will begin to land, i.e., schedule an landed state event. Otherwise, the aircrafe must circle around, which I add this aircraft to the queuing system.

2) Landed State

The landed state of an airplane means it has completed its landing at the airport. The number of arrival passengers will be added here. Then after a certain period of on-ground time, this aircraft will need to depart. So an occurance of a landed state will automatically schedule a depart event.

3) Depart State

The depart state of an airplane means the aircraft finishes its ground service and is ready to takeoff. But it needs to check if the runway is free. It will begin to take off if runway is free otherwise be added to queuing system.

4) Left State

The left state of an airplane means the aircraft is actually taking off from one airport to another airport. Then an arrival event will be scheduled automatically based on the distance between airports and speed of the aircraft. Also, the number of departure passengers will be added at this state.

C. Queuing System

The queuing system won't be used if the runway is always free. This won't happen in life. Then a queuing system needs to be introduced to schedule events if the runway is occupied. I use two queues, arrival queue and departure queue, to keep track of the events. There are three kinds of "deque" methods: Landing First, Departing First, and Time First.

1) Landing First

Landing first is the system which clears arrival queue first when the runway is free. This idea is intuitive from reality since each airport has only one runway and the aircrafts in the air usually carries limited volume of gas. Air controller takes safety as the priority and runway is given to arrival events when both queues is not empty.

2) Departing First

Departing first, on the contrary of landing first system, is the system which clears departure queue first when the runway is free. This is used to compare the results from other systems.

3) Time First

Time first system seems to be what we use in real world. Airplanes are scheduled based on the time it requests to use the runway. The one comes first has the high priority to use the runway.

IV. Results

After a certain period of user-defind simulation runs, the circling time of each airport and number of passengers arriving and departing each airport can be generated. For my simulation, I set the simulation period of 6000 minutes (events are scheduled in minutes). The number of aircrafts in the simulation system is set as 10, 20, 50, 100, and 200.

A. Total Circling Time

FIGURE I. Log-Circling Time for ATL

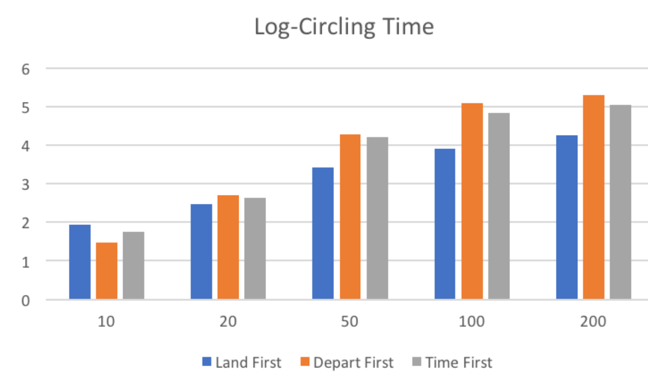


Figure I shows the logrithmatic total circling time of ATL with 10, 20, 50, 100 and 200 aircrafts in the systems. It shows that as the number of aircrafts increases, total circling time for ATL grows exponentially. It shows that when the number of crafts is big enough (>50 in the system), landing first queuing system would be the best for reducing circling time. This is obvious since landing first system always chooses to land an aircraft when the runway is not busy. This trend is obvious for all airports.

FIGURE II. Circling Time of 50 Aircrafts

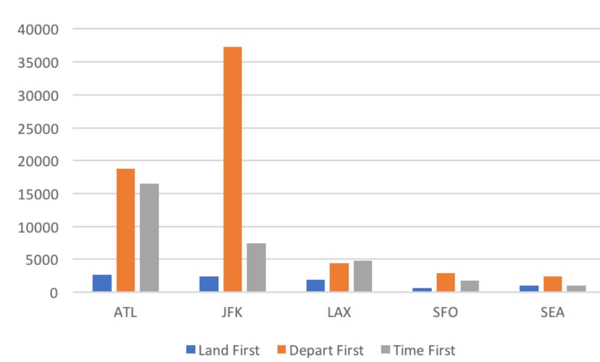


Figure II shows the total circling time for 5 airports when the simulation system contains 50 aircrafts. It is clear that land first queuing system gives the shortest total circling time and departing first queuing system gives the longest total circling time for all 5 airports.

From the results above, it can be concluded that if the number of aircrafts is relatively big (>50), land first queing system would be preferred.

B. *Arrival and Departure Passenegers*

FIGURE III. TOTAL NUMBER OF ARRIVAL PASSENGERS – 50 AIRCRAFTS

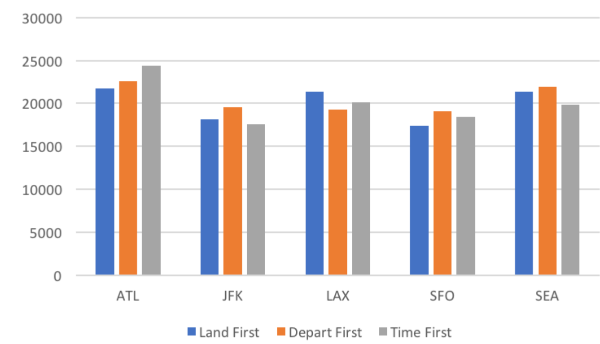


FIGURE IV. TOTAL NUMBER OF DEPARTURE PASSENGERS – 50 AIRCRAFTS

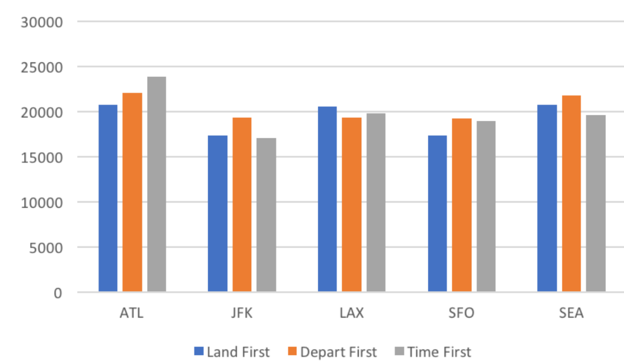


Figure III and IV show the number of arrival and departure passenegers in the system given 50 aircrafts. It tends out that there is no big difference for arrival and departure passenegers among the three queuing systems. Also given a specific queuing system, there is no big differnece between arrival and departure passengers. The similar results should come from the assumption that the load capacity of each airplane is randomly distributed between 50% to 100% and the maximum capacity of each airplane is randomly distributed between 100 to 360 persons. Given large number of rounds of simulation, the number of arrival and departure passengers should some constants. But each airport has its own landing time and on-ground time, small differences remain.

Figure V and VI show the number of arrival and departure passenegers for SFO given different number of aircrafts in system. There is a clear linear increasing trend between the number of aircrafts in system and the number of arrival/departure passengers. It show as the number of aircrafts increases, the number of arrival/departure passengers will increase accordingly. Also, it also shows there is not much difference among queuing systems given the same number of aircrafts in system.

FIGURE V. ARRIVAL PASSENGERS FOR SFO

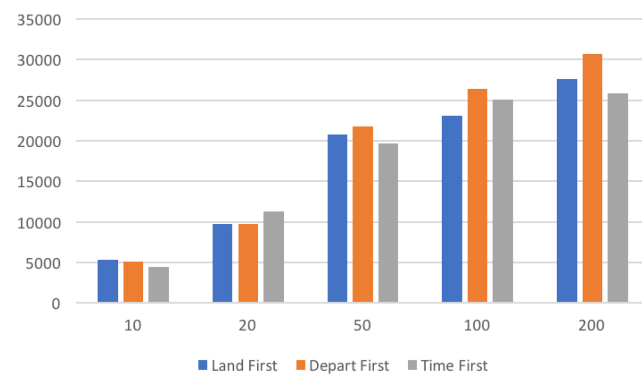
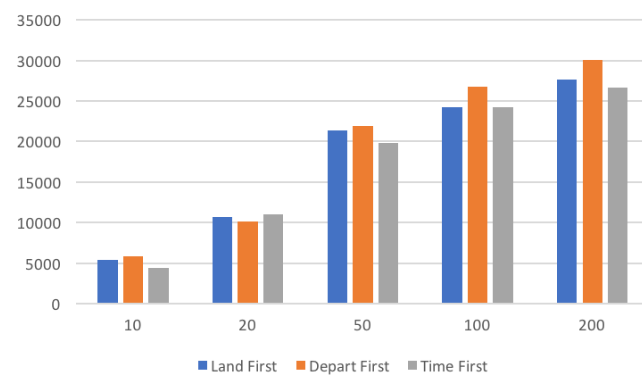


FIGURE VI. DEPARTURE PASSENGERS FOR SFO



V. CONCLUSION

From the analysis above, it can be concluded that landing first queuing system gives the smallest total circling time. And the circling time for a given airport increase exponentionally with the number of aircrafts in the system.

As for the number of arrival and departure passengers, it is positively correlated with the number of aircrafts in the system. But three systems would not differ so much on the number of arrival and departure passengers given a specific number of aircrafts in system. These results are generated based on my assumption and design of the simulation.

VI. FUTURE STUDIES

This project simulates the very simlpe condition where each airport has only one runway. And some plain assumptions are made on the airplane types as well as air traffic process time. To make the simulation more related to the real world, it requires more complex simulation with more randomization on the parameters in the model. If time permitted, the model can be improved by using the real distribution of airplane landing, on-ground and departing time. And these time measures depend on the type of the airplane. Also, adding runways would make the model more similar to what happens in real life.

In addition, many other factors might have influence of the simulation model. Weather for example, is a very important factor for airport operation. But it is even harder to model the weather condition. In a word, a simple model can give the basic idea, but the accuracy and preciseness of the simulation requires lots of factors to be included in.

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