Airport Simulation and Modeling

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***Abstract*—The efficiency and safety of airport schedule is of major importance in designing the airport system in the aviation industry. This article presents a airport and air traffic model based on the Discrete Event Simulation(DES). The results and discuss are presented in the study.**

I. Introduction

How efficient an airport runs and how busy the air traffic is have becomep a crucial question for the airport designers and engineers. The approaches of simulation will improve researcher understanding the process of how the airport schedules planes landing. In this article, we will present an airport modeling and simulation framework based on discrete event simulation. We will also show the result and analyze the relationship among different factors that have impact on the airport operation, and propose some model-based improvement strategy in the discussion.

The article is composed of three section. First, we give a brief introduction about the study background and discrete event simulation technique. In the second section, our airport model is described, the model framework details including assumptions and corresponded parameters will be presented. Then the results conducted by several simulation under different condition is shown. Finally, we present the analysis of simulation results and propose correspond suggestion based on modeling.

II. Study Background

A. Discrete Event Simulation

A simulation model addressing a real-world system problem can be viewed as discrete or continuous. The discrete event simulation is the description of a discrete event system, of which the interest change value and state at discrete point in time, instead of continuously evolving along the time[1]p.

B. Airport Simulation Framework

The airport traffic simulation is among plenty of discrete event examples, which will be discussed in the study. The airport traffic research mainly focuses on objects like runways, taxiways, traffic network control that affects the airport operation[2]. In this study, our aim is to mimic the behavior of airport traffic system using discrete event simulation. We focus on how the airplane lands and leaves the airport in addition to the passengers number at the airports

The schedule events of the airport operation can be considered as airplanes landing and taking off. A more detailed approach is to describe the airplane behavior by four sequent events: *arrives, lands, departs* and *take off*. In this model, the airplanes will continue these four behavior at different time step by cycle. The figure 1 show this process.

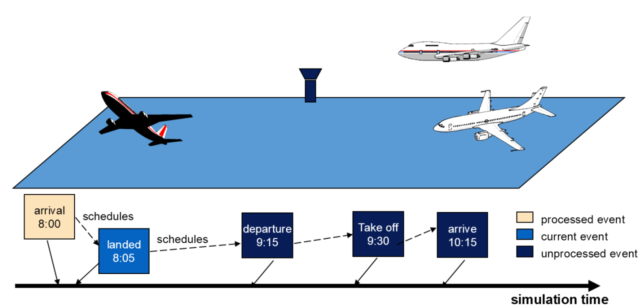

Fig. 1: Airport Simulation Event

In particular, there are four time step between the event sequence above, which are *prunwayTimeToLand, RequireTimeOntheGround,runwayTimeToTakeoff* and *FlightTime*. In the physical airport traffic system, the airplane needs a descending and landing time after it arrive the region. This comes the *runwayTimeToLand* from arriving to landing. Then the airplane stays on the ground for refuel and maintenance for a while as *RequireTimeOntheGround*. After that the airplane will continue its fly and ready to depart. the period from airplane departure to take off is defined *runwayTimeTotakeoff*. It will takes *FlightTime* for the airplane to arrive the next airport. The airplane event is scheduled based on its previous behavior following this process.

The main simulation studies the scenarios of a collection of planes with amount of passenger travels among multiple airports. The travel destination of airplane is random and the passenger carried by the airplane is randomly assigned in a range of capacity.

However, due to the limits of runway of the airport, the models have restrains that not allowing multiple planes landing or taking off at the same time for only one available runway. This requires the *Queue System* for arranging the landing and taking off event in other to avoid the coincidence. Two different queue is introduced in the airport simulation: the *Land Queue* and *Depart Queue*. For every arriving plane, the land queue adds in and schedule landing if the runway is free. Then the queue remove the first event element once a landing event is schedule, while the runway will become unavailable. it is Similar for the depart queue and take off event. The queue system also help us to schedule landing or taking off event by the priority of time. Namely, the event between these two types with earlier schedulep time will be processed first. The queue system enable us to schedule the event without the conflict of runway use.

The implement of class *Airport* introduce the take off process and the corresponded event handler in addition to the previous code.There are some important members modified in the class *Airport* as following.

m_peopleIn: States of how many passengers arrive at the airport.

m_peopleout: States of how many passengers depart from the airport.

m_circleTime: The time period between airplane arrives and landing.

m_totalCircleTime: The total circle time of all the airplane .

Algorithm 1 Airport Object class

Constructor *(Name,runwayTimeToLand,requiredTimeOnGround, requiredTimeOnGround, id)*

```
    Public void handle(Event event)
    switch :
    Case 1: Arrive
    LandQ.add, inTheAir++
    if runwayfree then
        Schedule landingEvent(runwayTimeToLand,this)
        runwayfree=false
        Break
    end if
    Case2: Land
    LandQ.remove(), inTheAir–
    Schedule departEvent(requireTimeOnGround, this)
    if LandQ.element.Time≤DepartQ.element.Time then
        Schedule landingEvent( runwayTimeToTake-
    Land,this)
    else Schedule takeoff Event( runwayTimeToTakeoff,this)
    end if
    runwayfree=false
    if LandQ and Depart is empty then
        runwayfree=true
    end if
    Case3 : Depart
    DepartQ.add, onTheGround++
    if runwayfree then
        Schedule landingEvent(runwayTimeToLand,this)
        runwayfree=false
        Break
    end if
    Case4: Take off
    DepartQ.remove(), OnTheGround–
    Schedule arriveEvent(FlightTime,Destination)
    if LandQ.element.Time≤DepartQ.element.Time then
        SchedulelandingEvent(runwayTimeToTakeLand,this)
    else Schedule takeoff Event( runwayTimeToTakeoff,this)
    end if
    runwayfree=false
    if LandQ and Depart is empty then
        runwayfree=true
    end if
```

III. Model Building and Simulation

A. Model Construction

This discrete event simulation is programmed by pJAVA on the object-oriented programming. In this section we briefly introduce the detail of the simulation program, and the parameter setting based on the real-world case.

The studies focus on five different airports in USA, which are located in city Los Angles(LAX), Atlanta(ATL), New York City(JFK), Chicago(ORD) and Houston(HOU) in respect. These airports are the most important airplane traveling hub of USA and is of interest in our study. The fly distance among this airports is presented below[3].

Airport	ATL	LAX	JFK	ORD	HOU
ATL	0	1937	760	607	689
LAX	1937	0	2472	1743	1378
JFK	760	2472	0	1743	1378
ORD	607	1743	739	0	927
HOU	689	1378	1417	927	0

TABLE I: Airport Distance (miles)

The airplane has the *attribute* of *passenger capacity* and *cruise speed*. The *flightTime*is calculated by the distance over airplane 80% cruise speed. The reduction is a consideration of the slow period of ascending and landing process. The airplane we choose comesp from the dominating and popular plane in the civil aviation. The following table is ten different serials of airliner with its main attributes[4][5][6][7]. While the cruise speed is the same for different serials of the airliner, the passenger carrying capacity may vary.

Airport	Cruise Speed (mph)	Capacity
B737-300,400,MAX	520	126,147,180
B787-800,900,1000	562	242,290,330
B757-200,300	531	200,243
A330-200,200F,300	552	246,246,300
A350-900,1000	571	440,440
A380-800	561	544

TABLE II: Airliner Attributes

In practice, we consider the airplane in our model has the speed attribute varies from 520 to 561 and passenger capacity in the range of 126 to 500. The actual attribute will be generated randomly. For the carrying passenger of a plane, we consider the passenger can be 40% to the full capacity size. The number of passenger fluctuates in different seasons especially in weekdays and holidays. But we consider the air company have to make sure a certain percentage (the assumption we make is 40) will be the lower bound in order to make profit.

The landing and taking off event will take time very differently in special airport and weather condition. In, General, the landing and taking off event will take 10 minutes up to 30 minutes[8]. Also, the time for airplane to refuel and maintenance will vary from hours.

B. Experiment Design

The main task of the study is to explore the relationship between airport and airplane attribute (Time to land, take off, numbers of airplane) and the airport transportation status (passenger numbers and total circle time).

We have design different scenarios for the result analysis, the following table are the experiment parameters setting.

Airport Number	Landing	Taking off	On the Ground
10	0.2	0.2	1
20	0.25	0.25	**2**
30	**0.3**	**0.3**	3
40	0.35	0.35	4
50	0.4	0.4	5
60	0.45	0.45	6
70	0.5	0.5	-
80	-	-	-
90	-	-	-
100	-	-	-

TABLE III: Experiments

In particular, we use a vector (airplanes,landing,taking off,on the ground)to describe the parameter when we explore how the number of airplanes affect the simulation, we will fixed the rest parameter (airplanes,0.3,0.3,2) as the bond printing above. Tphis is similar for other three parameter setting. The simulation time period is selected as half month (300 hours). For each parameter setting, we conduct several experiments and derive the average output as results.

IV. Results and Discussion

A. Airplane Amount Factor

1) Passenger-Circle Time: In the first part, we implement three times experiment. For each experiment, the simulation airplane number change from 10 to 100. The total experiment is 30 times. The following figure is the relationship between the passenger in and out of the airport and the total circle time. each scatter data point represents a simulation scenarios for corresponding airport and the amount of airplanes. The total data point is 150.

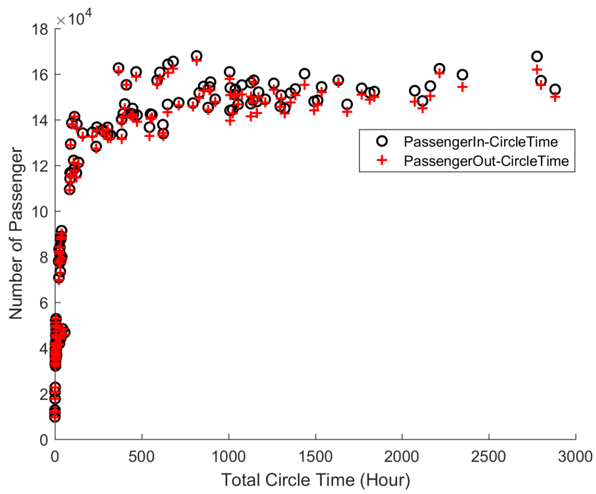

Fig. 2: Relationship of Passenger and Circle Time

We can see that for each airport, the passenger number and circle time follows some sort of *log* relationship. It clearly shows that at very first, the passenger number increase without arising too much circle time. However, as the passenger number reach to the amount about 140000, the circle time will increase but not improving the amount of passenger travels. The reason may be the air traffic is too much congestion that no much passenger can be carried by airplanes anymore.

2) Amount of Plane-Circle Time: Since we have five airport and the airplane has random destination for each travel, this is some stochastic process for the individual. we will focus on the average circle time for all the airports under one simulation condition. The following figure is the relationship between amount of airplane and average circle time for the airport. It demonstrate that the circle time will increase with the rising of airplanes;

3) Amount of Airplane-Passenger: The total passenger in and out of the airport is straightly connected to the amount of airplane traveling. However, it doesn't always increase in a fixed rate since the air traffic jam would become heavy when the airplane number reach to some certain point. This also confirm the trend of the the relationship between circle time and airplane.

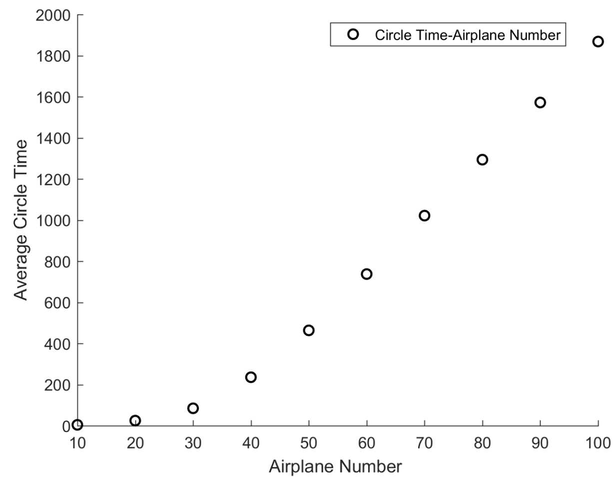

Fig. 3: Relationship of Airplanes and Circle Time

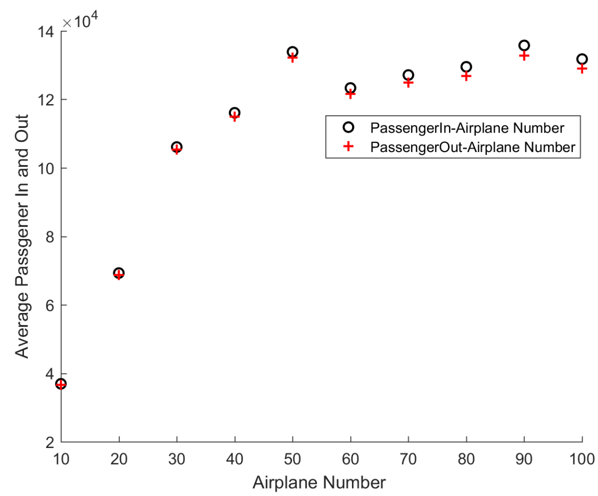

Fig. 4: Relationship of Airplanes and Passenger

B. Runway Time Factor

In this section, we explore the how the runway time will affect the airport operation. Intuitively, a shorter runway time could provide more landing and taking off in the limit of runway. We fixed the airplane number to 60 and time on the ground to 2. The runway time will varies from 0.2 (very fast) to 0.5 (a slow landing). For convenience, we consider the take off time to be the same as landing time for assumption. The result is the average of eight independent experiment for each parameter set. The following figure shows the relationship between runway time to land and total amount of passengers.

The result confirm our prediction of the trend. With the increasing time for landing, the total number of passenger will

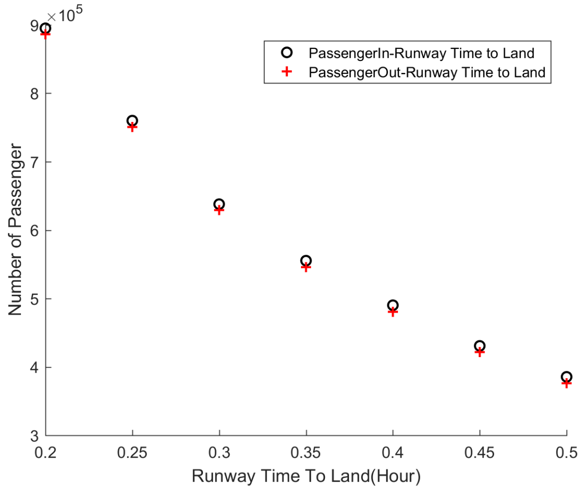

Fig. 5: Relationship runway time to land and Passenger

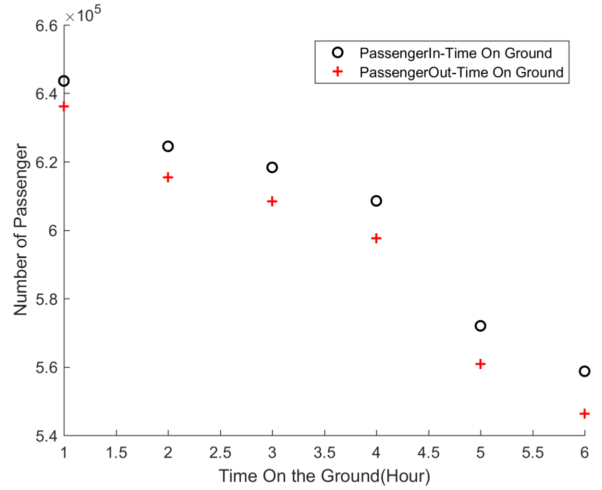

Fig. 7: Relationship time on the ground and Passenger

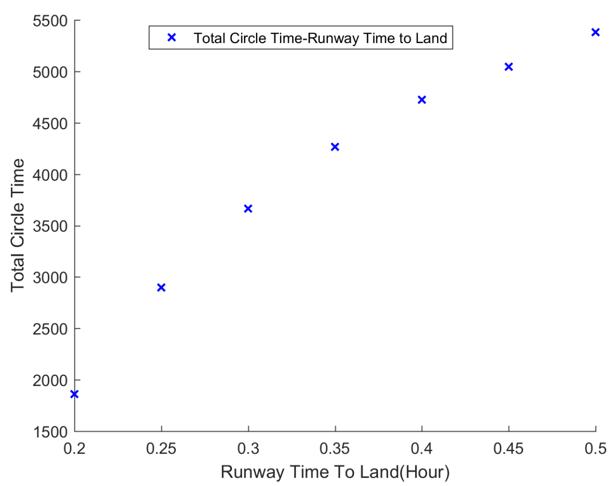

Fig. 6: Relationship runway time to land and total circle time

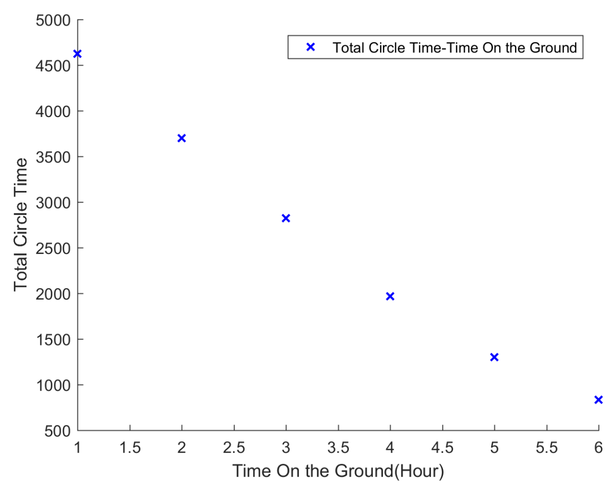

Fig. 8: Relationship time on the ground and total circle time

decrease because fewer airplane is available to land and take off. The total circle time will increase since more amount of time is taken by the landing and taking off process.

C. Time On Ground Factor

The require time on the ground for airplane will also have impact on the air traffic system. The more time on the ground require, the fewer airplane need to take off and thus results in fewer carried passengers and circle time. The experiment will fixed the number of airplane at 60 and runway time for 0.3 hour, while changing the time on the ground from 1 to 6 hours. For each parameter set, we calculate the passenger and circle time for the average of five airports. We also conducted eight experiment and averaging the output as the final result.

The results shows that with the increasing time required on the ground, the either and incoming passenger or the outgoing passenger will decrease because fewer airplane travel could be scheduled. In addition, the total circle time decrease when the time on the ground drops since in that case fewer airplane will be ready to depart and save the runway. It's also interesting to notice that The amount of outgoing passenger is smaller than the incoming passenger. The reason may be the since the airplane have to wait longer to depart, the outgoing passenger will be less than the incoming one.

V. CONCLUSION

In this article, we propose a framework of airport and air traffic simulation which enable us to explore the relationship among different factors: number of airplane, time to land, time to depart and etc. Several Experiments are conducted for the scenarios analysis. We demonstrate that the total passenger travel and the total circle time, which could cause air traffic congestion and even catastrophic accidence, have close relationship with these factors above. In conclusion, while the more airplane travel could bring more passenger in a amount of time, it will increase the circle time and the efficiency of carrying passenger falls off due to the limited runway. As for the landing and take off time, the shorter for a airplane to land or take off, the less circle time will be. Time required on the ground will also be considered for the airport design. When the time arise, the circle time drops for fewer airplane will be schedule. However, it also has negative impact because of the decreasing passengers.

Based on our simulation and scenario analysis, some suggestion about the airport design and operation are proposed. Firstly, the airport should be considered a *threshold* for the total amount of passenger flow. Beyond this point we may not be able to stand the increasing circle time while the passengers doesn't increase as fast. The airport operation should control the daily plane in a maximum number to maintain the efficiency of landing and taking off. Second, reduce the landing and taking off time if the airport and weather condition allows. That will dramatically increase the efficiency of airport. In addition, the time for airplane to stay on the ground should bring about the balance of circle time and passengers. The designer should consider these both factors since they goes in opposite direction.

VI. Future Work

The airport modeling and simulation bring useful result and help us to analyze the airport operation system to some extend. However, there are some ways that we could bring improvement in the future. Firstly, the passengers and airplane destination would take more real-world case into consideration. For example, the desire of destination would be very different in different seasons. Also, the model may be incapable to describe an airport system in complex condition because if just considers very simple sequence of events. In reality, there might be some factor outside the system has influence on the airport system such as weather. The future model could combine more complex phenomenon to enhance the ability of simulation and predicting events.

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