# CSE6730 Project I: Airport Simulation

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***Abstract*—Not long time ago, the airport simulation was a brand new concept for airport planning. This changed during and after 1990s when aviation transport researchers first experimented with modeling and simulation techniques, considering them to be better tools for understanding airport operations. Nowadays, more and more airports are using airport modeling and simulation techniques to improve airport event operation and service. In this project, the author used Java to simulate the airport events, including arriving event, landed event, taking off event and departing event, and adjust some parameters, such as numbers of airplanes and landing time, to find the relationship between them and number of passengers, circling time and others. The paper will describe the simulation program based on discrete event theory at the end.**

***Index Terms*—Airport, Airport Event, Simulation, Airport Operation, Java.**

## I. Introduction

THE most airport modeling and simulation consists of many interacting and interrelated models and simulation processes that are integrated. Understanding the special characteristics and basic knowledge of an airport is important to build the simulation model. Moreover, it would be helpful to be familiar with concepts of simulation. Simulation models are the views of the real world could be divided into two categories, discrete or continuous. Discrete-event model simulation can describe system state changes discretely at isolated times called events. The airport simulation is a representative discrete-event model. The author's project is a simple airport modeling and simulation program, the modeling consists of four parts, arriving event and departing event, landing event and taking off event. All of above are airspace simulation and airport airside simulation of aircraft operating on the airfield and the terminal airspace. An airplane would go through arriving event, landing event, taking off event and departing event in sequence and repeat again, which is same as the real world. After adjusting the parameters in the program, it is necessary to analyze the results, which may have the practical significance. The author tried to find similar simulation modeling to verify the simulation result, but there is a few simulation modeling[1][2][3], so the simulation result of this project needs to be verified in the future.

## II. Discrete-Event Simulation

Simulation goes on from one scheduled event the next, where simulation events are executed based on a preset schedule. The simulation clock is based on the current event's scheduled initiation, not the fled clock time[4]. Based on this rule, many inherent events could be created for external events. But sometimes events are simultaneous, which means that multiple events could share the same initiation time, then they are processed in order without time consuming of simulation clock. In a discrete event system, it is assumed that nothing happens betwen two consecutive events, that is, no state change takes place in the system between the events[5]. In the airport simulation, some parameters settings are based on real-world objects, such as runway in an airport, route between two airports, which are engaged in activities that airplane will go through.

## III. Simulation Modeling

### A. The process of simulation model development

1) System evaluation and the identification of the problem.
2) Problem analysis and formulation.
3) Data collection.
4) Model translation into computer code.
5) Model verification and validation
6) Analysis of results
7) Future improvement

### B. System evaluation and the identification of the problem

There are four main events in the airport simulation, as mentioned above, arriving event, landed event, taking off event and departing event, and an airplane will go through these four events in order and repeatedly. There problems is to simulate the real world as much as possible. In the project, each airport only possesses one runway for landing or taking off, when there is an airplane landing, no airplanes could take off and vice-versa. Moreover, when an airplane can't land or take off, it has to wait for the right time to land or take off, which means that there should be a landing queue and a taking off queue.

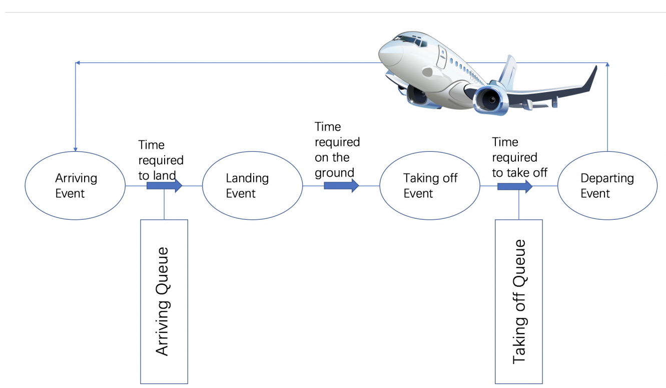



Fig. 1. The concept modeling of the airport events.

### C. Problem analysis and formulation

First, I need to create a landing queue and a taking off queue to store the airplanes with corresponding requirements. Second, after one airplane landing at the airport, I have to judge wether the runway is free for landing or taking off, if there are other airplanes waiting for landing or taking off and which event is earlier.

### D. Data collection

The first data is distance between airports, I have five airports, Boston Logan International Airport, Portland International Airport, Philadelphia International Airport, Washington Dulles International Airport and McCarran International Airport. The distance could be obtained from many resources. The second data is about the airplanes, I use Boeing 747 airplane, its max speed is 614 mph, and the max capacity is 467. The third data is about the airports, the time required by landing and taking off, the time needed on the ground, I can't find the reference about the exact time mentioned above, but I will adjust the time to find its effect on number of passengers and circling time.

TABLE I
DISTANCE BETWEEN AIRPORTS (MILE)

| DISTANCE | BOS | PDX | PHL | IAD | LAS |
|---|---|---|---|---|---|
| **BOS** | 0 | 2530 | 280 | 411 | 2375 |
| **PDX** | 2530 | 0 | 2400 | 2322 | 762 |
| **PHL** | 280 | 2400 | 0 | 133 | 1519 |
| **IAD** | 411 | 2322 | 133 | 0 | 2061 |
| **LAS** | 2375 | 762 | 1519 | 2061 | 0 |

### E. Model translation into computer code

In this project, I use Java to build the modeling and simulate the airport.
There are nine class and one interface in the program, the EventHandler interface, Simulator class, SimulatorEngine class, SimulatorEvent class and Event class are to actuate the whole simulation event. And I utilize the other five classes to simulate the actual situation of airports and airplanes.

1) Airport Matrix class
In this class, I 'build' five actual airports, Boston Logan International Airport, Portland International Airport, Philadelphia International Airport, Washington Dulles International Airport and McCarran International Airport. For each airport, I have set the information of each airport. Then I put the five airport into a one-dimensional airport array.
As mentioned above, the distance between airports is used to calculate the flight time, so I put an two-dimensional array in the Airport Matrix class.
With the help of the constructor, every time I utilize the class to create a new airport matrix object, the new object will contain the information.
2) Airplane class
The airplane class possesses the name of airplane, the index of airplane, the number of passengers, the index of airport that airplane arrived at (landed at or took off from), the index of airport that airplane is flying to and the speed. To simulate the process that passengers get off a airplane or aboard a plane, I create a function to set the new number of passengers when an airplane is leaving a airport, and the airport would accumulate the number of passengers that landed at or departed from itself.
3) AirportEvent class
The AirportEvent is the event that happens in the airport. There are four main events in the airport, arriving, landing, taking off and departing event, for each event I set one index to distinguish them. And when one airplane arrived and landed at the airport, the airport needs to know the information about the airplane, for example, the number of the passengers. Then the airport would set the new destination airport for airplanes that are going to take off.
4) Airport class
This is the most important class in the program. In this class, I set the airport with the name, time required to land, on the ground and take off. In order to ease of programming, I set the index for each airport and put the flight time as one of the properties of the airport. The Airport class will handle all events in the handle function.
The aim of the handle function is to schedule the four events in each airport step by step.

   a) Arriving event
   When one airplane arrives at one airport, the program will judge the condition of arriving queue, if there is no airplane waiting to land, then the program will judge the condition of the runway, if it is free to land, the program will schedule a landing event, then the runway is not allowed to land or take off. In other conditions, the program will put the airplane into the arriving queue.
   b) Landing event
   When one airplane landed at one airport, the program will schedule a taking off event. Before taking off, the program needs to make more judgments. If both arriving queue and taking off queue are empty, then the runway must be free to land or take off. If arriving queue isn't empty or taking off queue isn't empty, the program will schedule a landing event or taking off event respectively, it is obvious that the program need to handle the events that have already waited in the queue first. If both queues are not empty, the program needs to compare the scheduled time of first event in both queue, and handle the earlier event.
   c) Taking off event
   When one airplane is going to take off from one airport, the program will do the similar judgment in arriving event.If taking off queue is empty and runway is free, the program will schedule a

departing event. In other conditions, the airplane will be put into taking off queue waiting for taking off at appropriate time.

d) Departing event
When one airplane is departing, the program will set the destination airport randomly and flight time and schedule a arriving event for the airplane. Because the arriving event will occupy the runway lately, the program will judge the condition of the runway, same as the judgment in landing event.

e) Number of passengers and Circling time
In landing event case and departing event case, the program will accumulate the number of passengers in each airport, including arriving passengers and departing passenger. And the definition of circling time is the time required from arriving to landing, that is the time one airplane waiting in the air.

5) AirportSim class
This is the main class in the program, in this class, I could define the number of airplanes and create the 'actual' airplanes with its own information. After that, I set every airplanes with its own airport event. Then set the total simulation time and make it run!

### *F. Model verification and validation*

After finishing the simulation program, it is necessary to test the program. Since the route of the airplane is randomly distributed, the process of the simulation is very random. I adjust every parameter in the program to find if there is any unconscionable result.
The results show that the program works well.

### *G. Analysis of results*

I focus on four relationship.

The first is relationship between number of airplanes and number of passengers. In Fig.2, the total simulation time is 200000 mins, and the time required to land or take off or on the ground is fixed. With the number of airplanes increasing, the number of passengers will not increase distinctly. It means that after 90 airplanes, most airplanes could not land, because there are too many airplanes waiting in the arriving queue.

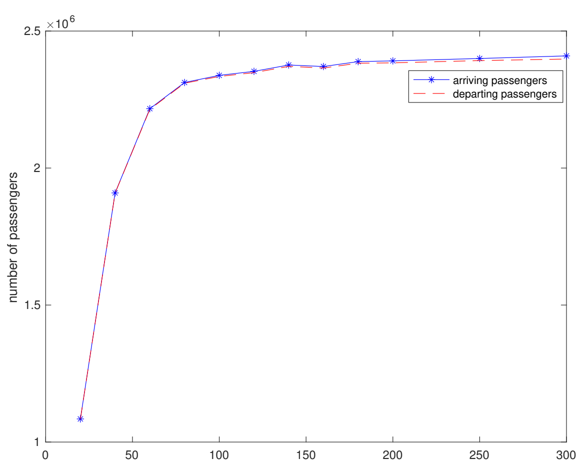



Fig. 2. The relationship between number of airplanes and number of passengers.

The second is the relationship between number of airplanes and circling time.

In Fig.3, with the increase of number of airplanes, the total circling time and average circling time both has linear relationship with number of airplanes. And the impact is same in total circling time and average circling time.

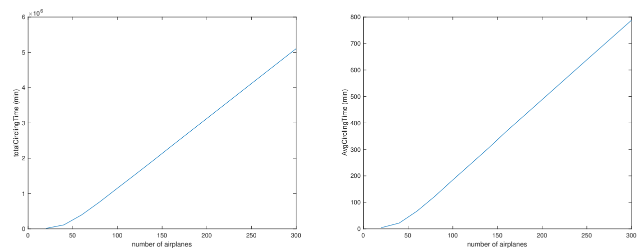



Fig. 3. The relationship between number of airplanes and circling time.

The third is the relationship between time required to land and number of passengers and circling time.

The Fig.4 shows that as the time increasing, the less passengers will arrive at the airport, and the relationship between time required to land and average circling time is linear. The more time required to land, the longer one airplane need to wait.
The fourth is relationship between time required on ground and number of passengers and circling time.

Fig.5(a) shows that the trend is decreasing, although there are many small fluctuations. It is interesting to find that the more time required on ground the shorter that one airplane need to wait in the air. The more required on ground means that more airplanes could stay on the ground at the same time period.

### *H. Future Improvement*

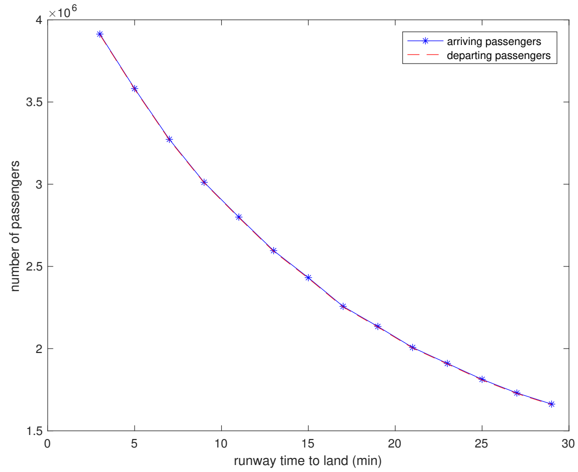
Since many limitations exist in the simulation programs, after analysis of results, I find I should improve the program in three aspects.

The first is to refine the airport event process, there are only four events in current program, but in real world, there could be dozen events taking place in order in one airport.

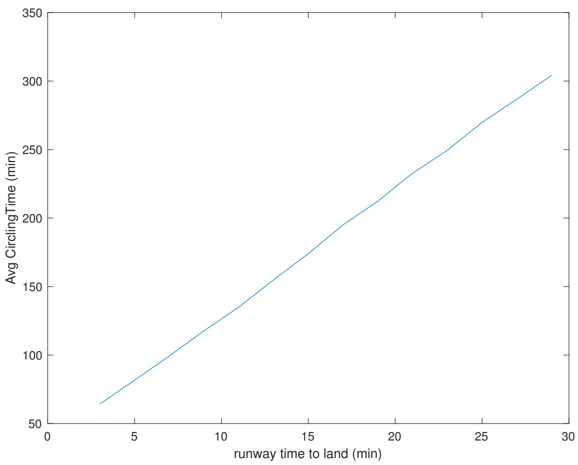
The second is to set more reasonable parameters in the program. In current program, the speed of the airplane is fixed, and the time required to land, take off and on the ground is fixed. They should be changed in a scope. The last one is to set more than one runway in the program.

## IV. Conclusion

The project is based on discrete event theory. Many aspects, including time required to land and time required on the

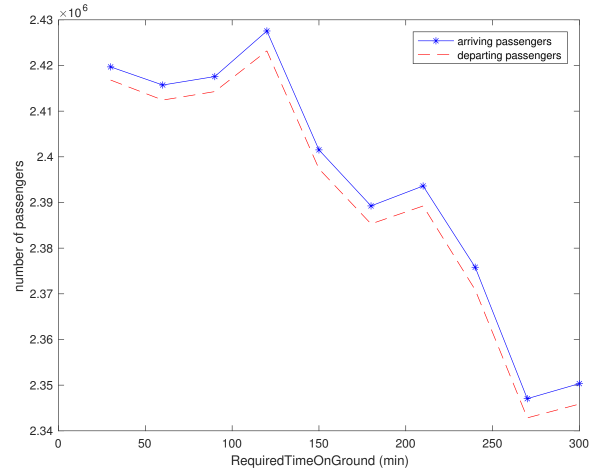



(a) Time required to land and number of passengers

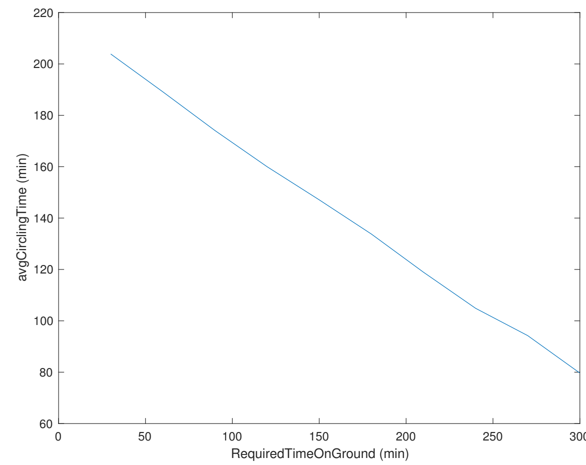



(b) Time required to land and average circling time

Fig. 4. The effect of time required to land




(a) Time required on ground and number of passengers




(b) Time required on ground and average circling time

Fig. 5. The effect of time required to land

ground, are taken into consideration to find the relationship with number of passengers and circling time of each airport. Increasing number of airplanes,decreasing time required to land and on the ground in a fixed time period will result in increasing number of passengers. While decreasing number of airplanes, decreasing time required to land and increasing time required on the ground will decrease the average circling time. This result may have practical significance in airport operation.

## References

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# APPENDIX A

| Sim t = 200000, | run = 15,takeoff = 15,req = 90 | n = 20 | n = 40 | n = 60 | n = 80 | n = 100 | n = 120 | n = 140 | n = 160 | n = 180 | n = 200 | n = 250 | n=300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOS | Circling time | 12027.3 | 107202 | 377573 | 779432.9 | 1170360.6 | 1453678.6 | 1943956.6 | 2604372.3 | 1579889.5 | 3698890.2 | 2310791.5 | 5483072.8 |
| | avg circling time | 4.16602009 | 21.090301 | 64.1476385 | 126.162658 | 187.648004 | 231.036014 | 304.838733 | 410.460567 | 251.055061 | 573.471349 | 362.079521 | 845.370459 |
| | arriving passengers | 1079068 | 1899930 | 2218249 | 2313578 | 2339635 | 2348741 | 2391755 | 2376653 | 2360577 | 2405806 | 2376134 | 2426185 |
| | departing passengers | 1083240 | 1901888 | 2211863 | 2327497 | 2317473 | 2344119 | 2376635 | 2368547 | 2369278 | 2394661 | 2399431 | 2407647 |
| PDX | Circling time | 12835.9 | 101378.7 | 407471.7 | 749544 | 1132787.1 | 2568100.4 | 2413151.9 | 1479522.4 | 2531529.6 | 4094496.8 | 6718015.3 | 3299867 |
| | avg circling time | 4.4109622 | 20.0829437 | 68.7367915 | 122.015953 | 181.886175 | 403.218778 | 378.414913 | 232.739091 | 397.66409 | 637.573466 | 1030.5285 | 517.301615 |
| | arriving passengers | 1090979 | 1889148 | 2225227 | 2300363 | 2349454 | 2400966 | 2377772 | 2388743 | 2384354 | 2404269 | 2436601 | 2398404 |
| | departing passengers | 1098119 | 1876562 | 2221054 | 2298949 | 2336449 | 2377048 | 2404292 | 2371941 | 2372600 | 2400585 | 2394457 | 2391602 |
| PHL | Circling time | 12471 | 102289.2 | 364605.6 | 813830.7 | 1654274.6 | 1151026.4 | 1621158.1 | 2343953.3 | 2328102 | 3117436.9 | 2919539.2 | 7241065.9 |
| | avg circling time | 4.38040042 | 20.2032787 | 62.1769441 | 131.114983 | 264.176717 | 183.284459 | 259.219396 | 370.234292 | 367.092715 | 491.554226 | 461.806264 | 1104.15765 |
| | arriving passengers | 1068286 | 1894137 | 2198099 | 2326542 | 2348119 | 2343978 | 2350598 | 2358609 | 2391945 | 2367872 | 2366111 | 2412013 |
| | departing passengers | 1059391 | 1910772 | 2191789 | 2312738 | 2349515 | 2356032 | 2341429 | 2361554 | 2387795 | 2378878 | 2364938 | 2389469 |
| IAD | Circling time | 13172.2 | 119427.5 | 373121.4 | 552587.9 | 1103684.8 | 1478041.3 | 2138570.4 | 1491288.8 | 3629862.1 | 2112290.2 | 3033008.1 | 2486867.5 |
| | avg circling time | 4.56417186 | 23.3988049 | 63.9782922 | 91.2614203 | 176.251166 | 237.818391 | 336.517766 | 238.606208 | 563.468193 | 331.651782 | 471.476465 | 388.876857 |
| | arriving passengers | 1091104 | 1911022 | 2181793 | 2286698 | 2344175 | 2327272 | 2377929 | 2351522 | 2408696 | 2387573 | 2404915 | 2385383 |
| | departing passengers | 1080968 | 1912384 | 2194528 | 2270689 | 2355099 | 2337418 | 2363707 | 2336425 | 2402278 | 2373278 | 2411575 | 2387011 |
| LAS | Circling time | 12660.2 | 125263.8 | 458655.3 | 907407.2 | 701964.9 | 1057138.8 | 1557832 | 3758684.4 | 3588309.9 | 2606319.3 | 5602876 | 7015724 |
| | avg circling time | 4.31793997 | 24.1495662 | 76.2392453 | 145.604493 | 113.807539 | 168.737239 | 246.765722 | 589.875141 | 561.462979 | 407.046588 | 866.781559 | 1084.17926 |
| | arriving passengers | 1092457 | 1951710 | 2259597 | 2333851 | 2310083 | 2343496 | 2382343 | 2377290 | 2396716 | 2390278 | 2415538 | 2424699 |
| | departing passengers | 1094967 | 1941292 | 2252856 | 2338516 | 2312855 | 2326553 | 2369362 | 2387106 | 2381253 | 2371981 | 2390540 | 2413321 |

(a) Number of airplane effects on four aspects

| n = 100 | Sim t = 200000,takeof | t = 3 | t = 5 | t = 7 | t = 9 | t = 11 | t = 13 | t = 15 | t = 17 | t = 19 | t = 21 | t = 23 | t = 25 | t = 27 | t = 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| BOS | Circling time | 744350.6 | 750430.3 | 1079503.9 | 1027851.4 | 732176.7 | 1013209.5 | 1184379.9 | 1647261.7 | 1108685.5 | 882559.5 | 1081725.4 | 1023307.9 | 961279.5 | 1379127.7 |
| | avg circling time | 70.8298221 | 78.5626361 | 123.188851 | 128.12907 | 99.3455495 | 147.827473 | 181.375176 | 269.86594 | 194.5745 | 166.363713 | 211.978326 | 215.433242 | 211.782221 | 309.499035 |
| | arriving passengers | 3930657 | 3577130 | 3283827 | 3004525 | 2779522 | 2580763 | 2452626 | 2278636 | 2136265 | 1991509 | 1905361 | 1772499 | 1705689 | 1676646 |
| | departing passengers | 3925475 | 3574339 | 3272655 | 3011404 | 2753640 | 2562680 | 2445236 | 2288998 | 2147258 | 1995136 | 1915265 | 1766017 | 1696808 | 1658239 |
| PDX | Circling time | 621753.8 | 656922 | 682527 | 1052745.4 | 1170269.4 | 904728.4 | 1334651.9 | 1121973.5 | 1539769.4 | 1255593.3 | 1972750.4 | 1141564.6 | 893971.3 | 1456386.5 |
| | avg circling time | 59.8473193 | 69.1424061 | 78.9413602 | 129.298133 | 156.223388 | 131.558587 | 205.679134 | 186.933272 | 267.879158 | 233.511865 | 379.95963 | 235.422685 | 194.004188 | 328.978202 |
| | arriving passengers | 3899871 | 3564858 | 3224357 | 3064692 | 2783343 | 2587844 | 2448227 | 2237672 | 2159941 | 2015617 | 1939053 | 1824026 | 1715954 | 1663692 |
| | departing passengers | 3877184 | 3556174 | 3243014 | 3017251 | 2809412 | 2575954 | 2442753 | 2249313 | 2149097 | 2019053 | 1933988 | 1803181 | 1719655 | 1656830 |
| PHL | Circling time | 662767.7 | 796946.7 | 716288.2 | 1023613.8 | 1129836.3 | 996864.7 | 914905.4 | 1025177.5 | 1301204 | 1590376.6 | 991014 | 1031981.6 | 1345722.4 | 1487914.1 |
| | avg circling time | 63.9860687 | 82.6708195 | 82.1997016 | 127.426092 | 150.765452 | 144.598883 | 143.155281 | 170.380173 | 227.046589 | 295.170119 | 195.65923 | 215.670136 | 295.114561 | 336.175802 |
| | arriving passengers | 3869026 | 3614983 | 3263681 | 3017782 | 2798318 | 2575672 | 2405299 | 2258779 | 2154313 | 2031713 | 1898908 | 1790540 | 1710858 | 1652057 |
| | departing passengers | 3887487 | 3610337 | 3249357 | 3022250 | 2809627 | 2586392 | 2397674 | 2249344 | 2153128 | 2004123 | 1905722 | 1806581 | 1717168 | 1643235 |
| IAD | Circling time | 628216.2 | 808798 | 977105.7 | 979627.8 | 873860.5 | 1458786.5 | 1027310.4 | 1175757.5 | 1084138.2 | 1648246.7 | 1103696.4 | 1565308 | 1475245.5 | 1399894 |
| | avg circling time | 59.9500143 | 84.8419175 | 110.745291 | 121.13612 | 116.795041 | 207.00816 | 159.100263 | 195.308555 | 192.393647 | 304.666673 | 217.519984 | 322.146121 | 315.628049 | 313.807218 |
| | arriving passengers | 3930359 | 3572160 | 3309054 | 3030324 | 2809471 | 2642797 | 2420024 | 2249482 | 2098403 | 2008743 | 1905160 | 1823243 | 1742702 | 1662217 |
| | departing passengers | 3934287 | 3580624 | 3304996 | 3029709 | 2793392 | 2627142 | 2434479 | 2250298 | 2101363 | 2013161 | 1887870 | 1825217 | 1734405 | 1679658 |
| LAS | Circling time | 701907.9 | 888149.6 | 890886.3 | 653993.7 | 1142882.7 | 993624.5 | 1169239.8 | 911004.5 | 1017876.1 | 871060.2 | 1231672.2 | 1778486.7 | 1978947.7 | 1025240.5 |
| | avg circling time | 66.9184765 | 93.0486747 | 101.978743 | 82.8994423 | 152.120684 | 143.483682 | 181.137072 | 152.750587 | 179.836767 | 164.196079 | 242.216755 | 360.747809 | 417.499515 | 232.428134 |
| | arriving passengers | 3936014 | 3579766 | 3284089 | 2941537 | 2829553 | 2592632 | 2431555 | 2259721 | 2124623 | 1986978 | 1900374 | 1854583 | 1775048 | 1657600 |
| | departing passengers | 3924635 | 3570389 | 3276943 | 2963124 | 2816975 | 2606732 | 2418814 | 2228011 | 2105012 | 1987522 | 1891030 | 1842704 | 1766870 | 1657167 |

(b) Time required to land effects on four aspects

| n = 100 | Sim t = 200000,takeofftime = 15 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | req = 30 | req = 60 | req = 90 | req = 120 | req = 150 | req = 180 | req = 210 | req = 240 | req = 270 | req = 300 |
| BOS | Circling time | 1295566.2 | 1045022.4 | 1196389.7 | 750874 | 813211.1 | 579673.2 | 848874 | 669016.9 | 547330.3 | 479168.4 |
| | avg circling time | 203.034979 | 163.335792 | 184.514143 | 116.922143 | 127.084091 | 91.8221448 | 132.65729 | 106.193159 | 87.0436228 | 75.8778147 |
| | arriving passengers | 2393005 | 2395769 | 2426361 | 2418521 | 2399996 | 2378111 | 2410123 | 2352786 | 2352234 | 2360763 |
| | departing passengers | 2398348 | 2385481 | 2424227 | 2407170 | 2388980 | 2347658 | 2376294 | 2337273 | 2345455 | 2362710 |
| PDX | Circling time | 1436558.9 | 925749 | 635520 | 756071.8 | 715265.6 | 1329833.1 | 747233.8 | 722735.9 | 628199.4 | 461595.4 |
| | avg circling time | 223.20679 | 145.124471 | 100.87619 | 118.043997 | 112.78234 | 205.792804 | 117.341991 | 113.245989 | 99.6193149 | 74.450871 |
| | arriving passengers | 2398072 | 2385050 | 2359294 | 2400897 | 2381387 | 2423892 | 2385738 | 2393939 | 2363003 | 2318321 |
| | departing passengers | 2401818 | 2391901 | 2355905 | 2407211 | 2368968 | 2418043 | 2399203 | 2372625 | 2350098 | 2326325 |
| PHL | Circling time | 1230218.9 | 1229838.7 | 1063911.3 | 1262488.7 | 788339.2 | 701882.4 | 768972.8 | 620373.1 | 466801.1 | 583808.7 |
| | avg circling time | 189.760743 | 187.96251 | 163.956126 | 193.21835 | 122.756026 | 110.776894 | 120.736819 | 97.7581311 | 75.5341586 | 92.4625752 |
| | arriving passengers | 2429187 | 2444181 | 2425906 | 2457903 | 2390555 | 2376213 | 2382249 | 2370407 | 2308113 | 2375102 |
| | departing passengers | 2415259 | 2436277 | 2418712 | 2452925 | 2409322 | 2375711 | 2378505 | 2377467 | 2305001 | 2350689 |
| IAD | Circling time | 1239540.6 | 1584528.5 | 1769113.8 | 1244986.5 | 1129038.1 | 821059.5 | 647208.8 | 648161.1 | 585608.3 | 495595.8 |
| | avg circling time | 189.793385 | 242.430921 | 268.088165 | 191.861073 | 177.159595 | 128.210415 | 100.984366 | 102.185259 | 93.6374001 | 79.2572845 |
| | arriving passengers | 2450277 | 2441693 | 2456136 | 2432846 | 2392355 | 2388367 | 2386693 | 2368517 | 2338223 | 2349252 |
| | departing passengers | 2434096 | 2431430 | 2471408 | 2440381 | 2381945 | 2411190 | 2404538 | 2370006 | 2342018 | 2342969 |
| LAS | Circling time | 1385764.4 | 1339355.8 | 984563.2 | 1158224.4 | 1276927.5 | 840382.6 | 781144.7 | 671796.5 | 729544.7 | 478943.3 |
| | avg circling time | 213.588841 | 206.850317 | 152.929978 | 179.932329 | 195.697701 | 132.343717 | 122.898789 | 105.001016 | 115.361275 | 76.313464 |
| | arriving passengers | 2427915 | 2411909 | 2420194 | 2427610 | 2443286 | 2379650 | 2403260 | 2393440 | 2373611 | 2348251 |
| | departing passengers | 2434518 | 2417039 | 2401163 | 2408292 | 2437665 | 2373952 | 2387637 | 2396948 | 2371590 | 2346608 |

(c) Time required on the ground effects on four aspects

Fig. 6. Raw data