The Ordered Outside-in System for Boarding Airplane

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Abstract

Many papers have analyzed the main factors influencing the boarding time.in detail, Simultaneously, they put forward some strategies to cope with them. Most of all the researches concentrated on the congestions of the aircraft aisles, seats passengers and the aircraft dimensions and so on.We provide a new Ordered Outside-in policy for aircraft boarding. Then, we simulate the system and calculate the total boarding time can be reduced to 320 s, less than the result of previous methods , that is about 1300 s to board A320.

Theoretically, we can reach the optimization result. In practice, it is the fact that we can't take all the factors under control. In essence, the problem is that how to succeed in making all the thing that are out of order to be in order . Generally speaking, whatever kind of strategy you carry out, You could do well in controlling every passenger, but the better you control the passengers ,the more resources like human resource the airlines must consume and most people don't like being bossed around too much.In order to get rid of the bottleneck, we present the Ordered Outside-in system. Before boarding an airplane, we can obtain an ordered sequence through the system. So it will lowest the seat interference.

The emphasis of this paper focuses on validating that our approach is more efficient and robust than the previous methods. To determine it , We simulate and analyze the process of passengers boarding an airplane by computer simulation, then show how to implement the procedure of boarding.

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1 Introduction

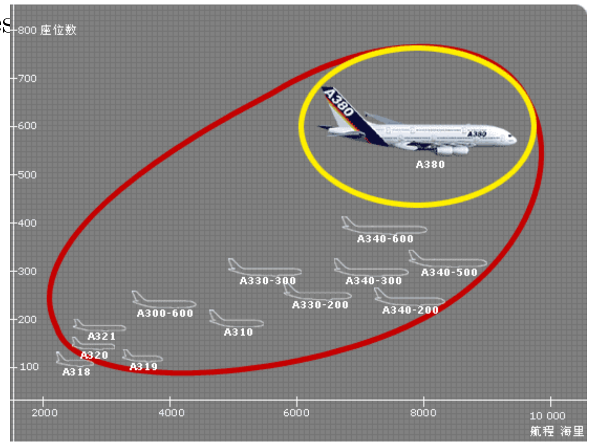


Fig 1: The changes of AirBus in recent years

The figure 1 as shown right,illustrates the changes of AirBus having taken place in recent years.Furthermore it also occur to the other types. As for the payload, the dimensions and the terminal service of airplane, they are still changing every year.With the development of technology and the cooperation among countries, The airline transport has made rapid progress. One indication of it is that the number of seats aboard and the Range is increasing quickly. But, as we all known, an airline always measures its productivity and profitability by turntime(called turnaround time). Therefore a great deal of attention is paid to the turntime, because that the success of discount airlines is the quick turnaround of their airplanes, which helps them achieve high airplane utilization.

It is reported that more and more people choose the airline vehicle for travel or commercial businesses. From the viewpoint of the airlines, it is a piece of good news.But at the same time, it is still a challenge for them to minimize passenger frustration and the congestion of boarding airplanes. To solve it, some airlines are adopting to new ways of boarding. By now There are a variety of boarding strategies in the hope of reducing the turnaround time for airplanes' boarding time.

Many people are doing research in it to find an efficient and feasible method. Therefore there are many strategies to try out to solve it, but there are still many troubles in implement the each procedure. In contrary, some researcher declare that "there is no optimization result in practise, All we can do is to improve and optimize our method or strategies with the new problems come out ". Airlines have always looked for ways to improve efficiency, for example, "Back-to-front" "boarding Rotating-zone" "boarding Random (assigned seats)" "boarding Block boarding" "Reverse-pyramid boarding" " Outside-in boarding" and so on. Some of them are still being used in up to date airports.

"Congestion is the major issue," said Dr. Bachmat, an expert on the research of boarding airplane." Whatever kind of strategy you carry out, You could do better by controlling every passenger, but people don't like being bossed around too much."It is the key point we should overcome with our wisdom and nowadays' technology tools.

As for the previous ideas, we can conclude that in the cabin, after entering the gate, the dominant factor that influence is the interference before all the passenger get their satisfied seats. It is the key point that we take into account firstly. But we also pay more attention to the time of the passengers' waiting for boarding the airplane. All the methods or strategies are competing for the more convenient way to reduce the interference during all the procedure of boarding the airplane.But they all ignore the waiting time.

In the paper, We analysis the troubles from a complete new point of view based on the previous interference research of the problem.

2 Analysis of the Problem

As described above,it is an obvious conclusion that the total boarding time lies in the number of the interferences that occur in the process of boarding the airplane.Whether the airline gate agents let the passengers enter randomly or not,we can analysis the process according to the strategy "Outside-in".If the entering passengers are in order, we consider it as an entity and passenger boarding delays usually occur because of three reasons: gate agents cannot process passengers fast enough to keep a steady flow of passengers moving into the aircraft, unexpected random events (such as a terrorist threat onboard a grounded aircraft), and boarding interferences - conflicts between passengers during the boarding procedure. The problem of keeping steady flow passengers boarding the aircraft due to the slow processing procedures of gate agents can easily be solved with the introduction of one or more gate agents into the system. The occurrence of random events that delay cannot be reduced easily. Although boarding interferences are more complex in nature and can rarely be avoided or corrected ,it can be definitely reduced. An interference model will be used in this paper to determine the boarding method that uses the least amount of time on average.We divide all the factors that effect the velocity of the proceeding into two types of boarding interferences as follows.

Within a passenger aircraft, two types of boarding interferences can occur during the boarding of an aircraft, both of which cause delays at the gate and have the potential to cause a decrease in passenger satisfaction.

- **Aisle Interference**
  This type of boarding interference occurs when a passenger loads carry-on luggage into the overhead storage compartments of the aircraft. To perform this action however, the passenger loading the carry-on luggage must stand in the narrow aisle and momentarily act as an obstacle to those waiting to get to their seats. Unless passengers can squeeze past the person loading his or her carry-on luggage, the boarding of passengers is momentarily halted.
- **seat interference**
  Seat interferences arise when a passenger route to his or her seat is blocked by another passenger sitting in the same row, but closer to the aisle as rows are usually clustered together with not much legroom for passengers. The situation worsens if one has to get past two or more passengers who are already sitting in their seats located closest to the aisle within a half-row. Passengers waiting to be seated may do one

of the following: ask the passengers already seated to stand up and move into the aisle while they move into their seat further away from the aisle, or they may choose to simply attempt to move into the seat without asking the already seated passengers to move.

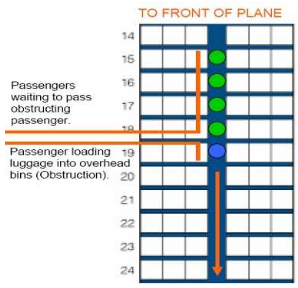


Fig 2: Aisle Interference

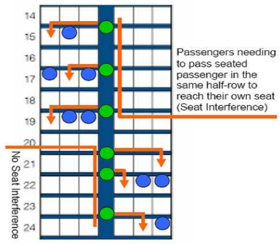


Fig 3: Seat Interference

With either of these two types of boarding interferences, it is obvious that if the frequencyof interferences increases during the boarding of an aircraft, the boarding time increasesand thus gate delays occur. Therefore, one of the methods to reduce boarding time is tofind or develop a procedure that tries to reduce the amount of seat and aisle interferences.

3 Design of the System

As discussed above,The emphasis in the model is to make the variable validity for protect the mistake we made in our model. The Order Outside-in system we present in our model.The flowchart illustrate the procedure of boarding the airplane .

Fig 4: The flowchart of outline boarding airplane

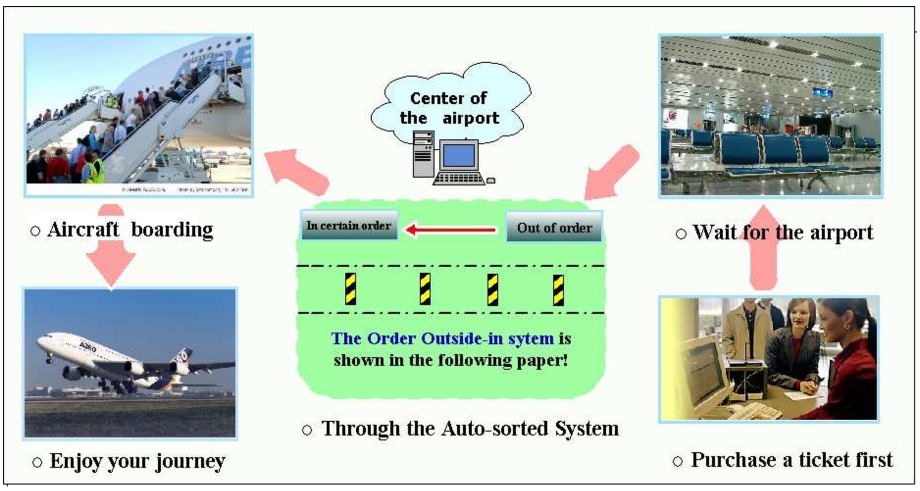
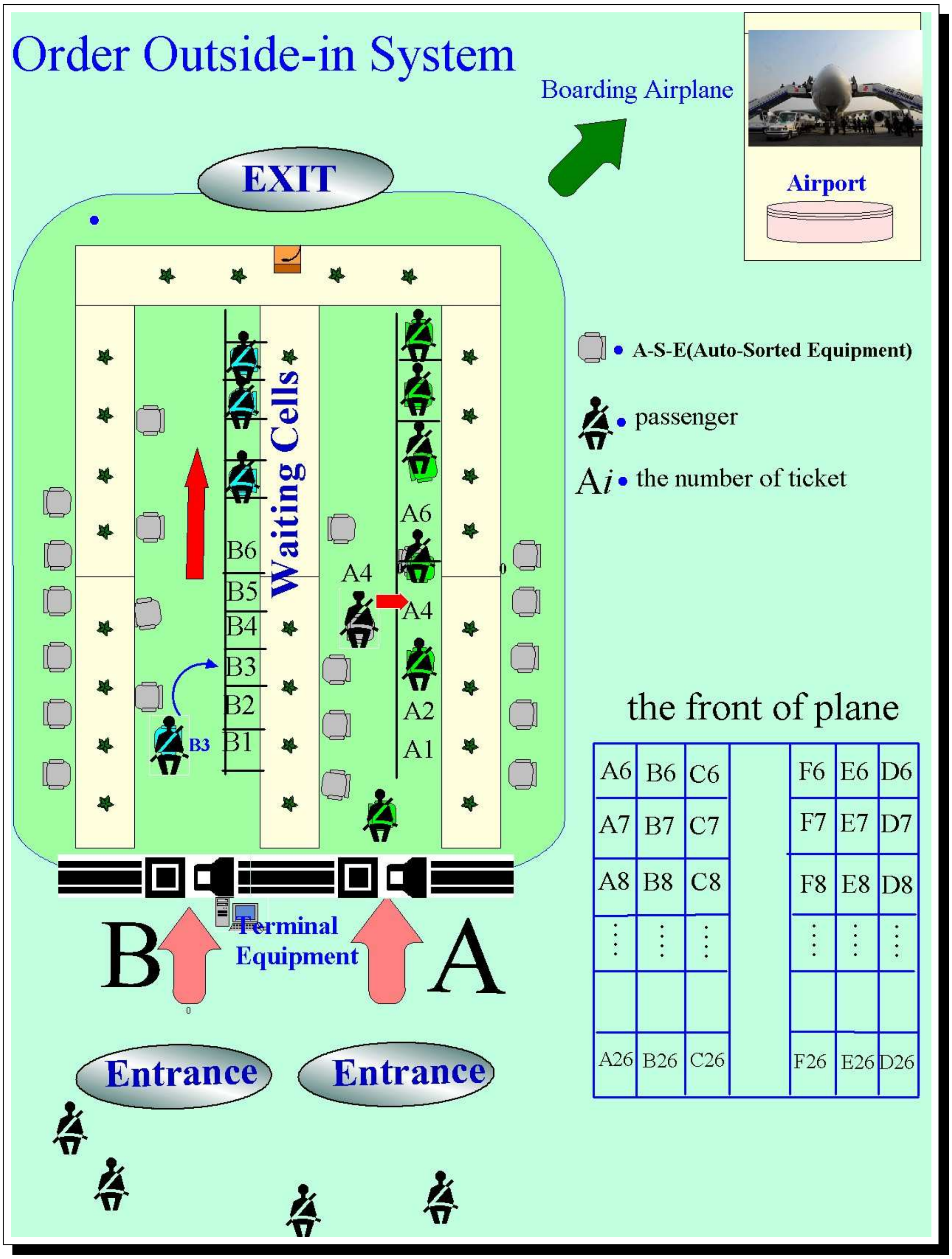


Fig 5: The flowchart of boarding airplane



4 How Does It Work

Our order outside-in system is shown in the picture below , It can be designed for airports to solve the bossed boarding problem. How does it work and why it can reduce the cost of time for boarding any type of airplane? We will introduce it step by step as described in the following paragraph.

Firstly, you must show your ticket to make sure that you are the members of the flight. and you can enter the system. Then you will be arranged on a equipment(that is , the auto-sorted equipment) which carry you to the position in the waiting cells all by itself , and the number of the cells is still the your seat number aboard, and in the waiting cell you can receive our service which is provided by airport.

To illustrate it , we can see the picture shown below, if your seat NO. is B_3,and you will be taken to the waiting cells signed B_3, to make sure you can reach the right seats on the airplane.

Secondly,when the airplane arrive in time, the account agent announce that it is the A_i's

(whose seat number is begin with the letter A) turn to board the airplane, In fact ,the A_i is aside the windows of airplanes. then it take the turn to the other windows , and go on with this turns till all the passengers are aboard.Note that it must be about 20s' interval between the loop to reduce the aisle interference.

Finally,the system will welcome the passengers of the next flight. and then go on with the loops.

In practise,it is an easy-to-understand system, When the fist group of passengers the time of boarding the airplane is the time which used to get to the personal seat, and put their luggage aside.In real condition. As for a group, all the boarding time lies in the last one's velocity and each time of the group is more or less the same. We can know that there is no Seat interferences during the period of boarding the airplane. So we can evaluate the interference possibility by simulation.

5 Simulation

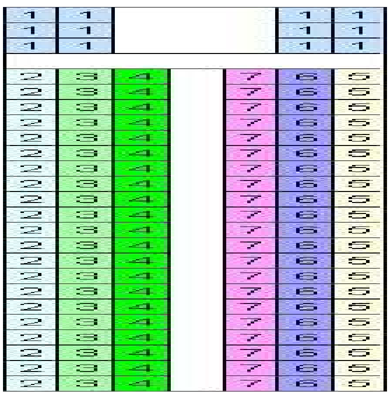


Fig 6: The Order of the boarding airport

Simulations of boarding methods for this paper were performed using a model built within ProModel 2001 by Menkes H.L. vanden Briel of the Arizona State University. The team from ASU had obtained videotapes of actual airplane boarding, and recorded data essential to the creation of an enplaning simulation.

From these videotapes they found:

1. The arrival rate of passengers entering the aircraft from the terminal (time between passengers or more or less the speed of the gate agent-assumingone gate agent is present at boarding) was an exponential distribution with anaverage of 9.0 seconds (the exponential distribution accounted for late arrivals at the terminal).
2. Row speed, the speed of passenger travelling from one row to the next, was a triangular distribution with a low of 0.6 seconds, an average of 0.95 seconds,and a high of 1.3 seconds.
3. 60% of the passengers had a triangularly distributed luggage speed, or thespeed that passengers place their carry-on luggage into the overhead bins,with a low of 3.2 seconds, an average of 7.1 seconds and a high of 38.7seconds. The other 40% of the passengers had a luggage time of zeroseconds, as they had no large carry-on luggage place in the overheadluggage compartments or decided to place their luggage beneath their seats.
4. Also related to luggage speed, a pass ratio was determined. Sometimes,when a person was loading his or her luggage into the overhead bins, thestalled passengers would slide past or pass the aisle interference without using much time. On average, one passenger out of every ten would do this.
5. Seat interference time was found to be a triangular distribution with a low of 7.4 seconds, an average of 9.7 seconds, and a high 15.5 seconds.
6. An average of 29 parties (groups of people that have requested that they sit inadjacent seats and board at the same time e.g. a family, a group offriends/colleagues) when were found to board a plane. It was found that anaverage of twenty parties of two and nine parties of three boarded. Largerparties were rare and were not integrated into the study.

The simulation that the team from *ASU* built afterwards, which is used extensively by this paper, was built using this data. The model is based on the interferences mentioned previously as an indication of the time it takes for passengers to board. When interferences occurs within a boarding procedure simulation, a predetermined penalty is applied to the overall time. It needs to be noted that the simulation is based on a few assumptions. These include:

- A "call-off" system will be will be used. This is where a gate agent calls out groups to be boarded next using a P.A. system.

- All first class passengers are to be boarded first in every boarding method. Therefore, this study will mainly apply to the boarding of passengers in the economy class.
- Passengers do not sit in the wrong seat and they do not walk past the row containing their seat.

Each boarding method simulation was run 100 times, which allowed for a confidence interval of less than 60 seconds for each different boarding procedure tested.

6 The Results and Observations

37 different boarding orders were simulated and tested under the following categories:

1. **Random(RAND)**:All passengers in the economy class are boarded together as one group. First class passengers are boarded first as one group, followed by coach class passengers.
2. **By Block** (B):Passengers are boarded by groups with each group containing a number of contiguous rows.
3. **By Half-Row/Half Block** (HR):Same as "By block", except the block spans only half a row (ABC or DEF).
4. **By Seat Row** (R): A single row of seats (ABC DEF) equals a group.
5. **By Seat Column** (C): A single column of seats ($A, B, C, D, E, or F$) equals a group.
6. **By Reverse Pyramid Type** (RP): Based on the boarding order created by the ASU team. All boarding procedures that use the same, general, outside-in / back-to-front hybrid method used by the Reverse Pyramid approach was placed under this category. The original Reverse Pyramid boarding process is labeled RP1.
7. **By U-Boarding Type** (U): This category features new and experimental boarding procedures where seats belonging to a group forms a U-shape.
8. **By Seat** (S): Each passenger forms its own group and is called individually by row and number.
9. **By Airline Pattern** (AP): Alaska ($AP1$), Delta($AP2$) and United Airlines' ($AP3$) recently implemented boarding processes.
10. **By Special Pattern** (SP): Any other pattern that does not fit any of these categories. Consisted of a two nonsymmetrical boarding processes.

Based on the previous data we collected, We simulate the procedure of the boarding the airplane.and compared our result with them.We obtain the agreement that all our result is less than the other strategies. By now, the result of the "back-to-font" is about 1400 s with the type of airplane A320. and as to the strategy of "Outside-in" is more or less 1360s with the some condition.Compared with our result,we can conclusion that the Order Outside-in is more efficient for the boarding airplane.

7 Conclusions

The models and implementation results show that outside-in boarding outperforms traditional back-to-front boarding. Therefore, based on this result, we develop an Ordered Outside-in boarding strategy. Through simulation, we obtain an astonishing result . Hence, our method is an excellent alternative for reducing passenger boarding time, so long as the airport can provide room and more services to make A-S-E run steadily. Despite this system needs a lot of finance and resource support, we are sure it will make a lot of benefit in a long run . We hypothesize that the best boarding strategy depends on such factors as airplane design and the profile of the passengers boarding the plane.

8 A Summary

As the rapid development of the air traffic,the problems often brought our progress to halt like the nowadays boarding problem.It is very ordinary but disturbs our normal lives every time when you travel out by air or plane. Today,We will give you a system that can change your attitude to the boarding airplane. We believe that the "Order Outside-in"system'll makes you love your journey from now on.

As we all known, when you on board,interference or congestions often disturbs us.but you have no idea,Today, our method I'll introduce to you in the following section. Although the interference have been paid more and more attention.but they can't solve it completely.We first do a lot of research on the problem and give birth to this"Order Outside-in" system that can cope with the interference aboard in cabin. We believe the reason of interference is the "out of order",so we produce the system to keep comfortable in order to boarding airplane.How it works is not important,but the convenience it bring in will appeal to the crew and the airline executives.and our customers.This system can reduce the cost of operator a airline ,like human resource,space-time resource.It also save your time for the turnaround time and the boarding time. We have calculate the cost of the system,and compared to the investment,It has enough appeal to everyone.If you are Airline executive I think that Following our system you'll get more than what you can imagine and if you are a common clerk you may want to work in a comfortable environment,especially in the airline.It can make your dream come true. If you are a usual customer,you'll enjoy your life more after being served.

To make two long story short,this is a new-research,and we have enough confidence to be sure that it will change the airline,and even your life.

9 Evaluate of the Mode

10 Strengths and weaknesses

Like any model,the one present above has its strengths and weaknesses. Some of the major points are presented below.

10.1 Strengths

- **Applies widely**
  This system can be used for many types of airplanes, and it also solves the interference during the procedure of the boarding airplane,as described above we can get to the optimization boarding time.We also know that all the service is automate.
- **Improve the quality of the airport service**
  Balancing the cost of the cost and the benefit, it will bring in more convenient for airport and passengers.It also saves many human resources for the airline.
-

10.2 Weaknesses

- The airport should invest to build this Ordered Outside-in system for the airlines,It also take up certain part of the airport.
- Groups of people that have requested that they sit in adjacent seats and board at the same time e.g. a family, a group of friends/colleagues) when were found to board a plane.

Appendix A

Here are simulation programmes we used in our model as follow.

The programme of simulation

```
function randomVector = trirnd(minVal, topVal, maxVal, varargin);
%TRIRND generates discrete random numbers from a triangular distribution.
%   randomValue = TRIRND(minVal, topVal, maxVal);
%       The distribution is defined by:
%           - a minimum and a maximum value
%           - a "top" value, with the highest probability
%       The distribution is defined with zero probability at minVal-1 and
%       maxVal+1, and with highest probability at topVal. Hence
%       every value in the range (including the maximum and minimum values)
%       have a non-zero probability to be included, whatever topValue is.
%       The output is a random integer.
%   randomMatrix = TRIRND(minVal, topVal, maxVal, nrow, ncolumns)
%       returns a (nrow x ncolumns) matrix of random integers.
%
% Written by L.Cavin, 01.08.2003, (c) CSE & ETHZ
% This code is free to use and modify for non-commercial purposes.
%
% NOTES:
% * This is a numeric approximation, so use with care in "serious"
%    statistical applications!
% * Two different algorithms are implemented. One is efficient for large
%   number of random points within a small range (maxVal-minVal), while the
%   other is efficient for large range for reasonable number of points. For
%   large ranges, there is a O(n^2) relation with regard to the product of
%   range*number_of_points. When this product reach about a billion, the
%   runtime reach several minutes.
% * To inspect the resulting distribution, plot a histogram of the
%    resulting random numbers, e.g. "hist(trirnd(1,87,100,10000,1),100)".

% Version History:
% ----------------
% Version 2.0 - 20.10.2004 -- added alternate algorithm for large ranges.
% Version 1.5 - 14.02.2003 -- made similar to Matlab functions (nargin order
%                             and checks).
% Version 1.0 - 01.08.2003 -- initial release.

% check arguments...
if nargin < 3
    error('Requires at least three input arguments.');
end
nrows = 1;
ncols = 1;
if nargin > 3
    if nargin > 4
        nrows = varargin{1};
        ncols = varargin{2};
    else
        error('Size information is inconsistent.');
    end
```

```
end
 if  topVal > maxVal || topVal < minVal || minVal > maxVal
     randomVector = ones(nrows, ncols).*NaN;
     return;
end

% go for the randomization
mxprob = maxVal-minVal+1;
 if  mxprob < 51 || (mxprob < 101 && nrows*ncols > 500) || (mxprob < 501 && nrows*
      ncols > 8000) || (mxprob < 1001 && nrows*ncols > 110000)
          vector  = ones(1,mxprob).*topVal;
          j  = (topVal-minVal+1);
          slope  = 1/j;
          j  = j -1;
          for  i  = (topVal-1):-1:minVal
          vector  = [vector  ones(1, floor (mxprob*slope*j)).*i];
          j  = j - 1;
          end
          j  = (maxVal+1-topVal);
          slope  = 1/j;
          j  = j -1;
          for  i  = (topVal+1):maxVal
          vector  = [vector  ones(1, floor (mxprob*slope*j)).*i];
          j  = j - 1;
          end
          randomVector = vector(unidrnd(size(vector,2),nrows*ncols,1));
 else
          probs = mxprob:-1*mxprob/(topVal-minVal+1):1;
          probs = [probs(end:-1:2) mxprob:-1*mxprob/(maxVal-topVal+1):1];
          probs = cumsum(probs./sum(probs));
           if  nrows*ncols*mxprob > 1000000
          % dealing with large  quantities  of  data,  hard on memory
          randomVector = [];
          i  = 1;
          while nrows*ncols*mxprob/i > 1000000
               i  = i * 10;
          end
          probs = repmat(probs, ceil(nrows*ncols/i),  1);
          for  j  = 1:i
               rnd = repmat(unifrnd(0, 1,  ceil (nrows*ncols/i),  1),  1,  mxprob);
               randomVector = [randomVector sum(probs < rnd, 2)+1];
                    end
          randomVector = randomVector(1:nrows*ncols);
           else
          probs = repmat(probs, nrows*ncols, 1);
          rnd = repmat(unifrnd(0, 1, nrows*ncols, 1),  1,  mxprob);
          randomVector = sum(probs < rnd, 2)+1;
          end
end
% generate desired matrix:
randomVector = reshape(randomVector, nrows, ncols);

function  [t ,seat , aisle ]=OI6Sim(n,target,seated)
```

```
% OI6
%    n
%    target
%    seated

%   t simulation time
%   seat  ,seat  interference
%    aisle  , aisle  interference


% Initial  data
% setting passengers' Value:
%                         walking              .....     1
%                         waiting              .....     2
%                         putting luggage   .....     3
%                         passing the seat   .....     4
%                          sitting               .....     0


% on initial  time, everyone is  waiting,except the  first  one

seat=0;
aisle =0;

status=2*ones(1,n);
status(1)=1;

%
%          0          .6 row
pos=-(0:0.6:(n-1)*0.6);



    pri=[-1,1:n-1];
    next=[2:n,-1];


RowSpeed=trirnd(0.6,0.95,1.3,1,n);

pab=rand(1,n);
for  i=1:n
      if  pab(i)<0.4
          aisleTime(i)=0;
      else
           aisleTime(i)=trirnd (3.2,7.1,38.7) ;
      end
end

% seat interference  time
seatTime=trirnd(7.4,9.7,15.5);
```

```
t=0;
while sum(status) ~=0

    t=t + 0.1;
    for i=1:n

        switch status(i)
            case {0}

                 if  next(i)>0 &&abs(status(next(i))-2)<0.1
                        status(next(i))=1;
                    end

%                   disp('have sit down');

            case {1}

%                   disp('Walking');

                    if  next(i)>0 &&abs(status(next(i))-2)<0.1
                        status(next(i))=1;
                    end


                    pos(i)=pos(i)+RowSpeed(i)*0.1;

                    if abs(pos(i)-target(1,i))<0.2

                        status(i)=3;
                        if abs(aisleTime(i))<0.01
                            aisle=aisle+1;
                        end

                            if  next(i)>0 &&abs(status(next(i))-1)<0.1

                                status(next(i))=2;
                        end

                     end


            case {2}

%                    disp('Blocking');
                  if  next(i)>0 &&abs(status(next(i))-1)<0.1

                          status(next(i))=2;
                    end

            case {3}            %put luggage     aisle  interference

                  disp('aisle interference');
```

```
                    if abs(aisleTime(i))<0.01

                      if   n==12 && target(2,i)==1 && seated(target(1,i),2)==1
                            status(i) = 4;
                            seat=seat+1;
                        elseif   n==12 && target(2,i)==4 && seated(target(1,i),3)==1
                            status(i) = 4;
                            seat=seat+1;
                        else

                             status(i)=0;
                             seated(target(1,i),target(2,i)) = 1;
                        end

                    else
                        aisleTime(i)=aisleTime(i)-0.1;

                    end

              case {4}              % seat interference

                  if abs(aisleTime(i))<0.01   %
                      status(i)=0;
                      seated(target(1,i),target(2,i)) = 1;
                  else

                      seatTime(i)=seatTime(i)-0.1;
                  end



          end  %switch
      end %for

  end %while

  function k=myRandn(n)

  n=12

  k1=n*rand(1,n)

  k2=sort(k1)

  %
  % Boarding airplane OI6
  %
  %   2007-2-11 15:33

  % A380 time30-45min optimuzation time:24min
  clc
  clear  all;
```

```
close all ;



count=5;
for k=1:count


    seated =zeros(26,6);     % set a value  to  check the seat

       n=12;

      a   =[1:3,1:3,1:3,1:3;1:4,1:4,1:4];

      index=myRand(12);
      target=a(1:2,index);

     [t(k),seat(k), aisle (k)]=OI6sim(n,target,seated);

      n=28;

      a=[13:26,13:26;ones(1,14),6*ones(1,14) ];

      index=myRand(28);
      target=a(1:2,index);

     [t2,seat2, aisle2]=OI6sim(n,target,seated);
     t(k)=t(k)+t2;
     seat(k)=seat(k)+seat2;
     aisle (k)=aisle(k)+aisle2;




      n=28;
      a =[18:26,18:26,8:12,8:12;2* ones(1,9),5*ones(1,9) ,ones(1,5),6*ones(1,5) ];

      index=myRand(28);
      target=a(1:2,index);

     [t2,seat2, aisle2]=OI6sim(n,target,seated);
     t(k)=t(k)+t2;
     seat(k)=seat(k)+seat2;
     aisle (k)=aisle(k)+aisle2;

     n=28;

  a =[4:7,4:7,8:17,8:17; ones(1,4),6*ones(1,4),2*ones(1,10),5*ones(1,10) ];

      index=myRand(28);
      target=a(1:2,index);
```

```
    [t2,seat2, aisle2]=OI6sim(n,target,seated);
    t(k)=t(k)+t2;
    seat(k)=seat(k)+seat2;
    aisle (k)=aisle(k)+aisle2;

  n=28;
 a =[4:7,4:7,17:26,17:26;2* ones(1,4),5*ones(1,4),3*ones(1,10),4*ones(1,10)];

     index=myRand(28);
     target=a(1:2,index);

    [t2,seat2, aisle2]=OI6sim(n,target,seated);
    t(k)=t(k)+t2;
    seat(k)=seat(k)+seat2;
    aisle (k)=aisle(k)+aisle2;

  n=26;
  a=[4:16,4:16;3*ones(1,13),4*ones(1,13)];

     index=myRand(26);
     target=a(1:2,index);

    [t2,seat2, aisle2]=OI6sim(n,target,seated);
    t(k)=t(k)+t2;
    seat(k)=seat(k)+seat2;
    aisle (k)=aisle(k)+aisle2;

end

t
sum(t)/count

seat
sum(seat)/count

aisle
sum(aisle)/count
```