Computer Simulation of a Heavy Traffic Single Runway Airport

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Abstract

Waiting for service is part of our daily life. The study of queues determines the measures of performance of a queuing situation. This information is used to decide on an appropriate level of service for the facility may be offered. We consider in this study the simulation of a heavy traffic single runway airport. We are interested to study the situation for two different cases: first, the service offered to the airplane that reaches first (either landing or taking-off), the second, the priority is given to the landing airplanes rather to takeoff airplanes. The later case is crucial, because it is a matter of risk in waiting for a long time for landing. However, the taking-off airplanes will not get permission to takeoff unless there is no airplane predisposition to landing. Our objective is to provide decision makers with comparative information that may be of help to take an appropriate action to determine a suitable service level for the airport. The airport aims to reduce the waiting time for the landing airplanes beside keeping the takeoff airplanes waiting for a reasonable time.

Introduction

The waiting phenomenon is not an experience limited to human beings only. Jobs wait to process on a machine, planes circle in a stack before given permission to land at an airport and cars stop at traffic lights… The study of queues determines the measures performance of a queuing situation, including the average waiting time and the average queue length, among others statistical measurements. This information is then used to decide on an appropriate level of service for the facility. The result of queuing analysis may be used in the context of a cost optimization model, for details see [3], [4] and [9].

Simulation is the best thing to observing a real system in operation. It allows us to collect pertinent information about the behavior of the system by executing a computerized model. We are interested in implementing this technique as a solving problem technique to imitate the behavior of the airplanes that require to land or takeoff. Estimation of simulation output is based on random sampling. This means that the output of simulation is subject to random variations, and thus, should be examined using statistical test.

A computer simulation begins with a model of the behavior of some system the researcher wishes to investigate. The model consists of a set of equations and/or transformation rules for the processes by which the variables in the system change over time. The model is then translated into computer code, and the resulting program is run on the computer for multiple time periods to produce the outcomes of interest, see [6] and [7]

Our study focuses on two different disciplines. The first one is First-In-First-Out (FIFO). This means the first airplane arrives to server, control space station, asks for permission to land or to takeoff. This airplane gets the required permission regardless of whether it wants to land or takeoff. The next airplane should wait in a queue as long as the server is still busy with the previous one. Once the server becomes free the permission is given to the next airplane and so on until all airplanes are served. The second discipline gives a priority to landing request rather than the takeoff request. The takeoff airplane will not get permission to be served as long as there is an airplane asking for landing. So, those airplanes should wait in a queue when the server is busy. When the landing queue is empty, then the permission to serve is given to airplanes that wait in the takeoff queue. We present some results of this study using plots charts and statistical measurement tables. The most interesting charts are the number of airplanes waiting in landing queue and takeoff queue for both disciplines, beside a comparison charts for number of airplanes in each event that occurs in a total simulation period. The statistical relationships that is given in the coming section is "performance measurements".

Simulation of an Airport

Let us consider a small but busy airport with only one runway. In each unit of time one plane can land or one plane can takeoff, but not both. Planes arrive ready to land or to takeoff at random times, so at any given unit of time, the runway may be idle or a plane may be landing or taking-off, and there may be several planes waiting either to land or takeoff. We, therefore, need two queues, which we shall call landing and takeoff, to hold these airplanes. Because of a risk matter, it is better to keep a plane waiting on the ground than in the air, so a small airport allows a plane to takeoff if there are no planes waiting to land, i.e., the landing queue is empty, see [2] and [8].

A key step in our simulation is to decide, at each unit time, how many new planes become ready to land or takeoff. There are many ways, through which these decisions can be made. One of the most interesting and useful onesis to make a random decision. In this study, we generate non-uniform random varieties using an exponential distribution. Different parameters of a random variety have been examined, for details see [1], [5] and [9].

The Exponential Distribution

Many simulation problems require the use of the exponential distribution. This is especially true of problems that involve a sequence of arrivals and departures. Suppose that x represents time. The probability of a random event occurring between times x and $(x + \Delta x)$ is $\alpha\Delta x$, where α is a known positive constant. The probability that the event will not occur within this time interval is $(1- \alpha\Delta x)$. The cumulative distribution function is determine as

$$F(x) = 1- e^{-\alpha x} \qquad \ldots\ldots (1)$$

Where the probability density function is:

$$f(x) = \alpha\, e^{-\alpha x} \qquad \ldots\ldots (2)$$

The mean, μ, for the exponential distribution is

$$\mu = (1/\alpha) \qquad \ldots\ldots\ldots (3)$$

By solving equation (1) for x, we get

$$x = -(1/\alpha)\ \ell n\,[1 - F(x)] \quad \ldots\ldots (4)$$

Since F(x) is uniformly distributed, therefore we can write

$$x = -(1/\alpha)\ \ell n\, U \qquad \ldots\ldots (5)$$

Where x is the desired exponentially distributed random variety, and U is a uniformly distributed (0, 1) random number. Now suppose that x is required to be greater than or equal to some specified positive value, x_0, that is, $(0 < x_0 \leq x)$. So, equation (5) must be modified to read

$$x = x_0 - (1/\alpha)\ \ell n\, U \qquad \ldots\ldots (6)$$

Also, the relationship between α and x_0 is

$$\alpha = 1/(\mu - x_0) \qquad \ldots. (7)$$

for more details see, [1], [3] and [9].

Mechanics of Discrete Simulation

All discrete simulation models represent queuing situations with two basic events: arrivals and departures. These events define the instants at which changes in the system's statistics can occur. This section details how typical statistics are collected in a simulation model.

Let us assume that the simulation is run for 20 airplanes, 10 of them will be landing and another 10 taking-off. The airplanes are served on a First-In First-Out (FIFO) basis. The first approach does not distinguish between the landing and taking-off airplanes. In the second approach the prior service is given to the landing airplanes rather than the taking-off airplanes. Suppose that the service time to landing airplanes is uniformly distributed between 3 and 25 minutes, and for a taking-off are 4 and 50 minutes. The inter-arrival time of landing airplanes and takeoff airplanes is exponentially distributed with the mean of 12 minutes and 20 minutes, respectively. Table (1) demonstrates all the possibilities of the simulation model logic. The queue length and the facility utilization are known as the time-based variable, because their variation is a function of time. No limitation on the number of airplane waiting for service should be considered.

Measures Performance

The objective is to develop a simulation model that can be used to analyze the single runway situation in term of the following statistics relationships, see [1].

- $$\text{Average Utilization} = \frac{\Sigma \text{ Service Time}}{\text{Length of Simulation}}$$
- $$\text{Average Service Time per Airplane} = \frac{\Sigma \text{ Service Time}}{\text{No. of Airplanes Served}}$$
- $$\text{Average Waiting Time per Airplane} = \frac{\Sigma \text{ Waiting Time}}{\text{No. of Airplane served}}$$
- $$\text{Average Content of Waiting Time} = \frac{\Sigma \text{ Total Waiting Time}}{\text{Length of Simulation}}$$
- $$\text{Percentage of Time Runway (Server) is idle} = \frac{\Sigma \text{ Total Idle Time}}{\text{Length of Simulation}}$$
- Average number of Airplanes in queue $$Lq = \frac{\Sigma m_i t_i}{T},$$

  m_i is a Number of Customer in queue of interval t_i , T is the total simulation time.

- Average number of Airplanes in System $$Ls = \frac{\Sigma n_i t_i}{T},$$

  n_i is a Number of Customer in system of interval t_i .

Results and Discussion

In order to illustrate the manner in which the calculations are carried out, let us implement equations 6 and 7. The landing airplanes exponentially arrive with a mean μ = 12 minutes, and landing (service) times with a mean of μ = 8 minutes, and a standard deviation of x_0 = 2 minutes. The taking-off airplanes exponentially arrive with a mean μ = 20, service time μ = 10, and deviation x_0 = 5. Table 1 shows a few random events of the landing and taking-off airplanes with the given parameters.

Table 2 shows a detailed history of the first few simulated events for the second approach, when landing airplanes have priority to the taking-off airplanes. The calculations were carried out using the next-event model previously described. Columns titled Landing-Airplanes include the Begin-Time, Finished-Time, Waiting-Time, and Idle-Time. Columns titled Taking-off include the Begin-Time, Finished-Time, Waiting-Time, and Idle-Time. Waiting-Time column indicates the amount of time for which a landing airplane should waits before the landing occurs. Finally, the columns labeled Idle-Time indicate the status of landing airplane whether they are busy or idle.

The statistical performance for the simulation study is given in table 3. We compare the results for both approaches mentioned previously for landing and taking-off services. We found out the average utilization of the airport, the average service time, the average waiting time per airplanes, the percentage that the server is idle, and the average number of airplanes in queue and system. The statistical result shows the landing waiting time and the number of landing airplanes will be remedied when the priority is given to the landing airplanes.

Figures 1 to 4 shows the number of airplanes in a landing queue and a taking-off queue for both approaches at each occurrence events through all the simulation session, respectively. Figure 1, shows the number of airplanes in both queues (landing and taking-off) are almost the same. But figures 3 and 4 shows a significant reduction in the number of airplanes in the landing queue relative to the taking-off queue.

Figures 5 and 6 show the number of airplanes in the landing queue and the taking-off queue for both approaches, respectively. Again the comparison is quite clear and agrees with previous results.

Table 1, Landing and Takeoff Data
Landing: (Arrival x_0 = 10, μ =30, Service Time x_0 = 8, μ = 15)
Takeoff: (Arrival x_0 = 10, μ =35, Service Time x_0 = 5, μ = 10)

No.	Landing Arrive Time	Landing Service Time	Taking-off Arrive Time	Taking-off Service Time
0	27.1	14.4	42.8	16.5
1	39.2	14.4	55.4	13.0
2	53.7	19.3	68.0	8.5
3	77.6	12.9	108.1	16.5
4	94.7	24.1	148.2	11.0
5	118.6	19.3	215.8	16.5
6	138.8	24.1	231.4	6.8
7	181.0	16.4	281.6	6.8
8	223.2	24.1	294.3	11.0
9	237.6	12.9	306.9	6.1

Table 2, detailed history of the first few simulated events for the second approach

	Landing Airplanes						Taking-off Airplanes					
No.	Arrive Time	Service Time	Begin Time	Finished Time	Waiting Time	Idle Time	Arrive Time	Service Time	Begin Time	Finished Time	Waiting Time	Idle Time
0	27.1	14.4	27.1	41.5	0.0	27.1	42.8	16.5	75.2	91.7	32.5	42.8
1	39.2	14.4	41.5	56.0	2.3	0.0	55.4	13.0	172.1	185.1	116.7	0.0
2	53.7	19.3	56.0	75.2	2.3	0.0	68.0	8.5	201.6	210.0	133.5	0.0
3	77.6	12.9	91.7	104.6	14.2	2.3	108.1	16.5	210.0	226.5	101.9	0.0
4	94.7	24.1	104.6	128.7	9.9	0.0	148.2	11.0	263.5	274.5	115.3	0.0
5	118.6	19.3	128.7	148.0	10.1	0.0	215.8	16.5	274.5	291.1	58.7	0.0
6	138.8	24.1	148.0	172.1	9.2	0.0	231.4	6.8	291.1	297.8	59.7	0.0
7	181.0	16.4	185.1	201.6	4.2	8.9	281.6	6.8	297.8	304.6	16.2	0.0
8	223.2	24.1	226.5	250.7	3.4	21.6	294.3	11.0	04.6	315.6	10.4	0.0
9	237.6	12.9	250.7	263.5	13.0	0.0	306.9	6.1	15.6	321.8	8.8	0.0

Table 3, The statistical measurements for both simulation approaches.

	Without Priority		With Priority	
	Landing	Takeoff	Landing	Takeoff
The Average Utilization:	56.5%	35.0%	56.5%	35.0%
The Average Service Time per Airplane:	18.2	11.3	18.2	11.3
Average Content of Waiting Time	30.2	29.4	6.9	65.4
The Average Waiting Time per Airplane	0.9	0.9	0.2	2.0
The Percentage the Server is Idle	8.4	13.3	18.6	13.3
Average No. of Airplanes In Queue	0.2	0.2	0.0	1.1
Average No. of Airplanes In System	0.5	0.8	0.3	1.6

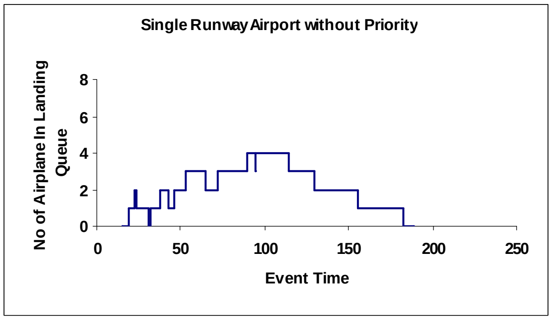

Figure 1, Number of Airplanes in Landing Queue for first approach.

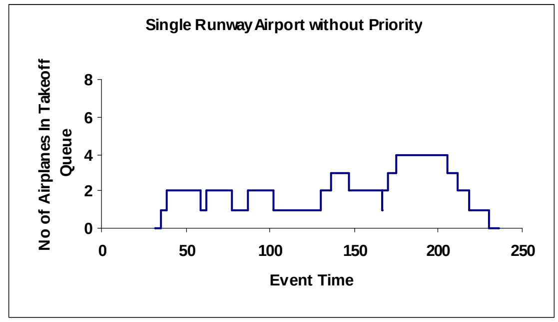

Figure 2, Number of Airplanes in Taking-off Queue for the first approach.

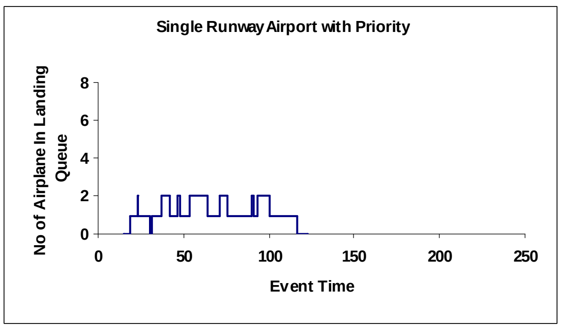

Figure 3, Number of Airplanes in Landing Queue for second approach.

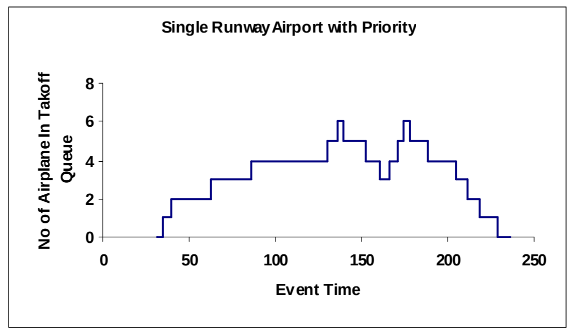

Figure 4, Number of Airplanes in Taking-off Queue for the second approach.

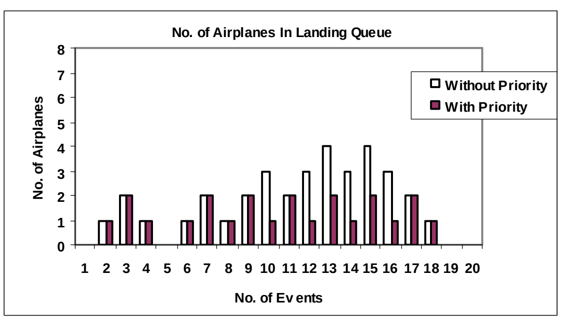

Figure 5, Number of Airplanes in Landing Queue for both approaches.

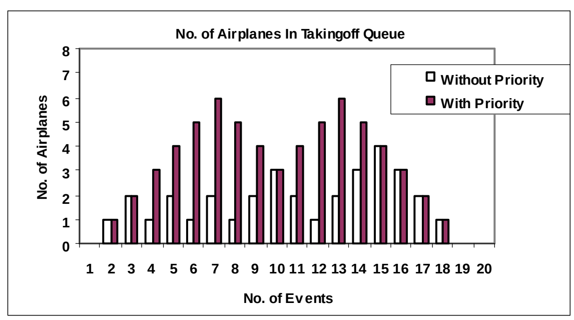

Figure 6, Number of Airplanes in Taking-off Queue for both approaches.

References:

[1]- Bank, J., Carson, J., Nelson, B., and Nicol D. Discrete-Event System Simulation, Prentice Hall, 2005.

[2]- Kruse, Robert P., Leung Bruce P., and Tondo, Clovis L. "Data Structures and Program Design in C", Prentice-Hall, 1991.

[3]- Law, A. M. & Kelton, W. D. " Simulation Modeling and Analysis", New York, McGraw-Hill, 2000.

[4]- Obaid T. "Computer Simulation of a Heat Transfer Using Mone Carlo Technique", J. of Science Faculty AlManufia University, 14 (2004) 123-139.

[5]- Pritsker, Alan, A. & O'Reilly, Jean, J. "Simulation with Visual SLAM and AweSim." John Wiley & Sons, 1999.

[6]- Repenning, N. P. A simulation-based approach to understanding the dynamics of innovation implementation.

Organization Science, 13:107 – 127. 2002.

[7]- Richard, H. J. , Glenn R. Carrol, and Kathleen M. Carley, "Simulation Modeling in Organizational and Management Research." Academy of Management Review, Vol. 32, No. 4, 1229-1245. 2007.

[8]- Stalling, W. "Queuind Analysis", williamStalling.com/studentsuport.html. 2000.

[9]- Taha, Hamdy A., Operations Research Prentice-Hall, 7th edition 2002.

محاكاة الحاسب لإقلاع و هبوط الطائرات لمطار ذو مدرج منفرد

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الخلاصة

أصبح الانتظار للحصول على خدمة معينة جزء من الحياة اليومية. ان دراسة نظم الانتظار (الطوابير) تساهم في قياس إنجازية نظم الخدمة. فالمعلومات التي نحصل عليها تساعد قد متخذي القرارات بتحسين الخدمة المقدمة. تركز الاهتمام في هذه الدراسة على محاكاة حركة الطيران (هبوط و إقلاع) من مطار ذو مدرج منفرد. وقد تناولنا في هذه الدراسة حالتين: الأولى منها تعط الخدمة على أساس نظام الخدمة المعروف " الذي يصل أولا تقدم له الخدمة أولا First-In-First-Out (FIFO)" إن كانت الطائرة ترغب بالهبوط أو الإقلاع. إما الحالة الثانية: تقديم الخدمة للطائرات التي ترغب بالهبوط أولا و لا تقدم الخدمة للطائرات التي ترغب في الإقلاع إلا عندما لا تكون هناك طائرة تنتظر للهبوط. و السبب في الحالة الثانية هو تجنب المخاطر الناتجة من انتظار الطائرات في الفضاء. الهدف هو تزويد متخذي القرارات بمعلومات مقارنة للحالتين و التي تساعد في اتخاذ القرار المناسب لتقديم أفضل خدمة. و ذلك بتقليص وقت الانتظار للطائرات التي ترغب بالهبوط و في نفس الوقت تقليص فترة انتظار الطائرات التي ترغب بالإقلاع لوقت معقول.