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SIMPLIFIED MODEL FOR ESTIMATION OF AIRPORT CHECK-IN FACILITIES

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Abstract: The model explained here explores influence of the type of queue and operator service time on the check-in process at airports. The proposed model is based on queuing theory concepts and attempts to compute the optimum number of check-in counters. A time block concept related to counting periods is adopted. A graphical output indicates delays and passenger waiting times over the period of analysis. The congestion levels can be analyzed under given number of service counters in operation. This analysis method is then able to compute the optimum number and the configuration of check-in counters. The optimization is based on cost minimization. Comparison with real operations in five international airports is included.

Key Words: Airport, Congestion, Check-in area, Queuing.

1. INTRODUCTION

Two interrelated issues inspired this paper: the expected quality of service at airport check-in areas and the congestion caused by flight scheduling.

The importance of quality of service for customers has been recognized by many researchers including Janic (2000) and Martel and Seneviratne (1990). The customers in this context are passengers and airlines; however, this study is focussed on passenger activity only. The scope of this research work is to provide a convenient methodology to make approximate estimations for passenger processing areas. Passengers are typically the main source of revenue for airports (Martel and Seneviratne, 1990). Therefore, the design of service facility needs to consider passenger requirements.

However, passengers are subjected to increasing levels of congestion in airport environments. This congestion is caused by three interrelated problems. The first is fluctuations of demand. Variations of demand occur at various time frames ranging from days to months. Sometimes special events create demand spikes. The second cause of congestion is related to network issues. However, this aspect is considered beyond the scope of this paper. The third cause of congestion in check-in areas is related to flight scheduling. Here, the congestion is caused by arrangement of scheduled departure times of aircraft. Figure 1 is an attempt to schematically display the congestion caused by overlapping passenger arrival periods of three aircraft. It can be seen that overlapping passenger arrival distributions concept presented in Figure 1 assists in estimation of the period of congestion. The work presented here attempts to extend this method using simple numerical methods.

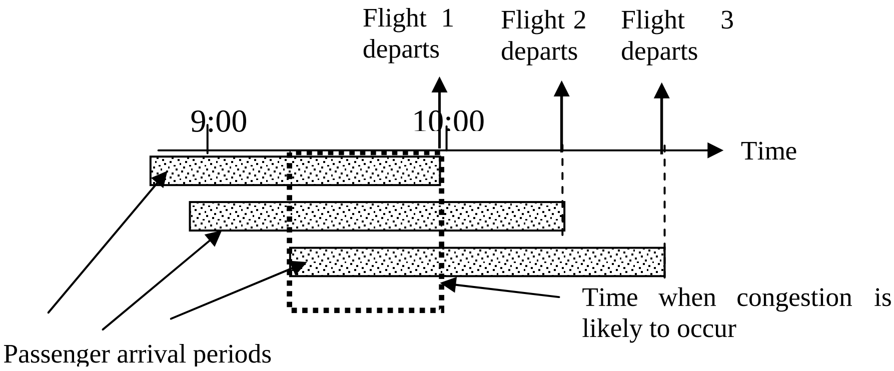


Figure 1. The Congestion Caused by Flight Schedule Arrangements

Congestion is also related to facilities design. Facilities in airport check-in area include check-in counters (desks) and space for queues of passengers including any associated furniture.

A number of researchers have attempted to formulate the space required at airport check-in areas. Work presented by Ashford (1988), IATA (1989), Horonjeff (1994), Seneviratne and Martel (1995) and Subprasom et al. (2002) are particularly relevant in this context. Martel and Seneviratne (1990) have investigated the relative importance of performance measures using a field survey. International Air Transport Association (IATA, 1989) provides formulae for estimation of the number of check-in counters and recommended space for passengers in queues. These formulae are based on peak hour passenger flows. However, passenger arrival distributions, queue arrangement and check-in counter sizes are also important elements in designing check-in area facilities.

This paper presents a time block concept making use of counting periods adopted in data collections related to passenger flows. The selected counting period is divided into time blocks of equal size based on the average service time. In the example provided here a ten-minute counting period has been adopted. This is convenient because the earliness distribution of passenger arrivals documented in IATA (2000) is based on ten-minute intervals. The selected counting period is then subdivided into segments according to the length of average service time to compute the queuing process. The method adopted here is based on a simplified assumption that ignores variability of service time.

A graphical output allows analysts to focus on periods of delays and conditions of excessive passenger waiting times over the duration of operation. A cost minimization has been applied to compute the optimum number and the configuration of check-in counters. The model accounts for capital cost of airport space, cost of equipment including furniture, computers and peripherals, labor cost and penalty associated with passenger waiting time.

2. THE CONCEPTUAL MODEL

The time block concept is developed as a method of simplifying the analysis process. A counting period is selected and it is divided into time blocks of equal size based on the average service time. In essence, the period of operation is divided into counting periods and these counting periods are divided into time blocks. The purpose of this process is to group passengers into blocks so the analysis does not have to focus on individual passengers. In the example covered here the counting period is selected as 10 minutes. This is consistent with the counting periods adopted in IATA earliness distribution, as mentioned earlier. This earliness of passenger arrival pattern is shown in Figure 2 where different distributions have been specified according to the time of day.

The IATA arrival earliness distribution as presented in Figure 2 has already attempted to incorporate factors such flight type (short or long haul, business or leisure) that might influence the fluctuation of inflow passengers. However, other factors such as distance from the airport and access mode were not considered in the current form of the proposed model. The IATA earliness distribution in its original form is applicable for domestic travelers. For the application of international travelers the distribution has been stretched by 60 minutes in keeping with observations made by Ashford (1976).

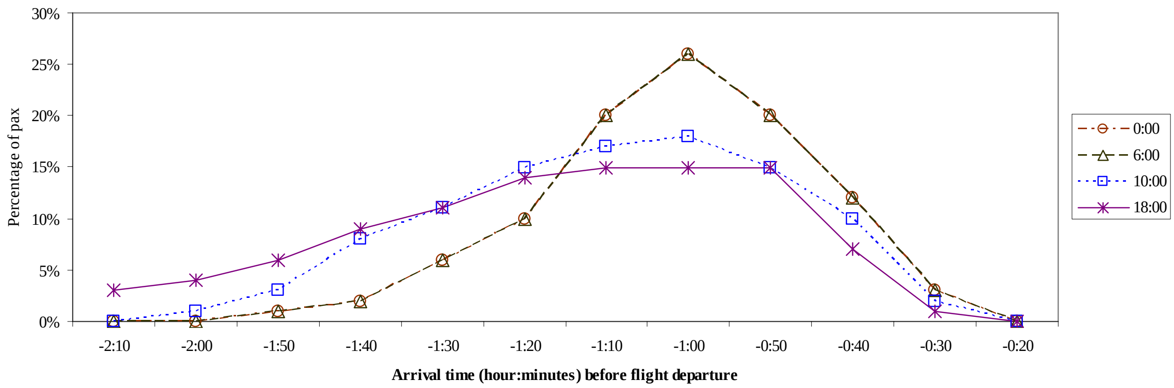


Figure 2. IATA Arrival Earliness Distribution

Now, if the average service time is 5 minutes, then each counting period consists of two time blocks. It is important to note that the maximum number of passengers that can be served during one time block is equal to the total number of servers. This observation facilitates a simple method to enumerate exit counts at the check-in area, at intervals of time blocks, as shown in Table 1.

Table 1. Assignment of Passengers to Time Blocks

Time	Arrivals in counting period	Time blocks (service sequence) 0	5	10	15	20
4:30	51	51	0	0	0	0
4:40	76	62	14	0	0	0
4:50	104	62	42	0	0	0
5:00	147	62	62	23	0	0
5:10	191	39	62	62	28	0
5:20	204	0	14	62	62	46

The illustration in Table 1 is developed from the scenario where the average service time is 5 minutes and the number of servers is 62. If the number of arrivals is less or equal to the number of servers, all passengers will be served during the first time block provided there were no residual queues in the immediately preceding time block. This group of passengers is called to service counters straightaway and is counted as exiting the check-in space at the end of that time block. On the other hand, if the arrival count in the counting period is more than the number of servers, the remainder is allocated to a second time block of the service sequence. Passengers in this group must wait for 5 minutes (a time block) before they are called to the service counters.

At time 5:10 there are 191 arrivals. But 23 are left over from the previous time period shown in the third service sequence column. Thus, only 39 (that is 62 minus 23) are selected from the current arrivals for first time block. This time, the third column for service sequence is saturated (i.e. 62 passengers), which forces a zero in the first time block of the first time block starting at 5:20.

The time block method is designed to apply in the context of multiple servers (airline agents) serving a single line of passengers. The variables involved in computation of number of servers can be identified in the following form.

$$N_s = f\ [t_s, a, Type, C] \tag{1}$$

Where N_s = number of servers
t_s = service time
a = array representing arrival counts
Type = check-in counter configuration
C = cost of check-in area facility

The proposed model has been prepared as four interrelated modules in an Excel spreadsheet to compute the required number of servers in keeping with relationship suggested by Equation 1. The basic structure of this spreadsheet arrangement is shown in Figure 3.

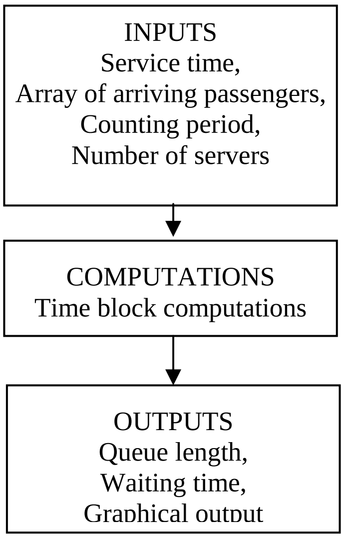


Figure 3. Structure of the Spreadsheet Computation Method

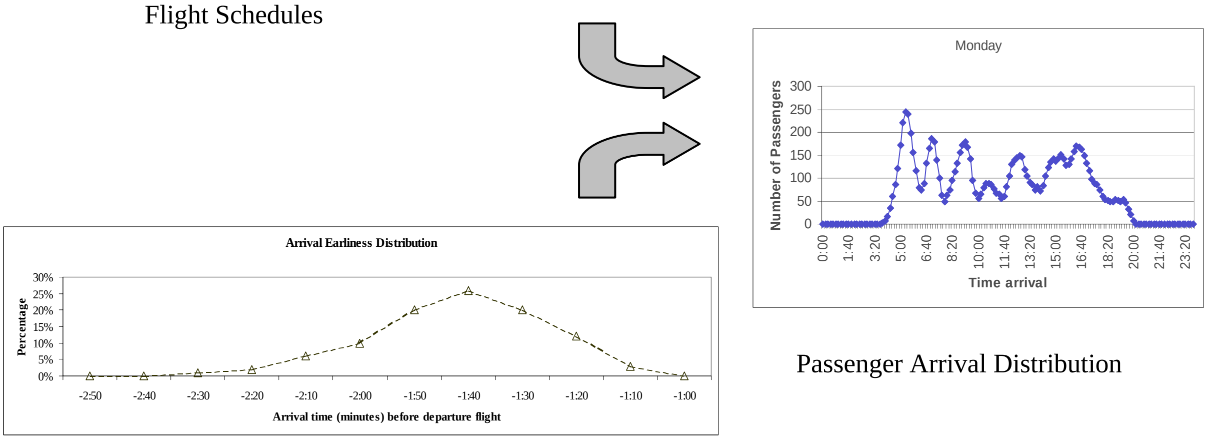
The passenger arrival distribution for the airport is synthesized from systematic addition of passenger earliness pattern for each flight. The flight departure time and aircraft size of each flight have been taken into account. This process is explained in Figure 4. First, IATA earliness distribution is scaled according passenger capacity of the flight. Then these distributions are overlapped in a staggered arrangement according to flight departure times. Addition of these distributions results in the synthesized passenger arrival distribution.

3. THE MODEL

The proposed model provides an alternative method for planning and operational analysis of airports. This method may be useful for applications where accurate data or forecasts are difficult to obtain, such as in new airports of significantly different magnitude for a particular region. The model may be also useful for planning relocation of airports. A unique feature of the model is the graphical output of delay profile. This output may be useful for operational planning purposes alerting operators to congestion periods.

DESTINATION	NUMBER OF PASSENGERS	DEPARTURE TIME
Aberdeen	56	15:10
Amsterdam	76	6:10
Barcelona	99	10:35

Flight Schedules



Earliness Distribution

Figure 4. Computation of Passenger Arrival Distribution

The proposed program is developed in four modules. These are *Central*, *Queuing*, *Waiting Time*, and *Optimization*. *Central* is a preliminary input-output module. The inputs are consistent with elements in Equation 1. All output from other modules are deposited in *Central*. *Queuing* and *Waiting Time* are sections that present the queue length and waiting time distributions respectively. *Optimization* is the module where all variables that may influence the optimization process including cost element, are gathered.

Figure 5 outlines relationships among the four modules. Preparation of inputs includes preparation of passenger arrival distribution. As mentioned earlier and depicted in Figure 4, the passenger arrival process is synthesized from the use of earliness distribution, flight departure time and aircraft size.

The passenger arrivals specified in *Central* are used in the *Queuing* module to produce the arrival distribution and apply the block partitions as shown in Table 1. The result, in the form of the maximum and average number of passengers in queue, can be viewed from *Central*. The waiting time of passengers in *Queuing* is estimated in the *Waiting Time* module. The information in *Central* together with additional information required to perform optimization is stored in the O*ptimization* module. The program does iterations for different number of service counters to obtain the optimal result.

The program can be executed with or without optimization. The optimization option makes use of the 'solver' routines of the adopted spreadsheet platform. The optimization process is based on cost minimization, where the costs include refurbishment costs and space cost based on annualized value of construction cost. Default cost values are adopted mainly from annual report of Brussels International Airport Company (1999). The optimization process accounts for the relationship between the required queue space and number of counters.

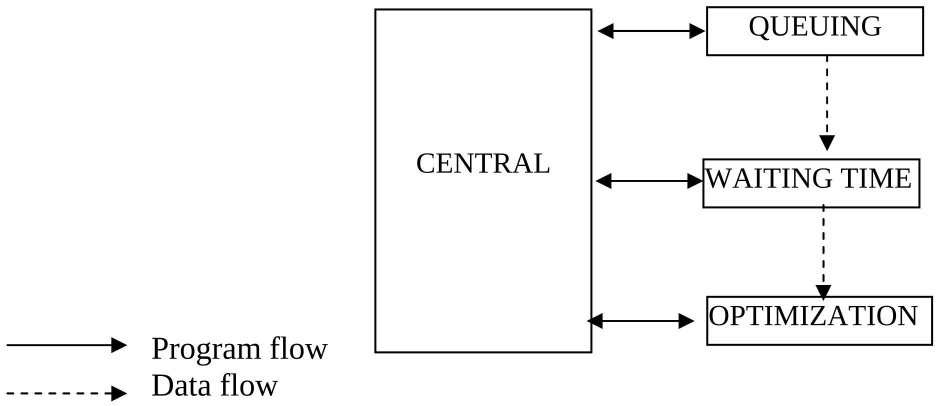


Figure 5. Relationships Among The Four Modules

The results include the number of servers required, average waiting time, queue length and minimum cost. The output also provides a graph of cumulative arrivals and exits (as shown in Figure 6). As mentioned earlier, the fluctuations of inflow depend mainly on the flight schedule of the particular airport. The maximum rate of exiting passengers is a constant determined by the maximum server capacity during busy periods when the rate of passenger arrivals exceeds the maximum processing rate.

Congestion occurs when the number of exiting passengers is less than the number of arrivals. Figure 6 shows that at certain periods the passenger arrival rate increases and the server capacity is insufficient to treat passengers without delay. As a result, a queue forms and waiting time increases. Queuing theory provides a simple method to compute the queue length and waiting time using the black shadow area of this graph.

Figure 6 is a result of computations for the arrival pattern for Birmingham airport. It is assumed that the check-in area is served by 55 agents at an average service time of 5 minutes. The graph shows that there is congestion from 5.00 to 12.00 and 15.00 to 18.00. This graph is useful in assisting planners during preliminary design to find out the number of servers required to avoid congestion. This can be achieved by changing the number of servers in the *Central* module and exploring different scenarios. The graph can also assist the operators of existing airports to evaluate the service performance.

4. APPLICATIONS

The program has been applied to passenger inflows synthesized for five international airports. Aircraft departure schedules for Birmingham (UK), Brisbane (AUS), Hong Kong (China), Melbourne (AUS), and Orlando (USA) have been used for this purpose. These airports were selected in this study because of the ready availability of complete flight schedules and other relevant information.

The data provided from the selected airports are presented in Table 2. The average service time for Brisbane and Melbourne w assumed to be 5 minutes as data was not available.

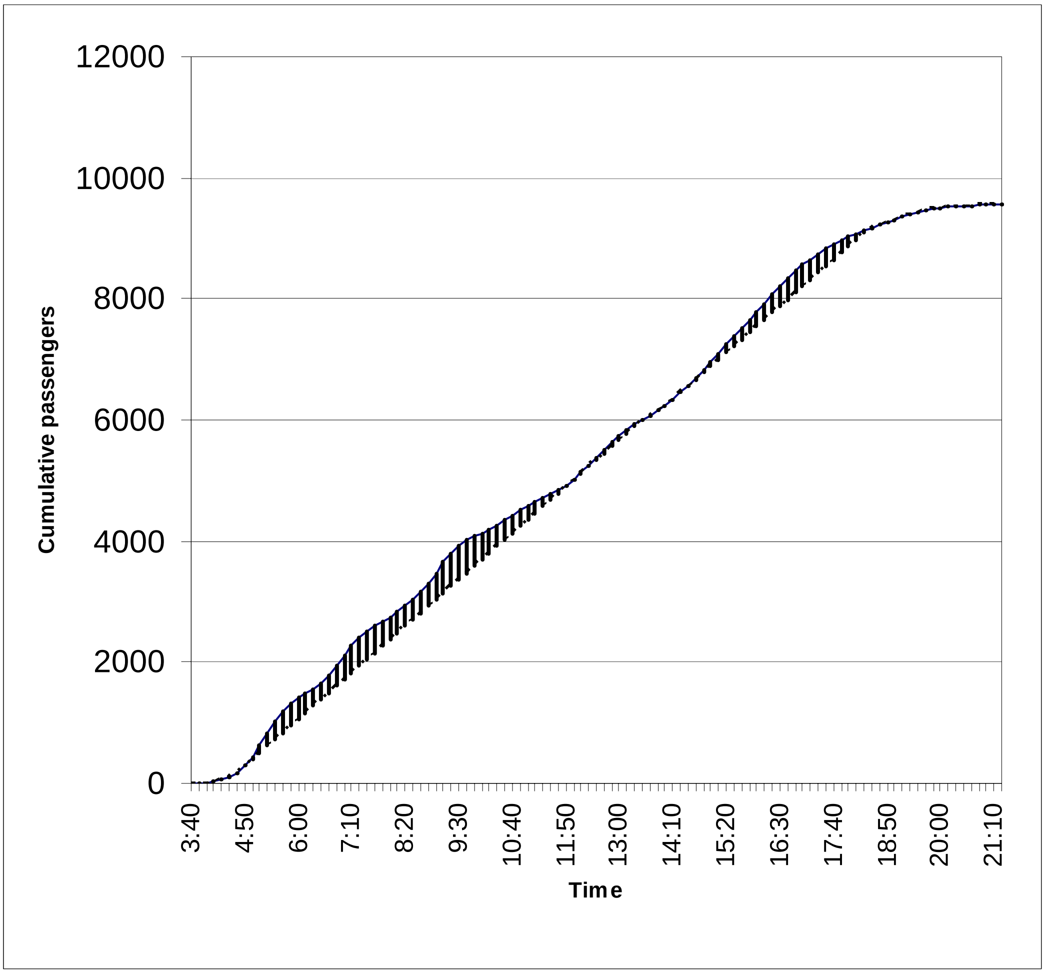


Figure 6. Graphical Representation of the Queue Formation

The ability to account for local demand conditions is available in this model through manipulation of passenger arrival distribution. Data to reflect local cost parameters can be readily incorporated into the model because of its spreadsheet platform.

4.1. Waiting Time and Queue Length

Table 3 presents the waiting time value in minutes. As mentioned earlier, in the time block program, passengers are grouped based on counting periods and time blocks. This method generalizes the waiting time for passengers in one group. There is no delay for everyone in group in a time block if they are in the first time block. Thus the computed average waiting time may be underestimated. However, this is an anticipated outcome of decision to ignore variability of service times and adopt a simplified analysis method where the service time is treated as a constant.

A particular difficulty with the time block arrangement is when the service time is not a factor of the counting period. For example, in the Hong Kong scenario, the counting period is 10 minutes but the average service time is 3 minute. This requires additional work in the passenger assignments to counting periods. It is easier to explain the problem by first describing the condition when the counting period is an exact multiple of the time block. Figure 7 shows main elements required in computation of waiting times and queue lengths when the counting period consists of exactly two time blocks. This is similar to the conditions explained in Table 1. Figure 7 shows a time period when there were 204 passenger arrivals. Here the time block is 5 minutes long. The 204 passengers are grouped into time blocks as shown in the diagram. The waiting time for each time block is shown by the number above the blocks. Now, the average waiting time can be obtained by a weighted multiplication.

Table 2. Inputs Values for Airport Scenarios

Airport	Average service time (min)	Service time applied (min)	Operation duration (hr)	Passenger inflow per day
Birmingham	2.1	2	20	9550
Brisbane	5.0 (*)	5	20	4252
Hong Kong	3.18	3	24	57727
Melbourne	5.0 (*)	5	20	6386
Orlando	4.3	5	20	3116

(*) The actual average service time was not available and an assumed value is used.

Table 3. Estimated Passenger Waiting Times

Airport	Waiting time (minutes)		Waiting number
	Maximum	Average	(average)
Birmingham	16	3	100
Brisbane	25	3	200
Hong Kong	18	7	950
Melbourne	25	6	80
Orlando	25	1	200

On the other hand, for the Hong Kong conditions the selected time block is 3 minutes and counting period is10 minutes. A time period consists of three full time blocks and 1/3 of the next time block as shown in Figure 8. This condition adds a complication contradicting the simplicity objective of the selection of the time block arrangement. Nevertheless, the proposed time block arrangement provides a method of estimating waiting times and the number of passengers in the waiting space. The graphical output shown earlier is a useful tool to identify time periods with high level of congestion.

4.2. Comparison between the actual operation and model recommendations

The number of servers is the key variable selected to formulate the comparison. The number of servers in the airport check-in area influences the required space for counters and passengers in queue. The more servers are available the more space is required for check-in counters, and the less space for queuing area. The computations are designed to find the optimum space leading to the minimum overall cost.

Table 2 presents data applied in the computations. The average service time is known for three airports. For the other airports, the average service time is assumed. The spreadsheet software considers service time in whole minutes. Thus the service times applied are 2, 5, 3, 5, and 5 minutes for Birmingham, Brisbane, Hong Kong, Melbourne, and Orlando airports respectively.

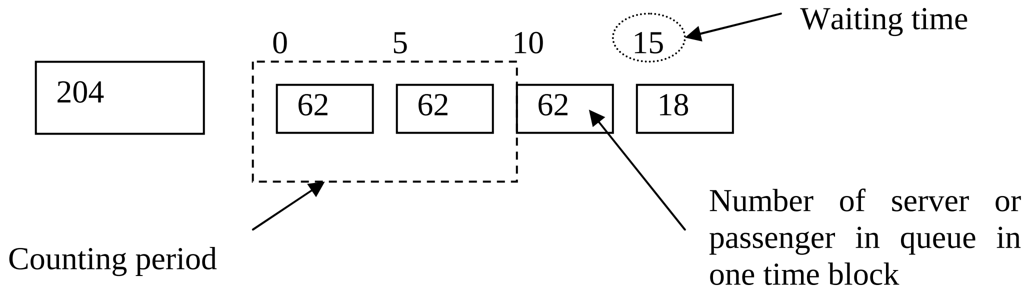


Figure 7. Process of Waiting Time Estimation

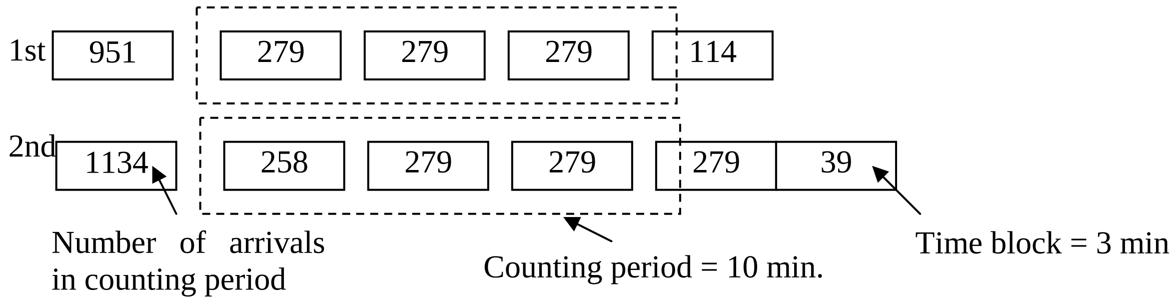


Figure 8. Time Blocks in the Hong Kong Case Study

The computation process also requires data for counter size and cost elements in order to calculate the optimum total space required. The length and width of the average passenger with a cart are considered to be 1.72 m and 0.64 m respectively. The length and width of counters are considered to be 5.40 m and 2.20 m respectively. The cost of a counter is incorporated to the model and the value used here is A$ 4.10 per day per counter. In addition, there is a labour cost, and each agent is considered to cost A$ 50 per hour. The value of space is considered to be A$ 12 per day per sqm. The penalty value for waiting more than 20 minutes has been selected as A$10 per min.

There is a large discrepancy among cost values available from various sources such as airports (Brussels International Airport Company, 1999), industry organizations (Airport Council International, 2000) and vendors such as furniture manufactures. Values used here have been arbitrarily selected from a large available range.

The operational time is based on the time span of flight schedules at the selected airports. In this analysis, only Hong Kong International airport has a 24-hour service. During computations, the operational time effects the estimated cost of workers per day.

The passenger flow values were computed from yearly values. Thus, totals of international passengers per day were 9,550; 4,252; 57,727; 6,386; 3166 for Birmingham, Brisbane, Hong Kong, Melbourne, and Orlando airports respectively.

Figure 9 presents the optimum number of servers obtained from the cost minimization. Corresponding values for the real operation of Brisbane and Orlando were not available. However, recommendations of the model can be compared with actual operations for the other three airports, shown in the figure. Figure 9 indicates that the optimum number of servers obtained from the proposed method is generally less than the number of servers in the real situation. This is to be expected as the proposed method has ignored variability of service time. It can be observed that the proposed simplified process provides a lower bound solution. Therefore, the model is able to provide useful information for planners and analysts performing preliminary computations and attempting to verify results from complex methods.

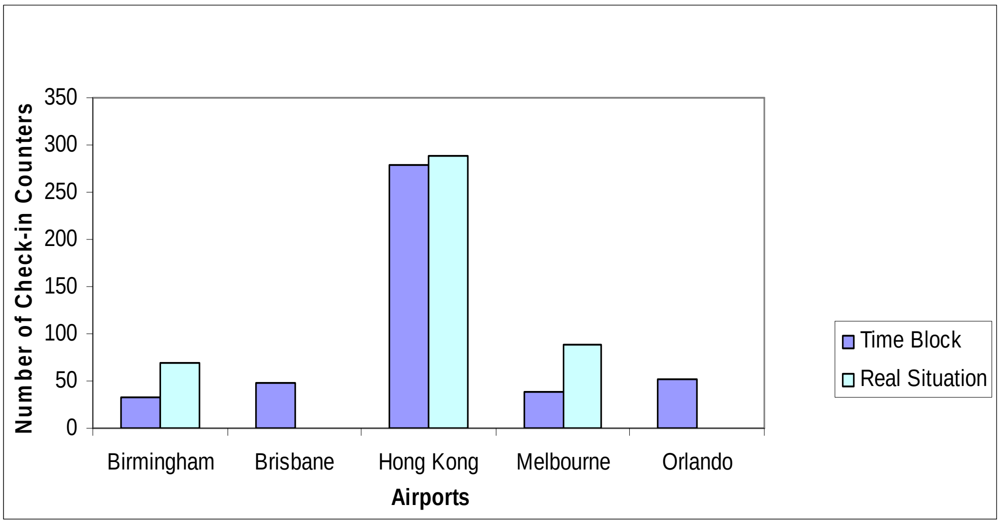


Figure 9. Comparison of Program Results and Real Situation

There are four other issues analysts should consider in refining the model recommendations. The first aspect is the use of space demarcations among airlines. The proposed model has assumed shared resources among all airlines. However, the general practice is to adopt space and facility segregation among competing airlines and this practice increases the overall resource requirements from the airport point of view. Nevertheless, it is interesting to note that Birmingham airport encourages mix use of counters using a proprietary software system. The second aspect is related to the separation or mixing domestic and international flights in one airport. Birmingham airport claims it mixes counters for domestic and international flights. In other airports, it was likely that the domestic counters were separate from international counters. The proposed model can handle this aspect provided a clear distinction is made during data collection. The third issue is the need for different counters for business and first class passengers. Again the model can handle this if detailed breakdown of passenger categories are available. However, in routine preliminary applications, it is unlikely to expect that level of detail. The fourth issue is the need to over-design the airport to allow for further growth of business.

Table 4. Impact of Daily Demand Variations

Day	Number of Passengers	Maximum Waiting time (minutes)	Maximum queue length
Monday	10254	8	150
Tuesday	10180	9	175
Wednesday	10567	12	214
Thursday	11450	18	325
Friday	11003	2	45
Saturday	5263	1	9
Sunday	8139	2	35

4.3. Investigation of effect of demand fluctuations

The number of arriving passengers applied in the simulation program is the average of seven days of the week. Design of the number of check-in desks could be based on the busiest day, which may lead to an over design. Table 4 presents the variation of number of passengers at Birmingham International Airport during seven days of the week and the results for corresponding maximum waiting time and maximum queue length under optimum number of servers for the average day. In this analysis the optimum number of servers for the average day has been estimated to be 39. This is based on a passenger count of 9550 for the average day of the week.

It is encouraging to note that the maximum waiting time is below the acceptable limit of 25 minutes (Martel and Seneviratne, 1990). However, the model allows exploration of conditions that may lead to over-saturation. Results from such an experiment are presented in Figure 10. Here the passenger demand has been incremented by intervals of 25% and waiting times have been computed. Figure 4 shows that the acceptable waiting time limit is breached at about 55% above the adopted daily average of passenger demand. The emphasis of above simulation experiment has been to demonstrate the potential use of the model as an analysis tool.

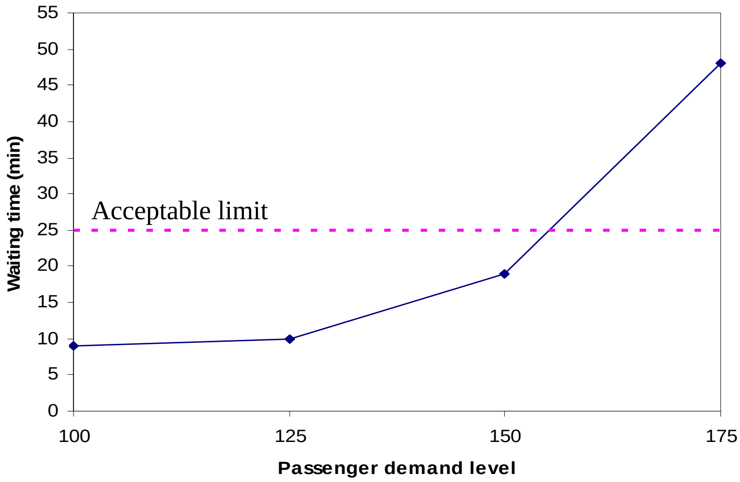


Figure 10. Effect of Passenger Demand Level on Waiting Time

5. CONCLUSIONS

Time block is the basic building block of the proposed method. A time block is equal in length to the average service time. Thus, the passenger service capacity during a time block is equal to the number of servers. Number of time blocks form a counting period adopted in data collection related to passenger arrival distribution.

The spreadsheet program developed in this project is designed to obtain the optimum number of servers as the key output. The optimization is based on minimization of system cost. The system cost includes cost of space, furniture and penalty for waiting more than a specified time limit. Inclusion of cost of space makes this methodology a useful tool in estimation of the optimum size of the check-in area. As the method was intended to be simple it was expected to compromise the estimation accuracy. The analysis presented here was focussed at understanding the bias imposed by the simplistic assumptions incorporated in the model. It has been shown that the proposed model results are acceptable for preliminary analysis work and anyhow appear to provide the lower bound solution for resource requirements. The spreadsheet based method also provides graphical and numerical tabulations useful for analysis of airport congestion.

Two significant problems arose during the model development. One is lack of consistent data related to cost of various components. This problem is handled by allowing cost parameters to be controlled via the user interface. Therefore, when reliable data are available they can be easily incorporated into the model. The second problem was the difficulty to obtain passenger arrival distributions. Therefore, the model adopts a work around when arrival distribution is not available. This process is based on using the aircraft schedule to synthesize passenger arrivals. This method incorporates the profile of earliness of arrivals into the analysis process.

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