Airport Check-In Optimization by IP and Simulation in Combination

Ahmad Thanyan Al-Sultan

Abstract—The check-in area of airport terminal is one of the busiest sections at airports at certain periods. The passengers are subjected to queues and delays during the check-in process. These delays and queues are due to constraints in the capacity of service facilities. In this project, the airport terminal is decomposed into several check-in areas. The airport check-in scheduling problem requires both a deterministic (integer programming) and stochastic (simulation) approach. Integer programming formulations are provided to minimize the total number of counters in each check-in area under the realistic constraint that counters for one and the same flight should be adjacent and the desired number of counters remaining in each area should be fixed during check-in operations. By using simulation, the airport system can be modeled to study the effects of various parameters such as number of passengers on a flight and check-in counter opening and closing time.

Keywords—Airport terminal, Integer programming, Scheduling, Simulation.

I. INTRODUCTION

THE common characteristics of busy international airports usually involve serving a large number of different airlines, a large number of flights over day, and accommodating various types of aircrafts. The increase of air traffic has also affected the passenger facilities of airport terminals due to the major rise of passenger flow. Two important objectives in this respect are customer satisfaction and cost effectiveness. Both objectives are important for check-in processes, with queues on the one hand and limited capacities on the other. Over the last couple of years there has been a strong development of self-service check-in facilities. Nevertheless, traditional check-in counter will certainly remain present for a number of reasons such as security, logistical baggage aspects and, last but not least, traveler preference for personal treatment and ease of use. The quality of service is the degree of passenger satisfaction when receiving some services from the system. In this project, a software were designed to estimate the optimum arrangement of check-in zones (areas) and to evaluate and improve operational and personnel planning.

Opening and closing hours for each individual flight, at weekly level for flight allocation and reservations, at monthly level for contract negotiations with airlines and finally at yearly level for the total counter capacity required.

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Clearly, for any of these levels an optimization of capacity resources is thus required at the most detailed level of its daily utilization, as depending on the primary queuing processes and flight demands.

Much work has been centered on the airport check-in optimization problem. P. E. Joustra et al. [6] introduced practical simulation approach to evaluate check-in at airports. In [7] only the pure deterministic scheduling problem is studied. In [2], the total staffing requirements are determined during the day at four security points based on the total passenger flows. A related approach as applied to check-in counter scheduling is presented in [3]. Here simulation is combined with constraint based reasoning which leads to a repetitive algorithm for optimization under constraint patterns. The approach seems of interest but does not seem to guarantee a formal optimization. Nico M. et al. [5] has also centered on a combined stochastic and deterministic approach with corresponding tools. The research purely considered the check-in planning problem at the level for which the flight demands are known. T. Huisman et al. [8] proposes a solvable queueing network model to compute performance measures of interest without requiring timetable. A historical queueing reference for the check in service process, in contrast, is the paper by [1]. And [4] introduced practical problems for simulation and queueing theory.

In the current project, we will purely consider the check-in planning problem at the level for which the flight demands are known. That is, with the flights and check-in times for these flights known at a daily level. The number of actual travelers and the traveler arrival times and the check-in times will be estimated. We will study the situation when the airport terminal is decomposed into several check-in zones (areas) and the airport check-in scheduling problem requires both a deterministic (integer programming) and stochastic (simulation) approach. In the operations research approach, the optimization essentially involves two steps:

Step 1. Deals with scheduling and thus deterministic nature which is an optimization (minimization) of the total number of counters and staffing hours in each check-in zones (areas).

Step 2. Deals with queuing and thus stochastic aspects which is a computation and optimization of the number of counters for an individual flight (or group of flights that share a common check-in), in order to meet a specified service level (in term of waiting times). The stochastic approach for step 2 would at best lead to a feasible planning and would not meet the objective of minimizing the overall counter capacities (staffing

hours and number of counters). The deterministic approach would ignore the essential stochastic aspects that are intrinsically involved and related to the other objective: customer satisfaction (waiting time perceptions and service norms).

II. DATA COLLECTION AND PROBLEM DESCRIPTION

We will apply our model for Kuwait international airport (KIA). KIA has one terminal that has four passenger check-in zones (areas). Each zone has different check-in counter capacity. Zones 1&4 have 32 counters while Zones 2&3 have 18 counters. We have collected all flights departure schedule for one week period such as airlines flight number, type of aircraft, departure time and day. The check-in process is usually about two hours period. The check-in process starts three hours before flights departure and closes before one hour before departure. Our interest is to estimate the number of departure passengers per flight and check-in counters needed for all airlines.

To estimate the number of departure passengers per flight, we have collected a historical data and forecast the number of departure passengers and flights frequency for all airlines. For each airline, we divide the number of departure passengers by flights frequency to get the estimated number of departure passengers per flight.

For the number of check-in counters needed, usually it depends on the number of departure passengers and the average processing time per passenger. In this project, we will let the value β be the assumed number of passengers that can be served for one counter during check-in period. To estimate the number of check-in counters needed, we divide the estimated number of departure passengers per flight by β. For example, if the estimated number of departure passengers per flight for an airline is 200 passengers and let $\beta = 40$. Then the number of check-in counters needed for this airline is 5 counters.

From the collected data, we have 881 departure flights and with 40 airlines. We have calculated the number of counters needed for whole week for each check-in zones for the current airline to zone allocation. Fig. 1 describes the current situation for number of counters needed if we let $\beta = 40$. We can notice from the graphs that the number of counters needed is over the capacity especially at night flights in Zone 2&3.

III. INTEGER PROGRAMMING FORMULATIONS

The objective of the first stage is to define the optimum airline to zone assignment while minimizing the number of check-in counters for each zone. In addition, minimization of the counter capacities and staffing hours for all flights given that the counter requirements for each flight is known.
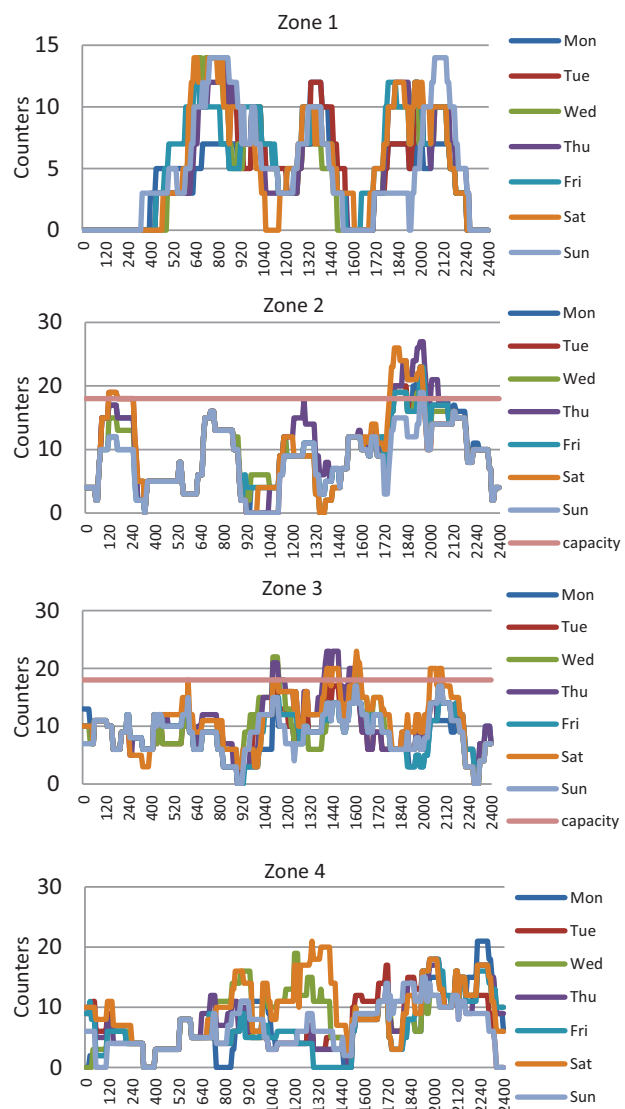

Fig. 1 The current situation for number of counters needed if we let $\beta = 40$

In each zone, there is a limited number of check-in counters. So the total number of counters assigned for each zone does not exceed the capacity of a zone for all times. We will let the value α be the desired number of counters remaining in each zone. The total number of assigned counters should not exceed the difference between α and the maximum capacity of each zone. The benefit of using the value α is to let a remaining number of counters in each zone in case of operating extra flights or an immediate need of extra counters due to the increasing of passengers in peak hours times.

The problem of minimizing the total number of counters, given the counters requirements and the adjacency constraint, can be formulated as:

Minimize

$$Z = \sum_{j=1}^{m} \sum_{i=1}^{n} x_{i,j}$$

s.t. (Each airline should be assigned to one zone).

$$\sum_{j=1}^{m} x_{i,j} = 1$$

(The total number of assigned counters should not exceed the difference between α and the maximum capacity of each zone).

$$\sum_{i=1}^{n} (c_{i,j} * x_{i,j}) / \beta \le cc_j - \alpha$$

Note that the value of $(c_{t,i} * x_{i,j}) / \beta$ when $x_{i,j} = 1$ is equal to the number of counters needed in time t for airline i where

$$x_{i,j} = \begin{cases} 1 & \text{If airline } i \text{ assigned to zone j} \\ 0 & \text{Otherwise} \end{cases}$$

n: Total number of airlines; m: Total number of zones; t: Time period; α: Desired number of counters remaining in each zone; β: The number of passengers that can be served for one counter during check-in period; $c_{t,i}$: Expected number of passengers in time t for airline i ; cc_j: Counter capacity for zone j.

The IP model was implemented using the GAMS modelling language. When we solved the IP model, we let $\beta = 40$ and the maximum value of α that we can put to get a feasible solution is 7 counters. Fig. 2 represents the output for the number of counters needed after solving the IP model.

IV. SIMULATION APPROACH

Simulation is used to evaluate and improve operational and personnel planning in order meet a service level for each separate flight. We used C sharp programming language to apply the simulation model. We have collected the necessary data to look for the appropriate data distribution for passengers' inter-arrival times for each airline. Expertfit and Input Analyzer were used to come up with the appropriate data distributions. Inter-arrival times mostly fit to Gamma (2.907407, 14.700486), and the distribution of one counter service time is assumed to be Uniform (1, 3). In the simulation model, we will compare between the actual and IP results for airlines to zone allocation. Passengers are treated as individual entities and we have put in our consideration the opening and closing time for each counter for each flight, the expected number of passengers for each airline and the number of counters needed for each airline. Fig. 3 shows the passengers arrival pattern before flight departure time after fitting the Gamma distribution.
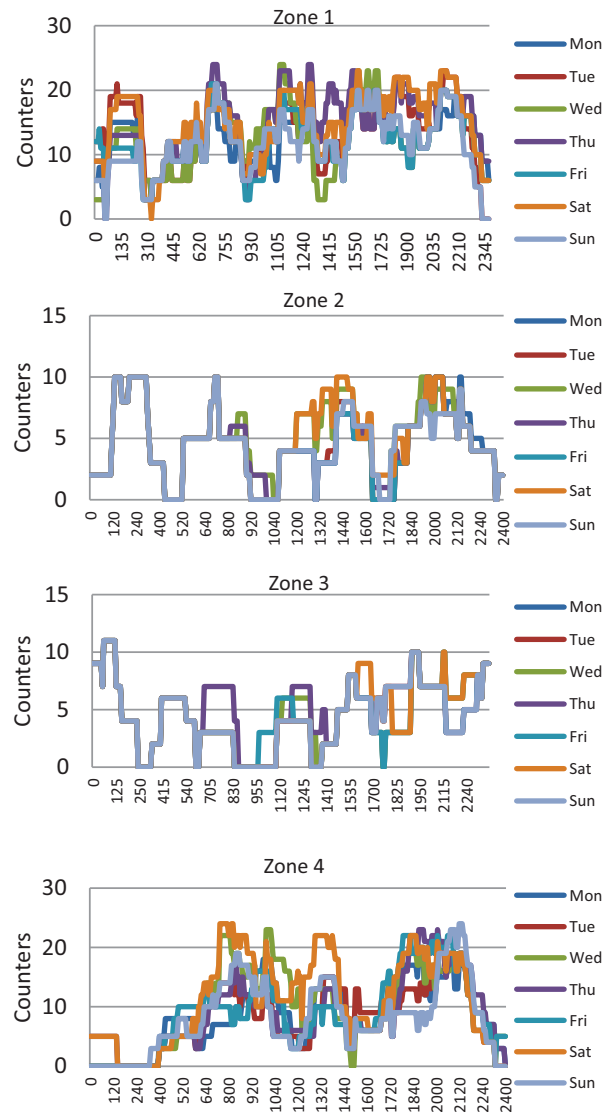

Fig. 2 Output for the number of counters needed after solving the IP model
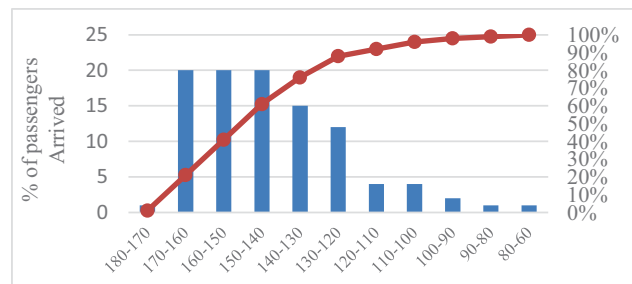

Fig. 3 Passengers arrival pattern

The number of check-in counters during the opening period does not need to be constant. For example, it is thus allowed to adjust these numbers beforehand, say by the hour, as based upon the arrival pattern or even dynamically as based upon the

actual number of passengers waiting. This feature can be exploited for check- in allocation in order to reduce the number of counters and staffing hours. For a minimization of the counter capacities and staffing hours for all flights, we will compare three scenarios. In scenario 1, the number of counters is constant during the working hours. While scenario 2 we reduce one counter in the second hour after opening the counter. In Scenario 3, we add one extra counter in the 1st hour and reduce two counters in the 2nd hour after opening the counter. Fig. 4 describes an example for a flight which needs 4 counters during the two hours check-in period. For scenario1, the total staffing working hours is 8 hours. While in both scenarios 2&3 is 7 hours.
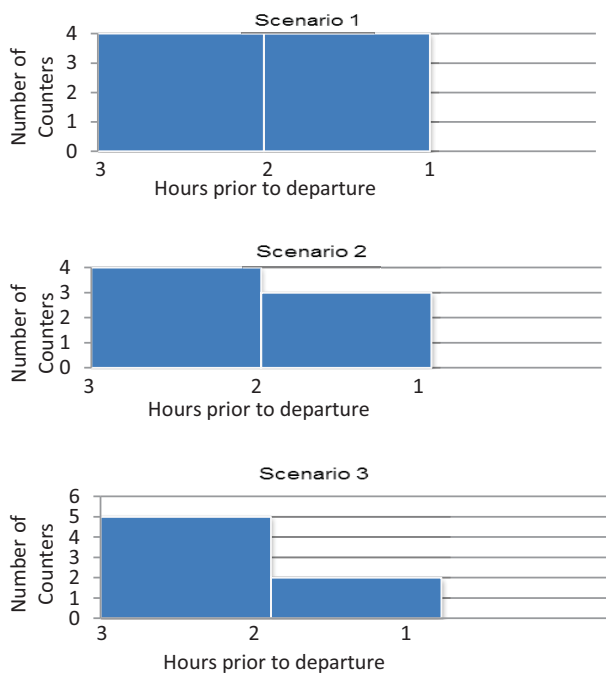

Fig. 4 Example for staffing working period for scenario 1, 2 and 3

From the actual one week KIA data, the total staffing working hours for scenario 1 is 5,582 hours. While in scenario 2&3 is 4,604 hours (18% change). Each airline has different daily or weekly flights frequency with different expected number of passengers which leads to different waiting time and queue length. When we applied the IP model, the airlines were rescheduled to zone area. We have noticed that about half of the flights that were in zone 2 and 3 have moved to zone 1 or 4. Table I represents the simulation results for passengers average waiting time for both actual or current situation and IP result for airline to zone allocation. The maximum value of α that we can put to get a feasible solution is 7 counters when $\beta = 40$ and only 2 counters in case of $\beta = 30$. Due to the flights shifting from zone to another, there is a few cases when the actual allocation gives better results than the IP results. Scenario 3 for IP results give the minimum average waiting time especially when we choose $\beta = 30$. In

this case, the staffing working hour will increase 2,429 hours. The number of counters required for the period facing the peak of passenger arrivals will generally be larger than the number required for the constant counter capacity case. In the actual airline allocation, the number of counters required reaches over the capacity in zone 2&3 in peak of passenger arrivals. While in the IP model, we used the constraint of zone capacity and let α be the desired number of counters remaining in each zone.

TABLE I
SIMULATION RESULTS FOR PASSENGERS AVERAGE WAITING TIME (MINUTES)

Scenario	$\beta = 40$			$\beta = 30$		
	Actual	IP Result	%Saving	Actual	IP Result	%Saving
1	61.072	41.615	32%	23.050	20.524	11%
2	48.752	54.088	-11%	22.669	19.449	14%
3	27.130	33.740	-24%	17.553	17.349	1%

V. CONCLUSION

In this study, we have developed a check-in allocation for airport terminal which decomposed to several check-in zones which have different counters capacity. We have made a combination of a stochastic and deterministic OR-approach for real world applications. For the check-in problem this combination concerns a two-step approach: Step 1: Mathematical (integer) programming in order to minimize the staffing and counters capacities for each zone. Step 2: Simulation in order to study the queuing processes. We have compared two Airlines to zone check-in allocations (Actual & IP Results) for 3 scenarios for counters staffing hours.

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