ANALYSIS OF AIRPORT CHECK-IN COUNTER ALLOCATION POLICIES USING SIMULATION

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ABSTRACT
This study tackles the check-in counter allocation problem of Ataturk International Airport. Check-in process is required for all passengers and has to be completed 30 minutes before the flight time. Resources of this operation are check-in counters which are allocated to airline firms. This study analyses two different check-in counter allocation policies. The first policy allocates a fixed number of counters for a fixed duration of time to each flight. Second policy is the dynamic allocation policy - which allows airline firms to rent new counters or release counters dynamically by considering the time left until flight and the number of passengers that have not checked in yet. We used simulation to analyze the effects of these policies on passenger waiting times and counter utilizations. Results showed that dynamic policy reduce the waiting times by using counters in a more efficient way.

Keywords: check-in counter allocation, airport resource allocation, resource allocation policy evaluation, airport simulation

1. INTRODUCTION

The check-in counter allocation problem is different from other resource allocation problems in terms of uncertainty about the amount of resources required to meet the demand. The check-in process is stochastic due to passenger arrival, and the number of required check-in counters varies with time since the total number of passengers per flight differs over time (Chun and Mak 1999). System requirements change dynamically with respect to the time and date of the flights. Considering this complexity, accurate prediction of the resource requirements is nearly impossible in a non-computerized way.

There are some variations of the problem in the practice. These differences arise from passengers' class, check-in policy and the flight type. The passengers can be divided into categories such as economy and first class, and they are serviced independently. Different check-in process policies include completely restricted system, common check-in system and composite check-in system (Lee and Longton 1959). Furthermore, there is some performance standards related to check-in process specified by the airport management. The airline companies have to satisfy these requirements along with providing more qualified service for customers, to survive in highly competitive market.

In this study, we considered Istanbul Atatürk International Airport and focused on a side of a specific counter block (island) which consists of 16 counters. There are 10 flights assigned to these counters in a given day. The check-in process policy is a completely restricted system for these counters.

The outline of this paper is as follows. First, related literature is expressed in Section 2. Section 3 describes the simulation model and alternative scenarios. Results and output analysis are presented in Section 4. Section 5 presents the conclusion and future work.

2. LITERATURE

Check-in counter allocation and check-in process problems are mostly approached in the literature with three methods: pure deterministic (operational research) method, deterministic method with the integration of stochastic nature of problem, pure stochastic approach (simulation).

Lee and Longton (1959) tried to determine the best type of check-in system among complete restricted, common check-in and composite check-in system. Indeed, the problem researchers handled is determining the optimal transfer time, and determining number of check-in clerks required for that transfer time in a composite check-in system. Wai Chun and Tak Mak (1999) present an integrated system which consists of an intelligent resource simulation system and check-in counter allocation system. Airlines enter their seasonal check-in counter requests through the database forms input facility. The authorities of airport use the intelligent resource simulation system to predict the minimum number of check-in counters needed to satisfy the predefined service levels of airline. The constraint-based scheduling system will then use both the simulated and requested values to perform check-in counter allocation. Dijk and Sluis (2006) consider check-in process as a two stage problem. Stages are the stochastic stage which designates the number of check-in desks to meet a determined service level for each individual flight by simulation. Second stage is a scheduling and optimal capacity allocation stage in which the minimum total number of desks and desk hours required over all periods are optimized by integer programming under the realistic constraints. Parlar and Sharafali (2008) developed a stochastic dynamic programming model to determine the optimal number of counters.

Appelt et al. (2007) identified the delays in the check-in process and created scenarios to improve the efficiency of the check-in procedure. In the simulation model, three basic scenarios and three combinations of them were created to analyze whether the delay in system differ according to check-in modes serviced to passengers by the airline. Joustra and Dijk (2001) denoted that traditional queuing models are very limited for check-in process and simulation is a necessary tool to evaluate it in a more valid way. In their study they used a check-in simulation toolbox to evaluate the effects of various factors in check-in process. Takakuwa and Oyama (2003) built a simulation model to examine the passenger flow. The number of passengers who miss their flights is aimed to be reduced by considering the issues that affect the waiting times. A special-purpose data generator is designed to determine the experimental data to execute the simulation. Park and Ahn (2003) developed an effective model that determines the number of check-in counters to be opened and duration that these counters should remain operating. They conduct a survey to determine the time when passengers arrive at airport before their flight departure times. After that, they used passengers' arrival distributions to find the appropriate number of check-in counters and duration of operation. They also take the time of the flight into account - whether it is in peak hours or on a special day.

3. SIMULATION MODEL

3.1. System and Assumptions

Airport check-in process has stochastic and deterministic components. The stochastic nature of passenger arrivals and variable check-in process times requires analyzing the problem by simulation modeling. In the airport, the flight features and the initial allocation of check-in counters are deterministic. The airport management is informed about the flight schedules by the airline firms and allocates the current counters among the firms such that all counters allocated for a flight are adjacent. Considering this information in the simulation model, first we selected 10 flights randomly, and assigned a specific counter block to these flights in a given day. The counter opening time and the total duration of check-in process for each flight are assigned to the counters.

Arrival profiles of the passengers are modeled according to two different flights observed in the airport. One of these flights intensively consists of Turkish passengers (arrival profile-1); the other one intensively consists of passengers which are foreign tourists (arrival profile-2). The arrival profiles of these two flights are denoted in Figure 1 and Figure 2 respectively. The durations that the counters of these flights are open, are divided in 8 equal periods with a starting period (period 0). The length of period 0 is equal to 30 minutes and in this period the passengers who show up before counters are open, arrive. This period starts exactly 30 minutes before counters are open. Figure 1 shows the arriving passenger proportions which are calculated by: Number of passengers arrived period i/Total number of passengers. The proportions of all periods are determined according data obtained from the observations.

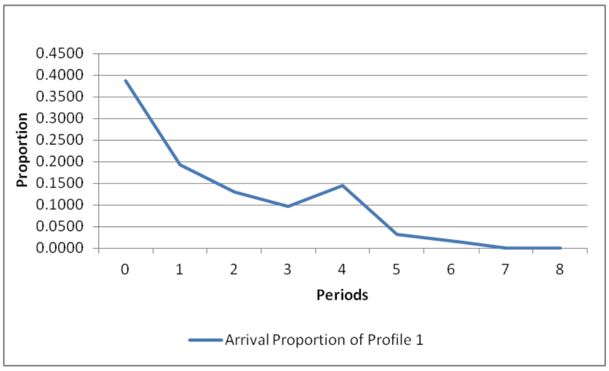

Figure 1: Arrival Profile 1

Since we are conducting the study for Istanbul Ataturk International airport, we assumed that arrival profile of the passengers for 60 percent of all flights fit to arrival profile-1 and the passenger profiles for the remaining flights fit to arrival profile-2. The arrival proportions used in the simulation model for each flight are denoted in Table 1.

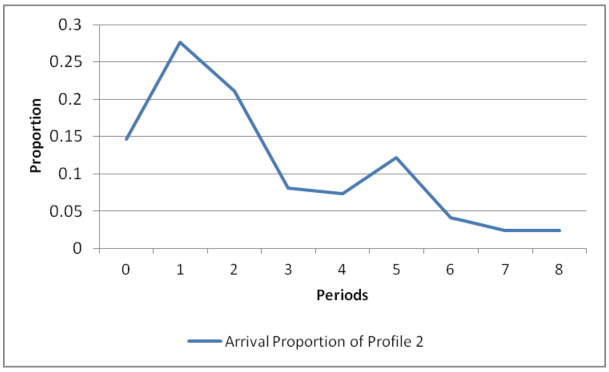

Figure 2: Arrival Profile 2

Table 1: The Passenger Proportions per Flight

Periods	Flight Numbers	
	1-3-5-7-9-10	2-4-6-8
0	0.39	0.15
1	0.19	0.28
2	0.13	0.21
3	0.10	0.08
4	0.15	0.07
5	0.03	0.12
6	0.02	0.04
7	0.00	0.02
8	0.00	0.02

Table 2 shows the total number of passengers for each flight. We used triangular distribution to express the total passenger count in each simulation run, as the number of passenger checking-in can change from time to time and planes are not always flying at full capacity.

Table 2: Number of Passengers for Each Flights

Flight	# of Passengers
1	TRIA(272,303,333)
2	TRIA(360,400,440)
3	TRIA(79,88,96)
4	TRIA(85,95,104)
5	TRIA(167,186,204)
6	TRIA(31,35,38)
7	TRIA(110,123,135)
8	TRIA(93,104,114)
9	TRIA(354,394,433)
10	TRIA(192,214,235)

Moreover, check-in process times differ according to the flight profiles. This difference can be caused by either the passenger profiles or the check-in staff or both. To determine the probability distributions of the check-in processing times of these two flights, the processing times were collected per passenger for each of the flights. After collection of the data, the distributions were determined for each of the flight profiles by using ARENA Input Analyzer (see Table 3).

Table 3: Check-in Processing Times

Profiles	Processing Time (in seconds)
Arrival Profile 1	24+WEIB(91, 1.05)
Arrival Profile 2	18+WEIB(134, 1.24)

3.2. Objectives and Performance Measures

The objective of this study is to analyze and compare different check-in counter allocation policies. The revenue of the airport management will increase when more counters are allocated to airline firms through an efficient allocation policy. The goal is to decrease the waiting times of passengers by increasing utilization of the counters without changing the total number of available counters.

We used the following performance measures:

- Average counter usage: This performance measure indicates average counter usage ratio for all counters. Counter usage ratio equals the total time a counter is open divided by simulation time.
- Average waiting time of passenger in queue.

3.3. Model Development and Alternative Scenarios

We developed a different simulation model for each policy, using ARENA 12.0 simulation software package. The first simulation model belongs to the base case scenario which is the fixed counter allocation policy in a 16 counters-10 flights airport day. The second model analyses the dynamic counter allocation policy in the same 16 counters-10 flights simulation day.

3.3.1. Base Case and Simulation Model

This study represents the currently used check-in system as the “base case”. The check-in counters are pre-assigned to airline firms by the airport management based on a schedule. These counters are called as startup counters after this point in this paper. The counters are opened at the beginning time and serve for a specified time. Passengers arrive at the check-in service area and wait in the queue if all counters are busy. At the end of the service time the counters are closed. A basic representation of the check-in process system is given in Figure 1.

Simulation model of the base case is quite simple. Passengers are the only entities of this model. Passengers belonging to a specific flight start arriving at the check-in service area when the counters of that flight are opened. They leave the system when their check-in operation is completed. Resources of check-in process are counters in the system. A passenger’s arrival at the counter, beginning and completion of check-in process constitute the events of base case model.

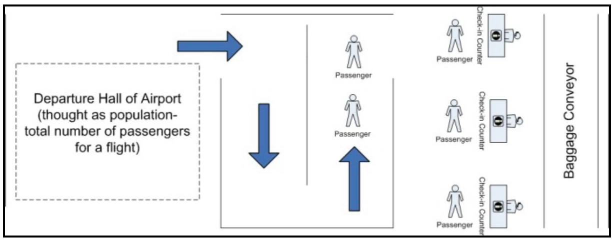

Figure 3: Basic Representation of the Check-in Process System

3.3.2. Dynamic Case and Simulation Model

In this model, the main assumption is that the number of counters which are used for any flight can be changed dynamically while the check-in process is continuing. The change can be made through the use of startup counters of other flights whose check-in operations have not started yet, or releasing some of the counters which are currently used. By this way, the utilization of the counters which are defined as resources of the system will be improved. Dynamic change is depended on a value called k which is calculated periodically, as in

$$k = \left\lceil \frac{\text{Expected check-in process time*Remaining number of passengers to be served}}{\text{Remaining time}} \right\rceil$$

The dynamic allocation policy and the terms used in the policy are explained in detail below. Figure 2 illustrates the counter block and corresponding counter positions.

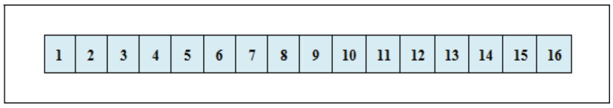

Figure 4: Illustration of Counter Block and Counter Positions

Definition 1 "Available counter" *is a counter that*;

i. In counter releasing operation, has the smallest ID or the largest ID of the dealing flight, edge of adjacent counters (resources) for any flight (counter 1 and 4 for flight 1, and counter 7 and 10 for flight 2 in Figure 3),

ii. In counter seizing operation, is adjacent to edge counters and will not be used for another flight not started yet for next 30 minutes (counter 5 for flight 1, and counter 6 and 11 for flight 2 in Figure 3).

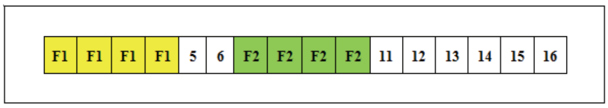

Figure 5: Illustration of Available Counters

Definition 2 "Additional counter" *refers to an available counter when a seizing operation is completed. This seized counter is an additional resource to startup counters for corresponding flight (counter 6 is seized by flight 2 in Figure 4).*

Definition 3 "Current flight" *is the flight that is analyzed through k value for seizing and releasing operations (flight 2 in Figure 4).*

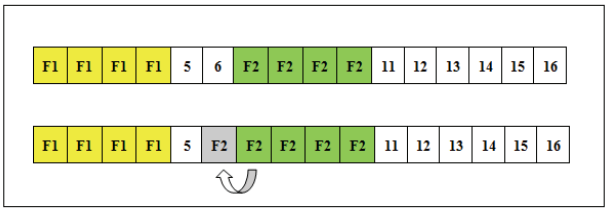

Figure 6: Illustration of a Seizing Operation

Definition 4 "neighbor flight" *refers to the flight which serves at the counters adjacent to the counters of current flight while check-in process of current flight continues (flight 1 is neighbor of flight 2, changing counters between them occurs as flight 2 releases counter 5 first, then flight 1 seize that counter in Figure 5) .*

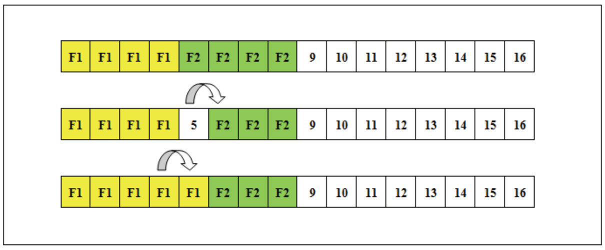

Figure 7: Illustration of Changing Counters between Flights

The seizing and releasing operations are made on available counter/s. The case in which the flight has only one counter, it will remain open until the end of check-in process regardless of the k value.

The mechanism of the dynamic counter allocation policy is as follows:

Phase 1: Each flight is initially allocated a number of startup counters (number and place of counters decided by airport management). The starting and ending time of the check-in operation for each flight refer to the opening and closing time of the startup counters respectively. The number of passengers of each flight, which expresses the limited population for the check-in operation, is assigned as an attribute to this flight. All the data is set into the model are summarized in Table 4.

Phase 2: Once the counters for a flight open, the k value is calculated every fifteen minutes. The decision for seizing or releasing a counter is made according to the k-value. In order to seize an additional counter, there must be at least one available counter.

Phase 2.1: If we decide to seize a counter, it is important to check at what time this additional counter will be opened as a startup counter of another flight. The starting time of next flight assigned to this additional counter must be taken into account and the operation of current flight at this counter must be terminated 30 minutes before flight starting time. If this time minus 30 minutes is greater than the ending time of the current flight check-in process, this counter can be used until the ending time (Simulation model is presented in Figure 8 in Appendix A).

Phase 2.2: In the case of releasing a counter, the counter selected should be suitable for the neighbor flights to seize. According to the k value, if there is need for one more counter, the released counter can be seized again if it is still an available counter (Simulation model is presented in Figure 8 in Appendix A).

Phase 3: When the check-in operation is completed for a flight, all the counters used for that flight are closed.

Table 4: Input Data for Simulation Model

Flight	Duration of Check-in	Starting and Ending Time (in minutes)	# of Startup Counters	Startup Counters
1	130	685-815	5	12,13,14,15,16
2	160	635-795	6	2,3,4,5,6,7
3	95	360-455	2	11,12
4	105	585-690	3	9,10,11
5	100	840-940	4	13,14,15,16
6	85	200-285	1	15
7	105	525-630	3	13,14,15
8	125	815-940	2	9,10
9	165	965-1130	9	1,2,3,4,5,6,7,8,9
10	120	800-920	4	2,3,4,5

3.4. Verification and Validation

Both of the simulation models are verified by using TRACE element in the ARENA 12.0 software. Trace is one of the most powerful techniques to verify a simulation model (Law 2007). TRACE element provides a list which keeps events happened, state variables, some other statistics about the system during the simulation. Thus, potential mistakes would exist in the simulation model can be detected by model developer. While development process, output of the TRACE element was checked and it can be seen that the both of simulation models operate as intended.

Although we used real input data about the flights and startup counters, we could not obtain any data about passenger waiting times in the base case therefore we could not use statistical validation tools. Instead we compared the system behavior with the simulation results and verified face validity of the model.

4. RESULTS AND OUTPUT ANALYSIS

In this section we compare the two scenarios in terms of average counter usage and average waiting time of passengers. A single run for each scenario starts when the counter opens for the first flight and ends when all the day's flights finish their check-in processes. The number of replications is determined using the relative error method (relative error of 5 percent). Thus, 20 replications are enough for both performance measures while simulation models are run for two hundreds replications to narrow the confidence intervals of the difference between the performances of the models. Table 5 presents the results for each simulation models with respect to performance measures.

Table 5: Results-Means and Half-widths

	Base Case	Dynamic Case
Waiting Times	28.67±2.9104	26.02±2.8130
Counter Utilization Rate	0.2713±0	0.3284±0.0114

Paired t-test is used to compare the policies and determine which policy is better in terms of the performance measures (Law 2007). Table 6 presents the 90% confidence intervals for the difference between the scenarios. Confidence intervals show that the waiting times in the check-in process of the dynamic system is shorter than that of the current system, in other words the proposed system is resulted statistically significant improvement of waiting times.

Results show that counter usage rates increased when dynamic allocation policy is used. In the current system, it is necessary to use additional resources for decreasing the queue length. To do this, the airline firms want to increase the number of counters they demand. However, the resources are limited and it can be impossible to allocate the counters to the airline firms based on their demands instead of their needs.

The illustrations below explain the differences between the base case and the dynamic case more clearly. In Figure 8, the counter labeled as C3 is not assigned to any flight. In the base case, this counter can be initially assigned to flight1 (F1), flight2 (F2), or none. If this counter is assigned to any of the flights, it can remain idle in the some portion of the time while it is open. If it not assigned to any of the flights, it cannot be utilized when flights need more counters.

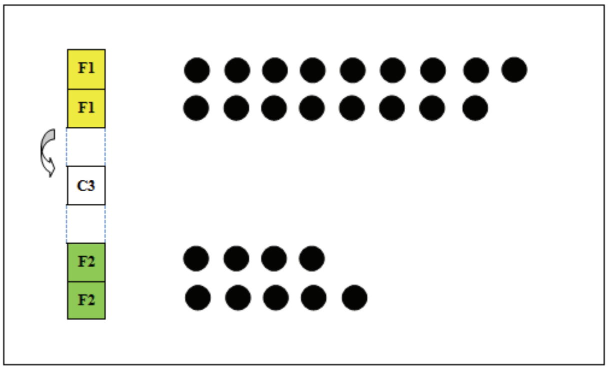

Figure 8: Illustration of Proposed System Procedure

In the proposed system, counter 3 (C3) can be utilized by both of the flights (one flight at a time) when one of them needs additional resources to minimize passenger waiting times. For instance, counter 3 is seized by flight 1 in the situation represented in Figure 8 as the queue length of flight 1 exceeded the k value. The seized counter will be released when the queue length of flight 1 fall below the k value as in the situation represented in Figure 9. This releasing operation also enables flight 2 to seize the same counter to minimize passenger waiting times since the queue length of flight 2 exceeds the limit now. Through the proposed method, flight 1 and 2 which are neighbor flights to counter 3 can reduce the passenger waiting times by seizing the additional available counter. In addition to this, utilization of counter 3 is increased by serving to neighbor flights when the number of passenger waiting in the queues increase.

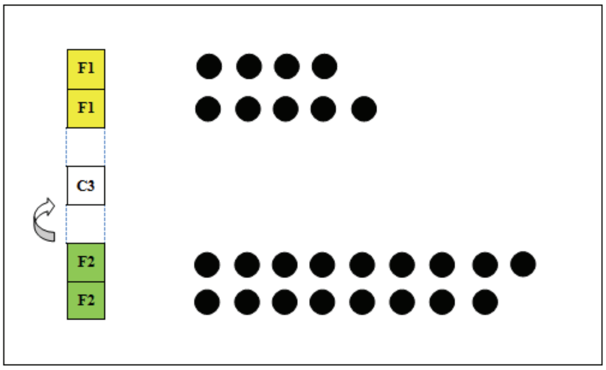

Figure 9: Illustration of Proposed System Procedure

In the proposed system, the number of counters is dynamically changed and as a result, counter usage rate increased. As it pointed out before, the proposed system also decreases the waiting times which means that the profit of airline firms may be increased through a positive impression on passengers. Additionally, since for a country international airports are the gates opening abroad, the quality of service is very important. The waiting times in the check-in process queue of passengers who travel overseas should be decreased even if an additional cost is bore by either airline firms or airport management. Moreover, the less time spend waiting in the check-in queue will result in more time spent in the duty free area which is a very important source of revenue for the airports.

Table 6: Confidence Intervals for Performance Measures

	Lower Limit	Mean	Upper Limit
Waiting Time (in minutes)	0.6008	2.6509	4.7010
Counter Utilization Rate	-0.0685	-0.0572	-0.0458

5. CONCLUSION AND FUTURE WORK

In this study, we considered the check-in counter allocation problem. Target of the airport management is to increase the counter usage of each flight which means that more counters are provided for each flight. Thus, airline firms are able to decrease the waiting times of the passengers by using more counters. By taking this into account, we compared two different counter allocation policies. In the first policy each flight uses a constant number of counters during the check-in process (base case). This policy is currently used in many airports. The other policy is one that the number of counters can change dynamically during the check-in process (dynamic case). Simulation models and scenarios are developed for these two policies. Results show that the dynamic case is better than the base case in terms of passenger waiting times.

As a future study we are planning to investigate the case where passengers are not of the same type. As it was mentioned before, all the passengers are assumed to be homogenous (apart from the arrival profile difference) in this study. However, the luggage sizes and the number of luggages per passenger can differ for each flight with respect to the distance of flight in reality and as a result, the check-in process time of a flight will be affected. Furthermore, it is known that there are differences in arrival behavior of passengers due to cultural differences. This study included two types of passenger profiles but in an international airport we may have more than two cultural profiles. The cultural features of passengers should also be considered in future studies.

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APPENDIX A

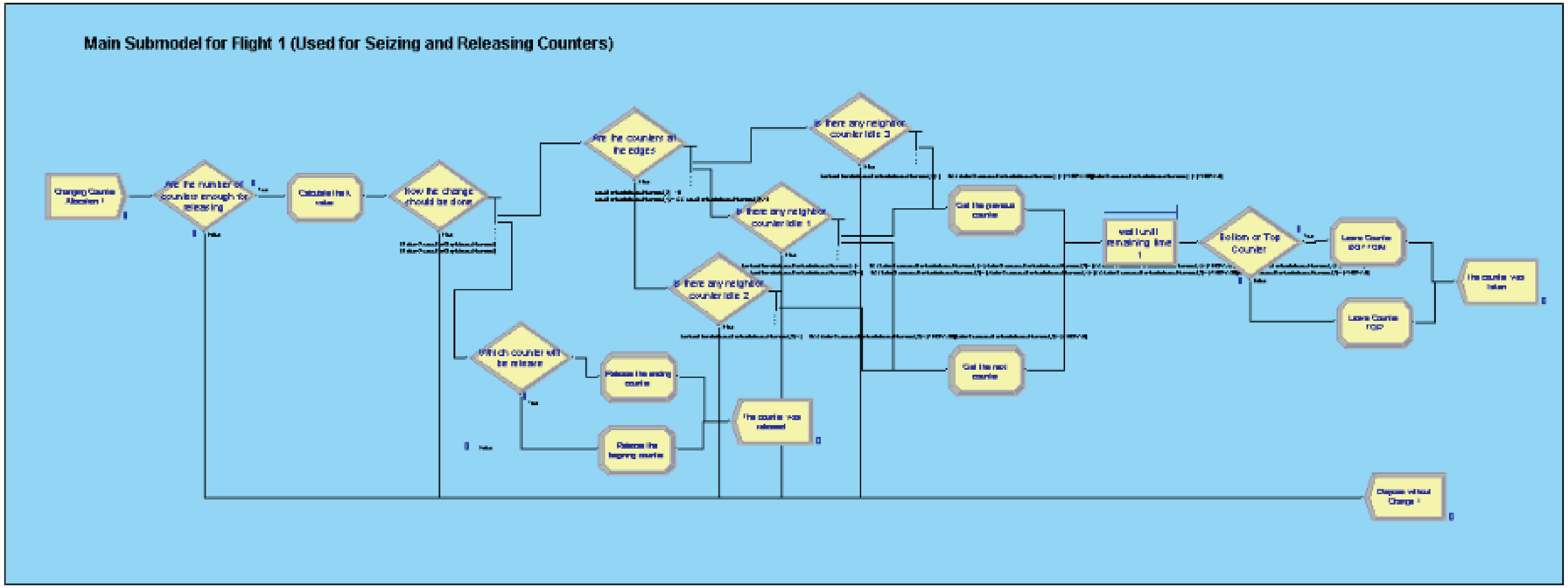

Figure 10: ARENA Simulation Submodel-Used for Seizing and Releasing Operations