INTERNATIONAL PASSENGER AND BAGGAGE PROCESSING AT KENNEDY AIRPORT

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Summary

A computer simulation model (written in GPSS) was developed to analyze passenger and baggage flow through the International Arrivals Building at New York's Kennedy Airport. Capacities and staffing at various federal inspection, baggage claim, and sky cap areas can be initialized before each simulation. Given any input schedule of flights, the program utilizes stored information on processing rates and walking times to provide queue statistics, waiting times and facility utilizations throughout the Arrivals Building as well as statistics for pre-selected individual flights.

Results are being used to develop and evaluate physical and operational plans, especially as affected by the introduction of the new generation of larger aircraft.

Introduction

The Port of New York Authority operates the International Arrivals Building (IAB) at New York's Kennedy Airport. It is the Authority's responsibility to develop and evaluate plans for expansion to meet future demand. These physical and operating plans must be coordinated with the operating procedures of the required federal inspections: Immigration, Public Health, Agriculture, and Customs.

Approximately 75% of international air travellers enter the United States through Kennedy Airport. As many as 22,000 passengers per day were processed in the peak periods of the summer of 1969. The introduction of larger aircraft (up to 400 passengers) will have a major impact on IAB operations. It was important, therefore, to develop an effective means of evaluating new proposed physical and operating plans to meet the future demand.

A task force comprising several groups* within the Port Authority was formed to develop a computer simulation model of the Passenger and Baggage Processing at the IAB. The model deals with all the federal inspections and baggage claim for arriving passengers.

The IAB Operation

Figure 1 is a schematic layout of the processing area showing passenger and baggage flow. Arriving aircraft are assigned a gate position. Depending on the gate's location, passengers may either walk or be transported by bus to the IAB. All arriving passengers then proceed to the primary inspection area (upper left in figure 1). Visitors and U.S. citizens are processed in separate areas for the primary inspection. During this primary inspection, color coded folders are issued to the passengers indicating which of the secondary inspection processes are required. Most passengers proceed directly to the appropriate baggage claim area for their flight, while others must first pass through a secondary public health and/or immigration processing before proceeding to the appropriate baggage claim area.

As passengers disembark from aircraft, their baggage is unloaded onto carts and delivered to the baggage claim area where bags are displayed on a continuous conveyor belt (A through E in figure 1). After claiming their bags, passengers move through a series of checkpoints where federal inspectors direct them to either a secondary customs (baggage) inspection or directly to a sky cap pick-up area. Passengers may choose to take advantage of the sky cap service to assist them in transporting their baggage to the lobby. Those passengers who are required to pay duty must make payment at the duty counter before exiting to the lobby.

The operations within the IAB are very dynamic. For example, it is possible to have only 100 passengers arrive during one-half hour period and more than 1,000 arrive in the next. Practically all the important variables are stochastic and strongly inter-dependent and the use of average expected values for passenger flows and processing rates would give misleading projections. Preliminary analysis indicated that analytical models would have required too many simplifying assumptions and yet could become overly complex to solve. The complexities involved in the analytical approaches are exhibited in an earlier Port Authority Study[2] which deals with the interactions of passengers and baggage arrivals at the baggage claim area and the resultant queues. Such analytical results, while not adequate for analyzing the actual operation, were useful in testing the simulation model since they provided solutions to simple cases.

Scope of the Model

A key problem in any simulation and one on which its success or failure may hinge is the setting of the model's scope. The real situation must be abstracted and structured into a model that provides an accurate representation of the physical and operational system. It was decided that the simulation model should begin with the parking time of the aircraft and end with the exiting of passengers with their baggage into the building lobby. A separate study was requir-

*Aviation Planning, Aviation Economics, Airport Operations, Scientific Programming and Operations Standards.

ed to project the level of air traffic to be expected (e.g. in 1975). This included flight schedules, types of aircraft and the passenger load factors. The origins of the flights and the airline were used to predict the per cent citizens.

An analysis of the relationship between scheduled and actual arrival times of flights showed that the number of aircraft scheduled to arrive during the peak periods was a good predictor of the actual number arriving, although the peak might occur at a different time of day. Schedules were projected for the entire peak day and gate assignments were based on the future physical plans and operating requirements. Based on these analyses a peak three-hour period is selected for a simulation run.

Model Logic

On the basis of preliminary data collection and analysis it was decided to structure the data for the model in two ways:

1. Walking and busing times are normally constants, but additional delays are added to take account of congestion. All of the required data values for walking, bussing and congestion delays are stored in tables.

2. Passenger characteristics and processing rates are stored in cumulative density functions (CDFs). For each characteristic or processing rate, the number of separate CDFs needed is based on a statistical analysis of the operational data. For example, at primary inspection the CDF chosen for a particular passenger group is a function of size of the group, its citizenship, and the color code of the folder assigned to it.

The passenger and baggage flow through the IAB is represented in a flow chart in Figure 2.

The simulation model takes all passengers from each flight and converts them into transaction groups which flow through the remainder of the logic. Each transaction has the following eleven parameters:

1. Airline carrier
2. Flight number
3. Gate position
4. Aircraft Type: (regular - up to 180 passengers stretch - up to 250 passengers, or large - over 250 passengers)
5. Group identification number
6. Group size - a group is defined as those passengers listed on a single U.S. Customs Declaration Form
7. U.S. citizens or visitors
8. Primary color code which determines the inspections required
9. Number of bags for the entire passenger group
10. Use of Sky Cap
11. Baggage claim area

The first five parameters are assigned as the transaction is generated and serve to identify it. The next five are assigned by CDFs. The baggage claim area assignment for both passenger and bags of a particular flight is made later by the model logic.

After all transactions of a flight have been assigned their parameters, transactions are advanced in time to the primary inspection area. This time is dependent on the gate position of the flight and occurs in three parts: a variable time to leave the aircraft (based on observed passenger departure patterns), travel time from the aircraft to the IAB entrance (by bus if a remote gate is assigned) and walking time from the building entrance to the primary inspection area.

Each transaction is advanced to either the citizens or visitors primary inspection area and is assigned to the shortest queue. When its turn to be processed arrives, it receives a processing time by sampling the appropriate CDF based on the transaction's group size, citizenship and color code.

Normally all transactions with the citizens parameter are processed through the citizens facility. The model, however, like the real operation, permits citizens to be processed in the visitors area to correct an imbalance in queue lengths. When the average queue length in the citizens area is greater than a specific value X while the average queue in the visitors area is less than a smaller value Y, transaction groups are diverted from the citizen's to the visitor's processing unit. After primary processing the transaction proceeds either directly to its assigned baggage claim area (to a waiting area if no baggage claim area assignment has been made as yet)* or to secondary public health and immigration inspection. After queuing and processing at the secondary public health and immigration the transactions proceed to baggage claim.

After passengers were transformed into transactions their bags were generated by a Split Block. Each baggage transaction represents one bag and carries the following parameters:

1. passenger group identification number
2. airline
3. flight number
4. gate position
5. baggage claim area

Bags are generated in the same sequence as passenger transactions, but are then mixed with any desired degree of randomness. A "randomness" variable is assigned a value between 0 and 1. This value determines what proportion of the group's baggage will remain together. The remainder will be randomly mixed. When bags are randomly mixed, each one is assigned a random number. Bags of a transaction which are to remain together as a unit, are all assigned the same random number. After this process has been accomplished for all of the bags on a given flight, a second pass is made assigning random numbers to break any ties which have occured in the first assignment of an ordering.

Bags of a given flight are delivered to the baggage claim area in a number of cart loads. The departure time (elapsed time) of a loaded cart from the aircraft and the number of bags on a cart are determined by sampling CDFs. The number of bags on a cart is directly related to the elapsed time for loading that cart. This is taken into account by using the same random number for sampling the distributions of the number of bags loaded and the elapsed time.

* Queue block statistics are gathered although physically no such waiting area exists.

A similar procedure is used for subsequent loads until all the bags for the flight have been unloaded and delivered to the baggage claim area.

Effective rules for assigning baggage conveyors to flights were needed for the simulation model. The rules developed took into consideration the new large jets in which bags are to be divided into two groups, each with its own separate baggage conveyor assignment.

The logic for conveyor assignments is based on the three types of aircraft. First a set of basic rules was developed as follows:

1. Conveyors are normally assigned to flights in the order of their arrival.
2. The furthest conveyor from point of passenger entry is given preference in initial assignments. (e.g. conveyor E is assigned first)
3. After one flight has been assigned to each conveyor, the next flight is assigned:
   (a) to the conveyor with a flight from the same airline, or if this is not possible,
   (b) to the conveyor with the fewest unclaimed bags assigned to it.
4. If there are two flights assigned to each conveyor, the next flight normally cannot be assigned and must wait until one of the conveyors becomes available. However, this procedure can be speeded up by "forcing the conveyor free". This occurs when there are less than a pre-specified number of bags remaining to be claimed for a given flight.

In addition to these rules, the following two assignments are not permitted by the model logic:

1. Two stretch flights cannot be assigned to the same conveyor.
2. Both halves of the same large jet flight cannot be assigned to the same conveyor.

The baggage arriving at the assigned conveyor will be loaded onto the conveyor unless another cart is still in the process of unloading. The rate at which bags are loaded onto the conveyor depends on the crew size, and the number of bags returning unclaimed to the loading area. In order to account for this in the model, the conveyor is divided into equal sections each with a known capacity. Each section of the conveyor is represented by a storage in which the number of bags loaded onto the section and removed from it is constantly being updated.

Passenger transactions arriving at the assigned baggage claim area are reunited with their baggage through the use of a Match Block. The maximum number of passengers able to search simultaneously for their bags is an input variable. The baggage claim conveyor operation was the most difficult part of the process to model. Motion picture analysis of the conveyor area was necessary to determine the relevant relationships and to identify how the interaction between passengers and bags takes place. Observations indicated that almost all passengers remove their bags during the first cycle for which both the passenger and the bags are in the conveyor baggage claim area. While the transaction group quickly claims each of its bags through the use of a Match Block, the group does not leave the area until all of its bags have been claimed. After leaving the baggage claim area, the transaction is processed through one of a series of inspection checkpoints. Based on its assigned parameter, the transaction then queues for processing at secondary customs inspection, sky cap service and/or duty payment before proceeding to the lobby.

The Program

Because of the nature of the operation involving a multi-stage queuing process, it was decided that a simulation language was desirable. The scientific programming group, considering their background and experience, the hardware available and the problem requirements, chose GPSS-II as being the most appropriate for the problem. The model was run on an IBM 360 Model 75. Program dimensions are as follows:

770	statements
80	functions
57	variables
350,000	core allocations
5,000	maximum number of transactions in the system at one time
90	facilities
110	queues
67	storages

The normal package GPSS-II output reports were obtained. Generally these were called at the end of each simulated half-hour. These standard reports were supplemented by special listings giving the status of every passenger and baggage transaction for particular pre-selected flights. About one-half hour of central processing unit time is required to simulate a three hour peak period in which approximately 4,000 passengers are processed.

Data Collection and Validation

Data on all the pertinent operations were collected during the summer of 1969. A team of four to five data collectors used a random cluster sampling method to obtain data on each operation. All the data collection was stratified to include different periods of peak activity on all days of the week. As the data were obtained, they were analyzed and used in structuring the model. At the primary inspection area, for example, the number of people in the group, citizenship and color code were important factors, while at the secondary customs inspection, only the number of bags was important.

A validation team of 26 people collected the data on the entire system for two days. This data collection team simultaneously measured both input and output data on the operation for later comparison with simulated results. In the validation process, the block arrival times and gate assignments of the flights, the number of passengers and bags on board, the per cent citizens and the conveyor assignments were fed into the model as inputs. Flow rates and queues at each point in the process were compared with actual output. This validation test insured that the model logic was operating correctly and that the stored CDFs were accurate. Analysis of results showed generally good correspondence and a correct model logic. At certain times, however, simulated results fluctuated more than the actual. The cause was traced to certain extreme sample values from CDFs which were not sampled frequently enough to reach their expected values. As a result, the extreme values from these distributions were truncated. This reduced the differences between the actual and the simulated to an acceptable level.

Results

Tables 1 and 2 give samples* of input data. Table 1 shows a sample of the airline schedule; Table 2 lists the initializing data for the operational system. These are the normal inputs variables; however, any of the stored CDFs, tables of walking times etc, can be changed whenever desired. For each run, the simulation results were summarized from the GPSS output into a management report, a sample* of which is shown in Table 3 and Figure 3.

Output evaluations were developed based on the future physical and operational plans. The results were used to identify potential problem areas. As a result of the base run of expected conditions, additional runs were made based on the following types of changes in the process:

1. number of primary inspection facilities
2. number of baggage claim conveyors
3. speed of baggage delivery to conveyor area
4. conveyor assignment logic
5. gate assignments

As a consequence of the presentation of these results to the Aviation Planning Division, the facility management and Federal Agencies, modified physical plans are being developed and will be evaluated using the simulation program. Concurrently, new operating procedures have been developed and implemented and additional ones are under study.

Conclusions

As mentioned above, the simulation program is being used to evaluate short range expansion plans for the International Arrivals Building. It is expected that the experience gained in this endeavor will streamline and refine long range planning both at Kennedy and at other airports. The presentation and discussion of results of the simulation program has provided a very strong management information and communications vehicle for the various closely interacting groups responsible for the planning and operations of the IAB.

The total Aviation Transportation System is extremely complex. Theoretically, the limits of such a simulated system could include: air traffic congestion, runways and taxiways, roadways and even mass transit systems. This study, however, has demonstrated the value of simulation in analyzing a large complex transportation system and providing accurate information needed for the planning of an important public facility. It has provided a strong motivation to develop simulation models for the remaining sub-systems of the total air transport picture and this larger system could be coupled together by generating job-tapes from each system output to be used as initializing inputs to the next simulation sub-system. Simulations of airport parking operations and some aspects of scheduling, taxiing, and runway utilization have already been modeled at the Port Authority.[1,4] Development of a model for predicting airport roadway traffic is now in progress. Many other facets of air transport operations have been modeled by others.[3,5]

* Hypothetical

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TABLE 1

SAMPLE SCHEDULE OF FLIGHTS

Airline	Flight	Aircraft Type*	Block Time	Gate Assignment	Number Pax	% Citizens
21	01	R	100	1	140	77.4%
01	02	L	900	5	296	68.0%
05	03	S	1800	6	230	68.0%
02	04	L	2400	8	288	59.1%
41	05	R	2500	14	160	59.1%
08	06	L	2700	3	330	65.0%
24	07	R	2900	2	110	65.0%
30	08	R	3000	9	139	73.0%
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* R = Regular
S = Stretch
L = Large

TABLE 2

SAMPLE INITIALIZING INPUT

Number of Booths Open:

- Primary Inspection Citizen 10
- Primary Inspection Visitor 15
- Secondary Public Health 2
- Secondary Immigration 1
- Secondary Customs 20
- Duty 2

Number of Conveyors In Use 5

Crew Size at Conveyor 3

Number of Inspectors at Check Points .. 10

Number of Sky Caps. . . UNLIMITED

Number of Bags on Conveyor 150

Minimum Number of Bags on Conveyor before Conveyor can be freed 50

Citizens processed in Visitors Area when average queue lengths at Citizens Booths is greater than . . . . 25 and in Visitors Booth is less than 10

TABLE 3

SAMPLE SUMMARY OF RESULTS

	Max. Queue In Area	Avg. Queue In Area	Ave. Waiting Time (min)
Visitors Primary	150	30	6.0
Citizens Primary	390	160	15.0
Conveyors, Pax/Conv.	70	20	6.0
Conveyors, Bags/Conv.	140	50	10.0
Check Points, per ck. pt.	5	0	0.1
Secondary Customs	90	10	2.0

	AVG.	MAX.	UTILIZATION
Sky Caps Used	10	25	50%

	Max. Queue	Avg. Queue	Avg. Wait. Time	TOTAL
Number of Passengers Waiting for Conveyor Assignments	250	100	15	900

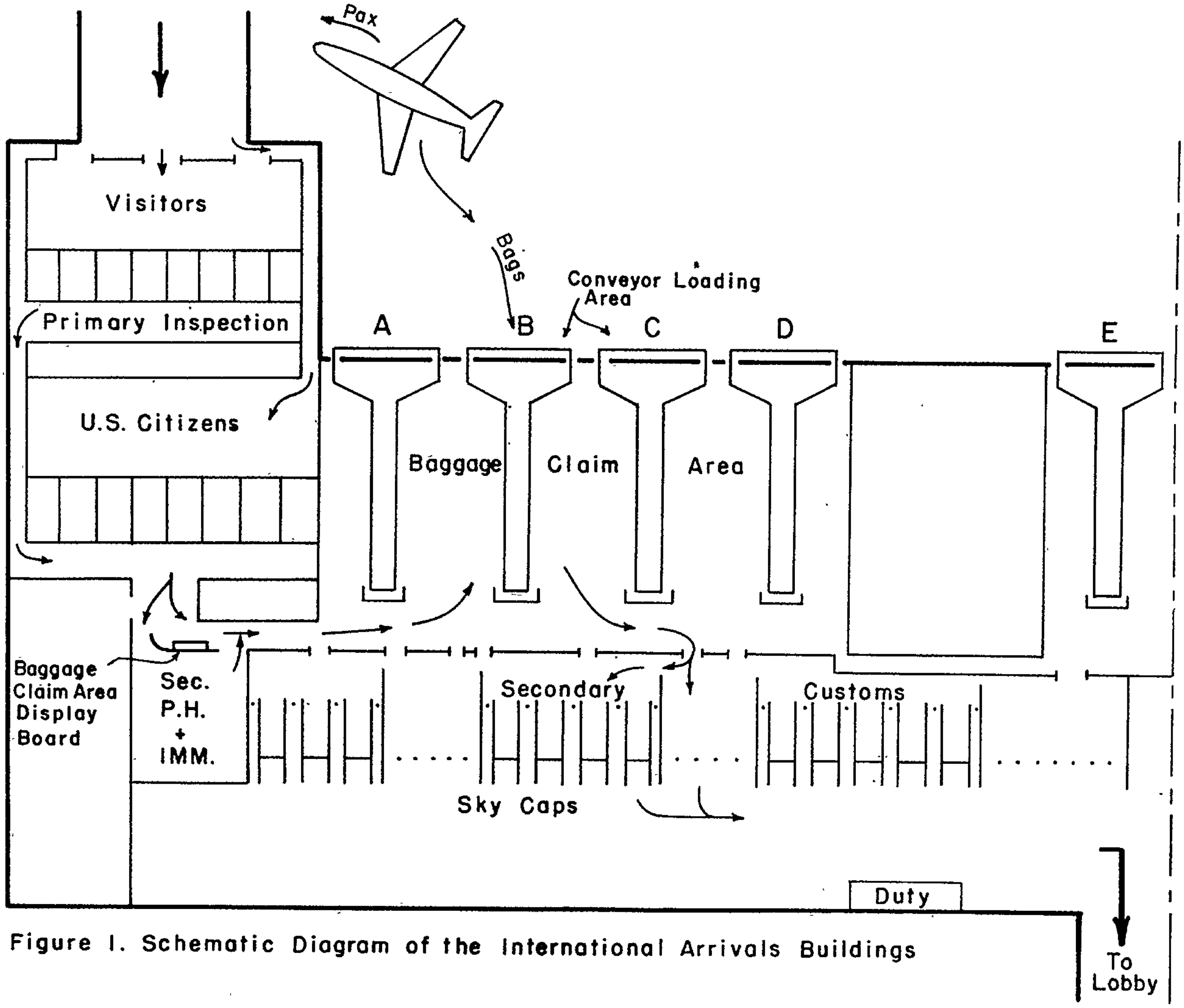

Figure I. Schematic Diagram of the International Arrivals Buildings

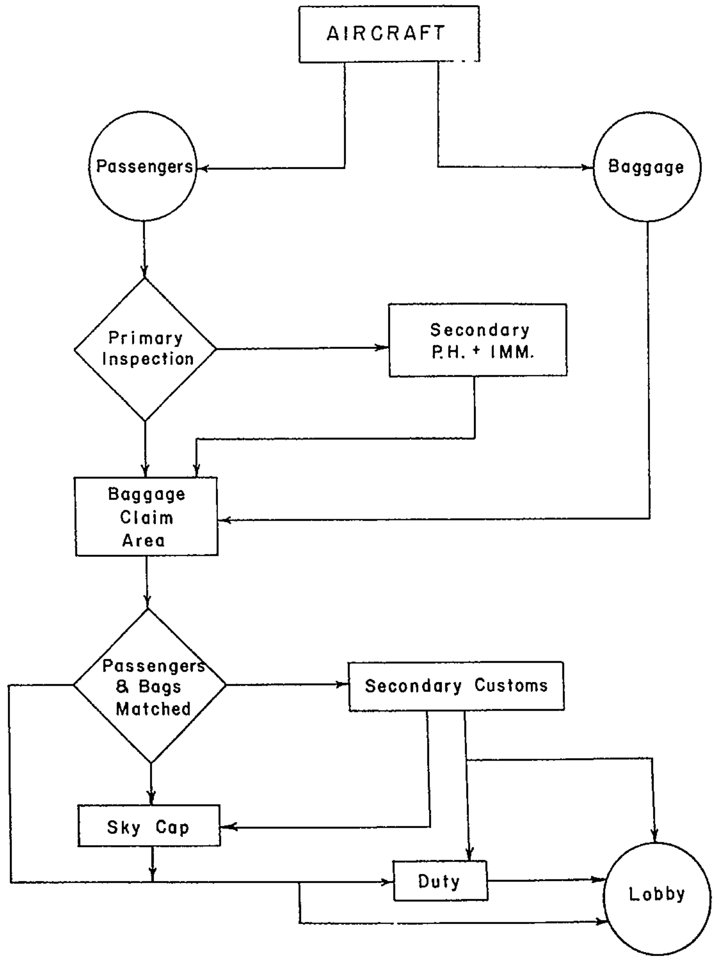

Figure 2. A Flow Chart of Passenger & Baggage Processing

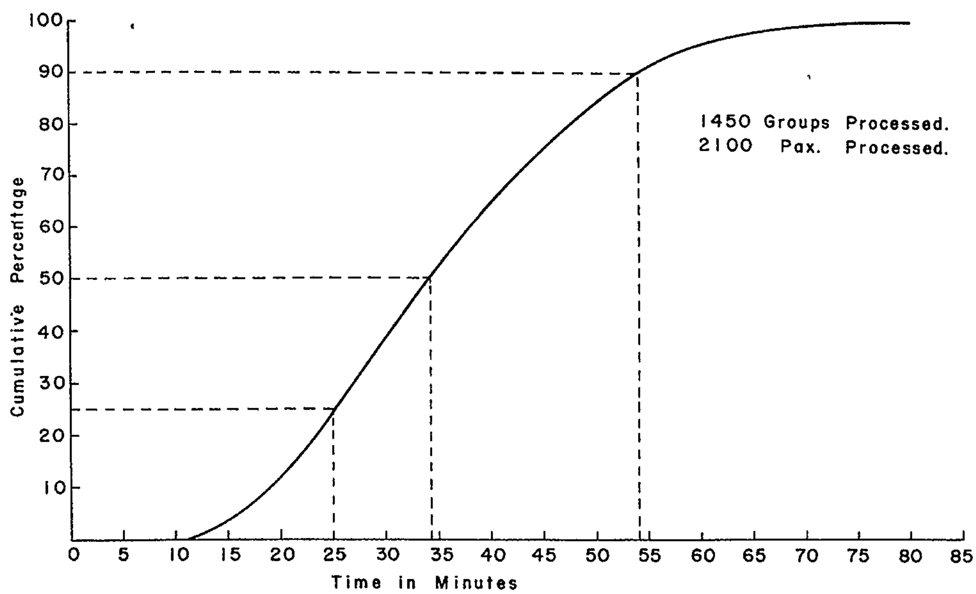

Figure 3. Time Spent in System (Aircraft to Lobby)