Designing an Improved International Passenger Processing Facility: A Computer Simulation Analysis Approach

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During the past 20 years, the management engineering and analysis group of the Port Authority of New York and New Jersey has periodically performed design and operational evaluations of the international passenger processing system facilities at the John F. Kennedy International Airport. The most recent effort included the development and validation of a computer simulation model of the Federal Immigration and Naturalization and Customs Services and the baggage processing operations. This model was developed to perform operational analyses of planned improvements to the federal inspection facilities. The simulation was initially used to evaluate the expected operational performance of two alternative baggage system expansion plans. The model development, initial model application, and results are described in this paper.

The Port Authority of New York and New Jersey is a public agency responsible for promoting and facilitating trade, commerce, and transportation in the New York–New Jersey region. It is a self-supporting bistate agency that finances it activities through bonds paid off by its own revenues. It has about $6 billion invested in existing transportation (tunnels and bridges, airports, bus and marine terminals, rapid transit, etc.) and trade and commerce facilities (World Trade Center, industrial parks, etc.). An equal amount of capital expenditures is currently being spent for new facilities and improvements of existing ones.

The three major New York metropolitan airports are operated by the Port Authority under long-term leases from local governments, and the authority is responsible for such common-use facilities as runways and taxiways, heating, ventilating and air conditioning plant and equipment, roadways, and security, among other things. The Port Authority plans an approximately $3 billion package of expansions and improvements for John F. Kennedy International Airport (JFK), which will include new roadways, a new transportation center, a hotel, and passenger and baggage distribution systems that will serve some 45 million passengers a year by the turn of the century. More than 30 million air travelers currently use JFK annually. The goal is that it will remain competitive and meet air transport needs in the year 2000 and beyond. The International Arrivals Building (IAB) is a common-use facility that handles about 50 international air carriers and their passengers. The Port Authority is responsible for the planning, design, operation, and maintenance of this facility. Both the Port Authority and the airlines using the common federal inspection services (immigration, customs, and agricultural processing) at the IAB are, of course, concerned about the levels of service provided during the interim period from now until the end of the 1990s when the airport redevelopment program is completed.

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MODEL DEVELOPMENT

Objectives and Scope

JFK staff requested the Port Authority to develop a simulation model of the federal inspection services and baggage claim processes. Upon development and validation, the model would be used to evaluate alternative plans, facilities and equipment, and operations in terms of their expected service levels and adequacy to handle future projected demand. It was agreed that the full federal inspection system from "blocking" (arrival at gate) of the aircraft through immigration processing, baggage delivery and pick up, and customs inspection should be modeled because these operations are integral to the system. Desired evaluative data included estimates of flows, queues, and space requirements for each process as well as the expected elapsed times for different categories of passenger from block time to clearing of customs. The initial application, described later, was to evaluate alternative plans to replace existing baggage claim devices, because some extended delays were occurring during peak periods.

Study Duration and Approach

Model development was designed to be completed in 4 months, including model structuring, data collection to obtain processing rates, programming in General Purpose System Simulation (GPSS), validation testing, and reporting on the evaluations. An appropriate model was needed to complete the initial application within 6 months. Primary reasons for choosing GPSS for personal computers was to maintain independence and reduce coordination requirements and possible delays in a mainframe environment. Also, the GPSS "gather" command facilitates increased accuracy in analyzing baggage claim operations by keeping track of individual passenger and bag movements. The simulation assigns each bag to the associated passenger, randomly mixes bags, and models the matching process at the baggage belt so that each passenger leaves the area only when all of his or her bags have arrived. This provides the potential for greater accuracy than treating baggage claim as a fixed processing-rate activity or estimating the number of passenger-bag matches by formula.

Model Assumptions and Inputs

The development of a simulation model of the federal inspection and baggage claim process was important to international airlines to ensure competitiveness and service levels while maintaining reasonable costs at the IAB. Therefore, the management engineering and analysis study team and the Port Authority manager who requested the study met on a number of occasions with the Kennedy International Airport Tenants Association (KIATA), a group representing airline needs and viewpoints, to obtain concurrence on its plans and objectives and to develop a set of assumptions on which the model would be based. Thus, the basic assumptions and methodology were agreed upon before programming the model began. The major concepts and relationships used in the simulation are described in the next section. Input data on flow rates, passenger walking times, baggage delivery and unloading rates, and so on, were obtained by direct observation and data collection. Projected airline schedules and citizen and visitor passenger loadings were available from a previous forecasting study. For the initial application of the model these inputs and assumptions were reviewed and modified as necessary (e.g., level and time frame for passenger demand and arrival) to satisfy the specific requirements of the analysis.

Model Structure

The conceptual basis of the simulation model is that the passenger and baggage flows in the model will predict flows in the actual operation; thus the flowchart mirrors the operation that occurs at the airport. Figure 1 is a simplified flowchart

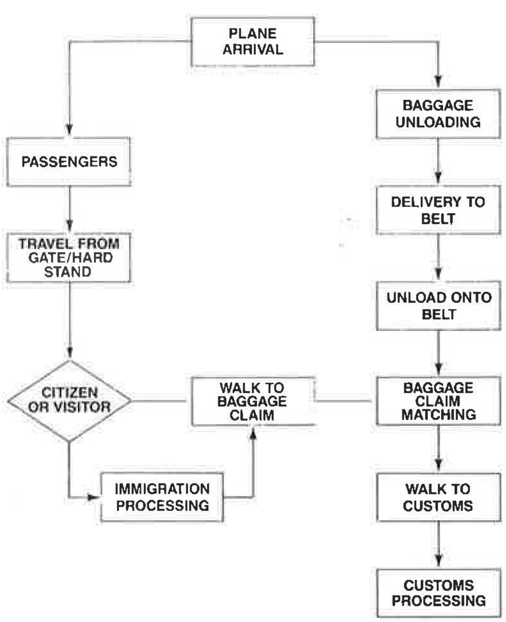

FIGURE 1 Conceptual model of the operation.

of the operation and of the model for each aircraft arrival. Of course, the simulation has its "internal clock" and keeps track of all planes, passengers, and baggage in the system. This flowchart describes the sequence of operations for each plane arrival.

When the simulation reaches the arrival time of the plane, the program stores key data including the block time; the citizen-to-visitor ratio; location of plane arrival at a wing, finger, or remote gate; and the number of passengers and bags. Passenger "transactions" are generated; these are the units that are tracked as they progress through the remainder of the simulation logic over the time being simulated. The model also generates and randomly mixes the apropriate number of bags, each carrying a special code (parameter value) to identify the passenger to whom it belongs.

On the basis of the blocking location (wing, finger, or remote gate) of the flight, passengers are assigned walk times to immigration processing (for those from outside the United States) or to baggage claim (for citizens). Immigration processing rates are based on direct observations of immigration outflows for different numbers of booths in operation. Similarly, times required for delivery of bags to assigned baggage belts and unloading rates for the transfer of bags from delivery cart to belt are based on actual rates observed for specified unloading crew sizes. The passenger-bag matching process at baggage claim is modeled so that a passenger does not leave until all associated bags are available on the belt and claimed. Observations showed that once the passenger and associated bag or bags were available, the bag or bags were claimed within one revolution of the baggage belt. This time is incorporated into the travel to customs for each passenger.

The modeling of the customs operation allows for the designation of three different processing rates—one for "red" booths (for passenger with goods to declare), one for "green" booths (for other passengers), and an expedited processing rate for cases in which total queues exceed a certain level—and "rovers" (additional moving inspectors) are introduced to speed processing.

Output Information

Because the simulation tracks each passenger and bag through the process, there is great flexibility in the types of output that can be obtained to meet a user's needs. Examples of typical output information are described. For each major processing area (immigration, baggage claim, customs), the simulation routinely summarizes waiting time and queue-length data. Queues at each of these operations are typically provided at 5-min (or shorter, if needed) intervals so that the performance of the component parts of the federal inspection process can be tracked through the peak period and interrelationships identified. For example, in baggage claim, this would include both the number of passengers and the number of bags so that estimates of required belt capacities and floor space can be calculated. Delays in unloading bags due to unavailability of belts are also accumulated, if desired. The elapsed times to or between each of the key points in the operation (immigration, baggage claim, and customs) are routinely provided. A wide variety of specialized outputs can be obtained by making minor modifications to the program.

Validation

In addition to cooperative development of assumptions with facility and airline staff and establishment of processing rates and other operational data on the basis of on-site observations to ensure realism and accuracy in the model, an extensive validation test and analysis were performed. On a peak day, two data teams visited the IAB and simultaneously collected operational data. One team obtained input and processing-rate data—plane arrivals, passenger loads, crew sizes, baggage unloading rates, and so on; the other obtained data on flows and service levels—passenger flows out of baggage claim, queue length at 5-min intervals, and so on. The input data were run through the simulation to obtain simulated results at each step in the process for each time period for comparison with the actual observed results. Whenever significant differences occurred, the data were analyzed in detail to determine whether the differences resulted from unpredictable fluctuations (e.g., in citizen-to-visitor ratio or in customs inspection processing rate) or whether they indicated an area in which changes in the model could improve the correspondence between actual and predicted results. This led to a number of model enhancements (e.g., the specification of wing or finger arrivals rather than simply a building gate as opposed to a remote gate arrival).

In sample validation results (Figure 2) as well as all other numerical results in this paper, reasonable but hypothetical values are used because of the sensitivity of the data (in particular the various processing rates for federal inspections). In the authors' opinions, this does not detract from the value of the comparative analyses that were performed and reported here. The remainder of this paper will describe the initial application of the model. Further applications at both JFK and Newark International Airports were subsequently requested.

MODEL APPLICATION

The Federal Inspection Services (FIS) hall is in the IAB, one of nine separate terminals at JFK. International air travelers arriving on foreign-flag carriers are processed through federal immigration and customs inspections at this facility. As noted earlier, following passenger arrival the federal inspection process includes immigration inspection, baggage claim, and customs inspection.

The ability to efficiently process significant numbers of passengers at the baggage claim is critical to providing an efficient overall federal inspection process. This ability has been compromised for some time because of the unreliability and limited baggage processing capabilities of the existing claim devices, which were installed in 1965. These devices do not have sufficient capacity to handle baggage being generated by the predominately wide-body aircraft that now characterize arrivals at the IAB. As a result, bags sometimes must be removed from the devices and stored on the floor to permit subsequent flight arrival processing. Because of downtime and lack of adequate storage capacity, passenger processing times have exceeded desired service standards on occasion. Consequently, arriving international passengers sometimes experience congestion and delay at the baggage claim area. Also, there was concern that desired standards be achieved with the expected increases in passenger volume projected through the 1990s. This concern resulted in a decision to replace the existing claim devices.

Following a review of several design concepts, two alternative baggage system designs were selected for further evaluation of expected service level. The systems were characterized generally as being either "in-ceiling" or "at-grade." Both systems would include eight baggage claim devices, four each in the east and west wings of the IAB. The systems additionally would be continuous-loop flat-plate devices that have interlocking movable plates (covered by a rugged material) that are supported and guided and travel along a framed structure. The systems differed in how the desired baggage storage capacity and the required number of devices within the existing confines of the hall would be achieved. The in-ceiling system would use available unused space and loop above the hall; the at-grade system would employ devices with snakelike configurations using available space on the airside apron adjacent to the hall (Figures 3 and 4). Each system would consist of high-capacity claim devices capable of holding baggage generated from a fully loaded, wide-body aircraft (e.g., 747).

Simulation Modeling Approach

The evaluations of expected service levels for 1990 and 1995 (chosen to evaluate the projected short- and long-term performance of the proposed baggage systems) were done using the GPSS computer simulation model developed for the FIS

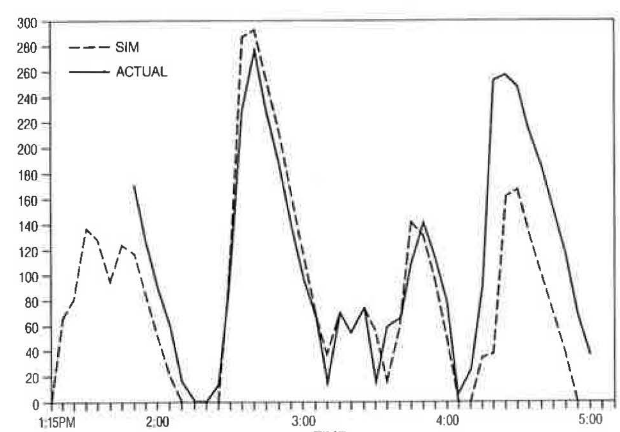

FIGURE 2 FIS model validation—total immigration queue, simulated versus actual.

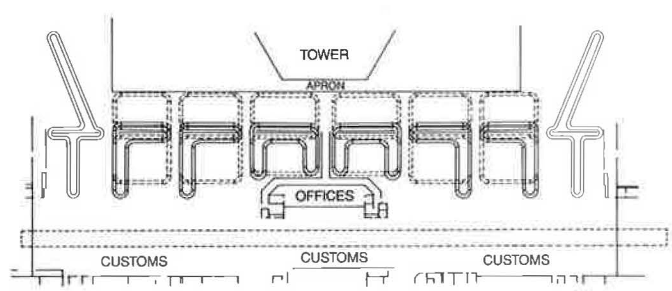

FIGURE 3 Proposed new baggage system—in-ceiling device.

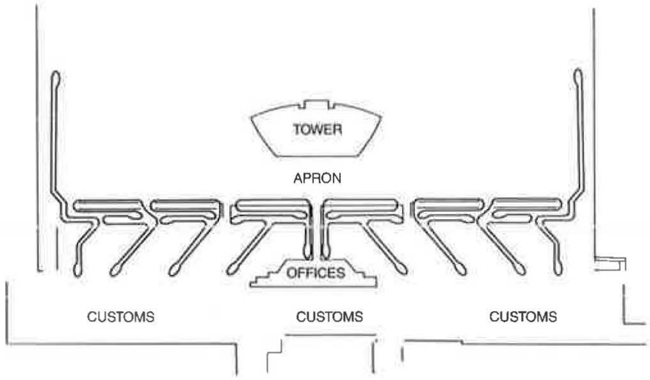

FIGURE 4 Proposed new baggage system—at-grade device.

processes and baggage claim operation. Structuring the simulation model to evaluate the performance of the proposed baggage systems required a modeling approach that incorporated the applicable components of the FIS and baggage claim operations. Specifically, the simulation included the flow and processing of arriving passengers from the plane block through primary immigration inspection or citizen bypass (at immigration) to baggage claim. Similarly, baggage flow from the plane block to the claim device, including dolly train processing and loading onto the claim devices, was simulated (Figure 5). A key element was modeling the matching of passengers and bags, which determines the time spent in the baggage claim area.

Modeling assumptions and input parameters that were broadly discussed earlier were developed for this particular application of the model. The simulation was then run, using summer peak-period passenger demand estimates for 1990 and 1995. This provided information (output at simulated 5-min intervals) for a peak 4-hr period of flight arrivals, which included the number of queued passengers and unclaimed baggage by flight in baggage claim (selected indexes of system performance).

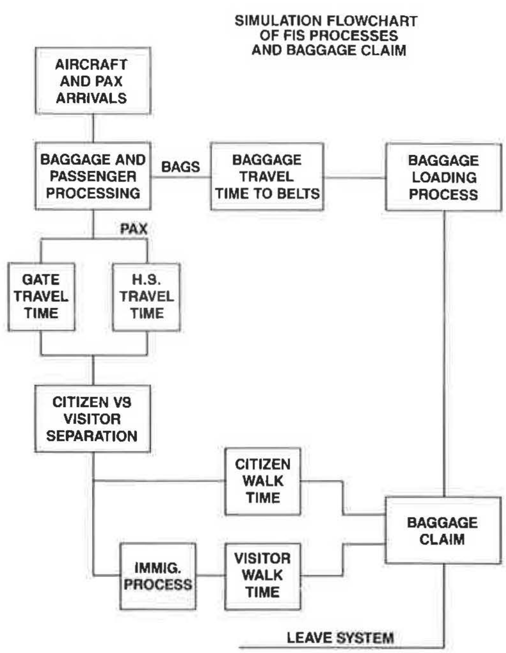

FIGURE 5 Simulation flowchart of FIS processes and baggage claim.

Model Assumptions and Inputs

Passenger Demand

To establish base demand, actual aircraft and passenger arrival information for 26 summer Friday and weekend days in 1987 (which approximated peak conditions) was reviewed. This information was entered into a PC-based spreadsheet to identify the rolling peak hour of demand for each day (e.g., 2:10 to 3:09 p.m.). The average (3,505 passengers) of these peak rolling hours was recommended for use as a base demand volume.

To simulate the processing of passengers through the FIS operation, information relating to actual aircraft arrival times, passenger loadings for a peak period, including a peak rolling hour, was selected from data on the 26 days surveyed. The day chosen was July 3, 1987, with a peak rolling hour volume of 3,468, which approximated the average demand for the 26 days surveyed. Demand was documented for a 4-hr period, which was necessary to "load" the simulation to report results for the peak 3 hr period (2:00 to 5:00 p.m.).

To establish future year demand estimates, growth factors for 1990 and 1995 were documented. These factors were applied to the chosen base passenger loadings to establish the future demand estimates for 1990 and 1995 (Table 1).

The number of citizens and visitors by flight was established by applying a 40:60 percentage split (used by aviation staff for planning purposes at JFK), respectively, to the 1990 and 1995 forecast passenger loadings.

Passenger Travel Time from Plane to Immigration

Travel times for hardstand and gate locations were based on available information and data collected at the IAB (see Table 2).

Visitor Processing

Visitor processing, through primary immigration inspection, assumed full staffing of booths. Also, it was agreed that the modeling of visitor processing through immigration inspection would be based on the current practice of preclearance at the airport of origin for Aer Lingus, Air India, and El Al flights (expected to have this status by 1990). Visitors on these flights therefore did not require primary immigration inspection at JFK. The primary immigration inspection rate used was based on past data collection and discussions with the Immigration and Naturalization Services.

Citizen Walk Time to Baggage Claim

Citizens bypass primary immigration inspection and proceed directly to the baggage claim area. Citizen walk time from

TABLE 1 FUTURE YEARS' PEAK PERIOD DEMAND ESTIMATES

FLIGHT	TIME	WING	BLOCK LOC	PASSENGERS 1987	1990	1995
FF33	1305	EAST	HS	476	533	643
SR110	1305	EAST	F	322	361	435
VA800	1315	EAST	W	47	53	63
SF4116	1325	WEST	HS	469	525	633
EI103	1350	EAST	W	330	370	446
SK903	1405	WEST	F	211	236	285
DF3306	1425	EAST	HS	359	402	485
AZ610	1435	WEST	F	353	395	477
NW43	1435	EAST	HS	283	317	382
SK911	1440	WEST	F	225	252	304
PK715	1440	WEST	W	304	340	410
KL645	1450	EAST	F	373	418	504
LH410	1455	EAST	W	77	86	104
SR100	1455	WEST	W	331	371	447
AF077	1500	WEST	W	318	356	429
BB692	1510	WEST	HS	345	386	466
NW37	1510	EAST	HS	127	142	171
IB951	1515	EAST	F	373	418	504
BR267	1525	WEST	F	242	271	327
LH408	1540	EAST	W	214	240	289
AY105	1545	WEST	HS	224	251	302
MS985	1555	EAST	HS	385	431	520
NW18	1600	EAST	HS	329	363	444
LH404	1605	EAST	W	312	349	421
SK901	1610	WEST	W	220	246	297
EI105	1625	EAST	F	246	276	332
AI109	1635	WEST	F	385	431	520
OA411	1640	WEST	HS	195	218	263
KL641	1650	EAST	W	382	428	516

Hypothetical Data

TABLE 2 PASSENGER ARRIVAL DISTRIBUTIONS

LOCATION	ELASPED TIME BLOCK TO PASSENGER ARRIVAL AT IMMIGRATION	NUMBER OR PERCENT OF ARRIVING PASSENGERS
Hardstand 1	20 minutes	first passenger
Hardstand	25 minutes	66% of flight
Hardstand	30 minutes	100% of flight
Gate/Wing 2	10 minutes	first passenger
Gate/Wing	15 minutes	75% of flight
Gate/Wing	20 minutes	100% of flight
Gate/Finger 2	5 minutes	first passenger
Gate/Finger	10 minutes	75% of flight
Gate/Finger	20 minutes	100% of flight

1. Hardstands are remote locations from the IAB where planes block

2. Wing or Finger denote different gate locations at the IAB where planes block

the beginning of the bypass in the immigration area to baggage claim was measured at 2 min and was used as the basis for simulating this movement.

Baggage Processing

The modeling of baggage processing encompassed the movement of bags for each arriving flight, from plane blocked at a building or remote gate to loading onto claim devices. The assumptions and inputs used for simulating these activities included the following:

- The number of bags by flight was 1.5 bags/passenger (consistent with current planning assumptions).
- Dolly train travel time, from plane block to the claim device area for the first consist, was measured at average values of 15 min for flights arriving at building gates and 20 min for remote gates. From the data collected, baggage loading from the dolly trains to belts for each flight was observed to be a continuous operation, with no delays occurring between loadings from the dolly transports.
- A staffing level of 12 handlers/wing (east and west) in the load area was assumed on the basis of discussions with JFK operations staff and observations made. A loading rate of 6 bags/min/handler was used (consistent with observations and current planning assumptions). This figure represented an average processing rate, with allowance for handler fatigue.

Baggage Claim

It was assumed that passengers claim baggage individually and that all pieces must be claimed before the passenger can depart from the claim area. Passengers were randomly assigned a processing time for seeking, claiming, and loading baggage onto a cart from a time distribution ranging from 3.5 to 6.5 min. This time distribution was based on the observation that passengers claim baggage before a second full revolution of their baggage on the claim device occurs and that passenger seek time includes their movement from the baggage area entrance to a specific claim device and time required to locate and select their baggage.

Approach for Evaluating Alternative Baggage Claim Systems

Output from the simulation model on the number of passengers and bags in the baggage claim area by flight by 5-min interval was used as input for the Lotus 1-2-3 spreadsheet for each system, year (1990 and 1995), and east or west wing of the IAB. The spreadsheet also included the characteristics of each baggage system under review (e.g., number of devices and maximum baggage storage). The information contained in the spreadsheet and the operating procedures in the claim area, which were documented by discussions with baggage operations staff, were used for making flight assignments by claim device (Figure 6) and subsequently for evaluating the performance of each system. The criteria used for making the assignments are as follows:

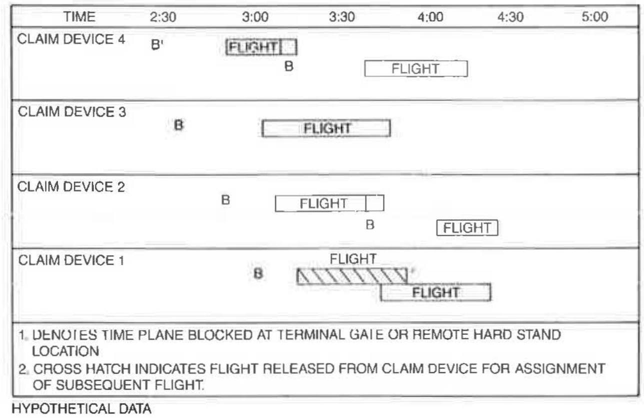

FIGURE 6 Proposed new baggage systems—example of flight assignments by claim device, year 1995, east wing.

1. Flights arriving at each wing (east or west) are assigned to a claim device on a first-come, first-served basis, and
2. When all devices in a wing are in use, the device serving the flight with the minimum number of bags left to be claimed is chosen for the assignment of the next arriving flight. This practice causes bags for the flight being served to be removed from the claim device and placed on the floor.

For each of the systems under review, information concerning the maximum number of bags that could be stored on the claim devices and the area available for passengers or passengers and bags around the devices was developed and input into the spreadsheet as constants for evaluative purposes. Then, given the flight-to-claim device assignments, number of bags in claim areas by device, and the storage characteristics for each of the proposed systems, formulas were employed within the spreadsheet logic to generate (at 5-min intervals) the number of bags on a device versus on the floor by claim device. Similarly, using this information and the number of passengers in the claim area by device, the percentage of floor area in use around each claim device was derived. The numerical results for these two measures of device performance were then translated graphically for each of the alternative systems by year (1990 and 1995) and by east and west wing of the IAB.

Results and Recommendations

On the basis of design and installation considerations, either the in-ceiling or at-grade system was identified as being an acceptable alternative for replacement of the existing baggage claim system. For this reason, a comparative evaluation of the systems' operational performance was considered a critical ingredient to the decision-making process. As mentioned previously, the criteria used to evaluate system performance in years 1990 and 1995 included

1. The number of bags removed from a claim device and placed on the floor because the bag storage capacity of the device was exceeded or because the device had to be cleared

for assignment so that a subsequent flight arrival could be assigned; and

2. The percentage of dedicated floor space around each claim device used for the storage of bags removed from a device and passengers waiting to claim baggage.

Although the in-ceiling system had only moderately lower practical operational capacity, it showed a significantly lower level of performance when compared with the at-grade system. For the in-ceiling system, large volumes of bags would be required to be placed on the floor, with the situation worsening markedly from 1990 to 1995 (Figures 7–14). This was largely because the storage capacity of the devices was exceeded and not a result of bag placement on the floor to clear devices for flight assignment. Also, the increase in passenger demand levels projected for 1995 would generate higher numbers of bags and therefore exacerbate situations exceeding storage capacity.

Generally, significantly less floor space was used by the at-grade alternative when compared with the in-ceiling proposal (Figures 15–22). Interestingly, for 1995, there was a noticeable decrease in service level (floor space criterion) for the in-ceiling system, although for the at-grade system, projected

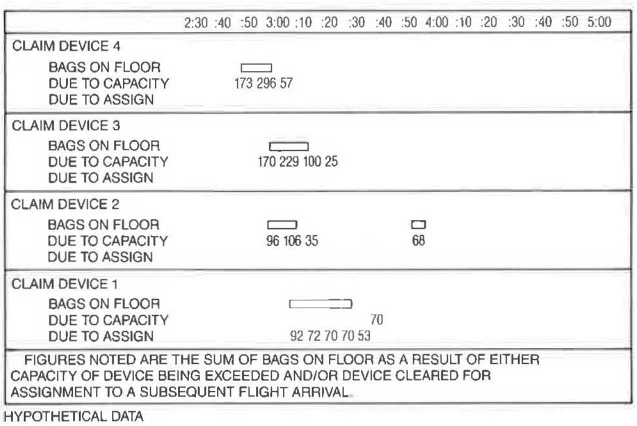

FIGURE 7 Proposed new in-ceiling baggage system—year 1990, bags on floor—east wing.

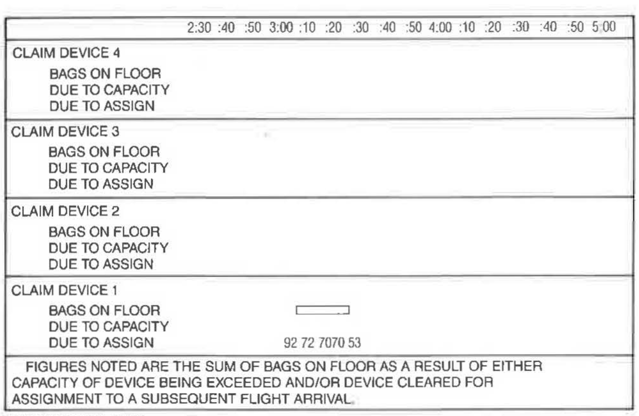

FIGURE 8 Proposed new at-grade baggage system—year 1990, bags on floor-east wing.

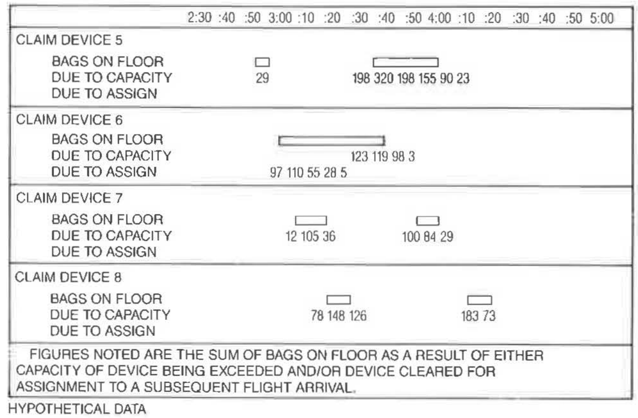

FIGURE 9 Proposed new in-ceiling baggage system—year 1990, bags on floor—west wing.

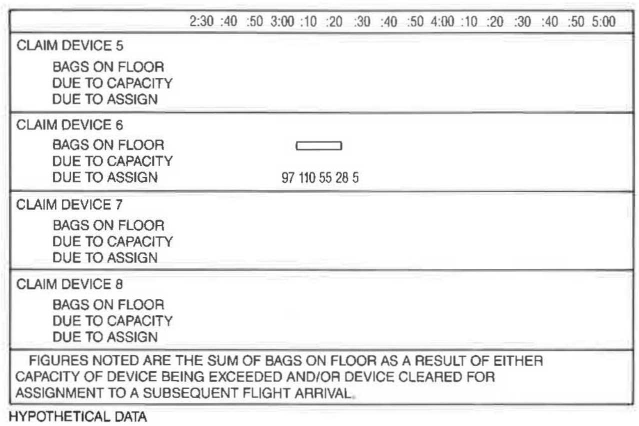

FIGURE 10 Proposed new at-grade baggage system—year 1990, bags on floor—west wing.

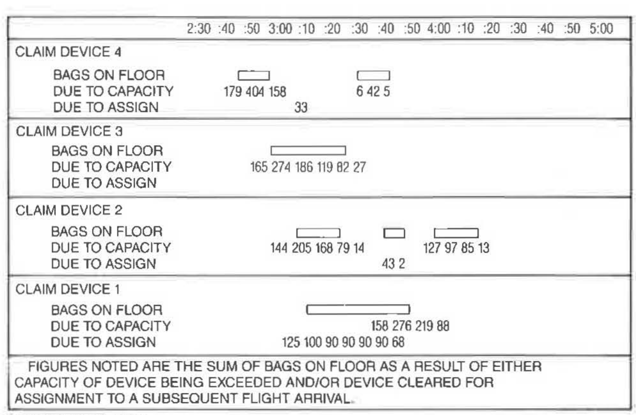

FIGURE 11 Proposed new in-ceiling baggage system—year 1995, bags on floor—east wing.

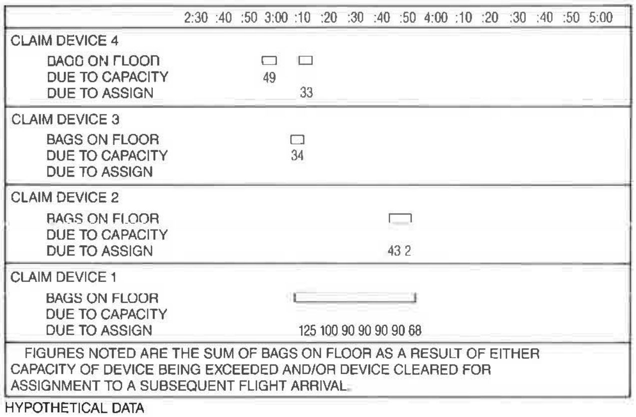

FIGURE 12 Proposed new at-grade baggage system—year 1995, bags on floor—east wing.

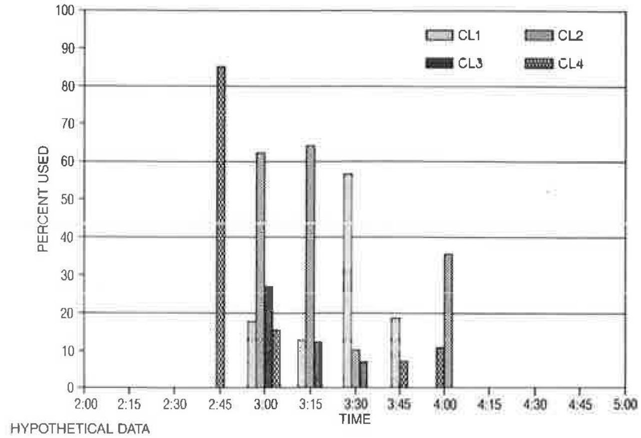

FIGURE 15 Proposed new in-ceiling baggage system—1990 percent of floor space utilized—east wing.

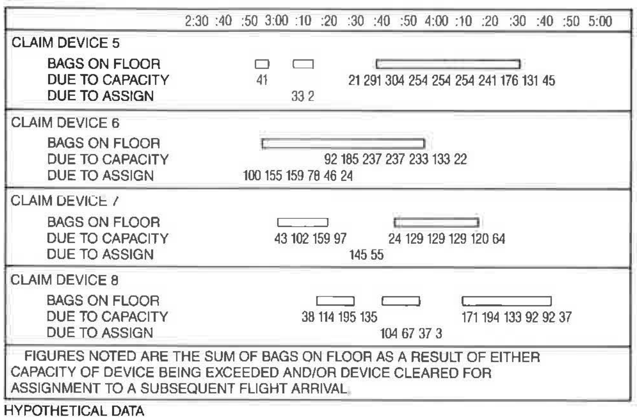

FIGURE 13 Proposed new in-ceiling baggage system—year 1995, bags on floor—west wing.

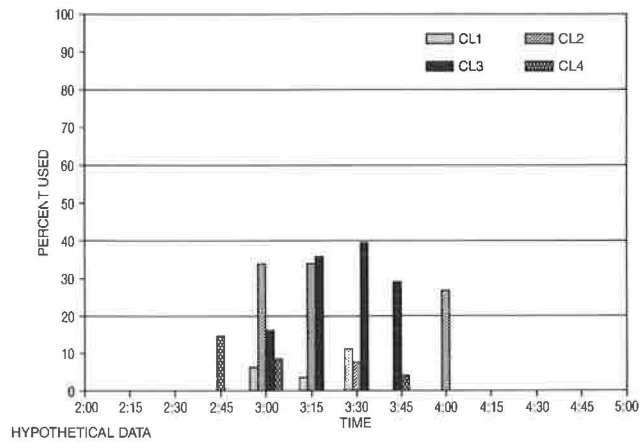

FIGURE 16 Proposed new at-grade baggage system—1990 percent of floor space utilized—east wing.

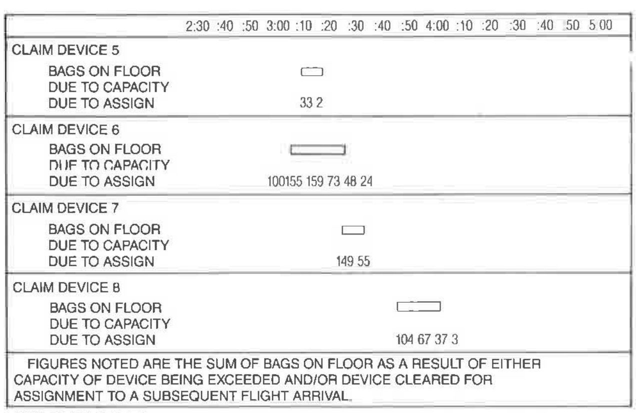

FIGURE 14 Proposed new at-grade baggage system—year 1995, bags on floor—west wing.

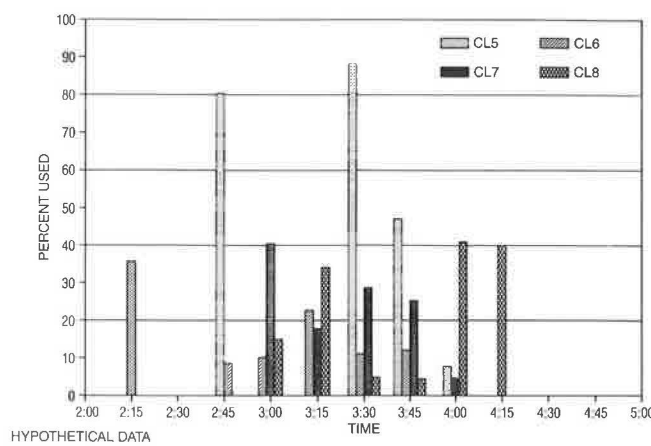

FIGURE 17 Proposed new in-ceiling baggage system—1990 percent of floor space utilized—west wing.

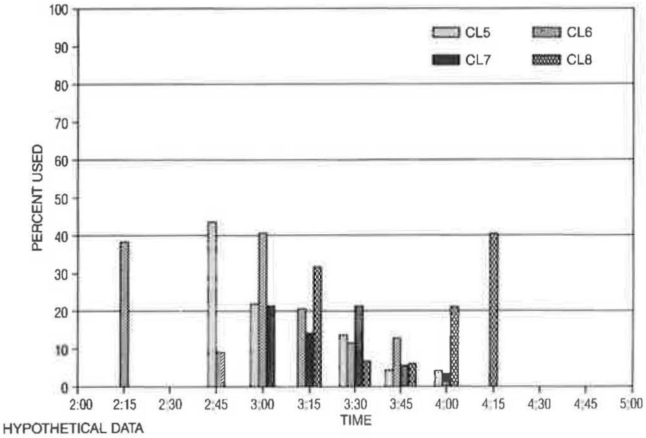

FIGURE 18 Proposed new at-grade baggage system—1990 percent of floor space utilized—west wing.

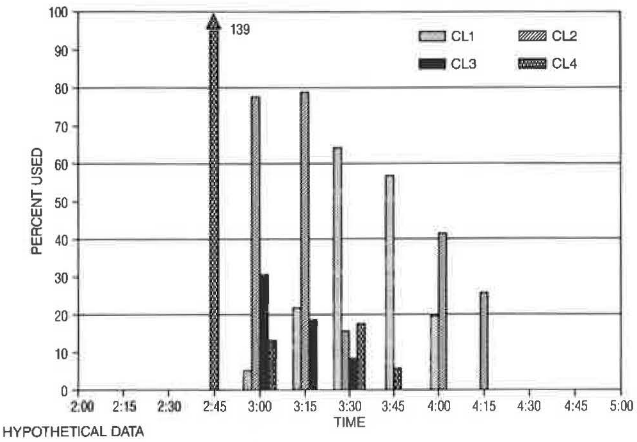

FIGURE 19 Proposed new in-ceiling baggage system—1995 percent of floor space utilized—east wing.

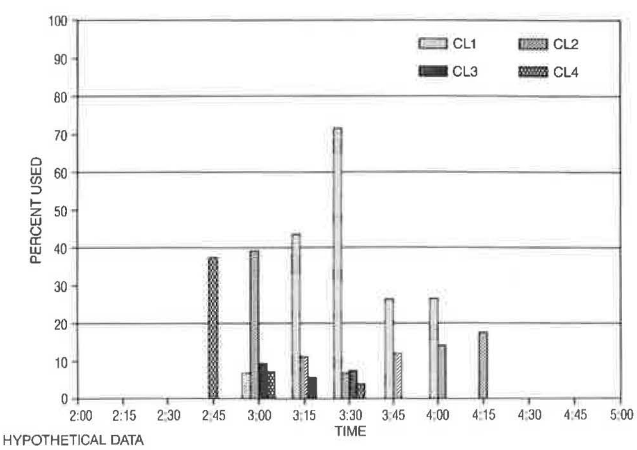

FIGURE 20 Proposed new at-grade baggage system—1995 percent of floor space utilized—east wing.

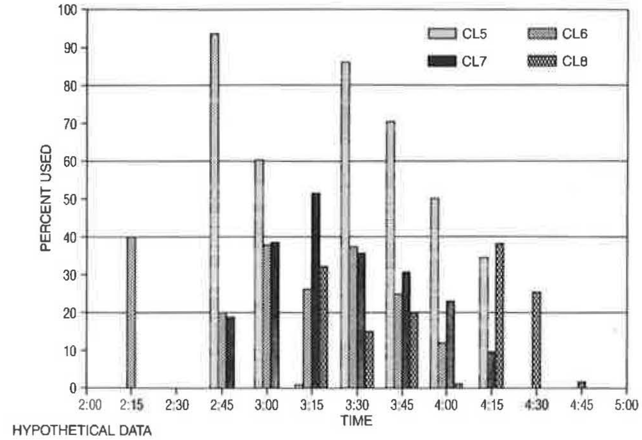

FIGURE 21 Proposed new in-ceiling baggage system—1995 percent of floor space utilized—west wing.

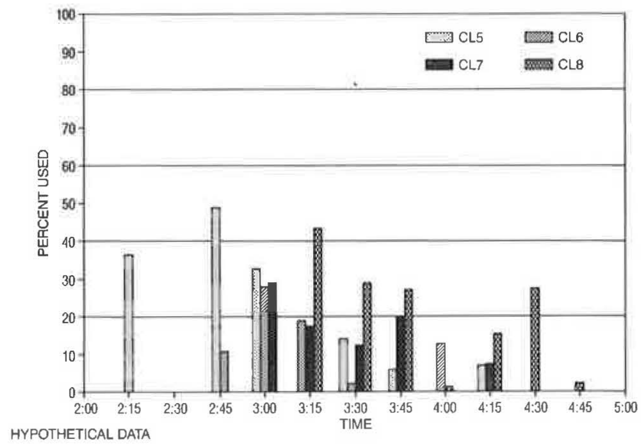

FIGURE 22 Proposed new at-grade baggage system—1995 percent of floor space utilized—west wing.

service levels for 1990 were generally maintained through 1995, despite the higher expected demand level.

Hence, because of higher service levels projected for the at-grade system, it was preferred operationally and was recommended to replace the existing system. The system, which was also found to be less costly than the other alternative, was being installed at the time of this writing.

SUMMARY

This project developed and validated a computer-based simulation model that could be used for various analyses relating to the Federal Immigration and Naturalization and Customs Inspection Services system facilities. The initial application of the model led to selecting a new baggage claim system, largely on the basis of its operational attributes, which were shown through the model to improve service levels for international air travelers through the 1990s.

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