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THE ROLE OF MODELING DEMAND IN PROCESS RE-ENGINEERING

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ABSTRACT

Process modeling of airline passenger processes from their arrival at the airport until they board their flight requires a model of the arrival process of passengers at the airport. The model of passenger arrival describes the varying arrival rate of passengers at the airport. This paper describes a method for quickly modeling passenger arrival using publicly available airline data.

1 INTRODUCTION

Passenger airport process modeling via discrete-event simulation requires modeling of the arrival process of passengers at the airport prior to their flight. Accurate modeling of the arrival process enables simulation analysis of the capacities of airline ticket counters, security checkpoints and airline gate counters. The passenger airport process is a service system in which passenger arrival rates vary over time. As a result of the varying passenger arrival rate, the need arises to match capacities with demand so that the passengers experience an acceptable service level. Matching capacity with demand also prevents overstaffing of personnel. An example of the service level would be 100 percent of passengers wait less than 10 minutes at the ticket counter queue.

Passenger arrival at the airport is driven by four factors:

1. Flight schedules
2. Passenger load factors
3. Passenger transfer rates
4. Passenger arrival behavior

1.1 Flight Schedules

Flight schedules vary by month and day of week. Typically more flights are scheduled during the summer months than winter months. Flight schedules are obtained from public sources for a week (the flight schedule for the chosen week contains the volume of passengers that meets design requirements of the process modeling).

1.2 Passenger Load Factors

Passenger load factors are the number of passengers who flew on the aircraft divided by the total available seats. Passenger load factor is an airline industry term and should not be confused with the ratio of a specified load to the total weight of the aircraft (specified load is expressed in terms of any of the following: aerodynamic forces, inertia forces, or ground or water reactions <http://www.faa.gov/avr/afs/fars/far-1.txt>). The airline industry term refers to the ratio between passengers and seats. For example, an airplane with 100 seats that has 90 passengers onboard would have a load factor of 90 percent. Passenger load factors also vary by airline, day and by time of day. Passenger load factors are typically greater on Monday, Thursday and Friday and lower on Tuesday and Wednesday. The days on which the load factors and schedules are greater than other days of week are known as peak days. The days with the lower load factors than the peak days are known as non-peak days.

1.3 Passenger Transfer Rates

Transfer rates are the percent of passengers who arrive at the airport via an arriving flight and depart on a connecting flight. During the transfer passenger's journey from one flight to another they never leave the secure sterile area of the concourse. In regard to transfer rates, airports are classified as origin-and-destination airports and hubs. Origin-and-destination airports typically have lower transfer rates than hubs because passengers either begin or end their travel at these airports. Average transfer rates at origin-and-destination airports are approximately 5 percent. Airport hubs typically have a higher transfer rate than origin-and-destination airports because passengers are using the airport to connect between their origin and destination cities. Hub airports can have up to an 80 percent transfer rate. Eighty percent of the passengers who depart from the hub airport do not go through the passenger airport process and must not be included in the model of passenger arrival at the airport.

1.4 Passenger Arrival Behavior

Passenger arrival behavior at the airport is captured by passenger arrival distributions. The passenger arrival distributions describe the number of passengers and the time at which the passengers arrive at the airport prior to departure of their flight. Industrial engineers at airlines measure the time at which passengers check in prior to their flight and then create a passenger check-in distribution. The graph of the passenger check-in data is known in the industry as a "check-in curve" (See Figure 1).

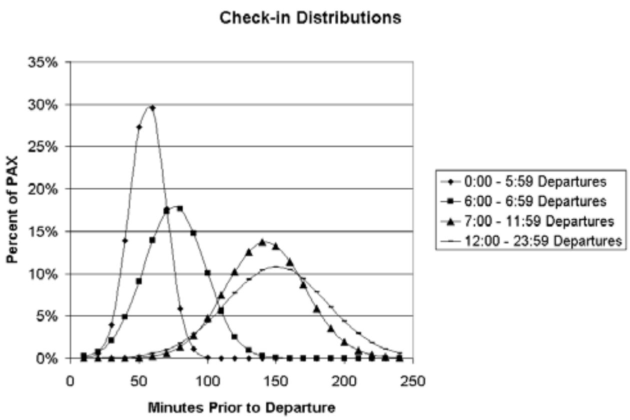

Figure 1: Passenger Check-In Distributions

Check-in distributions are used by airlines to staff the number of personnel at ticket counters and gate counters. Passengers often have many choices for the check-in location. For example, the passenger can check in with the skycap on the airport curb, an electronic kiosk, a ticket counter agent or a gate agent.

Passenger arrival behavior varies by factors such as time of day, airport check-in rules and type of traveler. All factors should be considered before choosing a distribution for the modeling of passenger arrival. Passenger arrival distributions with a shape parameter that makes them narrower typically apply to early-morning flights and business travelers. The morning passenger arrival distribution tends to have a narrow shape because passengers are arriving as close as possible to their departure time. As the day progresses the distribution tends to become wider and flatter, indicating passenger arrival is more dispersed and the passengers are arriving at the airport earlier to allow more time between their arrival to the airport and their scheduled departure time. The mean arrival time for passengers on early-morning flights is approximately 50 minutes (See Figure 1). The mean arrival time for passengers for afternoon flights is approximately 144 minutes (See Figure 1). Business travelers minimize their time at the airport by arriving closer to the flight departure time than leisure travelers.

2 APPROACH

Modeling of the passenger arrival process provides an estimate of how many passengers arrive at the airport during each day and time of day. The modeling approach summarizes the passenger data into the number of passengers who arrive at the airport in 30-minute intervals. The raw passenger volume per time interval is the end product of the analysis and is referred to as the passenger arrival pattern (See Figure 2). The passenger arrival pattern can be converted from the raw arrivals per interval into the appropriate arrival rates required for non-stationary Poisson processes. The passenger arrival pattern provides the number of passengers who arrive in 30-minute intervals for a 7-day period.

2.1 Data for Model

The next sections outline the data collection approach for the four key inputs.

2.1.1 Flight Schedules

Flight schedules can be obtained from public sources such as Official Airline Guide (OAG) or Flight Schedule Data System (FSDS). The model of the passenger arrival process is built for the design week. Capacity modeling of the ticket counters, security checkpoint and gate counters requires a schedule that is representative of a peak volume week so that infrastructure can be built to meet acceptable service levels.

2.1.1.1 Determine Peak Week

Queries in the FSDS database can estimate the peak passenger volume month and then peak passenger volume week. This estimate of peak volume is based on the number of passenger seats available. The FSDS reports provide for a given airport the number of seats available per month. For example, at Chicago O'Hare International Airport (ORD) a report provided by the FSDS estimated that the peak month defined by seats in 2001 was August (See Table 1).

Table 1: Report Data from FSDS: Monthly Seats Scheduled (August Peak Month) at ORD

FSDS Report

From 01/2001 To 12/2001 | Departure=ORD

Date	Flights	Seats
Sub Total For : 08/2001	**42,441**	**4,945,456**
Sub Total For : 07/2001	41,873	4,867,426
Sub Total For : 09/2001	40,423	4,723,521
Sub Total For : 05/2001	40,424	4,702,933
Sub Total For : 10/2001	40,069	4,659,248
Sub Total For : 06/2001	39,694	4,633,804
Sub Total For : 03/2001	39,174	4,565,324
Sub Total For : 01/2001	38,988	4,523,713
Sub Total For : 04/2001	38,569	4,516,915
Sub Total For : 02/2001	35,301	4,089,883
Sub Total For : 12/2001	34,701	3,919,722
Sub Total For : 11/2001	33,761	3,848,388
Total:	465,418	53,996,333

At O'Hare International Airport, August was the peak month with 42,441 flights with 4,945,456 seats. The next step is to find the peak week in August. An FSDS query on just August will provide the seat volume by day (See Table 2).

Table 2: FSDS Report Data: Seats by Day at ORD

FSDS Report

From 8/1/2001 To 8/31/2001 | Departure=ORD

#	Date	Departure	Lve.Airport Name	Flights	Seats	
1	8/1/2001	ORD	CHICAGO O`HARE INTL	1,391	160,761	Wednesday
2	8/2/2001	ORD	CHICAGO O`HARE INTL	1,400	162,497	Thursday
3	8/3/2001	ORD	CHICAGO O`HARE INTL	1,387	161,790	Friday
4	8/4/2001	ORD	CHICAGO O`HARE INTL	1,287	151,625	Saturday
5	8/5/2001	ORD	CHICAGO O`HARE INTL	1,342	156,317	Sunday
6	8/6/2001	ORD	CHICAGO O`HARE INTL	1,386	161,807	Monday
7	8/7/2001	ORD	CHICAGO O`HARE INTL	1,386	161,051	Tuesday
8	8/8/2001	ORD	CHICAGO O`HARE INTL	1,392	160,658	Wednesday
9	8/9/2001	ORD	CHICAGO O`HARE INTL	1,398	162,324	Thursday
10	8/10/2001	ORD	CHICAGO O`HARE INTL	1,384	161,256	Friday
11	8/11/2001	ORD	CHICAGO O`HARE INTL	1,283	151,272	Saturday
12	8/12/2001	ORD	CHICAGO O`HARE INTL	1,341	156,483	Sunday
13	8/13/2001	ORD	CHICAGO O`HARE INTL	1,385	161,872	Monday
14	8/14/2001	ORD	CHICAGO O`HARE INTL	1,384	161,040	Tuesday
15	8/15/2001	ORD	CHICAGO O`HARE INTL	1,389	160,651	Wednesday
16	8/16/2001	ORD	CHICAGO O`HARE INTL	1,397	162,250	Thursday
17	8/17/2001	ORD	CHICAGO O`HARE INTL	1,385	161,688	Friday
18	8/18/2001	ORD	CHICAGO O`HARE INTL	1,285	151,597	Saturday
19	8/19/2001	ORD	CHICAGO O`HARE INTL	1,339	156,064	Sunday
20	8/20/2001	ORD	CHICAGO O`HARE INTL	1,383	161,565	Monday
21	8/21/2001	ORD	CHICAGO O`HARE INTL	1,384	160,995	Tuesday
22	8/22/2001	ORD	CHICAGO O`HARE INTL	1,389	160,628	Wednesday
23	8/23/2001	ORD	CHICAGO O`HARE INTL	1,397	162,268	Thursday
24	8/24/2001	ORD	CHICAGO O`HARE INTL	1,386	161,794	Friday
25	8/25/2001	ORD	CHICAGO O`HARE INTL	1,284	151,233	Saturday
26	8/26/2001	ORD	CHICAGO O`HARE INTL	1,341	156,484	Sunday
27	8/27/2001	ORD	CHICAGO O`HARE INTL	1,383	161,861	Monday
28	8/28/2001	ORD	CHICAGO O`HARE INTL	1,383	161,105	Tuesday
29	8/29/2001	ORD	CHICAGO O`HARE INTL	1,389	160,757	Wednesday
30	8/30/2001	ORD	CHICAGO O`HARE INTL	1,396	162,191	Thursday
31	8/31/2001	ORD	CHICAGO O`HARE INTL	1,385	161,572	Friday
Total:				42,441	4,945,456	

From the monthly query, the peak week in August 2001 was estimated as Monday, August 13, 2001, to Sunday, August 19, 2001. The next step is to obtain flight schedules from the FSDS for the August 13 week.

A week in July or August generally represents peak volume. An analysis of 70 Category X (largest airports) and Category 1 airports indicated that 45 of the airports have the most seats available in August or July.

2.1.2 Passenger Load Factors

Average Passenger (pax) load factors by month can be obtained from Department of Transportation (DOT) sources or directly from the airlines. Load factors are reported as a percent.

$$\text{Pax Load Factor} = \frac{\text{Pax boarded}}{\text{Total Pax Seats on Aircraft}} \qquad (1)$$

Collect average load factors for each airline for each day of the week.

2.1.3 Passenger Transfer Rates

Transfer rates vary by carrier but are generally assumed to be constant by time of day and day of week. Collect average transfer rates for each airline.

2.1.4 Passenger Arrival Behavior

Choosing the correct passenger arrival distribution requires an understanding of the time the first wave of flights ends in the morning, the percent of business vs. leisure travelers and any airport or airline check-in rules. Choose passenger arrival distributions that match the characteristics of the airport.

2.2 Build Model

The approach for obtaining the number of passengers who arrive at the airport starts with the number of airline seats available per day. The number of seats available is then reduced by the number of empty seats on the aircrafts. At this point, the number of passengers departing from the given airport is known. The third step is to apply the transfer percents and remove passengers who transferred from one flight to another and never went through the security process. At this point, the number of passengers who arrive at the airport and the passengers' departure time is known. The fourth and final step is to calculate at what time the passengers arrive at the airport. The passenger arrival distribution determines at what time prior to passengers' flight departure time they arrive at the airport. The next section describes how the collected data is combined to produce the passenger arrival pattern for one week.

2.2.1 Combine Inputs

Organize the flight schedule data so that the following data are available for calculations: flight departure time, airline carrier and number of available seats per flight. At this point, the total number of seats by flight time is known. The empty seats must be removed from the passenger total. Apply each airline's average load factor by day to each flight to calculate the average number of seats occupied on each aircraft. At this point, the average total number of seats occupied per flight is known. The third step is to remove the number of passengers who transferred from one flight to another flight. Using the transfer rates, calculate for each flight the average number of passengers who transferred from another flight and subtract the total from the seats occupied. At this point, the number of passengers who arrive at the airport is known as well as the time at which their flight departs the airport. The fourth and final step is to estimate the time at which each passenger arrived at the airport. Using the passenger arrival distributions, calculate for each flight the number of passengers who arrive at the airport prior to their flight time for each 10-minute interval. For each flight, the total passenger count would be divided into 24, 10-minute buckets. Each 10-minute interval bucket would contain the number of passengers who arrived during that interval.

Each passenger is assigned an arrival time. The first arrival time is the departure time minus 10 minutes and the second arrival time is the departure time minus 20 minutes, etc (See Table 3).

Table 3: Example of Spreading 135 Passengers Using a Morning Passenger Arrival Distribution

3:00 PM Departure of Flight		
Passenger Arrival Time	Passenger Check-in Distribution	Number of Passengers Per Interval
3:00 PM	0%	0
2:50 PM	1%	1
2:40 PM	2%	3
2:30 PM	5%	7
2:20 PM	9%	12
2:10 PM	14%	19
2:00 PM	17%	23
1:50 PM	18%	24
1:40 PM	15%	20
1:30 PM	10%	14
1:20 PM	6%	8
1:10 PM	3%	3
1:00 PM	1%	1
12:50 PM	0%	0
12:40 PM	0%	0
12:30 PM	0%	0
12:20 PM	0%	0
12:10 PM	0%	0
12:00 PM	0%	0
11:50 AM	0%	0
11:40 AM	0%	0
11:30 AM	0%	0
11:20 AM	0%	0
11:10 AM	0%	0
Total:		135

After spreading the passengers using the passenger airport arrival distributions, the data set contains a set of passengers and their arrival times. The next step is to organize the passenger arrival times into the raw number of arrivals during 30-minute periods for the 24-hour day. The 7-day model is built by repeating the process for the remaining 6 days of the week.

The graph of the data series of the passenger arrival depicts various peaks, troughs and periods of complete inactivity (See Figure 2). The peaks represent the greatest arrival rate of passengers at the airport.

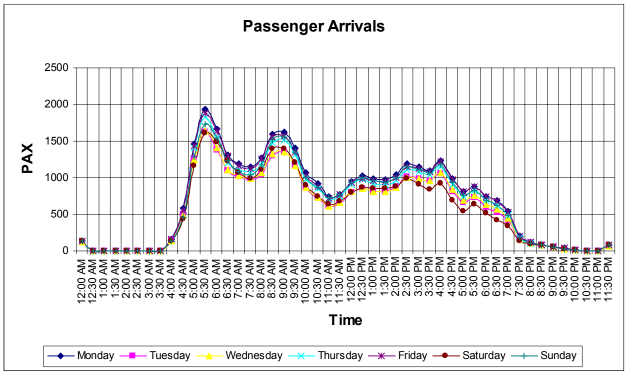

Figure 2: Intra-Day Passenger Arrival Pattern for 7 Days for a Large International Airport

2.3 Validate Model

Validation of the model is accomplished by observing actual passenger arrivals at the security checkpoint lines. During passenger observation, the time at which each passenger joins the security checkpoint line is recorded. Observations should be made during all major peaks and troughs. The collected observation data can be organized into the same format as the passenger arrival pattern for comparison to the model. The passenger arrival data series can be divided into peak and non-peak days. Figure 3 depicts the graph in which observed passenger arrival data were graphed with the model data. Figure 4 depicts a detailed view of peak passenger arrival graphed with observed passenger arrival data.

2.4 Revise Model

If the pattern of the observed data does not match the pattern predicted by the model data, then assumptions in the model should be revisited. A starting place for updating the model is to verify that the passenger check-in data is valid. Differently shaped passenger check-in distributions should be applied. In addition to differently shaped check-in distributions, the time at which the curve applies can be changed. For example, the morning rush might extend to 8:00AM rather than ending at 7:00AM. As a result, the narrowly shaped morning rush distribution should be applied to flights that depart at or before 8:00AM.

3 RESULTS

The modeling approach described in this paper enables the rapid development of the passenger arrival process at the airport. The model is built using publicly available data and provides a passenger arrival pattern for 30-minute intervals over a 7-day period. The model describes how many passengers arrive at the airport as well as the time of their arrival.

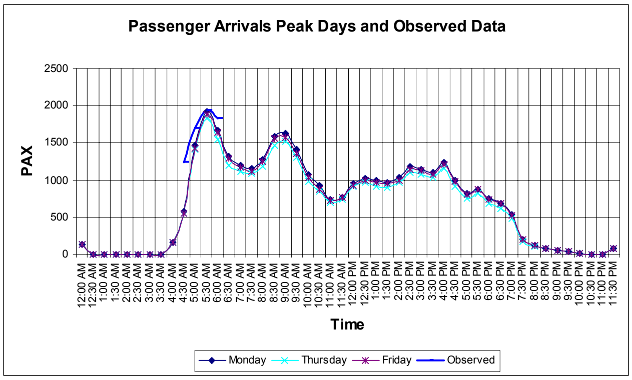

Figure 3: Intra-Day Passenger Arrival Pattern from Model for Peak Days with Peak Day Observed Passenger Data

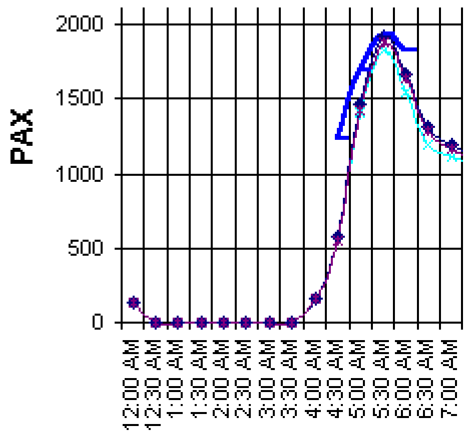

Figure 4: Detailed View of Peak Passenger Arrival with Observed Passenger Arrival Data

For the passenger arrival pattern, flight schedules and check-in distributions act as shape parameters, and load factors and transfer rates are volume factors.

After verification, the model can be used to build a set of arrival rates to define a non-stationary Poisson process needed for simulation modeling of the airline passenger process.

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