SIMULATION ANALYSIS OF PASSENGER CHECK IN AND BAGGAGE SCREENING AREA AT CHICAGO-ROCKFORD INTERNATIONAL AIRPORT

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***Abstract* – Air transportation today is probably the most effective and convenient mode of traveling, considering the short travel time and the increasing affordability for people. The airport is always a place of rush with people traveling back and forth, as well as a large number of flights flying in and out of the region. The various operations inside the airport terminal are not always easy. At peak times, airport operations can become very busy and cumbersome. By using simulation, the airport system can be modeled into a computer program, and the effects of various parameters – such as number of passengers on a flight and number of flights a time – can be studied. Thus steps can be taken for effective operation during such conditions. In this paper, the passenger check in area and the baggage screening area have been simulated using an object based simulation modeling tool, FLEXSIM. After completing the model, various scenarios were evaluated to provide an optimum working scenario for efficient operation.**

I. INTRODUCTION

Defining the various functions, operational units and constraints of a working system, providing a certain set of input variables and operational conditions, and observing the resulting changes in the output variables in a virtual computer based model in order to understand the effects of changing conditions in a system may be considered as Discrete Event Simulation (DES). Simulation is a very efficient tool for optimization and development of systems. When the variables of the system are deterministic and simple linear methods can be applied to solve for the optimal solution, simulation may not be a good option to represent the system. However, when the variables of the system are probabilistic and there exists a lot of stochasticity, using simulation is the perfect representation of the system. The working system being studied in this paper is an airport management system. In an airport the basic variables that need to be considered are passenger arrival rate, check in times, number of passengers on a flight, baggage screening times, security checking times, waiting times, etc. All of the mentioned variables are probabilistic and thus it is necessary to consider these stochasticities while trying to solve for an optimal solution for effective operation.

With the increasing number of people traveling both domestic and international, efficient operation of an airport system to minimize customer inconvenience, without having to compromise with security standards, becomes an important issue. Simulation tools have proven to be very effective in this sector for providing forecast models of various scenarios, which help in making operational decisions in airport management. The various sectors that can benefit from simulation analysis are Passenger Check-In, Security Checkpoint, Baggage Screening, Baggage Claim at Arrival, Air Traffic Control and Taxiway Management, and Facility Design for Development. Simulation can also be used to model other specific areas within the airport such as parking, shuttle system, and passengers waiting at specific concourse. Among the above mentioned points, the ones that directly deal with customers are Passenger Check-In, Security Checkpoint, and Baggage Claim. Since it is very important to consider customer satisfaction in a service sector, using simulation at these places to help study and reduce customer waiting times or process times seems plausible.

II. ROCKFORD INTERNATIONAL AIRPORT

Located 68 miles northwest of Chicago, Rockford International Airport is a medium size airport, which provides non-stop flights to nine destinations – such as Las Vegas, New York City, Orlando, Phoenix, Cancun, etc – operated by four air service providers. Even though it only operates flights to selected destinations, the airport still has up to 31 departures per week, depending on the season. Since 2007, the number of passengers traveling through Rockford has increased to 215,000 [7].

Rockford International Airport RFD has a two level terminal, with passenger check-in, baggage claim and an airport cafe on the lower level; and security, departure gates and a restaurant on the upper level. When the passengers arrive at the airport, they first stand in a queue and wait for one of the check-in agents to be available. Passengers usually arrive in groups of one to four, but sometimes there may be families with seven or more members. For every flight there are usually three check-in agents attending the passengers. The agents check-in the passengers and weigh their baggage. After weighing, the baggage is put on a conveyor belt, which transfers the baggage to a baggage screening area. Then each baggage is screened through an automatic screening machine. The screened baggage is tagged and sent to the aircraft. If there are suspicious items, the baggage is taken out and re-checked by hand. Some items cannot be screened through the automatic machine and have to be hand checked. Transportation Security Administration (TSA) is responsible for all security procedures including the baggage screening. After the check-in is complete, the passengers are sent to the upper level, where they go through a security check and wait in the lounge to board the airplane.

Rockford Airport is a medium capacity airport facility that usually operates one flight at a time. For this reason, there isn't a lot of rush at the terminal during normal operation. However, at peak hours and holiday seasons the flow of passenger increases and the airport facility can become very crowded and busy. These high capacity hours can be easily foreseen according to the number of flights arriving and departing at a certain time, and thus necessary arrangements can be made to handle such situations. The number of check-in agents can be increased up to a certain number, but the baggage screening process cannot be quickened. The total number of TSA personnel in the baggage section can also be increased as necessary depending on the urgency of the situation. The total number of passengers taking a flight may also vary and the number of flights may increase during high capacity operations.

In this paper, the effect of various parameters in airport operations were studied for the average waiting time for passengers, processing times and idle times for the agents, and maximum queue content of baggage. For this purpose the lower level of the airport – consisting of the check-in area and the baggage screening area – were simulated in an object based simulation tool, Flexsim. The building of the model will be discussed in brief in the following sections. Various scenarios were set up to study the effects of multiple flights, number of passengers on flight, number of check-in agents and the baggage screening mode. These scenarios and case studies will also be discussed further in the paper.

III. Data Collection and Analysis

The necessary data required for the study had to be taken in the beginning. In order to do this, the Rockford Airport was visited during operational hours prior to flight departures for observation of the passenger arrival pattern, check-in procedures and baggage screening procedures. A stopwatch was used to record the times between passenger arrivals, taking into account the number of passengers arriving together as a group. The time taken for the check-in process was also observed and the number of baggage checked in were recorded. In the baggage screening area, it was observed that, although an automatic screening machine was used, the conveyor belt was not connected to the machine. As a result, the agent had to manually load the machine and manually load out the bags from the machine. The time taken to load the baggage into the machine, load baggage out of the machine, screen the baggage, and manually check the baggage were all recorded. In order to have enough information and accurately represent the system, data was taken over multiple days.

After collecting the necessary data, the data distributions had to be evaluated to feed into the simulation model. Expertfit and Input Analyzer were used to come up with the appropriate data distributions. For the inter-arrival times of the passengers, the data was first randomly split into three parts. Two-third of the data was fit into Input Analyzer, and a gamma distribution GAMM (3, 38.7, 1.3) was observed (Fig. 1). Next, the remaining one-third of the data was used to validate this distribution by fitting the previous parameters into the data and observing the corresponding p-value of the chi squared test. Since the p-value was 0.329, which is much greater than 0.05, the gamma distribution was selected. Also, the entire data was entered into Expertfit, which returned a distribution of **Gamma (2.907407, 38.700486, 1.303549)**. This further validates the distribution for the inter-arrival times of the passengers.

Similar methods were applied to formulate the distribution for passenger check-in times which resulted in an exponential distribution **Expo (44, 86, 1)**. In the baggage screening area, the distributions for scan time, load in time and load out time were evaluated using Expertfit. The distribution for scan time was found to be **Loglogistic (34.698113, 8.120486, 2.348135)**; for load in time the distribution was **Weibull (3.933333, 3.199017, 0.744261)**; and for the load out time the distribution was **Gamma (0.000000, 0.906343, 13.653779)**. The process of recheck by hand is only done 10% of the time, so sufficient data was not available to fit a distribution. According to the few data collected, a uniform distribution of **Uniform (235,**

313) was used. These distributions were later used in the various objects of the simulation model.

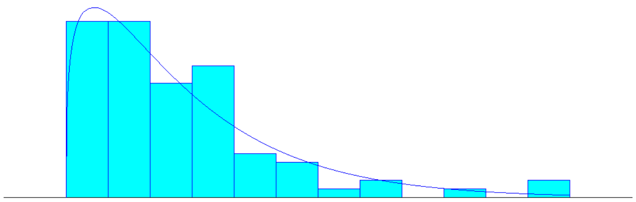

Figure 1. Two third data for inter-arrival times fit to Gamma distribution

IV. DEVELOPING THE MODEL USING FLEXSIM

The simulation model consists of two major sections: the passenger check-in and the baggage screening section connected by a conveyor belt that transfers baggage from check-in area to baggage screening area. A source object was used to create the passengers arriving into the airport. The source was fed with the distribution for inter-arrival time, as calculated in the previous section. To represent the different number of people coming in groups, different “itemtypes” were given to the flowitems on creation. According to data collected, the numbers of people in a group were 1, 2, 3, 4 and 5 for 43%, 36%, 13%, 5% and 3% of the time respectively. This causes Flexsim to assign different itemtypes according to a percentage. For example, a flowitem having an itemtype of 3 would represent a group of 3 passengers. A global table “counter” was also defined to count the number of passengers arriving. A code was given in the source object, which increased the value of the counter table by the number of itemtypes of the flowitem. By keeping track of this counter table, the total number of passengers that have arrived can be observed and the source object can be stopped when the maximum allowed number of passengers is reached. This maximum number of passengers can also be stored and retrieved from another global table.

After the passengers were created, they have to be sent into a queue to wait for available check-in agents. The source object was connected to an accumulating conveyor object “entrance lane”, which represents the queue of passengers. The output port of the “entrance lane” was then connected to the processor objects representing the check-in counters. The flow rule for the flowitems from entrance lane to the check-in counters was set as first random port available. For building purposes four check-in counters were created, which later may be closed or opened depending on requirements. For each counter an operator was used, so there were four check-in agents at the start of the model. To simulate the baggage weighing and drop off process, the message and creating flowitems on message functions were utilized. A code was written on exit of each passenger, to evaluate how much baggage to check in. According to collected data, the number of baggage checked in for every check-in process was 0, 1, 2, 3 or 5 for 27%, 52%, 15%, 4% and 2% of the time, respectively. The parameter 0, 1, 2, 3 or 5 would then be evaluated according to the given percentages and the message would be sent to the center port object, which in this case was a queue object representing the weighing scale. The queue object on receiving this message would then create a number of flowitems equal to the parameter from the message. Figure 2 shows the passenger check-in counters and the agents putting baggage on the conveyor.

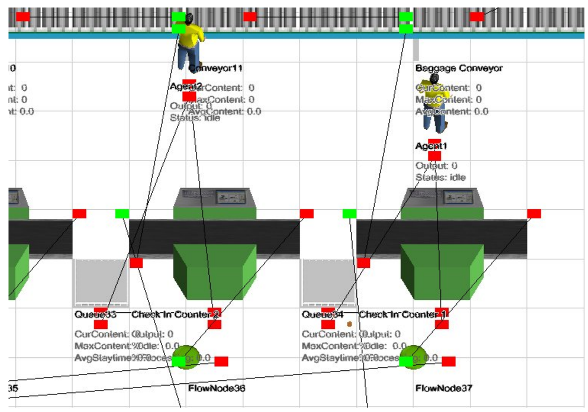

Figure 2. Part of the simulation model showing the check-in counters and agents

A conveyor was used behind the check-in counters, and the queue objects – which create baggages – were connected to the conveyor. The check-in agents were made to transfer the baggage onto the conveyor according to high priority. After the passengers complete the check-in process, they are made to exit the model via a sink object, simulated to go to another section of the airport not considered in the model. The baggage then goes into the baggage screening section through the conveyor. In the baggage screening area, two different types of screening methods are modeled. A single automatic screening machine was modeled by using a processer with the loglogistic distribution. Three manual screening machines with the uniform distribution were also placed. The conveyor was connected to the automatic machine but utilized an operator to load in the baggage and another operator to load out the baggage. Ten percent of the baggage coming from the check-in area were sent to the manual machine for manual checking, which utilized another operator. The automatic screening machine was given a capacity of three, so it could scan three bags at a time. Out of the screened baggage, 10% was considered for recheck and sent back to one of the manual machines for manual checking. After the checking was complete the baggage was sent through another conveyor to a sink object to take it out of the system, simulating the baggage going into the aircraft. There were three agents at the baggage screening section. Figure 3 shows the baggage screening area as well as a slight overview of the entire simulation model.

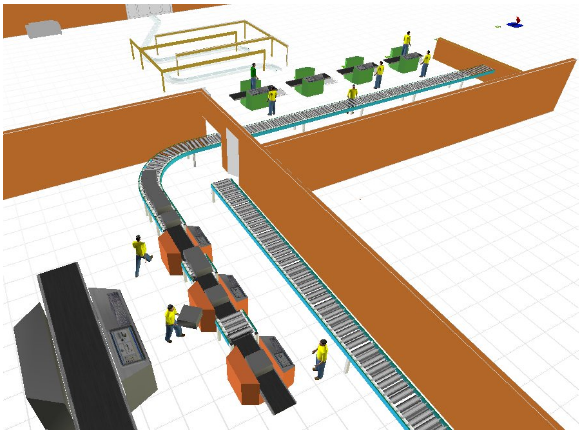

Figure 3. Baggage screening area

For the purpose of evaluating different scenarios, various global tables and user events were used in the simulation model to facilitate for the change of variables. The maximum numbers of passengers on a flight were recorded on a global table "Maximum number of passengers". Since three source objects were incorporated to simulated scenarios with multiple flight operation, the varying numbers of passengers on these flights were recorded in the global table. These values can be changed later for different cases. The selection of the check-in agents were done by using a global table "Selecting check-in agents". This table had four rows for the four agents with values of either 1 or 0. The value 1 corresponds to an agent being active and operative; whereas a value of 0 means that the agent is inactive. These values can be manually changed to select the agents and the selecting process is done by incorporating a user event at the beginning of the simulation.

At time 0 Flexsim evaluates the given event. If any of the global table values for check-in agents are found to be 0, then the input port of the corresponding check-in counter is closed. This prevents flowitems from going to that processor and simulates the agent being inactive. Also, to open the source object for multiple flights, a user event is used such that the output port of the source objects are opened or closed as desired. At time 0, source for flight1 is opened and the others closed. Then according to the departure time of the second and third flights, user events are used at the particular times to open the source for flight2 and flight3.

V. MULTIPLE SCENARIOS AND ANALYSIS

In order to do simulation analysis of the system, various cases and scenarios were evaluated. This paper provides three case studies, each with different scenarios.

A. *Case I*

The first case was evaluated for various responses by changing the method of baggage screening procedure. It was observed that, since the conveyor was not attached to the automatic machine, an operator had to manually load and unload the machine. Also, it was known that the baggage screening process was completely manual before the purchase of the automatic screening machine. Three scenarios were observed: the current procedure, completely automatic (without manual load in/out) and completely manual screening. In almost all the cases, the variable parameters were the number of passengers on the flight and the number of check-in agents to use. Various output parameters such as average waiting time for passengers, maximum content of baggage queue, and the utilization of check-in counter were observed. For Case I, the number of passengers used was 215 and number of check-in agents was 3.

B. *Case II*

The second case evaluated the responses of the system by changing the number of passengers on the flight and also the number of check-in agents. This evaluation was done for the current baggage screening process and for a single flight only. Nine different scenarios were set up in the Experimenter tool in Flexsim. In the Experimenter, the number of experiment variables was set and the path for the variable was given from the tree nodes. Then, various scenarios were added and the variables changed. The simulation was run for 10 replications for each scenario, and the results were obtained at the end of the experiment in an MS Access format. The different scenarios for Case II were selected as shown in Table 1.

TABLE 1. SCENARIOS USED IN CASE II

Scenario #	No. of passengers	No. of check-in agents
1	215	2
2	215	3
3	215	4
4	100	2
5	100	3
6	100	4
7	175	2
8	175	3
9	175	4

C. *Case III*

The third case evaluated the effect of multiple flights. For this user events were used to open the source object for the remaining flights. The source for flight1 was opened at time 0, the source for flight2 was opened at time 5400 (after 1.5 hrs) and the source for flight3 was opened at time 10800 (after 3 hrs). Then, six different scenarios were set up by changing the number of passengers on each flight and the number of check-in agents. The scenarios were set up as shown in Table 2.

TABLE 2. SCENARIOS USED IN CASE III

Scenario #	No. of passengers (Flight1)	No. of passengers (Flight2)	No. of passengers (Flight3)	No. of check-in agents
1	200	200	200	3
2	200	200	200	4
3	200	100	200	3
4	200	100	200	4
5	100	150	150	3
6	100	150	150	4

VI. RESULTS AND CONCLUSION

Running various scenarios in this model supports a lot of decision making processes in the airport management system, such as how many agents to keep, scheduling various resources and flight scheduling according to available resources. The results of the various scenarios can be obtained through simulation modeling such as this, and the effects of various changes in variables can be studied without actually having to change the variables in the real system. For each of the cases defined above, the different scenarios were run for 10 replications each, and the results were studied. In this section the results of the three cases will be briefly discussed.

For case I, the effects of different baggage screening methods were studied. The model was run for three different scenarios; the current procedure, completely automatic (without load in/out) and completely manual screening. For each of these scenarios, the results were obtained. It was discovered that for the manual screening method, the maximum baggage content on the baggage conveyor was 20, compared to only 6 for the current method. The average waiting time for a baggage on the conveyor greatly reduced from 844.22 sec to 29.97 sec by adding the automatic screening machine to a manual method. It can further be reduced to 17.56 sec by connecting the conveyor to the machine and eliminating the load in/out process. The method of baggage screening does not affect the check-in process, but increases the waiting time of baggage on the conveyor and decreases throughput rate of the baggage.

For Case II, the number of check-in agents required, according to the changing number of passengers on a flight, was studied. For a flight with 215 passengers, increasing the check-in agents from 2 to 3 to 4 caused a significant decrease in the average passenger waiting time: from 715.06 seconds to 94.14 seconds to 37.63 seconds. Similar results can also be seen for flights with 100 and 175 passengers. It was observed that the average waiting time for passengers does not significantly change for 100 and 175 passengers, even though it decreased from 715.06 seconds to 418.92 seconds when the number of passengers reduced from 215 to 175. Also it was seen that the average wait time for the baggage on the conveyor increased when using more check-in agents. This clearly shows that, by having more check-in agents the average waiting time for the passengers is reduced, but the baggages on the conveyor are increased due to faster processing.

For Case III, the effect of multiple flights was studied. The model was set to create passengers for three different flights departing 1.5 hours apart. The first source created passengers at time 0, the second source started creating after 1.5 hours and the third source opened after 3 hours. These three different scenarios were evaluated for Case III. We can see that for a constant passenger arrival with 200 passengers on all flights, the average waiting time reduces from 948.15 seconds to 34.58 seconds by using 4 agents instead of 3. This extremely high waiting time may be a result of the high number of passengers arriving at certain point of time. By reducing the number of passengers to 100 on the second flight, the check-in process is eased even more. The average waiting time was found to be 271.15 seconds for this scenario, which was further reduced to 35.79 seconds by using 4 agents. In the case of low passenger arrival (100, 150 and 150 passengers on the respective flights) the average waiting time was even further reduced to 67.20 seconds with 3 agents and 25.83 seconds with 4 agents. Thus, the waiting time of the passengers depends on the number of passengers arriving for a flight.

By conducting this simple scenario analysis in the simulation model of the airport, conclusions and decisions can be made regarding the behavior of the system in different scenarios. This may prove to be a helpful tool in airport management systems to forecast, optimize and make important decisions in airport facility management. Similar to this model, simulation can be extended to other sectors of the airport as well, to study the effect of one section to another on a completely different level.

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