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SIMULATION OF AN AIRPORT PASSENGER SECURITY SYSTEM

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ABSTRACT

As part of the new security environment at the nation's airports, discrete event simulation modeling was applied shortly after 9-11 to understand the operational dynamics of passenger security screening in conjunction with the redesign of the passenger checkpoint. In a rapid six week effort, a discrete event simulation model was built to represent the passenger and luggage screening system at Baltimore Washington International Airport (BWI). BWI was the first airport to undergo enhancement, and the project was reported in "BWI's Subtle But Serious Security," *Washington Post*, March 4, 2002. After the value of simulation was demonstrated at BWI, the simulation methodology was applied to develop resource requirements at all Category X and I airports in the United States.

1 INTRODUCTION

Security measures allow the public to continue to live normal lives in an increasingly dangerous world. Because of the increasing dangers, security precautions are becoming standard part of daily life. The cost to the public for increased security includes inconvenience and time delays. In response to these concerns, an initiative was started to redesign the passenger checkpoint process to adhere to security policy while minimizing inconvenience to the public.

At the heart of the challenge was to design a passenger checkpoint process which adhered to policy directives, provided a consistent passenger experience, and met or exceeded agreed upon service levels. In support of this effort it was decided to build a baseline (*As-Is*) simulation model which adequately described the dynamic balance between passenger demand, airport characteristics, process flow, policy directives, and staffing. The baseline model was used as a foundation for alternative future (*To-Be*) designs. The concept was to rapidly prototype and evaluate the merits of alternative designs and include the knowledge capital gained into the next generation of designs. This process was repeated until the final design emerged. With the final process designed approved and implemented, the simulation effort could move into a new phase which focused on policy development and developing resource requirements.

2 THE APPROACH

The "Simulation Modeling Approach" was comprised of several key activities that contributed to the creation of an "As Is" and a "To Be" capacity simulation. The simulation creation process began with an intensive data collection effort that was structured around three main areas:

1. Process Decomposition – A graphical depiction of the "As Is" sequence of events customers follow from "curb to gate" was developed. The process was broken down into basic activities in a highly structured manner. The simulation team used the As-Is Process Flows as the "blue print" for the simulation design.
2. Process times & percentages – Process decomposition serves as the blue print in which more detailed data is captured for the simulation. Process times including the minimum, mode, and maximum were captured for each activity through a time motion study. Percentages for each decision area of the process (e.g. alarm rates) were captured to lead customers through the proper sequence of events for the situation.
3. Distribution of customer arrivals – Customer arrival volumes and patterns were captured using the departure schedule and the airline loading factors. Customer behavior information such as ticket counter versus curbside check in was also captured. This information created an accurate customer arrival pattern at the security checkpoint.

Working closely with the process design team, the simulation team collected and refined the required data. Combining all of the collected data with the process decomposition model essentially created the blueprint for the "As Is" simulation. It was used as a baseline of comparison for future process improvement ideas generated by the process team. Improvement ideas were captured and compared to the baseline during rapid prototyping for "To Be" process selection. Once the "To Be" process design was selected, the "To Be" simulation was refined for further experimentation purposes. Figure 1 graphically depicts the simulation creation process used in the effort and its relationship to the process redesign.

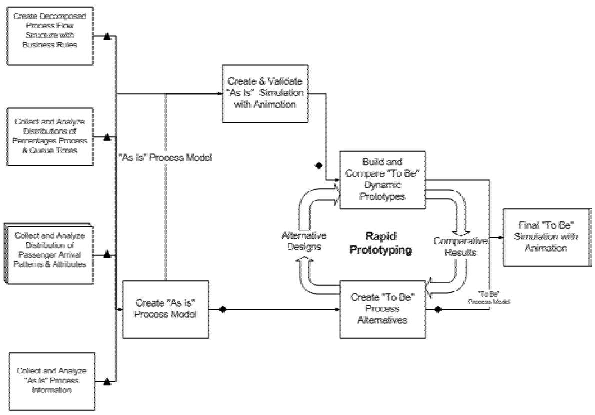

Figure 1: Using Simulation in the Process Redesign Process

3 DEMAND MODELING

Robertson, Shrader, Pendergraft, Johnson and Silbert (2002) provides a detailed procedure for modeling passenger arrivals. Modeling the passenger arrival process estimated how many passengers arrived at the airport during each day and time of day. The demand modeling approach summarized the passenger data into the number of passengers who arrived at the airport in time intervals or "time buckets". The raw passenger volume per time interval was the end product of the analysis and was referred to as the passenger arrival pattern. From the raw airport passenger arrival pattern, additional analysis generated the passenger arrival pattern at different points in the process (check-in, baggage security, security checkpoint, etc.). The arrival patterns were then converted from the raw arrivals per interval into the appropriate arrival rates required for non-stationary Poisson arrival processes.

The passenger arrival pattern for the checkpoint was generated using several key inputs: passenger arrival behavior, flight schedules, aircraft capacity, load factors and transfer rates. These factors were combined to generate the time dependent passenger demand for the terminal security check-point.

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 was then reduced by the number of empty seats on the aircrafts. At that point, the number of passengers departing from the given airport was known. The third step was to apply the transfer percents and remove passengers who transferred from one flight to another and would not go through the security process. At this point, the number of passengers who arrive at the airport and the passengers' departure time was known. The fourth and final step was to calculate at what time the passengers arrive at the airport. The passenger arrival distribution described how early a passenger would arrive at the airport in advance of the departing flight time. Using the passenger arrival distributions, the number of passengers arriving in 10-minute intervals prior to their flight was calculated for each flight. The final step was 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 above technique was used to produce the passenger arrival pattern for one week. Figure 2 graphically depicts the passenger daily arrival pattern for a typical week at BWI pier C.

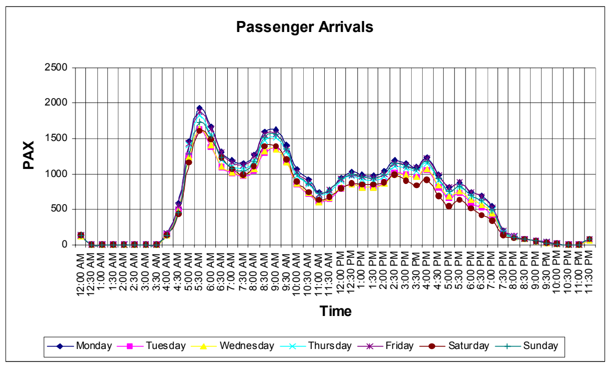

Figure 2: Intra-Day Passenger Arrival Pattern for 7 Days for a Large International Airport

Validation of the model was accomplished by observing actual passenger arrivals at the security checkpoint lines. During passenger observation, the time at which each passenger joined the security checkpoint line was recorded. Observations were made during all major peaks and troughs. The collected observation data was organized into the same format as the passenger arrival pattern for comparison to the model. The passenger arrival data series was divided into peak and non-peak days.

4 SIMULATION DESIGN

The simulation design was started by creating a decomposition of the process beginning with the passenger check-in process and moving through the passenger's exit of the terminal security checkpoint. The decision was made to include the passenger entry processes to accurately model the impact of those processes on security checkpoint demand. In fact, the simulation demonstrated the buffering effect of check-in counters which are inadequately staffed by airline personnel. This effect has an overall positive impact on the security checkpoint performance, but has an overall negative impact for customer experience.

In general, the high level process steps considered in the overall process design were: Passenger Check-in, Baggage Security, Terminal Checkpoint Security, Passenger Boarding, and Exception Handling. Each area was decomposed into several deeper layers for the purpose of creating the "As-Is" and the "To-Be" design. The simulation design focused on the first three process steps.

The following description provides a broad overview of the process steps included in the simulation. The description is not meant to be an exhaustive description of everything considered, but should illustrate the approach used to mimic the processes the passenger experiences at the airport in the simulation.

The simulation design starts where the demand modeling ends. Arrivals were generated using a constant arrival rate and call thinning techniques to dynamically change the arriving passenger rate for each time interval. Once passengers enter the airport they have several options of where to check-in larger bags or the option to precede directly to the security checkpoint. These passengers either have no baggage or are checking-in at their gate. The percentage which describes the passengers using the different alternatives is known as the by-pass ratio and was provided by airlines as a data element. Passengers checking larger bags were also subject to the possibility of further bag screening at the Explosive Detection System (EDS). The model was designed to accommodate a percentage (including 100%) of all checked bags. Each step of the process at the EDS was built into the simulation which again was modeled to account for the impacts of the EDS process at the terminal security checkpoint.

Following check-in, passengers then enter the security checkpoint queue. Before entering the security checkpoint, the passenger further determines whether she is carrying a special item that requires a separate search. If the passenger has any special items, such a laptop computer or camera equipment, the passenger removes this item for special screening. Special searches were modeled as time delays corresponding to its associated distribution.

Before entering the security checkpoint, the passenger further determines whether she is carrying any personal items to be removed. Generally, the passenger removes items such as keys, coins, jewelry, etc. that may interfere the security tests performed in the security checkpoint. If the passenger has any such items, the passenger removes these items and positions these items for screening with their personal luggage. The decision process for divesting personal items was not explicitly modeled. The number of personal items were modeled with a discrete distribution which included all personal items placed on the x-ray regardless of the checkpoint entry decision process. Once the passenger loads the luggage on the x-ray, the baggage screening process and the passenger screening process run separate, but simultaneously.

Loaded baggage and personal items enter a device (typically an x-ray) that allows security officials to view the contents. The screening device (or the personnel manning the device) may produce an alarm. If an alarm is produced, then the alarm must be resolved before that baggage is allowed through the security checkpoint. Also, even if an alarm is not produced, the baggage may be randomly selected for a more thorough search based on policy. All alarms were modeled using a static branch probability set during initialization of the simulation. Alarm resolution was not explicitly modeled, but rather the time delay incurred by the combinations of tasks performed created by probabilistic branches. Once the final task was performed the alarm was considered resolved. Random searches were modeled using a policy compliance level (0 to 1) which was used as a probabilistic decision of using available resources.

Resolving an alarm entails a more thorough examination of the baggage. First, security officials generally locate the passenger, so that the passenger may view any examination of his baggage. Security officials may then perform a screening using an alternative technical device such as an Electronic Trace Detector (ETD) and/or a manual search of the baggage to identify the cause for the alarm. In reality, the manual search may vary according to the results of the initial findings. Specifically, the manual search may vary depending on whether a restricted item was identified during x-ray screening. Restricted items are objects such as pocket knifes, nail files, and tweezers that passengers may not carry on the plane. When a restricted item is seen during screening, the security officials may do a quick manual search to locate and confiscate that restricted item. However, if screening did not identify a particular item, then the security official does an extensive manual search in order to identify the cause for the alarm. For modeling purposes, the intricacies of linking the findings from the initial screening to the more in-depth search has been left for a future model enhancement. The current simulation models all manual searches with the same distribution based on the time motion studies conducted during data collection. It should be noted that other security tasks or combinations of tasks associated with the additional screening have been incorporated into the screening process.

The screening of passengers generally includes the use of some type of rapid testing device, such as a magnetometer (MDD) also known as a Walk Through Metal Detector. A certain percentage of the people will activate an alarm thereby requiring resolution of the alarm. Increasing the sensitivity of the device may be simulated by increasing the percentage of people that set off the alarm. Also, a certain percentage of passengers may be randomly selected for more extensive screening, even if these people do not activate the alarm.

Alarm resolution for a passenger may require a combination of searches. For instance, a wand search, a shoe inspection, and possibly other tests may be required to resolve the alarm. These tests are meant to identify the cause for the original alarm condition. In the wand search, a security official uses a handheld metal detector to identify objects causing the alarm. A security official may also manually inspect a passenger's shoes or send the shoes through an x-ray. Other security tests (e.g., a frisk) may also be performed as necessary. Again, alarm resolution was not explicitly modeled. The same approach was used for modeling passenger alarm resolution that was used in baggage alarm resolution presented above.

Finally, once the passenger has successfully traversed the security processes, they collect their personal items and exits the checkpoint.

5 WORKING IN A VIRTUAL ENVIRONMENT

The "As Is" environment was created by using all of the information gathered during the effort. The information was combined and used as input into the simulation creating the virtual "As Is" model. Once validated, the model of the "As Is" was used as a baseline to compare future "To Be" design alternatives. The alternative "To Be" process designs were rapidly prototyped by the process team and compared to the "As Is" baseline in the virtual environment. The results were analyzed and new designs created. The simulation verified that agreed to performance levels were met or exceeded. The process team continued these iterations until the final "To Be" process design was created. Finally, the simulated results of each design experiment were documented to provide a history of the design alternatives considered.

6 POLICY DEVELOPMENT

The simulation team provided analytic support for airport operations focusing on resources requirements (equipment & staffing), process performance, customer experience and cost. The simulation team assisted with policy development by providing decision makers with quantitative modeling support and analysis. This support was provided in addition to standard sensitivity analysis for decision makers to develop fact based recommendations for policy decisions concerning the following issues:

- The development of the 85/10 methodology where 85% of passengers wait less than 10 minutes
- Checkpoint staffing requirements (required number of wanders, number of bag searchers, etc…) for standard configurations
- Checkpoint equipment requirements (required number of x-rays, shoe x-rays, MDDs, ETDs, etc.) for standard configurations
- Recommended staffing for peak volume operations
- Continuous (random) policy compliance levels for wanding and ETDs
- Alternative gender-based wanding policy impact
- Impact of allowing "meeters and greeters" to enter sterile areas beyond the passenger security checkpoint
- Impact of eliminating MDDs and hand wanding all passengers
- Check-in counter wait time impact on security checkpoint demand and wait times
- Higher MDD alarm rate impact on checkpoint operations
- Reduced staffing impact on checkpoint operations

The team also provided more limited analytic support and thought leadership concerning policies on crisis management, consequence management, and the following areas:

Resource Requirements

- Employee work rules (impact of number of breaks, lunch, training etc.)
- Reduced lane staffing requirements (impacts of reduced staff on checkpoint operations)
- Reduced airport staffing requirements (optimized scheduling of shared resources across airport)
- New staffing requirements based on process changes (i.e. checkpoint selectee screening)
- Annual labor planning based on seasonal demand (Workforce management on annual basis)

Process Changes

- Process changes or re-designs (i.e. new security directives which change process steps or time)
- New technology inserted into the existing or re-designed process
- Emergency response planning (Concourse dumps, checkpoint shutdowns, etc.)

Customer experience

- Alternative service level requirements (i.e. different service levels for non-peak operations)
- Alternative queue management techniques
- Designated & dedicated lanes and lines, such as designated lanes for premium customers

It is important to note that many of these issues were analyzed across all the areas addressed above. Our experiments showed that changes in one area typically impact other areas significantly.

All policies have cost impacts, which must be addressed prior to implementing the policy. The assessment for any potential policy must consider both the associated cost and operational impacts. In fact, the detailed analysis of the operational impacts typically drives the cost estimate. This places the operational impact analysis team in the best position to analyze impacts to both operations and cost.

7 RESULTS

The simulation created at BWI proved successful at adequately describing and predicting impacts of system changes. Due to the time frames allowed, a formal validation process was not used to validate the model; however, the simulation was able to accurately mimic checkpoint performance under a host of different scenarios. The model proved invaluable to the overall successful checkpoint process redesign effort and provided valuable insights to policy development. The effort was considered so successful that the simulation and demand modeling methodology was later used to develop resource requirements (x-rays, metal detectors, ETDs, etc..) for all 80 Category X & I airports in the United States.

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