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SIMULATION OF TRANSPORTATION SYSTEMS

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ABSTRACT

This tutorial describes the benefits of using simulation to evaluate the performance of transportation facilities and systems. SABRE Decision Technologies presents specific examples in which simulation analysis has been applied to the transportation industry.

1 INTRODUCTION

SABRE Decision Technologies (SDT) is a consulting and systems development firm of over 2500 operations research/management science, industrial engineering and computer science professionals specializing in cost reduction, revenue enhancement, quality improvement and strategic decision evaluation for the transportation and related industries. Based in Fort Worth, Texas, the firm was originally the Operations Research department for American Airlines and began providing products and consulting services worldwide in 1988 as American Airlines Decision Technologies (AADT). In early 1994, the company reorganized as SDT underneath The SABRE Group of AMR Corporation to consolidate the corporation's software development and consulting services into one organization.

During the past ten years, SDT has extensively applied simulation to transportation problems. The first section describes the benefits of using simulation to model the various transportation areas that SDT has studied. Examples of these transportation areas include passenger and baggage flow through airport terminals, aircraft movement in the airspace and airfield, and pedestrian traffic flow within monorail and people mover systems. The following sections present project work in the above three areas in which simulation assisted in making statistically reliable decisions.

2 BENEFITS OF SIMULATION

Simulation is a valuable decision support tool for evaluating transportation facilities or systems. There are many reasons why one should consider simulation in making decision in the transportation industry.

SDT simulation projects evaluate the flow of vehicles, passengers, bags, and aircraft in the airport environment and pedestrian and other vehicle traffic in the non-airport environment. In the airport environment, passengers travel in different numbers, at different speeds, and are serviced in a number of ways in facilities depending upon their origin and destination, citizenship, travel class, etc. Using concepts such as queuing theory or mathematical equations to determine flow are intractable as the combinations of characteristics for a passenger are numerous. Simulation allows SDT to assign specific characteristics to each passenger and to allow the passenger to undergo different processes depending upon those characteristics. Similarly, simulation can capture statistics on the variability of these characteristics on an hour-to-hour, day-to-day, or seasonal basis.

Similarly, aircraft have many characteristics or parameters that dictate how each one moves on the airfield or the airspace. Some of these characteristics include size, airline, weight, and engine type. These aircraft characteristics affect how an aircraft responds to the rules and procedures for taxiways, runways, and various decision points in the airspace. In addition, safety factors require aircraft separation for wake vortex, runway usage, and airspace routings.

Another advantage of using simulation is the ability to trace entities--passengers, bags, pedestrian traffic, etc.--through a system of multiple processes and operations. In most situations, the processes an entity undergoes through a transportation system are not independent. For example, if an entity incurs a long processing time in one area, it will most likely experience an increased time in the facility. Other entities in queue will also be affected, and any one entity may require expeditious treatment at the next processing area in order to meet a processing requirement or standard. Also, if entities occupy the entire queuing area, additional entities may be held at an upline processing station until ample queuing area is available. From this example, one can observe that a single occurrence in a facility can affect the upline and downline areas as well. These rippling effects are impossible to capture in pure mathematical terms because of the various interactions that are possible. As simulation will process each action and adjust depending upon the outcome of that process, the upline and downline effects are captured for all possibilities.

There are also excellent economic reasons SDT encourages clients to study transportation issues with simulation. Simulation analysis can be performed with minimal risk to clients. By performing simulation analysis prior to construction of the transportation facility or system, changes can be made to the system design at a fraction of the construction cost. Also, simulation is very flexible for providing what-if analyses with little further development. Once a simulation model of the base operation is built, the client will spend minimal resources evaluating numerous alternatives, such as increasing demand levels, changing passenger, baggage, or aircraft flow, and increasing or decreasing the size of the transportation facilities.

3 PASSENGER / BAGGAGE FLOW IN AIRPORT TERMINALS

3.1 Berlin

The Berlin Brandenburg Flughafen Holding GmbH (BBF) is responsible for planning and operations at the three existing commercial airports in Berlin: Tegel, Tempelhof, and Schönefeld. During the last 17 years, Tegel was the primary airport for the former West Berlin. Currently, Tegel is Berlin's busiest airport and is approaching capacity. Tempelhof, former West Berlin's older and smaller airport, is limited to small and low-noise aircraft and general aviation. Schönefeld previously served East Berlin as the hub of East Germany's Interflug air carrier. Expansion measures planned for Schönefeld included an Interim West Terminal that will serve charter and intercontinental flights.

SDT was selected by the BBF to analyze the proposed design of the Interim West Terminal at Berlin Schönefeld Airport. SDT was tasked to analyze passenger and baggage flows within the terminal.

The Interim West Terminal for Schönefeld is planned to accommodate the predicted shortfall in existing airport capacity in the Berlin airport system. The existing Berlin airport system will not be able to handle the expected increase in air traffic demand and will require a long-term solution of an international airport with significantly greater capacity than the existing airports. In the short term, the Interim West Terminal expansion at Schönefeld was the most practical way to add capacity to the Berlin airport system that is constrained by a lack of terminal facilities.

The BBF wanted to ensure that the design of the Interim West Terminal maximized both passenger and baggage throughput in the facility. Using simulation and an accompanying animation, SDT evaluated the performance of the terminal from a passenger and baggage flow perspective, identified bottlenecks in the terminal design, and suggested modifications to improve passenger and baggage flows.

For the Schönefeld analysis, SDT developed a discrete event simulation model of the Interim West Terminal that accounted for all passenger and baggage movements through the facility. Using this simulation model, SDT introduced two possible levels of passenger and associated baggage throughput into the terminal based on the anticipated flight schedule. By modeling the individual passenger and baggage movements through the terminal, SDT identified areas of the terminal in which bottlenecks and over-crowding occurred. To alleviate the congestion and improve facility throughput, SDT performed a number of additional analyses to verify recommendations of staffing and procedural changes.

Some of these recommendations included: dynamically assigning the check-in positions, opening lower-level departure lounges simultaneously with check-in counters for departing flights, and increasing outbound passport control positions. In addition, SDT determined that the planned bagroom was not appropriately sized. Subsequently the BBF was able to revisit their bagroom design before construction on the facility began. Also, the BBF revised procedures for terminal operations.

3.2 Miami

In recent years American Airlines (AA) has experienced a dramatic increase in its international as well as domestic travel at Miami International Airport (MIA). As a result, AA is planning to expand its jet and commuter operations at MIA to accommodate its future growth and demand. Since the planned expansion can not be accommodated in AA's current MIA facilities, AA has asked SDT to perform studies to analyze AA/AE passenger flow, people mover system requirements, baggage delivery operations, and airspace/airfield operations of the future, to ensure the adequacy of the facilities to accommodate the projected passenger flow and air traffic. Two distinct designs were considered.

AE operations are relatively independent of the option of choice and are to be located at a remote site. AE passengers are bussed to and from the main terminal.

The first option incorporates the expansion of Terminals D and E to accommodate 47 gates. Each terminal, would contain an independent 2-station people mover system.

The second option is to expand the existing A and D terminals to accommodate 47 gates with three mutually exclusive alternatives: Without a people mover system, with a 3-station people mover system, and with a 4-station people mover systems.

Using simulation, SDT evaluated the performance of the proposed designs with respect to passenger and baggage flow, as well as air traffic operations, identified design flaws, bottlenecks, and air traffic problems. The study included comparative analysis of the proposed designs and recommendations were made to improve the operations.

SDT developed discrete event simulation models in SIMAN to analyze passenger and bag flows within each of the proposed designs. Airspace and airfield operations were studied through simulation models developed in SIMMOD. By modeling the individual passenger, and baggage movement, SDT identified the design option which best meets AA's future operations at MIA. Furthermore, using the SIMMOD model, SDT was able to identify problem areas and to make recommendations to improve airspace and airfield operations at MIA.

The airspace/airfield analysis determined the current facilities were not sufficient regardless of the option chosen. Further sensitivity analysis revealed that an additional runway and a new arrival route are needed to ensure operational adequacy.

4 AIRSPACE / AIRFIELD ANALYSES

The recent Airport Master Plan Update for Spokane International Airport (SIA) recommended the construction of a new runway to meet forecasted traffic demand. However, the Master Plan did not resolve possible interference of SIA runways with Fairchild Air Force Base (FAFB). Since FAFB and SIA are only 4 miles apart, the airports share some final approach flight paths. The proposed runway location is between SIA and FAFB, bringing SIA flight tracks in potential conflict with the FAFB runway. In addition, Felts Field is located approximately 11 miles from SIA with runways parallel to SIA's primary runway. SDT performed an airspace simulation analysis of these three airports--SIA, FAFB, and Felts--to quantify delays associated with traffic forecasts and to evaluate the proposed runway alignment at SIA.

For this project, SDT used the FAA's Airport and Airspace Simulation Model, SIMMOD, for its ability to model multiple airports and airspace conflicts. Simulation modeling was the tool of choice to study the joint use airspace plan for Spokane and to ensure the airspace will accommodate current and future traffic demand for both Spokane International Airport and Fairchild Air Force Base. SIMMOD provides measures of aircraft delay in the airspace and on the ground, which can be used to determine available capacity.

SDT developed a model of the terminal airspace, including airfields for SIA, FAFB, and Felts Field. After building the model, SDT validated the model by comparing the simulation output to data collected on-site. Data typically used for validation include airspace travel time, taxitimes, and departure queuing statistics.

SIMMOD requires many parameters that describe the modeled airports and the aircraft that use those airports. Since many of the parameters and data input for a SIMMOD study remain constant over each scenario, a number of scenarios can be evaluated quickly. For example, the validated model was used to determine the impacts of future SIA traffic (year 2010) and the future FAFB mission on the existing airspace system in instrument conditions, or low visibility. This analysis of forecast traffic determined that the airspace delays were within acceptable levels, thus the existing airfield/airspace system would operate within capacity.

SDT also evaluated two airfield alternatives. First, a proposed connector taxiway between SIA and FAFB could be used in severe weather conditions. Even though the airfields are very close, there are often times when one is "fogged in" while the other is open for operations. Results on taxi distance, taxitime, and gate arrival delays were presented to SIA, FAA, airlines, and private company operators to ensure the costs of the taxiway construction are offset by the benefits to the airport users. Second, the new runway alignment proposed in the Master Plan Update was analyzed to determine the gain in capacity it will provide. Also, the results showed that the airspace structure will accommodate the excess SIA traffic without negatively impacting FAFB operations.

5 MONORAIL / PEOPLE MOVER SYSTEMS

Las Vegas recently experienced a significant increase in hotel and casino construction. As each new hotel opens, Las Vegas receives more and more tourists, each wanting to visit the different hotels and casinos on the Strip. In an effort to improve pedestrian access between casinos and hotels, some neighboring casinos have entered into partnerships by building light rail shuttle systems. Although there are two small systems currently in place, each system provides very limited capacity. When

MGM Grand and Bally's decided to be the next group to build a light rail system, they envisioned having a system that will be a main source of transport between the two hotels.

VSL and Gensler & Associates Architects contracted with MGM Grand/Bally's Monorail Corporation to design and build the monorail system. In May 1994, VSL and Gensler asked SDT to assist in evaluating the performance of the monorail design prior to construction. The two-train shuttle rail system has two platform stations, each station containing two areas for train loading and unloading. From the MGM Grand and Bally's monorail stations, customers reach the respective hotel and casino via lower levels that have access to shopping areas and parking garages.

SDT was responsible for evaluating monorail system performance in two phases. Phase I concentrated on ensuring the monorail system would provide a sufficient level of service for all activity at the platform stations. This evaluation included validating the station designs, quantifying system performance during peak usage, and identifying any customer bottleneck areas at the stations. Phase II concentrated on ensuring MGM Grand and Bally's provide enough shopping and corridor space in the lower levels for customers to walk between the casinos and the monorail.

SDT modeled all customer movements and operations between the casinos and the monorail stations. After modeling the base operation, SDT identified the areas where customers did not have the required space for walking or queuing. Through simulation, SDT quickly ran new scenarios with different parameters and compared each scenario to the base operation.

SDT found that the monorail system provides sufficient throughput to accommodate expected customer demand for traveling between MGM Grand and Bally's. While trains experienced longer than anticipated dwell times at each station, the monorail system still had sufficient capacity. SDT's analysis assisted MGM Grand in deciding to provide alternative access to and from the MGM Grand shopping level in the form of additional escalators and stairs. Various escalator speeds were simulated: to observe the increase in ridership on the monorail, and to distribute the flow and passenger occupancy levels evenly between the shopping areas and the monorail stations. Based on the analysis, MGM Grand selected an escalator speed that provided an efficient and safe monorail system.

6 SUMMARY

The consulting projects described above represent typical transportation issues that lend themselves to simulation modeling. SDT still encounters people in the industry that do not realize the benefits simulation brings to transportation planning. The response is significantly different from the planning personnel who have invested in simulation studies. Planning personnel have saved millions in construction costs by appropriately sizing a transportation facility or accurately assessing the requirements for runways and taxiways.

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