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ANALYSIS OF AIRPORT/AIRLINE OPERATIONS USING SIMULATION

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ABSTRACT

Facilities and procedures at large airports must be modified to maintain a quality level of service to passengers as the demand for air travel grows. Simulation modeling has been used extensively by American Airlines Decision Technologies to determine the changes in facilities and operational policies required to maintain a quality level of service. This paper discusses specific areas of airline operations such as baggage handling, passenger flow, and customs operations that have been evaluated using simulation methods.

1 INTRODUCTION

American Airlines Decision Technologies (AADT) is a consulting and systems development firm of over 350 operations research/management science, industrial engineering and computer science professionals specializing in cost reduction, revenue enhancement, quality improvement, and strategic decision evaluation for transportation and related industries. Based in Fort Worth, Texas, the firm was originally the Operations Research department for American Airlines and became a subsidiary of AMR Corporation in January 1990 to provide products and consulting services to clients worldwide.

The Airport Consulting Group of AADT works with architectural, engineering, and construction firms, airport authorities, and airlines to develop cost effective airport planning alternatives that meet future requirements. Simulation analysis has been used extensively by the airport consulting group to effectively discriminate between competing airport planning alternatives.

AADT's history has provided the airport consulting group a wealth of knowledge and experience in airport operations and requirements, and in applying simulation technology to these areas. AADT has completed numerous projects for American Airlines' hub airports, such as: Chicago O'Hare, Dallas/Fort Worth, Miami, Nashville, Raleigh-Durham, San Jose, and San Juan. AADT has also completed numerous simulation projects for external clients (Airport Authorities, International Carrier Associations, etc.) in Chicago, Honolulu, Houston, Los Angeles, Kiev, Madrid, New York, Nashville, Palm de Majorca, Stockholm, Sydney, and Tokyo.

The following sections discuss the general approach of an AADT simulation study, introduce the reader to airline operations by explaining the hub and spoke concept, and present examples of airport/airline projects that have been performed by AADT.

2 GENERAL APPROACH

The approach for evaluating airport planning issues using simulation consists of six major tasks. Assuming an in-depth understanding of the process to be modeled, these tasks are: problem definition, determination of system performance measures, model development, validation/verification, experimentation, and evaluation of results. Figure 1 summarizes the general approach for using simulation to model airport/airline operations. The nature of the consulting environment and the inherent complexity of real-world systems require emphasis on client participation during the initial phases of the project.

The first step in any simulation project is problem definition. In many ways, this is the most important step, especially in a consulting environment. The consultant must thoroughly understand the client's problem as well as any related issues. Problem definition includes collecting data and developing assumptions about the system. Data collection may include traditional time studies and measured observations of the system. Such observations allow

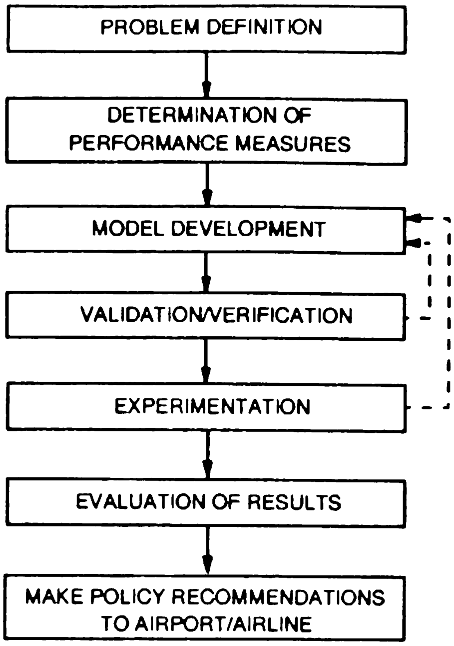

Figure 1: General Approach for Using Simulation to Model Airport/Airline Operations

the analyst to understand the system to be modeled as well as gain necessary rapport with the client. Developing a complete set of assumptions about the system and reviewing them with the client ensures that both the consultant and the client understand the system that will be modeled and accept the approach for modeling the system.

A major challenge in the problem definition phase of a project is determining the level of detail to be modeled. Too little detail results in over-simplification and inadequate analysis of the problem, but too much detail makes models overly complex. Trade-offs must be made in order to reach an appropriate level of detail that will allow appropriate analysis of the problem.

The next step is determining system performance measures. These are statistics that will best describe the performance of the system being modeled. It is prudent to include any statistic that might be of interest, since most are easier to include in a model as it is being developed but may become more difficult as the model reaches completion. In practice, it is a good idea to include the client in discussions of performance measures to ensure that all areas of interest will be measured. Some statistics of interest may be difficult to obtain. For example, a client may want to know how many passengers are waiting in a particular area of the terminal during every minute of the day. This is more difficult than determining the maximum number of passengers waiting in the same area during the day. All performance measures necessary to adequately describe performance of the system must be included.

Model development is the next step of the simulation project process. In all successful simulation projects, a significant amount of work has already been done before this step is reached. Both the client and the consultant understand the problem and are comfortable with the objectives and assumptions. Model development involves writing computer code, refining assumptions, and adding performance measures as necessary. Sometimes assumptions turn out to be too difficult to model in a timely manner. So the project assumptions may have to be revised.

After the model is running, the analyst must verify and, if possible, validate the model. Verification is always an essential element of a successful simulation project. All models must be thoroughly verified to ensure that the system is being accurately modeled. Validation is also very important; however, only projects involving an existing facility may be validated. In practice, simulation projects often involve a proposed facility or schedule. In these cases, validation is not possible and verification must be used to ensure that the model is working correctly.

Upon completion of the model verification/validation, the analyst may begin running simulation experiments. This process may expose problems with the model which require correction. Also, the analyst may discover a need for additional performance measures. Thus, successful completion of this process may require some additional model development.

After simulation runs have been completed, the consultant can evaluate the preliminary results. The evaluation process may uncover coding errors or deficiencies, in which case the analyst must return to the model development step and make appropriate changes. Also, some assumptions made may not be feasible in practice. In this case, the assumptions are revised after discussion with the client, and the appropriate changes are made to the model.

Following any necessary coding changes, the analyst can obtain final results and present them to the client. These steps can be performed only after all of the above tasks have been completed. The consultant must consider the project objectives and present only the significant results rather than methodically reporting all model statictics, which would overwhelm any client. Presentation techniques greatly affect the client's acceptance of results. The consultant must present results using wording that the client can understand since most clients do not have in-depth knowledge of simulation techniques or terminology. Also, presenting graphical displays of results is important because the client can "see" the results rather than have to read them.

3 BACKGROUND - AIRLINE HUB AND SPOKE OPERATIONS

In order to describe simulation applications in the airport environment, the concept and nomenclature of an airline's hub and spoke operation must be understood. The hub and spoke concept has been vital to the growth of all major airlines in recent years. In a hub and spoke operation, flights arrive to hub airports from upline spokes, then depart to downline spoke airports. For example, a flight departs from Las Vegas (upline spoke), travels to Dallas/Fort Worth (a hub), then continues on to Memphis (downline spoke). Usually, upline and downline spokes will be located in geographically different directions. So, arrivals from west spokes - cities located to the west of the hub - will be followed by departures to east spokes. These arrivals and departures usually occur during a complex - a sequence of closely spaced aircraft arrivals followed by a short amount of ground time and then a set of closely spaced aircraft departures. This scheduling technique ensures the ground time for all aircraft to be as short as possible, thus maximizing the utilization of the aircraft. Most importantly, hubs allow airlines to effectively increase the number of market pairs they serve since a passenger on any arrival in a complex can connect to any departure in the same or a later complex. Figure 2 illustrates the hub and spoke concept.

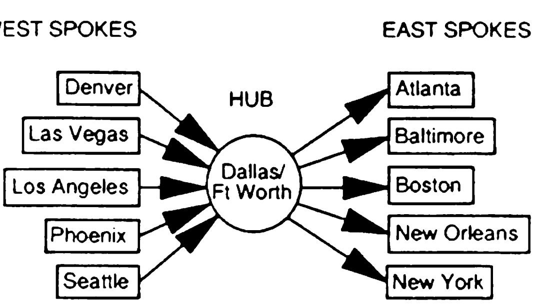

Figure 2: Hub and Spoke Concept

A considerable amount of activity occurs at hub airports during a relatively short connection window (45-60 minutes). Passengers and bags must connect from inbound to outbound flights. This means passengers must deplane their inbound flight, travel to another gate, and board their outbound flight. Bags are unloaded from the inbound aircraft, transported on carts to outbound aircraft, and loaded on the outbound flight. In a reasonably large hub operation such as American's Dallas/Fort Worth (DFW) hub, each complex has approximately 45 arrivals. Assuming each flight carries an average of 125 passengers, there will be over 5600 passengers traveling through DFW in each complex. If each passenger carries an average of 1.7 bags, over 9500 bags will have to be transported from inbound to outbound aircraft during the connection window. This large number of connecting passengers and bags creates the potential for bags to be mishandled and passengers to miss flights. The airline is responsible for ensuring that bags and passengers are all connected properly, i.e., that an appropriate level of customer service is provided.

The next section will describe three areas of airline operations which have been critically evaluated using simulation modeling.

4 EXAMPLES

4.1 Baggage Handling Operations

Baggage handling is an area of airline operations that is a very important element of customer service. Passengers depend on picking up their bags when they reach their destination, and mishandled bags comprise a large portion of customer complaints for airlines.

The most important part of baggage handling is connecting bags between aircraft at a hub. Hubs allow airlines to effectively serve many markets by connecting passengers and bags from numerous inbound cities to numerous outbound cities. This operational strategy requires intense baggage handling at the hub station. At American Airlines (AA) hub airports, bags from all inbound aircraft can connect to any outbound aircraft in that complex or later. This results in a very large number of bags that must be unloaded and transferred during a relatively short connection window. Bags which should depart on flights in the current complex are ramp connected - transported directly from one aircraft to another. Some bags arrive, however, that do not connect to a flight that is currently on the ground. These are called future bags, and are typically sent to a bagroom to be sorted and sent on a later flight. The demand on bagroom facilities will continue to increase as the number of flights in a complex increases.

AADT has recently worked on a project which evaluated the current bagroom facilities at an AA hub using a future schedule with an increased number of flights. The bagroom at this hub handles future connecting, local originating, and interline (connecting from another airline) bags. The project involved building a detailed model of bagroom systems and procedures. This model included all parts of the bagroom system including the input belts - conveyor segments on which future bags are placed to enter the bagroom, sortation - a system of conveyors and scanners which sorts the bags by outbound flight number, and piers - conveyor segments used to store sorted bags. Bagroom procedures that were modeled include drop-offs - bags being placed onto input belts, and cart staging - bag carts used to transport sorted bags to departing aircraft are placed beside piers until full and then moved to a staging area until they are taken to the aircraft. This model was validated for current operations by comparing bag processing times and number of bags processed to model output statistics.

The results showed that the sortation system will be adequate to support the increased demand of the future schedule. However, the results showed excessive queueing of bag carts at the drop-off locations and inadequate space in the current bagroom to stage the number of baggage carts that will be needed under the future schedule. Although additional bagroom space requirements and drop-off locations needed for successful operation of the future schedule have been determined, more work is needed to investigate procedural changes that would allow the current bagroom facilities to handle the future demand.

4.2 Passenger Flow Operations

Another important level of service issue at hub airports is passenger flow. Passenger flow primarily includes the large volume of people who connect through the hub, but this passenger flow also includes meeters/greeters (people meeting arriving passengers), well-wishers (people accompanying departing passengers), and local originating and terminating passengers. All of these people use limited resources such as people-mover systems, seating areas, and corridors, and the demand for these resources will grow as airline traffic increases.

AADT has been involved in projects which determined the level of service provided by current facilities under a future schedule. These projects have evaluated performance of a people-mover system, compared the amount of available and required seating in particular areas of the terminal, and estimated corridor congestion during complex connection windows; these studies used existing schedules as well as various alternative schedules with increased aircraft operations and passenger demand on the terminal.

A recently completed project evaluated the performance of the DFW TRAAM, a people-mover system consisting of several trains moving on a closed-loop track. The client provided train speeds and TRAAM car capacities. System performance under future schedules was evaluated by estimating denied passenger boarding rates at the various TRAAM stations. Passengers being denied boarding at a station was an unacceptable level of service and required additional trains to be added during peak times in order for all connecting passengers to board their first available TRAAM.

The same future schedule was used to evaluate current seating capacities in the terminal waiting areas. Since passengers waiting at any gate can also sit at adjacent gates, a moving 3-gate seating zone was evaluated. The number of departing passengers that would not have a seat available in each seating zone was estimated and found to be significant during certain times of the day. Additional seating requirements by seating zone were determined and presented to the client.

The impact of a future schedule on terminal corridor congestion was also evaluated. Since the TRAAM has a limited number of stations, connecting passengers must still walk at least a minimal distance to reach their departure gates. Also, local originating and terminating passengers as well as meeter/greeters and well-wishers create additional traffic in the corridors. Corridor congestion under a future schedule was measured by counting the number of passengers in zones throughout the terminal. The results showed significant congestion during certain times of the day. Additional analysis was performed to determine corridor occupancy by 1-gate rather than 3-gate seating zone. This 1-gate zone corridor analysis clearly identified highly congested corridor areas that, if possible, should be widened to improve passenger flow and reduce connect times.

4.3 Customs Operations

An area of passenger level of service concern not necessarily at a hub airport is Federal Inspection Services (FIS) operations. FIS operations are present at all U.S. airports with international arrivals.

AADT has been involved in numerous projects involving FIS facilities through which all passengers arriving from international countries (except Canada) must pass. A typical FIS facility is comprised of the following areas: Immigration and Naturalization Service (INS), baggage claim, primary U. S. Customs Service (USCS) inspection, secondary USCS inspection, and U. S. Department of Agriculture

(USDA) inspection. All passengers must pass through INS, bag claim if they have checked baggage, and primary USCS. Secondary USCS and USDA inspections are required only if the passenger is suspected of transporting prohibited substances.

Although FIS facilities are controlled by government agencies, airlines are concerned about FIS operations because of their impact on connecting passengers. All arriving international passengers must be processed through the FIS before connecting to domestic flights. The maximum time for a passenger to be processed through the FIS facility will determine the minimum international to domestic connection time. Thus, it is in the airline's best interest to ensure that the FIS facility is adequately sized and staffed.

AADT has performed FIS studies for both existing and planned facilities. The goal for all FIS studies is to determine facility requirements to meet U.S. government guidelines regarding passenger processing times through FIS facilities. For an existing facility, typical issues include determining the impact on a facility of: changes in staffing levels, improvements in processing rates, schedule changes, and layout/flow changes. Issues in facilities which are still in the planning stages usually include sizing decisions: how many INS booths, bag carousels, USCS and USDA inspection stations, and facility exits should the facility contain. Also, since a planned facility is evaluated using a projected schedule, the estimated robustness of the facility to schedule changes may be of interest.

A recently completed existing FIS facility study evaluated facility performance using a proposed layout change and a planned summer 1992 schedule which contained a traffic increase from the current schedule. The layout change involved adding an additional USCS primary inspection point, which would allow passengers to be processed through either of the checkpoints. Using current operating procedures, this additional checkpoint inproved passenger flow exiting the bag claim area and moving through the checkpoint, but also negatively impacted passenger flow through the USCS and USDA secondary inspection areas. As a result of preliminary results showing potential problems in the secondary inspection areas, operational procedures were modified to help alleviate these problems. Final results indicated significant improvement using the modified procedures.

A recently completed project for an FIS facility in the planning stages evaluated system performance using a projected schedule, facility layout, and resources. The analysis showed that the planned layout and resources were more than adequate to meet the U.S. government guidelines on maximum processing time through the facility. Numerous experiments were then performed to determine how many INS booths, bag carousels, and primary USCS inspection officers will be needed in order to meet the maximum processing time requirements and reduce the cost of construction for the facility.

5 CONCLUSION

A number of complicated processes interact during complexes at hub airports. Effective facility planning requires quantitative assessment of these processes and their interactions. For example, passengers and their bags must be connected from arriving to departing flights in a relatively short time window. For passengers arriving from international cities, this process is complicated by the requirement that they must be processed through an FIS facility before they can go to their departure gate. As airlines add flights, the number of passengers and bags connecting through hub airports will continue to increase. Airlines must have adequate facilities and procedures in order to provide a high level of service to their passengers.

AADT has performed numerous simulation projects to determine whether existing facilities and procedures will effectively handle anticipated increases in airline traffic. These projects have identified facilities and procedures that will be inadequate under an increased schedule. As a result, AADT is working with clients to determine long-term bagroom facility requirements and to investigate new baggage handling procedures that will allow existing facilities to handle anticipated short-term growth at one of its major hubs. At the same hub, AADT's clients are also currently finalizing plans to add more seating in the terminal waiting areas to accomodate increased passenger demand.

AADT has also evaluated the expected performance of planned facilities using projected schedules. These projects estimated the utilization of resources and identified any differences in planned and required capacity. As a result of these findings, clients are revising design parameters to improve system performance when necessary, and reduce construction costs when possible.

AUTHOR BIOGRAPHY

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