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APPLYING SIMULATION IN A CONSULTING ENVIRONMENT – TIPS FROM AIRPORT PLANNERS

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ABSTRACT

This paper describes the typical steps performed in a simulation consulting project in the aviation industry. While the aviation consulting environment does require some differences in the specific approach, the general framework has been applied successfully in the more traditional areas of logistics and manufacturing.

1 SIMULATION IN AIRPORT DESIGN

Airport design is, by far, the largest practice area for TransSolutions. This is a unique area, with many differences from typical simulation in manufacturing or logistics.

Passengers and bags arrive at the airport by the plane-load. At the busiest airports the arrivals and departures are coordinated, so that several flights arrive within a short time. Then, after a short time on the ground the aircraft all depart again. A large number of passengers move through the facility during the peak period between the flight arrivals and the departures. After that, the facility will be empty until the next bank of arriving flights. The terminal facilities must be sized to handle these waves of passengers throughout the day.

Space within the terminal building is at a premium. Most travelers are aware of the ticket counters, gate lounges, corridors and shops in the public areas. Hidden behind the scenes are the various offices, control rooms, and break areas for the airport and airline employees. The baggage system and various maintenance functions take up most of the space on the ramp level below the passenger areas.

The usual question asked by the architects is: “will the facility, as designed, satisfy the needs of the tenant airlines?” This involves comparing the “performance” of the facility to minimum acceptable standards. A typical example is that all passengers connecting from an arriving flight to a departing flight must be able to reach their departure gate within 30 minutes of arrival. Another example it that all baggage must be delivered to the claim area within 20 minutes of the flight arrival. There may be many other performance requirements, depending on the size and scope of the project.

We will briefly describe some of the basic areas within the airport environment where simulation can be readily applied. The aviation environment is rich with areas where simulation or other stochastic methods can be applied. Some of the major applications of simulation in the airport environment are summarized in the following sections.

1.1 Airspace/Airfield Capacity

The US Domestic Airspace can be thought of as a large link and node network. Aircraft are required to maintain separation between other aircraft. As aircraft approach an airport they are funneled closer together – with many routes converging into common links. Simulation is useful to evaluate the capacity of the link node network and to evaluate alternative link node structures that could improve capacity.

Additionally, ground movements of aircraft represent another link node network. Arriving aircraft move from runways to taxiways to taxi-lanes and eventually to their gates. Aircraft may need to hold on the airfield before reaching to their gate due to general ramp congestion or due to gate unavailability. Departing aircraft follow the reverse process and also usually wait in a departure queue before accessing the runway for take-off.

The movement of the aircraft must be carefully planned since many taxi-lanes and taxiways are bi-directional and can only accommodate aircraft movement in one direction at a time. Additionally, aircraft need to be able to stop or park at designated areas on the airfield so that they do not impede the movements of other aircraft.

Simulation is frequently used in airfield analyses to determine the benefit (capacity improvements or delay reduction) of adding new runways, taxi-ways, and taxi-lanes, as well as evaluating how alternative gate allocation strategies impact airfield capacity.

1.2 Ramp Operations

Ramp operations are generally much more complicated than most people realize. There are many different functions working in coordination with each other to ensure the efficient utilization of aircraft.

Services performed on aircraft include fueling, catering, lavatory cleaning, baggage loading and unloading, cargo loading and unloading. The vehicles performing these service all compete for usage of the same roadways.

1.3 Cargo Handling

Airports are large centers for cargo distribution. In addition to planning the pick-up and deliver goods from aircraft, most large airports have main cargo buildings where cargo sortation is performed.

1.4 Baggage Handling

Each airline and airport must be able to get a passengers' bag from either the curb or the Airport Ticket Office (ATO) to the departing aircraft. At smaller airports, bag handling is often performed manually, after a bag is delivered to the ramp side of the terminal via a conveyor belt. Larger airports utilize very complex sortation systems to route bags to specific piers or circulating make-up devices. A bag system may also incorporate security screening, early bag storage, and manual encode stations (to identify and manually re-direct bags with missing or unreadable bag tags.)

The bag system must ensure that all bags handled throughout the airport can be delivered to their destination gates in time to reach the departing flight.

Three technologies dominate airline baggage handling today: conventional conveyor, tilt-tray, and automated guided vehicles.

1.5 Passenger Flow

Passenger flow is described in three component sections: general circulation, automated people mover systems, and Federal Inspection Services.

1.5.1 General Circulation

Airport facilities should ensure that passengers experience an acceptable level of service while in the facility. This includes factors such as not having to wait too long in queue at a ticket counter or gate, not having to walk extremely long distances in the terminal, not being crammed into elevators, hallways, or waiting areas where there is little or no ability to circulate.

Most importantly all passengers should be able to comfortably reach their gate by either walking or using a moving walkway or airport train.

Simulation is frequently used to predict passenger connection times, to determine expected occupancy levels at various locations throughout an airport terminal, or to determine how long passengers will wait at various points throughout the terminal.

1.5.2 Automated People Mover Systems

Most large airports have a light rail system that will connect passengers between terminal buildings. For these systems additional design issues must be considered such as transport time, capacity and station location.

1.5.3 Federal Inspection Services

Passengers arriving to an airport coming from a destination outside of the US and its territories are required to be screened through Immigration, US Customs, and US Agriculture. These facilities must also be properly sized to ensure that all of the passengers using the facility are processed in time to meet connecting flights.

2 STEPS IN A SIMULATION PROJECT

The purpose of a consulting project is to provide added value to your client. The client rarely cares how a problem is solved, so long as a solution can be reached that both the client and consultant are confident is correct. The purpose of a consulting study is RARELY to build a simulation model. The model is the means to reach the end; it is generally not the end.

In our business, our consulting tasks generally revolve around making recommendations as to the best options for accommodating changes in airport use or accommodating expected changes in demand levels. The client is usually someone that is making decisions on large facility design or expansion projects.

The term client is applicable regardless of whether the analysis is working as an outside consultant or within a company. The client relationship also applies to analysts working on internal project. There is always someone "commissioning" the study that has an interest in the results.

We will discuss the stages of a typical consulting study that uses simulation: problem identification, data collection / data analysis / assumptions development, model development and verification, initial experimentation, validation, subsequent experimentation, analysis of results, and preparation and presentation of the results. Each of these is described in more detail in the following sections.

We must add a cautionary note here. While it is convenient to present the framework as a list, the steps rarely progress in a smooth sequence. The data analysis may show that some information is missing, requiring additional data collection. The initial model may not be valid and may require additional information. In other cases the analyst may model one area as a "black box", then return later to fill in the details of that area.

2.1 Problem Identification

The first step in any study is to determine a few basic requirements: the system to be studied, the objective of the study, and the timeline for the results. This is never as straightforward as it seems. In some cases the problem identification takes place before a notice to proceed has been given. The client often wants to be convinced that the consultant can solve his problem before agreeing to pay him any money.

The problem identification step is critical to ensuring the project ends in success. Showing up a few months and hundreds of billable hours later with a great answer to the wrong question doesn't make a client happy.

Many people have the misconception that a computer model, once built, will be sufficiently flexible to answer any additional questions. This is clearly not true. The same facility can be accurately modeled in many ways, depending on the desired output information. It is important to know as many of the questions up front to guide the model development. It is not unusual to negotiate on some of the lesser objectives if the work effort substantially increases to obtain a minor result.

Another common dilemma is that the prospective client says they want the results from your simulation for a meeting next Tuesday. There is always some give-and-take on the timeline with simulation studies - you can work longer to get a more accurate (and expensive) model or you can accept a less detailed model more quickly. There is a lower limit on providing a realistic model. If the client really needs results sooner, then we have to explore approaches other than simulation.

The last step in problem identification should be the development of a work plan that describes the work to be performed, the data required to perform the work, and the timeline for completion. A formal quote is usually required for a new client, while existing clients are usually satisfied with a less formal work plan.

As part of problem identification every effort should also be made to identify the performance criteria. The performance criteria establishes the guidelines for being able to make a decision regarding the results obtained from an analysis. It is very frustrating if you have modeled multiple systems and have all types of data regarding how the systems differ, but no decision can be made because no one ever understood what was to be done with the results once they were produced.

2.2 Data Collection /Data Analysis/ Assumptions Development

Once you have a clear idea of what the problem is that is being addressed, all of the data that needs to be used by the model must be collected.

Large-scale simulations require a lot of data. Invariably, the information gathering for the model is the longest part of the project. It is typical for the data collection and analysis to take one third to one half of the total project, even more time than the model development. In some cases the required information is readily available, in some form, from existing records provided by the client. Other must be collected by field observations.

In this part of the project the analyst has to recognize their role as an integrator pulling information in many different forms from many different sources. Within organizations people tend to have responsibility for certain areas while the simulation analyst may be modeling across several areas. Also different clients will provide the same information in varying levels of detail. In one airport study we received a detailed probability distribution for service time for one type of ramp vehicle, an approximate average for another, and a "depends on a lot of things" for a third. The analyst must make the decision whether the available data is sufficient or whether field observations will be necessary.

Other parameters may be taken from standard references. For example, passenger walk speed is almost always taken from standard references. This is very difficult to measure in the field and not something that anyone is likely to track. Care must be used with standard data, anything that does not come from the client site is likely to be considered "suspect". Architects and engineers that use standardized data in design work are more accepting of this in simulation models.

During the data collection and analysis we always prepare a comprehensive "Assumptions Document" containing the results of data collection and analysis including a description of the system to be modeled, the objectives and any assumptions that will be used to create the simulation model. These documents can be massive. Whenever possible there should be a meeting held with the client to review all assumptions and analysis of any data to be used as input to the simulation.

Documenting the assumptions is possibly the most critical step in the modeling process. There is always someone that does not benefit from the findings of the study. The easiest way to discredit any study is to discredit the underlying assumptions. The client's ultimate acceptance of the final results should begin with their acceptance of the assumptions.

The process of developing the assumptions document also is an opportunity to identify what type of sensitivity will need to be performed during the experimentation phase of the project.

We were working on a project where two of the major project stakeholders had a fundamental disagreement on a key assumption for a bag system. Two different sources, both considered to be reliable and accurate provided estimates for the number of checked bags per passengers that differed by nearly 50%. Since it appeared to be impossible to reconcile which data was correct, we decided to evaluate the performance using both sets of assumptions. We deferred making a decision on deciding which data was better until we could determine if the differences in assumptions produced any significant difference in model results. This decision saved a lot of time and money, because we were able to avoid wasting time trying to reconcile differences that weren't very important.

2.3 Simulation Design, Development, and Validation

This is probably the most straightforward step in the study. It may be technically challenging, but it is the one step that is probably the easiest to control.

Design generally does not start until after the assumptions document has been completed. In reality, there is almost always down during the data collection phase when we start designing the model. There is a risk associated with doing this since anything developed prior to the client acceptance of the assumptions document may be wasted if the assumptions are changed or amended. During the design process you may discover additional information that needs to be clarified from the assumptions. This is a natural by-product of the process. Not every piece of information required can be identified before design begins, and design can't begin before you know what kind of data is available. If new assumptions are made after the client has approved the original document – be sure to go back and get the new assumptions approved too!

We have used a couple of methods for very large studies that require more than one analyst developing simulation code. In some cases it is possible to develop independent models that pass information externally through files. Extreme care must be taken to control logic, naming conventions and code structure at the beginning of the coding process if the sub models must be merged together. On one project it took as long to merge the two sub-models as to develop them originally.

Finally, once the model is built always test your code to be sure is behaves as you had intended it to. This is the verification step. It has absolutely nothing to do with validation. At this point you are only trying to identify and correct logic errors or mistakes made during the code development process.

2.4 Initial Experimentation

Initially, you will need to run some experiment. The initial design of the model generally reflects the baseline scenario. Baseline results should be generated and validated (see next section).

Be sure to use sound simulation practices to determine number of replications needed to give you statistically meaningful results. Project timeline pressures invariably influence or limit the number of replications that can be made.

2.5 Validation

Validation is the process off ensuring that the model (with some degree of confidence) represents the true system.

Two types of validation are commonly used:

a) If the process being studied already exists, and historical performance data is available, then statistical methods should be used. In most cases simple hypothesis testing techniques can be used to perform the validation.
b) If the process is currently not already in operation then a "Face Validation" needs to be performed. "Face Validation" is the process of reviewing results by experts (usually your clients) to determine the reasonableness of the results. They may alert you to surprising results, which you should thoroughly investigate by reviewing assumptions and the model logic. "Face Validation" should be repeated until the experts agree that the baseline results are reasonable.

2.6 Subsequent Experimentation

In the manufacturing studies we have conducted there are typically several alternatives and the objective is to determine which is best. In terminal design studies, on the other hand, there is usually only one proposed design. The initial objective in this situation is to determine whether the design "works" under typical conditions. In the first case we are comparing the results from two (or more) model configurations while in the second we are comparing the results from a single model to acceptance criteria.

Once the design has been shown to work, there may be many additional experiments to evaluate the details of the design. These are typically determined based on the original results. In airport terminal design it is common to study things like changes in the number of ticket counters, alternative uses for the available roadways, and changes in the number of baggage cart deliveries prior to flight departure. In each case this is probing to determine whether the design can be made to work better, or as well with fewer resources.

It is also common to study the performance of the airport as operating conditions deviate from ideal conditions. Flights delays introduce another large source of variance into the system. Extreme care must be taken in this type of analysis, however, since operating practices change at some point during the deterioration. It is the role of the analyst to ensure that the simulation is not being used outside its range of providing accurate results. This example is specific to terminal designs but similar problems occur in other studies.

2.7 Analysis of Results

After all of the experiments be sure to carefully analyze all of the results. The results from one experiment usually helps you determine if other scenarios should also be evaluated.

2.8 Develop Report and Present Results

The final step in the study is to evaluate the results and communicate them to the client. We will concentrate on how the information should be presented. There are many references for the various statistical methods used in the analysis.

It is important to provide the results to the client in a format that they will understand. As a general rule architects like information graphically while operations people are more comfortable with numbers in tables. Another rule is that the client will more readily understand a result if it is in a format that the client currently uses for similar reports, such as an inventory tracking report. The client already understands the meaning of data in that format and can focus on the results, rather than having to determine what is being reported.

Always think about who will be reading the report. If you presenting results to Senior Management they probably don't care about getting into a lot of detailed statistics – keep this report high level. Two types of reports are frequently generated: An Executive Summary (which just focuses on the major results), and a comprehensive summary of the findings from all of the experiments performed.

The client will invariably ask why any noticeable results occur. Simulation is not particularly good at providing this type of information, so the analyst should learn to track the results to determine the causes. For example, with baggage delivery systems it is possible to have conveyors get blocked while others are busy. A statement that the worst case delivery time is 45 minutes is not very informative. Stating that this was caused by the simultaneous unloading of four aircraft on two adjacent belts is much stronger. This second statement explains the unexpected result and suggests possible corrections. Extreme results without explanation are more likely to generate suspicion of the model than of the system being studied.

As a final note, facility decisions are based on many factors. The simulation results represent one of these, operational performance. Cost and projected timeline are other quantifiable factors. Less quantifiable factors, such as confidence in the supplier, are also considerations. It is rarely necessary to determine whether one alternative is statistically better than another is when the simulation analysis shows that two alternatives are close. Some other criteria is likely to be more critical to the final decision.

3 CONCLUDING REMARKS

Throughout the years TransSolutions and its preceding companies have made extensive use of simulation modeling to provide information for clients on facility design and expansion projects. The practices described in this paper have evolved over time based on the experiences from numerous projects.

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