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AN AIRCRAFT TAXI SIMULATION MODEL FOR THE UNITED PARCEL SERVICE LOUISVILLE AIR PARK

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ABSTRACT

The Louisville International Airport arrives and departs over 200 flights on a daily basis for United Parcel Service (UPS). The number of arrivals and departures continues to grow with the expansion of the airport and UPS.. A simulation model was developed to analyze the daily taxi and takeoff operation of UPS aircraft. Inputs to the model include aircraft schedules, flight patterns and runway information. Customized outputs include aircraft departure statistics for each flight and runway utilization. The model assists planners in developing aircraft departure schedules that minimize taxi and ramp delay times.

1 INTRODUCTION

Each day over 150 UPS aircraft arrive and depart at the Louisville International Airport. Taxi and ramp delays during the operation of these flights can interrupt the service commitment of over one million packages. Customers are demanding later pick-ups, earlier deliveries, competition is increasing and the market is expanding rapidly, which increases the effects of poor planning or decision making. Just a single aircraft departing late can result in thousands of dissatisfied customers and a potential loss of millions of dollars.

Over the past five years, both UPS and the Louisville International Airport have expanded. These combined expansions have resulted in limited ramp space and modified taxi paths. Limited ramp space has made taxi paths, departure times and parking positions even more critical to a successful launch. All three must be carefully planned in order to minimize delay times.

The Taxi Simulation Model was designed to represent the aircraft departure operation under normal operating conditions. The model takes into account the flight schedule, parking positions, direction of takeoff and other variables based on aircraft type and airport regulations. The model has been modified several times to accommodate planned expansions to both the airport and UPS. It has also been modified to analyze proposed changes to UPS and airport properties that would potentially reduce ramp and taxi delays.

2 PROBLEM DEFINITION

2.1 Objectives

The Taxi Simulation Model has gone through several phases due to changes in airport and UPS properties. The modifications made to the model have created different objectives. There have been three main objectives of the Taxi Simulation Model that have evolved over time.

The first objective of the Taxi Simulation Model was to be able to determine the taxi times, taxi delays and ramp delays associated with various changes in flight departure schedules and parking plans. Planners could analyze the effects of changing one or all departure times and/or parking positions, allowing them to make decisions regarding departure operations without interrupting the delivery of the packages.

The second objective of the model was to analyze the stages of the airport expansion and potential changes in the airport property. The original Louisville runways were in a "T" or "X" formation, where both runways could not be used at the same time. After the first phase of the airport expansion, the runways were in a "V" formation, where one of the old runways was in use with one of the new runways. The "V" formation allowed both runways to be used at the same time, but were still limited. After the final phase of the airport expansion, the runways are now in an "H" or parallel configuration. These runways can now be used at the same time, increasing the arrival and departure rate in Louisville. Each of the three phases required extensive planning since the airport and UPS must operate

during the construction. The model allowed the planners to formulate a parking plan for each phase.

After the final airport expansion, the third objective of the Taxi Simulation Model was to analyze the different stages of the UPS changes and expansions. Some of the changes in UPS property were caused by the airport expansion, but most are due to the current Hub 2000 expansion project. Hub 2000 is the construction of a new hub (terminal) within the middle of the airport, between runways, for UPS 's use in the sortation of packages during the operation.

The Hub 2000 project will increase the number of aircraft that UPS can process. It involves new buildings and parking positions which will change ramp and taxi procedures. The project has many phases, all of which need operating procedures. The Taxi Simulation Model will help the planning team determine the best plan for each phase years in advance.

2.2 Model Scope

The taxi model simulates the aircraft arrival and departures at the UPS Louisville Air Park (see Figure 1). The model runs in two different scenarios depending if the aircraft are departing or arriving. The departure model is designed to evaluate the effect of changes to aircraft schedules and aircraft parking positions. The model scope of this paper is limited to the operations directly related to the departure of aircraft. The daily operations in Louisville include both Next Day Air (night) and a Second Day Air (day) sorts. The two sort operations are separate and the model was written primarily for the Next Day Air Sort. During the Next Day Air sort, there are UPS arrivals and departures, along with sporadic delays from other arriving aircraft during the operation. The model assumes that there are no arrivals on the main runways during the departure sequence, but can accommodate small aircraft arrivals on the cross runway.

The model begins with the aircraft ready for departure from its ramp parking position. The aircraft will begin its taxi procedure with the removal of the chocks and pylons. The marshalling crew will direct the plane to move into the middle of the ramp. The aircraft then proceeds down the ramp to the throat of the ramp where it will access a taxiway. The plane will travel down the taxiway to the runway where it will be ready for takeoff. The plane will then takeoff and exit the system.

3 MODEL DEVELOPMENT AND PROJECT ORGANIZATION

The Taxi Simulation Model was developed using Arena® from Systems Modeling Corporation. The first version of the model represented the original “T” or “X” airport configuration. After this model was validated, a second

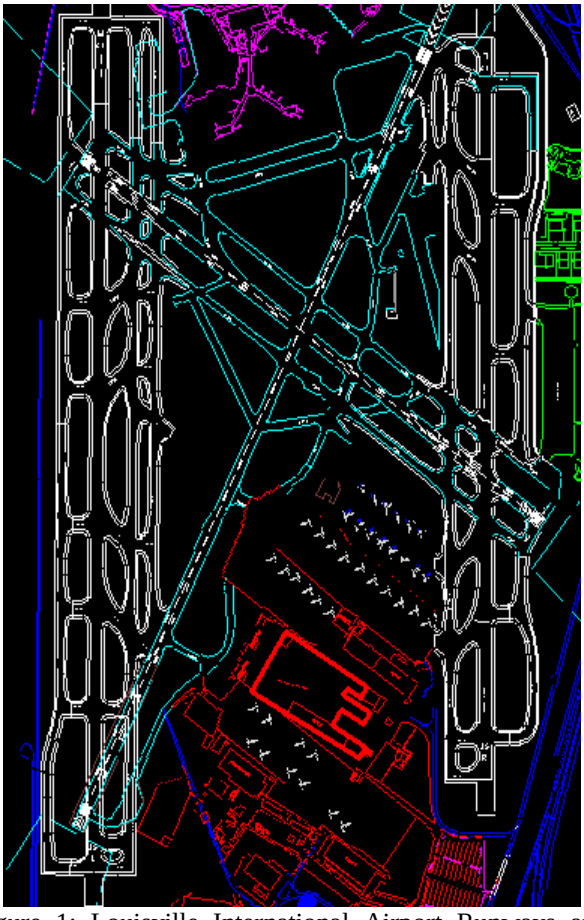

Figure 1: Louisville International Airport Runways and UPS Facility Layout

model was constructed to examine the future parallel runway layout.

The processes in the simulation model include the following:

- Model initialization
- Aircraft blockout
- Travel on the UPS ramps
- Travel on the taxiways
- Aircraft rollout and liftoff

Input data files were built by identifying the requirements for the model. Then, data fields were created for initializing the aircraft entities. All data files are read first to initialize the model.

Aircraft blockout is the first step in the model and occurs at the time read from the data file. The ramps are divided up into sectors and a simulation resource is used to ensure only one aircraft per sector is allowed to block out at the same time (see Figure 2).

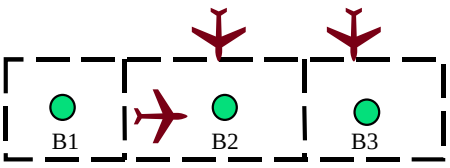

Figure 2: Ramp Sectors and Resources

Travel on the ramps is modeled as an aircraft moving from sector to sector. A simulation resource must be seized before an aircraft is allowed to move into a sector. After traveling through the sector, the resource is released. Ramp taxi speed is an input variable and is applied to all aircraft moving on the ramps, Ramp sector distances are set by an input variable to the model.

Once an aircraft reaches the end of the ramp, it must enter the FAA-controlled taxiway. The taxiways are modeled using the guided transporter constructs of the Arena® simulation language. A network of links and intersections was constructed to represent the travel paths. The aircraft entity boards a transporter and moves to its assigned runway. Movement and travel on the taxiways is then automatically controlled by the transporter logic. Traffic is controlled at the intersections on a FIFO basis. One hundred foot zones were defined in the network links to maintain a minimum following distance of two zones.

The aircraft transporter's destination is the beginning of the runway. Air Traffic Control clearance is modeled by a simulation resource representing the controller. After obtaining clearance, the aircraft must then seize the runway resource. The resource is held for a given amount of time equal to the takeoff separation for that aircraft type.

The project group included representatives from Ramp Operations Industrial Engineering, Flight Operations IE, and Operations Research. Flight schedules, ramp parking plans, and ramp movement procedures were gathered from the Ramp Operations IE interviews. Flight Operations IE supplied the FAA taxiway and runway rules needed to accurately describe the actions of the pilots.

4 MODEL DESCRIPTION

4.1 Model Inputs

The model is designed to be as flexible as possible so the user can change system parameters in external data files without having to alter the actual model. The Taxi Simulation Model is driven by 3 external data files:

- Departure file: Contains statistics on each outbound aircraft, including departure time, destination, flight number, aircraft type and parking position.
- Path file: Defines the runway that each destination will use to take off, depending on the direction of takeoff due to weather.
- Arrival file: Contains flights arriving on the shorter cross runway. This runway is used for small jets and propeller driven aircraft.

4.2 Model Features

The Taxi Simulation Model details the movement of aircraft from the parking position to the runway. An aircraft on the ramp will not travel until the space ahead is clear and there is no cross traffic.

Aircraft movement on the taxiways is even more detailed to include controlled intersections and minimum following distances. Acceleration, deceleration, and turning velocity can also be specified in the model settings.

Since the model is data driven, new scenarios can easily be created by editing the input files. Parking assignments and departure times can be changed without having to re-compile the model.

An AutoCAD® drawing of the airport property was imported as a background for the animation. Scaled drawings for each aircraft type were also used to accurately depict the operation. These animation features allowed the planners to visualize their changes, (see Figure 3).

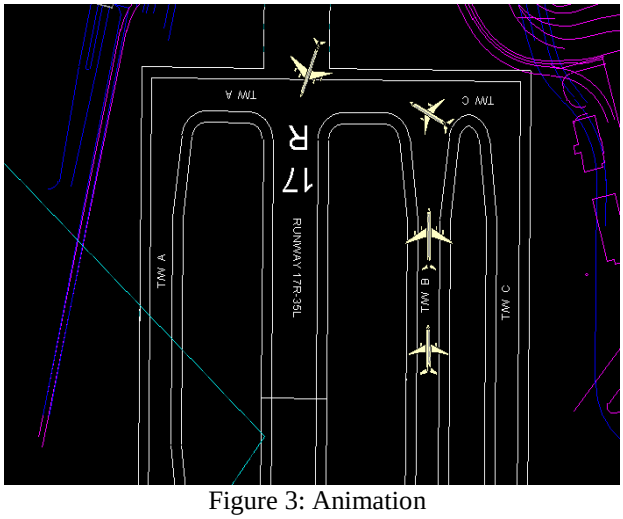

Figure 3: Animation

4.3 Model Outputs

Runway and aircraft performance parameters are collected and reported in multiple output files. Overall statistics by flight are directed to a customized output report file. Statistics reported in the customized output report include:

- Flight Number
- Parking Position

- Scheduled Blockout
- Actual Blockout
- Minutes Late
- Ramp Taxi Time
- Taxi Delay Time
- Total Taxi Time
- Turbulence Delay
- Takeoff Time
- Runway Utilized

The additional following statistics are included in the Arena output report:

- Time Between Departures for each runway
- Number Waiting for each runway
- Number Waiting at intersections
- Number Waiting on the ramps
- Runway Utilization

The collection of these statistics was facilitated through the use of the Arena® Time Persistent Statistics and Tallies features for discrete systems.

5 MODEL VALIDATION

The Taxi Simulation Model was validated concurrently with the model development and is ongoing. There are two main methods being used in the validation process: the examination of output reports and model traces, and visual validation through observation of the model's animation. Validation has followed the same basic order as the model development:

- Input Data
- Aircraft Taxi
- Aircraft Takeoff

Approval of the input data for the external data files was the first step in the validation process. Because the input data came from a number of different sources, it was thoroughly examined for consistency and accuracy. Initially, some of the information provided was out of date and was subsequently updated.

Validation of the taxi process included examination of the following processes:

- Parking Procedures
- Ramp Travel
- Taxiway Travel
- Intersection Decisions
- Takeoff Procedures

The parking procedures involve where the aircraft is parked and how the it is positioned. If the aircraft is parked with the nose in, additional time is required to push the aircraft out into the ramp.

Ramp and taxiway travel validation involves UPS and airport procedures that determine which way aircraft can travel on the ramps and taxiways. Intersection decisions are needed when two aircraft come head to head to determine which aircraft has the right of way. Takeoff procedures are determined by the aircraft type. Certain aircraft types take longer to get off the ground and require a longer time in between departures due to turbulence.

Once these processes were confirmed, the output reports were used to validate them. The simulated taxi times from the output report were compared to actual taxi times captured by real-time UPS systems. This comparison reassured the users that the model was an accurate depiction of the operation.

Various users, including UPS industrial engineers and planners, as well as operational personnel have been closely involved in validating the model. This collaboration has been critical to the success of the validation process. The model animation allows users to visualize aircraft taxiing and departing. Observing the model animation also increases awareness of the other operations (marshaling, maintenance, fueling, unloading, loading, etc.) and raises questions that are extremely helpful during validation. In addition, this involvement creates excitement and instills confidence in the model.

6 SUMMARY

The Taxi Simulation Model was developed as a flexible, data driven model to investigate the aircraft departure procedures at the UPS Louisville Air Park. It has been modified to fit the needs of United Parcel Service as additions and changes have been made to the airport property. The results of the simulation have assisted the industrial engineers in making critical decisions concerning parking positions and departure times. The initial success and acceptance of the taxi model for parking and departing aircraft laid the groundwork for its transition into a useful operational tool. Currently, the model is used to analyze the phases of the Hub 2000 project. The Taxi Simulation Model will help determine the parking plans and departure schedules for the 21st century.

AUTHOR BIOGRAPHIES

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