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Airport Flight Scheduling: A Focused Look at XNA

Identify a Problem

Over the past two decades, the Northwest Arkansas National Airport (XNA) has served a rapidly expanding population of Northwest Arkansans. With this growth and interest in the regional airport as a mean of quick connection between Northwest Arkansas, the United States, and the world, looking at flight scheduling proves to be beneficial in understanding how the airport currently operates and how it could operate in the future. This problem is especially pertinent in the flight scheduling capabilities of the airport. This subject also holds interest in relation to previous coursework, such as job sequencing and machine scheduling. Furthermore, this specific research topic is based on typical industrial engineering research in operations research on flight scheduling, shown in Barnhart et al. (Barnhart), Salazar-González (Salazar-González), and Simpson (Simpson). These resources describe airport scheduling, crew scheduling, and time sensitive methods.

For our specific project, we want to address a flight assignment problem for XNA. Within this problem, there will be a given number of flights into/out of XNA between three other airports — Hartsfield-Jackson Atlanta International Airport (ATL), Dallas/Fort Worth International Airport (DFW), and Chicago O’Hare International Airport (ORD) — based on historic data from the Federal Aviation Administration (FAA). We will determine appropriate flight assignments for runway efficiency, given an average enroute flight duration between locations and taxi times at either airport. This objective would minimize the amount of time used taxiing; thus, it will minimize the arrival time of flights after the XNA airport is closed.

Formulate an Optimization Model

When formulating this model, we considered the job sequencing mixed-integer program approach of scheduling the flight departure times. Thus, some parameters need to be defined:

the number of airports

the specified time that must be in between flights on the same route in minutes

large number for either/or constraints

average taxi time at airport in minutes (

average enroute flight time for route à in minutes (

number of flights to schedule for route à (

opening time of airport in minutes since midnight (

closing time of airport in minutes since midnight (

For each of the airports , 1 is XNA, 2 is ATL, 3 is DFW, and 4 is DFW. Additionally, decision variables need to be defined:

start time of flight from à in minutes since midnight

(

1 if flight on route à departs before flight on route à , 0 o.w.

(

1 if flight on route à lands before flight on route à , 0 o.w.

(

objective linking value for mini-max problem

Constraints needed include:

(

This constraint returns the latest arrival times of flights to XNA to be used in the minimization of the objective function.

(

This constraint ensures that all flights depart after the airports open for flight scheduling.

(

This constraint ensures that all flights depart before the airports close for flight scheduling.

These constraints are either-or scheduling constraints for flights departing from airport . They ensure that a flight on any route from airport is before or after another flight leaving from this airport. This is for all flight routes possible and flight combinations, making sure that it only considers flights that can be compared (not from airport 1 to 1 or not flight 1 compared to flight 1 on the same route).

These constraints are either-or scheduling constraints for flights arriving at airport . They ensure that a flight on any route to airport lands before or after another flight arriving at this airport. This is for all flight routes possible and flight combinations, making sure that it only considers flights that can be compared (not from airport 1 to 1 or not flight 1 compared to flight 1 on the same route).

These constraints are either-or scheduling constraints for flights on the same route 🡪 . They ensure that a flight on any route 🡪 departs a specified time before or after another flight departing on the same route. This constraint ensures that all flights on this route do not depart at the same time; thus, modeling spaced out flights that occur in airports. This is for all flight routes possible and flight combinations, making sure that it only considers flights that can be compared (not from airport 1 to 1 or not flight 1 compared to flight 1 on the same route).

These constraints formulate the conditions at which we can observe our objective function:

Minimize

This minimizes the difference between the arrival time of the last flight into XNA and the closing time of the XNA airport. The offset of the airport closing time lets us gauge how well the scheduling occurs.

In creating the model, we had to make assumptions that simplified pieces of the model to make the problem feasible. The first of which is all airports have two runways: one runway is used for flights taxiing out and departing and the other is used for flights arriving. This assumption allows for a constraint for arriving and departing flights occurring at the same time at the same airport to be dropped; thus, this assumption lets the model produce a feasible solution. This, however, is not the case at XNA. There is only one runway at this airport, but all other airports have at least two runways. Although it is unlikely that the flight time between two airports is the same in both directions, we have chosen to assume that factors such as windspeed are negligible so that we may use mean travel time gathered from individual flight data to schedule flights. The varying influences on flight time are often unpredictable, making them too complex to include in the constraints of the model. Our model assumes that planes do not require maintenance during operating hours of the airports. This assumption allows us to schedule flights at any time during operating hours of an airport. The other main assumption our model runs under is that taxi time is the same for every plane exiting and entering a given airport. Many uncontrollable factors can delay a plane from takeoff and landing, so the taxi time used is an average of all flights at each airport. These assumptions allow us to schedule flights in the most optimal fashion and allow for a reasonable feasible solution.

Gather and Synthesize Data

The data used in this model was gathered from the FAA’s Operations and Performance Data website under the Aviation System Performance Metrics (ASPM) section. The city pair analysis was used to get pair-wise data between XNA and the other three airports. This data was taken for the 2022 calendar year for all flights. These reports include departure and arrival time, flight counts for city pairs, taxi time into and out of airports, and in-air flight times, and flight delays. The averages of taxi time for airports, flight time for routes, and flight route counts were calculated and used as parameters. Using an entire year of data allows for averages that mitigate the fluctuation and variability of air travel throughout the year.

We set some parameters for our data. The parameter was set to be the end of the day, equivalent to 24 hours after midnight. The parameter was selected to be 40 minutes for ample time to finish taxiing and begin each flight. The parameters and were chosen to be 360 and 1320 respectively for each airport to standardize flights that generally depart beginning at 6:00 AM and ending at 10:00 PM.

Solve and Analyze the Model

After solving the optimization model in AMPL, the objective value given was -598.228, which represents that the final arrival time at XNA for all scheduled flights was 598.228 minutes before XNA’s close time at 10:00 PM. This resulted from the following departure times from airport 🡪 for scheduled flight :

For flight [] the flight departure time is:

|  |  |  |  |
| --- | --- | --- | --- |
| [1, 🡪,**↓**] | 2 | 3 | 4 |
| 1 | 450.283 | 393.522 | 1103.24 |
| 2 | 490.283 | 1320 | 1143.24 |
| 3 | 360 | 507.044 | 1183.24 |
| 4 | 530 | 1166.48 | 1223.24 |
| 5 | 1263.24 | 1240 | 1063.24 |
| 6 | NA | 433.522 | 376.761 |
| 7 | NA | 547.044 | NA |
| 8 | NA | 1280 | NA |

|  |  |
| --- | --- |
| [2, 🡪,**↓**] | 1 |
| 1 | 496.548 |
| 2 | 536.548 |
| 3 | 416.548 |
| 5 | 456.548 |
| 6 | 360 |

|  |  |
| --- | --- |
| [3, 🡪,**↓**] | 1 |
| 1 | 520 |
| 2 | 640 |
| 3 | 600 |
| 4 | 360 |
| 5 | 400 |
| 6 | 560 |
| 7 | 440 |
| 8 | 480 |

|  |  |
| --- | --- |
| [4, 🡪,**↓**] | 1 |
| 1 | 496.98 |
| 2 | 536.98 |
| 3 | 416.98 |
| 4 | 456.98 |
| 5 | 360 |
| 6 | 576.98 |

Some observations from this solution include the objective value being so negative. This value indicates that flights scheduled with priority given to XNA’s scheduling allow for historical flights to be scheduled very quickly. Additionally, the limiting constraint in between scheduling for flights seems to be the specified time in between flights on the same route. There are a lot of flights with our selected time of 40 in between the scheduled flights on the same route. This case is especially true for flights departing from airports other than XNA (2,3,4).

Extend the Model

From our solution to the model, we saw that the objective value was very negative, so we were curious about how reducing open hours could lead to the objective value becoming positive, indicating that a flight had arrived at XNA after it closed. To pursue this, we decided to run the model with changed opening hours, reducing the operating hours of each airport, until the objective became positive. This would show us more efficient operating hours for the airports based on our given model.

To accomplish this goal, our model was recreated in Java using Google OR tools and openCSV. After creating the model, we tested running it with SCIP compared to AMPL’s CPLEX. This method proved to be very time consuming due to the algorithm for SCIP; however, further testing showed that limiting the time ran for finding each solution allowed for solutions very similar to those produced in CPLEX. Thus, the time each iteration of the model solving in Java is set to 10000ms (10 seconds).

While implementing this model in Java, we then created a loop to run each iteration of the solution for modified opening time for each of the airports, increasing them by 60 minutes each time. The iteration that returned the first positive objective value was then selected and printed to the console, along with the solution flight assignment departure times.

This process resulted in an opening time of 4:00 PM for each of the airports with a closing time of 10:00 PM returning an objective value of 1.71. This shows us that for all the given flights to be scheduled, only about six hours are needed to effectively schedule them.

Reflection

Through troubleshooting with our constraints and trial and error with an interesting objective, we gained a better understanding of the complexity of airport flight scheduling. The similarities between our model and the job sequencing/machine scheduling models gave us insight into how quickly a seemingly simple task can become incredibly difficult to solve. Though the assumptions we made in our model cannot be guaranteed in real-life flight scheduling, we were able to learn how to handle constraints for a variety of scenarios and ultimately create a model that simulates XNA on a small scale. Although we originally assumed that XNA would need to be operational for 16 hours a day to accommodate all the scheduled flights, our extension revealed that only 6 hours are needed to cycle all the flights to and from ATL, DFW, and ORD. Even though our model only accounts for flights between XNA and three other airports, our findings show that there is time that could potentially be cut out by the Northwest Arkansas airport to save money and increase efficiency. Furthermore, we learned differences in solver algorithms and tools used to assess different types of problems. Java is effective for running easily changeable and manipulative code; however, some tools could prove time- and resource-consuming. This difficulty allowed us to assess how the solver approaches solving optimization problems and what acceptable solutions could be.

Works Cited

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