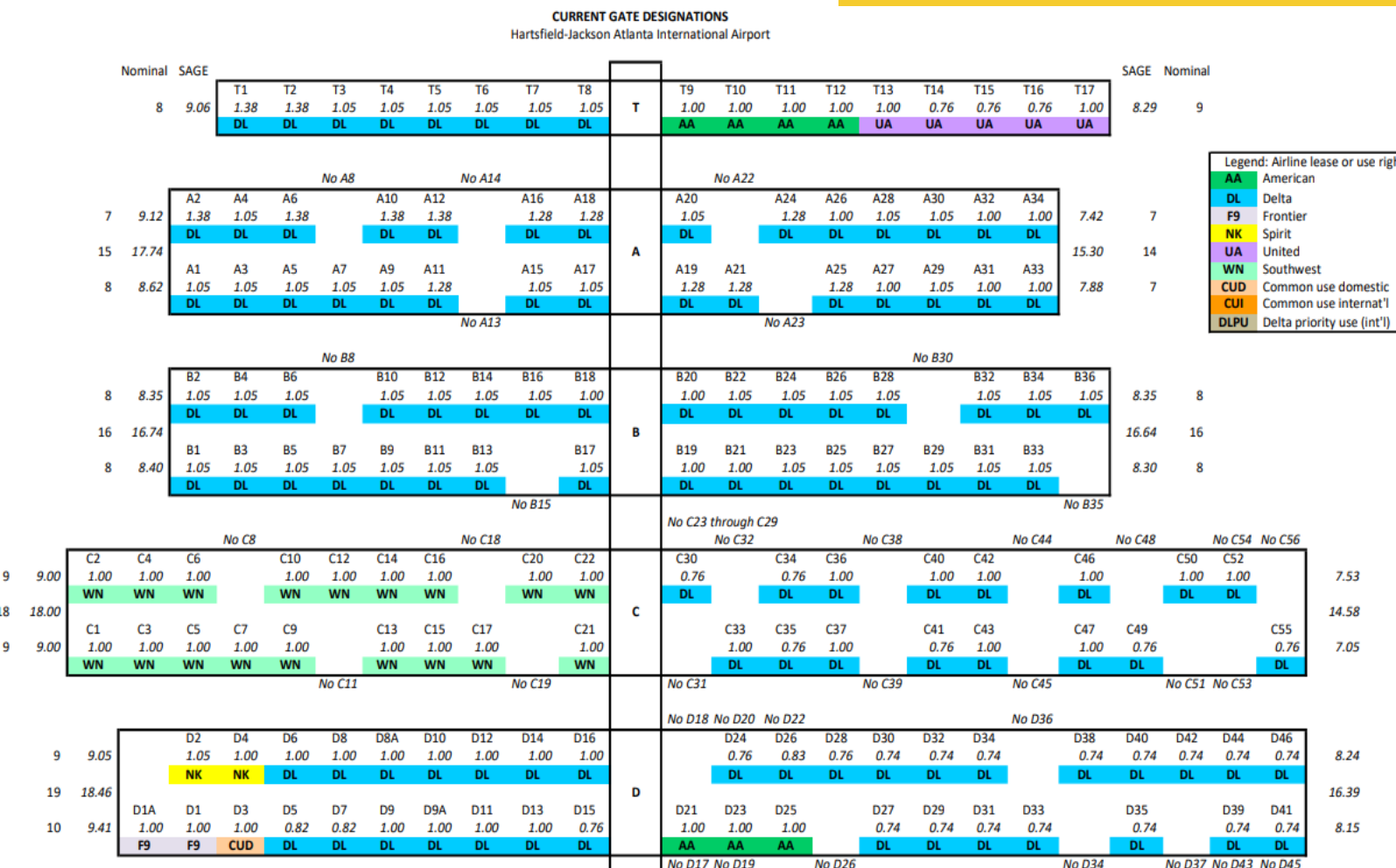


Overview

AeroWorks is partnering alongside the Airport Cooperative Research Program to address airport needs and maximizing airport capability. AeroWorks' product, Aero is a solution that can be applied to all commercial service airports, aiming to improve the gate assignment procedure for arriving flights and reducing congestion in the ramp area and taxiways for departures. Hartsfield Jackson Atlanta Airport is used as a case study to prove the effectiveness of Aero. A queuing model and assignment problem are formulated to reduce the total average time that an aircraft spends on the ground. The customer for this solution is the airport, rather than the airline. With the help of the publicly provided data by the Federal Aviation Administration (FAA) data, Aero uses real time taxi-in and taxi-out times, arrival and departure times, percentages of delayed flights, and runway landing counts. Furthermore, AeroWorks also intends on using the Hartsfield Jackson Atlanta Airport schedule for July 18, 2022, provided by Tom Nissalke, the Assistant GM for Planning and Development at ATL.

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Assignment Model



Current Process

All Flights / Gates	Distance (ft)
DL	379,419
AA	8,605
WN	42,609
NK	6,024
Total	436,658

South Runway to South Gates

South Flights / Gates	Distance (ft)
DL	123,997
WN	42,609
NK	6,024
Total	172,631

$$\text{Min } Z = \sum_{i=1}^n \sum_{j=1}^n c_{ij} x_{ij}$$

$$\text{s.t. : } \sum_{j=1}^n x_{ij} = 1, i = 1, 2, \dots, n$$

$$\sum_{i=1}^n x_{ij} = 1, j = 1, 2, \dots, n$$

$$x_{ij} = 0 \text{ or } 1$$

Results for New Method

North & South Flights / Gates	Distance (ft)
North	319,182
South	172,630
Total	491,182

North Runway to North Gates

North Flights / Gates	Distance (ft)
DL	310,577
AA	8,605
Total	319,183

Assignment Problem Formula

Variable	Description
i	Flight
j	gate
n	Total number of gates/flights
x_{ij}	Binary variable: 1 if flight i assigned to gate j, 0 otherwise
c_{ij}	Cost of flight i not getting assigned to gate j

Assignment Problem Variables

Gate Designation

Size (feet)	SAGE factor	Max. aircraft
101.5	0.74	ERJ-145
105.3	0.76	E170
113.4	0.82	B-737
138.0	1.00	B-737-900
144.8	1.05	B-757-300
176.1	1.28	B-767-300W
190.3	1.38	B-767-400
233.0	1.69	B-747-400

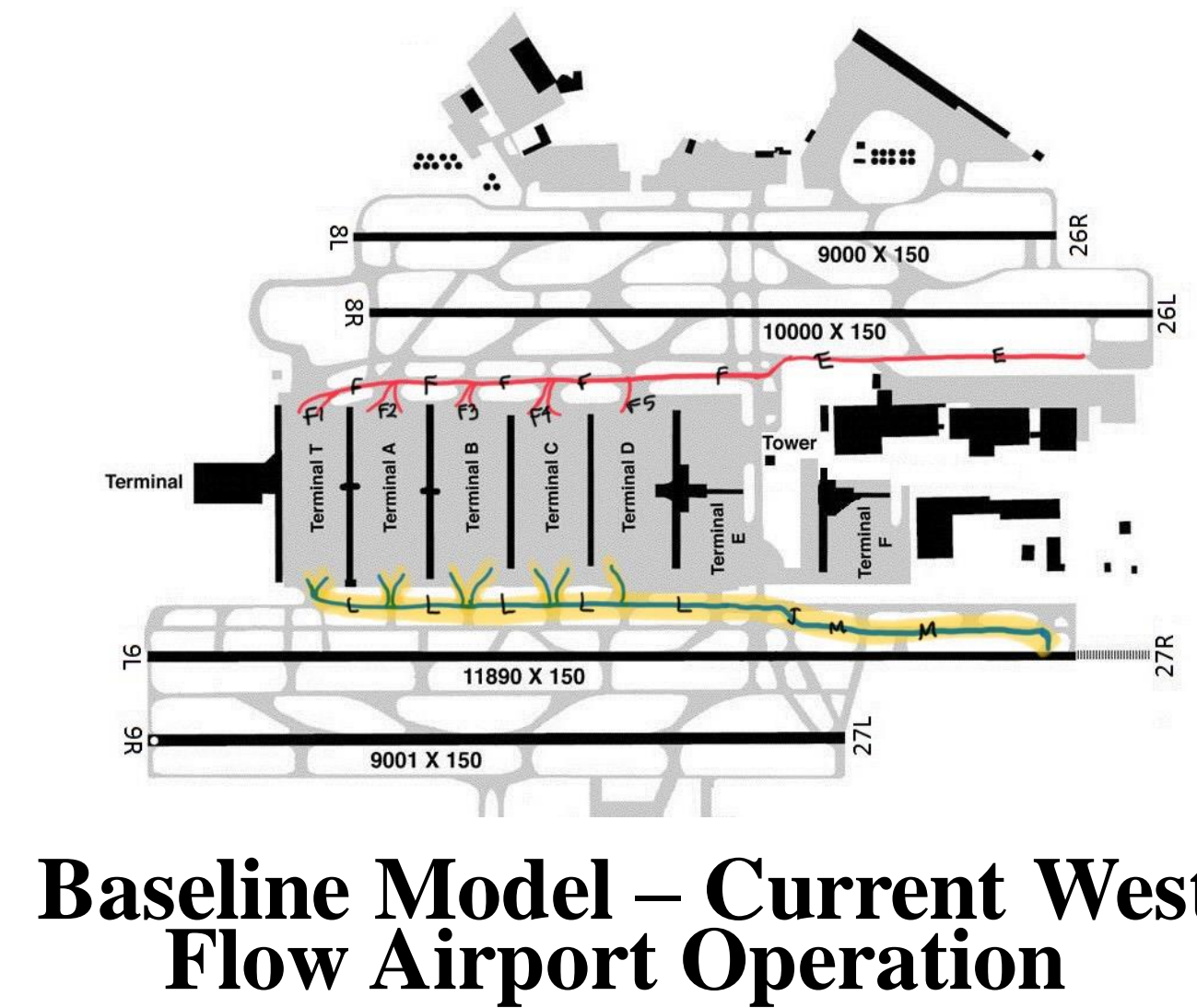
Sage Factors

Problem Solving Approach

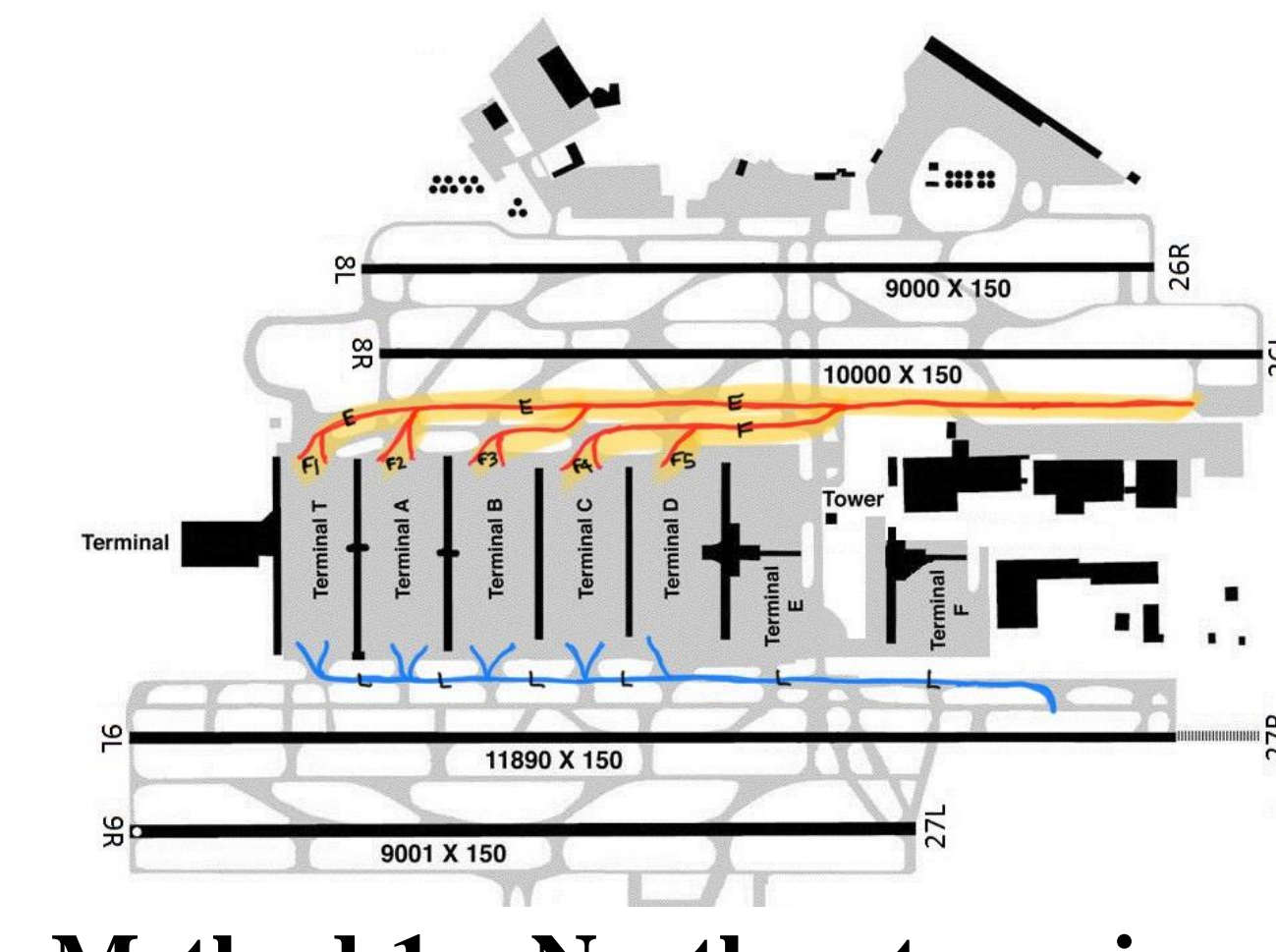
The assignment problem is modeled with the aim of reducing the total distance that an aircraft travels on average. AeroWorks will be creating two different model, the first will represent the current process for gate assignment, and the second will be a method created by AeroWorks which will divide the flights and gates depending on whether it lands on the North or South Runway. The first constraint in the assignment problem is based on the SAGE factor, which determines the gates an aircraft can be assigned to. The second constraint ensures that every flight is assigned to a gate, while also considering the business constraint that ensures that only one flight is assigned to each gate if available. Using estimated, yet realistic distances, AeroWorks created the model in LINGO to be able to determine which strategy is optimal. Real data from the Hartsfield-Jackson airport is used, such as the total number of gates, average arrival rate, and the average arrival rate for each runway.

The queuing model uses a M/M/s queuing model to compare current processes to potential alternatives. Due to the lack of capacity on the ground at most airports, congestion is a common problem that causes delays, excess fuel consumption, and wasted resources. By studying the current procedure for departures and creating queues for each concourse to the departing runways, AeroWorks can compare other routes and determine which alternative will produce the shortest wait time in the queue. The arrival rate is calculated as the inverse of the total time in minutes that an aircraft spends from the gate to the entrance of the runway. The service rate is the average number of flights that leave the runway per hour, based on the July 2022 flight schedule for ATL airport. The wait time in the queue is compared for each alternative in the figures to the right.

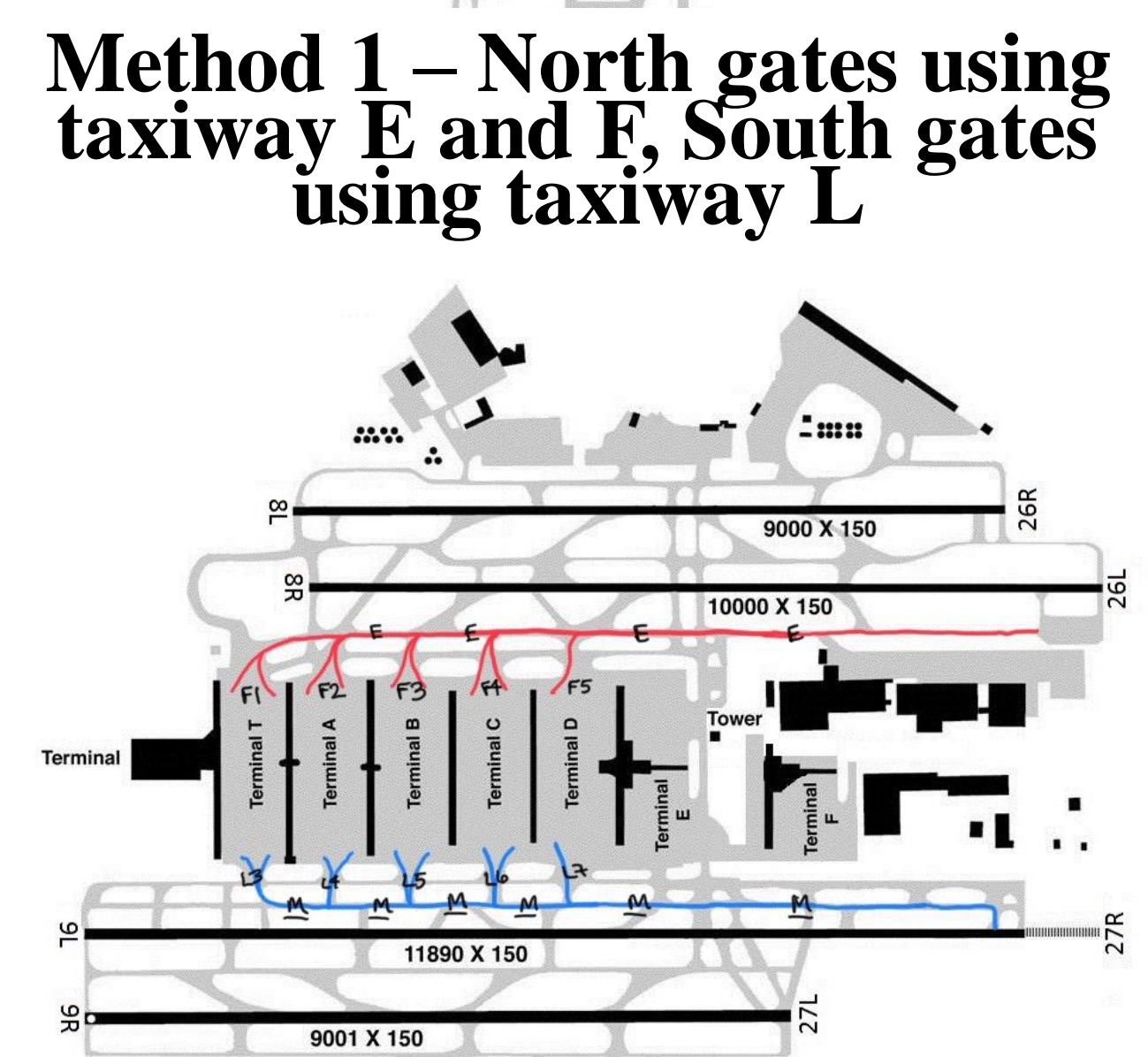
Queuing Model



Runway	Mu	Servers
North Runway to all gates	0.9823	2 Servers
South Runway to all gates	0.9823	2 Servers
North & South Runway to all gates	0.9823	2 Servers
North Runway to North gates	0.231	1 Server
South Runway to South gates	0.751	1 Server



Runway	Mu	Servers
North Runway to all gates	0.9823	2 Servers
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North & South Runway to all gates	0.9823	2 Servers
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South Runway to South gates	0.751	1 Server

$$\rho = \frac{\lambda}{s\mu} \quad P_0 = \left(\sum_{n=0}^{\infty} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^s}{s!} \times \frac{1}{1 - (\lambda/s\mu)} \right)^{-1}$$

$$L_q = \frac{(\lambda/\mu)^s \rho}{s!(1-\rho)^2} P_0 \quad w_q = \frac{L_q}{\lambda}$$

Queuing Model Formulas

Findings

After creating the LINGO model, AeroWorks determined the minimum distance for all flights arriving on July 18, 2022, between 7:00 AM and 8:00 AM. The total distance from the exit of the runway to each gate for all 85 flights is 436,657 feet. Due to Delta being the largest leading airline in Atlanta, most gates are committed to a long-term lease with them. The second assignment model provides the minimum total distance taken by the flights in the North and South side of the terminal. The total distance for the South terminal flights is 172,630 feet, while North terminal flights is 319,182 feet. Similarly, to the first assignment problem, Delta had the most distance due to the high number of Delta flights arriving in comparison to the other airlines. The total minimum distance for all the flights using this procedure is 491,812 ft. Arrival flights are not evenly distributed by the North and South terminals, which led to an increase in distance with the second assignment problem. The North terminal typically experiences a higher volume of arrivals than the South, causing the flights to have a smaller number of gates available

Regarding the queuing model, the method 1 for flights departing to the North runway (26L), combining a route via taxiway E for concourse T, A and B, and taxiway F to taxiway E for concourse C and D, produces shorter wait times than the current model. These wait times are shorter by roughly 0.0001- 0.0002 minutes, which look insignificant at first, but can save both airlines and airports considerable costs. The baseline model, which is currently used at Hartsfield Jackson, shows a South runway route via taxiway L to M. This provides shorter wait times than the alternative models that were tested. The baseline model is roughly 0.00005 minutes faster than the alternative methods. Regarding the method where only North terminal gates are assigned to the North runway (26L), the route that only uses taxiway E provides the shortest queue wait time. Similarly for South gates being assigned to only the South runway (27R), the method that only uses taxiway M provides the shortest queue wait time. Method 2, shown in the left, provides the shortest wait times for a scenario where North and South gates are assigned to the respective runways.

Conclusion

According to the data that AeroWorks obtained using the model created in LINGO, it is more efficient to continue with the current operation of gate assignment for the assignment problem.

AeroWorks suggests Hartsfield Jackson Atlanta Airport to use both 26L and 27R for departing flights from all gates. By changing from taxiway F to taxiway E for North runway departures, wait times on the taxiway will be reduced. AeroWorks suggests that Hartsfield Jackson Atlanta Airport uses the current procedure for departures from the South runway (27R), using taxiway L to M. AeroWorks does not suggest assigning North and South terminal gates to the respective runways. Although the queuing model is not an optimization problem, different routes can be compared and tested with the input/output method to find the shortest wait time.