# IE 580 Final Project: Airport Terminal Operations Improvement & Analysis Via System Simulations

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# Outline

- Problem Description

- Data processing

- Simulation model

- Performances evaluation

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# Motivations

- **Congestion** is estimated to cost U.S. airlines $5B yearly

- To address congestion, many airports are considering **infrastructure expansion**

# Project Problem and Objective

- Explore feasibility of simulation to gain understanding of cost-effectiveness, and to support decision making
- Reference: O'Hare Airport
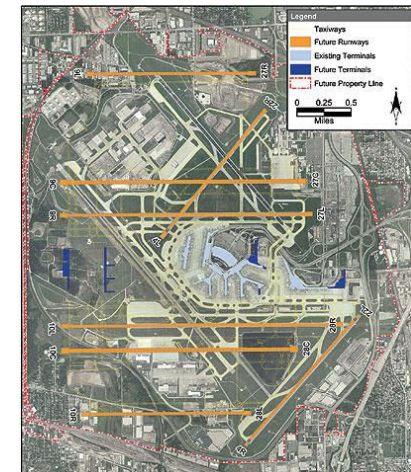
# Primary Assumptions

- Domestic and international commercial flight types
- Aircraft homogeneity: separation, runway use and gate assignments, but with varying priorities
- Parallel runway layouts, and no concurrent departure and arrival
- Consider only ground side in terminal operations, i.e. gate to runway, and vice versa

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# Data processing

Assumption:
- Every plane has same size and run speed at the runway and taxiway.

- Our team only analyzes the flight status: delay, landed and ignore the cancelled flights.

- According to current existed O'Hare airport data, we assume there are 50 domestic gates and 25 international gates on the Arena model.

# Data Processing - Data Collection

· This list contains flights for all airlines. Consider filtering by Airline. See airlines list

Flights Date: 2017-04-27
Check other time periods: (Check other days: Yesterday | Today | Tomorrow)
Detailed Departures information: 06:00 AM – 11:59 AM
Check other time periods: 12:00 AM – 05:59 AM | 06:00 AM – 11:59 AM | 12:00 PM – 05:59 PM | 06:00 PM – 11:59 PM

| Destination | Airline | Flight | Departure | Terminal | Status |
|---|---|---|---|---|---|
| Atlanta (ATL) | Delta Air Lines | DL 977 | 06:00 am | 2 | Landed – On-time [+] |
| Atlanta (ATL) | United Airlines | UA 1142 | 06:00 am | 1 | Landed – On-time [+] |
| Atlanta (ATL) | Asiana Airlines | OZ 6434 | 06:00 am | 1 | Landed – On-time [+] |

Flights Date: 2017-04-27
Check other time periods: (Check other days: Yesterday | Today | Tomorrow)
Detailed Departures information: 12:00 PM – 05:59 PM
Check other time periods: 12:00 AM – 05:59 AM | 06:00 AM – 11:59 AM | 12:00 PM – 05:59 PM | 06:00 PM – 11:59 PM

| Evansville (EVV) | JAL | JL 7354 | 12:00 pm | 3 | Scheduled – Delayed [+] |
| Evansville (EVV) | American Airlines | AA 2924 | 12:00 pm | 3 | Scheduled – Delayed [+] |
| Fort Wayne (FWA) | SkyWest Airlines | OO 3103 | 12:00 pm | 3 | Landed – On-time [+] |
| Fort Wayne (FWA) | Alaska Airlines | AS 4707 | 12:00 pm | 3 | Landed – On-time [+] |

Date: 2017-04-27
Check other time periods: (Check other days: Yesterday | Today | Tomorrow)
Detailed Arrivals information: 12:00 PM – 05:59 PM
Check other time periods: 12:00 AM – 05:59 AM | 06:00 AM – 11:59 AM | 12:00 PM – 05:59 PM | 06:00 PM – 11:59 PM

| Origin | Airline | Flight | Arrival | Terminal | Status |
|---|---|---|---|---|---|
| New York (LGA) | Republic Airlines | YX 5967 | 12:00 pm | 2 | Landed – On-time [+] |
| New York (LGA) | Delta Air Lines | DL 5967 | 12:00 pm | 2 | Landed – On-time [+] |
| Mexico City (MEX) | United Airlines | UA 1594 | 12:00 pm | 5 | Landed – On-time [+] |

Date: 2017-04-27
Check other time periods: (Check other days: Yesterday | Today | Tomorrow)
Detailed Arrivals information: 12:00 PM – 05:59 PM
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| San Francisco (SFO) | United Airlines | UA 734 | 12:11 pm | 1 | Landed – Delayed [+] |
|---|---|---|---|---|---|
| San Francisco (SFO) | Air Canada | AC 5390 | 12:11 pm | 1 | Landed – Delayed [+] |
| San Francisco (SFO) | Aer Lingus | EI 6221 | 12:11 pm | 1 | Landed – Delayed [+] |
| San Francisco (SFO) | Air New Zealand | NZ 9300 | 12:11 pm | 1 | Landed – Delayed [+] |
| Baltimore (BWI) | SkyWest Airlines | OO 2930 | 12:14 pm | 3 | En Route – Delayed [+] |

# Data Processing - Departure

| 12:00am-3:00am | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Flight | Carrier | Destination | Departure | Status | delay | international | delay t int | delay t in dom |
| SWQ 9011 | Swift Air | (BED) Bedford/Hanscom | 12:06 AM | Landed | | 1 | | |
| BR 55 | EVA Air | (TPE) Taipei | 12:20 AM | Landed | | 1 | | |
| AM 683 | Aeromexico | (MEX) Mexico City | 12:25 AM | Delay | 1 | 1 | 35 | |
| 4O 2983 | Interjet | (MEX) Mexico City | 12:40 AM | Delay | 1 | 1 | 23 | |
| RU 604 | AirBridgeCargo | (AMS) Amsterdam | 12:50 AM | Delay | 1 | 1 | 27 | |
| KE 233 | Korean Air | (SEA) Seattle | 1:25 AM | Landed | | | | |
| AM 661 | Aeromexico | (GDL) Guadalajara | 1:55 AM | Delay | 1 | | | 30 |
| 5Y 8359 | Atlas Air | (ANC) Anchorage | 2:00 AM | Landed | | | | |

# Data Processing - Arrival

| | | | | | delay | international | delay t int | delay t in dom | |
|---|---|---|---|---|---|---|---|---|---|
| 12am-3:00am | | | | | | | | | |
| UA 336 | United Airlines | (IAH) Houston | 12:08 AM | Landed | | | | | |
| NZ 6421 ^ | Air New Zealand | (IAH) Houston | 12:08 AM | Landed | | | | | |
| AA 486 | American Airlines | (PHX) Phoenix | 12:14 AM | Landed | | | | | |
| AB 525 ^ | Air Berlin | (PHX) Phoenix | 12:14 AM | Landed | | | | | |
| UA 1918 | United Airlines | (PHX) Phoenix | 12:15 AM | Landed | | | | | |
| AC 5802 ^ | Air Canada | (PHX) Phoenix | 12:15 AM | Landed | | | | | |
| UA 705 | United Airlines | (SFO) San Francisco | 12:24 AM | Delay | 1 | | | 23 | |
| AC 5332 ^ | Air Canada | (SFO) San Francisco | 12:24 AM | Delay | 1 | | | 23 | |
| NZ 9660 ^ | Air New Zealand | (SFO) San Francisco | 12:24 AM | Delay | 1 | | | 23 | |
| AM 660 | Aeromexico | (GDL) Guadalajara | 12:30 AM | Delay | 1 | 1 | 45 | | |
| DL 8047 ^ | Delta Air Lines | (GDL) Guadalajara | 12:30 AM | Delay | 1 | 1 | 45 | | |
| UA 1451 | United Airlines | (LAX) Los Angeles | 1:46 AM | Landed | | | | | |
| AC 5162 ^ | Air Canada | (LAX) Los Angeles | 1:46 AM | Landed | | | | | |
| CA 7274 ^ | Air China | (LAX) Los Angeles | 1:46 AM | Landed | | | | | |
| NZ 9166 ^ | Air New Zealand | (LAX) Los Angeles | 1:46 AM | Landed | | | | | |
| UA 2815 | United Airlines | (AUA) Aruba | 1:47 AM | Cancelled | | 1 | | | |
| CZ 431 | China Southern Airli | (ANC) Anchorage | 2:05 AM | Delay | 1 | | | 32 | |

# Data Processing Calculation

Departure

| | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|
| 12:00am - 6:00am | | | | | | | | | | |
| # delay | | delay & Int | # international | total # | P(delay & int) | P(delay & dom) | t(delay & int) | t(delay & dom) | Cancelled | P(cancelled) |
| | 6 | 5 | 6 | 125 | 0.833333333 | 0.008403361 | 31.6 | 30 | 0 | 0 |

Arrival

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6:00am - 12:00pm | | | | | | | | | | |
| # delay | | delay & Int | # international | total # | P(delay & int) | P(delay & dom) | t(delay & int) | t(delay & dom) | Cancelled(int) | P(cancelled) |
| | 63 | 5 | 60 | 999 | 0.083333333 | 0.061767838 | 30 | 30.29310345 | 1 | 0.001001001 |

# Departure and Arrival Time Distribution

| domestic arrival | interval | | international arrival | interval | | domestic time depature | interval | | international time departure | interval |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 8 | | 30 | 30 | | 115 | 115 | | 6 | 6 |
| 8 | 8 | | 30 | 30 | | 115 | 115 | | 20 | 14 |
| 14 | 6 | | 107 | 77 | | 120 | 5 | | 25 | 5 |
| 14 | 6 | | 257 | 150 | | 300 | 180 | | 40 | 15 |
| 15 | 1 | | 294 | 37 | | 300 | 180 | | 50 | 10 |
| 15 | 1 | | 294 | 37 | | 300 | 180 | | 270 | 220 |
| 24 | 9 | | 304 | 10 | | 300 | 180 | | 275 | 5 |
| 24 | 9 | | 315 | 11 | | 300 | 180 | | 390 | 115 |
| 24 | 9 | | 363 | 48 | | 300 | 180 | | 390 | 115 |
| 106 | 82 | | 363 | 48 | | 300 | 180 | | 390 | 115 |
| 106 | 82 | | 363 | 48 | | 300 | 180 | | 390 | 115 |
| 106 | 82 | | 363 | 48 | | 300 | 180 | | 390 | 115 |

# Explanation of attributes, stations and variables

A(1): 1, arrival; 2, departure

A(2): 1, international; 2, domestic

A(3): J (the number of station)

A(4): TNOW (the time of entity enter the system)

A(5): TNOW – A(4) (delay time before seize the runway)

A(6): signal to seize the taxiway

Station 1—50: domestic gates

Station 51—75: international gates

datime (4, 2)/aatime (4, 2): interarrival time of departure/arrival entities, 4: time slots, 2: job type

delaydtime (4, 2)/delayatime (4, 2): average delay time of departure/arrival entities

probddelay (4 ,2)/probadelay (4, 2): probability of departure/arrival entities will be delayed

Gate (75): the status of gate (M), 1: busy, 0: idle

Tway (86): the status of taxiway (M), 1: busy, 0: idle

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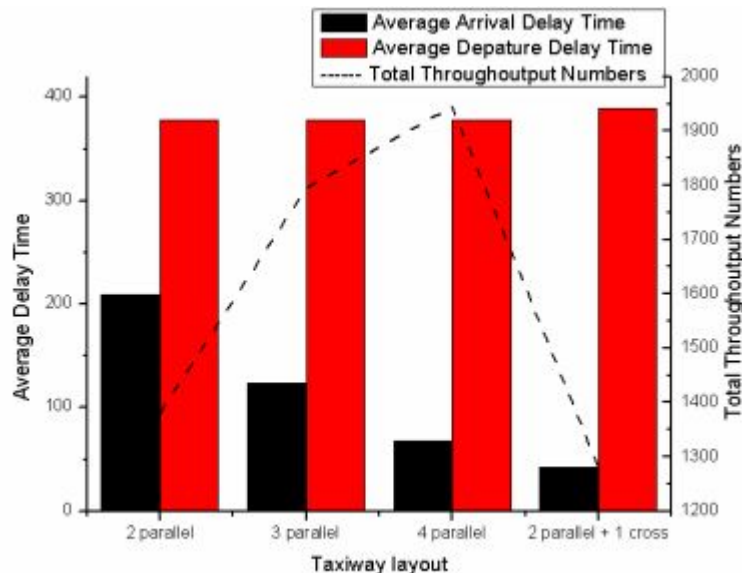
# 4. EVALUATION

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# Performance evaluation

Criterions based on the following aspects:

- Average arrival delay time

- Average departure delay time

- Airplanes throughput numbers. (The total number of departure and arrival within one day)

# Factors that influence the performance

1. The number of taxiways and their layout



Figure . The effect of taxiway numbers and layout on the average delay time and throughput airplanes.

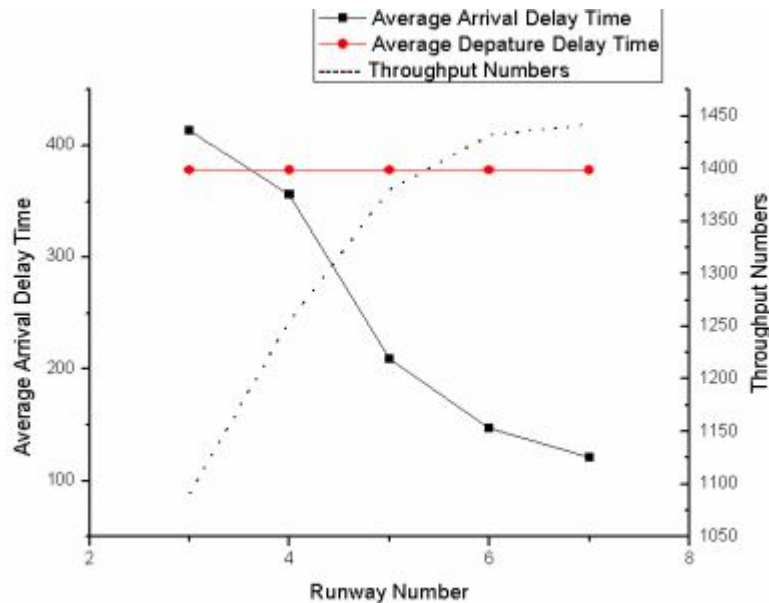| | S | Name | Program File | Reps | Num Reps | Avg arrival delay time | Avg departure delay time | Total_Throughput |
|---|---|---|---|---|---|---|---|---|
| | | Scenario Properties | | | Control | Responses | | |
| 1 | | crossTaxiway | 3 : IE 580 rev | 10 | 10 | 42.577 | 388.799 | 1282 |
| 2 | | 3_para | 6 : IE 580 rev | 10 | 10 | 123.523 | 377.791 | 1795 |
| 3 | | 2_para | 7 : IE 580 rev | 10 | 10 | 208.971 | 378.037 | 1380 |
| 4 | | 4_para | 8 : IE 580 rev | 10 | 10 | 68.238 | 377.920 | 1945 |

The increase of the taxiway numbers will shorten the average delay time and increase the throughput.

Average delay time goes down when one of the taxiway changes from parallel to crossed.

# Factors that influence the performance

- 2. The number of runways

| | S | Scenario Properties | | | Control | Responses | | |
|---|---|---|---|---|---|---|---|---|
| | | Name | Program File | Reps | Num Reps | Avg arrival delay time | Avg departure delay time | Total_Throughput |
| 5 | | 3_runway | 9 : IE 580 rev | 10 | 10 | 413.560 | 378.455 | 1091 |
| 6 | | 4_runway | 10 : IE 580 re | 10 | 10 | 356.431 | 378.248 | 1255 |
| 7 | | 5_runway | 11 : IE 580 re | 10 | 10 | 208.971 | 378.037 | 1380 |
| 8 | | 6_runway | 12 : IE 580 re | 10 | 10 | 147.318 | 378.363 | 1432 |
| 9 | | 7_runway | 13 : IE 580 re | 10 | 10 | 120.829 | 378.207 | 1442 |



The average arrival time declined a lot as the number of runways increases.

The total through output numbers increases with the runway numbers, and this relation is not linear, when the runway numbers adds from three to seven, the magnitude of the through output increasing declines gradually,

# Factors that influence the performance

- 3. The number of gates
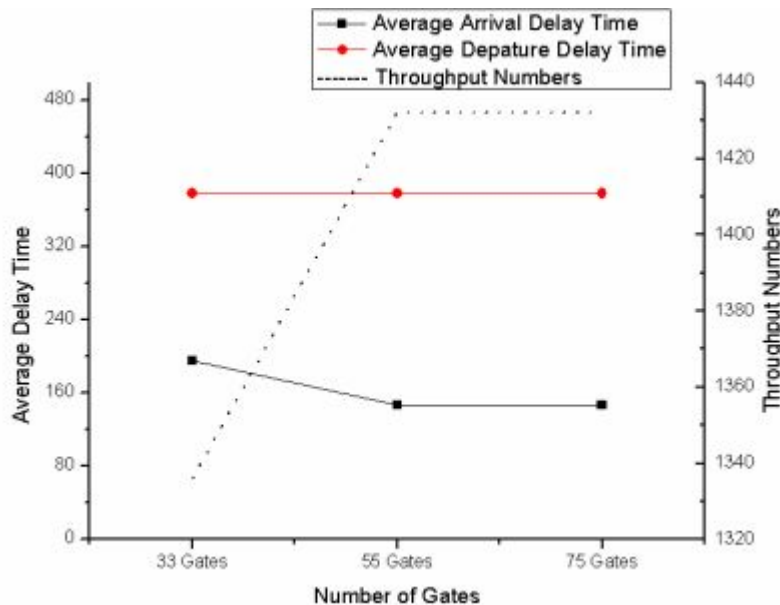
| | S | Scenario Properties | | | Control | Responses | | |
|---|---|---|---|---|---|---|---|---|
| | | Name | Program File | Reps | Num Reps | Avg arrival delay time | Avg departure delay time | Total_Throughoutput |
| 10 | | 55_gates | 3 : E 580 rev | 10 | 10 | 147.318 | 378.363 | 1432 |
| 11 | | 35_gates | 4 : E 580 rev | 10 | 10 | 195.803 | 378.366 | 1338 |
| 12 | | 75_gates | 5 : E 580 rev | 10 | 10 | 147.318 | 378.363 | 1432 |

The average arrival delay time exhibit a decrease, while the throughput number increases when the gates number change from 35 to 55,

When the gates adds from 55 to 75, all of the parameters including the average arrival/departure time and throughput number does not change at all. This indicates that 55 gates in the airport are already enough for the airplanes departure and arrival, there is no need to add more idle gates.

# Conclusion

- Taxiway:

  - 2 to 3(~ +400 throughput)

  - 3 to 4 parallel ( ~ +150)

  - 2 to 2+1 (~ -100)
- Runway and gates:
  - Steady small increase

- **For this setup: optimal taxiway design will yield most returns**

# Questions?

# backup slides