Airport Gate Assignment Optimization

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Abstract

Airport management comprises of a number of complex operations such as security, passenger check-ins, baggage management, taxiing, gate operations, retail, etc. These operations have many stakeholder touchpoints but we can categorize them to three distinct but related stakeholders namely the airport operator, the airlines and passengers. Those multiple operations affect the both experience and financials of these stakeholders. Our research will focus on one specific operation, which is gate management. The primary focus of the project is to determine the how the customers are affected by delays and cancellations and develop mathematical model based on the data analysys to maximize that number of passengers served through the gates.

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Introduction

The search for optimal assignment of flights to gates is of great importance to airport to elimate delays, maintain operations and maximize profits. An international airport is the most populated and busiest travel area where many people used to move around the world. Gate assignment is one of the most important tasks for airport ground operations, which assigns appropriate airport gates with high efficiency reasonable arrangement. It is important to notice that flights delays and cancellation have a negative impact on airport performance and do not provide an excellent experience to travelers. This study aims to propose a new airport gate assignment method to effectively improve the comprehensive operation capacity and efficiency. It will also help to optimize the number of gate allocated to each airline and improve travelers experience.

Gates are where planes park (in the apron), and where passengers disembark and get into the planes. These are also the locations where passengers wait before getting into their flights. Airports managed gates though a negotiation with the airlines who advise or requests airports to set aside a certain number of gates (called gate allocations) for certain dates in the upcoming season. In North America it is divided between the summer (May to Oct) and winter (Nov to April) seasons. These negotiations are based on these two seasons. The airports then do the gate allocation based on relationship with airlines, their flight history, their delay or cancellation profiles, etc. Airports analyze who to provide the gates then advise the airlines on what is the allocation to them. Airlines develop their route schedules which you will eventually see in their websites and travel sites, etc.. Airports on the other hand, then do their resource planning according to this schedule. Airports budget for personnel, get the necessary systems or services for systems, even spend for new facilities that need to be build around this schedule if needed with Capex program. Sometimes, airport shuffling airlines around the gates and when other airlines affected, airports work with these airlines.

Competitive Analysis

The area of airport gates assignment optimization is well researched. Several researches were trying to solve the problem taking into account multiple factors, like cost, passenger walking distances, networking of connected flights etc.

In one research (Azmi, Razali, Ibrahim, Aziz, & Aziz, 2016), in order to solve discrete optimization problem, the SKF algorithm is combined with angle modulated approach. Airport gate allocation problem refers to the search for optimal assignment of flights to gates at an airport. Assignment of flight to gates has become very complex nowadays, especially for a big size airport. In this study, the airport gate allocation problem is solved using a recently introduced angle modulated simulated Kalman filter (AMSKF). The objective of this study is to minimize the total walking distance. A small case study with 14 flights and 16 gates has been chosen. Preliminary results show that SKF is a promising algorithm for solving the airport gate allocation problem.

Another paper (Barnhart, Fearing, Odoni, & Vaze, 2012) summarizes research trends and opportunities in the area of managing air transportation demand and capacity. Capacity constraints and resulting congestion and low schedule reliability currently impose large costs on airlines and their passengers. Significant capacity increases that would solve these problems are not expected in the near- or medium-term. This paper outlines first a number of directions for effecting improvement through marginal capacity increases and better management of demand and available capacity. It then describes strategic initiatives that airlines and civil aviation authorities might undertake over time horizons of months to years as well as tactical measures that may be adopted on a daily basis in response to dynamic, real-time developments like poor weather or schedule disruptions. Research challenges in these areas are identified and classified in terms of specifying, allocating, and utilizing capacity. The first two categories reject challenges faced by infrastructure providers, the last category challenges faced by airlines.

Others(Bihr, 1990) think that positioning of incoming flights should take into account the distribution of passengers among connecting flights. The larger the number of passengers arriving on flight X for destination A, the closer flight X should be positioned to the flight departing for A. This inquiry looks conceptually at this problem, reducing the distance passengers must walk from gate to gate. The criterion selected is minimization of the total passenger-distance travel for a given arrival-departure cycle. The problem can be conveniently cast as a 0,1 Linear Programming (LP) problem].

Another paper (Ding, Lim, Rodrigues, & Zhu, n.d.) studies the over-constrained Airport Gate Assignment Problem, where the objectives are to minimize the number of ungated flights and the total walking distances or connection times. They approach the problem by first using a greedy algorithm to minimize ungated flights and by developing exchange moves which then facilitate the use of heuristics. Simulated Annealing and a hybrid of Simulated Annealing and Tabu Search are used.

Airport gate assignment is of great importance in airport operations. In this paper (Li, n.d.), the authors studied the Airport Gate Assignment Problem (AGAP), propose a new model and implement the model with Optimization Programming language (OPL). With the objective to minimize the number of conflicts of any two adjacent aircrafts assigned to the same gate, the authors build a mathematical model with logical constraints and the binary constraints, which can provide an efficient evaluation criterion for the Airlines to estimate the current gate assignment. To illustrate the feasibility of the model the authors construct experiments with the data obtained from Continental Airlines, Houston Gorge Bush Intercontinental Air-port IAH, which indicate that our model is both energetic and effective. Moreover, the authors interpret experimental results, which further demonstrate that our proposed model can provide a powerful tool for airline companies to estimate the efficiency of their current work of gate assignment.

To help researched see how your airport is performing with FlightStats monthly On-time Performance Report, this report ("Airline on-time performance reports," n.d.) compares the on-time arrival performance of major and regional airports around the world.

The (“Data elements,” n.d.) report presents Load Factor (passenger-miles as a proportion of available seat-miles in percent) for All Carriers and All Airports. Optimizing gate assignments at airport terminals is analysed in this article (“Optimizing gate assignments at airport terminals,” 1998). Airline On-Time Statistics and Delay Causes is presented here (“OST_R BTS Title from h2,” n.d.).

The research (Riedel, 2006) presents an approach for predicting operational performance of airlines on the basis of flight schedules and aircraft assignments. The methodology uses aggregate measures of properties of aircraft assignments, called Aircraft Assignment Key Performance Indicators (KPIs), and aims to find correlations between them and the operational performance of the airline. A simulation experiment is prepared to gather a large set of data points for analysis. A motivation is given for the use of control theoretic approaches in airline operations to utilize the KPIs as a basis for initial planning and corrective actions.

Proposed Plan

The focus of this study will be one of the major US airports - either John F. Kennedy Airport in New York or San Francisco Airport (SFO) depending on the data availability. The study will analyze airline gate operations performance measures over a 1997 to 2008 of publicly available data from bureau of transportation statistics. As an example - JFK Airport is located in the neighborhood of Jamaica in the borough of Queens, in New York, 30km (16 Miles) southeast of Midtown Manhattan. One of the busiest international air passenger airports in North America and the sixth busiest airpots in United States with close to 60 million passengers usint the facility a year (2016 data). The airport features six passenger terminals and four runways (see Figure 1). More than ninty airlines operate at JFK Airport using the more than 128 gates across six terminals. The focus of the research is to determine the effects of airlines’ performance on airport gate utilization.

Data Insights

Information from 22 years has been retrieved from airlines transportation database. These datasets are from 1987 to 2008 and are relative to United State airlines performance, for the data description (see Table 1). As an example, for the year 2008, JFK airport has 118.804 flights from 11 different carriers. The top 4 most important carriers are JetBlue Airways with 45% of total traffic followed by Comair Inc. (16%), Delta Air Lines (14%) and American Airlines Inc. (10%). Number of flights per carrier at New York John F. Kennedy Airport (JFK) presented here (see Tables 2,3 and 5). For that analysis the following datasets were analyzed:

- Airline on-time performance reports ("Airline on-time performance reports," n.d.);
- 1987-2008 US Flights statistics ("Data elements," n.d.);
- SFO Gate and Stand Assignment Information ("Sfo gate and stand assignment information - data. Gov," n.d.);
- 2015 US Flights statistics ("2015 flight delays and cancellations kaggle," n.d.);
- Aircraft registry ("Aircraft registry – releasable aircraft database download," n.d.).

Model estimation

Our research will focus on the impact of this delays and cancellations to the airport. What our research goal is to answer the following questions:

- What are the impacts of airline delays on gate management specifically on the following:
  - What is the current baseline of delay and cancelled events in terms of number of instances, flights and instances (Quantify and create a baseline)
  - Which airlines cause these delays?
  - What are the causes of these delays?
  - What is the impact of these delays into gate utilization

  - What is the estimated number of passengers affected by delays and cancellations
  - In the ballpark, what are the the financial costs, of delays and cancellation

- What is the future forecasted airline delays
  - Using historical data and linear progressing, what will be the estimated future delays and cancellations in the next 5, 10, 20 years?
  - Combining historical data and using scenario analysis of varying growths for each airlines, what is the estimated future delays and cancellations in the next 5, 10, 20 years using Monte Carlo Analysis
  - What is the estimated the potential impact of number of customers affected and financial costs of these future delay s and cancellations

- What should the airport consider as options to address potential future scenarios?

As the result of this analysis we are planning to build a model based on one of the variations of Linear Programming to optimize the gate allocation. The required for that methodology cost function will be developed after thorough data analysis where we are planning to use Linear Regression to extract behaioral parameters of airlines from the historical data.

The process

For the development of this project we are using CRoss-Industry Standard Process for Data Mining (CRISP-DM) (see Figure 2) was developed by Daimler Chrysler (then Daimler-Benz), SPSS (then ISL) and NCR in 1999. Compiling the current proposal document is a part of this process (see Table 2), in it's preparation our team has conducted 2 iteration of the CRISP-DM process.

Potential Risks

Use of assumptions including past performance to predict future performance. Simplifying cost estimates such as aggregate load factors and blended costs. Reliance of public data without management inputs. Data did not exclude normalization of data for abnormal, one-time events.

Cost/benefit analysis

Understanding gate performance of airlines enable airport management to proper plan airline gate assignments optimally that reduces lost revenues, maximizes the use of gate facilities and defers/avoids expansion of capex due to inefficient use.

If airlines perform as what was agreed with the airport, then the gates are managed optimally. However, there are instances when a number of flights, get delayed or even cancelled. There are various reasons for these delays. It could be the weather-related, security reason, or natural calamity or sometimes it is the airline (i.e. bad plan, route did not have enough passenger, labour strike, non-payment of leases (these planes are mostly leased financed).

When there is a delay or cancellation, the impact is two-fold from the point of view of the airport. First, customer (passenger) experience suffers. The second is that the airport would incur both actual cost (the personnel it hired, capex spent if applicable, deicing, electricity, use of systems, etc.), revenue lost (landing fees, terminal fees), and opportunity cost (airport could have given that particular gate to another airline).

From the point of the airlines, it is similar but the customer experience is more palpable than the airports. Typically, passengers view delays as the fault of airlines not airports (unlike delays in baggage retrieval is faulted to the airport when it is actually more of the airline). The airline also suffers financially such as cost of transporting the baggage and hotel accommodation, salaries for pilot and crew members, jet fuel costs, etc.

Conclusion

Airports perform complex operations that involve close coordination between the airlines, passengers and airport authority. Optimizing gate operations benefit all these stakeholders; Airlines can avoid the direct cost of delays. Passengers are able to have a better airport experience. Airports are able to maximize the use of gate facilities and avoid unnecessary capital builds.

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Tables

Table 1

Variable descriptions

Name	Description
Year	1987-2008
Month	1 - 12
DayofMonth	1 - 31
DayOfWeek	1 (Monday) - 7 (Sunday)
DepTime	actual departure time (local, hhmm)
CRSDepTime	scheduled departure time (local, hhmm)
ArrTime	actual arrival time (local, hhmm)
CRSArrTime	scheduled arrival time (local, hhmm)
UniqueCarrier	unique carrier code
FlightNum	flight number
TailNum	plane tail number
ActualElapsedTime	in minutes
CRSElapsedTime	in minutes
AirTime	in minutes
ArrDelay	arrival delay, in minutes
DepDelay	departure delay, in minutes
Origin	origin IATA airport code
Dest	destination IATA airport code
Distance	in miles
TaxiIn	taxi in time, in minutes
TaxiOut	taxi out time in minutes
Cancelled	was the flight cancelled?

Name	Description
CancellationCode	A = carrier, B = weather, C = NAS, D = security)
Diverted	1 = yes, 0 = no
CarrierDelay	in minutes
WeatherDelay	in minutes
NASDelay	in minutes
SecurityDelay	in minutes
LateAircraftDelay	in minutes

Table 2

Delay trend IN/OUT in minute for the top (JetBlue Airways) carrier at JFK.

JetBlue Airways	Delay IN	Delay OUT
Jan-08	12,802	35,088
Feb-08	59,040	58,630
Mar-08	55,435	62,378
Apr-08	25,965	46,178
May-08	16,423	15,769
Jun-08	96,536	57,520
Jul-08	115,981	96,075
Aug-08	115,300	109,549
Sep-08	3,036	22,868
Oct-08	-25,549	6,489
Nov-08	-13,828	26,594
Dec-08	66,061	87,718
Total	527,202	624,856

Table 3

Total Cancellations

Month	American Airlines	JetBlue Airways	Delta Airlines	Comair	Total
Jan-08	30	55	16	63	164
Feb-08	42	113	27	130	312
Mar-08	24	72	22	83	201
Apr-08	36	42	6	36	120
May-08	19	10	7	22	58
Jun-08	21	141	14	84	260
Jul-08	41	188	29	193	451
Aug-08	20	197	25	203	445
Sep-08	15	63	19	49	146
Oct-08	7	18	8	15	48
Nov-08	2	37	6	33	78
Dec-08	18	127	30	121	296
Total	275	1,063	209	1,032	2,579

Table 4

Proposed Plan Phases

Phase	Task Name	Schedule	Resources	Status
Business understanding		3 days	All analysts	Completed
Data understanding		2 days		In progress
	Data collection			Completed
	Data description			Completed
	Data quality check			In progress
	Exploratory analysis			In progress
Data preparation		2 days		In progress
	Selection			2 iterations
	Cleaning			2 iterations
	Construction			2 iterations
	Integration			2 iterations
	Formatting			2 iterations
Modeling		5 days		Not started
	Generate test design			
	Build model			
	Interpreter model results			
	Model evaluation			
	Refine and repeat			
Evaluation		4 days		Not started
	Assessment of results			
	Review of process			
	Determine actions			
	Refine and repeat			

Phase	Task Name	Schedule	Resources	Status
Deployment		1 day		Not started
	Deployment plan			
	Maintenance plan			
	Final report			
	Review project			

Table 5

Number of flights per carrier at New York John F. Kennedy Airport (JFK).

Month	B6	DL	OH	AA	CO	MQ	UA	NW	US	YV	EV
Jan-08	4,540	1,275	1,518	1,068	103	667	445	154	172	81	
Feb-08	4,375	1,238	1,399	996	100	625	430	153	164	75	
Mar-08	4,928	1,380	1,372	1,035	109	645	447	176	186	78	
Apr-08	4,690	1,341	1,230	1,019	108	617	464	175	180	77	
May-08	4,425	1,422	1,117	1,043	107	639	463	182	186	79	
Jun-08	4,444	1,434	1,476	981	107	616	475	175	180	5	46
Jul-08	4,764	1,494	2,508	1,048	111	666	472	178	186		76
Aug-08	4,811	1,451	2,495	1,051	108	640	448	170	175	4	70
Sep-08	3,886	1,338	1,446	936	29	616	383	150	147	33	2
Oct-08	3,936	1,366	1,437	961		605	395	155	147	35	
Nov-08	3,935	1,306	1,450	872		687	374	142	171	85	
Dec-08	4,162	1,348	1,478	936		713	387	121	182	89	
Total	52,896	16,393	18,926	11,946	882	7,736	5,183	1,931	2,076	641	194
	45%	14%	16%	10%	1%	7%	4%	2%	2%	1%	0%

Note. Month,JetBlue Airways (B6), Delta Air Lines Inc. (DL), Comair Inc. (OH), American Airlines Inc. (AA), Continental Air Lines Inc. (CO), American Eagle Airlines Inc. (MQ), United Air Lines Inc. (UA), Northwest Airlines Inc. (NW), US Airways Inc. (US), Mesa Airlines Inc. (YV), Atlantic Southeast Airlines (EV)

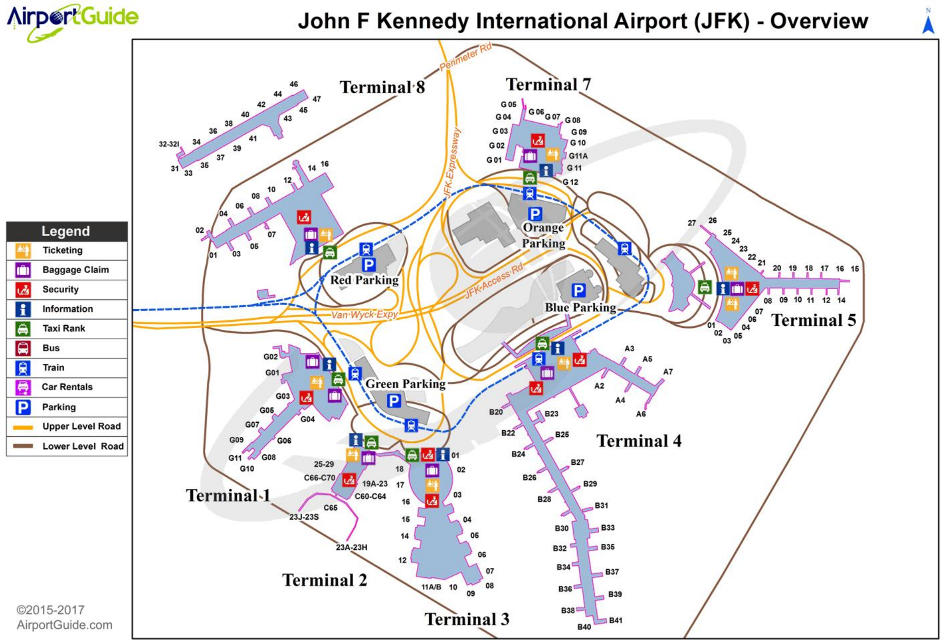

Figure 1. CRISP-DM Process Diagramm.

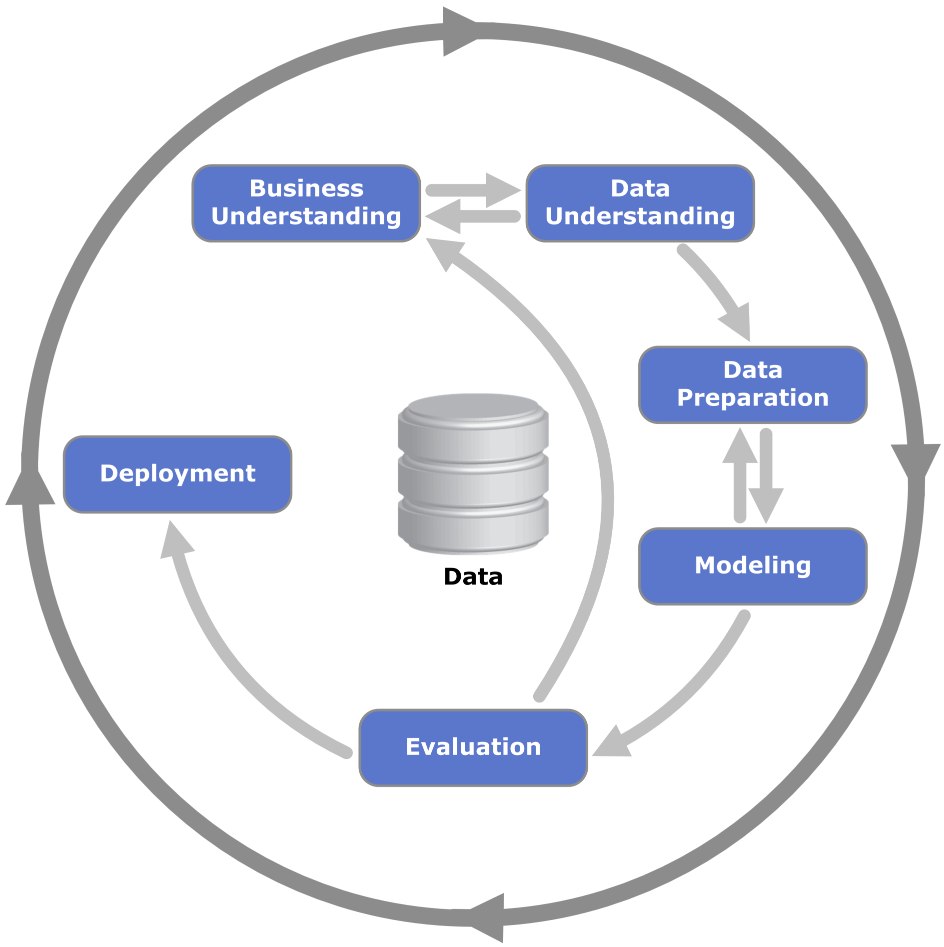

Figure 2. CRISP-DM Process Diagramm.