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Author(s)
Mujica Mota, Miguel; Zuniga, Catya; Boosten, Geert

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MODEL-BASED CAPACITY ANALYSIS OF INTRODUCING A380 IN MEXICO CITY AIRPORT

Miguel Mujica Mota [(a)], Catya Zuñiga [(b)] , Geert Boosten [(a)]

(a) Aviation Academy, Amsterdam University of Applied Sciences, The Netherlands
(b) Aeronautical University of Queretaro, Mexico

Recently the A380 started operations between Mexico City and Paris. Severe problems have been reported and it is a concern whether these problems can be overcome with the current facilities. AirFrance will start in March daily operations and also Lufthansa and Emirates are willing to use the A380 to operate from Frankfurt and Dubai respectively. In this article we present the capacity analysis of the operation performed in the airport of Mexico City using information for a particular day, we use a model-based approach which allows to simulate the daily operation of the A380 and it allows us to incorporate most of the restrictions besides the stochasticity inherent to the system.

1 INTRODUCTION

Mexico transported in 2014 over 65 million passengers, an increase of 8.5% compared with the previous year. The total number of operations have reached more than 1 million, 748,000 of the total correspond to national flights and 281,000 to international ones. This growth has supported the employment of 56.6 million people (direct and indirect jobs) and contributed over 2.2 trillion USD to global GDP. On the other hand, the domestic sector has been growing faster than the international one, it increased by 10% over the previous year transporting 34 million passengers (60% of the total) while the international increased a 7% moving 22 million passengers (SCT, 2015).

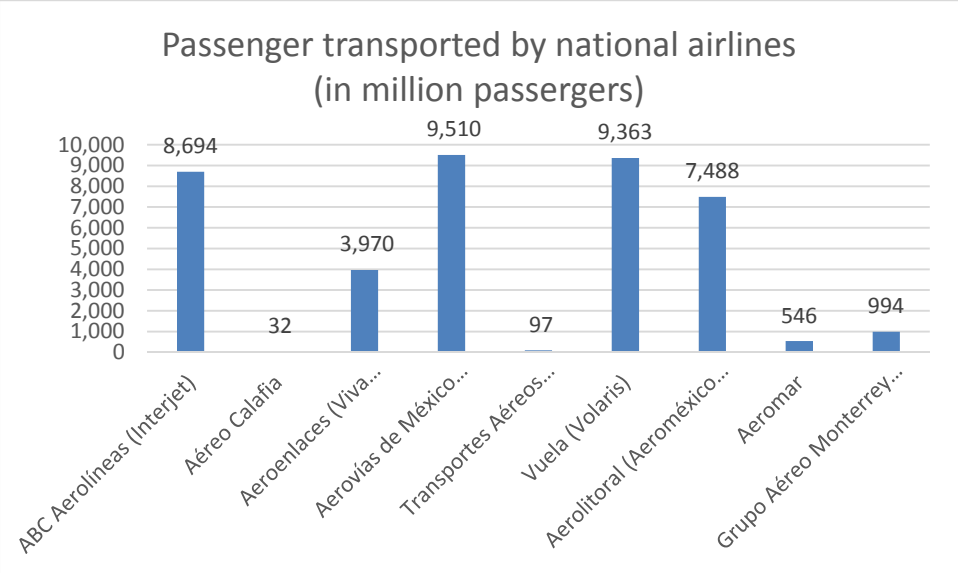

Figure 1. Passenger transported by national airlines in domestic and international routes in 2014

Figure 1 shows 7 out of the 9 regular passenger commercial airlines in México which served domestic and international routes in 2014. It can be noticed that the biggest national airlines in terms of transported passengers are Aeromexico, Volaris, Interjet and Aeromexico-Connect which moved 9.5, 9.3, 8.7 and 7.5 million pax respectively. The rest of passengers, i.e. 298,000, where transported by 8 charter airlines (SCT, 2015).

Viva Aerobus, which started operations in 2006 is growing quite fast and it is forecasted to be one of the leaders in the low-cost sector. In fact, as it can be seen in figure 2, the low-cost sector has been growing since 2005, and in 2013 it already accounted with 60% of the market. *Volaris* and *Interjet* together with *Viva Aerobus* are categorized as the current mexican low-cost carriers.

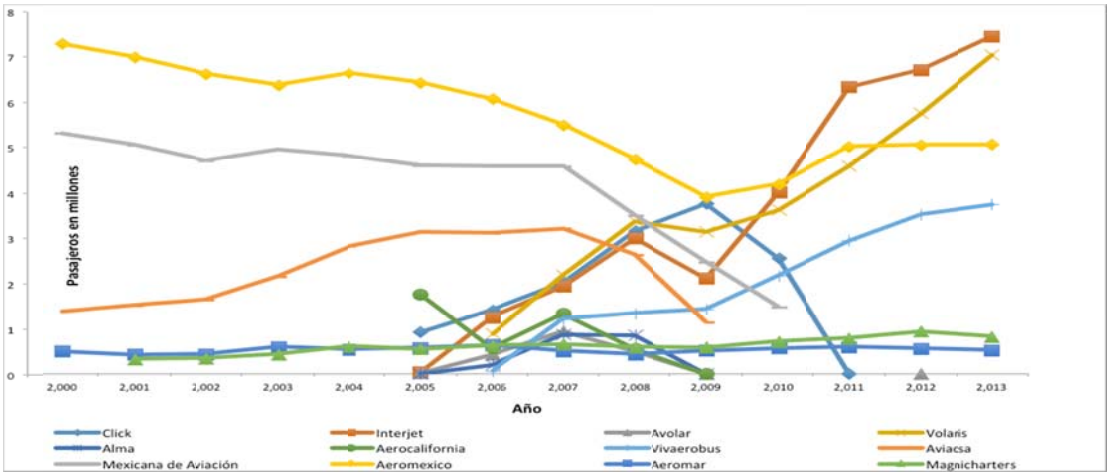

Figure 2. Main development of Mexican airlines since 2005

Table 1 introduces the top 10 domestic routes; from those routes, 47 concentrate 80.2% of the total passengers; while 80% of the international travellers use 94 routes and the 10 most frequent are presented in Table 2 (SCT, 2015).

Table 1 .Top 10 domestic routes in Mexico

	Origin	**Destination**	**Transported passengers (thousands)**		**Growing**	**Origin-Destination vs. Total %**	
			2013	**2014**	**2013/2014**	**2013**	**2014**
1	Mexico	Cancun	3,295	3,524	7.0%	10.8%	10.7%
2	Monterrey	Mexico	2,460	2,736	11.2%	8.1%	8.3%
3	Mexico	Guadalajara	2,278	2,379	4.4%	7.5%	7.2%
4	Tijuana	Mexico	1,241	1,266	2.0%	4.1%	3.8%
5	Mexico	Merida	1,050	1,131	7.8%	3.4%	3.4%
6	Tijuana	Guadalajara	941	1,025	9.0%	3.1%	3.1%
7	Villahermosa	Mexico	700	776	11.0%	2.3%	2.4%
8	Tuxtla Gutierrez	Mexico	684	728	6.5%	2.2%	2.2%
9	Monterrey	Cancun	673	712	5.9%	2.2%	2.2%
10	Puerto Vallarta	Mexico	527	606	14.9%	1.7%	1.8%

Table 2. Top 10 international routes in Mexico

	Origin	Destination	Transported passengers (thousands)		Growing	Origin-Destination vs. Total %	
			2013	2014	2013/2014	2013	2014
1	Mexico	Los Angeles	783	813	3.8%	2.7%	2.5%
2	New York	Cancun	731	803	9.8%	2.5%	2.5%
3	Los Angeles	Guadalajara	746	781	4.7%	2.5%	2.4%
4	New York	Mexico	710	760	7.2%	2.4%	2.4%
5	Cancun	Atlanta	661	704	6.6%	2.2%	2.2%
6	Miami	Mexico	718	694	-3.4%	2.4%	2.2%
7	Mexico	Houston	620	693	11.7%	2.1%	2.1%
8	Dallas	Cancun	630	678	7.7%	2.1%	2.1%
9	Houston	Cancun	561	585	4.3%	1.9%	1.8%
10	Mexico	Bogota	469	572	21.9%	1.6%	1.8%

Figure 3 shows the international traffic by region carried by the Mexican airlines in 2014. It can be noticed that most of the passengers come from United States. *Aeromexico* transported the biggest amount of passengers to United States with a total of 2.8 million in 2014, followed by *Volaris* with almost 1.7 million. Regarding Europe, Asia and Canada, *Aeromexico* was the only airline which transported passengers, a total of 384K, 120K and 83K passengers respectively. With regards to Central America and the Caribbean, *Aeromexico*, *Aeromexico-Connect* and *Interjet* transported 196K, 235K and 270K passengers, respectively. Concerning the traffic to South America, there were transported by *Aeromexico* and *Interjet* 881 and 76 thousand passengers, respectively (SCT, 2015).

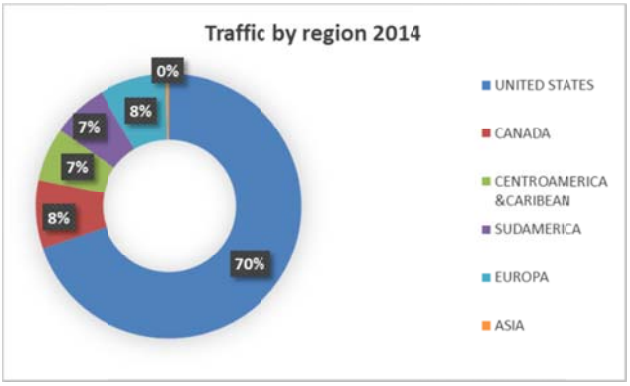

Figure 3.International traffic by region.

The Mexican Airline industry operated 8961 aircraft, from which 2011 were for commercial services, 6509 were private and 441 were for government service.

Mexico counts with 76 airports, 63 of them are international airports and 13 national, in addition there are 1431 aerodromes registered in the country. This places Mexico as one of the first countries in Latin America with the major airport network. Table 2 introduces the 10 top airports by passenger traffic within Mexico in 2015. It can be noticed that Mexico City International airport moves the 35% the total domestic traffic of the country, followed by far for four other airports: Monterrey (10%), Guadalajara (9%), Cancun (8%) and Tijuana (6%),

respectively. In the international context, Cancun International airport is a good opponent to Mexico City International airport moving 34% and 33% of the total, respectively.
It can be said that the busiest airport in the country is Mexico City International Airport (ICAO code: MMMX), located in Mexico city, and which also conforms, since 2003 the pillar of the Metropolitan Airport system, together with Queretaro, Puebla, Toluca and Cuernavaca. In 2014, it moved almost 34.2 million passenger, from which more than 22.7 million were national and around 11 million international. The amount of national and international passengers transported, located MMMX as the first and second top 10 airports in Mexico. The airport handled over 410 000 flight operations, most of them were commercial flights: 65% were domestic and 23% international; the cargo carriers performed 11 252 operations which represented the 3% of the movements. However, the domestic general aviation sector accounted with the 8.5% of the total movements.

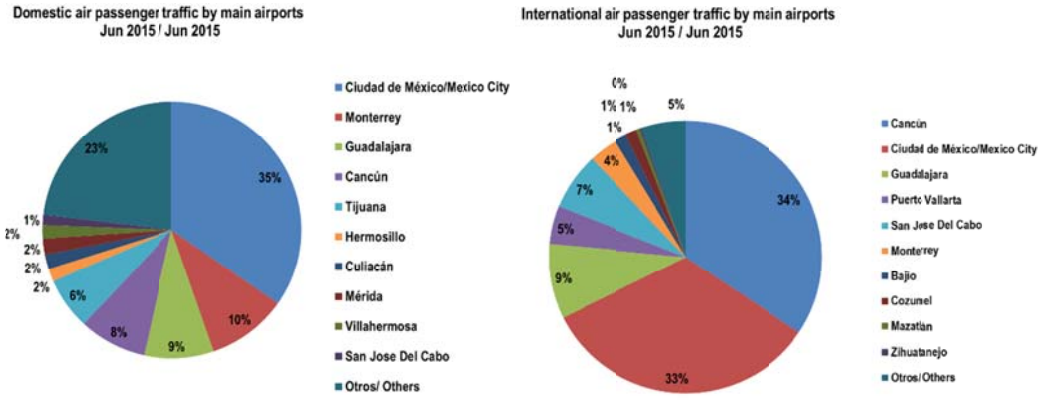

Figure 4.Domestic and International passenger traffic by main airports in Mexico

2 THE SITUATION OF MEXICO CITY AIRPORT

Mexico City Airport is considered key for the development of the metropolitan region in Mexico and also for the development of the country. Recently it has been announced the development of the new airport in Mexico City which will have a final capacity of 120 mill pax/yr. However this airport will not be operative until 2020 (only the first phase). In the meantime Mexico City as a destination is still growing and the country has also gained importance as a tourist and business destination. On the 12th of January 2016 AirFrance started a direct flight from Paris to Mexico City using the mega jumbo A380. At the moment the flight is only scheduled 3 times a week but it is planned that from March on it will fly on a daily basis. Each flight of the mega Jumbo transports 516 passengers and due to the dimensions and requirements for the operation some problems have raised in which delays are the most relevant ones.

The flight to and from Paris represents itself a challenge to the Airport due to different factors and in addition some problems have raised. One problem is that the clearances from the centerline at the taxiways are too narrow for the size of the aircraft and only some taxiways are enough for the code of the aircraft (F) which has caused that the aircraft follows a dedicated airport vehicle through a long route to the runway. This operative situation caused that the departure time suffers a delay of 10 to 56 mins with an average value of 36 minutes (Experience Skies).

On top of this situation, some years ago the airport authorities established a limit of 61 ATM/HR as the maximum hour capacity for the airport, for this reason some slots of the airport have been declared already congested. Furthermore, Lufthansa and Emirates have stated that they have intentions to start operating with the A380 from Frankfurt and Dubai to Mexico City respectively. For these reasons is critical to study the current and future operation of the airport with the use of tools that allow integrating different elements that other techniques are not able to such as variability and the dynamics of the different elements that participate in the system.

In this article we present the analysis we performed using a validated model of the Airport of Mexico City which allows the understanding of the potential problems once the daily operation of AirFrance takes place.

3 MODEL-BASED APPROACH.

The developed model is a discrete-event based model which allows to include the stochastic characteristics and level of detail that other analytical approaches would not allow. The level of detail is such that enables the integration of the technical restrictions, the operative restrictions imposed by the airport authority, the rules in place for the different aircraft such as wake-vortex separation and the taxiway routing for landing and takeoff. The elements that compose the complete model are: the two runways, taxi network, terminal buildings, parking stands of the two terminals. The model focuses only in the airside of the airport and it does not pay attention to the flow of passengers or vehicles that perform the services within it. Figure 5 illustrates the layout of the model that includes the taxiway network, airport stands and runways.

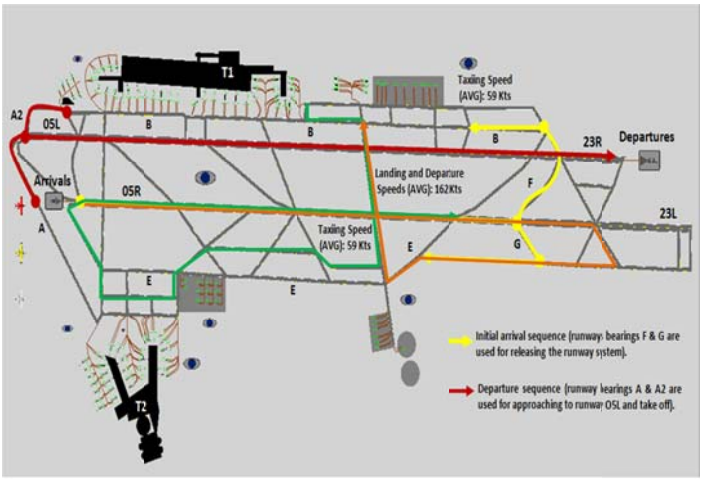

Figure 5. MMMX airport layout with A380

The yellow path illustrates the normal landing configuration and the red line represents the configuration followed for departing flights. However, the A380 follows the orange path and green path for arrival and departure respectively.

There are some characteristics that form part of the model and some assumptions have been made. The most relevant ones are presented in Table 3.

Table 3. Characteristics of the airside model

Parameter	Value
Landing Speed	Min:150 Knot, Max 175 Knot, AVG 162 Knot
Taxiing Speed	Min: 49 Knot, Max: 68 Knot, Avg: 59 Knot
RWY O5L-23R	Length: 3963 m
RWY 05 R-23L	Length: 3985 m
Number of Stands	T1: 50, T2:46
CenterLine Separation	310 m
Turnaround Time	Probability Distributions depending on the type of AC

For the flight schedule of the model we used information from a representative day. The information was taken from Flight Stats and Flight Radar and then the performance of the model was compared against the real number of air transport movements of the day.

In order to evaluate the impact of the A380 we collected information from the current operation, the type of information that we included in the model was:

- Route of Taxi In and Taxi-Out of the A380
- Speed of the Taxi In/out of the A380 in the Airport
- Tournaround time
- Current Schedule and gate allocation

The operation of the airport should have been modified in order to cope with the challenge of making space for the A380 to operate. Due to the limitations of the taxiways the route had to be modified so that the aircraft is able to get to the gate G34 which was the one modified for the operation of the A380.

3.1 Experiments and Results.

The preliminary results were obtained running first the case without the A380 in order to make possible to establish a base case for comparison. Once we obtained the results with the initial case we made the modifications to the model and we paid attention to the following performance indicators.

Table 4. Base Model without A380

Facility	Gate utilization	NO- A380		
	Max Avg	Min	Max	HW
Terminal 1 (36 Gates)	14.4	10	28	1.33
Terminal 2 (34 Gates)	15.2	11	21	0.88
	AVG	Min	Max	HW
Ratio T1Gates/T 2 Gates	0.43	0.34	0.57	0.02
TWY T1 queue	5.5	4	8	0.4
TWY T2, Queue	3.8	2	5	0.33

From the initial results it is interesting to appreciate that the traffic is apparently unbalanced since the Terminal uses more gates in average than the Terminal 1 during the day and in a more variable way as the HW shows. The maximum values represent that at some period of time during the day approximately more gates are used however not the full capacity of the terminal complex. In addition, the information of Ratio T1 Gates over the total capacity confirms that in average the T2 is more utilized than the T2.

In addition, it can also be appreciated from Figure 6 that as it has been already pointed out, the use of Terminal 2 is more intensive than the one for Terminal1 which might be due to the business model of the Flag Carrier in Mexico (AeroMexico) whose operation is mostly located in Terminal 2.

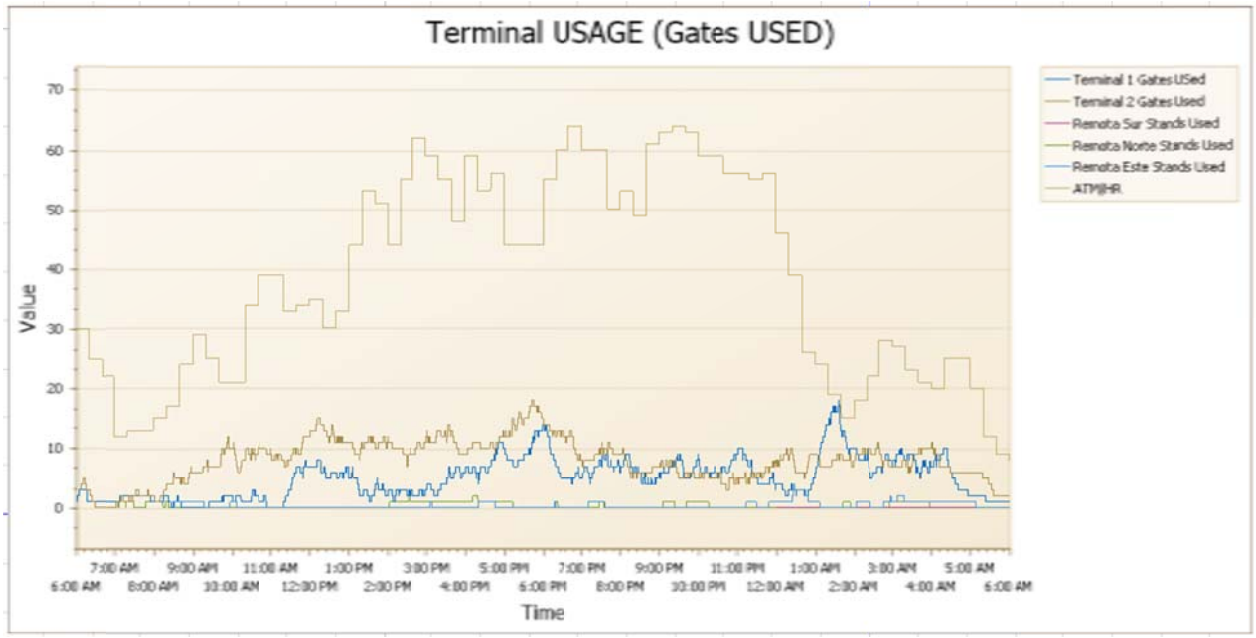

Figure 6. Gate usage and ATM/hr during the day

We could also identify that some queueing is built up in the TWY that goes to the Runway from T1 and the one from T2 with a maximum value of 8 and 5 aircraft during a period of time. Figure 7 also shows that the utilization of the runway is approximately 70%. All these numbers represent the performance indicators of the airport based on the information at hand.

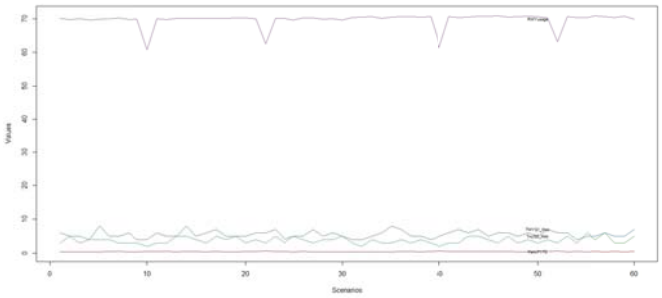

Figure 7. The evolution of runway and gate utilization

For the scenario that includes the A380, we used the same flight schedule but we added the flight for AirFrance at 6:40 pm using the gate G34 and following the route through the taxiway network that is currently using. Table 5 shows some of the results for the scenario with the A380. For this scenario 30 simulation runs were executed in order to evaluate also the impact of stochasticity within the system.

Table 5. Scenario with A380

Facility	Gate utilization	With- A380		
	Max Avg	Min	Max	HW
Terminal 1 (36 Gates)	14.16	10	21	0.86
Terminal 2 (34 Gates)	14.86	11	21	0.93
	AVG	Min	Max	HW
Ratio T1Gates/T 2 Gates	0.44	0.34	0.56	0.019
TWY T1 queue	5.6	4	8	0.38
TWY T2, Queue	3.7	2	6	0.39

Once we obtained the different values and the data of the operation we performed some tests to evaluate if the impact of the operation is statistically significant. We executed tests over the following indicators with a level of significance of 0.05:

- Ratio UsageT1/UsageT2
- Effect on Queue of T1
- Effect on Runway usage
- Effect on Queue of T2
- Average T1Gate usage

After running the different tests we could only identify a significant effect over the third performance indicator. This indicator deals with the level of congestion of the runway. In our study the runway usage went from 69.5% to 70.02 %. The values of the test are presented in the figure 9 and figure 8 illustrates how the values are shifted up due to the A380 operation.

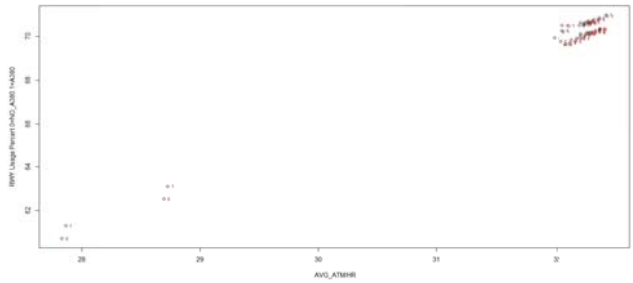

Figure 8. Effect in the RWY of the inclusion of A380

The next figure shows the hypothesis test performed for verifying the effect of the A380 in the RWY usage.

	Effect on RWY USAGE	
t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	69.48701814	70.02946
Variance	4.662065343	4.618695
Observations	30	30
Pearson Correlati	0.9966713	
Hypothesized Me	0	
df	29	
t Stat	-16.87623209	
P(T<=t) one-tail	7.74046E-17	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	1.54809E-16	
t Critical two-tail	2.045229642	

Figure 9. Values of the Hypothesis Test

This result is interesting since it means that the system is able to absorb more traffic as long as the runway is properly managed.

4 CONCLUSIONS

Airports in the globe are facilities that are very important for the development of a region in any country. Especially international airports have the function as the gateway to economic areas of development. In the particular case of Mexico, the international airport of Mexico City is a critical infrastructure which works as a catalyst for the development of the region in different aspects that range from tourism to business. In the present article we analyze through a model-based approach the situation of the operation of the mega jumbo A380 which recently started operations to and from Paris. We could identify interesting peculiarities of the operation of the airport such as the unbalance of the use of the gates in Terminal 1 and Terminal 2 and we could identify the runway as the bottleneck of the system. This result is interesting since it demonstrates that the A380 is not as disruptive as it was initially expected. However the runway is the most sensitive echelon in the system and the airport should put more focus in the runway management if they want to allow other carriers such as Emirates or Lufthansa fly to Mexico City Airport. As a future work we will study the particular situation of the peak hours of the airport in order to identify the slots that are less sensitive to the operation of a future A380 and the potential management of the runway until the new airport starts its operation.

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