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

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4 authors:

Miguel Mujica Mota
Amsterdam University of Applied Sciences

Catya Zuniga
Aeronautical university in Queretaro

Paolo Scala
Amsterdam University of Applied Sciences/Centre for Applied Research on Education

Geert Boosten
Amsterdam University of Applied Sciences/Centre for Applied Research on Education

IMPACT ANALYSIS OF REGULAR OPS OF A380 IN MEXICO CITY AIRPORT

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

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

ABSTRACT

Mexico City Airport is the busiest airport located in Mexico city, which also conforms, since 2003 the pillar of the metropolitan airport system, together with Queretaro, Puebla, Toluca and Cuernavaca. In 2014, it moved 34.2 million passenger, from which more than 22.7 million were national and 11 million international. The amount passengers transported in 2014 situated this airport as the first and second place in importance from all the airports in the country based on the national and international traffic respectively.
Mexico city airport is considered key for the development of the country. For this reason and because the airport has been declared congested, the development of a new airport in Mexico City has been announced recently to replace the old one, however the development of this new airport might take some years. In the meantime, the traffic in the country is still growing. On the 12th of January 2016 the first super jumbo A380 from AirFrance has landed in Mexico city revealing some capacity problems such as high delays, the seize of the runways during more time than necessary, long taxi times among others. Furthermore the plan is that it will operate on a regular basis two flights a day from March on. The previous situation if not properly addressed might cause big congestion problems affecting the whole operation of the airport. In this article we present a model-based analysis for the situation when the operation will be performed on a daily basis. Using the model we are able to reveal potential problems and solutions for the future situation. We use a holistic approach that includes the TMA and the airside of the system that allows us to reveal dependencies of the performance and strategies for solving potential bottlenecks within the system.

Keywords: simulation, Mexico airport, airport performance, congestion, simulation based.
Corresponding Author: Miguel Mujica Mota

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 has 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, SENEAMM, 2015).

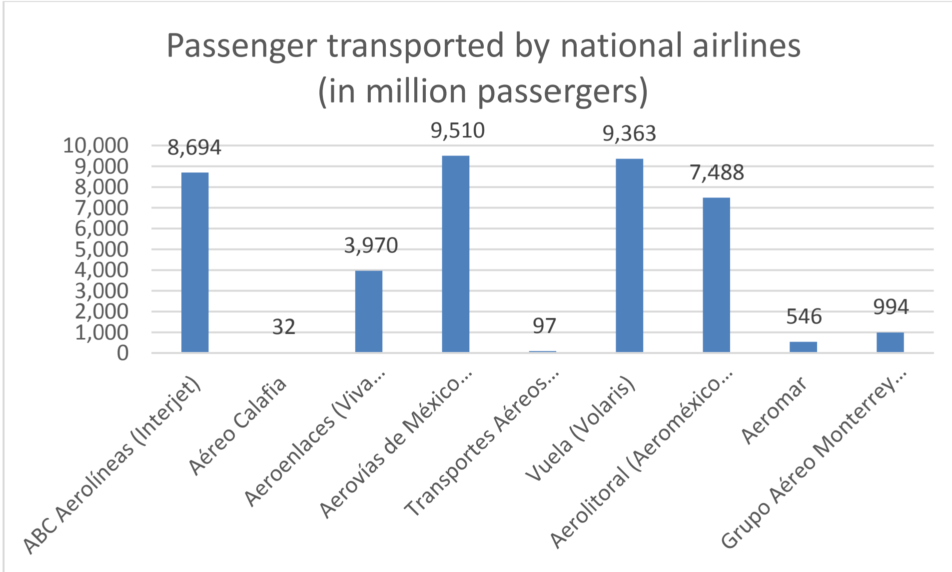

Figure 1. Passenger transported by national airlines in domestic and international routes in 2014

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 for 60% of the market. *Volaris* and *Interjet* together with *Viva Aerobus* are categorized as the current mexican low-cost carriers.

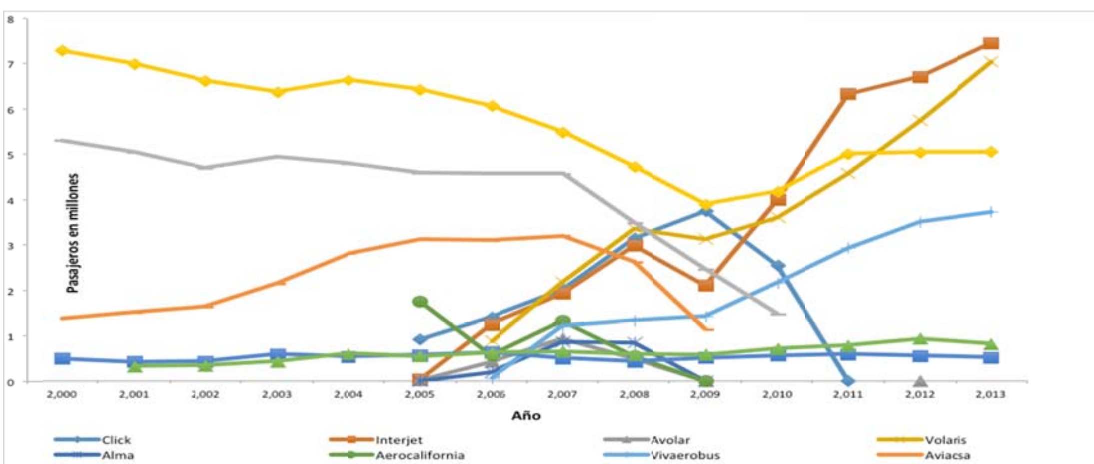

Figure 2. Main development of Mexican airlines since 2005

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 384 000, 120 000 and 83 000 passengers respectively. With regards to Central America and the Caribbean, *Aeromexico*, *Aeromexico-Connect* and *Interjet* transported 196

000, 235 000 and 270 000 passengers respectively. Concerning the traffic to South America, they were transported by *Aeromexico* and *Interjet* 881 and 76 thousand passengers, respectively.

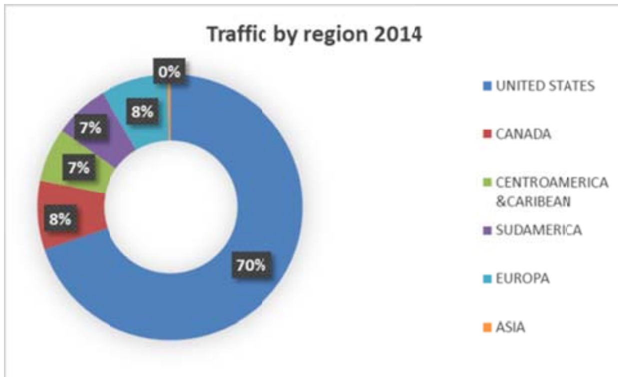

Figure 3. International traffic by region.

The mexican airline industry operated 8 961 aircraft, from which 2 011 were for commercial services, 6 509 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 1 431 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 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 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 locates MMMX as the first and second from the 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.

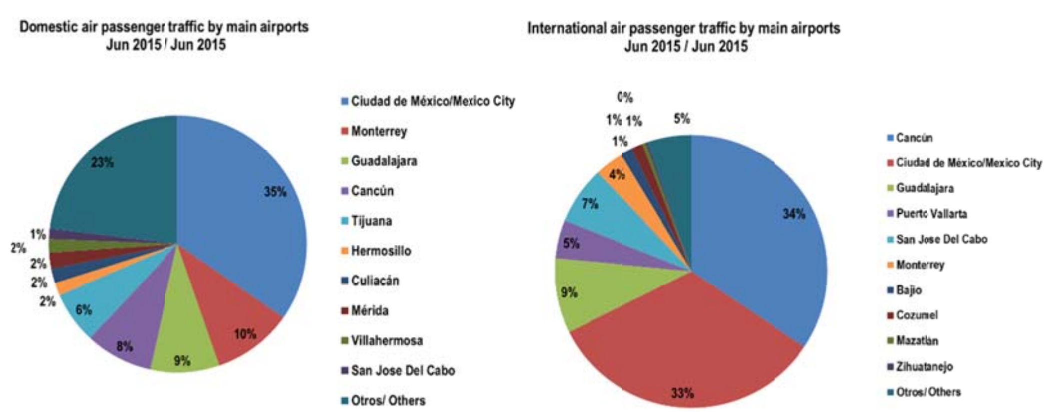

Figure 4. Domestic and International passenger traffic by main airports in Mexico

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 2015).

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 (CAPA 2014). 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 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 is composed by the airside operation and the TMA ones. This approach allows the understanding of the potential problems once the daily operation of AirFrance takes place.

3 METHODOLOGY

For the analysis of the situation of MMMX we developed a holistic approach based on the methodology developed by Mujica and Piera (2011) in which we modeled the airside on the one hand in which we included also information from previous studies such as the one from Herrera (2012) and the airspace (TMA) on the other. Then we coupled the models together so that it is possible to replicate the dependencies within the system. With the use of the integral model we designed an experiment for analyzing and identifying potential problems in the airside and the airspace once the A380 is under operation. We included the characteristics of the aircraft that were relevant for the development of the model such as taxi speeds, take off speeds among others (Airbus 2015). In the following subsections we present the principles of the models developed, the experiments performed, analysis and the conclusions about the study.

3.1 AIRSIDE of MMMX

Terminals T1 and T2 are located northern and southern from the runways and they are linked by the taxiway network, terminal 1 has 36 gates and terminal 2 has 34 gates for a total of 70 gates (contact points only). In Figure 5 the airside of Mexico City Airport is presented.

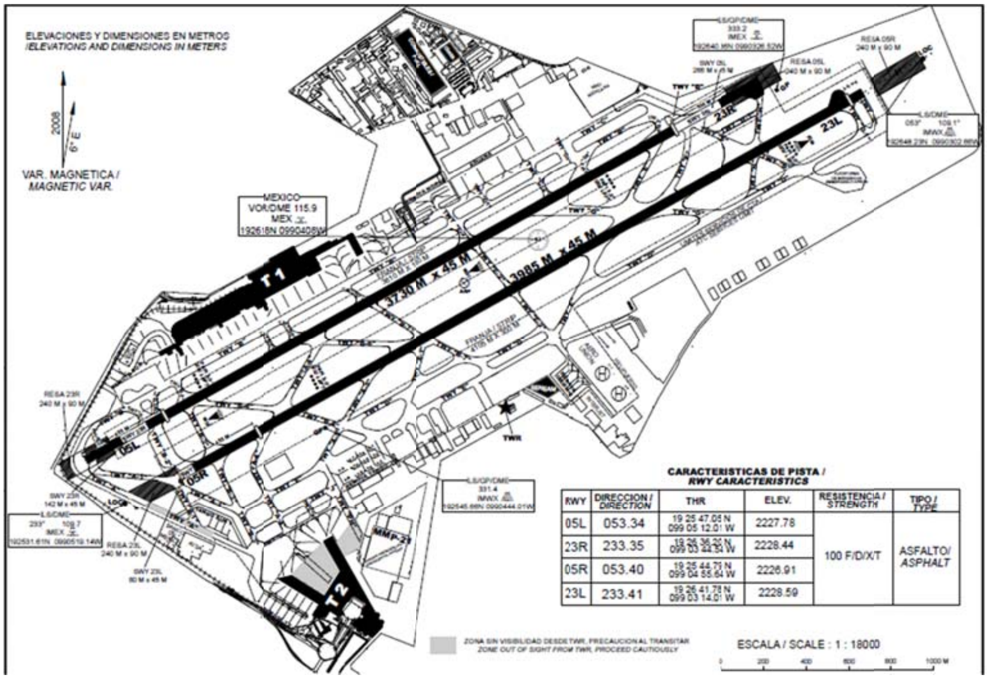

Figure 5. Mexico City Airport Airside

Regarding the modeling of the airside, we developed a discrete-event-based model which allows including 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. Figure 6 depicts the layout of the model that includes the taxiway network, airport stands and runways and it also shows the different paths that are followed by the traffic within the airside.

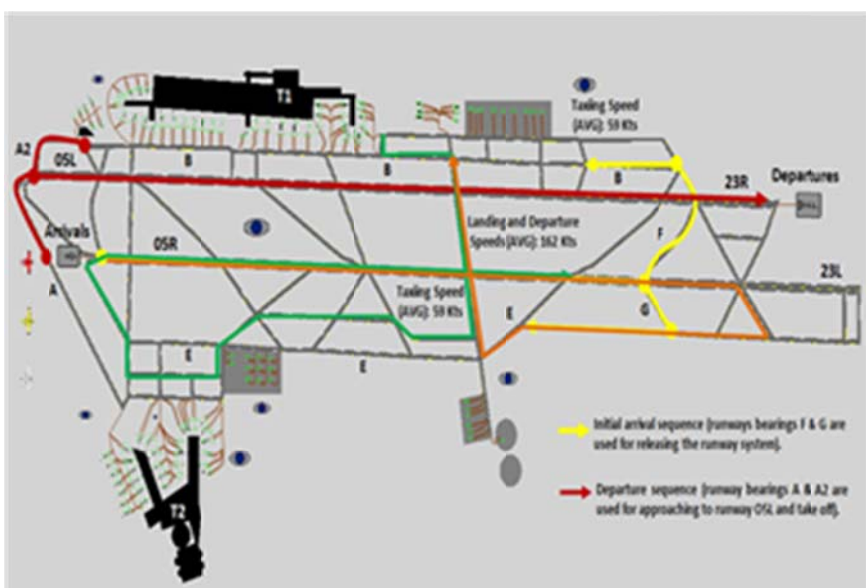

Figure 6. Model of MMMX with routes

The yellow path illustrates the normal landing configuration and the red line represents the configuration followed for departing flights. However, the situation of the A380 is slightly different; the A380 follows the orange path and green path for arrival and departure respectively (Mexico API 2015).

In order to make the model valid, different characteristics were included in the model besides different assumptions. The most relevant ones are presented in Table 3.

Table 3. Characteristics of the Airside Model

Parameter	Value
Landing Speed	Min: 135 knot, Max: 150 knot, Avg 142 knot
Taxiing Speed	Min: 4.9 knot, Max 6.9 knot, Avg 5.9 knot
RWY 05L-23R	Length 3 963 m
RWY 05R-23L	Length 3 985 m
Number of stands	T1: 50, T2:46
Center Line Separation	310 m
Turnaround Time	Based on probability Distributions

For the traffic generation of the model, we collected information from a representative day. The information was taken from FlightStats (FlightStats, 2015) and Flight Radar 24 (FlightRadar24, 2015) and some schedules from the airport (AICM, 2015) 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
- Turnaround time
- Current Schedule and gate allocation

The operation of the airport has been modified in order to cope with the challenge of giving space for the A380 to operate. Due to the limitations and restriction in the operation, the route of the aircraft is not the standard one but a modified one so that the aircraft is able to get to the gate G34 which was the one specified for the operation of the A380.

3.2 AirSpace of MMMX

Concerning the Airspace, the flight routes, similar to STARs and final approach routes were modeled. MMMX has two parallel runways, namely 05/23R and 05/23L. They cannot be used as independent runways due to the fact that they are not separated with enough distance, therefore they are used on a dependent configuration. Particularly runway 05R is dedicated most of the times only for landings and the 05L only for departures. In the model we assumed that all the time the operation for landings is performed in runway 05R, therefore in the model we took into account only STAR and final approach routes for runway 05R. In Tables 4 and 5 the general characteristics of STAR and final approach for runway 05R are described.

Table 4. Characteristics of STAR routes for runway 05R

STAR 05R					
STAR 1					
Waypoints	Santa Lucia		San Mateo		
Altitude	16000-13000 ft		12000 ft		
Speed	250 Kts		-		
STAR 2					
Waypoints	MEXICO	D-23 MEX	D-23 PTJ	D-12 SMO	San Mateo
Altitude	240FL	18000 ft	-	-	12000 ft
Speed	250 Kts	-	-	220 Kts	-
STAR 3					
Waypoints	VIVER	MEXICO	D-10 MEX	San Mateo	
Altitude	12000 ft	12000 ft	12000 ft	12000ft	
Speed	250 Kts	-	-	-	

Table 5. Characteristics of final approach routes for runway 05R

Final Approach 05R			
Waypoints	San Mateo IAF	D-7.7 MEX	D-5.5 MEX IAF PLAZA
Altitude	12000 ft	8800 ft	8800 ft

Depending on the flight schedule, aircraft arrive from one of the three STAR until they reach the merging point in correspondence to the Initial Approach (IAF). During the course on the air, aircraft are kept with a safe distance due to separation minima because of wake turbulence. In the model the separation minima applied is according to ICAO standard.

In correspondence to the IAF there is a Holding Pattern, this is a holding area where the aircraft are diverted in case of congestion on the route or due to disruptions on the ground. The holding is a racetrack-shaped segment and aircraft take around four minutes to complete a turn. In the model once the aircraft reach the IAF, they check if the route ahead is congested by two aircraft flying and also if the airside is congested. Concerning the latter, the airport operator has claimed that an indication of congestion is the number of aircraft queuing at the runway take off points, so in our modeling approach when a threshold is reached, aircraft will go on holding. Figure 7 shows the STAR and Approach routes and the Holding Pattern as they were implemented in the model.

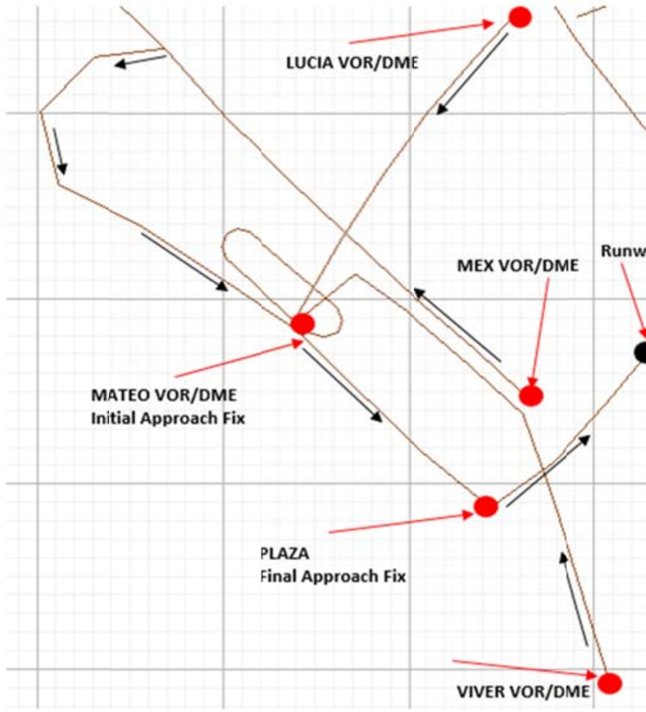

Figure 7. Airspace routes for MMMX

Regarding the speed, we modeled the different route segments by implementing the speeds according to values described in table 4 and 5 for STAR and final approach routes respectively.
Using this approach we modeled the ATC by using a rule of thumb in which landings are prioritized rather than departures. Therefore if an aircraft is flying in the final approach segment then aircraft that want to depart will wait in queue and take the runway after the aircraft has completed the landing and exited the runway.

3.3 Experimental Design

The first scenario is the base case in which we performed a statistical analysis for defining the performance of the system without the use of the A380. Tables 6,7 and 8 present the statistics focusing on the most relevant parameters of the system. In order to obtain these statistics we run 50 replications of the model.

Table 6. Descriptive Statistics for the Base Case (Airspace)

aircraft_MATEO_HP_AVG		AvailabilityOfRunway05R_AVG	
Mean	94.96603696	Mean	44.6267646
Standard Error	0.479492087	Standard Error	0.056564664
Median	95.08521561	Median	44.66914526
Mode	#N/A	Mode	#N/A
Standard Deviation	3.390521061	Standard Deviation	0.399972578

Sample Variance	11.49563307	Sample Variance	0.159978063
Kurtosis	-0.288782847	Kurtosis	7.200477185
Skewness	0.13575345	Skewness	-1.893346093
Range	14.83162213	Range	2.41292754
Minimum	87.98767967	Minimum	42.83530701
Maximum	102.8193018	Maximum	45.24823455

Table 7. Statistics for the Airside

TIME_IN_QUEUE_AVG		*TIME_IN_QUEUE_MIN*		*RATIOT1_GATEoverT2_GATE_AVG*		*Terminal1GatesUsage_AVG*		*Terminal2GateUsage_AVG*	
Mean	0.524760973	Mean	0.025820424	Mean	0.536245802	Mean	16.49888889	Mean	13.844
Standard Error	0.002095559	Standard Error	3.96508E-18	Standard Error	0.000852171	Standard Error	0.06445324	Standard Error	0.053815807
Median	0.52605432	Median	0.025820424	Median	0.536158835	Median	16.53333334	Median	13.9
Mode	#N/A	Mode	0.025820424	Mode	#N/A	Mode	16.64444444	Mode	13.75555556
Standard Deviation	0.014817839	Standard Deviation	2.80374E-17	Standard Deviation	0.006025762	Standard Deviation	0.455753234	Standard Deviation	0.380535221
Sample Variance	0.000219568	Sample Variance	7.86094E-34	Sample Variance	3.63098E-05	Sample Variance	0.20771101	Sample Variance	0.144807055
Kurtosis	-0.204591942	Kurtosis	-2.085106383	Kurtosis	5.483721036	Kurtosis	1.081147701	Kurtosis	-5.22297E-05
Skewness	-0.006389704	Skewness	1.031197389	Skewness	-1.219029045	Skewness	0.257369297	Skewness	-0.055092536
Range	0.064206845	Range	0	Range	0.038623693	Range	2.48888889	Range	1.72222222
Minimum	0.496338147	Minimum	0.025820424	Minimum	0.510873388	Minimum	15.36666667	Minimum	13.08888889
Maximum	0.560544992	Maximum	0.025820424	Maximum	0.549497081	Maximum	17.85555556	Maximum	14.81111111

Table 8. Statistics for the congestion indicators

TWYT1_AircraftInQueue_MAX		*TWYT2_AircraftInQueue_Max*	
Mean	7.02	Mean	14.58
Standard Error	0.294839977	Standard Error	0.114606692
Median	7	Median	15

Mode	7	Mode	14
Standard Deviation	2.084833474	Standard Deviation	0.810391692
Sample Variance	4.346530612	Sample Variance	0.656734694
Kurtosis	0.067366702	Kurtosis	0.673381789
Skewness	0.774681167	Skewness	0.449413995
Range	8	Range	4
Minimum	4	Minimum	13
Maximum	12	Maximum	17

We performed the analysis for a 30-hrs of operation and we implemented a threshold for prioritizing the landings as we mentioned before. For the base scenario we set the threshold to 15 which means that as long as there were no more than 15 aircraft in total waiting for the runway to be used the aircraft approaching will have priority for landing.

From the analysis we can highlight some aspects. One is that during the day we measured that 90 Aircraft are put on hold(aircraft_MATEO_HP_AVG). This means that in average 3 aircraft/hr are on hold during one day of operation. This situation does not mean that all the time aircraft are on hold but that during peak hours more than 2 aircraft will be diverted so that the operation can continue. Another noticeable result is that the runway is used very actively only during 15 hours or approximately 50% of the time (the peak hours). For the remaining hours the runway use can be improved.

If we put focus in the indicator of the values of Table 7 we can see that the aircraft in the ground in average 0.5 hrs, however the minimum values are about 1 minute. Another parameter to pay attention to is the *RATIOT1_GATEoverT2_GATE_AVG* which measures the utilization of T1 over the total allocation, generally speaking, most of the time the allocation is balanced however due to the skewness of the values the T1 sometimes T1 has a more active operation than T2.

Regarding the capacity of the contact points of T1 and T2 it is interesting to note that in average the capacity of both terminals is around 40% as the values of *Terminal1GatesUsage_Avg* and *Terminal2GateUsage_Avg* show. Finally regarding the lengths of the queues of the aircraft coming from T1 and T2 we can appreciate that in average 7 and 15 come from T1 and T2 respectively which is not surprising since our initial threshold is set to 15.

After determining the base case we investigated the effect of the A380 in the operation and how to improve the performance indicators of the system in general. From the simulation we could identify that the peak hours start from 12:00 pm until 12 am as Figure 8 shows.

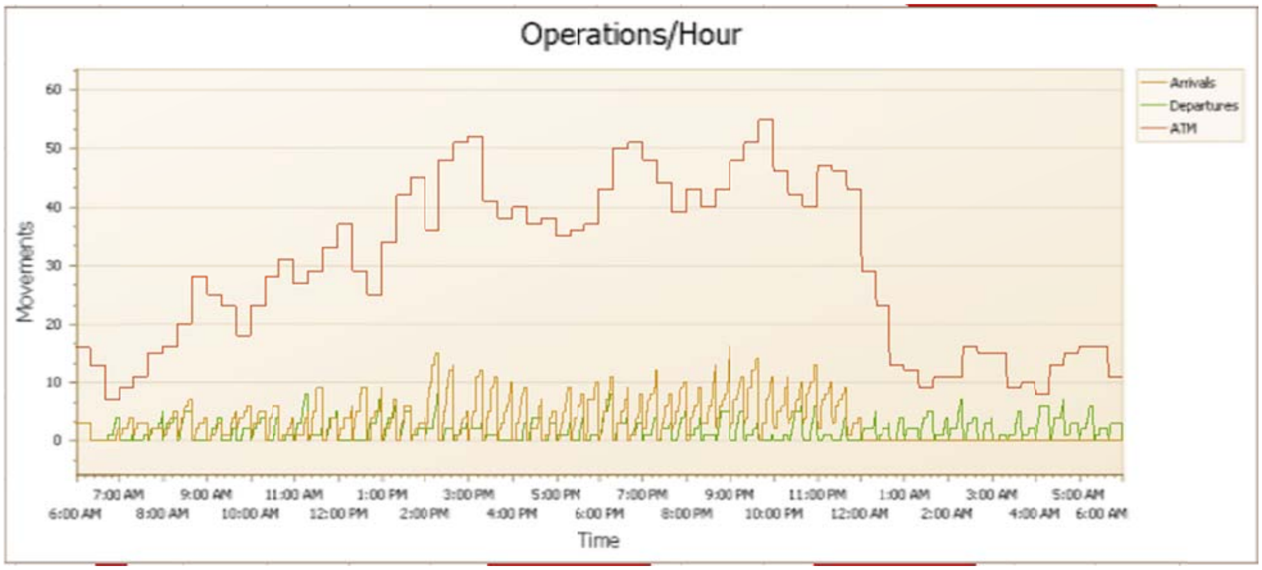

Figure 8. Evolution of ATM during the day

3.4 The operation of the A380

We performed the first treatment of the model in which the threshold was kept as 15 aircraft but this time we added the operation of the A380 as it is performed currently by AirFrance in MMMX. We obtained the values of the previous indicators and then we performed a *t-test* for verifying if the operation of the A380 has a significant impact in the capacity of the system. After performing some tests we could only identify a significant impact in the average usage of Terminal 1 as Table 9 shows.

Table 9. T-test for the avg. usage of T1

t-Test: Paired Two Sample for Means		
Terminal 1 GatesUsage_AVG		
	Variable 1	*Variable 2*
Mean	16.49888889	16.81244444
Variance	0.20771101	0.214142807
Observations	50	50
Pearson Correlation	0.570233185	
Hypothesized Mean Difference	0	
df	49	
t Stat	-5.206772294	
P(T<=t) one-tail	1.89628E-06	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	3.79257E-06	
t Critical two-tail	2.009575237	

As it is suggested by the numbers, the operation of the A380 only impacts the average usage of the terminal 1 while the rest of the elements are unaffected by the operation. It is important to mention that for the initial analysis we did not put focus in the peak hour analysis but in the 30-hr simulation.

3.5 Analysis of dependencies

For measuring the impact of the management of the airspace we decided to perform 3 more treatments varying the threshold of the aircraft waiting in queue at the runway heads(including the A380 in the system although it does not affect the system). In our case we evaluated 11, 7, and 3 aircraft as a threshold therefore modifying the priority for landing. With a scatter plot we identified dependencies in the capacity performance as Figure 9 shows.

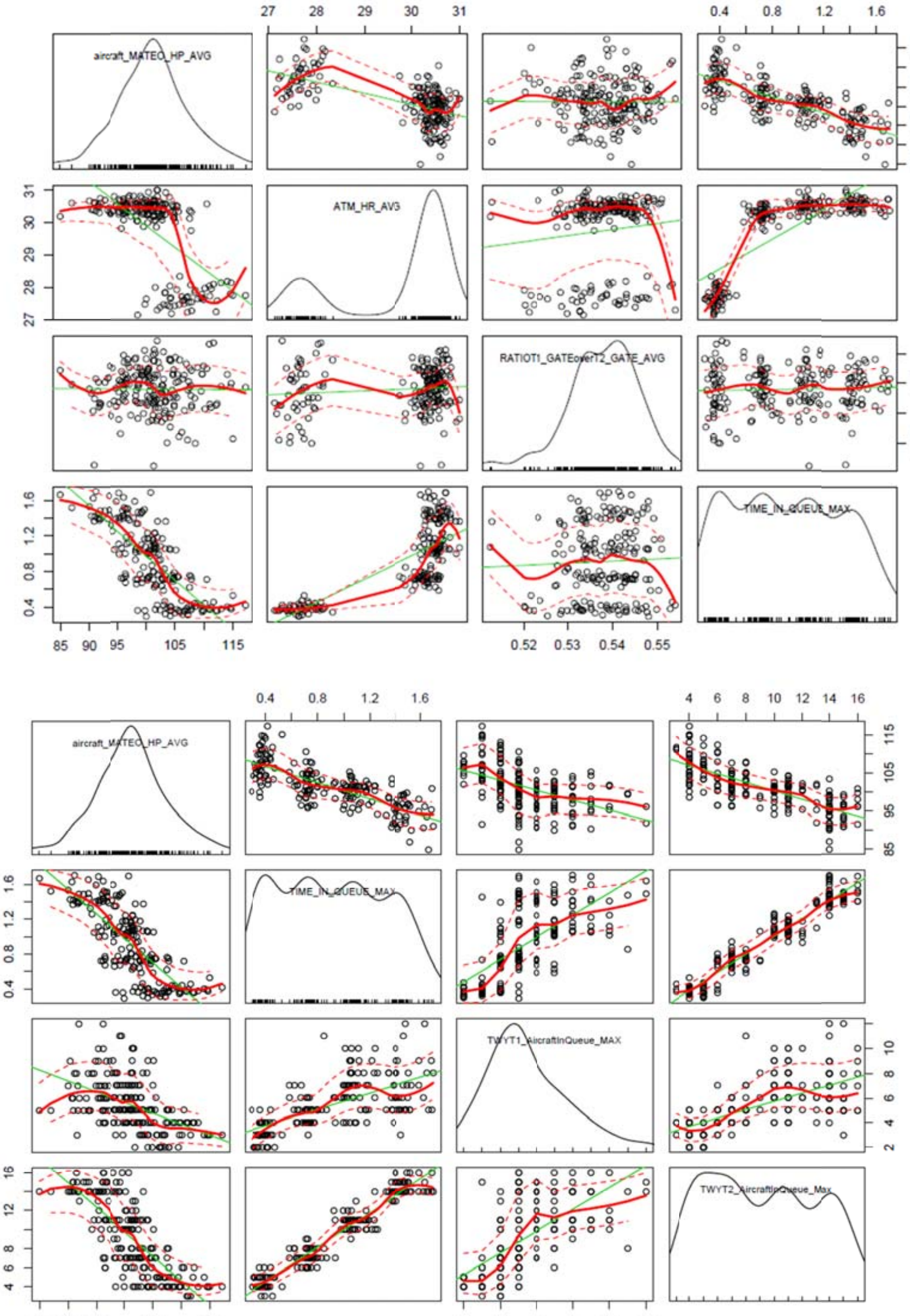

Figure 9. scatter plot for the relevant indicators in the system

The figures plot in the horizontal axis the values of the variable in the column versus the values of the variable that intersects horizontally the figure under study, for example in the first part of the graph, the graph corresponding to the first column and second row is plotting *aircraft_Mateo_HP_AVG* vs *ATM_HR_AVG*.

From the plots of the first column of Figure 9 we can identify the following:

- The number of ATM movements decrease with the increase of aircraft on hold, therefore if one wants to increase the ATM he needs to put attention at the airspace management.
- We can also see from the plot of aircraft on hold versus ratio of T1 gates used that the management of the gates (contact points) is independent from the operation at the airside, this might be due to the situation that both terminals are utilized in average 40% as we already metioned.
- The third plot illustrates that with the increase of aircraft on hold the time in queue at ground drops significantly which is a logical consequence of assigning priority in the ground operations.
- If we put focus on the second part of the figure (first column) we can identify that the maximum time in queue at the ground depends a lot on the number of aircraft on the two taxiways that go from T1 and T2 to the runway. However we can appreciate that the operation in T1 has much more dispersion than the one from T2. This might suggest that in order to operate efficiently the system we need to pay attention to the operation of T1 since it could be the case that sometimes with the increase of one aircraft in queue from T1 the increase in the time in queue is high while in the case for T2 the dispersion is minimal compared to the one from T1 thus make it more predictable.

Based on our previous analysis we decided to analyze the effect of the variation of the time in queue at the ground when we modified the assigned threshold. Figure 10 illustrates the trend we could identify with the experiments. We can see that the more we increase the threshold (putting priority to airspace) the more time the aircraft need to wait for the use of the runway.

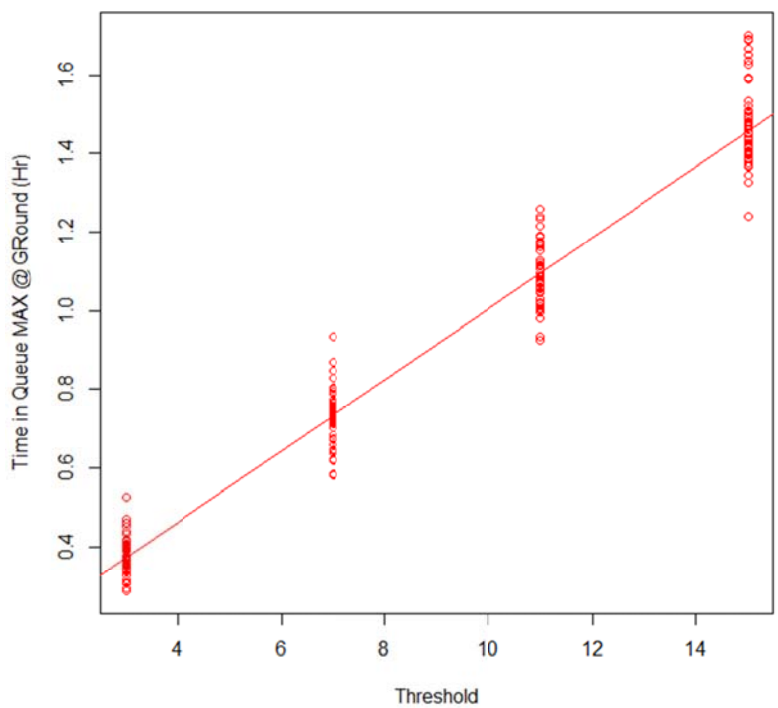

Figure 10. Dependency of Time in Queue vs. threshold

On the other hand if we pay attention to the variation of the aircraft that go on hold depending on the threshold assigned, we can see that the effect is the opposite as Figure 11 shows.

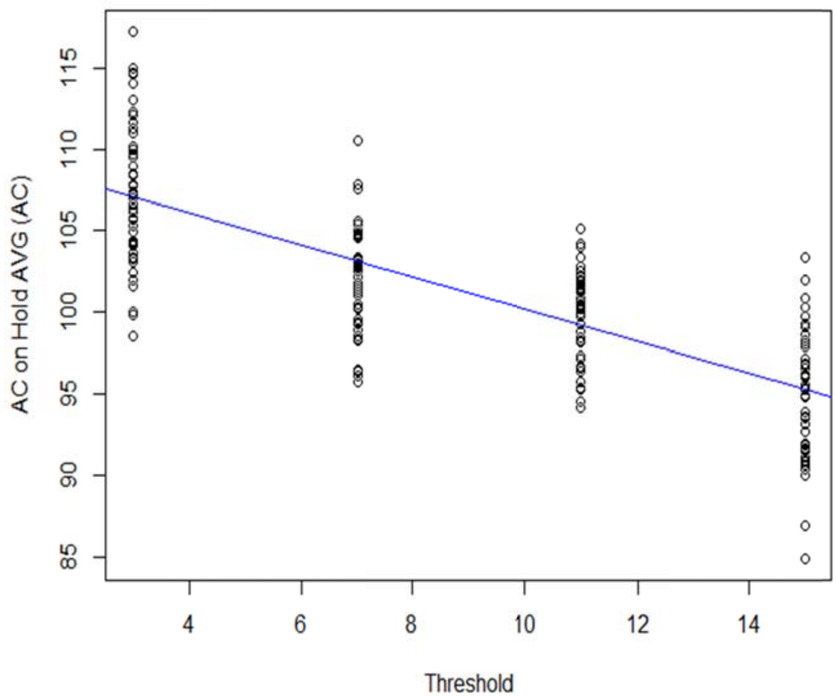

Figure 11. Dependency of number on hold vs. threshold

The combination of these two figures makes us realize the situation that a manager has to struggle with in order to keep a balance between the airside and the airspace operation. Figure 12 presents the previous two graphs overlapped so that it is possible to identify the point where the right balance can be achieved (in the case that we want to find an equilibrium for the operation). From the figure we can see that the equilibrium can be found with a threshold of 9 or 10 aircraft waiting in queue.

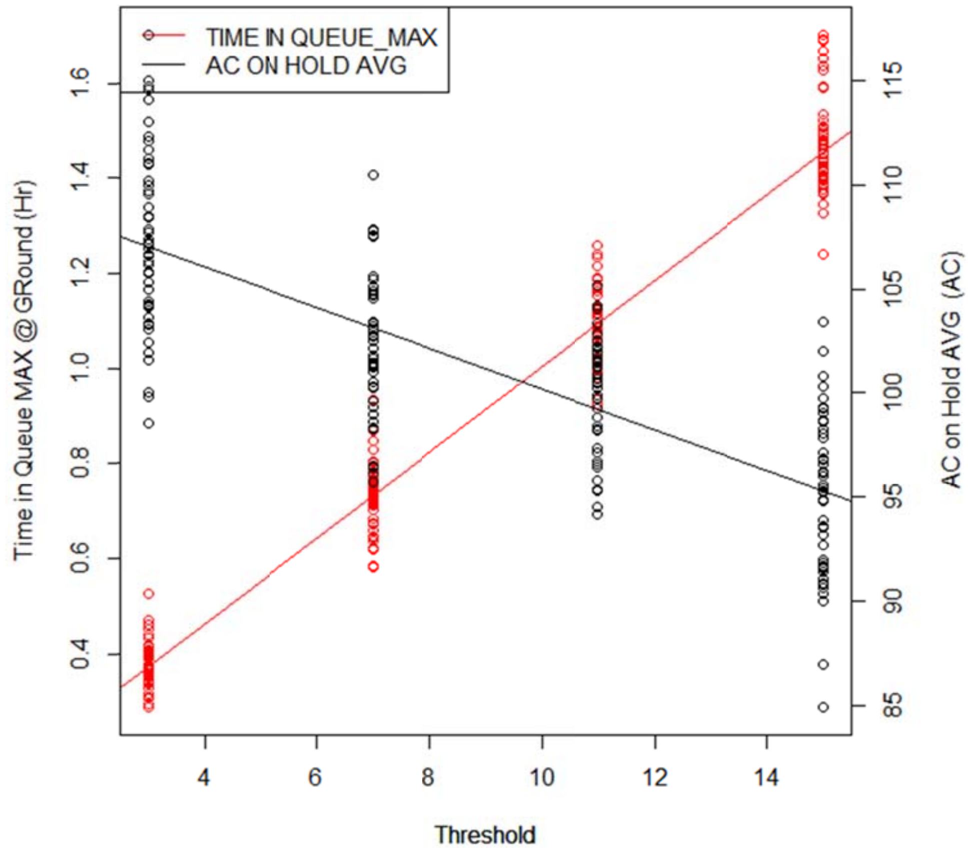

Figure 12. Identification of balance in an aeronautical system

This approach can be utilized in order to understand the dependencies of the different factors and then a more informed solution for managing the system. The approach presented can be applied not only in the factors presented here but also other factors that are becoming of interest for decision makers.

4 CONCLUSIONS AND FUTURE WORK

The article presents the analysis performed for the airport system that is composed by two subsystems, the airside and the airspace, to be more concrete the TMA of the airport of Mexico City airport. We analyzed first the main performance indicators that allowed us to identify the performance indicators of the system. Based on the analysis performed we could identify the effect of the airspace in the performance of the system. Regarding the different elements the runway is the one more utilized and the terminals still have spare capacity during the day of operation. For the analysis performed we have put focus on one day of operation, however as a future work we will develop an analysis of the peak hours taking into account the airline perspective so that we can identify the impact of the business model in the system. Regarding the A380 we did not identify in this study a relevant impact in the system, only in the terminal that performs the operation but as we mentioned the terminals have still capacity for handling the operation of more A380s. As future scenarios we will also evaluate the hypothetical case of including the operation of Emirates and Lufthansa with their A380s. We performed other treatments for identifying the dependencies of the system with the landing rules assuming that landings are always prioritized. We could identify that the management of landings affect the operation of the system since most of the indicators are positively correlated with the priority for landing.

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