Simulating Airport Capacity: Mexico City Airport Case

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Abstract

With the level of traffic growth worldwide there is an increase in demand for expansion of passenger & cargo facilities and also the need for a robust net connectivity. In addition, this growth causes higher workload to airport services and air traffic control activities. According to EUROCONTROL's forecast of IFR flight movements in Europe to 2035, the most likely scenario predicts 14.4 million flights, which is 50% more than in 2012. On the other hand, emerging markets in Latin America have also experienced strong growth in traffic; passenger traffic grew 6.9% (expressed in RPK), and 6% cargo traffic in 2012 compared to the same period in 2011. Traffic to, from and within Latin America is expected to grow at 5.2% annually over the coming 20 years, being Europe and North America its two largest traffic markets.

The case of Mexico City Airport is of particular interest since it has experienced outstanding growth during the last couple of years. Mexico transported in 2012 over 56.8 million passengers through 618 regular routes, 355 international and 263 domestic. As a consequence, it has reached its maximum capacity (61atm/hr.) during the last couple of years. Due to this increment Mexican authorities have declared saturation in eight slots in order to avoid congestion problems.

In order to overcome the problems that appear with higher airport and air traffic control workload, innovative strategies and methodologies besides the revision of aviation infrastructure are crucial.

The current work presents a simulation model that aims to analyze the effect of increasing demand for both landing and departures aircraft in a 24-hour period. It is aimed to tackle the airside of the airport as a key area to mitigate delays. The approach proposes five possible scenarios and analyses the effect of each one in some key performance indicators.

Keywords: airport, simulation, discrete event systems, logistics, airfield capacity.

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I. Introduction

ONE of the most important challenges for the aviation industry of this century is the continuous growth of air traffic. Diverse international institutions related with the aviation industry have elaborated forecasts about the behavior of the air traffic in the coming years. According to ICAO [1], in 2015 it is expected an increase of 6.3% in global passenger traffic. The global market forecast by Airbus [2], predicts an increase of the 6.6% annually for Latin America region (in terms of RPK[3]). Boeing states a similar forecast, with a 5.0% increase on the airline traffic per year (in terms of RPK) [3]. The National Chamber of Air Transport (CANAERO, by its acronym in Spanish) has estimated that in 2014 the flights market worldwide increase 4.7% annually meanwhile airlines in Latin America registered an increase of 5.9% [4].

Due to the imminent growth worldwide, it is very important to find some economic ways to propose effective solutions in the short, medium and long term, especially when the capacity of the airfield in major airports is reaching critical levels. In this sense, airfield capacity can be understood as the ability of a component of the airfield to accommodate aircraft, expressed in operations per unit of time. Although airport overall capacity is normally related to the runway system capacity, it can also be constrained by the ultimate capacity of other infrastructure elements such as runway system layout, apron area, or taxiway systems; the meteorological or environmental conditions; the demand characteristics; or even the business model of the airport, as well as their interrelation to each other [5, [6].

Hence, to overcome the increasing demand, it is helpful to analyze the capacity of other infrastructure elements related to airfield operations. Specially, the management of landing and departure flights to a specific gate is one of the key elements constraining the system which involves as key elements the runway and taxiway system. One way to analyze and find efficient solutions is by means of simulation models. Simulation is one the most popular techniques to plan airport operations because they provide realistic estimation by randomizing the various inputs parameters [7].

In this work, a discrete event system approach is used to study the main elements that constraint the capacity of the airside at Mexico City International Airport, i.e. runway and taxiway system and apron area in an integrated macroscopic approach. A preliminary model has been developed as a baseline to understand the current operation of the airport. The proposed simulation model incorporates the description of the airport operational environment and procedures to simulate air traffic movements. The operational environment consists mainly of airside facilities and associates operating procedures. Airside facilities include the runway, taxiway systems and apron areas. Operational procedures dictate runway use, taxi flows and gate allocation. Within this work, it is proposed a first approximation to the problem. Preliminary results have validated the approach and point out the benefits of it.

The structure of this study is described as follows: Section II describes the airfield components together with some important related works. Section III makes emphasis in the discrete event system approach as the technique; whereas section IV describes the modeling approach for the case study; section 5 analyzes the preliminary results obtained. Finally it is presented some conclusions about the case study.

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[3] Revenue Passenger Kilometers

II. Previous work

Typically, airport's facilities are divided into three components: airside, terminal, and landside. Airside facilities include elements that support the landing and takeoff operations, i.e. the transition of aircraft from air to ground and the movement of aircraft from parking (apron or storage areas) to runway. According to [8], the airfield itself is one component of the airside facilities, and typically encompasses the largest land area. Airside components include: manouvering area (runways, taxiways, holding bays), aprons and gates. Airside support facilities include airfield maintenance, marking and lighting, navigational aids, weather reporting stations, and ATC facilities [2,5].

The *manouvering area* can be understood as part of an airport to be used for the take-off, landing and taxiing of aircraft, excluding aprons. *Apron*(s) is defined by [9] as a defined area, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance. Aprons typically surround buildings, such as terminals and hangars, but also can be designed specifically to store aircraft out in the open using tied owns. A *runway* is defined as a rectangular area on a land aerodrome prepared for the landing and take-off of aircraft. Airports can have a single runway or multiple runways that may or may not be operated simultaneously [9]. The FAA [8] defines a *taxiway* as a paved strip of level ground along which aircraft taxi from the runway to a parking position (and vice versa) or from one part of the airport to another. Taxiways can also be used to temporarily hold aircraft waiting to take off or waiting for a gate. *Gates* within an airport are the access points between the aircraft and the terminal at which passengers typically embark or disembark. Gates may be at ground level or on an upper level, for which a loading bridge is provided to connect the aircraft to the door of the terminal building.

Diverse authors have tackled each of the elements of the airside to enhance capacity and other as integrated systems. These works can be classified respect to three main aspects: level of detail (macroscopic and microscopic), methodology (commonly analytical and simulation models), and coverage (a single element or integrated system).

Macroscopic approaches lead to approximate answers mainly for planning purposes and some design issues, with an emphasis on assessing the relative performance of a wide range of alternatives. These types of approaches allow a strategic perspective, which is crucial in the current context for the major airports around the world, especially when there is not enough financial resources for taking the decision of invest in the construction of more gates [10]. It can be found diverse literature that cover runway systems and gate allocation; there are very few models for taxiway systems or apron area.

There have been different approaches to enhance runway throughput. One of the first works dates from 1959 were it has been proposed an analytical probabilistic models for runway capacity estimation. Recently, a new perspective has risen from the air traffic management point of view. The landing sequence problem have been also studied to maximize runway throughput such as [11] based on Linear Programming which solves the static case presenting a mixed-integer zero-one formulation of the problem together with a population heuristic algorithm. A Dynamic-Programming-based approach which used a method called Constrained Position Shifting (CPS) as in [12]; In the work of [13], the merging and sequencing problems is addressed for a set of landing aircraft by genetic algorithms. It is aimed to minimize the number of conflicts encounter in landings while enhancing the runway feeding.

The gate assignment problem (GAP) has been studied from different approaches, but in general it aims to assign at every scheduled flight a gate, taking into account the total number of gates available in the airport, meanwhile keeping a balance between the time needed to receive the ground handling services, and the time for the next flight that it will be assigned at the same gate. The goal is to find an effective gate assignment for every scheduled flight using those scarce resources. It can be modeled in analogy to the NP-hard quadratic problem [14].

Tang and Wang [15] analyzed the GAP considering the airline's perspective in Taiwan Tao-Yuan Airport. In their approach, gate assignment is performed under airlines perspective rather than the airport authority. This study takes into account four components identified by the authors; the first two are related to the passenger service and the second ones with the operating efficiency. Through mathematical functions, they propose an objective function that seeks to maximize the combination of the four components. The results show that the third component, which seeks the maximization of the number of arriving flights assigned, and the subsequent departing flights assigned, to the same gate (if they are served by the same aircraft); dominates the other components and has a high importance in the gate assignment.

In the work of Diepen et al. [16], the gate assignment problem was analyzed with the case study of the Schiphol airport (Amsterdam). The main objective is to find a robust assignment of flights, presenting the problem as an integer linear programming with a cost function that assigns larger cost to schedules in which the probability of conflicts is higher. Through computational experiments, the authors found that with their method is possible to find practically optimal solutions for real-life instances in about 10 minutes, although they remark that the next step is to test the effect of optimizing their robustness objective in more detail and to analyze the quality of the solutions generated with the solutions presented by the software.

The departure metering is another approach to study the gate assignment problem. According to [17], this approach reduces taxi delays and emissions in the departure process while maintaining airport departure throughput. The authors used the traffic information of the LaGuardia airport (New York), through a queuing model intended to simulate potential queues on the airport surface. Thought the well-known tabu search technique, they solved the minimization the total overlap duration, which represents the major problem in the gate assignment that is known as gate conflict. The results show that the robust gate assignment helps airlines and air navigation service providers reap the benefits of departure metering because it leads to fewer disturbances to the gate assignment.

In the work of Narciso and Piera [10] it is remarked the important to study the behavior of the system, particularly the effect that delays could have in airport capacity. It is employed a causal modeling approach based on Petri nets formalism to analyze the system behavior. In their study, it is considered the effect of non-anticipated delay on gate occupancy. Their approach tackles the effect that delayed flights will have on the initial assignment of aircraft to gates at an airport, to design a robust gate assignment policy that mitigates arrival and turnaround delay effects while maximizing gate usability. The new policy takes into account the possibility to set up the total gates following four strategies: sequential assignment, distributed assignment, non-preemptive, and preemptive.

III. Discrete Event System

There is a large literature in the *Discrete Event System (DES)* field such as in [18], [19] or [20]. In this section, the concept of *Discrete Event System (DES)* will be introduced in order to understand the main approach used in this study. In that sense, the first key concept is *system*. According to Banks [18] a system can be defined as a group of objects that are joined together in some regular interaction or interdependence toward the accomplishment of some purpose. Weiner [21] defines a system as a natural or artificial entity, real or abstract, that is part of a given reality constrained by an environment. Another important author that has defined the system concept is Ackoff [22], which established that a system is more than the sum of its parts; it is an indivisible whole. It loses its essential properties when it is taken apart. The elements of a system may themselves be systems, and every system may be part of a larger system. Every system includes other systems (called sub-systems), but at the same time the whole system is a part of a superior system (supra-system). Because of that, the interaction and interrelation between each component of a system is fundamental to understand the whole system [19].

The contribution of Churchman [23] to the *System Approach* is to understand the vital importance of every part in a system, and the way in how they are interrelated (*System Thinking*). In addition, this author argues that the best way to understand a system is to define its role and purpose, and not by its structure. According to Gopal [24], a system implies two concepts: (1) *interaction* within a set of given or chosen entities, and (2) a *boundary* (real or imaginary), separating the entities inside the system from its outside entities. For that reason, when the goal is the analysis of a real life system, it is critical to have in mind, the natural constraints on the environment which make infeasible the experimentation with the real system. These constraints could imply the lack of sufficient resources like time, staff, expertise, or money; even it could be possible that the system does exist yet.

The components of a system are: *entity, attributes, and activities*. The *entity* is an object or component in the system which requires explicit representation in the model. An entity can be dynamic in that it "moves" through the system, or it can be static in that it serves other entities; the *attributes* are properties of that entity; whereas an *activity* represents a time period of specified length. Other important concepts within system theory are called the *states and events.* A *state* is the collection of variables necessary to describe the system at any time, relative to the objectives of the study; these variables are called *state variables;* while an *event* is an instantaneous occurrence that may change the state of the system [18].

Following the above definition, it is clear that most real life problems have too many interactions some hidden, some not, but then the question is – How to analyze a real life system if there are many interactions on it? It has been stated that humans have found different ways of dealing with these issues. One of them is to abstract the most important characteristics from the problem itself and then reason about it using a *model* of that problem. Then, a *model* can be defined as a representation of a system, and also as a simplification of the real system [18].

According to Weiner [21], systems can be classified depending on how the *states variables* and *time* are represented in the model as *continuous* and *discrete.* According to *time base*, there are *continuous time* paradigms, where time evolves continuously, and *discrete time* paradigms, where time evolves by advancing in discrete portions. On the other hand, if the values of the state variables are considered, there are *continuous models*, where the variables take their values from continuous set represented as a real number, and *discrete models*, where the variables are discrete and can be represented as a finite set of integer numbers.

It is possible to imitate a real-world problem through *simulation*, which means the imitation of the reality. Flores et al. [25] define the simulation as a numerical technique for producing experiments in a digital computer, using graphics, animation and others technological devices; which involve some mathematic and logical models, which describe the behavior of a system. Simulation involves the possibility to explore new policies and procedures without disrupting ongoing operations of the real system; also new systems can be tested without committing resources for their acquisition. In that sense, the time (an important resource) can be compressed or expanded with the simulation. Also the hypothesis of the researching can be tested for feasibility; and insight can be obtained about the interaction of variables. A simulation study can help in understanding how the system operates rather than how individuals think the system operates. In brief, the simulation can answer the question What *if?* This is useful in the design of new systems.

IV. Mexico City Airport Case Study

Mexico City International Airport (MMMX[4]) is the principal airport in Mexico; its traffic has had a continuous growth since the recovery of the 2008 world economic crisis. In 2012, over 56.8 million passengers were transported through 618 regular routes, 355 international and 263 domestic. Passenger traffic has been forecasting to increase around 4.6% annually (in RPK) [26]. On this matter, it is substantial to point out that at the moment; the 34% of the total passengers transported in Mexico together with the 23% of the total number of operations in the country are concentrated in Mexico City International Airport [27].

During 2014, Mexico City International Airport experienced a tremendous growth on passenger traffic and the total number of operations. In fact, at the end of the year, the airport overcame its maximum capacity with a total of 34.2 million passengers (+ 8.6% in comparison with 2013), that means 2.4 million passengers over the available capacity [28]. Mexican authorities had established and declared a maximum capacity of 61 operations per hour with a total of 16 rush hours (7:00 – 22:59) [29]. In addition, during the saturated periods, the maximum operations had been exceeded in more than 52 times. The most congested periods are between 8:00-9:00hrs and 10:00-11:00

[4] ICAO code.

hrs. Furthermore, according to Herrera [30] during the last trimester of 2015 Mexico City Airport would reach 80% of its total capacity, which means a technical limit for being operable.

In this context, Mexican authorities announced in 2014, the construction of a new airport that will support the air traffic growth. Nevertheless, it is necessary to find alternative solutions while the current facilities are operating, especially if the construction of the new airport has been estimated to take between 6 to 10 years [27]. It is worth to remember that in more than 60 years of operations of Mexico City International Airport, 4 projects have been performed to deal with the traffic growth by expanding and remodeling different infrastructure, both in the land and airside. The last project presented was in 2001, when Mexican authorities announced the constructions of a new airport to face the increase of air traffic, however this project was not implemented, due to some political and social tensions. Finally, within the same facilities, a second terminal building (T2) was built to alleviate traffic congestion. Nonetheless, it was clear that the facilities will not be enough to meet the demand of air traffic in a short-term period.

Despite the last announcement for building of new facilities, the current ones have to be analyzed in order to cope with the upcoming traffic demand. Therefore, it is needed to revisit some key elements in the system to be able to formulate strategic plans based on the performance of the overall system.

Mexico City International Airport has two passenger terminals called terminal 1 (T1) and terminal 2 (T2), interconnected by an internal train services and road access. The total surface area of the airport accounts for 756 ha. The airport is served by 26 passenger airlines and 17 cargo carriers [31]. See Table I for detail information.

Table I. Airport characteristics

	Terminal 1	**Terminal 2**
Surface area	548 000 m^2	242 000 m^2
Contact positions	33	23
Remote positions	11	7+10
Other positions	9	2
Baggage carousel	22	15
Airlines	20	6

The airport serves as the hub for Aeromexico (Mexican biggest airline), and, as the airline conforms the SkyTeam alliance, the airport has also become a SkyTeam hub.

Terminal 1 is mainly use for both national and international flights and it has a total of 44 gate/stand positons, 33 of them are contact gates (P1-P36) and 11 remote ones (S3-S8; P37-P40), as depicted in Fig.1. Terminal 2 is mainly use by international flights; it has 23 contact positions (G52-G74) and 17 remote ones (G75-G81) and (T1-T9; TA-TB) and a further area with 6 more positions (P48-P51; TC). There are also 7 customs clearance positions (P41-P47) in terminal 1. A total 107 gates are used at the airport; 56 are T1 and 51 in T2.

Figure 1. Macroscopic view of the model

The runway system consists on runway 05L/23R and 23R/05L with dimensions 3963x45m and 3985x45m, respectively. The declared separation between them is 1000 ft. (305 m). According to FAA [8], independent operations (landings and/or departures) need 3000-4300ft (914-1311m) separations between runways which constraints independent operations; therefore, it is operated as a single runway. In current operations, one runway is used for arrivals and the other one for departures.

Nowadays, in the airport, the gate assignment is performed according with the airline perspective, which means that some gates are exclusives for one airline. Depending on the availability, the airport authority assigns for every scheduled flight a gate where the airline operates in the terminal buildings.

The taxiway system has 19 runway bearing, Table II present the ones used within this work to model the taxiway. According to the airport policies an aircraft approaching to T1 exits runway by runway bearing F. In case the gate has been assigned form 1 to 36 then it is used runway bearing B to approach; it is used runway bearing C to arrive to north remote platform and customs clearance area. Aircraft assigned to T2 leave across runway bearing G. Once in the taxiway system, aircraft move on runway bearing E and D depending on the final destination of the aircraft. Aircraft use runway bearing E2 to approach to gates 48 to 51; runway bearing PH to approach to gates 52 to 55 and Tango remote; runway bearing J is cross to arrive to gates 56 to 57; runway bearing A4 is used when gates 58 to 68 are assigned; runway bearing B3 for gates 69 to 81; and finally runway bearing A and A2 are used for departing from T1 and T2, respectively.

Table II. Runway bearing characteristics

Runway bearing	Gate
A: 23 M ASPH PCN 85/F/B/X/T	Departing from T2
A2: 23 M ASPH PCN 80/F/C/X/T	Departing from T1
A4: 25 M ASPH PCN 120/F/C/X/T	Gates 58-68
B: 23 M ASPH PCN 100/F/C/X/T	Approaching to T1
B3: 23 M ASPH PCN 73/F/C/X/T	Gates 69-81
C: 23 M ASPH PCN 100/F/C/X/T	Gates 37-47
D: 23 M ASPH PCN 100/F/C/X/T	Approaching to T2
E: 23 M ASPH PCN 120/F/C/X/T	Approaching to T2
E2: 23 M ASPH PCN 75/F/C/X/T	Gates 48-51
F: 23 M ASPH PCN 100/F/C/X/T	To release runway 23L/05 R
G: 23 M ASPH PCN 100/F/C/X/T	To release runway 23L/05R
J: 25 M ASPH PCN 120/F/C/X/T	Gates 56-57
PH: 25 M ASPH PCN 120/F/A/X/T	Gates 52-55 & TA,TB

The preliminary model to analyze Mexico City International Airport airside capacity at a macroscopic level is depicted in Fig. 1. The system is integrated by the runway system, taxiways, apron area and gates. Each of these elements has been modeled under an object orientated paradigm. The simulation has been developed using the SIMIO software through the use of historical data. Operational procedures information was quite difficult to obtain due to the lack of public information, the one used within this work was obtained from [30], [32], [33] and [34].

The model logic is described in Fig. 2. The process begin with the arrival of the scheduled flights, each flight has been classified according with the FAA [35] as: Heavy, Large and Medium. Before allowing a landing/departure operation, the controller needs to verify the availability of the runway. It is worthy to remember that in our case study, the use of runways is not simultaneously. Once runway is clear, each aircraft is allowed to take its taxiway route sequence and speed to its assigned gate. As soon as the aircraft enters the taxiway system, both runways are released for another incoming/departure flight. It has to be also verified if the taxiway is clear; if it is, then controller allows aircraft

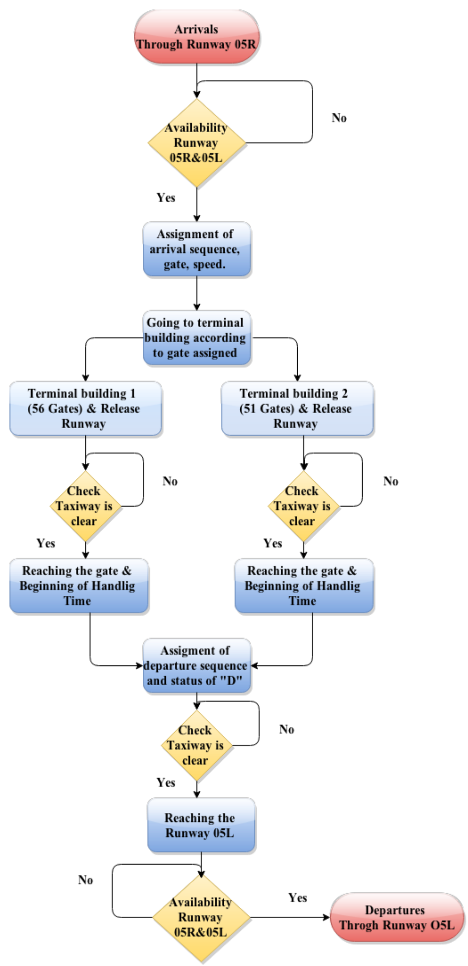

Figure 2. Process logic.

moves within it; in the opposite case, the flight waits until the taxiway is clear.

The handling operations are modeled by a time is consumed by the aircraft; each type of aircraft has been assigned with a different handling time in accordance of [30]. Once handling operations have finished, a depart sequence is assigned. The aircraft verifies again if the taxiway is clear, and when it is, aircraft is allowed to depart from its gate to runway 05L/23R. When aircraft reaches the runway bearing A or A2, it is verified against the availability of runways, if cleared, it starts its departing. The runway is release until the flight takes-off and leaves the final approach point. The process is iterative for all daily operations.

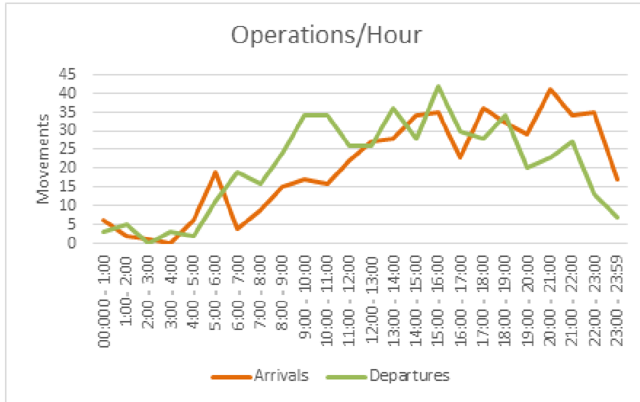

Figure 3. Demand example in a 24 hour

Fig. 3 depicts the real demand distribution over a 24 hour period. It can be pointed out that between 20:00-21:00hrs, it is performed highest amount of arrivals operations, meanwhile departures have its peak between 15:00-16:00hrs with more than 40 operations. The scenario presented in this Fig. 3 corresponds to February 1st, 2015 with a total of 976 movements (arrivals and departures), which in turn represents a medium season day. Each arrival flight has attached information about the arrivals such as: estimated time of arrivals, aircraft type, gate assigned, arrival sequence, and handling time.

Handling time was considered through the application of four probability distributions: *Jonson SB, Weibull, Pearson T6,* and *Beta*. Those distributions were extracted from the work of Herrera [30]; they are related to aircraft type and obtained from the airport authorities, see Table III.

Table III. Handling time distributions

Distribution	Aircraft Type
Interval between 00:00 and 6:00 hours	
Johnson SB (0.7382, 0.4198, 0.9089, 68.63)	For the three classes
Interval between 6:00 and 23:59 hours	
Weibull (0.8675, 46.16)	A319
Johnson SB (1.525, 0.7471, 0.0132, 101.8)	A 320
Weibull (1.100, 23.89)	ATR
Beta (0.5861, 1.198)	B737
Johnson SB (0.7382, 0.4198, 0.9089, 68.63)	For heavy class
Pearson VI (1.065, 4.835, 209.4)	For large class
Pearson VI (1.129, 2.721, 129.2)	For medium class

V. Results analysis

After several experiments with the simulation model, the results show that the runway system is being utilized in an average of 54.23% of its total capacity, which suggests that it could be possible to increase the number of daily operations, especially between 0:00 and 6:00 hours, which is the lowest demand period. During that period there were registered 58 operations (arrivals and departures), which represents the 5.9% of the total operations of the February 1st, 2015.

As mentioned in the precious section, the gate assignment at Mexico City International Airport is performed base on the airline's perspective, i.e. certain gates are used only for some specific airlines. In this regard, it is important to remark that Aeromexico, has the biggest number of gates assigned in T2 due to its role as major airline in the country.

The analysis also suggests that the capacity of the north and south piers in T2 could be increased, because both zones are used at the 18% of its total capacity. The table IV shows the time starved for every gate in each zone. The gates 52-81 at T2, are the gates with more time starved. The gates 75-81 have an average time starved of 278 min, while the gates 63-74 have a mean of time starved of 227 minutes. Gates 55, 56, 77, 79, and P75, are the one with highest time starved; which means that it could be possible to increase the utilization of these resources, at the same time than the capacity of the airport also increased.

Table IV. Gates less used (time starved).

South Pier		North Pier		Remote Terminal 2	
Gate	Time Starved (min)	Gate	Time Starved (min)	Gate	Time Starved (min)
63	204	52	216	75	309
64	238	53	177	76	243
65	256	54	155	77	436
66	187	55	450	78	185
67	209	56	281	79	327
68	279	57	325	80	185
69	172	58	189	81	262
70	166	59	168		
71	159	60	164		
72	156	61	180		
73	236	62	201		
74	178				

Regarding the utilization of each terminal, T2 is the busiest one during the period analyzed with 13% of utilization in contrast to the 9.3% of T1. Each percentage was calculated by the sum of the mean utilization of every gate in T1 and T2, respectively. Fig. 4 shows the utilization of the gates according to the terminal where they are located. It is important to point out that, in spite of T2 is the busiest terminal; the number of gates with less occupancy time (time starved) is bigger than in T1. On the other hand, it is also important to note the average holding time or delay of a flight for landing is around 18.61 min which corresponds to the delay applied by the controllers before landing while the idle time of the both runways (measured as a single runway) is 4.78 min.

Table V. Operations during 2014

Month	Movements	%Change
Jan	32,768	-
Feb	29,939	9,449213
Mar	33,657	12,41858
Apr	33,734	0,228779
May	35,060	3,930752
Jun	32,945	6,032516
Jul	35,972	9,188041
Aug	36,071	0,275214
Sep	33,276	7,748607
Oct	35,761	7,467845
Nov	34,597	3,254943
Dec	36,174	4,558199
Mean %Change		5,9

Based on the above, five scenarios were designed in order to increment the traffic within the system and analyze it is possible performance under this assumptions. The goal is to use the previous information and to introduce in the system, some hypothetical flights called "dummy flights" in those areas that have been register with lower utilization and hence, to assign more flights to gate. The scenarios were designed according with the mean of the monthly percentage change of the operations during 2014, see table V.

Table VI summarized each designed scenario together with some important information. As depicted in table VI, 29 dummy flights were introduced in the first scenario (S1), 3which sum a total of 517 flights. The total number of operations in this scenario is 1033 operations per day. In that case, the runway system presents a utilization of 54.57%, the average delay applied before landing was 16.48 min, and the idle time was 4.63 min. This experiment, suggests that it is possible to increase the capacity of the runway system and decrease the idle time of the whole system.

In the case of the second scenario, 30 flights are introduced in the system, 1 flight more than in the first scenario, and significant differences were found. The main one is the delay introduced, since it increases to 35.6 min, while the idle time of the runway system decreases to 4.51 min. In

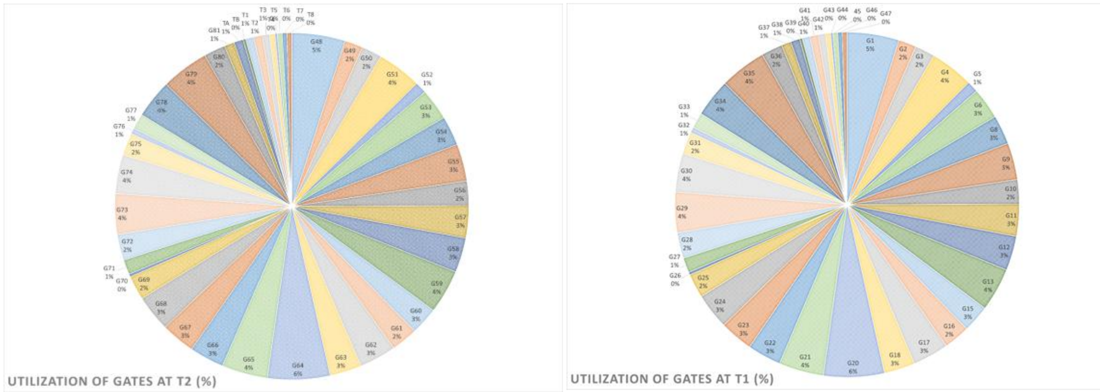

Figure 4. Gate utilization per terminal

this case, both runways are used at an average of 54.52%. On the other hand, it should be pointed out that for the third scenario, even 3 more flights were introduced (comparing with the first scenario) the utilization of runways is quite similar, with 54.51% but the delay introduced decreases compared to the one found in the second scenario, with an average of 16.90 min. Therefore, it has also been analyzed the behavior of the system based on the demand distribution over the day. Even more flights were introduced, these flights were added in the interval between 00:00 and 6:00 hours, and hence, the total delay introduced was quite similar to the first one. Then, not only on the number of flights added to the system affects the delay introduced, but their distribution per time slot.

Table VI. Scenarios

Scenarios	Dummy Flights	Number of Flights	Total Ops	Delay before landing	Idle Time
S1	29	517	1033	16.48	4.63
S2	30	518	1037	35.6	4.51
S3	32	520	1040	16.90	4.65
S4	125	613	1226	43.21	4.68
S5	161	649	1298	45.64	4.51

In the fourth and fifth scenario, the traffic increases significantly, with a total of 1226 and 1298 operations, respectively. The results note that the capacity of the runways system is used 54.59% and 54.4%, while the idle time increases to 4.68 and 4.51 min, for the fourth and fifth scenario respectively. As in the previous scenarios, flights were introduced in two different intervals. In the fourth scenario, the flights were added in the interval between 6:00 and 23:59 hrs meanwhile in the fifth scenario, flights were added in the interval between 00:00 and 6:00 hrs.

VI. Conclusion

To overcome the growing demand at airports, a revisit of different activities is needed. The current situation of Mexico City International Airport is more delicate, mainly because it has been declared saturated in different slots by Mexican authorities. This and other forecasts have raised the need of a new airport which was announced last year. But until this project finishes, it will be necessary to enhance the capacity of different areas in the airport to cope with the increasing demand. This study focused in the airside encompassing the runways, taxiway and apron area as being the most restrictive systems within the airport.

A preliminary model was developed to analyze the behavior of the real system and to be able to predict different upcoming scenarios. Five scenarios were developed, in each one, the daily traffic was increased. Three critical key performance indicators were analyzed: the percentage of utilization of runways; idle time the runway system; and the delay introduced by controllers before landing.

The result demonstrates that if the air traffic demand rises, daily operations will suffer delays up to 45 min, and the congestion problem at the airport could become worst. The consequences of the increment in daily operations will not only affects arrivals but the other subsystems such as taxi system, gate assignment and handling operations among others.

There is plenty of future work within this approach. First, the model has to introduce more operational restrictions, which unfortunately, are not easy to identify, mainly due to the lack of public information of the airport. Detail procedures for taxiway should be introduced together with other gate assignment policies. Ground handling services should be modeled in detail to obtain a more accurate model. And other sample data, low and high season, for example, should be employed.

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