MODULAR APPROACH FOR MODELLING AN AIRPORT SYSTEM

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ABSTRACT

Airport capacity, expressed as the maximum number of air traffic movements that can be accommodated during a given period of time under given conditions, has become a strict constraint to the air transportation, due to the scarce amount of resources on the ground and restrictions in the airspace. Usually the problem of capacity at airports is studied separating airspace operations from ground operations, but it is evident that the two areas are tied each other. This work aims at developing a simulation model that takes into account both airspace and ground operations. The approach used is a modular approach, in other words, the model developed is the result of the combination of four different models which in turn make a more powerful one. The four models refer to the airside (runway and taxiway and turn-around), and airspace operations (Terminal Maneuvering Area). This integrated approach allows to assess the system as a whole, identify possible bottlenecks and elements that affect the real system.

Keywords: simulation model, airport ground operations, airspace operations, modular approach, data driven decisions

1. INTRODUCTION

As many authors stated, airports are the main bottleneck of the global air transportation. Looking at the trends for the next coming years, it is expected that the demand of traffic will increase, therefore, the study of an efficient use of the resources involved in air transport operations is a key aspect. The actors involved in the air transportation industry come up with different solutions to cope with the problem of lack of capacity. For instance, a solution could be the building of new facilities such as new runways or new gates, other solutions regard the optimization of the existing resources in order to improve the efficiency of the various processes involved in airport operations. The former solution seems to be the more logical, but it is the worst in terms of time and investments needed, on the other hand, the latter seems to be a challenging one in which techniques from operations research gain importance due to the type of problems to be solved. Another solution could be the development of the so called multi-airport system (De Neufville and Odoni 2003), in which capacity is spread on a network of airports constituted by a main airport (hub) and some secondary airports (non-hub). The purpose of the multi-airport system is to relieve capacity at the main airport (hub) and increase the capacity of the overall system in order to satisfy the demand of their catchment area. Airports included in a multi-airport system need to be close to each other and well connected to each other in order to make the choice of the airport from/to which depart/arrive irrelevant.

Many studies have been made about the improvement of airport capacity, some refer to the optimization of ground operations and others to airspace operations and terminal capacity. Regarding ground operations, most of the studies were related to gate allocation, optimization of taxi-in and taxi-out routes, scheduling of departing aircraft and operations related to the turnaround process. From literature we can see that lots of methodologies were used for solving these kinds of problems, most of them employ analytical and heuristic solutions. For instance, in the work of Dorndorf et al. (2007) is provided a large survey about various models and solutions techniques utilized for the gate scheduling problem, Bolat (2000) solved the gate assignment problem using a Branch&Bound algorithm, combined with the use of two heuristics. In the work of Narciso and Piera (2015), a colored Petri net formalism was implemented with the objective of calculating the number of stands necessary in order to absorb the arrival/departure traffic. Other authors proposed models to avoid congestion on the ground using pushback control strategy (Pujet et al. 1999, Simaiakis and Balakrishnan 2014, Khadilkar and Balakrishnan 2014). For the terminal operations, the work of Mujica (2015a) presents the allocation of desks using simulation and optimization techniques.

Concerning the airspace, in the specific Terminal Maneuvering Area (TMA), the main findings are related to the sequencing and merging of aircraft flow problems, while other works face the problem of scheduling arrival aircraft. The main objectives are to ensure separation minima and avoid conflicts between aircraft (Michelin et al. 2009, Zuniga et al. 2011-2013), and optimizing the sequence of aircraft in order to decrease delays (Beasley et al. 2000-2001-2004, Balakrishnan et al. 2010, Murca et al. 2015). Recently we have found some works that employ discrete-event simulation approaches regarding airport capacity issues.

For example Mujica et al. (2014-2015b) put focus on the ground operations and also Scala et al. (2015) on airspace operations aiming at evaluating the performance of the systems in terms of capacity.

The links of airspace with ground operations are more evident when the ground is congested, then the airspace should to be capable of absorb this congestion accommodating as much aircraft as possible in order to avoid disruptions of the service. If the airspace has not the capability of absorbing the congestion occurred on the ground, a chain effect is triggered, with delays imposed by air traffic control to the aircraft in the airspace (e.g holding pattern procedures, alternative routes, speed control). On the contrary, delays occurred to aircraft in the airspace (e.g. due to weather conditions) are translated on the ground as well. This fact drove the study presented in this paper taking a holistic perspective, therefore, in this work an integrated model of airspace (Terminal Manoeuvring Area TMA) and ground operations was developed. The scope of the work was to evaluate the performance of the entire system and identify the main factors that affect it. To do that, it was developed a simulation model employing a modular approach in which four different models were integrated to obtain a representation of the entire system (Airspace + Ground side). It was used a Discrete Event Simulation (DES) (Banks et al. 2010) which suits for modeling the operations of a wide range of systems.

The paper is organized as follows, in section 2 is presented the modular approach employed in order to obtain an integrated simulation model, describing the characteristics of the sub-models and the way in which they were combined. In section 3 the different scenarios and the results obtained from the model were presented, and in section 4 some conclusions were made.

2. DEVELOPMENT OF THE SIMULATION MODEL

In this work, the simulation model of Lelystad airport was developed. Lelystad airport is a regional airport of the Netherlands, currently, it accommodates only general aviation traffic, but in the future it will accommodate commercial traffic (Alders 2014). This work takes into account not only ground operations but also airspace (TMA) operations, obtaining an integrated perspective of the airport system.

2.1. Integrated model

This section explain how a modular approach was applied in order to develop an integrated model, including four different sub-models. This approach allows to analyze the airport system as a whole. In line with a modular approach, starting from the sub-models, each one representing a part of the airport system, the integration of them has made possible to come up with a unique and integrated model that keeps the characteristics of the sub-models and gives as an output a more accurate and realistic view of the system. If we want to analyze the entire system, an integrated approach results better than analyzing separately the sub-models. In real cases, the operation represented in the sub-models, interact each other affecting the performance of the entire system. As mentioned in the introduction of this paper, all the studies related to the improvement of efficiency of the airport as a system were done separating airspace from ground operations, thus, this work results to be a novel approach to address that issue. Due to the modular approach, it was possible to have a larger view of the system, and also to be able to carry on a more accurate analysis obtaining more significant results. In order to develop the integrated model was used a discrete-event simulation software called SIMIO, it is a general purpose discrete-event simulation software that allows modelling a wide range of systems. The strength of this simulation software is that it allows to load different models as libraries, and in turn, run them separately or run them together if necessary. When the different model are combined together, some entities are shared, and then these entities undergo the logic of each of the sub-models. Figure 1 represents the interaction between the different sub-models.

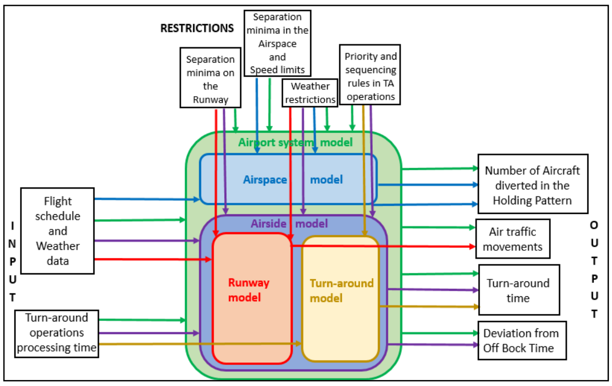

Figure 1: Representation of the interactions between the different sub-models in the integrated model

In the integrated model, the entity "aircraft" starts from the Airspace sub-model, where the logic of that specific model is applied such as separation minima between aircraft, speed limits, effect of the wind and the holding pattern procedure. Then it continues through the Airside sub-model where the "aircraft" entity lands, complete the taxiing-in, turnaround, taxiing-out and take off operations following the logic implemented in that model. In this case the airside model is already an integration of two models, Runway and Turnaround models, therefore, here the entity implicitly follows the logic implemented in these two models. Finally, after the "aircraft" crosses the runway for taking off, it enters again in the airspace model following the restrictions given by the logic implemented into the Airspace model until it reaches the last point of the model. Tables 1 and 2 show the characteristics of the system and the main assumptions taken into account.

Table 1: Characteristics of the Airport system

Number of Runways	1
Number of exitways	1
Taxiway type	Parallel
Number of Stands	16
Holding Pattern characteristics (number, capacity and speed limit)	1 (for each route), 2 Aircraft, 200kt
Mix of Aircraft	Code C (B737 – A320)

Table 2: Main Assumptions

Flight Schedule	Built taking into account traffic at Amsterdam Schiphol Airport in the peak hours
Airspace Routes	One route for each of the Runway configuration
Noise	No noise issues were taken into account

The main outcomes of the integrated model include the outcomes of the different sub-models, the difference is that from the integrated model can be obtained more accurate values since all the components of the system are taken into account simultaneously. At first glance, the main improvement obtained by the development of an integrated system, is the analysis of the delay, since both airspace and ground delays are taken into account. The evaluation of ground operations performance can be done with more accuracy when the airspace is also taken into account, for instance, when aircraft are diverted into the holding pattern, they will land later than the expected causing new scenarios on the ground side.

2.2. Sub-models

Each of the sub-models included in the integrated model, represent the following operations:

- Runway operations (first sub-model):

Operations related to runway, therefore, runway occupancy, mix of movements (landings and takeoffs handled) (Mujica et al. 2014).

- Turnaround operations (second sub-model):

Operations related to the turnaround process, therefore, boarding/deboarding of passengers, refueling, water service, catering service and baggage in/out. All these operations are made when the aircraft is parked at the stand (apron).

- Airside operations (third sub-model):

Operations related to the airport airside, therefore, landing process, taxiing processes, turnaround process and departing process. (Mujica et al. 2015b)

- Airspace operations (fourth sub-model):

Operations related to the airspace, in the specific the Terminal Manoeuvring Area (TMA). The main logic applied to the TMA are related to the operations made by aircraft during their approach and departure to and from the runway, they are: separation between aircraft; speed limit; holding pattern procedure; change of runway configuration; effect of wind direction and crosswind (Scala et al. 2015).

In the following paragraphs all the sub-models that were used to build the integrated model are presented, providing a description of their main characteristics and their main outcomes.

2.2.1. Runway operations

In this model all the operations related to the runway system of the airport (Lelystad airport) were represented. The infrastructure taken into account, includes the runway and the exitways. The main logic implemented were the separation between arrival-arrival, arrival-departure, departure-departure, departure-arrival aircraft on the runway; priority between arrivals and departures; weather conditions (crosswind and visibility); operational time. Different scenarios were tested based on different flight schedules (different volume of traffic) and different configuration of exitways (normal exitways or high-speed exitways) (see figure 2-3), the most relevant results obtained were about number of air traffic movements and runway usage among others. The model represented an early stage of the development of the entire airport system, from this model it was possible to obtain realistic values about runway occupancy time and runway usage, accordingly, instead values about number of air traffic movements needed a more accurate model with more restrictions to take into account such as the influence of the taxiway network, turnaround operations and airspace sectors. Results from the model pointed out the difference between the scenarios in terms of runway occupancy time, depending on the two different runway configurations, leading to have a more efficient use of the runway.

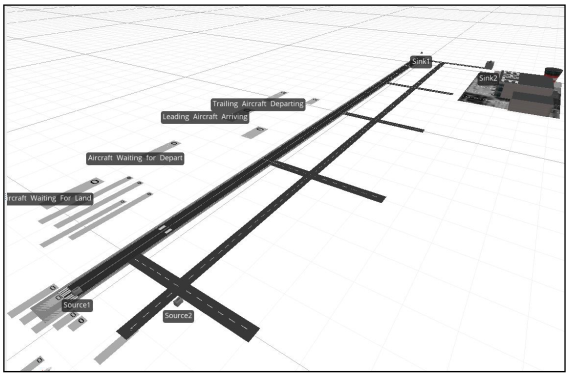

Figure 2: Runway Configuration with normal exitways

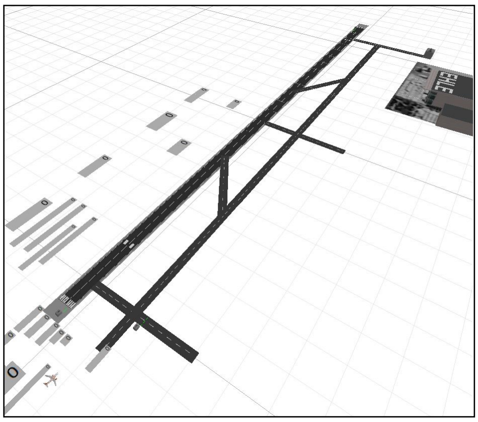

Figure 3: Runway Configuration with high-speed exitways

2.2.2. Turnaround operations

In this model all the operations made while the aircraft is parked at the stand were represented. The main operations are boarding and de-boarding of passengers, loading and unloading baggage, re-fueling, water service, cleanings and catering. Every operation needs a vehicle to be used, therefore we have these different types of vehicles in use: fuel truck, bus for passengers, trucks for baggage loading/unloading, catering service, cleaning service and water service. The purpose of the model was to simulate the total turnaround time, assuming that every operations spend a certain amount of time, and exist some sequencing rules between the operations to be made (e.g. boarding operations should be done after deboarding operations and fuel operations). Values about time were represented by random variables and data was gathered from the main manufacturers of aircraft for specific types of aircraft (Boeing 737, Airbus A-320) (see table 3). Depending on constraints about priority and sequencing rules within the turnaround operations, it was possible to identify the operations that most affect turnaround time. The logic implemented in this model make it general enough to be adapted for every airport type and for every aircraft type. (see figure 4)

Table 3: Times for Turn around operations

Operation	**Distribution**	**Time**
Positioning stairs	Random triangular	90,120,150 (sec)
De-boarding	Random triangular	3,4,5 (min)
Luggage out	Random triangular	5,7,11 (min)
positioning	Random triangular	40,60,80.9 (sec)
Luggage in	Random triangular	5,7,9 (min)
positioning	Random triangular	40,60,80.9 (sec)
Fueling	Random triangular	7,8,9 (min)
positioning	Random triangular	4,5,9 (min)
Cleaning	Random triangular	8,13,16 (min)
positioning	Random triangular	1,2,3 (min)
Water service	Random triangular	4,5,6 (min)
positioning	Random triangular	1,2,3 (min)
Boarding	Random triangular	4,5,6 (min)
Headcount	Random triangular	90,120,130 (sec)

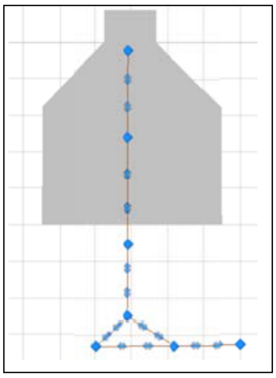

Figure 4: Turnaround operations model

2.2.3. Airside operations

In this model, the previous two sub-models (Runway operations, Turnaround operations) were combined. The result is a model that represent the airport airside, including runway operations (landings and take offs); taxiing operations; and turnaround operations. The Runway model was linked to the stands by the taxiway network, in this case we have 16 stands, in other words, the turnaround model was replicated 16 times. All the logic concerning the runway model and turnaround model were kept. In the taxiway network, the logic about speed regulation and path choice was implemented in order to let the aircraft cross the taxiway at the right speed and to go to and from the assigned stand. Once aircraft are landed, they occupy the first stand available from left to the right. The logic implemented make sure that aircraft do not have conflicts during taxiing operations, therefore, it is likely to have aircraft waiting in queues in some parts of the taxiway network, especially when there is high volume of traffic.

Different scenarios were based on incoming volume of traffic, different layout of taxiways geometry (see figures 5 to 7) and different number of vehicles involved in the turnaround operations. These scenarios were based on the characteristics inherited from each one of the two models included in this model, in the specific, different layout of taxiways for what concern the first sub-model (runway and taxiways), and number of vehicles for what concern the second sub-model (turn-around).

Figure 5: Configuration L-shaped stand with partial parallel taxiway

Figure 6: Configuration linear stand with parallel taxiway

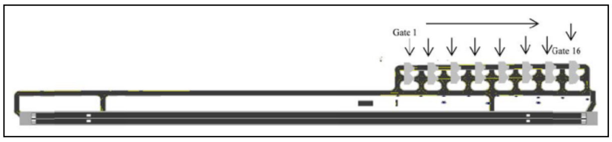

Figure 7: Configuration taxi-in taxi-out concept

The main results from this model are related to taxiing times, turnaround time and delay at the stand due to conflict between vehicles on the taxiway (deviation from off block time-DOBT). The integration between these two sub-models shows that the system is affected by the interactions between them, for instance, traffic congestion could be seen on the taxiway due to unavailability of stands, and this could be a consequence of high turnaround times, that is, in turn, a consequence of the unavailability of vehicle for turnaround operations. This make us able to conduct a more accurate analysis of the system, identifying possible interactions between components of the system and having a larger view of the entire system.

2.2.4. Airspace operations

In this model, the focus was put on the airspace of Lelystad airport, in the specific the TMA. The TMA is the airspace that surrounds an airport, it could be a very congested zone because of the volume of incoming and outgoing aircraft converging on the runway(s). In the TMA, aircraft should fly under some restrictions such as:

- speed
- altitude limit
- separation minima between aircraft
- weather (crosswind and wind direction)

In the model representing the TMA the aircraft approaching and departing phase to and from the runway was modeled. Another component that characterize this model is the holding pattern procedure, the holding pattern is an area in the airspace used to divert temporarily aircraft that needs to gain a delay due to congestion on the ground or congestion along the route in the airspace or due to disruptions (crosswind occurrences). The holding pattern has its own capacity, depending on the airspace sector in which it is placed. Moreover, aircraft into the holding pattern should fly at a certain speed, a turn in the holding pattern is assumed to take around four minutes. The airport taken into account as case of study has one runway that can be used in both directions, having, in turn, Runway 23 and Runway 05, therefore, we have two different routes for approach and take off to and from runway 23 and runway 05, respectively. The use of these specific runway configurations depends on the wind direction. The routes in the TMA, including the holding pattern, were modeled as a network, in figure 8 it can be seen where the main nodes of the network were placed (entry points, initial approach fix-IAF, final approach fix-FAF, exit points) and the topology of the routes. In this network, separation minima between the aircraft and speed limit was checked in each of the nodes, in tables 4 and 5 values for separation minima and speed limits are shown. Separation minima between aircraft (time based) was fulfilled controlling aircraft speed, accelerating and decelerating in turn. Moreover, the effect of the wind was taken into account (direction and crosswind), it was modeled referring to data of wind direction and crosswind collected in the 2014 and then translated into the model as probabilities of occurrences.

Table 4: Separation minima (NM) ICAO

		Leading Aircraft		
		Heavy	Medium	Light
Trailing Aircraft	Heavy	4	3	3
	Medium	5	3	3
	Light	6	4	3

Table 5: Aircraft speed range in the TMA

	Upper bound	Lower Bound
Entry Point	250 Kt	160 Kt
Initial Approach Fix	160 Kt	130 Kt
Final Approach Fix	-	130 Kt

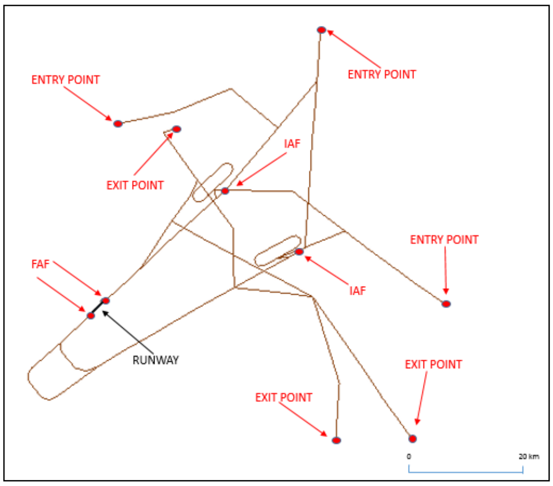

Figure 8: Network representing the routes for Runway 23 and 05

The different scenarios that were tested, were based on different volume of incoming aircraft, and the main results were about number of air traffic movements and number of aircraft delayed into the holding pattern, that are a measure of capacity and level of congestion of the system, respectively. Particularly, looking at the aircraft diverted into the holding pattern it was possible to derive the amount of delay occurred to them by keeping track of the time in which they were flying into the holding pattern.

3. SCENARIO AND RESULTS

The model developed was verified using the public information about the developments that will be implemented. Since it is a future project we did not have historic data to compare to. Therefore the verification was done comparing the obtained values versus the values of a similar airport of the region (Eindhoven). In order to evaluate the performance of the model and make a further analysis, some scenarios were tested. They were based on volume of incoming traffic and number of vehicles available in the turnaround process. Changing the amount of traffic as input we aimed at identify what was the maximum capacity that the system was able to handle without incurring in congestion. In this case congestion is represented by delay occurred in the airspace (delay caused by holding pattern procedure), and delay occurred on the ground (delay due to conflict between aircraft and vehicles in the taxiway). From the model it was possible to obtain results related to number of incoming and outgoing number of aircraft, number of aircraft diverted into the holding pattern (HP), delay due to airspace operations, turnaround time and ground delay due to taxiway congestion.

3.1. Experimental Scenarios

Scenarios were built taking into account two parameters: incoming volume of traffic and number of vehicles involved in the turnaround process. Regarding volume of incoming traffic, three different configurations were tested, in which the traffic was gradually increased. The second parameter used to build the different scenarios was number of vehicles involved in the turnaround process. Two different values were taken into account, a configuration with 8 vehicles available for each type of operation and another scenario with 16 vehicle available. It was simulated one day of operations and were made 10 replications for each scenario, in table 6 are presented the different scenarios that were tested.

Table 6: Scenarios

		Incoming volume of Aircraft		
		Flight schedule 1	Flight schedule 2	Flight schedule 3
Number of Vehicles	8	Scenario 1	Scenario 3	Scenario 5
	16	Scenario 2	Scenario 4	Scenario 6

3.2. Results

The following tables summarize the results from the different scenarios:

Table 7: Results from Scenario 1

Flight Schedule 1 – Number of Vehicles=8			
	Min	Avg	Max
Incoming aircraft Runway 23	21	32,7	48
Incoming aircraft Runway 05	9	17	27
Outgoing aircraft Runway 23	21	33,1	48
Outgoing aircraft Runway 05	8	16,3	26
Aircraft diverted into the HP (05)	1	1	1
Average number of turns made by each aircraft diverted into the HP (05)	1	1	1
Time spent into the HP (05) (min)	4	4	4
Total Time at the stand (avg) (min)	33,57	40,19	52,18
Turnaround Time (avg) (min)	30,54	32,39	35,43
DOBT (avg) (min)	2,06	7,39	19,01

Table 8: Results from Scenario 2

Flight Schedule 1 – Number of Vehicles=16			
	Min	Avg	Max
Incoming aircraft Runway 23	9	27,2	39
Incoming aircraft Runway 05	9	20,8	39
Outgoing aircraft Runway 23	10	28,5	40
Outgoing aircraft Runway 05	8	19,2	38
Aircraft diverted into the HP (05)	1	1	1
Average number of turns	1	1	1

made by each aircraft diverted into the HP (05)			
Time spent into the HP (05) (min)	4	4	4
Total Time at the stand (avg) (min)	33,39	39,15	53,21
Turnaround Time (avg) (min)	31,04	32,25	35,50
DOBT (avg) (min)	2,01	6,49	18,54

Looking at the values of the first two scenarios, it can be seen that the flow of traffic is smooth since there are no aircraft diverted into the holding pattern for runway 23 and there is only 1 aircraft diverted for runway 05. Also turnaround times and DOBT are similar, this means that at this stage, with the given amount of incoming traffic, this output is not affected by the number of vehicles. These values suggest that the system is able to handle this amount of traffic without incurring in congestion situation.

Table 9: Results from Scenario 3

Flight Schedule 2 – Number of Vehicles=8			
	Min	Avg	Max
Incoming aircraft Runway 23	29	47,8	67
Incoming aircraft Runway 05	8	21,33	38
Outgoing aircraft Runway 23	27	46	67
Outgoing aircraft Runway 05	12	21,11	39
Aircraft diverted into the HP (05)	1	1,4	3
Average number of turns made by each aircraft diverted into the HP (05)	1	1,2	2
Time spent into the HP (05) (min)	4	4,48	8
Total Time at the stand (avg) (min)	34,08	46,51	97,38
Turnaround Time (avg) (min)	31,16	32,34	34,19
DOBT (avg) (min)	2,20	13,55	64,09

Table 10: Results from Scenario 4

Flight Schedule 2 – Number of Vehicles=16			
	Min	Avg	Max
Incoming aircraft Runway 23	25	44	59
Incoming aircraft Runway 05	8	23	42
Outgoing aircraft Runway 23	24	43,4	55
Outgoing aircraft Runway 05	11	22,5	40
Aircraft diverted into the HP (23)	1	1	1
Aircraft diverted into the HP (05)	1	2	5
Average number of turns made by each aircraft diverted into the HP (23)	2	2	2
Average number of turns made by each aircraft diverted into the HP (05)	1	1,33	2
Time spent into the HP (23) (min)	8	8	8
Time spent into the HP (05) (min)	4	5,19	8
Total Time at the stand (avg) (min)	32,58	50,21	95,57
Turnaround Time (avg) (min)	30,41	31,49	33,56
DOBT (avg) (min)	2,06	16,40	55,54

In tables 9 and 10 there are the values related to the third and fourth scenario, they show that the number of aircraft diverted into the holding pattern is slightly increased together with the average number of turns made by each aircraft into the holding pattern. The latter, in turn, is translated into delay at landing. Turnaround times are in line with the previous scenarios but values of DOBT are increased, we have in average 13,55 min and 16,40 min for scenario 3 and scenario 4 , respectively.

Table 11: Results from Scenario 5

Flight Schedule 3 – Number of Vehicles=8			
	Min	Avg	Max
Incoming aircraft Runway 23	38	62,20	90
Incoming aircraft Runway 05	16	26,33	51
Outgoing aircraft Runway 23	38	64,4	87
Outgoing aircraft Runway 05	15	24,55	48
Aircraft diverted into the HP (23)	1	1	1
Aircraft diverted into the HP (05)	1	2,25	6
Average number of turns made by each aircraft diverted into the HP (23)	2	2	2
Average number of turns made by each aircraft diverted into the HP (05)	1	1,48	2
Time spent into the HP (23) (min)	8	8	8
Time spent into the Holding pattern (05) (min)	4	5,55	8
Total Time at the stand (avg) (min)	33,37	37,30	45,43
Turnaround Time (avg) (min)	30,33	31,56	33,43
DOBT (avg) (min)	2,34	5,33	13,01

Table 12: Results from Scenario 6

Flight Schedule 3 – Number of Vehicles=16			
	Min	Avg	Max
Incoming aircraft Runway 23	27	46,4	80
Incoming aircraft Runway 05	3	30,4	56
Outgoing aircraft Runway 23	21	44,7	83
Outgoing aircraft Runway 05	1	27,8	52
Aircraft diverted into the HP (23)	1	1	1
Aircraft diverted into the HP (05)	1	2,28	5
Average number of turns made by each aircraft diverted into the HP (23)	1	1,35	2
Average number of turns made by each aircraft diverted into the HP (05)	2	2	2
Time spent into the HP (23) (min)	4	5,24	8
Time spent into the HP (05) (min)	8	8	8
Total Time at the stand (avg)	112,33	117,1	127,40

(min)			
Turnaround Time (avg) (min)	30,11	31,19	32,52
DOBT (avg) (min)	81,55	85,58	96,12

In the last two scenarios presented in tables 11 and 12, under a high traffic inbound, we find again, for both runway 23 and 05, aircraft diverted into the holding pattern. Their amount is similar to the previous scenarios and this means that the system is not affected by the increase of traffic in terms of congestion. A particular focus is put in the value of DOBT for the sixth scenario that is very high unlike the other scenarios. It means that taxiway is over-crowded by vehicles and aircraft at the same time, and so aircraft are stopped at the gate for a long time before reaching the runway while are waiting that the taxiway will be free from other vehicles and aircraft. This fact leads to think about changing the design of the taxiway in order to better manage the traffic in it and avoid blockages.

4. CONCLUSION

In this paper, a simulation model that employs a modular approach is presented. The purpose of this work was to analyze an airport system using an integral approach. The model developed was done using a bottom-up modular approach in which several subsystems were modeled independently and then put together in a model that integrate the different ones airport (Runway, Stand, Airspace). From the results it is possible to verify that this approach suits well for performing data driven decisions since the information extracted from the model allows identifying potential problems in the system once the traffic has reached the levels that saturate the system. In addition, the model-based analysis allows going further into the identification of cause-effect relationships that affect the performance of the system at different levels. Furthermore, the approach allows identifying the subsystem that affect the most the overall performance thus putting more attention in the particular problems that hinder the flow of aircraft.

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