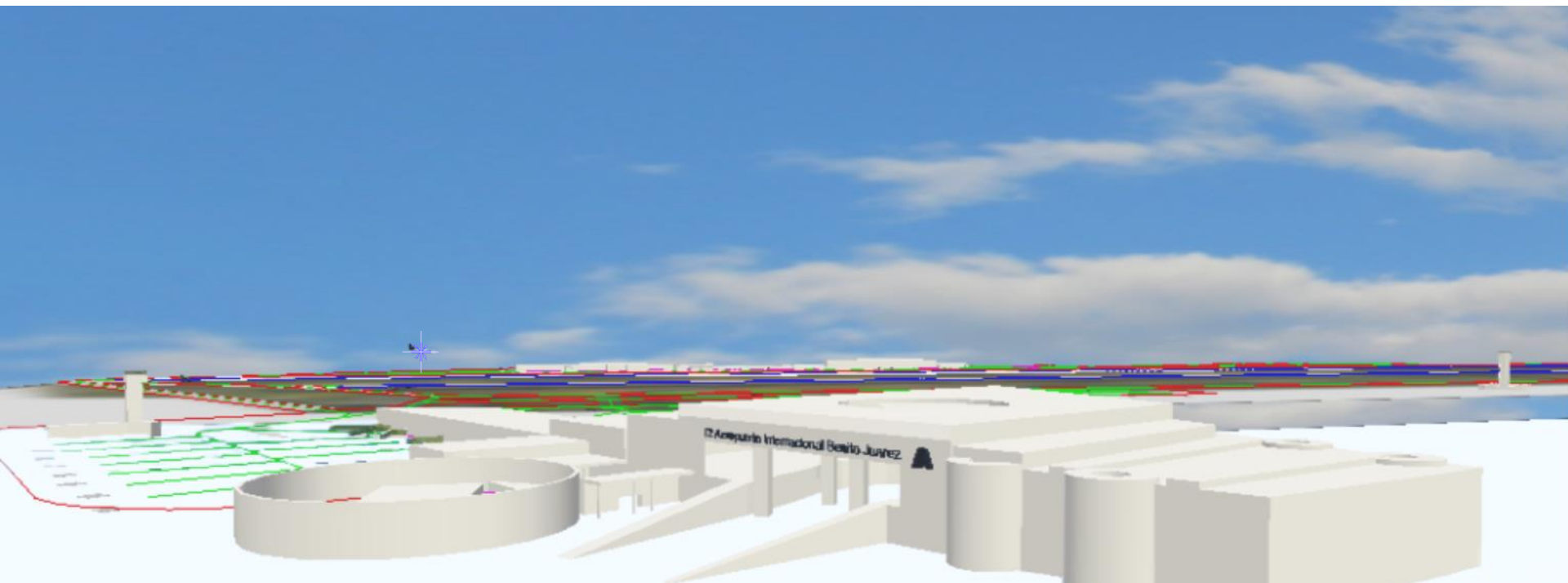


Alternative solutions to airport saturation: simulation models applied to congested airports.



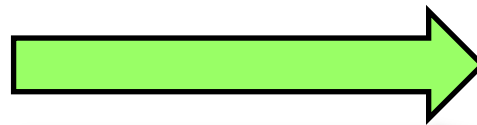
The objective of this paper is to explore several different ways of coping with the imbalance between the available airport capacity and the traffic demand through application of simulation modelling to explore potential solutions.

A. Investment in new infrastructure

B. Demand management

C. Spreading demand peaks

D. Operational and technological innovations



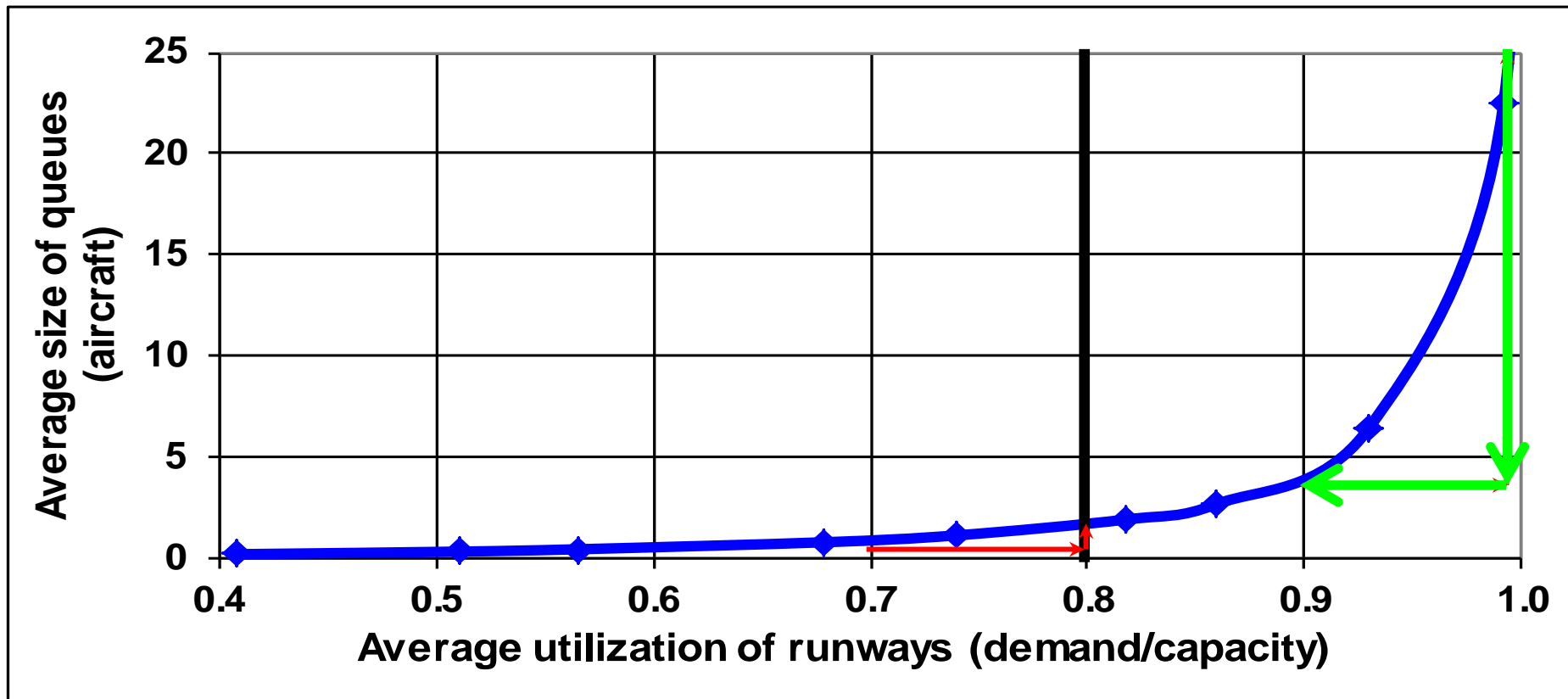
Computer modeling and simulation

The problem:

- ✈ The greatest problem of the aviation industry in Latin America is the lack of an adequate infrastructure, mainly in countries as Brazil, Mexico, Argentina and Colombia (IATA, 2014).
- ✈ The consumers in Europe are paying €2.1 billion a year in additional air fares, due to capacity constraints at airports (ACI, 2017).



- ✈ In the US, the three major New York area airports and Philadelphia International Airport will continue to experience major system constraints even after all currently planned capacity improvements are implemented (Mica, 2015).
- ✈ Aviation passengers in the United States bear nearly \$17 billion in additional costs every year due to flight delays (Mica, 2015).



Source: Original figure.

Average sizes of queues on Mexico City International Airport runways as a function of the average utilization of them.

The solution to the problem of airport congestion should therefore focus on finding ways to reduce the demand/capacity ratio.

$$\frac{\text{Demand}}{\text{Capacity}}$$

The solution to the problem of airport congestion have been divided into four options

A. Investment in new infrastructure

B. Demand management

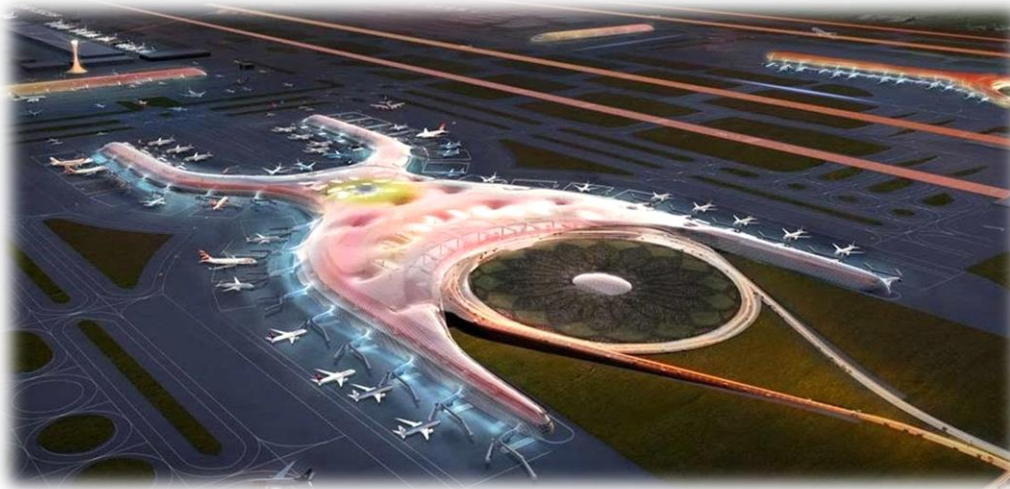
C. Spreading demand peaks

D. Operational and technological innovations

**A. Investment in
new infrastructure**

Build new airports

Expand existing airport facilities



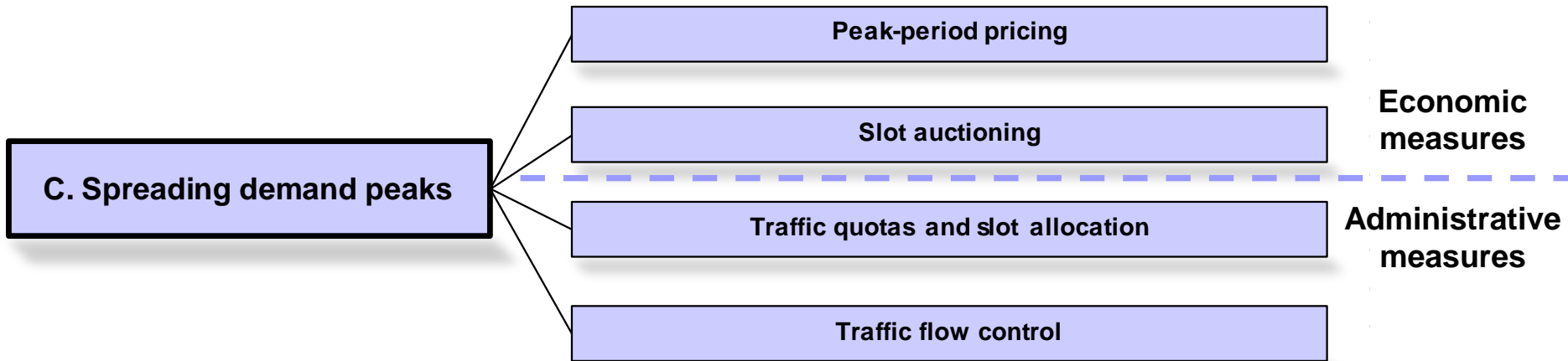
B. Demand management

Remote processing

Relocation of certain air traffic operations

Shift short-haul air traffic to other transportation modes

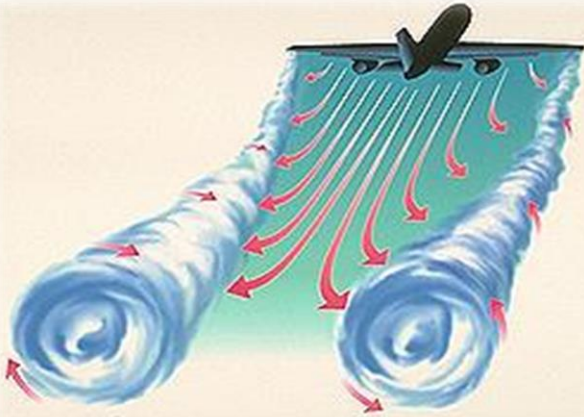




D. Operational and technological innovations

Operational practices

Technological innovations



Simulation is the representation of a process or system through time



Simulation models commonly take the form of a set of assumptions about the operation of a system. These models are used as a tool of analysis, or as a design tool.

APPLICATION OF SIMULATION MODELS TO CONGESTED AIRPORTS, THE CASE OF AICM.

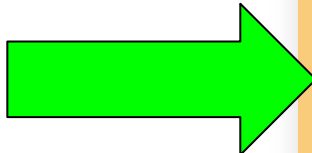
THE WORLD'S TOP 50 AIRPORTS 2015



TOP AIRPORTS BY PASSENGERS

TOP AIRPORTS BY MOVEMENTS

Rank	Airport	Airport Code	2015 Passengers	% Chg.	Rank	Airport	Airport Code	2015 Movements	% Chg.
1	Atlanta, Ga., US	ATL	101,491,106	5.5	1	Atlanta, Ga., US	ATL	371,510	1.7
2	Beijing, China	PEK	89,938,000	4.4	2	Beijing, China	PEK	331,510	1.7
3	Dubai, UAE	DXB	78,014,854	1.0	3	Istanbul, Turkey	IST	447,700	1.0
4	Chicago, Ill., US	ORD	78,014,854	1.0	4	Toronto, Ont., Canada	YYZ	443,958	1.0
5	Tokyo, Japan	NRT	77,000,000	1.0	5	Phoenix, Ariz., US	PHX	440,411	2.5
6	London, UK	LHR	76,000,000	1.0	6	Tokyo, Japan	HND	438,542	3.0
7	Los Angeles, Calif., US	LAX	75,000,000	1.0	7	New York, NY, US	JFK	427,897	3.7
8	Hong Kong, China	HKG	74,000,000	1.0	8	Mexico City, Mexico	MEX	426,761	4.1
9	Paris, France	CDG	73,000,000	1.0	9	San Francisco, Calif., US	SFO	413,707	-0.6
10	Frankfurt, Germany	FRA	72,000,000	1.0	10	Miami, Fla., US	MIA	412,915	2.5
11	Los Angeles, Calif., US	LAX	71,000,000	1.0	11	Guangzhou, China	CAN	409,674	-0.6
12	London, UK	LHR	70,000,000	1.0	12	Hong Kong, China	HKG	406,020	1.0
13	Los Angeles, Calif., US	LAX	69,000,000	1.0	13	Dubai, UAE	DXB	402,500	1.0
14	Los Angeles, Calif., US	LAX	68,000,000	1.0	14	Sydney, Australia	SYD	398,139	1.0
15	Los Angeles, Calif., US	LAX	67,000,000	1.0	15	Shenzhen, China	SZX	397,219	9.5
16	Los Angeles, Calif., US	LAX	66,000,000	1.0	16	Barcelona, Spain	BCN	397,126	5.7
17	Los Angeles, Calif., US	LAX	65,000,000	1.0	17	Shanghai, China	SHA	39,090,699	2.9
18	Tokyo, Japan	NRT	64,000,000	1.0	18	São Paulo, Brazil	GRU	38,985,000	-1.4
19	New York, NY, US	JFK	63,000,000	1.0	19	Orlando, Fla., US	MCO	38,809,337	8.7
20	Mexico City, Mexico	MEX	62,000,000	1.0	20	Taipei, Taiwan	TPE	38,473,333	7.5
21	San Francisco, Calif., US	SFO	61,000,000	1.0	21	Mexico City, Mexico	MEX	38,433,012	12.2
22	Miami, Fla., US	MIA	60,000,000	1.0	22	Kunming, China	KMG	37,523,345	16.4
23	Guangzhou, China	CAN	59,000,000	1.0	23	Newark, NJ, US	EWK	37,494,704	5.3
24	Hong Kong, China	HKG	58,000,000	1.0	24	Tokyo, Japan	NRT	37,328,213	4.9
25	Dubai, UAE	DXB	57,000,000	1.0	25	Manila, Philippines	MNL	36,583,459	7.6
26	Sydney, Australia	SYD	56,000,000	1.0	26	Mpls.-St. Paul, Minn., US	MSP	36,582,854	4.0
27	Shenzhen, China	SZX	55,000,000	1.0					
28	Barcelona, Spain	BCN	54,000,000	1.0	27	Beijing, China	PEK	315,217	1.0
29	Shanghai, China	SHA	53,000,000	1.0	28	Sydney, Australia	SYD	310,008	1.6
30	São Paulo, Brazil	GRU	52,000,000	1.0	29	Shenzhen, China	SZX	305,461	6.7
31	Orlando, Fla., US	MCO	51,000,000	1.0	30	Incheon, Korea	ICN	305,446	5.3
32	Taipei, Taiwan	TPE	50,000,000	1.0	31	Kunming, China	KMG	300,406	11.0
33	Mexico City, Mexico	MEX	49,000,000	1.0	32	São Paulo, Brazil	GRU	295,030	-3.1
34	Kunming, China	KMG	48,000,000	1.0	33	Chengdu, China	CTU	293,643	8.7
35	Newark, NJ, US	EWK	47,000,000	1.0	34	Orlando, Fla., US	MCO	292,600	6.8
36	Tokyo, Japan	NRT	46,000,000	1.0	35	Mumbai, India	BOM	289,163	8.6
37	Manila, Philippines	MNL	45,000,000	1.0	36	Barcelona, Spain	BCN	288,878	1.8
38	Mpls.-St. Paul, Minn., US	MSP	44,000,000	1.0	37	Xi'an, China	XIY	266,807	9.2
39	Beijing, China	PEK	43,000,000	1.0					
40	Rome, Italy	FCO	42,000,000	1.0					
41	Sydney, Australia	SYD	41,000,000	1.0					
42	Shenzhen, China	SZX	40,000,000	1.0					
43	Incheon, Korea	ICN	39,000,000	1.0					
44	Kunming, China	KMG	38,000,000	1.0					
45	São Paulo, Brazil	GRU	37,000,000	1.0					
46	Chengdu, China	CTU	36,000,000	1.0					
47	Orlando, Fla., US	MCO	35,000,000	1.0					
48	Mumbai, India	BOM	34,000,000	1.0					
49	Barcelona, Spain	BCN	33,000,000	1.0					
50	Xi'an, China	XIY	32,000,000	1.0					



Sources: ATW Research and direct reporting. For 200+ monthly airport traffic data, visit <http://atwonline.com/atw-data-1>

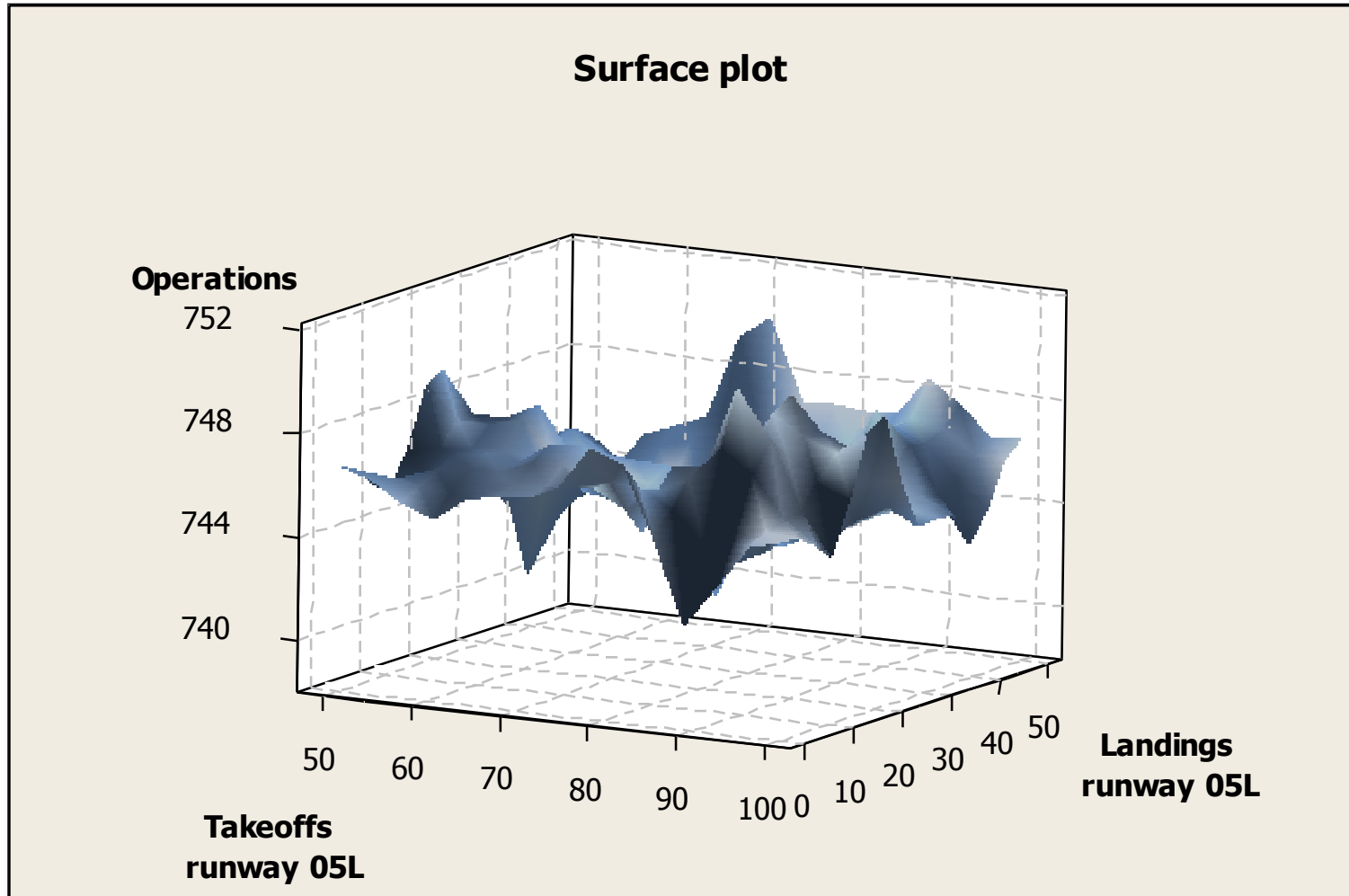
1) Effect on the aircraft movements performed when the takeoffs and landings are redistributed in the two runways of the AICM

In this case, the effect of shifting the proportions of takeoffs and landings performed at the two runways of AICM is analyzed. To do this, different proportions were established by each runway, and then using a simulation model the total number of operations performed for each case was estimated.



When this model was developed (2003) the real proportions of takeoffs and landings on runways were: 82.3% takeoffs and 9.8% landings on runway 05 left, and 17.7% takeoffs and 90.2% landings on runway 05 right.

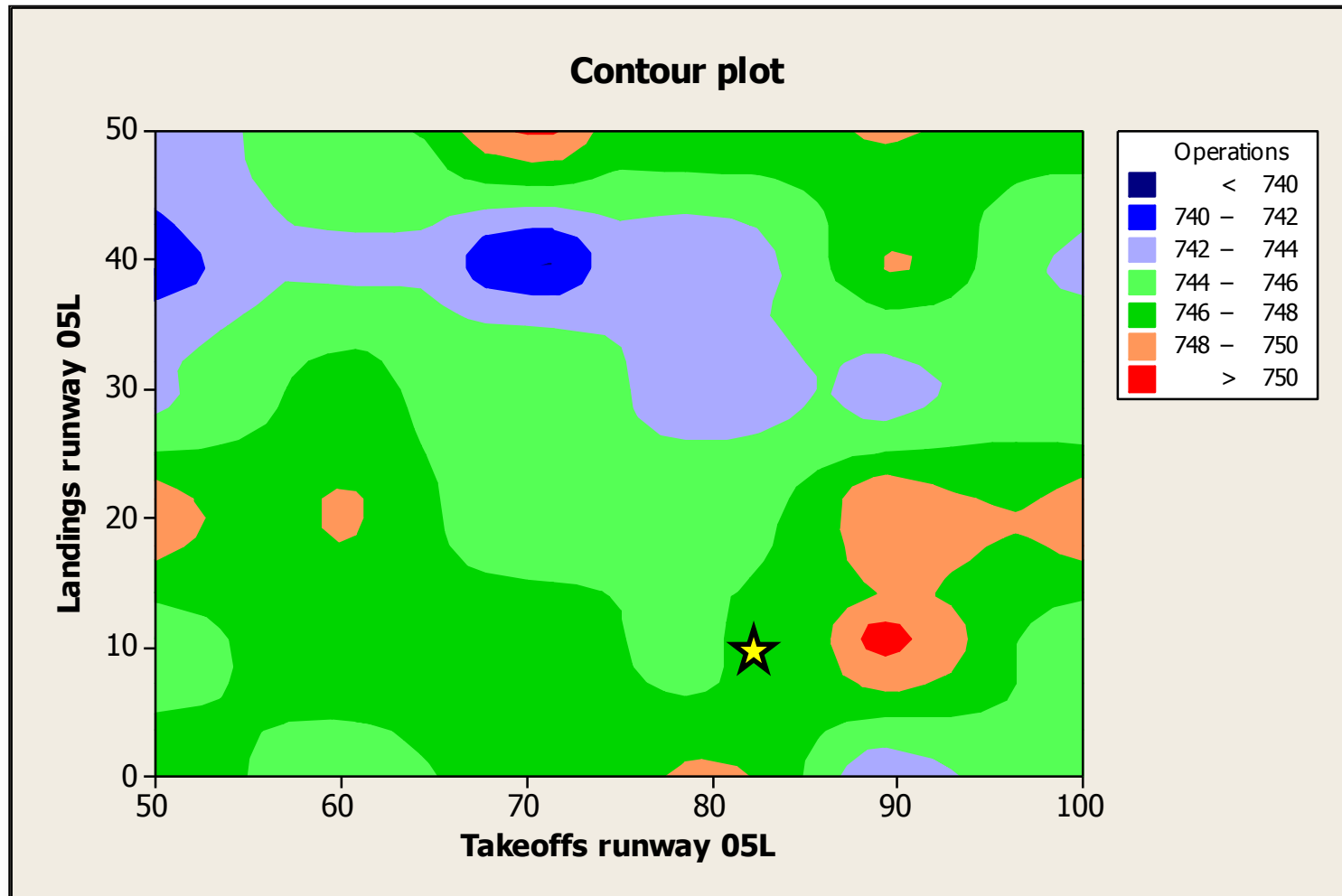
1) Effect on the aircraft movements performed when the takeoffs and landings are redistributed in the two runways of the AICM



Source: Original figure.

Operations processed according to the proportion of landings and takeoffs on the runways, for a daily operation between 07:00 and 24:00 hours.

1) Effect on the aircraft movements performed when the takeoffs and landings are redistributed in the two runways of the AICM



Source: Original figure.

Operations processed according to the proportion of landings and takeoffs on the runways, for a daily operation between 07:00 and 24:00 hours.

2) Effect of intensive use of aircraft with greater capacity

It was considered that a specific type of aircraft is replaced by another of greater capacity than the first. In this way, it is assumed that the new aircraft moves the same number of passengers but requires fewer ATMs.



For the considered demand conditions (January 2011), there was no operations of ATR 42 aircraft between 00:00 and 06:00 hours, however, for the interval between 06:00 and 24:00 hours, 40 landings and 39 takeoffs of aircraft ATR 42 were performed, which would be equivalent to 25 landings and 24 takeoffs of ATR 72 aircraft.

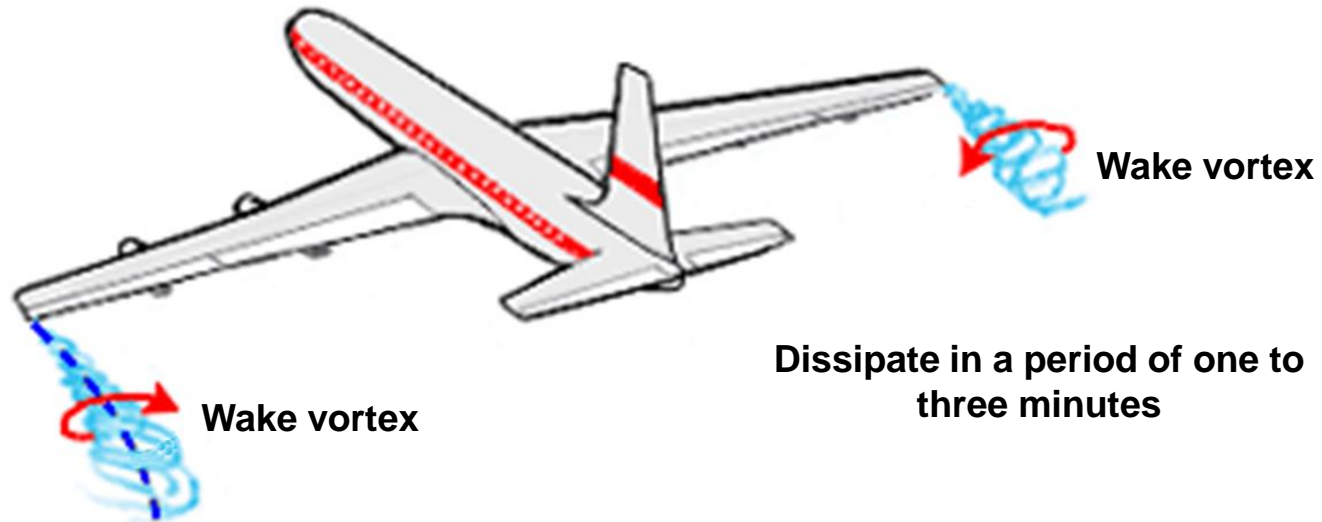
2) Effect of intensive use of aircraft with greater capacity

Quality of service on AICM runways with ATR 42 or ATR 72 aircraft, for the interval between 06:00 and 24:00 hours.

ATR 42 operation	Total operations	Queue size (aircraft)		Waiting time (minutes)	
		Maximum	Average	Maximum	Average
	788.90	10.80	1.32	11.86	1.82
ATR 72 operation	Total operations	Queue size (aircraft)		Waiting time (minutes)	
		Maximum	Average	Maximum	Average
	758.20	8.80	1.07	11.08	1.54
Comparative reduction	30.70	2.00	0.25	0.78	0.28
	3.89%	18.52%	18.99%	6.57%	15.48%

Source: Original figure.

3) Effect of new technology to increase the capacity of airports with close-spaced parallel runways



ICAO has established mandatory minimum separations based on the category of vortices generated.

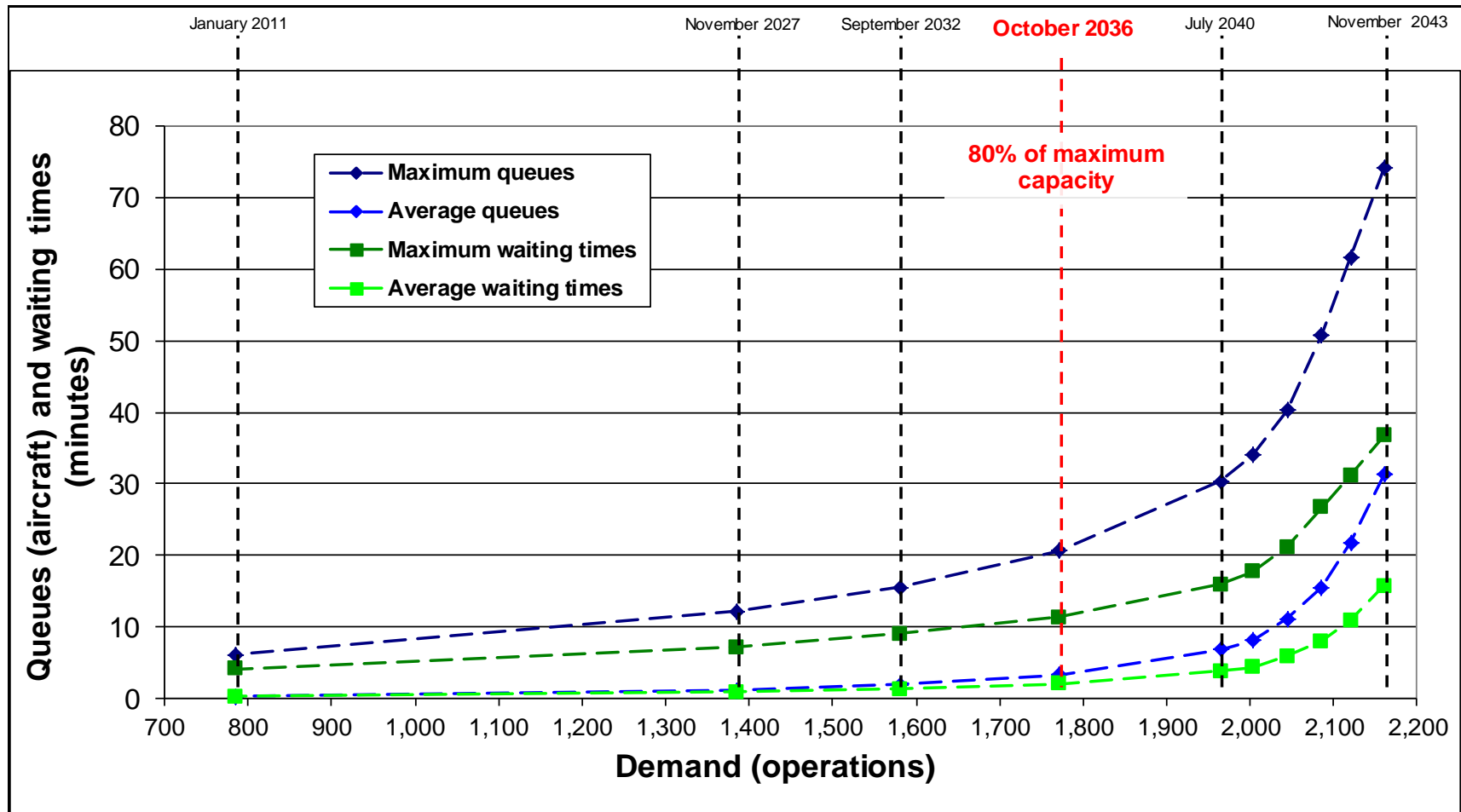
Knowledge of wake vortex behavior can increase capacity for airports with close-spaced parallel runways (Burnham et al., 2001). After several decades of research on vortex behavior, wake transport over short times is well understood. In order to increase the capacity of runways with the use of this knowledge, new criteria have been suggested to reduce the current operational limits at airports.

3) Effect of new technology to increase the capacity of airports with close-spaced parallel runways

To estimate the effects of this knowledge in the AICM, it was assumed that the capacity of its runways is increased to 120 operations per hour, in accordance with the operational implications identified by the research of Vernon and Larry (2008).

It was determined under this new condition when the congestion problems initiate at the AICM and the value of the corresponding amount of operations at runways.

3) Effect of new technology to increase the capacity of airports with close-spaced parallel runways



Source: Original figure.

Evolution of service deterioration at AICM during the interval between 00:06 and 24:00 hours, for a capacity of 120 operations per hour on runways²⁰

4) Potential benefits of applying a new policy to serve the aircraft at runways in order to reduce the passenger delays

In this case the impact of implementing a new policy to serve the operations at runways is estimated. This policy is different from the applied currently in the world (FCFS, first-come-first-served) and its purpose is to minimise the passenger delays.

The FCFS rule does not take into account that the operating costs and seating capacities of various aircraft are different.

452 pasajeros



48 pasajeros



$$PAX_{B-747} = 9.4 PAX_{ATR-42}$$

4) Potential benefits of applying a new policy to serve the aircraft at runways in order to reduce the passenger delays

Initially, 40 simulations were executed with the model, applying the current policy. The new strategy was subsequently evaluated, according to the proposal of Herrera y Moreno (2011) with 40 simulations performed. Afterwards the benefits in terms of waiting time reductions were determined comparing the current policy and the new strategy estimations.



4) Potential benefits of applying a new policy to serve the aircraft at runways in order to reduce the passenger delays

The results showed that if the new strategy is applied, it is possible to reduce the daily waiting time in 10,763.2 passenger-minute.

If the benefits are expressed in annualized terms, the reduction of waiting time is equal to 65,476.3 passenger-hours.



- ✈ The simulation models could help to establish the proportions of takeoffs and landings in order to maximize the operations in airports with several runways (case 1).**
- ✈ The use of aircraft with greater capacity that replaced to smaller aircraft could originate benefits in the operation of the airport, for instance, reducing the queue sizes and the waiting times (case 2).**
- ✈ The application of a new technology to increase the capacity of the runways, in the best case, to 120 operations/hour would produce significant benefits in the operation of the AICM. Under this condition the saturation issues could be deferred 21 years more (case 3).**

✈ It was estimated that if a new proposal to serve the aircraft during takeoff and landing phases at the AICM runways is applied, it is possible to obtain reductions in the passenger delays (65,476.3 passenger-hours annually (case 4).

✈ Finally, although the four cases described before were considered in an independent way, they could be considered in an integral case, since they are complementary.



IMT 30 AÑOS

GRACIAS

