THE IMPACT OF NEW TECHNOLOGIES IN AIRPORT PASSENGERS' PROCESSES

Nicola Gualandi
Luca Mantecchini
Filippo Paganelli
University of Bologna
Faculty of Engineering
Viale Risorgimento,2 41036 Bologna - Italy
n.gualandi@unibo.it, luca.mantecchini@unibo.it, filippo.paganelli2@unibo.it

ABSTRACT

The characteristics of airports passengers processes have undoubtedly undergone major changes in the last decade, due to both the evolution of airport technologies both to the changes in passengers behaviour as a consequence of air transport deregulation.

The impact of innovation affects several airport processes, that is to say for example the increased use of automatic self-service devices that has rapidly modified the passengers' habits by reducing the passengers' dwell time. These enhancements are strongly urging airport operators on to review the traditional terminal layout and airport authorities on to review the determination of LOS and the quality standards. Moreover, the increased percentage of short term vacationers, travelling only with cabin baggage, has put an extra pressure on security checks while the different check-in alternatives offered to passengers have determined more complex passengers flows inside airport terminals.

This paper analyses how the introduction and the increased use of self service technologies and the modification in demand characteristics have impacted on the airport terminal processes and quantifies the benefits and the issues through the use of IATA parameters and formulas.

1 INTRODUCTION

From the seventies onwards, the air traffic demand and the airport level of service have remarkably improved. In the last fifteen years many authors observed an expansion trend in terms of airport accessibility and a concentration trend in terms of ownership structure. The growth in accessibility is associated mostly with air transport liberalization and with the development of low-cost carriers, mainly in secondary and regional airports. The gradually increasing market share of low-cost carriers has produced an additional amount of demand, and currently low-cost carriers carry about the 35% of the total amount of passengers in European domestic flights. With regard to large airports and main hubs, in the same period, the traffic level went no further than 85%-90%. [1]

Furthermore, the expansion of independent carriers is jeopardized by the development of strategic alliances and merging among normal carriers: in this context the competition to attract new carriers is growing more and more fierce and airports are forced to increase non aviation-oriented business strategies in order to compensate the decline in aeronautic revenues. This new approach resulted in new airport terminal requirements, in order to satisfy the stakeholders' heterogeneous needs, with particular regard to the efficient allocation of terminal space. The strategy aims at optimising the space dedicated to passenger services keeping nevertheless an high level of service, in order to increase the space for commercial and entertainment activities. Therefore, "face-to-face" passengers' services have been gradually replaced with self-service devices: to make an example, airlines usually encourage passengers to use on-line check-in procedures.

Thence, a lot of new technologies have been developed for processing passengers, increasing the quality of service without additional costs to both airlines and airport operators: the main result is the differentiation of passenger flows, which might result in queuing and terminal congestion phenomena, especially in peak-hours.

2 DEMAND ESTIMATION METHODS

The air transport system is characterized by three main, strongly interrelated, stakeholders: the airport operators, the airlines and the users (passengers, airlines and freight). Forecasting air transport demand is extremely difficult because it does not only depend on the transport supply (routes, o/d pairs served, frequency...) but also on socio-economic characteristics.

The main parameters to be considered in an airport demand analysis are [2]:

- arriving, generating and transit annual passengers, for national and international traffic;
- annual movements per aircraft and operation type;
- peak hour movements and peak hour passengers;
- fleet mix characteristics;
- number of visitors;
- freight and mail processed;
- socioeconomic indicators of the airport catchment area, as economic growth rate.

In case of terminal forecasts, airport planners should evaluate the amount of space needed for each landside activities, taking into account internal demand flows for each terminal area by transforming general annual traffic forecasts in peak hour passengers flow.

Airport traffic forecasting methods can be classified in qualitative and quantitative methods. Qualitative forecast techniques are based on surveys and interviews aiming at obtaining information on passengers' opinion, without using mathematical formulas. While quantitative methods are usually based on large statistical databases and rely on rigorous mathematical and statistical models.

3 ESTIMATION OF DPH AT AIRPORTS

To estimate the passengers' loads in each airport terminal subsystem it is firstly necessary to distinguish between departing passengers, arriving passengers and transfer passengers and to determine the average amount of time passengers spend in a specific area [3].

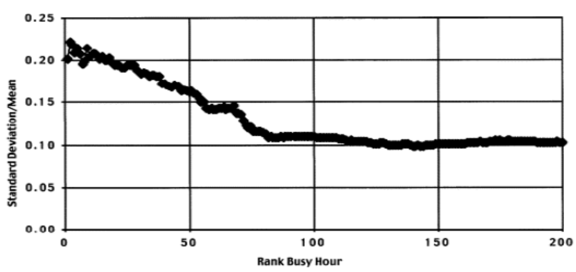
The aim of the analyst is to dimension terminal structures in order to withstand an hourly load higher than the average traffic but lower than the maximum peak. Then the focus is determining how much lower than the peak this design load shall be in order to assure passengers an high level of service. The Design Hour Passengers (DPH) load is the rush-hour volume (Peak-Hour, Peak Month, Average Day-Passengers) plus the amount of visitors and relatives. Many authors tried to correlate the hourly [Matthews (1995); Horonjeff and McKelvey (1994), Andrade (1993)], monthly and annual demand [Matthews (1995)] with DPH by estimating coefficients by the use of a regression analysis. The traffic peak of each airport depends on distinctive characteristics of the operating carriers: majority of business or leisure traffic, long vs short-haul flights and European vs intercontinental routes, the role of the airport in the national air transport's net (origin / destination or transit) [4]. The main hypothesis in the definition of DPH is that traffic volume may be exceeded only for a few hours during the year: the smaller this number the more overestimated the structure is during ordinary conditions. The main methodologies for determining the DPH are:

- the 20th - 40th busiest hour in a year (BAA, UK)

- the peak hour in the average day of the peak month (FAA, Usa)
- the peak hour in the average day of the two busiest weeks in a year (ICAO)
- the peak hour of 90th – 95th day among the 100 busiest days in a year: it is necessary to collect departing and arriving passengers data for each flight (handling agents normally do this) and to rank these data according to time (normally from xx:00 to xx:59)
- the peak hour of 7th or 15th busiest day in a year
- the peak hour of the 2nd busiest day in an average week of the busiest month
- the 95^{th} or the 85^{th} percentile. [3] [2]

Most of these definitions rely on the decreasing ranking of passengers volumes and on the specification of a target hour whose traffic output is expected to produce a bearable degree of congestion. The differences between the values of DPH obtained with different techniques are negligible if compared with the strong approximations made during the process, but when these methods are used to evaluate the annual LOS on the basis of real traffic the differences can be important.

A different approach to the problem has been presented by P. T. Wang & D. E. Pitfield: they collected data in 48 Brazilian airports for five years and highlighted that, as the busiest hours have different load values, it seemed reasonable to detect rush hours whose traffic levels were roughly constant rather than designing the terminal according to an isolated peak of demand. By calculating the standard deviation σ^2 of the 200 busiest hours for each year, dividing that values by the traffic of the 200^{th} busiest hour of each year and finally deriving the coefficient of determination R^2 for each year, they found a strong correlation between DPH and the traffic output.



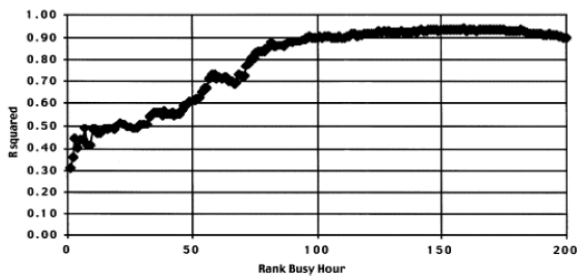


Fig. 1 (left): São Paulo International Airport-Guarulhos: Standard Deviation/Mean (source [5])

Fig. 2 (right): São Paulo International Airport-Guarulhos: Coefficient of Determination R^2 (source [5])

From figures 1 and 2 it is possible to notice that, after the initial fluctuation, the stability is reached at about the 80^{th} busiest hour and it corresponds to about the 3 - 4.5% of the annual traffic output, with higher values for secondary airports (<200,000 pax/year) [5]. Provided this situation and given the high slope of graphs for busy hours higher than the 80^{th}, it is clear that it is not a conservative choice planning airport terminals for traffic values corresponding to the 30^{th} busiest hour as suggested by previous methods since such passengers loads are seldom exceeded t during the year. The following figures and tables are some examples of rule of thumb correlations between DPH and annual traffic output derived from important air airport and air transport regulators and associations; the results are consistent with those obtained by the authors.

Tab. 1 (left): Correlation between DPH and annual traffic output (source [5])

Tab 2 (right): Correlation between DPH and annual traffic output at some American airports (source FAA, 1969)

Total annual passengers	DPH as a % of annual flow
30 millions and over	0,035
20 – 29,9 millions	0,040
10 – 19,9 millions	0,045
1 – 9,9 millions	0,050
500000 - 999999	0,080
100000 – 499999	0,130
Less than 100000	0,200

Total annual passengers	PHD as a % of total annual passengers
More than 20 millions	0,03
10 – 20 millions	0,035
1 – 10 millions	0,04
0,5 – 1 million	0,05

Tab 3: Correlation between $(DPH)_{month, peak}$ **and annual traffic output (source ACI, 1998)**

Total annual passengers	Average monthly peaking ratio	Range of monthly peaking ratio	Monthly peaking greater than 1.2
More than 20 millions	1.18	1.09 – 1.43	6 / 23
10 – 20 millions	1.25	1.08 – 1.55	9 / 13
1 – 10 millions	1.35	1.11 – 1.89	34 / 44

Tab 4: Correlation between annual traffic output and seats offered during DPH (source FAA, 1969)

Total annual passengers	Peak-hour available seats as % of total seats
More than 20 millions	7 – 10
10 – 20 millions	8 – 12
1 – 10 millions	9 – 20

It was finally shown that for airports with a single traffic peak, if the traffic increases the peak will become less sharp because the passengers flow tends to uniformity. The same result seems to hold for the flow during the peak hour [3].

4 DIMENSIONING AIRPORT TERMINALS: IATA PARAMETERS AND INNOVATIVE SOLUTIONS FOR AIRPORT PASSENGERS SERVICES

The process of dimensioning airport terminals and in particular each subsystem is based on the concept of the design load (i.e. Peak hour traffic). The LOS experienced by passengers is influenced by qualitative and quantitative factors, however the perception of the LOS is strongly dependant on the previous experiences and on the subjective culture of each passenger [6].

The first studies aimed at evaluating the airport terminal's LOS date back to the seventies (Heathington & Jones; Brink & Madison 1975) and were followed by studies that proposed methodologies based on the terminal characteristics (Transportation Research Board, 1987), on subjective factors (Mumayiz & Ashford, 1986) or on structural factors (Omer & Khan, 1988; Park, 1994). Ashford (1988) and Yen (2001) are among those authors that conjectured a correlation between the terminal space provided, waiting/queuing time and LOS. This methodology has subsequently been applied by the FAA (1969), obtaining then minimum standards, in terms of area, for each value of DHP. However, these standards are hardly applicable at present, since they refer to forty years old characteristics.

In the 1995, the IATA defined standards for dimensioning airport terminal subsystems on the basis of the LOS; space/pax is the only quantitative parameter and consequently the LOS increases as the space per passenger increases [7]; these standards have been reviewed in 2004.

As the traffic approximates capacity, the total delay and its variation increases up to instability. The description of the different level of services reflects this situation ([8], Tab. 5).

Tab. 5 (left): LOS IATA Standards 1995 (source [8])

Tab. 6 (right): IATA Standards (1995 vs 2004) – Check-in (source [8])

LOS	Flows	Delays	Comfort
A - Excellent	Free	None	Excellent
B - High	Stable	Very Few	High
C - Good	Stable	Acceptable	Good
D - Adequate	Unstable	Passable	Adequate
E - Inadequate	Unstable	Unacceptable	Inadequate
F - Unacceptable	--- System Breakdown ---		Unacceptable

• Old:

Square meters / Passenger for Level of Service				
A	B	C	D	E
1.8	1.6	1.4	1.2	1.0

• New:

→ Reflects impact of number of bags, carts

Row width	Carts bags	Square meters / Passenger for Level of Service				
		A	B	C	D	E
1.2m	few	1.7	1.4	1.2	1.1	0.9
	more	1.8	1.5	1.3	1.2	1.1
1.4 m	high	2.3	1.9	1.7	1.6	1.5
	heavy	2.6	2.3	2.0	1.9	1.8

The main limits of these studies are the use of a single parameter at a time and the hypothesis of considering the space provided uniformly occupied. The space required for check-in operations is considerably wide, since it includes the check-in desks, the space for the personnel employed by handling agents, the BHS carrousel and 1,84 m^2/pax. The total number of check-in desks is calculated on the basis of the peak-hour departing traffic, of the flight operations and on the basis of the queue length considered acceptable [9].

$$Area\left[m^2\right] = a\left[\frac{pax}{h}\right]\cdot s\left[\frac{m^2}{pax}\right]\cdot t\left[h\right] \qquad (1)$$

The residence time t is also needed for determining the total number of passengers which contemporaneously stand in a particular area, for this purpose the IATA suggests:

$$Area\left[m^2\right] = 1{,}1\cdot s\left[\frac{m^2}{pax}\right]\cdot t\left[h\right]\cdot\left[\frac{3(a+b)}{2} - a - b\right]\left[\frac{pax}{h}\right]$$
$$N = \frac{(a+b)\cdot t_1}{60} \qquad (2)$$

where:

a = departing passengers
b = transit passengers not in air-side
s = room available/pax
t = residence time
t_1 = mean service time at check-in

The traditional process of buying tickets and check-in is simple: the passenger buys the ticket, then at the airport proceeds to the check-in, where he receives the boarding card and delivers his baggage. Up to ten years ago this sequence was pretty normal for all passengers while they arrived at the airport with a uniform time distribution; however, the innovations in the passengers' services due to the liberalization of air transport have deeply modified the passengers' behaviors and their choices.

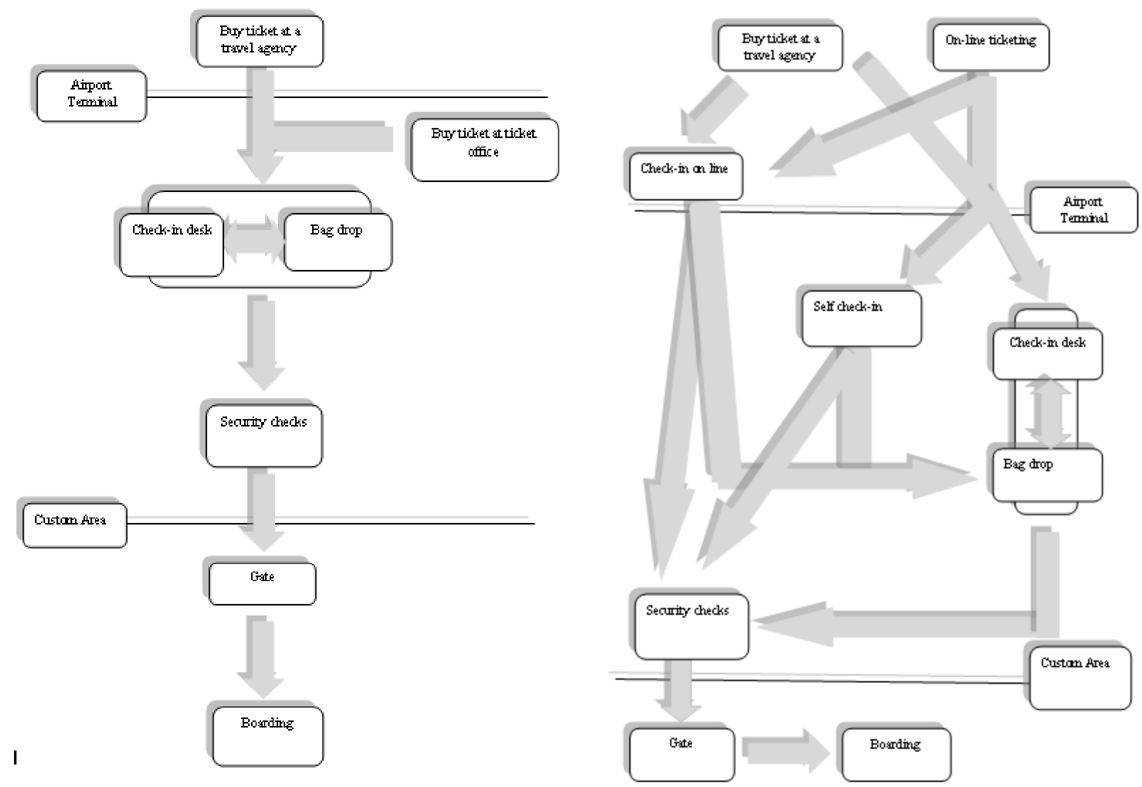


Fig. 3: Comparison between traditional and innovative passengers' services

The success of CUSS depended on the ability to decrease processing time, to lower costs and to decrease the queue length [10]. At present, self-service KIOSK are part of the air transport system and simplify the passengers' processes and decrease the costs: IATA estimations found out that 135 airlines use bar code boarding card and that millions of people use CUSS [11].

The extensive use of self-service technologies allows airport operators to decrease the space dedicated to check-ins and re-use these spaces for commercial purposes.

Statistic analysis [12] have proven that the benefits of using those techniques are:

- a reduction of space of around the 49%, a CUSS occupies 0,35m^2 while a traditional check in desk occupies about 4,57 m^2.
- The 87% of passengers perceives improvements in check-in processes;
- a reduction of the 50% in the transaction time,
- a huge in the investment costs

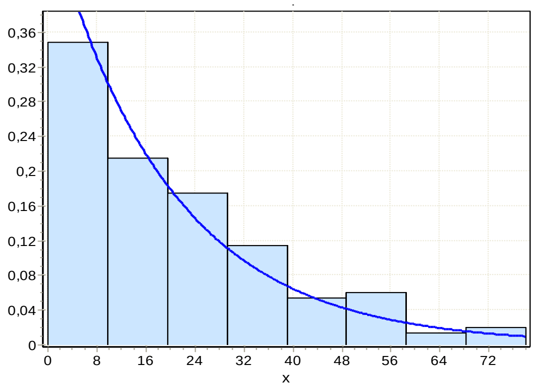
Despite the benefits, Kiosk and CUSS are not able to solve completely the problems: passengers arriving at the airport with checked baggage are required to proceed to a check-in desk after the self-service check-in for delivering the baggage [13]. This process tends to increase the processing time since automated baggage drop system are still seldom used, hence in this situation the total processing time is similar with that spent in a traditional process.

5 CASE STUDY

The queuing theory is a tool to simulate and predict the evolution of queue processes associated with waiting times at specific points of the subsystem. With queuing theory it is possible to derive mean and variance of service times, queue length and the average number of passengers in the queue stemming from the distribution of service times and information on the arrival rate. Arrival path are mostly Poissonian processes, while the distribution of the service times is a random variable depending on, to make some examples, flight characteristics, time of the day the flight takes place in, luggage, users' average age, presence of groups… Our case study considers single flights whose process of acceptance is modelled according to a M/G/2 distribution: the arrival times are distributed according to a negative exponential function (fig. 4 and formula (4)), while a Lognormal distribution has been proven to fit the distribution of the service times (fig.5 and formula (5)) [14].

$$f(x,\lambda)=\begin{cases}\mu\cdot e^{-\mu x}, x\geq 0\\ 0, x<0\end{cases} \qquad (4)$$

$$f(x)=\frac{\exp\left(-\frac{1}{2}\cdot\left(\frac{\ln x-\mu}{\sigma}\right)^2\right)}{\sqrt{2\pi}\cdot x\sigma} \qquad (5)$$



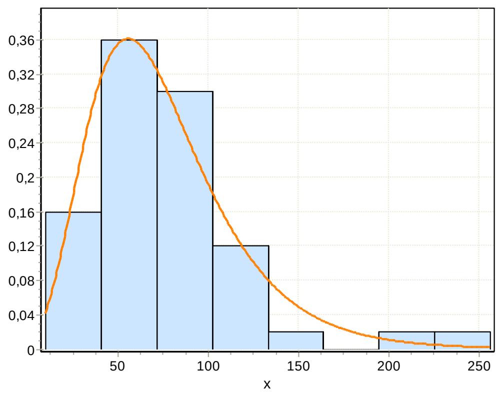


Fig. 4: Arrival distribution of passengers at airport check-in

Fig. 5: Service time distribution at airport check-in

In this analysis it has been considered one hour time check-in operations for two flights connecting the same O/D pair the first operated by a low cost carrier using a Boeing 737-800 with 185 seats and the second by a Regular Carrier using an Airbus A320 with a 160 seats configuration. Normally, at airport terminals it is possible to check-in from two hours to half an hour before the scheduled time of departure (STD), then in the formulas it is roughly assumed that in one hour 2/3 of total passengers will arrive at check-in desks.

Formulas (1) and (2) e tab.6 have been used to calculate how much space is needed and how many check-in desks should be operating to provide the passengers with a sufficient LOS. With the same formulas it has been possible to evaluate the queue length at Kiosk check-in devices.

Tab. 6-7-8: Data to evaluate terminal space during check-in operations according to IATA and FAA formulas

		Bags	Load factor	pax	Space [m²] FAA	Space [m²] IATA	Check-in desks	% kiosk
LC	X kiosk	50	80%	150	92	99	3	0%
	V kiosk	50	80%	150	69	75	2+kiosk	15%
RC	X kiosk	96	70%	112	91	138,5	4	0%
	V kiosk	96	70%	112	65	111,5	3+kiosk	15%

		Residence time [min]	Space/pax [m²] FAA	Space/pax [m²] IATA
LC	X kiosk	30	1,84	1,2
	V kiosk	24 / 15	1,84	1,2
RC	X kiosk	40	1,84	1,7
	V kiosk	35 / 20	1,84	1,7

		(μ service time)$^{-1}$ pax/min	Service time σ² h²	Mean-interarrival time pax/h
LC	X kiosk	0,7924	0,4578	0,324
	V kiosk	0,7979	0,395	0,322
RC	X kiosk	0,311	2,559	0,399
	V kiosk	0,3139	2,2443	0,361

The simulation tool chosen derives the average queue length, the average waiting time in queue, the utilization rate of the system and the cumulative probability of having more than *N* passengers in queue.

Tab. 9: Terminal space passengers loads and waiting times

		server utilisation % pax/min	customer in system L	customers in queue Lq	mean waiting time	mean waiting time in queue	prob coda>20
LC	X kiosk	99,36	25,80	23,80	7,89	7,28	80%
	V kiosk	99,09	17,64	15,65	4,98	4,42	41%
RC	X kiosk	54,79	3,32	2,13	1,46	0,94	4%
	V kiosk	34,68	1,04	0,26	0,50	0,13	0%

Both for Low-cost carriers both for Regular carriers, self-service check-in devices grant a 20-25% saving in terminal space needed. This case study highlights also some incongruities compared with the real time operation timetables: formulas have been derived referring to one hours check-in operations while normally passengers do check-in for longer times (up to 3 hours for charter and intercontinental flights); moreover formulas rely on the assumption that the whole of passengers are in the terminal at the same time with no hypothesis made on the random arrival path. This explains why terminal spaces required derived with FAA and IATA formulas are significantly bigger than those derived with the hypothesis on the distribution of arrival and service path even in the worst scenarios. Finally, IATA and FAA formulas consider no simultaneous check-in operations of M flights; designers' experience and air carriers' time-tables suggest that neither the number of the check-in desks nor the space needed will be *M* times bigger than those derived for the single flight: especially at hubs or at secondary airports with coordinated flight schedules, air carriers often provide common check-in areas consisting in some traditional desks and one or more desks set aside for bag drop, thus to save money on rent expenses for personnel and facilities (saving 20-30% of the theoretical resources needed).

The queue phenomena at kiosk devices are similar to those at check-in desks; the still not widespread use of such facilities and the still small percentage of passengers keen to use them instead of traditional check-in methods assure that the estimation made in our case study is not affected by remarkable errors. Nor we didn't estimate the optimum number of Kiosk in the airport terminal because their purpose is precisely to serve more flights simultaneously.

6 CONCLUSIONS

The recent evolution of air transport market and the innovations in passengers' service technologies have lead to changes in the space allocation in air terminals since passengers can nowadays choose between different services. The purchase of the ticket and check-in operations can be made in traditional way or through internet, otherwise a passenger can use informatics devices as Kiosk or CUSS platforms. In order to evaluate the impact of these new technologies on the requirement of terminal space a real case study has been implemented, for traditional and low-cost carriers. The average number of passengers in queue has been estimated with a specific tool, and then the terminal has been dimensioned using the IATA formulas. The results show that low-cost carriers generate more advantages for airport operators than traditional carriers, due to the lower number of passengers with baggage (the space saved is about 50%). Moreover, some discrepancies between IATA formulas and the real execution of the operations, as results from airlines timetables, have been identified.

According to our simulation, it becomes more and more evident that an effort from the IATA is needed to revise the formulas to suit the new standards. The challenge of airport planners seems to consist in the development of some innovative strategies to streamline the space allocation in terminals, in order to both maintain high level of service and satisfy the stakeholders' needs.

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