Journal of Air Transport Management 53 (2016) 73–84

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Determinants of daily fluctuations in air passenger volumes. The effect of events and holidays on Milan Malpensa airport

Paolo Beria [1], Antonio Laurino [*, 1]

Department of Architecture and Urban Studies (DAStU), Politecnico di Milano, Italy

A R T I C L E I N F O

Article history:
Received 20 April 2015
Received in revised form
26 January 2016
Accepted 26 January 2016
Available online xxx

Keywords:
Airport traffic
Demand estimation
Events

A B S T R A C T

Air traffic flows show large seasonal variability, but arrivals and departures may also be significantly influenced by specific events which generate peaks, which generate peaks rising above baseline traffic. While seasonal variations of air flows are well studied in literature, the daily variations and their causes are seldom analysed and quantified. The paper aims at filling this gap by exploring and quantifying the effect of holidays and events (conferences, trade fairs, sport events) in terms of passenger daily fluctuations.

We identified the elements affecting these variations and searched for correlations with daily demand fluctuations using an OLS econometric model applied to Milan Malpensa airport. The model allows one to reproduce the observed daily traffic, identifying the baseline component of traffic (depending on the calendar) and the additional effect ascribable to holidays and occasional events.

Results show which types of events generate a visible traffic increase. The effect of some of them can be very significant indeed. The largest international design and fashion shows taking place in Milan generate up to more than 20% extra passenger traffic compared to the normal baseline traffic. In addition, the analysis showed that their effect is not limited to the event days, but impacted on the surrounding days as well. Holidays also influence the patterns of demand, creating additional traffic on certain days and more pronounced peaks, which also differ according to seasons.

1. Introduction and aims

1.1. Aims

Air transport connectivity is a key element in a city's competitiveness and attractiveness. Milan, in northern Italy, plays a primary role internationally in the fields of fashion, design, commerce and services in general. This national and international importance translates into a large number of events annually taking place in the city, such as trade fairs, or conferences. In addition, Milan's area is among the most populated in the country and generates the largest outbound market in Italy, for both leisure and business traffic.

The effect of these events in terms of air traffic flows to and from the city, is not captured by seasonal or monthly fluctuations, which is the typical information available in statistics and studied in literature (see below). Similarly, the positioning of departures and arrivals during holidays is important to foresee the most crowded days. A more detailed analysis of fluctuations at the daily level allows to more precisely understand and interpret the effect of events and holidays, which is otherwise impossible at the seasonal scale.

a. Events such as trade fairs last a few days, but may involve a large number of passengers, generating large daily peaks not recognisable at the monthly scale;
b. When trade fairs follow very tight calendars, their effect may overlap, sharpening the peaks;
c. Holiday periods are not homogeneous, there are “peaks within peaks”. The duration of events and holidays also matters in determining when, and how spread out, the arrival/departure periods are;
d. The effect of holidays could be asymmetrical, with arrivals concentrated and departures spread out, or vice-versa;

* Corresponding author.
E-mail addresses: paolo.beria@polimi.it (P. Beria), antonio.laurino@polimi.it (A. Laurino).

[1] The authors contributed to the paper as follows. Paolo Beria is responsible for Sections 4 and 5. Sections 1, 2 and 3 are by Antonio Laurino. Paper's aims and conclusions are common.

http://dx.doi.org/10.1016/j.jairtraman.2016.01.005
0969-6997/

e. Peak days within the week may change according to the month/season.

This paper aims at filling this gap by searching for the main determinants of daily passenger fluctuations in Milan Malpensa airport, quantifying the effect of holiday breaks and events taking place in the city. This approach can be of interest to local decision makers to better understand the impact of specific events (conferences, trade fairs, sport events) and holidays, as well as to support airport managers and airlines in a detailed analysis of demand and its determinants.

1.2. Transport and major events

With respect to our purpose, literature on events focuses mainly on mega events such as Olympic Games, FIFA World Cup or Expo world fairs (Fourie and Santana-Gallego, 2011; Fourie and Sponk, 2011; Allmers and Maennig, 2009; Lee et al., 2008; Matheson, 2012). These studies mainly look at the potential impact on the hosting country or city in terms of economic returns, employment, government revenues, tourism and cultural awareness. Instead, literature analysing the relations and consequences in transport terms is still developing (Borodako and Rudnicki, 2014). Nonetheless, there is a growing interest in understanding the effect of events, which is crucial in everyday management of infrastructure, because it is concentrated in time and potentially problematic in the short term (Robbins et al., 2007) and in terms of city promotion. Many studies focus on the short-term challenges and specific transport and logistics requirements posed by mega events, in terms of transport planning aimed at providing effective and reliable services considering infrastructure, traffic management, ticketing, communication to the public, institutional aspects, etc. (Coutroubas et al., (2003); Booth (2010); Howcroft et al., 2003).

Hensher and Brewer (2002) discuss the actions undertaken and the effectiveness of the transport provision plans for the 2000 Sydney Olympics, highlighting how the outcome for the spectators was good while the patronage forecasts were not. Bovy (2006) discusses the main transport planning issues related to mega events while Bovy (2009) focuses on the main measures implemented during the 2008 Beijing Olympic Games. ECMT (2003) presents several international mega events in terms of impact, solutions and lessons learnt with regard to transport.

Other studies (Kassens-Noor, 2012, 2013) focus on the legacies of mega events such as the Olympic Games, highlighting the role and influence of the International Olympic Committee in shaping the urban and transport framework of the hosting city.

1.3. Estimating the impact of smaller scale events

While mega events have been considered in literature also looking at their transport implications, "smaller scale" events have received less attention. To the best of our knowledge, there are few studies which look at the relationship between events (big or small) and airport daily traffic fluctuation, despite the potential interest for airport managers and airlines. The paper focuses on this point.

The model considers the airport of Milan Malpensa. This choice derives from its relevance among Milan's airports (first in terms of passengers carried) and Italy in general (second after Rome Fiumicino). Moreover, with respect to the more specialised airports of Linate and Bergamo, Malpensa has a mixed supply, with both low cost and full service carriers, and thus represents the main gateway for the city for long-haul flights as well.

Even if total air traffic fluctuation is influenced by many variables (such as fuel price, airport and airline strategies, traffic congestion, economic trends), these elements tend not to vary from one day to another and can thus be considered constant in limited periods. As we limit our analysis to the daily variations during one single year, we can thus focus our attention on the sole variables describing the differences among single days (seasonality, day of the week, etc.), trying to isolate their effect on daily traffic.

The remainder of the paper is organized as follows. Section 2 recalls the literature on forecasting, followed by the description of Milan's context and airports (Section 3). Section 4 describes the model used, while Section 5 presents and discusses the results obtained. Finally, conclusions and policy indications are drawn.

2. Previous studies

The task of airport demand forecasting is crucial (Riddington, 2006) because it influences planning, infrastructure management and investment decisions, both in the medium-short and in the long term. Deciding on the appropriate forecasting model is influenced and limited by many factors, such as the availability of data, the time horizon, the costs. (Var and Lee, 1993).

With regard to the forecasting of future traffic, literature provides both qualitative methods (based on experience, surveys, knowledge) and quantitative ones (based on statistical relations or discrete choice models), aimed at systematically reducing forecasting errors and trying to track and isolate the variables that cause changes in the dependent variable (for a review see for example Doganis, 2010).

Among the quantitative techniques, the used approaches are behavioural (discrete choice models), non-causal (time series) and causal (econometric) methods (Vasigh et al., 2008; Song and Li, 2008; Peng et al., 2014).

Discrete choice modelling allows to evaluate the effect of specific situations, such as capacity constraints at the individual scale explaining future travel choice behaviours (Mandel, 1999; Pels et al., 2003; Hess, 2010).

Non-causal methods analyse the historical data to forecast future traffic, usually not considering the influence on air traffic of various economic, social and operational conditions (Ahmadzadeh, 2011).

To take into account the role played by external factors and the causal relationship between variables, econometric regression models are used instead (Dft, 2011, 2013; ICAO, 2006). Starting from the assumption that traffic variations have a cause-and-effect relationship with several variables such as GDP, population, travel costs, consumer spending, causal models try to explain how changes in one or more of these variables affect the level of demand (Karlaftis, 2008; Vasigh et al., 2008). In this way, it is possible to estimate how demand will change due to the predicted modifications in these exogenous variables.

The main group of such works deals with the effect of different aspects such as investments and policies on future airport demand. Chèze et al. (2011) use dynamic panel-data modelling to analyse the role and the magnitude of different variables on air traffic and to forecast the evolution of air traffic until 2025, highlighting the importance of regional heterogeneity in predicting traffic trends. Karlaftis et al. (1996) examine and test the predicting ability and forecasting accuracy of existing air-travel demand models using both criteria performance and post-fact analysis. Carson et al. (2011) compare the peculiarities of forecasting air travel demand, using aggregate data or through the sum of the airport-specific forecasts obtained from disaggregate data.

The issue of seasonality involves some specific interest, due to its implications both for airport management and for tourism. Abdelghany et al. (2011) quantify factors that contribute to airport demand variations and assess how external factors such as seasonality, macroeconomic conditions and major incidents affect airport activity levels. Profillidis (2000) uses an econometric approach for forecasting demand in a tourist airport with high seasonal demand, which is applied to the airport of Rhodes as a case study.

Seasonality is analysed in literature from a more general tourist perspective in particular, Hui and Yuen (2002) investigate the seasonal variations of Japanese tourist arrivals in Singapore, suggesting different policies to attract more tourists in different periods of the year. Lim and McAleer (2001a), after examining and comparing various smoothing forecasting methods based on tourist arrivals from Hong Kong, Malaysia and Singapore, point out the role played by seasonality in forecasting international tourism demand for Australia. In another study Lim and McAleer (2001b) estimate the monthly seasonal patterns in international tourism time series and the seasonal concentration of arrivals in Australia from the same three countries applying the moving average technique. Finally, many methods of seasonal adjustment using different approaches have been developed in different sectors (see Franses et al., 2005) in order to analyse the trends of a time series excluding the seasonal components (X-13-ARIMA-SEATS in US, BV4 in Germany, TRAMO-SEATS in Spain). While seasonality and long-term forecasts are studied, literature on traffic fluctuations in shorter periods has received less attention. We will try to start filling this gap in the following sections.

3. Milan air traffic

3.1. Milan's economic environment

The Province of Milan is one of the most densely populated areas in Europe, with more than 3 million inhabitants spread over an area of 1578 km^2 and surrounded by other densely populated provinces. Milan is the leading metropolitan area in Italy due to its economic importance, which is the result of economic activities including agriculture, industry and service sectors. Thanks to its numerous enterprises, the Province of Milan alone contributes to approximately 9% of the national GDP, with a GDP per-capita of more than € 35,000 (Provincia di Milano, 2011).

Over the last decades, the tertiary sector (in particular design, advertising, publishing, furnishing and fashion industries) has gained a central role in Milan's economy. The fashion industry, with nearly 12,000 companies involved in the "fashion system", generates more than 300 fashion shows every year with 200,000 visitors.[2] Milan's eleven universities and the high number of hospitals and leading centres in medical therapy and research also contribute to the attractiveness of the city. Lastly, Milan has one of the largest trade fair systems in Europe, comprising Fiera Milano (which hosts on average 75 events with more than 4 million visitors per year), Novegro Exhibition Park[3] (50 events for 350,000 visitors per year) and many other congress facilities both in the city and in its surroundings. In addition, the presence of two important soccer clubs (Milan and Inter), together with the proximity of Monza's F1 race track, contribute to attracting sports fans to the city.

The relevance of the city translates into a remarkable attraction power for both national and international users and tourists. Even if Milan is located in an area well served by both highways and railways, a relevant percentage of these visitors reaches the city using its three airports.

[2] Milan's municipality website accessed on May 2013.

[3] Fiera Milano and Novegro Exhibition Park official website, accessed on September 2015.

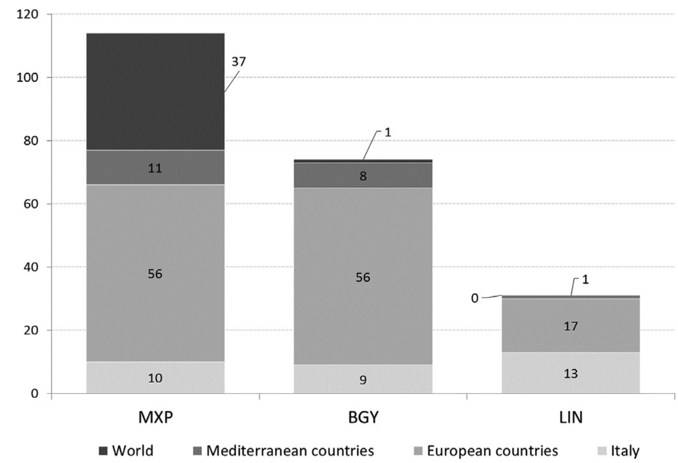

Fig. 1. Milan's airports ranked according to the number and type of destination (Source: our elaborations on OAG 2013, week 11–17 March 2013).

3.2. The airports

Milan's airport system comprises three airports. Linate, located 7 km east of Milan's centre, is artificially constrained in terms of capacity by a governmental decree issued in 2001 to foster the development of Malpensa (Arrigo, 2010). Bergamo Orio al Serio, 50 km east of Milan, has rapidly developed as a LCC airport thanks to the presence of Ryanair and other LCCs, which allow it to reach a number of passengers similar to Linate. Finally, Malpensa, the main airport of Milan and second largest in Italy, is the result of a huge redevelopment project of the late Nineties involving the existing airport. The project included a hub for Alitalia, but this configuration ended in 2008–9, with the crisis of Alitalia (Beria and Scholz, 2010). It is located approximately 50 km northwest of Milan, at the western border of a wide and economically active area with 3.9 million inhabitants.

Milan's air transport supply is the outcome of the radical and contradictory changes that occurred in the last twenty years. Looking at the network of routes, Bergamo is mainly focused on point-to-point Italian and European leisure connections (including seasonal destinations) due to the almost exclusive presence of LCCs. Linate focuses on Italian/European high frequency routes, served almost exclusively by traditional carriers. Malpensa, in order to face the considerable decrease in the number of flights which resulted from the 2008 *de–hubbing* of Alitalia (Beria et al., 2011), had to readapt its offer and now hosts many low cost services, with easyJet almost exclusively operating from Terminal2,[4] and numerous traditional carriers at Terminal 1 offering primarily European and intercontinental flights. Consequently, Malpensa today offers the broadest range of destinations, both domestic and intercontinental. Fig. 1 compares the routes of the three airports, classified according to four groups of destinations: Italy, Mediterranean countries,[5] European countries, rest of the world.

Malpensa's role as international gateway is proven by 37 extra – EU destinations departing from the airport in 2013. In 2014, more

[4] easyJet and other LCCs strongly contributed to avoiding a higher collapse in passengers due to the closure of Alitalia's hub. In 2014, the LCC market share in Malpensa was 46.2%, while in Bergamo and Linate it was respectively 91.3% and 6.4% (ENAC, 2014).

[5] The entire southern and eastern coasts of the Mediterranean sea. The countries actually connected are: Algeria, Cyprus, Egypt, Jordan, Israel, Lebanon, Malta, Tunis, Turkey.

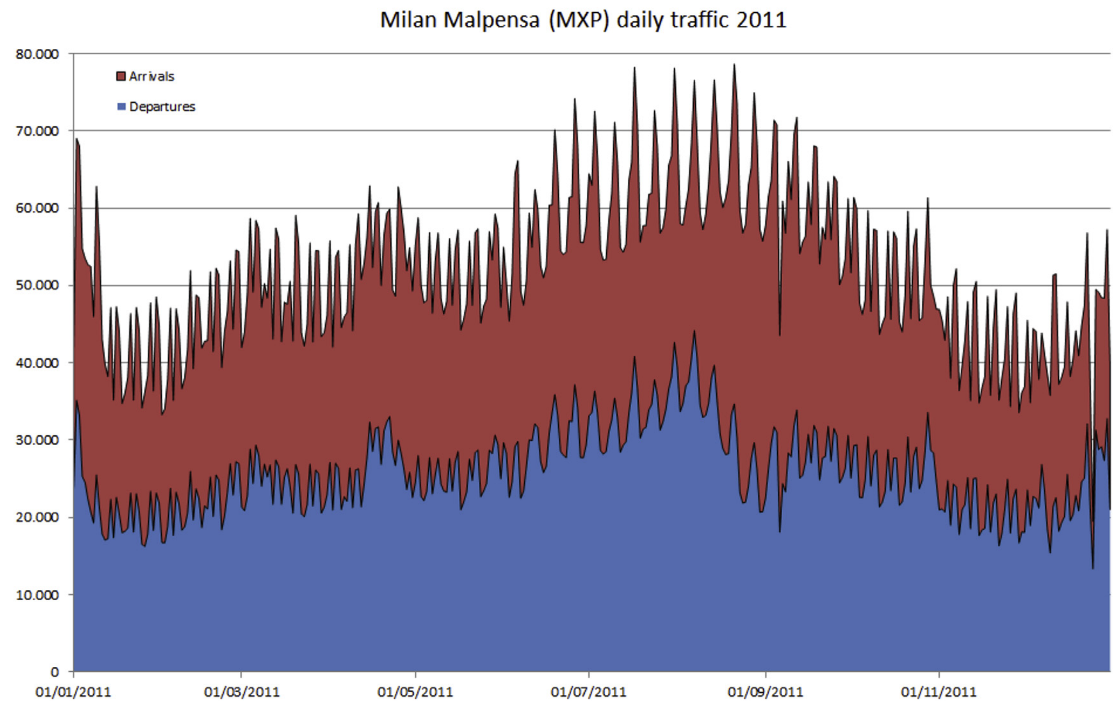

Fig. 2. Malpensa 2011 daily traffic (Source: our elaborations on airport manager data).

than 80% of its passengers travelled on international routes (both EU and extra - EU), while Linate is more focused on national destinations (57.1% of passengers carried) or EU capital cities.

In terms of traffic figures, Malpensa, after Alitalia's de-hubbing in 2008, registered a drop in passenger volumes from its 2007 peak (23.7 million passengers) to its 2009 value (17.3 million passengers), a figure that increased only slightly in the following years. Linate, on the contrary, after the decrease of traffic due to the opening of Malpensa (between 2000 and 2001 passengers decreased from 14.2 to 5.9 million), has been able to regain market shares in particular on national routes. Bergamo was a minor airport mainly for charter services until the arrival of Ryanair in 2002, which boosted growth from 1.8 million passengers to more than 8.5 million in 2014.

3.3. Daily traffic

In order to analyse the effect of events on air traffic, we focused on daily traffic data of Malpensa airport, provided by the airport manager SEA - Aeroporti di Milano.

Fig. 2 shows the daily traffic arriving in and departing from the airport during 2011. Some characteristics of the passenger trends are already evident: the higher traffic during main holidays (summer, Easter, Christmas, etc.), the peaks corresponding to weekend mobility, especially during spring (e.g. for leisure), and some further peaks, possibly corresponding to specific events.

Fig. 3 focuses on Monday and Friday, namely the days with the largest component of weekly commuters to and from Milan. Monday is on average the day with the largest traffic volume. It is also quite variable across the year, with smaller figures during winter and higher flows during warm months, suggesting the existence of a leisure traffic component. Friday, instead, is slightly less crowded, but more constant across the year. These kinds of variations will be analysed in the following sections using an econometric model.

4. The model

4.1. Methodology

Starting from the observed daily 2011 traffic (split into daily inbound and outbound passengers) in Milan Malpensa (MXP), we built two OLS models (one for arrivals and the other for departures), to correlate holidays and main events in Milan (in terms of attracted visitors) with the daily passenger flows.[6]

$$ARR_{day} = \beta_{c,ARR}\,Calendar_{day} + \beta_{h,ARR}\,Holiday_{day} + \beta_{e,ARR}\,Events_{day} + \gamma_{ARR}$$

$$DEP_{day} = \beta_{c,DEP}\,Calendar_{day} + \beta'_{h,DEP}\,Holiday_{day} + \beta'_{e,DEP}\,Events_{day} + \gamma_{DEP}$$

Since the available data refer to one single year, we excluded a time series approach and chose a regression model which provides a static picture of the traffic determinants. In both the models, the dependent variable is the total number of daily passengers arriving and departing (*ARR* and *DEP* respectively), resulting in 365 observations each (*day*).

It is worth stressing that the model, in the current formulation, is not intended as a future forecasting tool and consequently it ignores the effect of exogenous variables (oil prices, GDP, etc.) that influence total demand (which can be assumed constant in one single year). However, once the expected effect of an event is known, it can be applied to exogenously determine total yearly traffic, to foresee the future daily flows.

While we can easily set the value of some of the independent

[6] The airport of Malpensa has been chosen as a case study because of data availability and because it is the largest airport of northern Italy with all traffic components. Moreover, it is the only one hosting intercontinental traffic, which is relevant for summer leisure traffic and for incoming business traffic related to main international events.

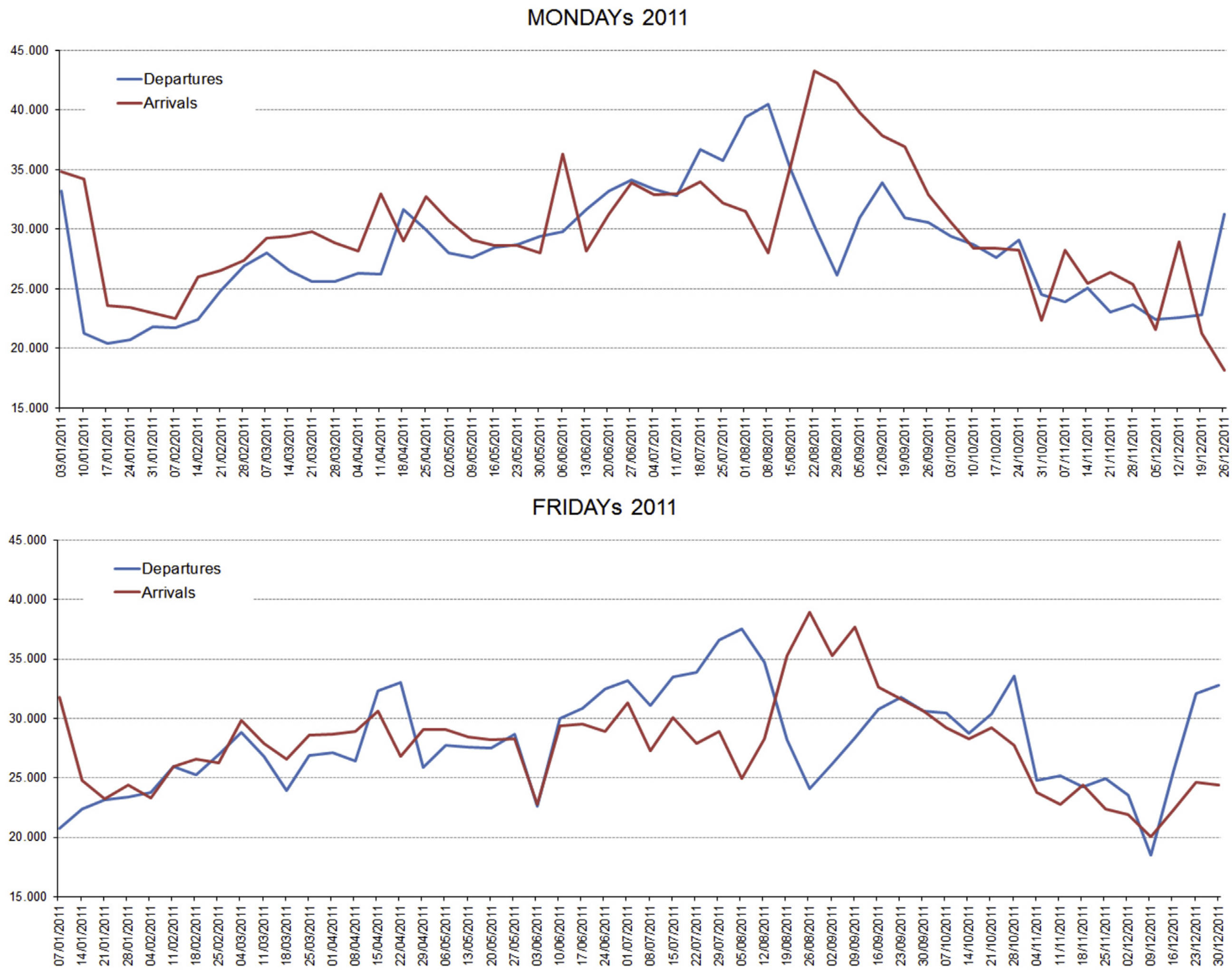

Fig. 3. Malpensa 2011 traffic values on Mondays and Fridays (Source: our elaborations on airport manager data).

variables (typically those related to the *calendar*), the effect of holiday breaks and events requires interpretative work to be modelled. Once a first regression is performed, we verify the differences (positive or negative) with respect to the observed traffic and fix the gaps occurring in holiday periods only by changing the days of the break. For the other days, the gaps with the "baseline" flows remain temporarily unexplained as probably due to specific events. Subsequently, we introduce the list of events in the model and try to understand if they can explain the remaining differences.

There are reasons for choosing daily traffic as a dependent-variable, thus ignoring supply in the correlations. Supply is not constant during the year and during the week, but these variations are always set on a seasonal basis. Except for sporadic single flights, there are no cases of additional supply due to single events, including the large ones. From an industrial point of view, airlines cannot easily change the timetables for just a few days, but can easily increase fares or, under some conditions, switch different aircrafts from other routes (Warburg et al., 2008; Yan et al., 2008) introducing limited supply changes. For this reason, we can affirm that supply is relatively constant, namely it does not depend on the daily fluctuations we are dealing with. Using the load factor as dependent variable, which is introducing supply aside to demand, may instead cause endogeneity. Airlines adapt their supply to the expected traffic, for example reducing flights during off-peak weekdays (Tue, Wed), in order to keep load factors above a certain threshold.[7]

4.2. Independent variables considered and data source

To perform the regressions we built a unique database made of 365 double observations (inbound and outbound passengers). We grouped the tested independent variables into three categories:

a. the *calendar* variables: the day of the week, the month and the season. All of them are treated as dummy variables (e.g. Monday = [1.0]) and for reasons of simplicity they are not fully listed in the Table 1 below;
b. the *holiday break* variables: we collected all 2011 school and bank holidays[8] in Milan. However, as one would expect, air traffic peaks do not perfectly match with the break days. For

[7] The only element which is not considered is the closure of an airline or the introduction of a new route. However, single route variations generally involve some hundreds of passengers per day and can thus be considered marginal (below estimation errors) in explaining Malpensa's traffic of 30,000–70,000 passengers per day. On the contrary, a bigger event like Alitalia's de-hubbing in 2009 could not be ignored.

[8] Actually, bank holidays always match with school holidays, while shorter. In fact bank holidays, if analysed together with school holidays, are not significant and thus they have been omitted from the rest of the analysis.

Table 1
Model variables.

Type of variable	Variable name	Description	Unit
Dependent	*ARR (DEP)*	Number of daily arrivals (departures) in Milan Malpensa	pax
Calendar	*Mo, Tu, …*	Day of the week	dummy
	Jan, Feb, …	Month of the year	dummy
	Summer, …	Season	dummy
Holiday	*Break_DEP*	Days of departures	dummy
	Break_DEP_peak	Extra variable, describing peak days of departures	dummy
	Break_DEP_green	Extra variable, describing off-peak days of departures	dummy
	Break_ARR	Days of arrivals	dummy
	Break_ARR_peak	Extra variable, describing peak days of arrivals	dummy
	Break_ARR_green	Extra variable, describing off-peak days of arrivals	dummy
	Family_day	Variable to control low-traffic days (e.g. Christmas)	cardinal
Events	*Strike*	Presence of air strikes	dummy
	Events_INT_IN	International visitors trade fairs/events (applied to arrival days)	visitors
	Congress_INT_IN	International visitors congresses (applied to arrival days)	visitors
	Events_INT_OUT	International visitors trade fairs/events (applied to departure days)	visitors
	Congress_INT_OUT	International visitors congresses (applied to departure days)	visitors
	Sport	Main sports events	dummy

Table 2
Number of events considered in the model.

	No. of fairs	No. of conferences or similar	No. of other events	Range of visitors at the events
FieraMilano centre	45			2000 ÷ 3,003,000
MiCo - MilanoCongressi	3	42		500 ÷ 15,000
F1 circuit in Monza			1	~100,000
Soccer matches			52	n.a.
Big concerts			3	~60,000

Note: the “unified” events, such as different furniture trade fairs taking place in the same period, have been considered as one and the total visitors have been considered.
Source: events data provided by Fondazione Fiera and Fiera Milano Congressi. Press releases for F1 race and concerts attendance.

example, as Milan is more a generator of tourist traffic, departures tend to be concentrated in the first part of the break while arrivals in the last. Moreover, the peaks of flows are distributed before and after the period of the break, while during the central days people move less because at destination. To consider this, we divided the information on breaks into seven variables, which proved to be the most explanatory. Three dummies are used for departures: *Break_DEP* assumes value 1 on departing days, *Break_DEP_peak* amplifies the departures in peak days, *Break_DEP_green* represents the central days with low departing traffic. Three similar variables are used, with the same meaning, for arrivals (Break_ARR, etc.). Finally, we added a further variable, *family_day*, to take into account some special days in which traffic is extremely low because usually spent at home, typically Christmas. We did not find a “summer holiday” variable relevant because summer holidays for workers in Italy match with August. University classes generally finish at the end of June and thus July is characterised by increased student mobility.

c. the *event* variables: this group of variables describes all main trade fairs, conferences and other events in Milan, for a total of 146 events (Table 2). With regard to soccer matches, we considered only those involving supporters from far away[9] (e.g. teams from the south of Italy or from abroad). Trade fairs and congresses are described with a continuous variable representing the number of national and international visitors attending the event (0 if there is no event). We also considered airport *strikes* as a dummy variable.

The dependent variables are the observed daily scheduled passengers[10] arriving in and departing from Malpensa airport. The source of this data is the airport manager.

The following table summarises the variables considered with a brief description.

Other variables were considered, but proved to be not significant (e.g. national visitors at trade fairs) and consequently they are not present in Table 1. Some of them will be discussed in the next paragraphs.

4.3. Modelling the events

Table 2 summarises the number and type of events considered in the model. For the events and the holiday breaks, we assumed the presence of “queues” before and after the central days. This choice allows us to model the distribution of the arrivals/departures in a more realistic way, since visitors (but also the staff during the trade fairs) may arrive/leave not only on the day of the event, but also in the days preceding or following it. This aspect is especially true for the holidays breaks.

As previously discussed, we introduced three variables for arrivals and three for departures in the model. The following tables exemplify the approach used to model long weekends (Table 3) and trade fairs/conferences (Table 4). Holidays are described case by case, while we used a standardised structure for trade fairs and conferences.

[9] Given the importance of Milan's teams and the dimension of the stadium (80,000 seats), we aimed at testing the effect of soccer matches. In addition to visiting supporters, the numerous fan clubs of Milan's teams (Inter FC and AC Milan) existing in southern Italy can buy group tickets and thus may play a role in daily fluctuations. Thus the potential arrivals in Milan could involve visitors supporting, for example, Naples (namely the visiting fans, strictly controlled and small) and the ones supporting Milan (the fan club visitors), both coming from different parts of Italy.

[10] We considered only the scheduled passenger traffic and not the general aviation traffic, which however represents a minor share of Malpensa's volumes.

Table 3
Scheme used to model Easter 2011 and the long weekend of the 1st of May.

			Departures			Arrivals			
			DEP	peak	green	ARR	peak	green	Family_day
21/04/2011	Th		1	1					
22/04/2011	Fr		1						
23/04/2011	Sa		1						
24/04/2011	Su	Easter	1		1				1
25/04/2011	Mo	Italian freedom day	1		1	1			
26/04/2011	Tu		1			1	1		
27/04/2011	We		1		1	1			
28/04/2011	Th					1		1	
29/04/2011	Fr					1		1	
30/04/2011	Sa					1			
01/05/2011	Su	Workers day				1			1

Table 4
Standard scheme used to model all trade fairs and conferences.

	Day of the fair	Arrival days	Departure days		Day of the conference	Arrival days	Departure days
Before		1					
Fair	1	1		Conference	1	1	
Fair	1	1	1	Conference	1		
Fair	1		1	Conference	1		1
After			1				

Trade fairs and conferences have been described according to the number of Italian visitors (that later resulted to be not significant) and the number of foreign visitors. A few "exceptions" have also been introduced in order to correct specific errors:

1. In the case of the most important events related to fashion, we gave a weight of 2 to visitors arriving on the first day of the event. This was necessary because the number of visitors considered (the buyers) differs significantly from the real number of people involved in the events (models, staff, etc.).
2. In the case of soccer matches we assumed the arrival of supporters on the day of the match.
3. The analysis of traffic trends showed how, for some months, the first days have figures similar to the previous ones. In particular the first week of February has the same flows as January, and the days between 1–4 October are similar to the ones in September. Consequently, these days have been "forced" into the previous month. Similarly, 18, 19 and 20 of June have been considered "summer" days even if they belong to the last weekend of spring.

5. Results

5.1. Model results

Table 5 below shows the results of the models.

The regressions show very good R-squared of 0.94 (0.95), meaning that 94% (arrivals) and 95% (departures) of daily variations are explained by the independent variables used. We also performed the multicollinearity test among variables, which showed that all of them are below 5, except *Summer*, which is used together with week days.

The day of the week is highly significant in all the cases. *Monday* is the most crowded day, together with *Friday* and *Sunday*. In these days, weekly commuters go back home and business trips end or start. The other days (*Tuesday*, *Wednesday*, *Thursday* and *Saturday*) have 4500 to 6000 fewer passengers compared to *Mondays* for arrivals and 3500 to 5300 for departures.

January and *December*, excluding Christmas, are the least crowded months, together with *November*. With respect to *January*, our base variable for months, traffic values for the other months range from 2500 to 8900 passengers/day more in each direction.

The effect of school holidays, which in Italy match entirely with Summer season, is caught by the variables of the months of *June*, *July* and *August*, corrected by the variable *Summer* (from mid-June to mid-September) for inbound traffic only.[11] In addition, days from *Wednesday* to *Sunday*, if in the *summer*, give an extra effect ranging from − 3000 to + 2500 arrivals per day and from −1000 to +3500 departures per day. This shows that during the summer, the peak of travels is even more concentrated in the weekend, while typical winter peak days such as Friday are smoothed. This is reasonable, as many business trips occurring during weekdays disappear. Interestingly Saturday, a typical off-peak day during working periods, significantly increases traffic during summer. The phenomenon can be also seen in Fig. 4, which shows traffic trends on Saturdays in Malpensa, with respect to the previous Friday. During the summer the ratio clearly passes from 0.7 to 0.8 to 1 and more.

This depends on the periodicity of tour operators' packages and tourist patterns in general which foresee that users fly out and back on the same day of the week (Doganis, 2010). In fact, the majority of charter services (both on UE and extra-UE destinations) in Malpensa are generally provided during weekends (especially Saturday and Sunday). The higher number of charters during the summer season thus explains the otherwise absent Saturday peaks.[12]

Variables describing school breaks are all extremely significant. "Normal" arrival days account for 5200 extra passengers compared with the baseline, and 6400 for departures. "Peak" days differ between arrivals and departures, with 4800 additional arrivals compared to 3000 extra departures. In general, arrivals were found

[11] This takes into account that arrivals are shifted of about half month (in particular they are concentrated in the first half of September), while departures match with the months of June, July and August. This shift is visible in Fig. 6.

[12] Data provided by the airport manager show that during summer, charters account for 4–18% of total movements, with the highest figures limited to Saturday – Monday, whereas in the rest of the year charters seldom account for more than 5% of total traffic.

Table 5
OLS results.

Type of variable	Variable	Unit	Arrivals		Departures	
			Beta	Pr(>|t|)	Beta	Pr(>|t|)
Intercept			23,890	***	22,060	***
Calendar	*Tu*		−5890	***	−5375	***
	We		−5417	***	−4325	***
	Th		−4533	***	−3455	***
	Fr		−822	**	814	**
	Sa		−6079	***	−4321	***
	Su		−471		106	
	Feb		2616	***	2516	***
	Mar		4592	***	4426	***
	Apr		4717	***	4204	***
	May		5396	***	5121	***
	Jun		6253	***	5597	***
	Jul		5668	***	8237	***
	Aug		4686	***	8913	***
	Sep		8276	***	8075	***
	Oct		4086	***	5445	***
	Nov		584	°	1160	***
	Dec		−1157	***	763	**
	summer		3325	***	−463	
	*Tu*summer*		−788		−211	
	*We*summer*		−1464	*	−879	°
	*Th*summer*		−1968	***	−956	°
	*Fr*summer*		−2904	***	−2639	***
	*Sa*summer*		1668	**	3438	***
	*Su*summer*		2454	***	2633	***
School breaks	*Break_ARR*		5278	***		
	Break_ARR_peak		4810	***		
	Break_ARR_green		−1415	***		
	Break_DEP				6468	***
	Break_DEP_peak				3035	***
	Break_DEP_green				−2932	***
	Family_day		−4902	***	−2179	***
Events	*Strike*		−8653	***	−5994	***
	Events_INT_IN	(1000 pp)	28	***		
	Congress_INT_IN	(1000 pp)	−327	*		
	Events_INT_OUT	(1000 pp)			38	***
	Congress_INT_OUT	(1000 pp)			157	°
	Sport		319		10	
Multiple R-squared:			0.95		0.961	
Adjusted R-squared			0.9452		0.9572	

Significance codes: 0 *** 0.001 ** 0.01 * 0.05° 0.1.

to be more concentrated in peaks than departures. The corrective variable for off-peak days is also asymmetric: - 1400 arrivals and − 2900 departures with respect to the previous variables. Finally, on some specific days the total traffic results very low, because passengers are at destination or because those days are typically spent with families (*family_days* variable, like January 1st, 24th and 25th of December). The net reduction of travellers is - 4900 for arrivals and - 2100 for departures.

Finally, we estimated the effect of events.

The value found for strikes is −14,500 passengers in total, but there was only one major strike in 2011, so it cannot be taken as a reference for other years.

Among the variables used to explain the effect of events, trade fairs and congresses, the only ones which resulted significant are those accounting for international visitors. The variables *Events_INT_IN* and *Events_INT_OUT* (arrivals and departures, respectively) are used for trade fairs and other large events and both were found to be highly significant. This means that, for every 1000 international visitors of the trade fair, there are 28 extra arrivals and 38 extra departures for each day of the event. We will comment below on this apparently small figure. Congresses are modelled in the same way, but their significance is barely sufficient, probably because their average dimension is much smaller than trade fairs and makes them "invisible" in normal traffic. Finally, we also included the main sport events, namely the international soccer matches and all Italian soccer matches involving teams coming from far away (Naples, Puglia, Sicily, Sardinia), both inbound and outbound. However, the effect of soccer matches was found to be small and not significant at all.[13]

5.2. Comment on discrepancies

While the R-squared is rather high and the significance of single variables is often excellent, some single observations show discrepancies between simulated and observed values. Fig. 5 depicts the differences between simulated and real values (total traffic, arrivals + departures).

Fig. 5 shows that for 309 days the error between our simulation and the actual total traffic is negligible, below 5%; 55 observations have an error above 5% and just one above 10%. The separate simulations of arrivals and departures present slightly worse results:

[13] For a comment see Section 4.2.

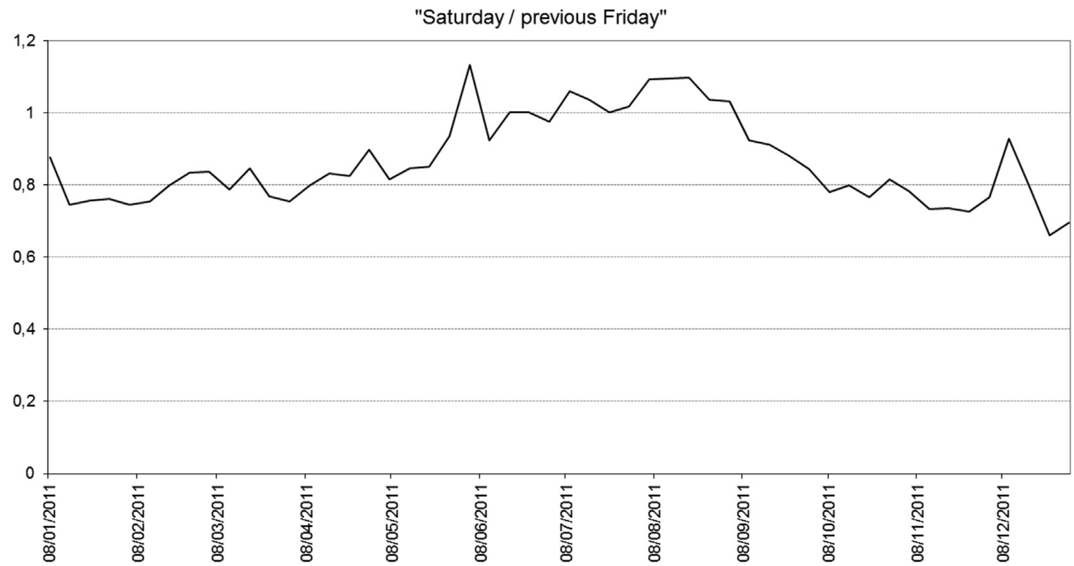

Fig. 4. Ratio between Saturday traffic and the previous Friday traffic (Source: our elaborations on airport manager data).

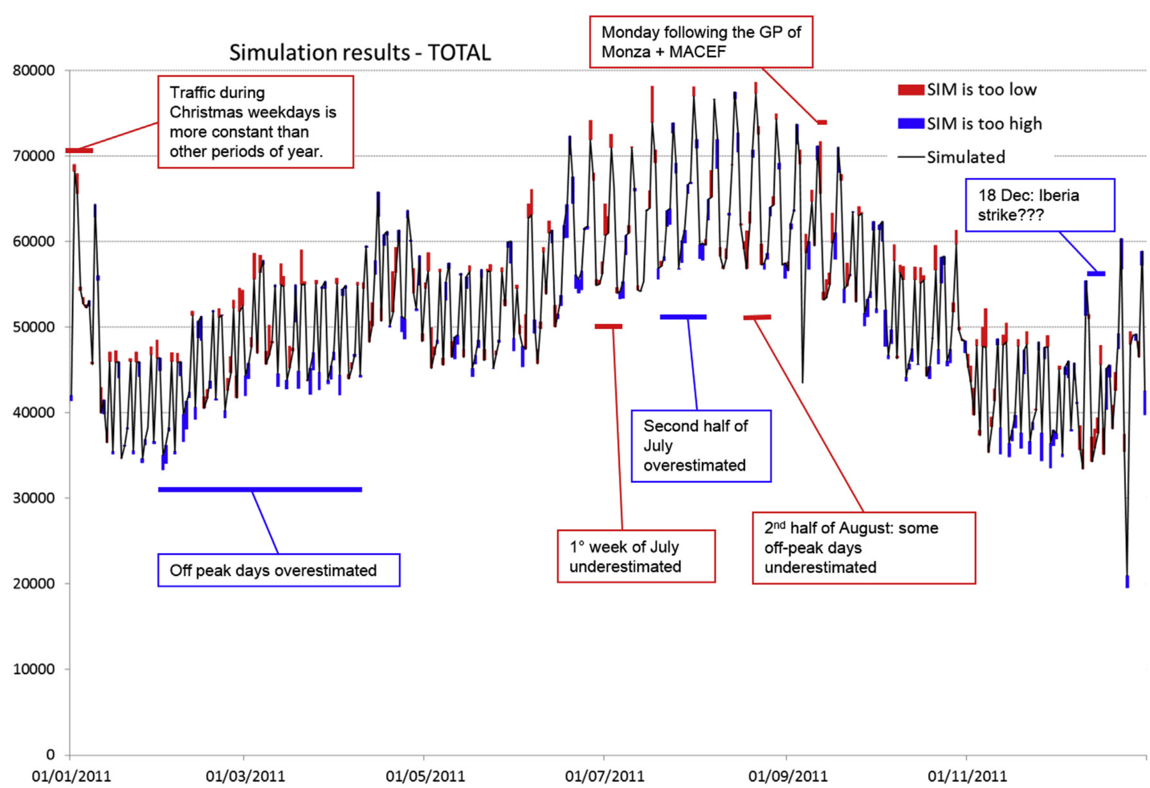

Fig. 5. Analysis of differences between simulated and actual daily traffic (Source: our elaborations).

for arrivals, 235 observations are below 5%, 20 above 10% and 106 above 5%; for departures 277 observations are below 5%, 7 above 10% and 81 above 5%.

Nevertheless, some observations with higher errors can be explained ex-post. For example, the off-peak days of February, March, April and November are slightly overestimated, even if by a few percentage points. In the same periods, peak days are slightly underestimated.

Another source of errors comes from specific events. For example, one departure day after the Monza F1 GP appears as heavily underestimated, but it overlaps with other events (such as MACEF, an international home show) and with the beginning of the school term. In any case, it is likely that this kind of event generates a peak of departures which is exceptionally concentrated compared to other events such as trade fairs. In addition, for the Fashion Weeks the number of people involved, apart from the “proper visitors” (i.e. buyers), is higher than in other kind of events. The type and the travel habits of participants (for example the organisers and the models) are above the average of other events, resulting in a systematic underestimation of overall traffic between

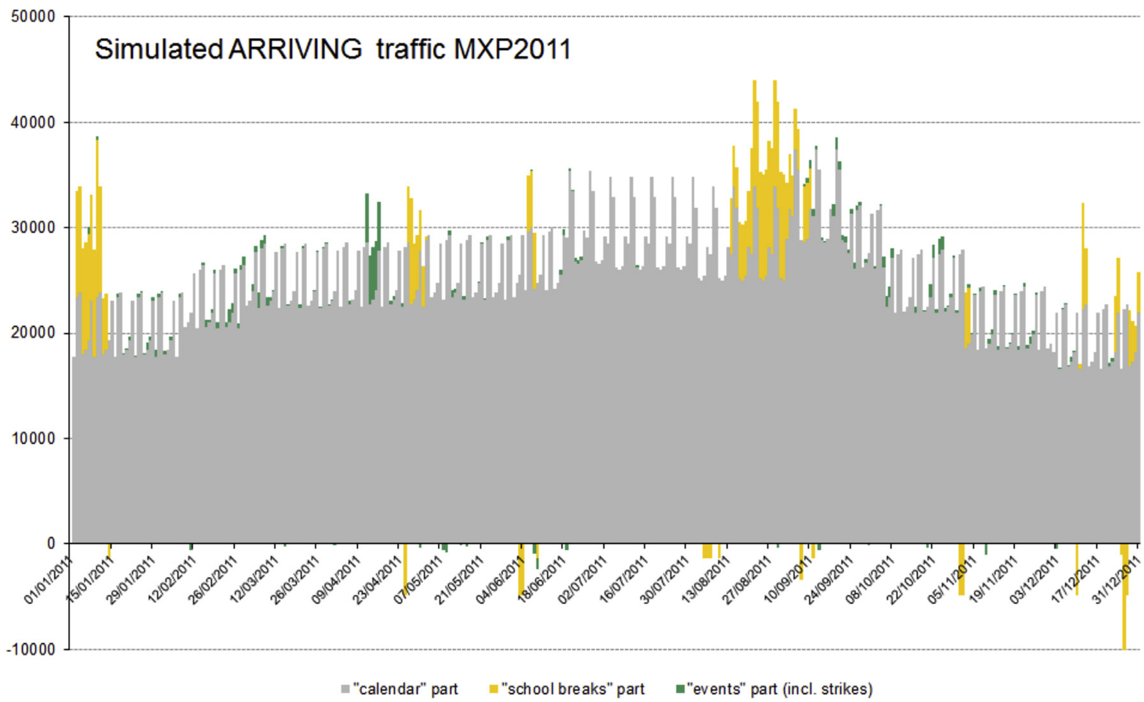

Fig. 6. The effect of calendar, events and breaks on daily traffic arriving in Milan (Source: our elaborations).

2 and 6% despite the corrections introduced.

Some errors in the estimations remain however unexplained, to the best of our knowledge. For example, traffic observed on December 18th is much lower than similar days. The only interpretation we can provide in this case is the effect of an Iberia strike, not included in the database.

5.3. Simulations

Finally, using the *beta* of the regression, we can estimate and represent the distinct effects of calendar, breaks and events variables in explaining the daily variations of Milan's airport traffic. The results are depicted in Fig. 6 and Fig. 7.

The negative values must be interpreted as a decrease in the baseline grey value and are related to strikes and to the off-peak days of holiday breaks.

In yellow, we can see the extra demand due to holidays and long weekends. The Christmas break effect is particularly visible, because it is surrounded by low demand periods. On the contrary, the effect of the summer season extends across more than three months (corresponding to the bank holidays, school holidays and their queues). In addition, the model predicts what actually happens in reality, with departures more spread from mid June to mid August, and arrivals concentrated from mid August to the first weeks of September.

Excluding the main holidays, we can also see:

- Easter (24 April), which is the first spring break, often used to visit relatives and for short trips. In addition, a tourist component of inbound traffic exists.
- June 2nd: an Italian bank holiday, which in 2011 allowed a break of at least 4 days.
- November 1st: All Saints.
- “Sant'Ambrogio”, Milan's patron saint break, which is a typical period for outbound travels for Milan's inhabitants.

In dark green we see the effect of trade fairs, events and congresses. Some are clearly marginal and probably many more unobserved minor ones exist. However, some main events have a visible effect on daily traffic, adding up to 23% extra passengers to the normal baseline traffic:

- 23 February – 1 March and 18–27 September: the two Female Fashion Weeks (with some related events) explain 500 to 1200 extra passengers per day per direction. Male fashion weeks attract fewer passengers.
- 12–17 April: the international furniture fair (“*Salone del Mobile*”) attracted more than 250,000 visitors in 2011 including 160,000international visitors. It generates a visible asymmetric increase of air traffic quantifiable in +4600 arrivals and +6200 departures per day (+23,000 and + 40,000 for the entire period) with respect to the baseline traffic.
- 6 September: national strike, with 13,000 passengers lost.
- Other international trade fairs, such as MICAM + MIPEL, MADE Expo, HOST generate up to 1000 extra travellers per direction.

It is interesting to note that for three among the largest trade fairs in terms of total visitors, namely the BIT (tourism), EICMA (motorbikes) and *Artigiano in Fiera* (handicrafts, with 3 million visitors), the model shows no effect on airport traffic, coherently with the observations. This is realistic since the catchment area of those events is mainly local (northern Italy and southern Switzerland) and involves local visitors in particular, excluding a few hundred international exhibitors. Coherently, only the variable related to foreign visitors proved to be significant while the one for Italian visitors was not.

Finally, it is worth commenting on why the simulated number of passengers for the events is smaller than the actual number of international visitors directly generated by them.

A first explanation is that visitors reach Milan via other airports (Linate and Bergamo) or by car/train from the nearest places of origin (Switzerland, southern Germany, etc.).

A second one could be that as long as the visitors purchase air tickets around the event, airline yield management systems raise

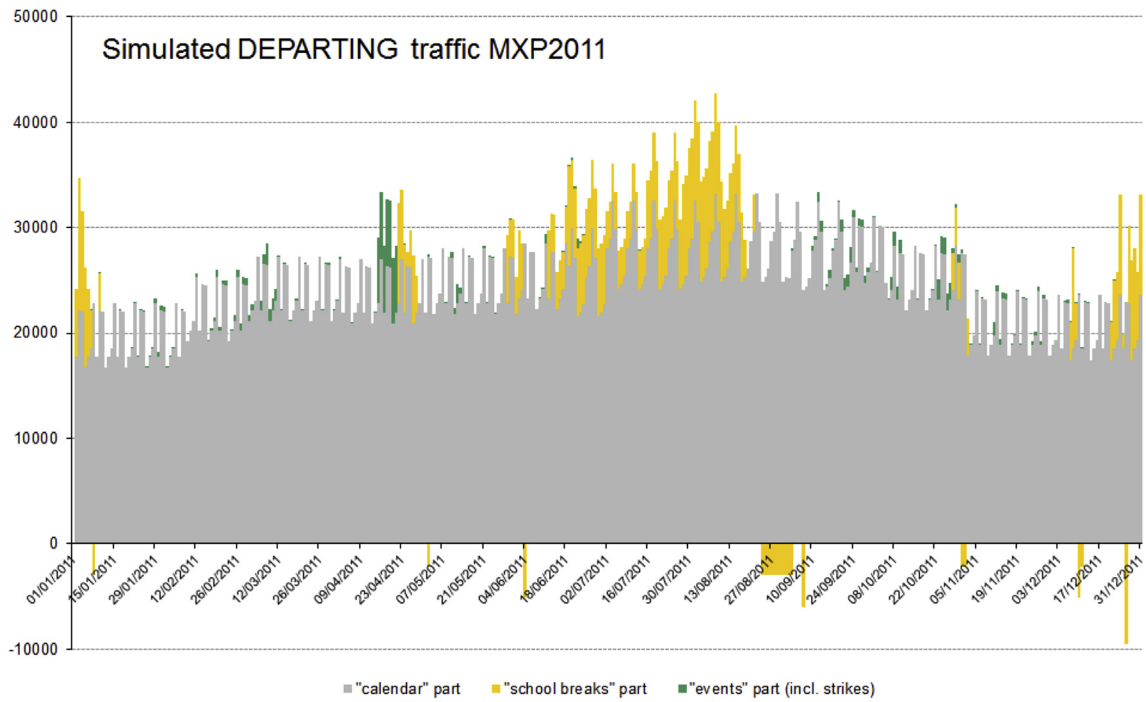

Fig. 7. The effect of calendar, events and breaks on daily traffic departing in Milan (Source: our elaborations).

the fares for the period according to load factor increase. So, as the supply of seats is relatively constant (flights are planned on a seasonal basis ignoring specific local peaks), the larger events may shift part of the other travellers to other cheaper periods. In other words, during and around events, planes likely carry more events visitors, taking the place of baseline visitors, for example the leisure ones, shifted to other days due to high fares.

6. Conclusions and policy indications

Literature on airport traffic determinants focuses mainly on the total traffic and on the capacity to attract passengers according to exogenous characteristics and the attraction power of the local market.

In this paper we tried to understand the factors influencing daily traffic variations, using the case of Milan Malpensa airport. A primary factor determining the variations is, unsurprisingly, the calendar, namely the day of the week and the month; both groups of variables proved to be very significant. We also showed that week patterns change during the summer season, when business traffic decreases and working days (Friday in particular) have systematically less traffic, while Saturdays and Sundays increase due to leisure trips.

Holidays also contribute to traffic variations, in particular school breaks, summer holidays and Christmas. These breaks are not, as intuitively obvious, limited to the break days only, but they also influence the surrounding days. Interestingly, holidays do impact peak days differently according to seasons, for example, summer peak days are much more concentrated at weekends compared to winter. Finally, we studied the impact of 146 events (including all the main conferences, trade fairs, sports events), taking place annually in Milan. The results show the relative importance of incoming visitors and exhibitors, particularly international visitors, on passengers flows at Malpensa airport. This effect has been quantified.

All variables analysed proved to be highly significant, except for sport events (with few non-local visitors) and congresses, which are too small to conspicuously impact the total traffic volume. When looking at day-by-day traffic, however, few singular effects remain unexplained. This is due to the incompleteness of the list of the events and to the simplifications introduced in the model. However, the analysis of singular mismatches between actual and simulated traffic points out quite well the effect of events that are not included, such as big concerts or other conferences, or events with specific characteristics (e.g. Fashion Weeks). In addition, at this stage, we did not consider the effect of Milan's other two airports, Linate and Bergamo Orio al Serio, for which different coefficients might have been found.

Despite these limitations, the model brings some evidence and may give indications for local authorities, airport managers and airlines.

Firstly, the "baseline" traffic, depending on calendar only, is clearly visible. 15–30,000 passengers per direction depend on the calendar. Events and holidays add further traffic, which can be well isolated, at least in their orders of magnitude, e.g. departures and arrivals in the summer holidays add another 10–15,000 passengers in the respective directions (Milan is more a generator than an attractor). In general, the traffic related to holidays and events can rise above the baseline traffic by up to 50%.

Secondly, the effect of events and breaks is not limited only to the days of the event, but it is distributed in the surrounding ones. Three reasons could explain this result. To begin with, with a fixed supply of seats, the visitors of the events shift part of the other users to the nearest available days. Secondly, the organisation of a large event involves the days surrounding it, i.e. when exhibitors arrive and leave the city. Thirdly, some visitors may decide to arrive sooner or leave later for tourism or other businesses. Consequently, arrival and departure peaks are less high but more spread out than the calendar of the event suggests.

Additionally, an analysis based on seasonal variations instead of daily ones would have missed a number of facts, such as the asymmetry of arrivals and departures both for events and holidays, or the variation of peak days due to the season.

This approach could have potential applications for airport managers, local administrators and airlines when there are likely to be spikes in demand, also allowing to forecast the size of the extra demand.

From the perspective of airport managers, it can contribute to better understanding (quantitatively as well) the effect of events on airport traffic, helping to deal with the peaks, to prepare infrastructure and spaces accordingly, but also to better tune the services at the airport.

Airlines and other transport providers (as airport buses) could receive valuable indications in particular when planning new routes for which no historical booking data is available. The approach could also provide insights to improve their yields considering the traffic generated by the events. It also gives indications on the displacement effect on the base traffic in the presence of high demand concentrated in time (trade fair or conference) and under constrained supply.

Local institutions (municipality, tourism agency, chamber of commerce, etc) could gain useful information to better manage peak flows occurring in a limited number of days and, in general, to organise and plan services in the city to deal with spikes. In particular, it can help to foresee if different events, which individually are not an issue, may cause problems because they overlap and, if possible, shift them in order to avoid capacity crises.

Further analyses can be done to improve the results. Linate and Bergamo traffic could be analysed as well, keeping in mind that, if a route is offered by more than one airport (e.g. Frankfurt), the users'/visitors' profile and the willingness to pay will strongly influence the decision on which airport they prefer (this may lead to the use of discrete choice models). Secondly, other event-describing variables can be added to visitors, such as the number and origins of exhibitors. The effect of exogenous variables (oil prices, GDP, changes in the supply of airlines) should be considered as well, to transfer these effects to different years.

Acknowledgements

Authors wish to thank Daniele Nepoti and Giovanni Biondelli, from SEA, Piero Bassetti and Veronica Trevisan, from Globus et Locus, Enrica Baccini and Antonia Ventura Kleissl from Fondazione Fiera Milano.

References

Abdelghany, A., Guzhva, V.S., Srinivasan, K.N., 2011. Addressing and Benchmarking variations in airport demand in the US domestic market. Transp. Res. Rec. J. Transp. Res. Board 2214 (1), 20–26.
Ahmadzadeh, F., 2011. Econometric time series model to forecast passenger of airport. Can. J. Sci. Ind. Res. 2 (9), 337–343.
Allmers, S., Maennig, W., 2009. Economic impacts of the FIFA soccer world Cups in France 1998, Germany 2006, and outlook for South Africa 2010. East. Econ. J. 35, 500–519.
Arrigo, U., 2010. Le infrastrutture aeroportuali in Lombardia, Rapporto di Legislatura. IRER e Guerrini e Associati, Milano, Italy.
Beria, P., Niemeier, H.-M., Fröhlich, K., 2011. Alitalia – the failure of a national carrier. J. Air Transp. Manag. 17 (2011), 215–220.
Beria, P., Scholz, A.B., 2010. Strategies and pitfalls in the infrastructure development of airports: a comparison of Milan Malpensa and Berlin Brandenburg International airports. J. Air Transp. Manag. 16 (2), 65–73.
Booth, R., 2010. Glasgow 2014 Commonwealth Games transport Strategic plan. In: European Transport Conference, Glasgow, October.
Borodako, K., Rudnicki, M., 2014. Transport Accessibility in business travel – A Case Study of Central and East European Cities. Int J. Tour. Res. 16 (2), 137–145.
Bovy, P., 2006. Solving Outstanding Mega-event Transport Challenges: the Olympic Experience. Public Transport International, TPI - No 06/2006, Brussels. Available at: http://www.mobility-bovy.ch/resources/21-UITP-TPI-EN-06.pdf.
Bovy, P., 2009. Beijing 2008 Olympic Games Success: Massive Public Transport Developments and Major Road Traffic Reduction. Public Transport International, TPI No 03/2009, Brussels. Available at: http://www.mobility-bovy.ch/resources/13.UITP_Beijing-EN.09.pdf.
Carson, R.T., Cenesizoglu, T., Parker, R., 2011. Forecasting (aggregate) demand for US commercial air travel. Int. J. Forecast. 27 (3), 923–941.
Chèze, B., Gastineau, P., Chevallier, J., 2011. Forecasting world and regional aviation jet fuel demands to the mid-term (2025). Energy Policy 39 (9), 5147–5158.
Coutroubas, F., Karabalasis, G., Voukas, Y., 2003. Public Transport Planning for the greatest event - The 2004 Olympic Games. In: European Transport Conference, Strasbourg, Sept 2003.
Dft, 2011. UK aviation Forecast 2011. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4503/uk-aviation-forecasts.pdf (accessed September 2015).
Dft, 2013. UK aviation Forecast 2013. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223839/aviation-forecasts.pdf (accessed September 2015).
Doganis, R., 2010. Flying off Course: the Economics of International Airlines. Psychology Press.
ECMT, 2003. Transport and Exceptional Public Events. OECD, Paris.
ENAC, 2014. Dati di traffico, 2014.
Fourie, J., Santana-Gallego, M., 2011. The impact of mega-sport events on tourist arrivals. Tour. Manag. 32 (6), 1364–1370.
Fourie, J., Spronk, K., 2011. South African mega-sport events and their impact on tourism. J. Sport & Tour. 16 (1), 75–97.
Franses, P.H., Paap, R., Fok, D., 2005. Performance of Seasonal Adjustment Procedures: Simulation and Empirical Results. Erasmus University Rotterdam, Econometric Institute.
Hensher, D., Brewer, A., 2002. Going for gold at the Sydney olympics: how did transport perform? Transp. Rev. 22, 381–399.
Hess, S., 2010. Modelling air travel choice behavior. In: Forsyth, P., Gillen, D., Müller, J., Niemeier, H.-M. (Eds.), Airport Competition: the European Experience. Ashgate, Aldershot, pp. 151–176.
Howcroft, K., Newton, D., Maunsell, F., 2003. The XVII Commonwealth Games Manchester - July/August 2002 'Transporting the games to success'. In: European Transport Conference, Strasbourg, Sept 2003.
Hui, T.K., Yuen, C.C., 2002. A study in the seasonal variation of Japanese tourist arrivals in Singapore. Tour. Manag. 23 (2), 127–131.
ICAO, 2006. Manual on Air Traffic Forecasting, third ed. Available at: http://www.icao.int/MID/Documents/2014/Aviation%20Data%20Analyses%20Seminar/8991_Forecasting_en.pdf (Accessed September 2015).
Karlaftis, M.G., 2008. Demand forecasting in regional airports: dynamic Tobit models with GARCH errors. Sitraer 7, 100–111.
Karlaftis, M.G., Zografos, K.G., Papastavrou, J.D., Charnes, J.M., 1996. Methodological framework for air-travel demand forecasting. J. Transp. Eng. 122 (2), 96–104.
Kassens-Noor, E., 2012. Planning Olympic Legacies – Transport Dreams and Urban Realities. Routledge, Oxford.
Kassens-Noor, E., 2013. Transport legacy of the Olympic Games, 1992–2012. J. Urban Aff. 35 (4), 393–416.
Lee, C.K., Song, H.J., Mjelde, J.W., 2008. The forecasting of International Expo tourism using quantitative and qualitative techniques. Tour. Manag. 29 (6), 1084–1098.
Lim, C., McAleer, M., 2001a. Forecasting tourist arrivals. Ann. Tour. Res. 28 (4), 965–977.
Lim, C., McAleer, M., 2001b. Monthly seasonal variations: Asian tourism to Australia. Ann. Tour. Res. 28 (1), 68–82.
Mandel, B.N., 1999. The Interdependency of airport choice and travel demand. In: Taking Stock of Air Liberalization. Springer, US, pp. 189–222.
Matheson, V., 2012. Assessing the infrastructure impact of mega-events in emerging economies. In: Working Papers 1203. Massachusetts: College of the Holy Cross. Retrieved from. http://college.holycross.edu/RePEc/hcx/Matheson_MegaEventsInfrastructure.pdf.
Pels, E., Nijkamp, P., Rietveld, P., 2003. Access to and competition between airports: a case study for the San Francisco Bay area. Transp. Res. Part A Policy Pract. 37 (1), 71–83.
Peng, B., Song, H., Crouch, G.I., 2014. A meta-analysis of international tourism demand forecasting and implications for practice. Tour. Manag. 45, 181–193.
Profillidis, V.A., 2000. Econometric and fuzzy models for the forecast of demand in the airport of Rhodes. J. air Transp. Manag. 6 (2), 95–100.
Provincia di Milano, 2011. Milano in Cifre – Dinamiche Ed Eccellenze Produttive Nell'area Metropolitana Milanese.
Riddington, G., 2006. Long range air traffic forecasts for the UK: a critique. J. Transp. Econ. Policy 297–314.
Robbins, D., Dickinson, J., Calver, S., 2007. Planning transport for special events: a conceptual framework and future agenda for research. Int. J. Tour. Res. 9 (5), 303–314.
Song, H., Li, G., 2008. Tourism demand modelling and forecasting - a review of recent research. Tour. Manag. 29 (2), 203–220.
Var, T., Lee, C.K., 1993. Tourism forecasting: State-of-the-art techniques. In: Khan, M.A., Olsen, M.D., Var, T. (Eds.), VNR's Encyclopedia of Hospitality and Tourism. Van Nostrand Reinhold, New York, pp. 679–696.
Vasigh, B., Tacker, T., Fleming, K., 2008. Introduction to Air Transport Economics: from Theory to Applications. Ashgate Publishing, Ltd.
Warburg, V., Hansen, T.G., Larsen, A., Norman, H., Andersson, E., 2008. Dynamic airline scheduling: an analysis of the potentials of refleeting and retiming. J. Air Transp. Manag. 14 (4), 163–167.
Yan, S., Tang, C.H., Fu, T.C., 2008. An airline scheduling model and solution algorithms under stochastic demands. Eur. J. Operational Res. 190 (1), 22–39.