

# **Analysis and forecast of air transport demand in Sardinia's airports as a function of tourism variables**

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## **Abstract**

The potential of an econometrics approach for forecasting air transport demand is examined. The aim is to identify and select the most significant variables for multivariable linear regression models. Each independent variable has been evaluated by means of ARIMA models after rendering the historical series stationary. The variables for the different cases examined have been chosen using Student's t-test and the correlation matrix to determine their level of significance and of correlation. The resulting models have been tested on three airports in Sardinia (Cagliari, Olbia and Alghero) in order to identify the most suitable and characteristic variables for representing air transport demand. Time series for annual passenger movements have been constructed for each airport expressed in absolute terms and index number.

## **1 Introduction**

The transport system is a complex system composed of three main subsystems:

- Planning and programming
- Structures and infrastructures
- Production and management

The objectives of the present study, concerned with transport planning, were to identify those factors generating air transport demand and to build a model for forecasting travel demand.

The purpose of the analysis was to highlight some fundamental characteristics of air transport, the past trend and evolution of air traffic, the future prospects and the effect that particular socio-economic variables and variables typical of transport systems have had in generating air travel demand.

For forecasting purposes a knowledge of the system's characteristics and the influencing variables are essential for determining the functional relationship between demand trends and the behaviour of the main demand parameters.

The most widely used forecasting techniques in the transport sector are *demand projections* and *econometric models*.

The model constructed here has allowed to develop passenger flow projections in each airport over the next 5-10 years using socio-economic variables and historical traffic data.

Furthermore, as new data are acquired it will be possible to update forecasts and the model itself, insomuch as rather than the classic deterministic methods, highly inflexible and constrained to the reference time interval, we adopted a probabilistic approach. Probabilistic methods are able to take account of the intrinsic randomness of air travel demand generating a flexible function that can be adapted to the observed data and continually updated over time.

In this way, a forecasting tool of general validity has been developed which, by introducing specific variables, is applicable to airports other than those examined here.

The choice of functional form of the econometric model constructed for demand forecasting, was dictated by estimation accuracy and ease of application.

## 2 Choice of analytical method

Forecasting passenger travel demand by means of econometric models requires the construction of functions for estimating both the independent variables of significance and the demand itself. A review of the pertinent literature showed that in the majority of applications a deterministic approach is adopted to tackle this problem, approximating the trend of the variables by means of a regression curve chosen from among those that best interpolate the observed data. Introducing the values thus obtained into the equation chosen for the dependent variable, one obtains an inflexible model, that is unable to account for the real dynamics of air travel demand and bases estimates of future demand on historical data alone.

This implies that the model will not remain valid over time, inasmuch as the smallest variation in the hypothetical trend will invalidate the projections.

Here an attempt has been made to use primarily the Box-Jenkins probabilistic techniques for addressing the problem, thereby relaxing the constraints imposed on the projections by the inflexibility of the regression. In this way a flexible model is achieved that better interprets the trend in the time series examined and can, if necessary, be updated with the latest data.

An econometric forecasting model has been constructed with a multivariable linear regression function. The choice of linear form stems from the fact that it is fairly simple to express mathematically and sufficiently reliable.

Comparison with other more complex mathematical forms showed that the linear form requires a smaller number of parameters to be estimated, thus reducing error margins.

Furthermore, as the function is multivariable, it takes into account the different variables influencing determination of air demand. In this regard, note that the independent variables to be introduced into the model have been chosen after significance testing on the major factors influencing growth in air travel demand. The analytical work comprised the following steps::

- *Choice of independent variables.* The independent variables were selected on the basis of Student's t-test for the statistical significance of the parameters and analysis of multi-collinearity, examining the correlation matrix .
- *Model construction for the independent variables chosen.* We chose the most suitable models for representing the variables. Both regression models and the so-called Box-Jenkins *ARIMA* models were considered. The models were calibrated with historical data on a 10 year basis.
- *Calibration of the econometric model.* This entailed estimating the parameters of the multivariable linear regression using the values of the independent variables calculated with the above models for the period 1980-1994. Two models with different variables were then chosen ,the final choice falling on the model that was more appropriate for demand forecasting.
- *Testing the econometric model.* The goodness of fit of the models was tested by comparing the calculated data with the data recorded for the previous five year period.
- *Air travel demand forecasting.* Demand forecasts were developed for the next five years with respect to the last available data.

### **3 Air travel demand forecasting**

Annual scheduled airline passenger movements (arrivals + departures) were analysed for the three major Sardinian airports:

- *Cagliari – Elmas*
- *Olbia – Costa Smeralda*
- *Alghero - Fertilia*

The historical annual passenger traffic flows for scheduled services were constructed for these three airports. Passenger movements were expressed both in absolute terms (pax/year) and in terms of percentage increase with respect to the reference year (1975), using the index number (IN).

Air travel demand has been forecasted by means of econometric models expressed as a function of significant socio-economic variables including variables typical of tourist accommodation in Sardinia, namely:

- *Resident population (P)*
- *Number of tourist beds (B)*
- *Per capita beds ( $B_{pc}$ )*
- *Tourist arrivals (A)*

The choice of independent variables to be introduced into the forecasting models relied on the statistical *Student's t test* and the correlation matrix: The first test determines the degree of significance of the variable considered for determining demand: The second indicates the degree of correlation between pairs of variables.

**Table 1:** Passenger movements and index number of the resident population and tourist arrivals variables in Sardinia over the period 1975-1995.

year	Resident population		Tourist arrivals	
	B	IN (%)	A	IN (%)
1975	1,550,498	100	652,526	100
1976	1,562,149	100.75	704,200	107.92
1977	1,572,549	101.42	762,800	116.90
1978	1,581,274	101.98	764,662	117.18
1979	1,588,960	102.48	783,970	120.14
1980	1,594,175	102.82	855,347	131.08
1981	1,594,627	102.85	932,294	142.87
1982	1,605,410	103.54	1,014,658	155.50
1983	1,617,265	104.31	988,129	151.43
1984	1,628,690	105.04	974,567	149.35
1985	1,638,172	105.65	1,013,933	155.39
1986	1,643,789	106.02	1,182,943	181.29
1987	1,651,218	106.50	1,261,888	193.39
1988	1,655,859	106.80	1,335,699	204.70
1989	1,657,562	106.91	1,336,219	204.78
1990	1,664,373	107.34	1,313,261	201.26
1991	1,646,771	106.21	1,376,475	210.95
1992	1,651,902	106.54	1,351,421	207.11
1993	1,657,375	106.89	1,261,821	193.37
1994	1,659,466	107.03	1,336,385	204.80
1995	1,660,701	107.11	1,400,483	214.62

Examination of the correlation matrix revealed the possible presence of collinearity. A more in depth investigation of this phenomenon, by means of stationarity analysis, allowed to eliminate those pairs of variables that were effectively correlated.

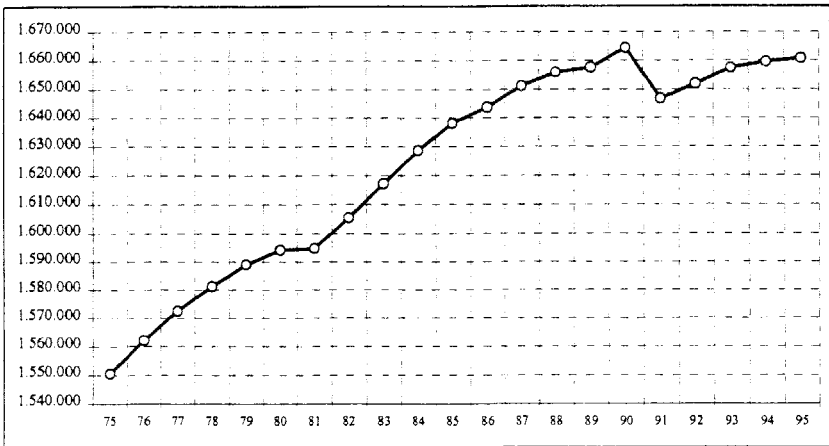


Figure 1: Trend of the resident population variable.

The figures and tables show the data and graphs for the socio-economic variables considered.

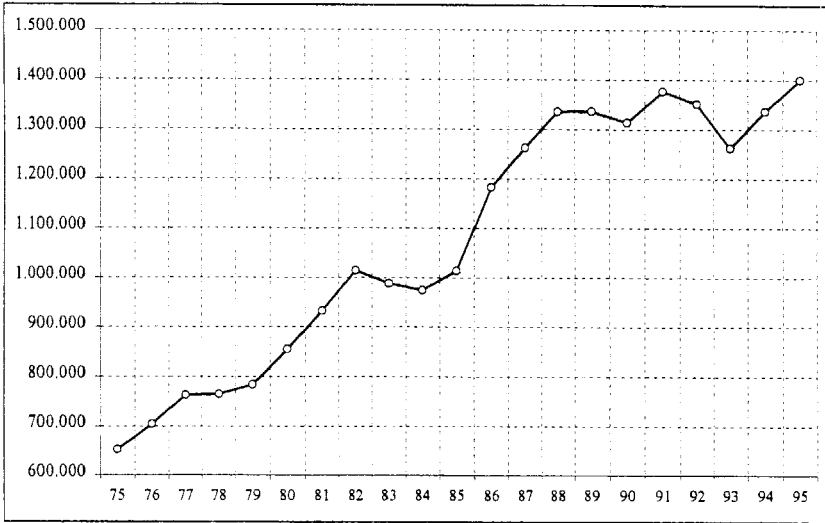


Figure 2: Trend of the tourist arrivals variable.

Table 2: Time series and index numbers of the number of tourist beds and per capita tourist beds in Sardinia for the period 1975-1995.

year	Number of tourist beds		Per capita beds	
	B	IN	B <sub>pc</sub>	IN
1975	33,540	100	0.0216	100
1976	34,688	103.42	0.0222	102.65
1977	36,672	109.34	0.0233	107.80
1978	39,503	117.78	0.0250	115.49
1979	56,004	166.98	0.0352	162.93
1980	57,859	172.51	0.0363	167.78
1981	80,037	238.63	0.0502	232.03
1982	75,324	224.58	0.0469	216.90
1983	82,328	245.46	0.0509	235.33
1984	87,854	261.94	0.0539	249.36
1985	101,780	303.46	0.0621	287.21
1986	106,489	317.50	0.0648	299.48
1987	110,781	330.30	0.0671	310.14
1988	119,507	356.31	0.0722	333.64
1989	118,146	352.25	0.0713	329.50
1990	108,455	323.36	0.0652	301.23
1991	111,849	333.48	0.0679	313.98
1992	118,082	352.06	0.0715	330.45
1993	120,576	359.50	0.0728	336.31
1994	122,392	364.91	0.0738	340.95
1995	127,247	379.39	0.0766	354.21

The ability of each equation obtained to fit the real data was evaluated considering different indexes, including the *coefficient of determination*  $R^2$ , which indicates the reliability of the results in terms of matching the real phenomenon.

The regression analysis was performed calibrating the models on the data for the period 1975-1996. The models were verified using the data for the years 1997-2000.

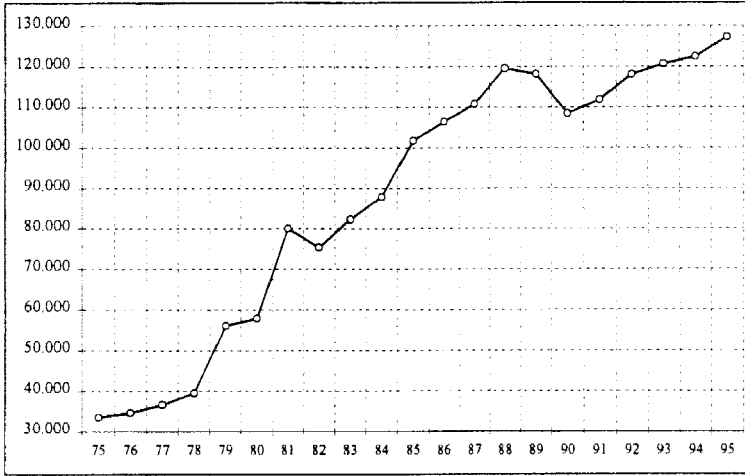


Figure 3: Trend of the number of tourist beds variable.

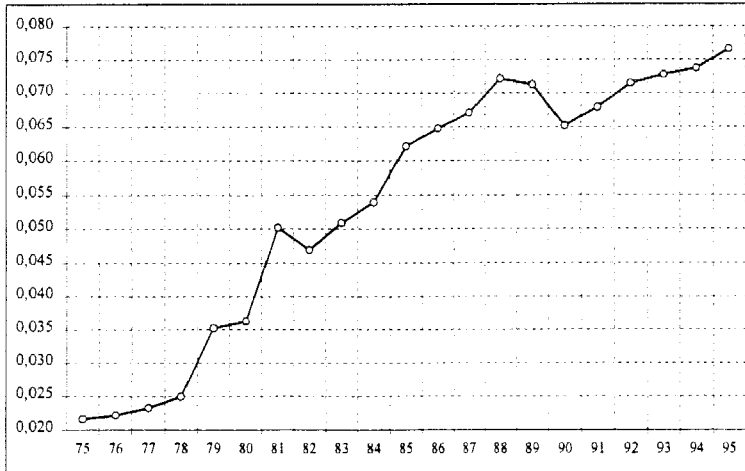


Figure 4: Trend of per capita beds variable.

### 3.1 Cagliari - Elmas Airport

Based on the results of the significance test conducted on the historical passenger movements data for **Cagliari – Elmas** airport, the socio-economic variables number of tourist beds (B) and resident population (P) were chosen.

The functional relationship of the forecasting model obtained is:

$$IN_{CAGLIARI} = 0.38 B + 0.54 P \quad (1)$$

The coefficient of determination is:

$$R^2 = 99.25 \quad (2)$$

**Table 3:** Scheduled airline passenger movements and forecasts for Cagliari-Elmas airport.

CAGLIARI – ELMAS AIRPORT					
year	Passengers/year	$\Delta_{year}$ (pax/year)	$\Delta_{year}$ (%)	IN (%)	$\Delta_{1975}$ (pax)
1975	720,859	-	-	100	-
1976	744,562	23,703	3.29	103.29	23,703
1977	800,906	56,344	7.57	111.10	80,047
1978	744,759	-56,147	-7.01	103.32	23,900
1979	736,049	-8,710	-1.17	102.11	15,190
1980	735,375	-674	-0.09	102.01	14,516
1981	783,199	47,824	6.50	108.65	62,340
1982	858,040	74,841	9.56	119.03	137,181
1983	868,618	10,578	1.23	120.50	147,759
1984	855,985	-12,633	-1.45	118.75	135,126
1985	930,644	74,659	8.72	129.10	209,785
1986	975,579	44,935	4.83	135.34	254,720
1987	1,078,254	102,675	10.52	149.58	357,395
1988	1,185,924	107,670	9.99	164.52	465,065
1989	1,294,039	108,115	9.12	179.51	573,180
1990	1,330,059	36,020	2.78	184.51	609,200
1991	1,283,338	-46,721	-3.51	178.03	562,479
1992	1,343,235	59,897	4.67	186.34	622,376
1993	1,310,410	-32,825	-2.44	181.78	589,551
1994	1,313,152	2,742	0.21	182.16	592,293
1995	1,288,862	-24,290	-1.85	178.80	568,003
1996	1,460,630	171,768	13.33	202.62	739,771
1997	1,680,566	219,936	15.06	233.13	959,707
1998	1,750,882	70,316	4.18	242.89	1,030,023
1999	1,824,385	73,503	4.20	253.08	1,103,526
2000	2,063,514	239,129	13.11	286.26	1,342,655
Growth from 1975 to 2000 = 1,342,655 pax = 186.26%					
Mean annual growth = 53,506 pax/year = 4.45%					
DEMAND FORECASTS TO THE YEAR 2010					
year	Passengers/year	$\Delta_{year}$ (%)	IN (%)		
2001	2,115,310	2.51	293.44		
2002	2,167,106	2.45	300.63		
2003	2,218,902	2.39	307.81		
2004	2,270,698	2.33	315.00		
2005	2,322,494	2.28	322.18		
2006	2,374,290	2.23	329.37		
2007	2,426,086	2.18	336.55		
2008	2,477,892	2.14	343.74		
2009	2,529,688	2.09	350.93		
2010	2,581,484	2.05	358.11		
Growth annual mean = 36,922 pax/year = 2.26%					
Growth with respect to 2000 = 517,970 pax = 25.10%					
Growth with respect to 1975 = 1,860,625 pax = 258.11%					

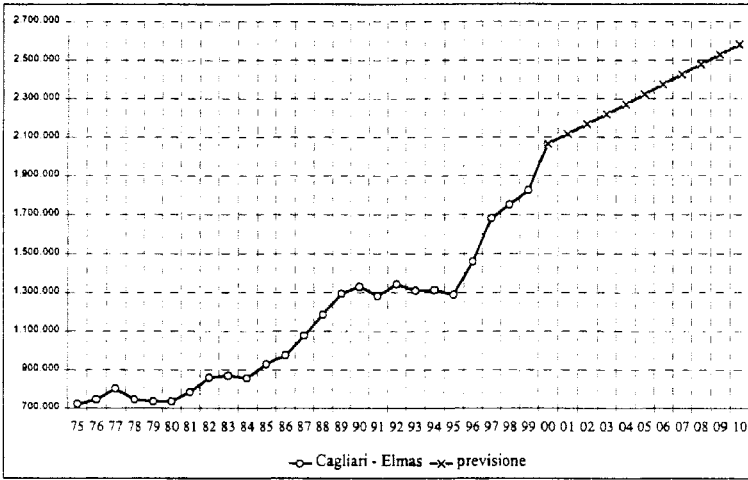


Figura 5: Scheduled airline passenger movements at Cagliari – Elmas airport from 1975 to 2000 and forecasts up to 2010.

### 3.2 Olbia – Costa Smeralda Airport

With regard to air travel demand estimates for the **Olbia – Costa Smeralda** airport, the socio-economic variables *tourist arrivals (A)* and *resident population (P)* proved to be significant.

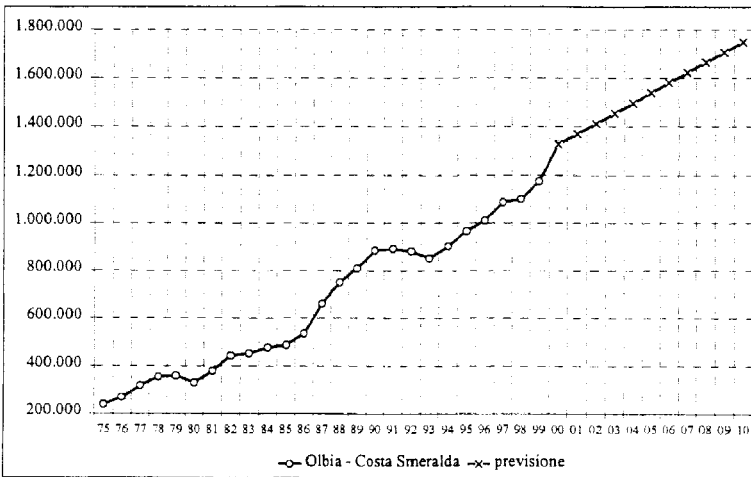


Figure 6: Scheduled airline passenger movements and forecasts for Olbia – Costa Smeralda airport from 1975 to 2000 and demand forecasts to the year 2010.

The following results were obtained:

$$IN_{OLBIA} = 2.69 A - 1.88 P \quad (4)$$

$$R^2 = 99.23 \quad (5)$$

**Table 4:** Scheduled airline passenger movements and forecasts for Olbia – Costa Smeralda airport.

OLBIA – COSTA SMERALDA AIRPORT					
year	Passengers/year	$\Delta_{year}$ (pax/year)	$\Delta_{year}$ (%)	IN (%)	$\Delta_{1975}$ (pax)
1975	238,169	-	-	100	-
1976	269,707	31,538	13.24	113.24	31,538
1977	317,373	47,666	17.67	133.26	79,204
1978	355,757	38,384	12.09	149.37	117,588
1979	360,482	4,725	1.33	151.36	122,313
1980	329,947	-30,535	-8.47	138.53	91,778
1981	380,744	50,797	15.40	159.86	142,575
1982	443,765	63,021	16.55	186.32	205,596
1983	454,060	10,295	2.32	190.65	215,891
1984	477,107	23,047	5.08	200.32	238,938
1985	487,124	10,017	2.10	204.53	248,955
1986	535,977	48,853	10.03	225.04	297,808
1987	660,132	124,155	23.16	277.17	421,963
1988	749,999	89,867	13.61	314.90	511,830
1989	808,545	58,546	7.81	339.48	570,376
1990	883,988	75,443	9.33	371.16	645,819
1991	891,120	7,132	0.81	374.15	652,951
1992	880,272	-10,848	-1.22	369.60	642,103
1993	850,250	-30,022	-3.41	356.99	612,081
1994	902,291	52,041	6.12	378.84	664,122
1995	965,714	63,423	7.03	405.47	727,545
1996	1,011,110	45,396	4.70	424.53	772,941
1997	1,087,116	76,006	7.52	456.45	848,947
1998	1,102,311	15,195	1.40	462.83	864,142
1999	1,174,479	72,168	6.55	493.13	936,310
2000	1,327,275	152,796	13.01	557.28	1,089,106
Growth from 1975 to 2000 = 1,089,106 pax = 457.28%					
Annual mean growth = 43,564 pax/year = 7.35%					
DEMAND FORECASTS TO THE YEAR 2010					
year	Passengers/year	$\Delta_{year}$ (%)	IN (%)		
2001	1,369,364	3.17	574.95		
2002	1,411,465	3.07	592.63		
2003	1,453,554	2.98	610.30		
2004	1,495,655	2.90	627.98		
2005	1,537,744	2.81	645.65		
2006	1,579,845	2.74	663.33		
2007	1,621,934	2.66	681.00		
2008	1,664,035	2.60	698.68		
2009	1,706,124	2.53	716.35		
2010	1,748,225	2.47	734.03		
Growth annual mean = pax/year = 2.79%					
Growth with respect to 2000 = 420,950 pax = 31.72%					
Growth with respect to 1975 = 1,510,056 pax = 634.03%					

### 3.3 Aeroporto Alghero - Fertilia

Air transport demand at **Alghero – Fertilia** airport was found to depend significantly on the *per capita beds* ( $B_{pc}$ ) and *resident population* ( $P$ ) variables

**Table 5:** Scheduled airline passenger movements and forecasts for Alghero – Fertilia airport.

ALGHERO – FERTILIA AIRPORT					
year	Passengers/year	$\Delta_{year}$ (pax/year)	$\Delta_{year}$ (%)	IN (%)	$\Delta_{1975}$ (pax)
1975	274,069	-	-	100	-
1976	226,666	-47,403	-17.30	82.70	-47,403
1977	241,011	14,345	6.33	87.94	-33,058
1978	287,311	46,300	19.21	104.83	13,242
1979	267,133	-20,178	-7.02	97.47	-6,936
1980	253,611	-13,522	-5.06	92.54	-20,458
1981	289,283	35,672	14.07	105.55	15,214
1982	309,775	20,492	7.08	113.03	35,706
1983	307,149	-2,626	-0.85	112.07	33,080
1984	301,631	-5,518	-1.80	110.06	27,562
1985	306,748	5,117	1.70	111.92	32,679
1986	348,641	41,893	13.66	127.21	74,572
1987	393,488	44,847	12.86	143.57	119,419
1988	418,117	24,629	6.26	152.56	144,048
1989	466,448	48,331	11.56	170.19	192,379
1990	509,691	43,243	9.27	185.97	235,622
1991	506,384	-3,307	-0.65	184.77	232,315
1992	520,177	13,793	2.72	189.80	246,108
1993	502,618	-17,559	-3.38	183.39	228,549
1994	484,419	-18,199	-3.62	176.75	210,350
1995	472,974	-11,445	-2.36	172.57	198,905
1996	495,464	22,490	4.76	180.78	221,395
1997	550,337	54,873	11.08	200.80	276,268
1998	562,488	12,151	2.21	205.24	288,419
1999	588,169	25,681	4.57	214.61	314,100
2000	668,023	79,854	13.58	243.74	393,954
Growth from 1975 to 2000 = 393,954 pax = 143.74%					
Mean annual growth = 15,758 pax/year = 3.95%					
DEMAND FORECASTS TO THE YEAR 2010					
year	Passengers/year	$\Delta_{year}$ (%)		NI (%)	
2001	686,415	2.75		250.45	
2002	704,809	2.68		257.16	
2003	723,200	2.61		263.88	
2004	741,591	2.54		270.59	
2005	759,982	2.48		277.30	
2006	778,379	2.42		284.01	
2007	796,770	2.36		290.72	
2008	815,161	2.31		297.43	
2009	833,552	2.26		304.14	
2010	851,948	2.21		310.85	
Growth annual mean = 15,008 pax/year = 2.46%					
Growth with respect to 2000 = 183,925 pax = 27.53%					
Growth with respect to 1975 = 577,879 pax = 210.85%					

The following results were obtained:

$$IN_{ALGHERO} = 0.35 B_{pc} + 0.44 P \quad (6)$$

$$R^2 = 98.69 \quad (7)$$

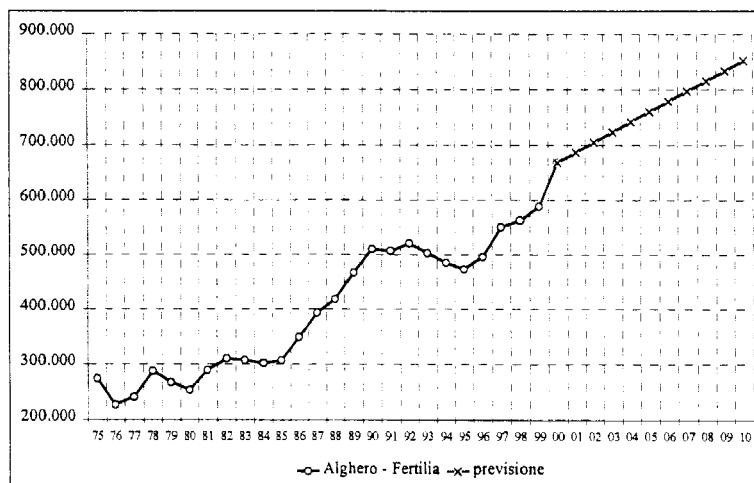


Figure 7: Scheduled airline passenger movements for Alghero - Fertilia airport from 1975 to 2000 and demand forecasts to the year 2010.

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