

# A Mathematical Model for Demand Distribution in An Air Transport Network: An Application to Sardinia

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## ABSTRACT

This article describes the great distance that separates Sardinia from mainland Italy has made the island – the second largest island of the Mediterranean – a marginal and remote region. Its system of ferry links for people travelling to and from Sardinia has such long journey times (8-12 hours) that it is clearly in no way a valid alternative to air transport. It was mainly on the basis of these reasons and with a view to protecting and ensuring the mobility of Sardinian residents that Public Service Obligations (PSO) were imposed on some of the main air routes starting from 2002. Our study is set against this background. It aims to resolve one of the main critical factors that distinguish the PSO network: the shortage of flights on certain routes and the concomitant over-scheduling of others. More specifically, the insufficient scheduling of weekly flights to certain airports, such as Verona and Turin, forces a number of passengers to decide not to travel at all and another part to use connecting flights to Rome/Milan airports or to travel using more than one route, via air or ground transport, with inevitably higher transport costs. The problem was addressed by using a linear scheduling model applied to a network of nodes and arcs representing, respectively, the airports and their connecting routes, and the airport of Cagliari. The decision variables identified were the number of passengers travelling on all of the arcs and the impedance measures associated with the distance travelled by the arcs, represented by the generalized cost of transport. The objective is to determine a network structure which corresponds to the distribution of passengers on the various branches capable of minimizing the total cost. This cost was considered as a useful parameter for comparing the various network scenarios which were obtained by changing the passenger load coefficient and the number of flights. Our study demonstrates that a simple intervention, aimed at the internal reallocation of the flights on the various routes, is able to guarantee categories of users (here divided into business and non-business users) greater access to air transport services. The scenario that more than others is able to improve service efficiency, granting undeniable benefits for all users without having an impact on the costs of air carriers, particularly stands out because it:

- Allows access to all network airports through direct flights;
- Decongests the Rome and Milan routes

## KEYWORDS

Air Transport, Demand Distribution, Milan, Network, Public Service Obligations (PSO), Rome

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## INTRODUCTION

### Sardinia and Its Air Route System

Sardinia is the second largest island of the Mediterranean and has a population of approximately 1,650,000 inhabitants (Table 1). Its economic and social system is based on a connection service with mainland Italy that handles a total of 7.4 million passengers (year 2014). This service is provided using maritime and air transport services: the former involves the ports of Cagliari, Porto Torres, Olbia and Golfo Aranci, the latter the airports of Cagliari - Elmas, Olbia - Costa Smeralda and Alghero – Fertilia, offering national and international services.

Sardinia's development has always suffered, and still continues to suffer, from problems related to its insular nature, notably as regards the transport of passengers. The distance that separates it from mainland Italy leads to there being no valid alternative to air transport. The journey time of the island's ferry services (8-12 hours) is so long, in fact, that travellers accessing the island must strictly depend on air transport.

Over the years, the highly critical situation of this type of transport, mainly due to its expensive fares and inefficient organisation – often aimed at satisfying company logics rather than users' interests, has made the island become practically inaccessible.

Despite this introduction, it is nonetheless important to recall how the air transport system has evolved radically over the past 15 years. It has seized the opportunities presented by the liberalisation of air transport cabotage offered by the European Union and the subsequent arrival of low-cost carriers (1997/2002), as well as those presented by the requirement of public service obligations (PSOs 2002/03), by the activation of a timely promotional policy focusing on the island's airports (end of 2004) and by the infrastructural modernisation of all three airports in Sardinia (Programma Operativo Nazionale (National Operational Programme) – PON funds). Figure 1 shows the geography of the context.

These changes have led to an increase in the number of passengers arriving and departing from the island. In 2014, this number was approximately 7.4 million, growing by 69% compared to 2002, when the total number of users did not exceed around 4.4 million. If we compare airports, the airport of Cagliari has grown by 68%, confirming its leading role (3.6 million passengers, 49% of total passengers) compared to Olbia - Costa Smeralda airport + 57% (2.1 million passengers, 29% of total passengers) and Alghero – Fertilia airport + 103% (1.6 million passengers, 22% of total passengers).

The global data indicate that the growth of domestic and international air traffic is attributable to several contributing factors, including: rapid travel thanks to the new “point to point” links to various Italian and European cities, high standards of comfort and lower fares, following the implementation of flights subject to Public Service Obligations (PSO).

Despite not being able to transform the historical weakness of Sardinia's economic and social system due to its insular nature, these profound changes have nevertheless made it possible, at least

**Table 1. Sardinia main characteristics**

	<b>Sardinia</b>	<b>Italy</b>
Surface [km <sup>2</sup> ]	24,090	301,338
Population	1,652,119	60,233,947
Employed population	673,570	25,514,924
GDP [M€]	31,212.0	1,609,462.2
Tourism- Arrivals	2,242,707	103,723,869
Tourism- Presences	11,448,683	386,894,732

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