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Flights and Their Economic Impact on the Airport Catchment Area: an Application to the Italian Tourist Market

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Abstract Traditionally, in the field of air transportation management airlines have been the main actors in the process of deciding which new flights to open in a given airport, while airports acted only as the managers of the operations. The changes in the market due to the introduction of low cost companies, with the consequent reduction of airports fares, as well as the increase in density of regional and secondary airports in many European countries are modifying the mutual roles of airlines and airports. Today, the final decision on new flights to be opened is the result of a negotiation between airlines, airports and public stakeholders. The airports must prove the sustainability of the new routes and forecast the economic impact on their catchment area. This paper contributes to advance the current state-of-the-art providing a standard methodology to analyze the economic impact of flights and new airport routes. Subsequently, the methodology is applied to the summer tourism market in Sardinia and the winter tourism market in the North of Italy, in order to verify the adaptability of our approach to different characteristics of the tourist market.

Keywords Multinomial Logit · Simulation-Optimization · Flow Forecast · Economic impact

AMS Classification 90B15 · 90B90 · 90C35 · 11K45

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1 Introduction

In the field of air transportation management, decisions on the flights that should be opened in a given airport involve studying the demand, supply and the economic and spatial relationship between the different actors (airlines, airport management, passengers and public stakeholders). Traditionally, airlines have been the main actors in this process, while airports acted only as the managers of the operations. The changes in the market due to the introduction of low cost companies, with the consequent reduction of airport fees, as well as the increase in density of regional airports in many European countries are modifying the mutual roles of airlines and airports. Today, the final decision on new flight to be opened is the result of a negotiation between airlines and airports, due to the incidence of airport fees on the final flight price and reduced marginal profits [1].

On the one hand, airports must ensure the sustainability of the new routes and satisfy the primary needs of the passengers in their catchment area. On the other hand, public stakeholders (regional councils and municipalities) require airport management to measure the economic impact of opened flights in order to grant financial support [2, 3]. Hence, passengers have a double role: they are both users of airport services and investors through public stakeholders. Similarly, evaluating airport efficiency can be seen from two different perspectives: on the one hand airports aim to evaluate the passenger flows, the market share, the passenger satisfaction; on the other hand, public stakeholders are interested in evaluating the return of investments in terms of gains for the territory (for instance, through tourism).

Airport management has become an active player in the process. It can directly contact the most suitable airlines for their stakeholders or, due to limited financial resources, choose from a list of possible destinations provided by the airlines. To facilitate this process, specific workshops such as Routes Europe have recently been introduced. In these meetings, airlines, airports, public stakeholders and tourist authorities meet, in order to share common growth strategies, negotiate deals and build relationships [4].

In order to understand this important phenomenon, it is necessary to model the competition in the system and measure the impact of the transformations in it. Furthermore, it is also necessary to develop new methods for dealing with decisions related to the potential profit and to the increase of traffic caused by changes in the system [5, 6]. This is interesting not only from a practical point of view, due to its relevant economic impact, but also from the methodological one. In fact, the complexity of the systems considered and the strong relationship between the different actors involved in the decision-making process make this problem a good testbed for the new methods.

This paper analyzes the economic impact on two Italian tourism case studies through AirCAST, a simulation-optimization framework [7], where the airport flight schedules play a key role. The first study involves the summer tourism market in Sardinia and the second concerns the winter tourism market in northern Italy. From a socio-economic point of view, the two markets differ in customer behavior and demand elasticity. From the optimization point of view, this paper introduces a new Two-Level Multinomial Logit model in AirCAST, which is able to describe the interaction between the tourists using the flights, the corresponding destination airports and the catchment area of the airports themselves.

This paper advances the current state-of-the-art along two axes. First, it provides a standard methodology for analyzing the economic impact of flights and new airport routes. Subsequently, the methodology is applied to the tourist case studies cited above in order to verify the adaptability of our approach and, in particular, of the AirCAST framework to different characteristics of the tourist market. The key contribution of this paper is that it constitutes the first study to consider the potential demand for the Italian tourist market [8]. The methodology presented can be extended to other cases such as mall locations in the Mass Retail Channel management, electric charge spot locations, and satellite depot locations in City Logistics applications [9–11]. These examples have several specific characteristics in common with the problem presented in this paper. All of them deal with complex systems characterized by strong spatial interactions between several stakeholders and users, which are affected by probabilistic behaviors. Moreover, all the above mentioned applications usually have a large set of available data collected by authorities or marketing companies. These data are normally aggregated and statistically valid for large geographical areas only. However, the same data are difficult to collect and estimate when considering smaller areas (such as urban areas in City Logistics and Mass Retail Channel, Regional air traffic, etc.). Furthermore, in this last case, data are strongly affected by uncertainty due to several factors (different customer segmentations, seasonal demand effects, partial overlapping of the catchment areas). The effects of the stochastic sources, when moving from large to medium-sized and small areas, become so relevant that they cannot be surrogated or relaxed and need to be explicitly considered.

This issue introduces the second direction of this paper: dealing with the uncertainty of some parameters in nonlinear models, and Multinomial Logit models in particular. Our work shows how this can be done by incorporating nonlinear programming methods into a simulation-optimization scheme. Mixed Integer Linear Problems are normally used as the optimization blocks in simulation-based optimization methods. This is due to the presence of general-purpose commercial and open-source solvers and modeling languages. Furthermore, the reduced sensitivity of the linear optimization models in terms of efficiency and effectiveness when the simulation module generates different operational scenarios is also a consideration [12–14]. In our case, the choice of Logit-based non-linear models for the optimization part is due to the vast literature in Discrete Choice models for modeling air demand, even if the method presented in this paper is, to our knowledge, the first example of incorporating a Logit-based optimization model in a simulation-optimization framework [15]. In fact, differently to other Multinomial Logit model applications, the peculiarities of the system under study, which presents several airports with partially overlapping catchment areas, forced us to extend the Multinomial Logit models to a stochastic version where the potential passenger demands are uncertain.

The paper is organized as follows. Section 2 gives an insight to the problem as well as a literature review on the issue. The overall scheme of the AirCAST and the model used in the framework are reported on Section 3. Case studies on the summer and winter tourism market are presented in Section 4 and 5, respectively. All the results have been validated by BDS s.r.l., an Italian consultancy company leader in customer satisfaction, customer profiling and airport management consulting. Finally, Section 6 presents the conclusions.

2 Problem Definition and State-of-the-art

Let us consider a set of airports and their flights as well as their flight schedule and overall passenger flows of each flight connection. Moreover, we consider a set of tourism areas, directly connected with airports, about which we know the accommodation and travel costs. Furthermore, we define the tourist perception of the area, in terms of number of hotels, quality of public services and access modes. Airports and tourist areas compose the air transportation system under analysis.

Passengers in the catchment area of each airport are unknown, but some forecasts on this data can be deduced from public database [3]. Then, the number of passengers is a stochastic variable with unknown probability distribution. For each flight, we deduce the mean cost paid by a single passenger for taking the flight, as well as the quality parameters of the airports. More in detail, the quality involves the time needed to reach the airport from the nearby areas and the time interval required to perform internal operations such as security checks and luggage delivery.

Our aim is to predict the passenger flows and the economic impact on the tourism areas caused by the changes of existing flight schedules or by the opening of a new route between a pair of airports. With this purpose, the present paper provides a standard methodology to assess the relationship between the air transport sector and the tourism market.

While several applications of Multinomial Logit Models can be found in other research fields, such as location and transportation [16–19], the literature on airport-choice modeling mostly focused on large and hub airports [15]. In particular, latest papers consider two geographical areas: the San Francisco bay area and the United Kingdom one. For what concerns the San Francisco bay area, Nested Logit models based analysis on the correlation between the choice of airport and airline [20] and on the sensitivity to the airport access mode on the user choice [21]. More recent studies introduced Mixed Multinomial Logit models for analyzing the joint choice of airport, airline, access modes and random taste heterogeneity [22–24]. Multinomial Logit Models has been realized for airport choice in the UK in order to study the most important attraction factors to airports [25, 26] and market share forecasts for a new airport [27]. More recently, a Cross-Nested Logit model has been introduced in order to model the choice of airport, airline and access-mode on the Greater London area, showing improvements over the previous Nested and Multinomial Logit models [28].

These methods show two main drawbacks. First, they focus on specific typologies of airports (large-sized and hubs) without taking into account challenging settings such as the competition of regional airports. In fact, by considering large airports/hubs, the geographic overlapping of the catchment areas is so limited that can be ignored. Thus, the mostly part of the cited papers deals with a single catchment area only. Then, this limits the possibility to apply the same models and solving methods to systems characterized by medium sized and regional airports placed in a geographic region with a high density of such airports, where the geographical overlapping of the catchment areas plays a significant role [7, 29, 30]. Second, in the previous works the only source of stochasticity is the passenger choice. This assumption is sufficient when only hubs and large airports that maintain historical data are considered in the system. However, dealing with many smaller airports, the system should explicitly take into account other source of uncertainty due to lacks of data and data estimation. One of the most significant sources of uncertainty is about the measure of the potential demand of a new route. This demand is usually done by forecasting and/or surveys, which can lead to overestimating such a demand. This is particularly true in smaller airports, where the overlapping of the catchment areas and the partial information about the ticketing introduce relevant errors in the demand forecasting [31]. Thus, at least this source of incertitude should be taken into account in the solution method. In addition, these studies are more focused on the pure transportation issue and they marginally consider the financial impact of the changes in the airport schedules on the surrounding area. Furthermore, they do not give a detailed description of how the economic data have been gathered, making difficult to replicate the process [7].

From the point of view of tourism management, several papers deal with demand modeling and forecasting. Unfortunately, they consider large macro-areas (usually a whole country), while, as highlighted in [8], no study considers the Italian tourism. Moreover, these papers marginally consider the transportation issues and their effects on the demand splitting between different regions (see [8] for a survey). Thus, to our knowledge, this paper is the first study dealing with both transportation and tourist issues at the same time.

3 The AirCAST Framework

The basis of this paper is an economic and spatial interaction Logit model aimed at modeling the dependency between the players of the air transportation system. This kind of models show an high adaptability and a wide efficiency, demonstrated in many fields, including transport and retail [32]. Moreover, in this paper the method is applied to areas with a large number of regional airports, where the catchment areas are strongly intersected each other. Modeling the system requires the introduction of an analytical tool able to evaluate the behavior of the entire system and to deal with uncertainties of the system. As stated in the Introduction, to deal with the uncertainty of the parameters, and the demand in particular, we defined a simulation-optimization method integrating a nonlinear model with a discrete event simulator. This approach is able to make an analysis of the financial impacts of a change in the flight schedule or in the features of one or more airports interacting in a given area. Uncertainty is managed by computing the Expected Value of the Perfect Information (EVPI) [33]. In the present version of the method, called AirCAST, EVPI is managed by the simulation module and computed by means of a Monte Carlo simulation (see Section 3.2).

AirCAST, depicted in Figure 1, is composed by a simulator implementing a Monte Carlo method, a Logit-based optimization block, a module for georeferenc-

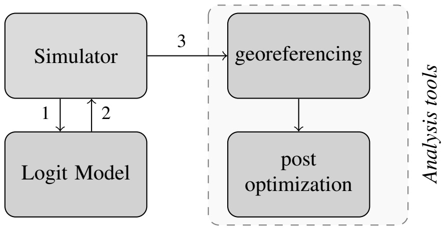


Fig. 1 Block diagram of the framework

ing the data and a post-optimization software. In more detail, the method works as follows:

- The Monte Carlo simulation module repeats the following process for a given number $|I|$ of iterations.
  - Given the distribution of the total supply of each airport and how it is split among the existing flights of the airport, the simulator generates a series of passengers demand scenarios.
    - The Logit model uses each scenario to calibrate the passengers flow matrix.
    - One or more changes are introduced in the passengers demand and the new passenger flows are forecasted.
  - A first statistical analysis on the aggregate results of the scenario-based optimization of a single iteration of the Monte Carlo simulation is performed. These data are used in order to check if one or more unrealistic or extreme situations have been introduced in the simulation itself.
  - In order to make a more accurate definition of travel times and cost matrices, the georeference module is used. The georeference feature is implemented by means of Google Earth APIs and it is also used to graphically represent the results of the AirCAST itself.
- The distribution of the simulation-based optimization solutions is computed and a series of statistical data are collected (including the EVPI).
- A post-optimization software module is devoted to choose the best features of the new flight (e.g. the kind of aircraft and the number of flight). Given the estimated passenger flows, the type of flight (domestic, European, etc.), and the constraints of single airports in terms of landing bays and aircraft landing capability, the module gives a list of possible aircraft types and schedules.

In the following, we focus our discussion on the Logit model, highlighting the optimization core of the framework (see subsection 3.1), and we give more details about the Monte Carlo method implemented by the simulation block (see subsection 3.2).

3.1 Two-level Logit model

The framework supports different variants of transportation Logit models. In this paper we will use the intermodal Logit model presented in [7]. The model is a two-level

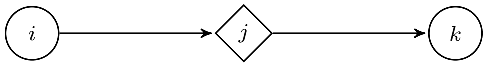


Fig. 2 A representational of a two-level transportation networks

model and represents intermodal or transshipment transportation networks. The structure of the system is showed in Figure 2, where airports and their catchment areas are represented by the transshipment nodes (indexed by j), while flows are originated from the different countries (indexed by i). Finally, the final tourist destinations are indexed by k. In this study, the set of destinations contains only one macro destination representing the tourist market in Italy, which collects all flows. Thus, the interpretation of the flow from the origin i to the destination k through the intermediate point j is the amount of tourists from country i using airport j to spend their vacation in the destination k. In the following, we refer to this model as two-level Logit, which measures the financial impact of a new route on destination areas.

Throughout this section x, $\boldsymbol{x}$ and $\mathbf{X}$ denote a generic scalar, a vector (lowercase and boldface) and a matrix (uppercase and boldface), respectively. Superscript $\widehat{}$ and $\widetilde{}$ will stand for the observed and estimated values, i.e. the values given to the Logit model as input by the simulator and flows obtained after a parameter calibration, respectively.

Given a set of n origins, a set of m intermediate points and a set of l destinations, let us define

- $i \in \{1,\ldots,n\}$: index of the countries origin of the tourist flows;
- $j \in \{1,\ldots,m\}$: index of the intermediate points, i.e. the airports under study and their catchment areas;
- $k \in \{1,\ldots,l\}$: index of the destinations, i.e. a macro area representing the whole tourist demand of the system;
- observed flows matrix $\widehat{\mathbf{T}} \in \mathbb{R}^{n\times m\times l}$, i.e. elements $\widehat{\mathbf{T}}_{ij}^{k}$ give the number of passengers depart between i and k using the intermediate point j;
- generalized flight cost matrix $\widehat{\mathbf{C_f}} \in \mathbb{R}^{n\times m}$, i.e. elements $\widehat{C_f}_{ij}$ give the travel cost of the flight arriving in j and departing from the airport i;
- generalized travel cost matrix $\widehat{\mathbf{C_t}} \in \mathbb{R}^{m\times l}$, i.e. elements $\widehat{C_t}_{j}^{k}$ give a possible travel cost between the intermediate point j and the destination k and an eventual subsistence cost in the destination k;
- average total cost $\overline{c} = \dfrac{\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{l} \widehat{T}_{ij}^{k}\left(\widehat{C_f}_{ij}+\widehat{C_t}_{j}^{k}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{l} \widehat{T}_{ij}^{k}}$.

Moreover, we define the set of destination-dependent supply vectors $\boldsymbol{o}^k \in \mathbb{R}^n$ of the origins, the total number of passengers $\boldsymbol{d} \in \mathbb{R}^m$ at the intermediate points, and the total demand $\boldsymbol{r} \in \mathbb{R}^l$ of the destinations as follows:

$$o_i^k = \sum_{j=1}^{m} \widehat{T}_{ij}^{k} \quad \forall i,k \tag{1}$$

$$d_j = \sum_{k=1}^{l} \sum_{i=1}^{n} \widehat{T}_{ij}^{k} \quad \forall j \tag{2}$$

$$r_k = \sum_{i=1}^{n} \sum_{j=1}^{m} \widehat{T}_{ij}^{k} \quad \forall k \tag{3}$$

The model aims at estimating of the flows matrix $\widetilde{\mathbf{T}}$ by considering both the avionic characteristics, as well as the peculiar features of the destinations. Moreover, it should be able to reproduce the matrix of the observed flows $\widehat{\mathbf{T}}$.

The two-level Logit model may be formulated as

$$\widetilde{T}_{ij}^{k} = o_i^k \cdot \frac{e^{\alpha_w \widehat{\Pi}_j + \delta_w} \cdot e^{\alpha_\psi \widehat{\Omega}_k + \delta_\psi} \cdot e^{-\beta\left(\widehat{C_f}_{ij} + \widehat{C_t}_j^k\right)}}{\sum\limits_{k=1}^{l} \sum\limits_{j=1}^{m} \left[e^{\alpha_w \widehat{\Pi}_j + \delta_w} \cdot e^{\alpha_\psi \widehat{\Omega}_k + \delta_\psi} \cdot e^{-\beta\left(\widehat{C_f}_{ij} + \widehat{C_t}_j^k\right)} \right]}. \tag{4}$$

subject to

$$d_j - \sum_{i=1}^{n} \sum_{k=1}^{l} \widetilde{T}_{ij}^{k} = 0 \quad \forall j \in \{1, \ldots, m\} \tag{5}$$

$$r_k - \sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{T}_{ij}^{k} = 0 \quad \forall k \in \{1, \ldots, l\} \tag{6}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \left(\widehat{C_f}_{ij} + \widehat{C_t}_j^k - \overline{c} \right) \widetilde{T}_{ij}^{k} = 0 \quad \forall k \in \{1, \ldots, l\} \tag{7}$$

The model (4)-(7) considers three main criteria of choice: the cost of stay plus the travel (β), the economic and structural features of the corresponding intermediate points ($\widehat{\mathbf{\Pi}}$) and the economic and structural characteristics of the destinations ($\widehat{\mathbf{\Omega}}$). In particular, $\widehat{\mathbf{\Pi}}$ includes the airport facilities and efficiency ($\boldsymbol{\pi_1}$) and the tourist area attractiveness ($\boldsymbol{\pi_2}$).

Following [7], the parameters α_w, α_ψ, and β are calibrated in order to reproduce the observed flows $\widehat{\mathbf{T}}$. This is done by means of the following calibration phase:

- Initialization. Set $\beta^0 = \frac{2}{\overline{c}}$ and $\alpha_\psi^0 = 1$
- While the values of β, α_w and α_ψ changes over a given threshold or a maximum number of iterations is not reached
  - Given $\beta^{\tau-1}$ and ${\alpha_\psi}^{\tau-1}$, find the values of α_w^τ which are the roots of the system (5).
  - Given $\beta^{\tau-1}$ and α_w^τ, find the values of α_ψ^τ which are the roots of the system (6).
  - Given α_w^τ and α_ψ^τ, find the values of β^τ which are the roots of the system (7).

The computation of α_w, α_ψ and β is implemented in each step is implemented by means of a fixed point algorithm. Notice that the procedure of system parameter estimation usually stops when the values of the parameters themselves at iteration τ do not differ from the values of iteration $\tau - 1$ more than a given threshold, set to 10^{-3}.

3.2 Simulator

Given the two-level Logit model, we can compute the new passenger flows by introducing the changes (e.g. the opening of a new flight or a flight cost change). While the model (4)-(7) is able to deal with uncertainties due to passengers choices, it considers all the parameters (and the vector $\boldsymbol{r}$ in particular) as deterministic. As stated in Section 2, this is the typical approximation done in the literature focusing on big airports, but it is not suitable when considering medium and small sized ones. Moreover, the high volatility of the potential demand due to the tourist market increases this effect. For this reason, the simulation model considers a stochastic version of model (4)-(7) where the component of vector $\boldsymbol{r}$, which defines the potential demand of the the destination k is affected by a stochastic oscillation. To handle this, a modular simulator has been developed in order to perform a scenario-based simulation, which is integrated with the optimization block.

In more details, the simulation module computes the EVPI of model (4)-(7) with the stochastic oscillation of the potential demand by means of a Monte Carlo method. Our Monte Carlo simulation repeats I times the following overall process:

- Identify a set of potential new flights, their mean expected potential demand of destination k and a distribution for the potential demand oscillation.
- For each new flight
  - Create S scenarios with the random demands $\boldsymbol{r}$. Consequently, change the observed flows matrix $\widehat{\mathbf{T}}$.
  - For each scenario $s \in S$, calibrate the values of α_w, α_ψ and β by means of the Two-level Logit model.
  - Given the optimal values of the parameters, introduce the new flight and obtain the new flows. The changes of the flows are computed as the difference between the flows $\widetilde{\mathbf{T}}$, obtained after introducing the new flight schedules, and the observed flows $\widehat{\mathbf{T}}$. This gives the new catchment area of airports in terms of passengers, as well as a forecast of flows for each flight.
  - Given the scenario optima, compute the expected value of the flow of the new flight.
  - Compute the distribution of the expected value of the flow of the newly introduced flight.
- Finally, by means of a post optimization procedure process, choose the best new flight (the flight presenting the best expected flow from the given origin to the airport under study) and choose the parameters of the flight selected, i.e. flight frequency, airplane size, ticket cost according to a prefixed vector of flight characteristics.

In order to obtain the most reliable results of the Monte Carlo simulation, we performed a set of tuning testbeds. The values for the parameters I (number of repetitions) and $|S|$ (number of scenarios) have been set such that the standard deviation of the distribution of the expected value was less than 1% of its mean. These values were $I = 10$ and $|S| = 30$.

Note that the model can evaluate more than one change in the system at a time. In particular, it is interesting that AirCAST allows to simulate reaction policies of existing airports by assigning different values to their economic and structural features. More in detail, an airport could chose to reduce its prices in order to face the competition of the new flight or the price of the tourist accommodation of the surrounding area.

In order to calibrate the model and to simulate the changes due to the introduction of a new schedule we need to feed the model with the following input data: number of arrivals registered in tourist facilities, cost of the flight, cost of accommodation, cost for the rental car, presence of the direct flight and the accommodation costs. This information is the basis needed to estimate the financial impact of the schedule changes.

In the following sections, we present how the different quantities can be deduced from public database and how the simulated results are analyzed.

4 Economic Impact of Cagliari Airport Routes: the Summer Tourism Market in Sardinia

In Sardinia there are three airports: Alghero, located in the north-west of the island in the province of Sassari, Olbia Costa Smeralda, in the province of Olbia-Tempio, situated in the north-east, and Cagliari (CAG in the following), in the southern area. Cagliari is the most important airport in the island in terms of traffic and size. It operates about 50% of Sardinia air traffic and can serve up to 4 million passengers/year. In 2009, thanks to consolidation of national and international direct links and the opening of 21 new routes, the CAG Airport has reached for the first time the 3 million passengers mark, 13% more than in the previous year.

The CAG Airport development strategy aims at identifying new potential customers that would increase airport profitability and would provide direct and indirect economic benefits to the local area. In order to identify potential groups of users, it is essential to consider the characteristics and attractiveness of the area. These aspects may confer a particular specialization at the airport.

Sardinia is an important destination for summer vacations for Italian and European tourists. For this reason, airports in Sardinia have the majority of their air traffic concentrated during the summer and closely linked to tourism. To identify new potential routes to open, the starting point is the analysis of Sardinia airports data to outline a general idea of the airport and situation of the region. Historical data [34, 35] show that the distribution of flights is quite different. The only routes that are shared by all airports are from Austria, Belgium, France, Germany, Great Britain and Spain. These data are confirmed by the analysis of the current schedules and by an estimation of the loading factors of the airplanes given by the mean loading factors of the past three years [34–36]. On some routes, the offer of flights is small or even absent. In particular, Cagliari does not offer any direct flight with countries of Northern Europe such as Sweden, Norway, Finland, and the Netherlands.

4.1 Analysis of the tourists flows

Due to the strong dependence between the presence of direct flights and the impact on tourism and aviation, we compare the airport data with the analysis of tourism in Sardinia. The analysis is carried by means of the data by ISTAT and it shows that in 2009 more than 60% of tourists from Finland, Sweden, Denmark and Ireland stayed in the macro area of Alghero. Infact, Alghero operates almost exclusively the connections to and from these countries [37, 38]. Besides, 27% of tourists from the Netherlands stay in Cagliari, even though it lacks an air link, while only 24% goes to Alghero, which handles 73% of connections Sardinia-Netherlands. Thus, it follows that the opening of new routes to the countries of Northern Europe and to Netherlands could be a potential development for the airport of Cagliari. In addition, to prefer Cagliari as tourist destination are mostly people from Russia, Eastern Europe (even if they constitute a very small amount), Belgium and United Kingdom. In particular, 68% of Russian tourists in Sardinia went to Cagliari in 2009. This percentage corresponds to more than 60 thousand Russians registered in the tourist infrastructures of the macro area of the capital.

The introduction of a route Cagliari-Russia represents a further and more interesting development for the airport of Cagliari. Providing this direct connection, Cagliari could reach a large pool of potential customers, distinguishing itself from the airports of Olbia and Alghero, which do not handle any connections with any of Russian airports. This new potential flight is not going to establish a competition in air traffic with the two other airports in Sardinia, but rather expands the scale of competition at airports in other regions (and therefore defined external competitors).

Examining the tourist data of Russia, Russian people choosing Italy as their holiday destination are concentrated especially in Emilia-Romagna, with 118,850 arrivals 2009 [37], 75% is related to the province of Rimini. The airport of Rimini has in fact many direct links with Russia. For this reason, the new connection makes Rimini the first competitor of CAG Airport, and from that emerge the necessity of adding Rimini as an arrival airports in the model.

4.2 Input data and their economic aspects

The aim of this case study is to predict the effect of the opening of one or more new routes on the flow of passengers from chosen origins to CAG Airport and to measure the economic impact on the closest area. The simulations performed on CAG Airport aim to establish the route, the type of airline (regular or low cost airline) and the season (high or low) that allows attracting the highest number of tourists. Basing on all considerations explained before, we choose Russia, Northern Europe, Netherlands and Central Europe as origins in the model, while the cluster of arrival airports and macro-areas for the tourist holidays has been identified in Cagliari, Olbia and Rimini. The tourist flow to the Alghero area is not comparable with the others and was not included in the simulation.

The only macro destination is Italy. In this case, Italy is a fictitious destination, necessary in order to allow exchanging of passengers between the three airports

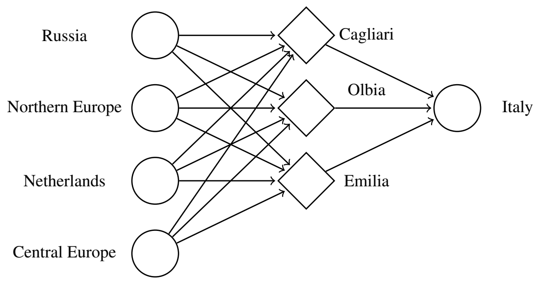


Fig. 3 Representation of the system model used in this study

(second-level nodes). In this way, the model reallocates flows from one airport to another, estimating how many tourists CAG could gain by taking them off at Rimini and Olbia.

The cost of accommodation has been estimated by combining the average price of hotels in the concerned area and the average number of overnight stays of tourists. The average price of hotels was determined with telephone and online surveys of the room price to the several hotels during both high and low season. Instead, the ISTAT tourist analysis shows that a holiday in Sardinia usually lasts seven nights, while in Rimini, in medium, four nights.

The choice criteria considered by model (4)-(7) are one for the airport facilities and efficiency and one for the socio-economic situation of the tourist region around each airport. The airport criterion depends on the presence or absence of direct flights between the airport and the origins and on a measure of customer satisfaction of the destination. More in detail, the satisfaction of customers is related to the ground transportation from the arrival airport, the services offered to tourists and the cost of subsistence obtained by averaging the prices of hotels. These data have been collected by BDS Consulting s.r.l., an Italian consultancy company specialized in airport management.

In order to identify potential overlapping of the catchment areas of the different airports, we mapped the results of a projection of the tourist data, identifying the locations easily reachable from the airports. This analysis, performed by data collected by passengers surveys at the airport and a crosscheck of the destination position with Google Maps, confirmed that, from the tourist point of view, the catchment areas are poorly overlapping [2]. Thus, the tourist destinations, represented by the set of possible destination points, are collapsed in a macro destination representing Sardinia and the eventual other tourist areas considered in this study, e.g. Rimini area (See Figure 3).

The economic impact on the territory has been estimated considering at first all the expenses that are supposed to be common to every tourist. To determinate the cost of the accommodation for each location, we computed an average cost of a typical holiday by means of a telephone and online survey to several hotels. In our survey we considered the price during both the high and the low season.

By [37, 38], the typical holiday has the following characteristics:

- People who go on holiday: 2 adults;
- Accommodation type: Hotel;
- Hotel stars: three stars or four stars hotel;
- Guest Rooms: double standard room, breakfast and dinner included;
- Duration: 7 nights (one week);
- Period: a week in July and August, high season.

Comparing the estimated costs related to the accommodation with same conditions, in Rimini tourist facilities are cheaper than in Sardinia. This advantage is also taken into account in the input data indicating the tourist attractiveness. In addition, the cost of accommodation is increased by the cost of car rental services. In fact, the peculiar geography of Sardinia makes necessary for tourists to rent a car to move from one location to another one in the island. This cost contributes to value the revenues on the Sardinia territory from direct effects of the opening of new route. On the contrary, the economic impact measured by the model does not consider the impulsive purchases like souvenirs or gadgets.

4.3 Analysis of the results

According to the results presented in Sections 4.1 and 4.2, we focus our what-if analysis on the opening of a direct route between Russia and CAG airport. Currently, the connection with Russia requires at least one stop at Rome Fiumicino airport. In more detail, we test the following cases:

- CAG Airport opens a direct flight to Russia in the high season (July and August represent the period of strongest competition between Cagliari and Rimini) and in the low season (June, September, and October represent the period during which Sardinia continues to be attractive thanks to its favorable climate, while Rimini significantly decreases its attractiveness). Moreover, we measure of the reaction of Olbia Airport, which opens a direct flight to Russia.
- We make a sensitivity analysis of the system in order to estimate the changes of the potential demand. In more detail, we consider two types of demand: *High price* (HP) and *Medium Price* (MP) demand. Moreover, we focus on the relationship between the demand elasticity and the most important driver of the system, i.e. the total cost of the tourist stay. This approach gives us the chance to model different behaviors for different market segments.

To simulate the first set of cases, a reduction of the cost of the ticket is considered. The flows due to the opening of the direct Cagliari-Russia flight are shown in Table 1.

The increase of Russian tourists in the Cagliari area is estimated to be about 90% in the high season. From an economic point of view, revenues on the territory from direct effects can be valued at about 12 million euros. Rimini airport, despite being the competitor that has contributed most to the flow of the new avionics offer, cannot respond to reductions of tourists as it already offers a direct flight from Russia.

Let us now assume that the new route between Russia and Cagliari has become a reality and Olbia opens a direct flight from Russia to address the cascading effects

Table 1 New Russia-CAG flight in high season, reaction of Olbia and low season case. The table reports the observed flow ($\mathbf{T}$), the flow after the opening of the direct flight Cagliari-Russia ($\mathbf{T}_D$) and its variation ($\Delta\mathbf{T}_D$) in the three cases

		Cagliari	**Olbia**	**Rimini**
	$\mathbf{T}$	6908	4534	74705
High	$\mathbf{T}_D$	13125	4216	68728
season	$\Delta\mathbf{T}_D$	+90%	-7%	-8%
Reaction	$\mathbf{T}_D$	12158	10156	63499
of Olbia	$\Delta\mathbf{T}_D$	+76%	+124%	-15%
Low	$\mathbf{T}_D$	22451	3627	59764
season	$\Delta\mathbf{T}_D$	+225%	-20%	-20%

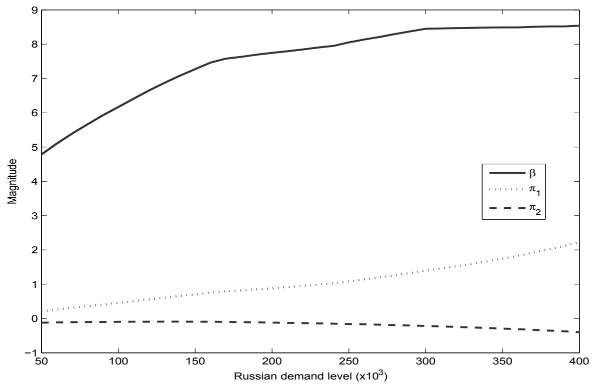


Fig. 4 Value of the weights of choice criteria in the summer tourism market when the potential demand varies

of the new offer of CAG Airport. This reaction would lead to competition within the island itself. Conversely, the simulation results shows an increase of tourists in the Olbia area of 124% and a negligible variation in the close area of Cagliari. Consequently, the two flights can coexist.

The last simulation consists in opening a direct route between Russia and Cagliari in the low season which involves, in addition to the reduction of the ticket cost, a decrease of the cost of subsistence in the territory. In fact, in this period hotels offer some discounts on their prices. The choice of this period also fits with the habits of Russian tourists in terms of holiday period. The resulting flow shows an increase of Russian tourists by 225% which, from a financial point of view, corresponds to an income of about 20 million euros.

In the second part of this result analysis, we analyze the sensitivity of flows between levels of the MP and HP demands. In particular, we discuss the proportion 80% MP and 20% HP, that corresponds to the actual proportion of the Russian demand levels in the summer market. In addition, the pure MP and pure HP cases are considered in this analysis, but both give poor results. In the sensitivity analysis, the Russian demand levels are drawn from the range [50.000, 400.000].

The summer tourism market shows a high sensitivity to the cost of stay plus travel and, for a large value of the Russian demand, to airport efficiency. Both these parameters increase according to the demand level, but β tends to become constant when the demand reaches 300.000 units. In particular, this demand value corresponds to the ISTAT estimations for the number of Russians in the Italian seaside areas.

Conversely, the attractiveness factor shows a negative trend. This is due to the increase of the demand level and to the difficulty of satisfying the needs of the new catchment area. Moreover, the resulting substitution of HP tourism with MP tourist brings to a negative net return and to the increase of the cost driver.

Figure 5 shows how the flows change according to different demand levels. Each sub-figure represents a different total cost level (C_{tot}) for staying and traveling in the Cagliari area. More precisely, we consider 4 cases: the current weekly price in high season (2400 Euros), the introduction of a direct Cagliari-Russia flight (2100 Euros), the weekly cost in low season with a direct flight (1900 Euros) and the limit case (1700 Euros) in which the weekly costs in Sardinia equal those in Emilia Romagna (Rimini). The last case is not realistic, but corresponds to the upper bound of the tourists flows yield by means of the Russia flight.

The four cases show different but consistent results. Cagliari considerably increases the flow of tourists and has the ability to attract new clients in the HP segment. This flow component saturates at a level of demand of about 300.000, where the curve starts to decrease. This means that the system is sensitive to the attractiveness driver of the destinations.

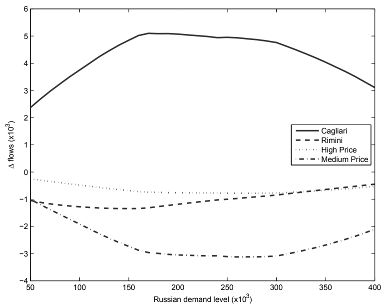
Considering the limit case (C_{tot} = 1700), the flow has the biggest variations and increases until a level of about 200.000, where flows reach saturation. The case with C_{tot} = 2100, that describes a more realistic case for the CAG Airport is more interesting. Here the numbers are one order of magnitude smaller and the Russian flow to the Cagliari area increases to a level of about 40.000 tourists.

The results of this case show a potential increase of Russian tourists in Cagliari of about 3 times the present level, and a decrease of about 16% in the Rimini area. The simulation results are not intended to be an exact measure, but rather they reveal an area for further investigation. Furthermore, no constraints on the tourist capacity of destinations are considered.

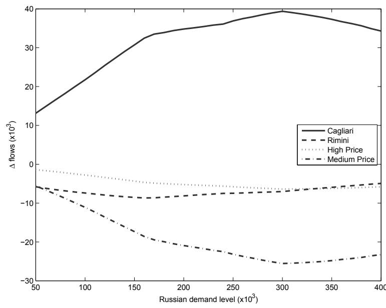
Again, we should take into account other costs such as advertising and promotion that would be necessary to sustain the new flow. The new Cagliari-Moscow flight needs a consistent financial return for both the local agencies and the air company to become a sustainable route.

Finally, in peak season, at least in the short term, there is no extra space for new tourists. This implies that the Russian flow will substitute other flows. This fact may not bring to an advantage, but it should be considered that Russian tourists are usually big spenders.

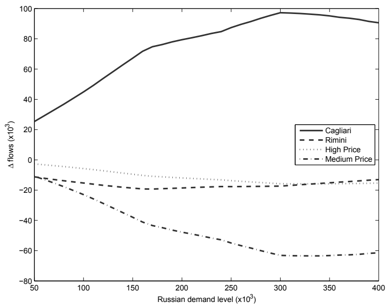
In monetary terms, the estimated revenues are about 40 million Euros, not taking into account other extra expenditures, such as restaurants, museums, etc. The resulting estimated flow of tourists from Russia to the Cagliari area is of 25.000 arrivals per year. A direct daily flight is not sustainable with this flow. A seasonal/charter flight could suit both tourists' needs and have an adequate load factor.



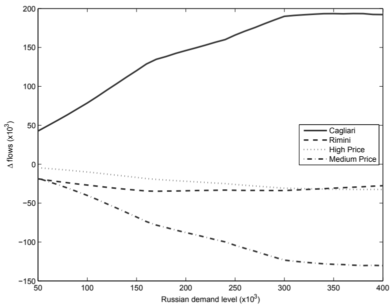
(a) Variations of tourist flows for C_{tot} 2400 Euro



(b) Variations of tourist flows for C_{tot} 2100 Euro



(c) Variations of tourist flows for C_{tot} 1900 Euro



(d) Variations of tourist flows for C_{tot} 1700 Euro

Fig. 5 Flows for Cagliari and Rimini when MP and HP are in proportion of 80/20 demand levels for different total cost levels

5 Economic Impact of Torino Caselle Airport Routes: the Winter Tourism Market in Piedmont

In this section, we apply the same methodology used for the Sardinia case to a completely different market: the winter tourism. The winter tourism in Italy involves the 11.6% of foreign tourists. There are over 25.000 accommodation facilities for a total capacity that exceeds 615.000 tourists. The regions of Northern Italy cover most of this tourism.

Considering the strong homogeneity of mountain ski locations of Northern Italy and their geographical proximity, we analyzed about 150 locations of 12 provinces. However, as the result of a first study on the relevance of foreign tourist flows, six provinces are considered in this analysis: Aosta, Torino, Sondrio, Belluno, Trento and Bolzano.

The number of tourists in the provinces is affected by several factors. In particular, the most relevant one is the number of ski resorts in each province. Trento and Bolzano have the highest number of ski resorts (about 40 each), followed by Aosta and Sondrio (about 25 each), Belluno (about 15), and finally Turin (about 10). This also gives us a measure of the overall length of ski runs and the number of hotels. We should also mention that the provinces of Trento, Bolzano and Belluno have made great efforts over time to promote the Dolomiti as a brand.

The provinces mentioned above have the reputation of pricey and charming. Aosta and Sondrio are well known in the Italian panorama and have good reputation for ski resorts, thus they are as charming as the others. Turin had some boost from the 2006 Olympic games, but still does not promote enough its ski resorts. However, it is interesting to note that the prices of stay are similar in the various provinces.

Considering these provinces, we selected all major airports in Northern Italy and all their direct links. The airports are: Turin, Milan Linate, Milan Malpensa, Bergamo Orio al Serio, Verona, Venice and Treviso. Note that the list lacks some airports in Northern Italy as Cuneo, Genova or Bolzano and does not considered foreign nearby airports. These airports are not included in the study because they show a minimal tourist traffic to Italian mountain provinces. The airports cited above generate an overall traffic of around 55 million passengers and are connected with approximately 150 destinations around the world.

5.1 Analysis of the tourists flows

Recalling that only tourists that use air transport are considered, in the winter tourism case, more than 80% of the foreign tourist flow is given from European countries. UK tourists account for almost 20% of our total. In the dataset Poland, Belgium, Swedish and USA present always a strong flow in the winter period. The last one is particularly important in the surrounding area of Turin. Finally, Russian tourists is evenly spread (in absolute means) across all the provinces except Turin [37, 38].

A good preliminary analysis of tourist flows must take into account both relative and absolute numbers. In facts, the provinces under study have very different overall flows: Turin is the smallest and has about 30.000 foreign tourists per year, while Trento and Bolzano are the biggest with about 400.000 foreign tourists per year.

Focusing on the province of Turin, it easy to note the unexpected different composition of the tourist flow. On one hand Turin has a much lower percentage of Russian, Polish and Swedish tourists (all about 2%). In particular, Polish tourists count for less than 2% in the Turin and Aosta area, while are more than 10% in average. The numbers for these tourists are very low (close to zero in some cases), so we should consider these groups as almost completely new potential tourists flows. On the other hand Turin has a high percentage of UK, and USA tourists (respectively 25% and 8%), with respect to an average of 15% and 5%. Although the percentage looks high, the absolute numbers are significantly lower than in the other provinces, thus looking as if an increase of this flow is possible. Between the two, USA looks even more interesting given the absence of a direct flight.

5.2 Input data and their economic aspects

The link airport-province is done looking at ski stations web sites, where information about local airports can be found. One airport can serve more than one province and one province can be served by several airports as well. Thus, the same airport can share its catchment areas with the other ones.

The Turin airport serves both the provinces of Turin and Aosta. The province of Sondrio has three airports in its catchment area: Milan Malpensa, Milan Linate and Bergamo Orio al Serio. Trento and Bolzano are both served by the Verona airport, and finally the Belluno province is served by the Venice and Treviso airports.

In order to identify what groups of tourists to study, we need to discard all the meaningless ones, in terms of numbers (i.e., too few to be economically significant) and in terms of distance. For instance, German tourists are discarded because they would rather choose the car rather than plane and therefore they choose Bolzano or Trento as their destination.

For these reasons the analysis is limited to a small group of origins: Belgium, Russia, Poland, Sweden, UK, and USA. The remaining origins are condensed in a group named World. Similarly to the Cagliari study, the touristic destinations are collapsed in a macro destination representing the North of Italy (see Figure 6).

The choice criteria considered in the simulations are one related to the social-economic situation of the mountain provinces and one for the airports accessibility. The accessibility concerns distances of airport from the surrounding locations. The socio-economic criterion is the measure of the customer satisfaction of the destination. It depends on the number of hotels, the presence of prestigious shops, the kilometers of ski slopes and the total number of tourists (including national tourism). The airport accessibility criterion takes into account the distance between airports and mountain locations of the covered provinces, the cost of any tolls, the number of provinces that are served by the airports and the size of these airports (i.e. the total number of flights).

The financial impact on the territory has been estimated considering the cost of the flight plus the accommodation and extra costs (i.e. weekly ski pass), not present in the summer market. To determine the cost for each location, we consider a typical holiday.

By [37], the typical holiday has the following characteristics :

- People who go on holiday: 2 adults;
- Accommodation type: Hotel;
- Hotel stars: three stars or four stars hotel;
- Guest Rooms: double standard room, breakfast and dinner included;
- Duration: 7 nights (one week)
- Period: a week in December, January and February, high season.

5.3 Analysis of the results

We consider six provinces served by seven airports for the winter tourism market in the North of Italy. We focus the analysis on two main aspects :

- The drivers of the Logit model in the winter market system. Recalling the choice criteria defined in Section 3.1, we denote with π_1 the airport driver, with π_2 the socio-economic attractiveness of the provinces and, finally, with β the cost driver of the winter holiday;

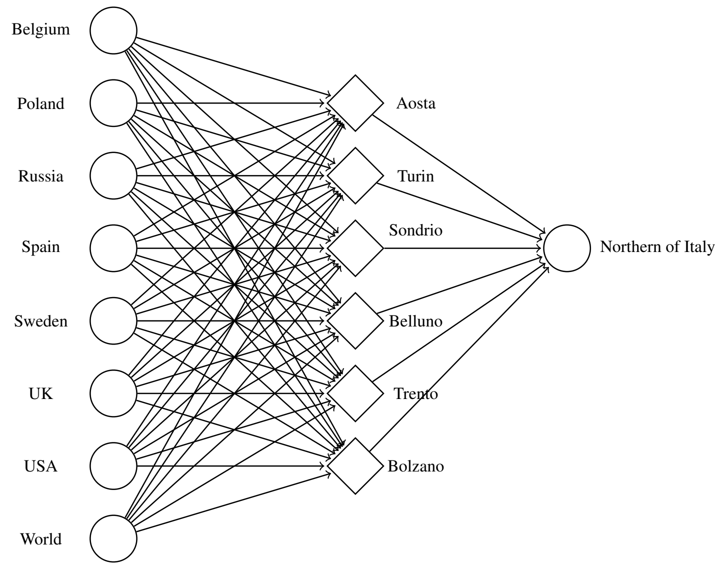


Fig. 6 Representation of the system used to study the winter tourism market

- The sensitivity of the system to the elasticity of the demand. More in detail, we consider a *Weakly Loyal* demand (WLD) in order to estimate the potential flows due to the introduction of changes in the system (i.e. new direct flight).

Figure 7 shows the importance of the driver of the winter market system when WLD is drawn from the range [10.000, 800.000]. Differently from what we observed in the summer tourism market, the cost factor is negligible due to the similarity of the price in the various provinces of the system. Conversely, the attractiveness of the destination (π_2) becomes the main driver of touristic flows, followed by the accessibility of the airport (π_1). Note that the decrease of the attractiveness factor due to the high WLD level cause the saturation of all drivers of the model.

Two important considerations arise: (1) the price elasticity of demand with respect to flight and stay costs is lower than in the summer tourism market and (2) customers in this market are more loyal and more work needs to be done to move tourist flows between destinations (i.e. expansion of the ski sloped and services for tourists).

Furthermore, several facts support this analysis:

- Extra costs (i.e., other than flight and stay) are much higher in the winter market (the ski-pass and the equipment rental costs, that could account for more than the whole stay plus flight costs).
- The type of tourists in this market is different than in the summer market. Usually just families with medium-high income spend winter holidays skiing, whether in the summer market the target is more heterogeneous.
- Finally tour operators are big players in this market. As stated before they package the entire holiday and tend to make strong agreements with destinations.

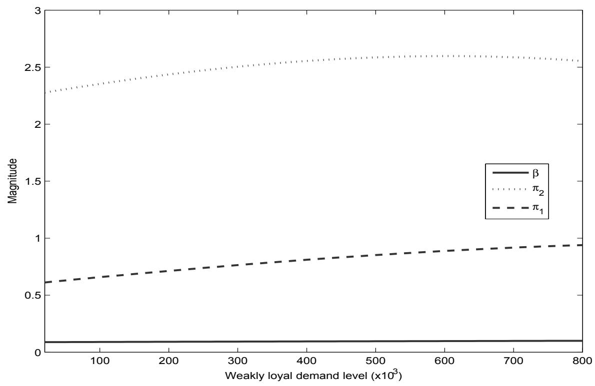


Fig. 7 Magnitude of model parameters in the winter tourism market

All this points lead to a market that naturally has more barriers than the summer market. High extra costs, loyal customers and tour operators are obstacles if one wants to increase its tourist flow.

From preliminary studies, we observed that the origin that only was worth to further investigate was USA. The changes we introduce during simulation are the increase of attractiveness for the Turin province and a direct flight on Turin Caselle as well. This implies a direct flight is also available for the Aosta province, since it is part of the catchment area of the Caselle airport. It is also plausible to think to a reduction of the flight ticket.

Summarizing, we consider four cases: (C_1) a minor expansion of Turin province, (C_2) a minor expansion of Turin province and the introduction of direct USA-Turin connection, (C_3) a major expansion of Turin province, (C_4) a major expansion of Turin province and the introduction of direct USA-Turin connection. Last two cases are less realistic in the short term because they involve a huge investment for renewing the main mountain resorts in the Turin's area and the expansion of ski facilities.

The simulated results are shown in the Table 2. The increase of the US tourists in the Turin province is estimated to be about 2 times the actual flow and 3 times when the direct flight is introduced. From an economic point of view, revenues on the territory from direct effect can be valued to about 9 million euros. The reductions of tourists in the other destinations are negligible and, difficultly, a reaction of competitors will be performed. Finally, cases C_3 and C_4 show a very promising results: the number of tourists from USA becomes about 4 and 7 times the actual presences.

More in detail, a tourist coming from USA does not perceive as very different going to ski in different locations in the North of Italy, while it does make a big difference for other tourists under study. Tour operators also have a major role. It is in fact very common to buy a package for winter holidays in Europe. This is especially true for European tourists. Thus, the tour operator packages the whole holiday, including flight, stay, ski pass, and equipment rental.

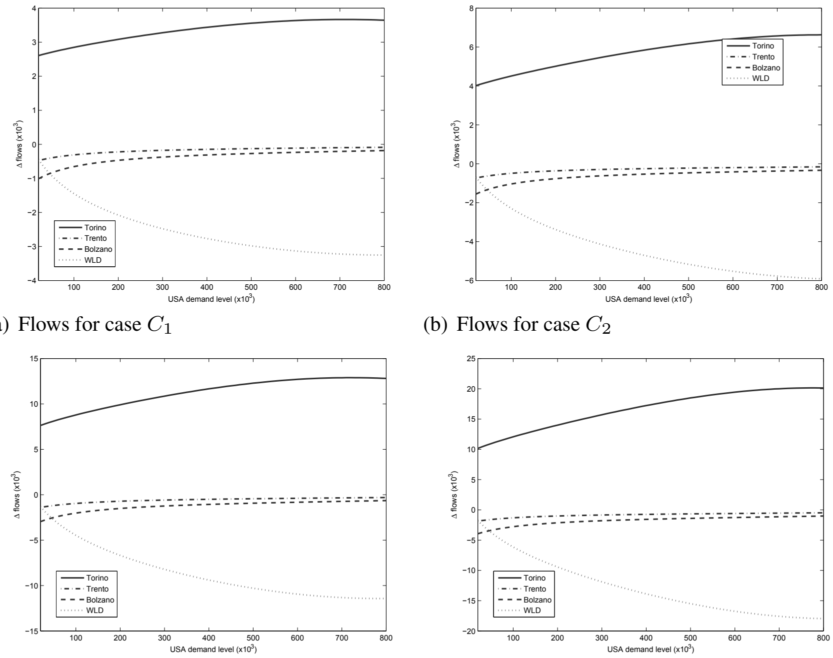
However there are very fewer tour operators that sell packaged winter holidays for such a long distance. This means that a tourist coming from USA will normally schedule his own trip, and this makes him more responsive to price changes and

Table 2 US flows after the changes on Turin Caselle and province. The table reports the observed flow ($\mathbf{T}$), the estimated flow in the cases ($\mathbf{T}_D$) and its variation ($\Delta\mathbf{T}_D$)

		Aosta	**Torino**	**Sodrio**	**Belluno**	**Trento**	**Bolzano**
	$\mathbf{T}$	6140	2327	2300	6556	10704	22629
C_1	$\mathbf{T}_D$	5761	5307	2158	6152	10044	21234
	$\Delta\mathbf{T}_D$	-6%	+128%	-6%	-6%	-6%	-6%
C_2	$\mathbf{T}_D$	5568	6826	2086	5946	9707	20522
	$\Delta\mathbf{T}_D$	-9%	+193%	-9%	-9%	-9%	-9%
C_3	$\mathbf{T}_D$	5011	11217	1877	5350	8735	18467
	$\Delta\mathbf{T}_D$	-18%	+382%	-18%	-18%	-18%	-18%
C_4	$\mathbf{T}_D$	4333	16550	1623	4627	7554	15969
	$\Delta\mathbf{T}_D$	-29%	+611%	-29%	-29%	-29%	-29%

direct flight. We should also mention that tourists from USA have a lower loyalty than others.

From these considerations, the sensitivity analysis is performed varying the WLD from USA for the four cases specified above. Figure 8 reports the more significant flow changes of the system. Simulations show a potential flow increase if Turin decides to target tourists from USA. As stated before these customers are less loyal and can be easily attracted. They also have a high sensitivity to a direct flight.



(a) Flows for case C_1

(b) Flows for case C_2

(c) Flows for case C_3

(d) Flows for case C_4

Fig. 8 Flows in winter market with the variation of demand level from USA

For obvious reasons a direct flight from Turin to USA cannot be hypothesized just on tourism analysis. Business men and many other targets (including inverse tourism) should be taken into account to prove the profitability of this route.

6 Conclusions

This study provides a systematic methodology, based on the AirCAST simulator, to assess the financial impact of a air transportation system. The proposed approach offers a road-map specifically devoted to identifying the key enabling factors of the tourist markets.

The potential of our methodology has been verified on two real tests on Italian airports, one on airport of Cagliari and one on the airport of Torino. The framework shows the capability to forecast new flows and the financial impacts due to the opening or the changing of the flight connections.

From a socio-economic point of view, the comparison between the summer and winter tourism market shows different behavior of customers and demand elasticity. The summer tourism market has a much higher price elasticity. Therefore, we should expected higher price competition in the summer market rather than in the winter market. However, it is difficult to isolate this effect from all the others. In fact, multiple factors interact in the system such as the attraction index, the direct flight and others that may have not been highlighted by the model. Indeed, the winter market is characterized by a strong loyalty of customer. In particular, the key lever of this market is the attractiveness of the destinations. Focusing on the transportation factors, we can clearly see that direct flights always have a strong weight in the choice.

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