Accessibility to Italian remote regions: comparison among different transport alternatives

Antonio Laurino[a], Paolo Beria[a], Andrea Debernardi[b], Emanuele Ferrara[b],

[a] Department of Architecture and Urban Studies (DAStU), Politecnico di Milano, Italy
Phone +39 02 2399 5424, antonio.laurino@polimi.it, paolo.beria@polimi.it
[b] Studio META, Via Magenta 15, Monza, Italy debernardi.andrea@gmail.com, emanuele.ferrara@metaplanning.it

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Historically, for geographically disadvantaged areas or those with a low level of infrastructure, air transport services are often considered to be lifeline services. In the last decades, investments in the airport sector have been promoted as a way to increase accessibility to many Italian regions. On the other side, transport services have also witnessed important changes as the entrance of low cost carriers, the development of high speed railway services or the liberalization of the long distance coach transport sector. These services, together with an improved intermodality, could provide an alternative to access areas of the country.
The paper, adopting a policymaker perspective, studies the different transport alternatives available to connect the zones in the catchment area of an airport without scheduled services, computing the minimum generalized cost (GC). Two scenarios are also analyzed in terms of possible strategies to improve accessibility levels reducing the GC. The first one assumes two daily public service obligations from the local airports to two main airports while the second scenario studies the effect of an improvement of the bus connections to the closest airport with scheduled services from the zones in the catchment area of the local airport. Simulations are based on a multimodal national transport model describing the entire Italian long distance supply for the period 2013/2014. It allows the calculation of the GC by road, rail, coach and air services. The GC provides a clear and comparable measure to understand the role of different transport modes in providing domestic connections. Results show how the more an area is remote the more a PSO could be effective while whereas ground alternatives are present the effect of air PSO is reduced. Moreover, improving ground accessibility to the main airports has a wider impact in terms of decrease of the minimum GC and in the number of zones experiencing a reduction. This paper aims to contribute to the literature on the accessibility from areas with a low level of infrastructure. It also represents a support for policy makers when promoting, drafting or reconsidering their own regional air transport programs and as well for airport manager when considering alternatives to improve airport ground accessibility.

Keywords: accessibility, remote regions, air transport, PSO

1. Introduction and aim

Understanding the accessibility level for citizens and its measure is a crucial issue since it has implications in terms of mobility, investments and their spillover effects, socioeconomic development, social welfare and cohesion which have been largely studied in literature (Geurs and van Wee, 2004; Bruinsma and Rietveld 1998; Vickerman et al., 1999; Spiekermann and Wegener, 2006; Gutiérrez et al., 2010; López et al., 2008; Niemeier, 1997). Policymakers have always seen air transport as the main alternative to guarantee access to remote regions (or those with a low level of infrastructure) and as a mean to favor the economic and social development. This view has strengthened following the liberalization of air transport that, thanks mainly to low cost carriers (hereafter LCCs), has made possible connections and higher frequencies at lower fares also from many secondary airports (Doganis, 2009; Dobruszkes, 2006; Campisi et al., 2010), which have gained increasing importance. The liberalization of air transport has entailed the general growth of traffic volumes and the emergence of LCCs that have contributed in enhancing the accessibility levels of some areas facilitating the mobility and migration of people on domestic and international routes thanks to the reduction of fares (Cattaneo et al., 2016; Button and Vega, 2008; Dobruszkes, 2009). Dobruszkes (2013) points out the prevailing role of LCC in determining 70% of the 1995–2012 increase in the number of intra-European flights or seats and 64% of the number of seat-km. According to CAPA (2016), on average, LCCs currently provide 37% of intra-Europe seats, ranging from 60% of Hungary to 11% of Finland. Finally, some LCC are currently evolving towards a hybrid model (Klophaus et al. 2012) to serve also business passengers. This choice is translating in a reduction of traffic in some secondary airports in favor of the primary ones (Dziedzic and Warnock-Smith, 2016) and it could further impact the results in passengers and financial terms of some airports worsening their critical situations (Laurino and Beria, 2014).
Despite the increasing role of LCC in improving the accessibility level of many areas, in some cases Public Service Obligations[1] (hereafter PSO) still represent the main solution to assure a minimum level of connectivity.
Nonetheless, whereas railway infrastructure is present, rail services under PSO could provide another option to assure connectivity if commercial services are unfeasible as in the case of Intercity services currently provided in some European countries. Finally, coach services, not requiring a specific infrastructure and being generally provided by private operators without public funding, represent a solution in particular for routes with a low level of demand. Therefore, when analyzing the accessibility levels of an area, policymakers should consider the characteristics of the transport services in terms of capacity, frequencies, connectivity, travel speeds, costs, etc. in order to introduce solutions aimed at reducing the generalized cost.

Starting from these premises, the paper aims at investigating the effect of alternative policy scenarios to improve domestic accessibility from areas having an airport without scheduled services. In particular, we compare the reference scenario (no scheduled services), with the option of adding PSO routes, versus improving the land accessibility to the nearest main airport. The two policies are implemented in the case of Italy. In the first one we introduce two daily PSO from six local airports to the airports of Rome Fiumicino and Milan Linate. In the second scenario, we

consider an improvement of the bus services linking hourly the six catchment areas with the closest airport with commercial services.
The metric used to evaluate and compare the three scenarios is the generalized cost that is computed using a national-scale transport model, including both infrastructure and services (frequencies, trip duration, departing/arrival time, fares, etc.) available in the period 2013/2014.
This approach could provide useful information to policymakers when comparing options to improve the level of accessibility, as the effect in terms of domestic accessibility might be substantially different. In particular, we expect that PSO improves the accessibility to main centers only. In the second case, a more homogeneous improvement, also towards secondary cities, is expected. In general, the paper contributes to the literature on PSO and to the studies on public transport integration between scheduled air and ground transport services.
The remainder of the paper is organized as follows. In the next section we describe the methodology of the study together with the transport model used to perform simulations. Section 3 discusses the Italian transport context and the definition of the study-areas. In Section 4 we define the three policy-scenarios simulated. In Section 5 we discuss the results of the simulations and in conclusion, we derive policy indications and suggest guidelines for future research.

2. Methodology

2.1 Approach

We base the answer to the research question on numerical simulations, according to the following steps:

- We identify the study-areas among those having an extra-time by car to reach the closest airport with scheduled services compared to the one without scheduled services (Section 3);
- We compute the average GCs to reach the rest of the country from the zones of the study-areas with four transport options (car, rail, air, coach), based on an average working day in 2013 in the reference scenario (Section 2.3);
- We define the two alternative policy scenarios and estimate the corresponding CGs (Section 4);
- We compare the minimum GC of the two scenarios with respect to the reference case, to point out for which destinations the tested policies determine a reduction of the GC (Section 5).

2.2 Transport model description

To perform the simulations, we use a transport model. In the model, Italy has been divided into 371 zones, each one representing a homogeneous aggregation of municipalities on the basis of population, orography and transport supply. To have the necessary detail, main cities are treated as individual zones, excluding Rome, which is further split into six zones. The rest of the country has been reassembled in aggregations, representative of accessibility conditions in sub-provincial level and corresponding to the statistical level NUTS-4.[2]
Travel choices depend on travel costs and on the perception of its components. Differently from private car that allows direct door-to-door travel, collective modes could have up to three sub-sections (Table 1) namely ground access to the stop (airport, station, bus stop), on-board trip, egress from the arrival stop to the destination. Regardless of the transport modes, two main components

[2] NUTS-4 level does have a correspondence with any administrative level in Italy.

contribute to the generalized cost: time (travel and waiting time) and cost (toll/fare and operating cost). In transport economics, the generalized cost is the sum of monetary and non-monetary (properly converted with conversion factors) costs perceived by the user to perform a certain trip (Zofio et al., 2014).

The values of the GC have been calculated using a standard transport planning model of Italian domestic transport, which considers both the infrastructure and the transport services available in the period 2013/14. The infrastructure network includes all the nodes (stations, airports, stops, etc.) of the national transport system as well as the links (in terms of road or transport services) connecting these nodes among them and with the 371 traffic zones. This allows simulating the entirety of the Italian long distance transport industry including car, train, air and coach services. For a detailed description of the model see [omissis] (2015). For the purposes of this paper, the model is used limitedly to the GC calculation, thus excluding the modules of modal choice and network assignment.

As different individuals perceive differently the cost components of a trip, the model must refer to a stylized demand segment, characterized by the availability or not of travel options and by the value of the parameters of the GC. The following Table 1 describes the generic travel-chain associated to each transport alternative.

	Origin zone	Access to the airport / station	On board	Hubbing	On board	Egress from the airport / station	**Destination zone**
CAR	*CAR*						
COACH SERVICES	*car passenger*		*COACH*	if possible	*COACH*	*public transport*	
TRAIN SERVICES	*public transport*		*TRAIN*	if possible	*TRAIN*	*public transport*	
AIR SERVICES	*car passenger*		*PLANE*	if possible	*PLANE*	*public transport*	

Table 1 - Assumptions for the calculation of the generalized cost

2.3 Generalized cost functions and parameters

The GC derives from the usual definitions (Ortuzar and Willumsen, 1990) and takes into account the assumptions made in Table 1. The private car GC is:

$$GC_{car} = \left[t^{car}VOT + cD + \gamma P^{car}_{toll}\right] \quad [1]$$

Where:
D is the distance [km]
t^{car} is the travel time by car [h]
P^{car}_{toll} is the toll [€]
c is the vehicle operating cost (0.25 €/km);

γ is a parameter describing the toll perception (60%)[3]

Public transport options include more components of GC:

$$GC_{coach} = \left[t^{accCAR\_pax}VOT + \gamma P_{toll}^{car} + cD\right] + \left[\sum_{i=1}^{N}\left(t_i^{co}VOT + P_i^{co}\right)\right] + \left[t_w^{hub}VOT_w + I_w^{hub}\right] + \left[t^{egrPT}VOT + P^{PT}\right] \quad [2]$$

$$GC_{train} = \left[t^{accPT}VOT + P^{PT}\right] + \left[\sum_{i=1}^{N}\left(t_i^{tr}VOT + P_i^{tr}\right)\right] + \left[t_w^{hub}VOT_w + I_w^{hub}\right] + \left[t^{egrPT}VOT + P^{PT}\right] \quad [3]$$

$$GC_{air} = \left[t^{accCAR\_pax}VOT + \gamma P_{toll}^{car} + cD\right] + \left[\sum_{i=1}^{N}\left(t_i^{air}VOT + P_i^{air}\right)\right] + \left[t_w^{hub}VOT_w + I_w^{hub}\right] + \left[t^{egrPT}VOT + P^{PT}\right] + \quad [4]$$

Travel time and fares components are:
t_i^{co} travel time on coach transport [h]
t_i^{air} travel time on air services [h]
t_i^{tr} travel time on train services [h]
VOT value of time [€/h]
P_i^{co} tariff on coach services [€]
P_i^{tr} tariff on train services [€]
P_i^{air} tariff on air services [€]

In addition, the model considers access and egress time and cost:
t^{accPT} access time to the railway station from the origin zone using public transport [h]
t^{egrPT} egress time from the railway station, airport, coach stop/station to the destination zone using public transport [h]
t^{accCAR_pax} access time by car as a passenger from the origin zone to the airport or the coach stop/station, [h]
P_i^{PT} public transport tariff [€]

And, where applicable, also interchange components:
t_w^{hub} waiting time between two connecting services [h]
VOT_w value of waiting time [€/h]
I_w^{hub} interchange penalty [€]

The value of time has been defined starting from the national guidelines of the Ministry of Transport which provides different values distinguishing between classes of distances (short and long) and reasons for traveling (business, commuting and other reasons). For long distances trips

[3] It considers how tolls differently impact on the total GC among user categories, providing a weight. In general, business users have a lower perception being more time sensitive while economy users may opt for a non tolled alternative, if present, thus using a tolled infrastructure has a higher weight.

and the category "other reasons for traveling", the guidelines suggest values of time between 10 and 25 €/h (MIT, 2016). The value used in the model is 20€/h.
The interchange component is made of two elements: a penalty equal to 25€ which takes into account the inconvenience suffered by the passenger and a component depending on time, valued 5€/h[4]. In terms of connecting time between domestic flights, the model excludes short interchanges below 60 minutes. Frequencies are modelled according to real services timetables. More specifically, the algorithm calculates the average daily waiting time running 24 iterations (one per hour) between all the origin/destination pairs. The GC is computed both for those relationships with direct services and for those where "hubbing" is possible[5].
Finally, the price/tariff component P for the collective modes is further defined, for every route, as:

$$P = p_0 + \rho D \qquad [5]$$

Where:
D is the distance
ρ is the fare component proportional to distance,
p_0 is a fixed component.
The parameters p_0 and ρ are calculated on the basis of real tariffs extrapolated from transport operator websites; they vary according to the type of service, purchasing period and presence of competition. Values are collected in Appendix 3.
The final generalized cost (or the time) between origin and destination is computed considering the shortest path (excluding congestion) according to the Dijkstra's algorithm.

2.4 Supply description

The calculation of GCs as described above requires a complete description of service supply, based on real timetables for frequency and travel time. Appendix 3 provides the values used to compute the fare component.
Concerning the private transport (equation 1), the model includes the entire national road network, subdivided in highways, provincial roads and main connections at the sub-provincial level. Roads are described in terms of geometric characteristics (number of lanes, intersections, etc.), average speed allowed on the basis of endogenous (type of road) and exogenous (orography and urban contest) and tolls where present. These parameters allow the computation of the travel time and distance.
Coach services (equation 2) are based on the timetables of an average winter weeks of 2013/2014. All information on routes, stops, frequency and fares derive directly from the websites of the coach companies (255 long distance bus lines operated by 55 different operators). The fares have been estimated starting from the collection of data obtained from the websites of the operators distinguishing between three fares typologies (full, discounted or family) and two service category (standard and low cost).
The database includes also the timetables of Italian rail services (equation 3), including the majority of regional services (average winter week of 2014). Simulations are based on all the long distance services provided by both Trenitalia and NTV. The rail fares derived from the collection of data

[4] This value takes into account that, once at the hub point (airport, station, bus terminal), users weight less the time since they are aware of the interchange.
[5] This is true for air service but also for coach and train services whereas respectively interchanges at the station or at the bus stops allow reaching indirectly other destinations. Intermodal interchanges are not included in this phase

related to a selection of different routes and are differentiated between regional and commercial trains, with or without competition.

Finally, air transport (equation 4) is based on OAG database (140 domestic routes) considering an average working day in the week 8 – 14 April 2013[6]. Fares were determined starting from a set of values for a sample of routes collected in October 2013 for flights on short (two / three days) and medium term (one month in advance). Differently from the other modes of transport, domestic air transport fares are not affected by the actual distance travelled. Nonetheless there is a distinction between full price (for business class) and discounted fare with advance purchase, and between routes with competition and those where there is only one operator. Finally a distinction between full carriers and low cost carriers has been introduced.

3. Context characteristics and definition of the study-areas

3.1 Population and airports

Thanks to the transport model we initially modeled the access time to all Italian airports (47 airports, including those without scheduled services) from the 371 zones in which Italy has been divided. In particular, the access time by car between zones and airports is the sum of the travel time value associated to each network link composing the quickest route between two points. As shown in Figure 1 (right chart) the airports with scheduled service are accessible by the vast majority of population within 60 minutes. Moreover, all the zones with the highest levels of density (Figure 2 left chart) are in the catchment area of an airport with scheduled services.

Access time [min] to the closest airport with scheduled services	*n° zone*	*Population 2011*
<30 min	99	24,414,216
30 – 60 min	156	23,638,587
60 – 90 min	74	7,702,255
90 – 120 min	27	2,489,981
>120 min	15	1,177,927

Table 2 - Distribution of population and access time to the closest airport with scheduled services from each zone

[6] In this period, we verified that there is no seasonal peak and there are no bank holidays or school breaks.

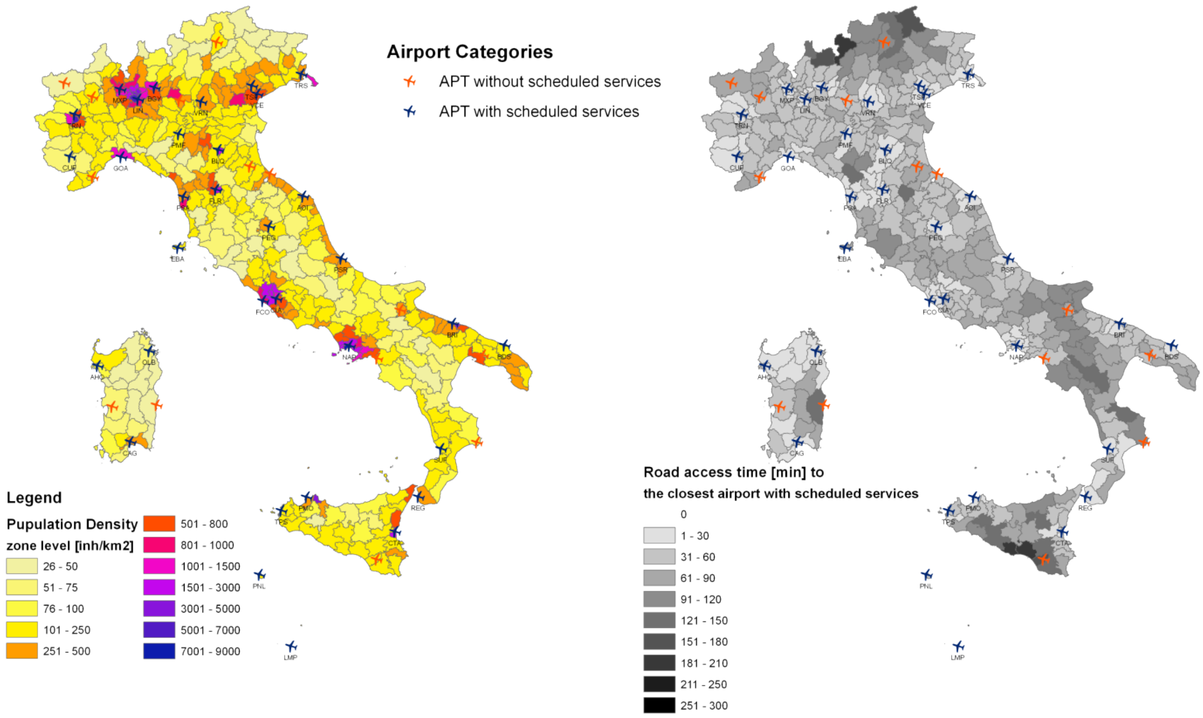

Figure 1 - 2011 Population density in the 371 zones (left-side map) and time to access by car (right-side map) the closest airport with scheduled services (Source: our elaboration on National Institute of Statistics –ISTAT 2011; access time our estimations)

The areas with the highest airport access time are in Southern Sicilia, Basilicata, Northern Calabria, Foggia province and Trentino Alto Adige in the North. In most of these cases, they correspond to low population areas, which are, in general, in dispersed villages or mountainous territory.

3.2 Definition of study-areas

In order to define the sample, we compute from each zone the access time by car a) to the closest airport and b) to the closest airport with scheduled services (if different). We considered only access by car since, as pointed out by Humphreys and Ison (2005), internationally, private car is the main mode to access airports. This is particularly true for airports that do not have the minimum level of demand to justify public transport services.

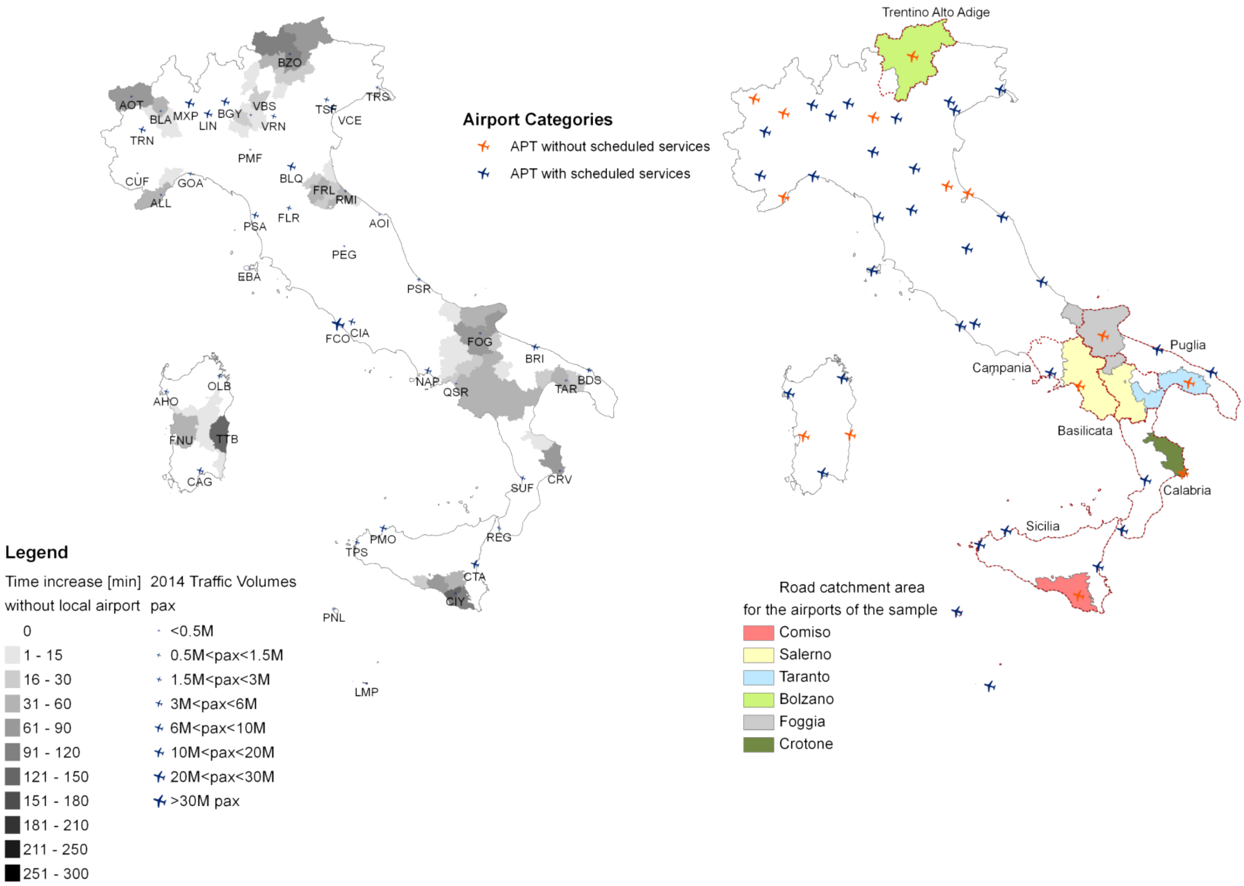

Figure 2 – Definition of the sample. Left-side map: extra cost to reach the nearest airport with scheduled services; Right-side map: catchment areas considered (Source: our elaborations, for traffic volumes ENAC 2014)

Figure 2 (left side) represents the difference between the two measures and identifies where the airport without scheduled services would actually reduce access time, regardless its level of supply. Blank areas are not influenced as the existing airports are the nearest option. Excepting few cases, such extra-time is however quite small. In a recent study, Redondi et al. (2013), evaluating the role played by small airports in European connectivity, show for Bolzano and Foggia negligible, and for Crotone a relatively small, connectivity loss generated by their closure. It is worth noting how, differently from the other airports in the sample, the airports of Bolzano and Foggia are not included in the recently approved National Airport Plan (see section 3.3).

Using the above extra-time values, we identified a sample of six areas[7], five located in the South of Italy and one in the North. Each area could potentially use the local airport but it is already in the catchment area of an operating airport, as shown in the Table 3.

[7] We did not consider the Sardegna case since it has a specific PSO program and due to the fact that air transport actually represents the main alternative to reach the area.

Area/ Region	*Local airport*	*Population in the catchment area*	*Closest operating airports*	*Passengers of the closest airport [2014]*
Basilicata	Taranto [TAR] Foggia [FOG] Salerno [QSR]	810.159 804.623 2.010.307	Napoli [NAP]; Bari [BRI]	5.917.256 [NAP]; 3.664.337 [BRI]
North of Puglia	Foggia [FOG]	804.623	Bari [BRI]; Pescara [PSR]	552.116 [PSR]; 3.664.337 [BRI]
South-west of Sicilia	Comiso [CIY]	645.829	Catania [CTA]	7.217512 [CTA]
South of Campania	Salerno [QSR]	2.010.307	Napoli [NAP]	5.917.256 [NAP]
Central part of Calabria	Crotone [CRV]	291.517	Lamezia Terme [SUF]	2.414.277 [SUF]
Trentino Alto Adige	Bolzano [BZO]	944.091	Verona [VRN]	2.755.171 [VRN]

Table 3 - Sample considered (Sources: for passengers figures ENAC 2014, for population our elaborations, for dominant carrier OAG 2013); At the time of the analysis the airports of Comiso and Crotone did not provide scheduled services.

Basilicata region, with low levels of population and density, is located between two bigger regions (Puglia and Campania) that, through their airports, provide connections at a reasonable driving distance for the majority of the region. In particular, the western part of the region gravitates mainly on Napoli (NAP) airport while the eastern one is closer to the airport of Bari (BRI).
In the southern part of Campania, Salerno's airport could represent an alternative to Napoli since it could serve a relevant catchment area (Table 3) due to its location close to the non-tolled highway A3 connecting Campania, Basilicata and Calabria.
Puglia is one of the largest region in terms of population and its airport system includes two main airports, one serving the northern part of the region (Bari) the other the southern one (Brindisi). Two minor airports, currently with no scheduled services, are also present (Foggia and Taranto).
In Sicilia, Catania in the east and Palermo in the north-west, have historically played a major role for the connectivity of the island. In the last five years, Trapani airport has gained importance in the western part of the region thanks to the presence of Ryanair, which established a base there. Finally, in the second half of 2013 a new airport, Comiso, started providing scheduled services in the southern part of the region, whose catchment area partially overlaps with that of Catania.
Calabria region has three certified commercial airports. Lamezia Terme is the main one due to its location in the middle of the region which attracts passengers from both the northern and the southern areas. Reggio Calabria is used mainly by passengers in the south or by users from Sicilia on the other side of the channel. Crotone's traffic trends are influenced by the vicinity of Lamezia airport (less than 100 km) and by the fluctuating presence of low cost carriers, as Ryanair.
Finally, Trentino-Alto Adige, in the north of Italy and one of the richest region of the country, has no scheduled services from its airports, Bolzano and Trento. In the past a PSO to Rome was provided from Bolzano, nonetheless the vicinity of Verona's (nearly 1h 30min) or Venice's airports, together with context characteristics (mountainous areas) and good rail connections partially justifies the lack of domestic flights.

3.3 Italian domestic transport

In the last two decades, there have been relevant changes in the Italian long distance transport sector both on the infrastructure and services sides that have influenced the travel choices of passengers.

Some elements should be considered and are currently included in the transport model described above:

- *High speed rail network*: in the last decades the core structure of the North – South network from Turin – Milan to Naples – Salerno has been opened. In 2012 a new operator, NTV SpA, has entered the market offering high speed services in competition with the incumbent Trenitalia SpA (Beria and Grimaldi, 2017). As pointed out by Desmaris (2016), competition in Italy has contributed to an increase of the consumer surplus through more capacity, frequency and connections, lower prices and better quality. Moreover high speed services have affected intermodal competition as on the route between Milan and Rome, where high speed services have gained increasing market shares with respect to the air sector forcing airlines to reduce fares (Bergantino et al., 2015) or to leave the route[8];
- *Rail transport Public Service Obligation*: historically there are more than 150 Intercity services mainly on North – South routes which are regulated in terms of fares, timetables, seats, etc. Beyond the direct services, passengers on night PSO can use a high speed service at a regulated fare changing in Rome (or Bologna);
- *Highway network*: the majority of highways are located in the central and northern regions (more than 4500km), only two highways, the non-tolled A3 on the west-coast and the tolled A14 on the east-coast, serve also the southern areas;
- *Coach services*: there are many operators which historically provide North – South connections and connections to Rome from all the southern regions. The biggest ones are located in Puglia and Calabria regions and have a hub & spokes scheme to distribute the passengers in the southern zones, more dispersed. The 2014 liberalization has entitled an increase in supply (frequencies and new routes) and a reduction of the average fare (Beria et al., 2017);
- *Air transport*: large increase of supply also on domestic flights due to the 90s liberalization. In particular, in 2015 low cost carriers reached 48,38% of market share (Enac, 2015) offering domestic routes also from many secondary airports. The National Airport Plan[9] approved in 2015 identifies 11 strategic airports and 26 airports of national interest. In the latter case a strategic business plan and an economic/financial plans should demonstrate the fulfillment of two conditions that make the airport of national interest, namely: “the airport must play a well-defined role within the area, with a substantial degree of specialization” and “the airport must be able to prove that it has achieved economic/financial equilibrium, which can take place progressively, as long as it is within a reasonable timeframe”.;
- *Air transport Public Service Obligation*: historically there are PSOs to connect minor islands to the mainland but PSOs have been applied or proposed from other regions as Valle d’Aosta (Aosta airport), Trentino Alto Adige (Bolzano airport) and Calabria (Crotone and Reggio Calabria airport);

Finally, in order to better analyze the results presented in the next sections, Table 4 provides data concerning the 2013 context for the study-areas in terms of available rail PSOs, number of long distance coach operators based in the region and destinations available from the closest operating airport.

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[8] Ryanair closed its service from Bergamo (BGY) to Rome Ciampino (CIA) similarily easyJet chasedits route Milan Linate – Rome Fiumicino.

[9] Available at http://www.gazzettaufficiale.it

Region	N° daily rail PSOs	N° domestic destinations available from the operating airport on a weekly base	N° long distance coach operators
Calabria	36	8 [SUF]	12
Campania	54	13 [NAP]	11
Sicilia	21	13 [CTA]	5
Puglia	33	16 [BRI], 3 [PSR]	7
Trentino Alto Adige	2	10 [VRN]	0
Basilicata	22	16 [BRI], 13 [NAP]	13

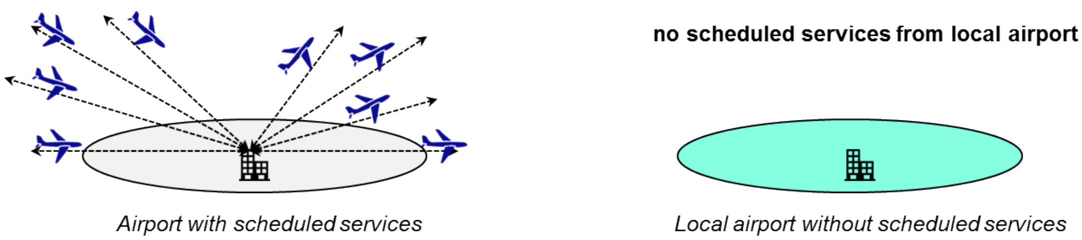
Table 4 - Characteristics of the regions in the sample (Source: our elaborations on Trenitalia 2013/2014 and OAG timetables 2013, coach operators websites accessed in 2013)

In terms of coach operators, Basilicata (and in part Campania) has the highest value however the majority of them serve only one route while the ones in Puglia, Calabria and Sicilia provide many routes with high frequency according to a hub & spokes scheme. In terms of rail PSO, the highest value for Campania results from the sum of its direct services and the ones to Sicilia and Puglia. Finally, excluding Pescara's airport, the other airports have domestic scheduled services to the main cities (see Appendix 1).

4. Policy alternatives considered

In order to study alternative transport policies to improve accessibility from the study-areas, two scenarios have been defined and compared with the reference scenario. The three scenarios have been compared in terms of variation of the GC to reach the rest of the country from the study-areas. More in detail, the reference scenario assumes no scheduled services from the six local airports identified. In this case, passengers use the closest airport with scheduled services or the other transport modes available (car, train or coach services) to reach destinations.

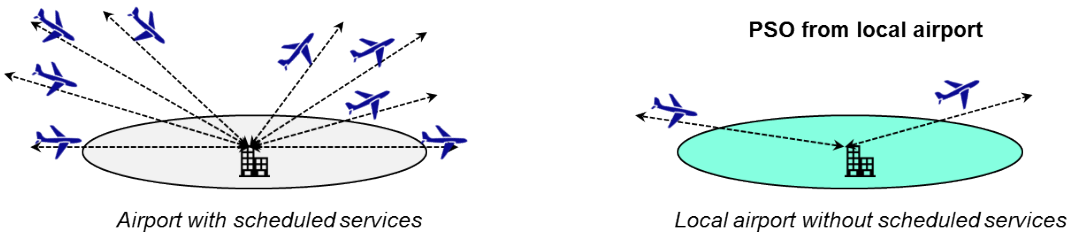
Figure 3 - Reference scenario 0



Scenario 1 considers the introduction of a PSO from the local airports consisting in two daily flights to Rome Fiumicino and Milan Linate airports that leave both at 7:00 and 14:00 and return at 17:40 and 20:40. Considering as a benchmark other PSOs used in the past in Italy, the fare considered is 77€ that corresponds to the case with no competition as shown in Table 10 .
This scenario allows testing the potential impact of a relatively common tool used to improve the level of accessibility of remote regions. PSOs are foreseen by countries whereas air services are deemed to be "vital for the economic and social development of the region which the airport serves" (EU Regulation 1008/2008) and where no air services are present due to their scarce viability in commercial terms. Ten countries currently apply PSOs in Europe mainly on domestic routes. However, Williams and Pagliari (2004), analyzing PSOs across the European Union, evidence different attitudes and approaches in the extent and way in which PSO mechanisms are applied by

countries. PSOs have been established towards peripheral remote communities (Norway), between regional airports and major cities or between major cities (France), between islands and mainland (Italy, Spain, Portugal). In France, PSO have been established even where traffic volumes could be commercially viable or where more convenient surface transport alternatives exist (Williams and Pagliari, 2004).

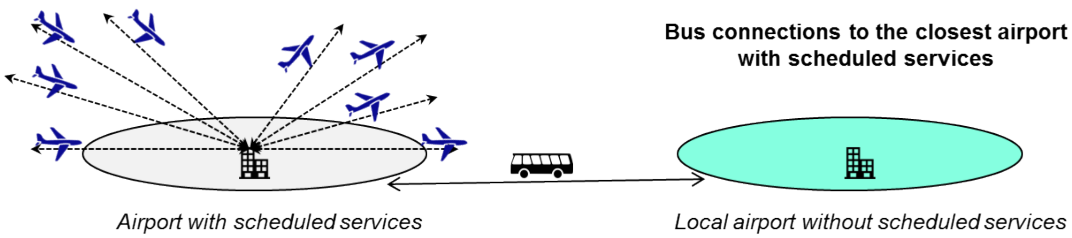
Figure 4 - Scenario 1



However, air PSOs are not the only possible strategy to improve connectivity of remote regions. Lian and Rønnevik (2011), concerning passengers' choice between local airports with PSO services and larger regional airports in Norway, find that travelers prefer to drive several hours to a larger airport to take advantage of lower fares and more convenient airline services.

Consequently, we test a second Scenario 2, which assumes an improvement of the bus connections (1 service per hour) to the closest airport with scheduled services from the zones in the catchment area of local airports. A recent work dealing with the potentialities of integrating bus and air services is the one of Merkert and Beck (2017). The authors use a stated preferences experiment to establish the willingness to pay for a hypothetical integrated bus service that matches arrival/departure times of scheduled regional air services. Results show how leisure travelers are willing to pay a premium for 45.88$ for this kind of service. Many factors may contribute to mode choice for ground access to airports (Kouwenhoven, 2008), in addition to travel time and travel cost (Skinner, 1976; Harvey, 1986). Other factors, more difficult to define, contribute to individuals' decisions regarding their trips to and from the airports: travel time reliability (Koster et al., 2011; Tam et al., 2011), passengers' socioeconomic and demographic characteristics, trip purpose and destination (Chang, 2013; Hess and Polak, 2005; Gupta et al., 2008; Akar, 2013), available transport modes together with their user-friendliness (Jou et al., 2011; Cirillo and Xu, 2010; Alhussein, 2011), departure and arrival time to the airport. This scenario allows testing the reduction in GC terms achievable from investing in ground access toward surrounding airports.

Figure 5 - Scenario 2



5. Discussion of the results

5.1 Accessibility of the study areas

In this section, we discuss the results of the model in two steps. Firstly we analyze the reference scenario for the six areas of the sample, in terms of minimum GC between road, rail, coach and air services to reach all the Italian zones, for an average working day in 2013. Later on, we discuss the variations of the GC with respect to the two simulated scenarios. Appendix 2 provides three charts for each case study. The first one shows the minimum GC and the corresponding mode in the reference scenario while the other two provide the percentage reduction of the minimum GC between the reference scenario 0 and, respectively, scenario 1 with air PSO from local airports and scenario 2 with an improvement of the bus connections to the closest airport with scheduled services. This comparison provides an indication on the potential effect of the two policies in improving the accessibility levels from the zones in the catchment areas of local airports. The next paragraphs comment the findings.

5.2 Minimum generalized cost in the reference scenario

Generally speaking, as shown in Appendix 2, minimum GC in the base case scenario is strongly influenced by context characteristics as geographical location of the area, infrastructure levels and services available. Whereas the geographical aspect is unfavorable and/or rail and road network are inadequate in terms of supply and level of services, the average GC has higher values. Examples are the zones in the catchment area of Crotone's and Comiso's airports which register the highest values of GC among the sample considered. Here, differently from the other case studies analyzed, long distance coach services play a role due to the lack of rail services or the low functional characteristics of the roads.

The distance from the airport plays however a crucial role in affecting the propensity to choose air transport if there are cheaper alternatives. For Comiso, geographical position makes air transport prevalent for most of Italy through the large airport of Catania. In the case of Crotone's catchment area, air transport is the best option only towards the large urban areas of the North, thanks to the proximity of Lamezia Terme, a mid-sized airport, while the rest of the country is reached via road or rail transport.

Where there are adequate transport networks (railway and roads) and the services are more appealing in terms of frequencies, fares and available destinations, the average GC decreases and its variation among zones is limited. This is the case of Salerno's and Foggia's catchment areas that have access to the two main highways corridors linking north and south of Italy, respectively the A3 (not-tolled) and the A14. In terms of railways services, both the areas have intercity services under PSO, intra-regional services at regulated fares but also commercial services. From Salerno there are high-speed services provided by the two operators *Trenitalia* and *NTV* which connect this area with Rome (2 hours travel time) and the north of the country offering frequent connections at competing prices. Consequently, despite the relative proximity of the two airports with scheduled services (Naples and Bari), air transport is the cheapest alternative only to the islands and few other areas of the country.

On the contrary, the absence of efficient and reliable rail infrastructure increases the probability of using the private mode to reach the closest destinations as in the case of Basilicata. Nonetheless, even with inadequate regional services (in terms of frequency, travel time and reliability), rail transport is the cheapest mode to the Northern areas due to the relatively proximity to Salerno which has both PSO and high-speed services or Foggia which offers many PSO services to Milano, Bologna and Torino. Coach services, although costly in GC terms, prevail towards Siena since rail service would require at least two changes making the GC higher.

Differently from southern areas, Bolzano takes advantage of the good rail connections, both direct or with an interchange through the station of Verona, providing many effective connections towards

the entire country. This makes Bolzano mostly accessible by rail, excepting the farthest areas of Sicilia, Sardegna and part of Puglia through Bari and Brindisi airports.
To make more effective the comparison, Table 5 shows the shares of the four transport modes in reaching Italian population. On the one side Bolzano, from where 75% of the country's population is reachable with train; on the opposite range, Comiso, for which the best mode is air towards 75% of population. Excluding Comiso, which is on an island, for the mainland areas the highest share of air is from Crotone, with just 25%.

	Crotone	**Foggia**	**Bolzano**	**Salerno**	**Comiso**	**Basilicata**
Car	26%	31%	10%	31%	21%	34%
Rail services	39%	58%	75%	61%	0%	53%
Air services	25%	7%	15%	8%	75%	13%
Coach services	10%	4%	0%	0%	4%	0%

Table 5 – Transport mode with the lowest GC to reach the rest of the country in terms of population (reference scenario).

5.3 Effect of policy alternatives

To assess the effect of the two policy scenarios, we compute the percentage of GC reduction with respect to the reference scenario.
Scenario 1 considers the effects on the GC of two daily PSO from the local airports to those of Rome Fiumicino and Milan Linate. These services guarantee a direct connection to the two main cities, but make also possible interchanging both with other PSOs (as Foggia – Rome Fiumicino – Comiso) and with commercial services available in the two airports (as Foggia – Rome Fiumicino – Venice). Of course, the higher is the waiting time between flights the higher will be the GC by air, reducing the effectiveness of the policy.
As shown by figures in Appendix 2, the effect of the PSO is far from homogeneous across the sample, as strongly depending on the costs of the other modes available. In general, the effect of PSOs is visible towards a limited number of zones, mainly Milan from southern origins, or Sardegna. Access to Rome as a destination, despite the addition of the direct connections, is never improved. This is because the distance from areas such as Foggia, Salerno or Basilicata is shorter and thus other ground alternatives are cheaper. The exception is Comiso airport, where the PSOs improve significantly the GCs towards large areas of Northern and Central Italy. The impact of PSO is larger towards zones where air transport is already the best option and in general when GCs are high.
The case of Bolzano suggests how the impact of PSO is relatively low even if the context characteristics appear as favorable (dispersed distribution of population along the valleys and mountainous areas). This can be explained by the fact that good rail services determine low GC and therefore PSO, with low frequencies, entails a general improvement only to the islands and to the catchment area of Crotone (via Rome).
Scenario 2, instead, assumes an improvement of the bus connections with one service per hour from the zones in the catchment area of a local airport to the closest airport with scheduled services. Bus connections allow to use direct flights from these airports thus avoid all the factors negatively evaluated by travelers which characterize indirect flights, namely longer travel times, transfer and extra waiting times together with the possibility of missing connections. Moreover, the higher

frequency of flights available from these airports compared to the limited supply of PSO from local airports results in a wider choice of departure and arrival times that could better match with travelers needs.

In general, as shown in Appendix 2, this strategy entails higher reductions in GCs and involves a higher number of zones compared to Scenario 1. This result is valid for all the six cases considered and reflects the connections available from the closest airport as shown in Appendix 2. Thanks to the improved ground accessibility, there is a sort of "boosting effect" of the scheduled routes available from the airports that translates in a higher number of destination zones experiencing a decrease of the GC.

Except for Bolzano, where there is no significant effect, the improvement of bus connections determines an average GC between 3 and 7% lower than with PSO (Table 6). At the same time, scenario 2 benefits a higher number of zones compared to scenario 1 (Table 7).

	Variation average GC scenario 0 vs 1	***Variation average GC scenario 0 vs 2***	***Variation average GC scenario 1 vs 2***
Comiso	-4%	-10%	-7%
Salerno	0%	-3%	-3%
Bolzano	-1%	0%	0%
Foggia	-1%	-4%	-3%
Crotone	-1%	-6%	-5%
Basilicata	0%	-4%	-4%

Table 6 - Variation of the GC between the three scenarios

	N° of zones with GC decrease scenario 1	***N° of zones with GC decrease scenario 2***
Comiso	204	284
Salerno	11	102
Bolzano	51	65
Foggia	31	102
Crotone	66	153
Basilicata	13	120

Table 7 – Number of zone in each case study experiencing a reduction in the GC in the two simulated scenarios

6. Conclusion

Accessibility is an issue commonly at stake when designing national transport policies. In many European countries, including Italy, the level of transport infrastructure has increased in the last decades (high-speed rail network, highways, etc) and the opening of the markets has broadened services and reduced fares (in air, coach and in Italy also in rail). Nevertheless, benefits rarely spill over to areas with scarce potential demand and consequently not interesting for transport operators. In these contexts, often, air accessibility is considered as the only option, but this usually requires some form of PSO and investment in local airports. However, PSOs have a cost and they are necessarily limited in terms of routes and frequency. Consequently, in some cases, improving the ground accessibility to main airports could be an option which is worthwhile to consider.

The paper, using a detailed measure of the generalized cost, analyses the conditions of Italian domestic transport for a group of selected areas characterized by the presence of an airport without scheduled services and quantifies the impact of two different policy scenarios, namely the introduction of PSO from these airports and the improvement of accessibility to nearby airports with scheduled services.

Results suggest that the more an area is remote, the more an air PSO could be effective in reducing transport costs. To the contrary, when ground alternatives are present the effect of air PSO is significantly reduced. In addition, PSO routes are limited to main cities or hubs, for example Milan and Rome. Consequently, the effect in terms of overall domestic accessibility tends to be extremely limited, as all destinations except the capital cities remain unconnected. Simulations for six Italian airports show very limited results, with the only exception of Comiso, in Sicilia, and Crotone only towards northern Italian main cities.

To the contrary, investing in ground accessibility towards airports where more numerous commercial air services already exist represents a more effective approach to improve accessibility as also pointed out by Redondi et al. (2011). Our simulations entailing an improved ground accessibility to the main airports confirm that there is a wider impact with respect to PSO, both in terms of decrease of the minimum GC and in the number of zones experiencing such reduction.

This approach could provide useful information to policymakers when comparing options to improve the level of accessibility, as the effect in terms of domestic accessibility might be substantially different. Airport operators could also benefit from promoting or investing in ground accessibility in order to wider their catchment areas.

Extensions of the work can go in two different directions. On the one side, the simulation model could be further refined, for example in terms of users' profiles, interchange costs, modal share simulations. On the other side, a more detailed answer about which policy is more sustainable in the different contexts would require to estimate the users benefits in terms of surplus gains in both scenarios and compare them with the cost of providing the services, being them air routes or ground access.

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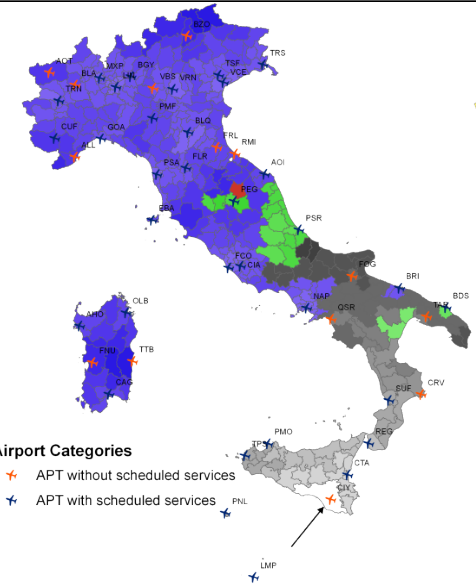
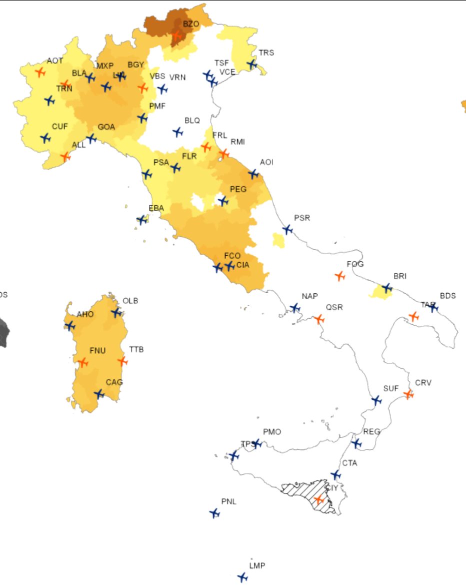
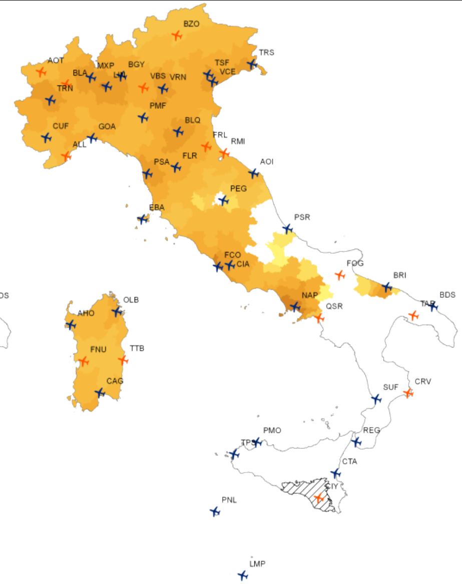
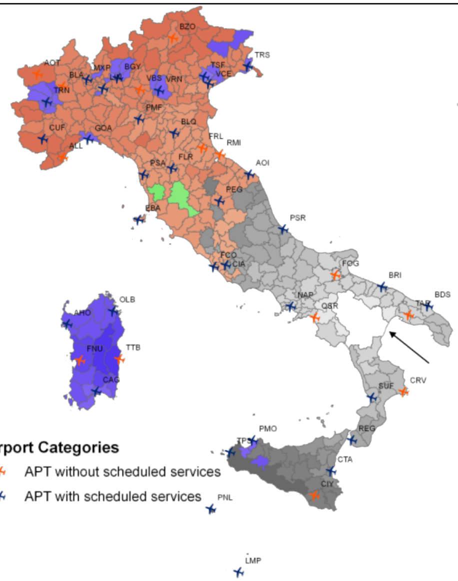
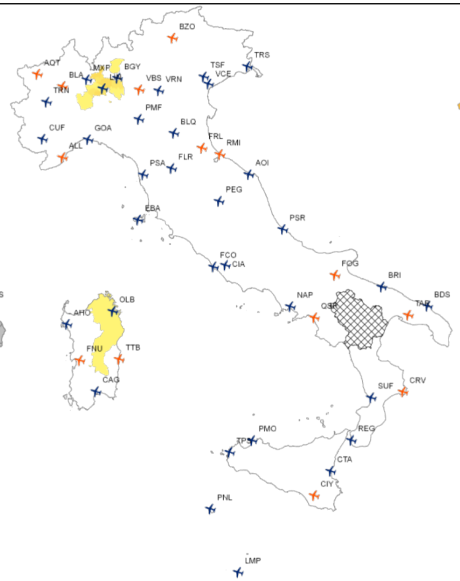
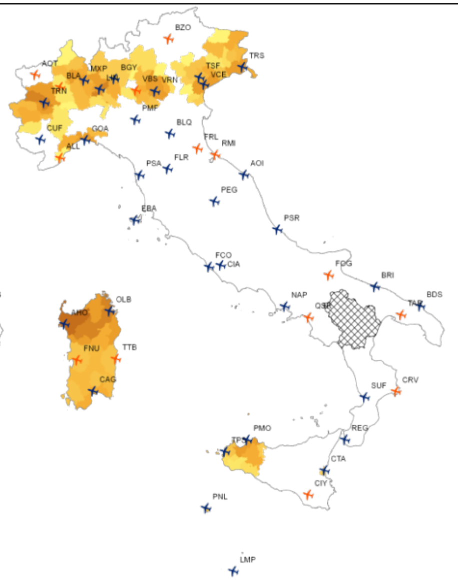
APPENDIX 1 – Domestic destinations available from the closet airports to the zones in the catchment area of a local airport (Source: OAG database, average working day in the week 8 – 14 April 2013)

		Airports with scheduled service in the sample					
		BARI	CATANIA	NAPOLI	LAMEZIA T.	PESCARA	VERONA
Destinations available	*Alghero*			x			x
	Bari		x				x
	Bergamo	x			x	x	
	Bologna	x	x		x		
	Brindisi						x
	Cagliari	x		x			x
	Catania	x		x			x
	Florence		x				
	Genoa	x	x	x			
	Milan Linate	x	x	x	x	x	
	Milan Malpensa	x	x	x	x		
	Naples		x				x
	Olbia			x			x
	Palermo	x		x			x
	Pisa	x	x		x		
	Rome Ciampino	x					
	Rome Fiumicino	x	x	x	x		x
	Trapani						x
	Treviso						
	Trieste	x	x	x			
	Turin	x	x	x	x	x	
	Venice	x	x	x	x		
	Verona	x	x	x			

APPENDIX 2 – Generalized cost in the base case scenario and percentage decrease with PSOs (scenario 1) or bus connections (scenario 2)

	Average Generalized Cost [€] – scenario 0	*% decrease of the GC – scenario 1*	*% decrease of the GC – scenario 2*
COMISO			
BASILICATA			

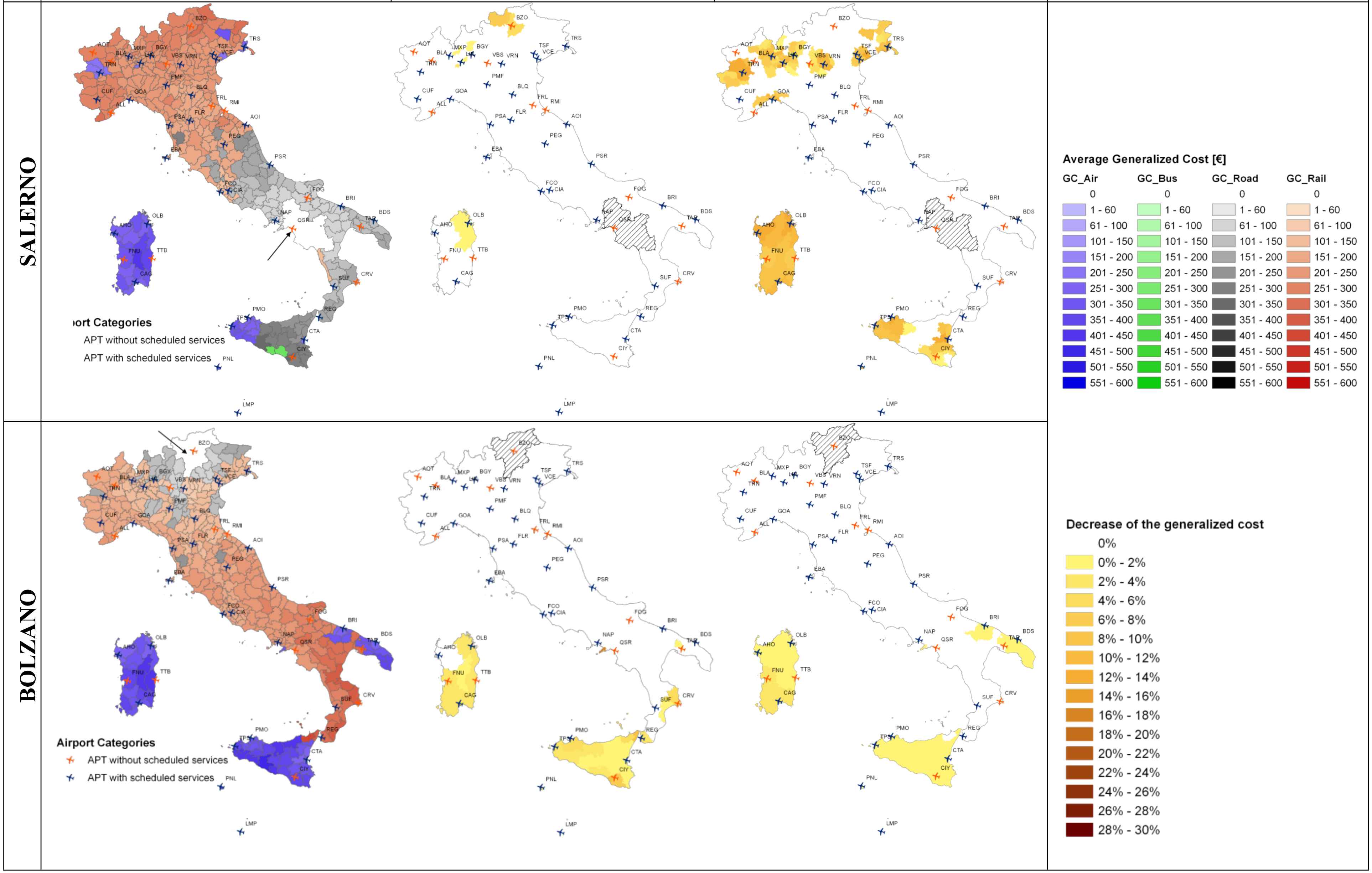
Average Generalized Cost [€]

GC_Air	GC_Bus	GC_Road	GC_Rail
0	0	0	0
1 - 60	1 - 60	1 - 60	1 - 60
61 - 100	61 - 100	61 - 100	61 - 100
101 - 150	101 - 150	101 - 150	101 - 150
151 - 200	151 - 200	151 - 200	151 - 200
201 - 250	201 - 250	201 - 250	201 - 250
251 - 300	251 - 300	251 - 300	251 - 300
301 - 350	301 - 350	301 - 350	301 - 350
351 - 400	351 - 400	351 - 400	351 - 400
401 - 450	401 - 450	401 - 450	401 - 450
451 - 500	451 - 500	451 - 500	451 - 500
501 - 550	501 - 550	501 - 550	501 - 550
551 - 600	551 - 600	551 - 600	551 - 600

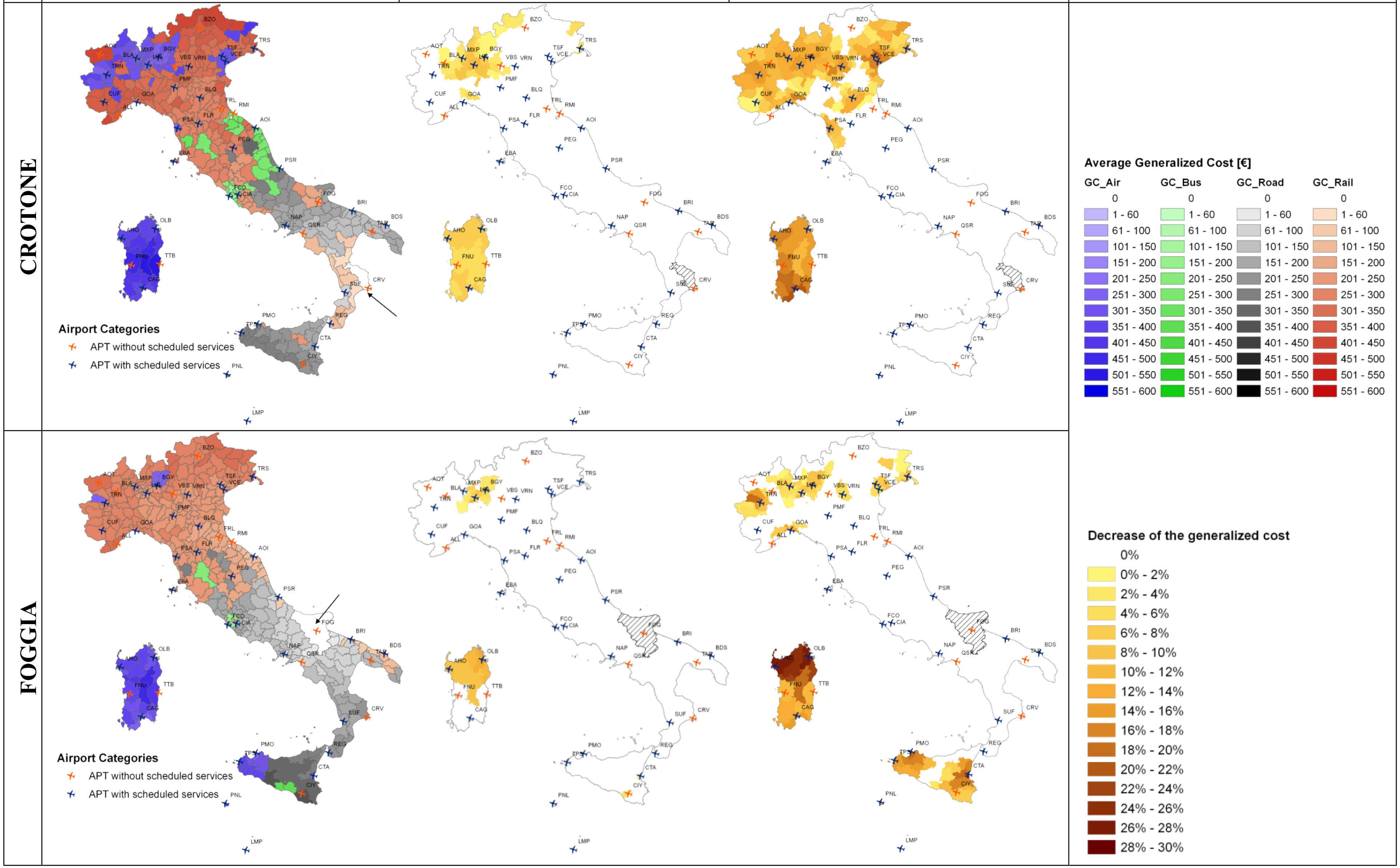
Decrease of the generalized cost

0%
0% - 2%
2% - 4%
4% - 6%
6% - 8%
8% - 10%
10% - 12%
12% - 14%
14% - 16%
16% - 18%
18% - 20%
20% - 22%
22% - 24%
24% - 26%
26% - 28%
28% - 30%

	Average Generalized Cost [€] – scenario 0	*% decrease of the GC – scenario 1*	*% decrease of the GC – scenario 2*	



	Average Generalized Cost [€] – scenario 0	*% decrease of the GC – scenario 1*	*% decrease of the GC – scenario 2*	



APPENDIX 3 – Parameters of the public transport fares, by mode.

Category	Fare typology	p_0 [€]	ρ [€/km]
Standard	Full	6	0.057
	Discounted	4.37	0.052
	Family	5.80	0.048
Low cost	Full	17.32	0.044
	Discounted	8.14	0.026
	Family	15	0.035

Table 8 - Values used to compute the fares for coach transport (Source: our elaboration on data collected on operators' websites)

Category	Competition	p_0 [€]	ρ [€/km]
Business	Yes	25.7	0.1618
	No	25.7	0.1618
	Subsidized services	1.23	0.067
Not business	Yes	6.83	0.05
	No	16.83	0.103
	Subsidized services	1.23	0.067

Table 9 - Values used to compute the fares for rail transport (Source: our elaboration on data collected on operators' websites)

Category	Competition [€]	No competition [€]
Business – Full cost	135	164
Business – Low cost	101	164
Economy – Full cost	57	77
Economy – Low cost	42	77

Table 10 - Values used to compute the fares for air transport (Source: our elaboration on data collected on operators' websites)

Highlights

- Two scenarios tested to improve domestic accessibility from remote areas: PSO from local airport and improvement of ground connection to the main airports.
- Comparison based on the calculation of the generalized cost using a national-scale transport model.
- The more an area is unconnected to the national network the more a PSO could be effective.
- Improving ground accessibility to the main airports has a wider impact than PSO in terms of decrease of the minimum generalized cost and in the extension of the areas with a reduction