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BETWEEN *FLYGSKAM* AND *TÅGSKRYT*

A BALANCED TRAVEL POLICY FOR POLIMI COMMUNITY

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EXECUTIVE SUMMARY

1. The study aims at understanding the possible effect in terms of CO_2 reduction of changes of modal shares applied to the real travels of Politecnico di Milano university.
2. We analysed the entire database of authorised travels of the Polimi community occurred in 2019, the year before the pandemic, consisting of nearly 18000 trips.
3. The database tells us the country and region of destination of the trip, the number of days, and all modes used in the entire mission (not just to reach the destination). This information has been integrated by a semi-manual geolocation of all destinations in Italy and in the countries in a range of 1200km (France, Monaco, Switzerland, Austria, Slovenia, Croatia, Czechia, Slovakia, Hungary, Luxembourg, Belgium and The Netherlands). For other destinations, an average distance has been applied on a country basis.
4. Modes used have been grouped according to our aims, in particular distinguishing between trips involving an air leg, trips using non-air public transport (train in particular), trips using only private transport. To each mode is associated a unitary emission factor in grams of CO_2 per km.
5. Italy is the main destination of trips (11000 out of 18000). Germany is the second. Considering Italian regions, the nearest ones clearly get most of trips. Lazio is however the region generating the largest amount of distances driven, due to the tight relations with Rome.
6. For short-range destinations, train is dominant for cities, while car is preferred for sparse destinations, which is realistic considering the dispersion of industrial attractors typical of Northern Italy. The share of car drops beyond 200 km. Train is the main mode between 200 and 600 km, with shares around 70% or more. Above 600 km train share decline and begins the “reign of air”, but important exceptions exist such as Naples (800km, well served by HS train).
7. These figures are, however, quite different if we look at countries. Because of the distances involved, central Italy and Campania are the domain of train (82%) and plane is as low as 10%. In southern Italy and Sardinia, the proportions are reversed: 86% by plane, just 9% by train. The smaller neighbouring countries are comparable in distance to Central Italy, but the modal share is completely different: as low as 22% of Austria and up to more than 60% to Slovenija and Switzerland. Trips to Germany and France are not homogeneous due to the size of the country but have a higher air transport share (70 to 80%) that is comparable to Southern Italy and the contribution of train does not go beyond 20%.
8. In designing *flygskam* policies to push travellers from air to train for “short distances” (typically below 600km), one must carefully consider the level of service of trains, which varies considerably. Milan is an interesting case, with relatively near cities just across the Alps (southern Germany, Lyon, Marseille, etc.) where train is *today* not a viable option for many trips, while much farther destinations such as Naples that already are dominated by train. However, the contribution of air travels to these relatively near destinations is negligible with respect to intercontinental trips.
9. To test *flygskam* policies, we designed four scenarios and calculated the related CO_2 savings if all air trips passed to train. Scenario 1 shifts all trips below 500 km. That looks reasonable, but actually just 84 trips are involved and the effect is negligible: -0.3% of all Polimi travel emissions saved. Scenario 2 is more draconian: all trips below 800 km must take train. The effect is a cut of 38 ton of CO_2 equal to 3.2% of all emissions. Since a 800km train trip may be long and involve half or even an entire day (e.g. to Vienna), in Scenario 3 we excluded travels shorter than 3 days. This nearly halves the savings: 21 ton

or 1.8% of emissions. Finally, Scenario 4 does not consider a distance threshold, but just destinations where train is already used by more than 50% of travellers. The effect is 16 ton saved, or 1.3%.

10. Overall, we can comment that, despite expectations, forcing travels from air to train gives very marginal effects, quite irrelevant with respect to the total of emissions. The reason is that where available, train is already largely used and where not available, trips are generally few and sparse. The limited group of destinations where train is not particularly doable, but trips are many (Munich, Stuttgart, Lyon, Bruxelles, etc.) generate an impact which is positive, but remains a small share of total emissions with respect to local car trips and intercontinental flights. Forcing Polimi community to train in these cases gives a negligible total impact, but hits hardly travel conditions for hundreds of working missions, that take much longer and sometimes also cost more in reimbursement.
11. The study has limits (multiple trips not considered, no consideration of first and last mile emissions, lack of information on real origin of the trip) and represents the situation of this particular university. However, methodology and size of effects can be used as a reference for other institutions or firms.

1. INTRODUCTION

1.1 STUDY AIMS

The growing concern on climate change has pushed states and enterprises to quantify, monitor and possibly reduce the carbon impact of their activities. Despite not being particularly energy-eaters, some universities are looking at their own energy consumption behaviour, quantifying the emissions related to their activities and, secondly, reducing them through various policies.

Flygskam, the Swedish word for "flight shame" is one of the increasingly implemented actions: it translates the idea that all "short" flights should be avoided in favour of public land transport because it is less polluting. While it is imperative to use air transport for a trip in the order of thousand kms, *flygskam* vision assumes that a trip of hundreds of km might take "some doable" hours and, consequently, must shift to train to reduce the negative impacts of aviation.

While this "philosophy" seems quite reasonable, **some aspects must be taken into consideration seriously before any non-voluntary application**:

a. Using simple distance thresholds may disadvantage areas where land transport is particularly ineffective. For example, from Milan to Central Italy or Switzerland, all main cities are reasonably well connected over hundreds of kilometres. However, trips to Southern Germany, Southern France, or Slovenia, even under 500km, typically require an entire day of travel by train, due to slow and, most of all, scarce connections.
b. With the exception of specific cases, short air trips (e.g. Milan – Zurich or Milan – Rome or even Pescara – Rome) exist mainly as feeder routes rather than for point-to-point traffic, which would be otherwise low due to good land alternatives. Consequently, a point-to-point traveller who chooses air transport (see next point) is typically a marginal traveller, and his emissions are not exactly additional.
c. A train trip of 5-6 hours during the day often means that most of the working day is spent on the train and the destination cannot be reached in the morning. On the contrary, early departures in air travel – even if total travel time is comparable – are there exactly to allow for arrival at the destination early (and depart later), and thus leaving the entire working day available. Night trains, that makes exactly the same job, have progressively disappeared since 2010 (Bird et al., 2018), with a partial return in the very recent years.
d. The modal choice – and thus the travel comfort – depends significantly on origin and destination of the trip. While a Milan – Rome trip is undoubtedly better by train, a Varese – Pomezia trip by train would be extremely less effective than by plane. Consequently, the point-to-point traffic observed on short air routes is often made also of these travellers, that live and/or are directed near airports.

Given these premises, **in this study we aim at understanding the possible – actual – effect in terms of CO2 reduction of changes to modal share applied to the *real* travels of Politecnico di Milano university** (hereinafter "Polimi") **community, to provide sound and informed background of possible *flygskam* policies**.

To do that, **we analysed the entire database of authorised travels of the Polimi community occurred in 2019**, the year before the pandemic. The elaboration of this database provides an extremely detailed picture of *where* and *how* Polimi travels have been directed, preventing the risk of misrepresentations based on personal and qualitative beliefs.

1.2 LIMITS AND TRANSFERABILITY OF RESULTS

We paid close attention to the cleaning and interpretation of the dataset (see section 2). Nevertheless, the study faces some intrinsic limits as well as limits in terms of transferability to other contexts.

Firstly, despite being extremely detailed, **the database lacks the origin of the trip**.[1] For example, we know that a trip reaches Rome by plane, but we do not know whether the person departed from Milan or from another place (another Polimi campus or simply his/her home located somewhere).[2] This fact slightly influences the calculation of CO2 emissions, but especially the hypotheses on modal change. In fact, it is totally different for the traveller directed to, let's say, Rome if the departure place is Milan – where a convenient HS train can be taken – or from the province of Varese – which is badly connected to Milan Central station but well connected to Malpensa airport.

A second intrinsic limit concerns **combined trips**. Even if we know that a mission is made of more legs/trips because the traveller has explained something in the description, this info has been discarded because it is impossible to geolocate and in many cases is insufficient to produce anything useful. As a rule, we considered the farthest destination to reduce the underestimation of emissions.

A third limit lays in the fact that **we ignored the first and last mile modes**, both because we do not really know them and ignore their length. Therefore, since our focus is on non-local trips, we assumed that the unit emissions per km are those of the "main" travel mode, as described later in methodology section.

In terms of **transferability**, of course, this exercise is biased by the fact that we focus on one specific institution, which is unique in terms of ties (with whom Polimi people collaborate) and in terms of location (being in Milan makes trips different from a similar institution located differently). Nevertheless, we believe that **the size of the effects and even the conceptual approach could be utilised as a reference for other non-peripheral European universities in defining their CO2 reduction policies**.

[1] This issue has been fixed in earlier years, but we preferred to focus on pre-COVID data.

[2] We also have trips directed to Milan: some are local trips, but others (for example when air transport is involved) are trips originated elsewhere and directed to Milan, for example by colleagues of other universities who received travel reimbursement from Polimi. We discarded all of these trips from the policy analysis, but they remain in the state-of-the-art analysis.

2. Data and Methods

In this section we introduce the database used and the operations done to perform the following analyses (Section 3) and scenario simulations (Section 4).

2.1 Data structure

The original database comprises the following relevant fields (Table 1). The main operations have been performed to reclassify modes, to group countries, to geolocate the free text destination for Italy and near Europe countries, and to associate a distance to every trip. These operations are described in 3.3.

Table 1. Fields of the original dataset

Nome	*Descrizione*	*Free field*
TIPO_CARRIERA	Career associated to ID number (staff., student, etc.)	
DETT_TIPO_CARRIERA	Sub-type of career (full professor, fellow, etc.)	
DES_STRUTTURA_AFF	Department of the traveller	
NOME_STATO	Country of destination	
NOME_REGIONE	(Italian) Region of destination	
DESTINAZIONE	Description of destination	x
DATA_INIZIO	Departure date	
DATA_FINE	Return date	
N_GIORNI	Number of days	
N_GIORNI_ESTERO	Number of days abroad	
TRENO_ORDINARIO	Mode used: train	
AEREO_ORDINARIO	Mode used: airplane	
NAVE_ORDINARIO	Mode used: boat	
BUS_TRAM_ORDINARIO	Mode used: bus or tram	
TAXI	Mode used: taxi	
TAXI_COLLETTIVO	Mode used: shared taxi	
NOLEGGIO	Mode used: car rental	
CAR_SHARING	Mode used: car sharing	
BIKE_SHARING	Mode used: bike sharing	
MEZZO_PROPRIO	Mode used: owned vehicle	
MEZZO_AMMINISTR	Mode used: Polimi vehicle	
MEZZO_TERZI	Mode used: third party's vehicle	
MEZZO_ALTRI_TIPI	Mode used: others	
KM	Distance travelled by own vehicle	x

The main missing information is related to the lack of origin of the trip: we do not know where the person lives. We decided to discard the information of the campus of work because it is not true that one lives in the nearby of the campus and many colleagues are formally associated to an external campus even typically work in Milan offices.

2.2 SAMPLING AND OBSERVATION PERIOD

The database includes 17957 entries, each one corresponding to a request of reimbursement. Typically a request matches with a trip, but it is possible – and treated informally – to group more trips. For example, one could depart from Milan, reach Rome for a meeting and then go directly to Naples for a conference before returning home. This chain of trips is described in the free field "Destinazione" (Destination) and managed by offices checking the travel receipts. This is clearly a problem because we must associate a destination to every entry. As a general rule, we referred to the farthest destination.

The database coves the entire 2019 and all Politecnico di Milano campuses: the two Milan ones, Lecco, Piacenza, Como, Mantova and Cremona. All campuses have been considered in the elaborations, assuming that all trips depart from Milan, which is clearly not true, but impossible to control for the already mentioned reason that we do not have the origin of the trip.

2019 has been chosen because it is the last one before COVID pandemic, and thus the one best representing the world "before" the sudden discover of teleconferencing and smartworking.

2.3 RECLASSIFICATION OF MODES

As one can see from the definition of fields, we have much information on modes used for the entire travel, but they are not necessarily associated to the trip from origin to destination, but to the overall mission (and consequent reimbursement). For example, the indication of car, train, plane, taxi and bus is not a sequence and could mean that the traveller has used his car to go to the airport, then took a taxi to the hotel and, during the days of the mission, has used also a train and local buses. In other words, we do not know the chain of modes from origin to destination, but all modes that has been used during the entire mission and whose receipts will be attached to the reimbursement.

However, as our focus is on air transport, we were able to simplify all the possible combinations of modes and define two levels of aggregation of modes. A first level, more detailed, is used for the analytical part and the second, more aggregated, is used to back the policies simulation.

Table 2. Classification of modes

Aggregation level 1	*Description*	*Aggregation level 2*
car	Combinations without any public mode (own car, moto, shared car, etc.)	Car
local PT	All local transport options (e.g. tram), with or without own car	Public
train	Only train, with or without own car	Public
train+PT	Train and local transport, with or without own car	Public
train+car	Train and private modes, with or without own car	Public
boat	Boat, with or without own car	Public
boat+TP	Boat and local transport, with or without own car	Public
air	Air transport, with or without own car	Air
air+PT	Air transport and local transport, with or without own car	Air
air+car	Air transport and private modes, with or without own car	Air

The main comment on level 1 is that the use of private car makes no difference for trips involving any public transport option. This is because we assume that own car is used from home to the access point of the network, but it is not significant for our discussion on air transport use. Private car is differentiated only when it is the only mode used. Similarly, from the point of view of emissions we assume that if air transport is used, all other modes are ancillary.

The second level further groups in private transport only, travels involving an air leg and all other travels involving public transport. Since in the following we will focus on long distance trips, this classification means that public transport almost always matches with train travels.

2.4 DISTANCES AND SEMI-MANUAL GEOLOCATION

The only geographical information we have directly from the database is the country of destination (NUTS-1) and, just for Italy, the region (NUTS-2). For the calculation of long-distance emissions one can, in principle, assume (see) that the access will be via air transport, through one specific airport,[3] and that the air transport emissions will dominate the emissions associate to access and last mile. However, in the range of hundreds of km, the path matters (there are more options to reach a place) and the average distance of a country cannot be used to define modal shift policies.[4]

For this reason, we proceeded with a differentiated approach to geolocation of trips

- Trips to Central and Southern Italy, France, Monaco, Switzerland, Austria, Germany, Slovenia, Croatia, Czechia, Slovakia, Hungary, Luxembourg, Belgium and The Netherlands (everything in a range of 1200km) have been manually geolocated and a calculated distance has been associated to each destination
    - The **land distance** is calculated via Google Maps from Milan to the city of destination;
    - The **air distance** is the distance from Milan to the nearest "useful"[5] airport, considering detours for airports not directly connected to Milan ones.[6]
- Trips to Northern Italy has been geolocated only partially,[7] enough to obtain a reliable "average distance", but at the same time to reduce the burden of the manual geolocation. Since our focus is on air transport these near destinations are irrelevant and the information on distance is needed just to have a reliable estimate of the contribution of their emissions to the grand total.
- Trips to all other countries (in Europe and abroad) are not located and get an average distance to the country.

[3] For example, 1003 km for Albania, which is the direct air distance between Milan and Tirana and assuming that plane is the only reasonable way to reach the country

[4] Going to Nice from Milan is totally different than going to Nantes and thus the "average distance of France" is not representative of anything.

[5] For example, Graz has an airport, but it is irrelevant when coming from Milan and consequently Vienna has been associated to Graz assuming that the last section of the travel is done by land transport.

[6] For example, there is no direct flight to Nantes (or is very infrequent), so it is considered a trip Milan-Paris-Nantes, assuming Paris as the most likely hub airport used.

[7] For example, in Lombardia we did *not* localise 1200 destinations out of 3900; in Liguria 31 out of 375.

2.5 QUANTIFICATION OF EMISSIONS

The last operation needed to perform the analyses is the quantification of unitary emissions. To maintain comparability, we used the same coefficients already used previously by Polimi in the emission balances (Caserini and Baglione, 2018) with minor adaptations. Coefficients are listed in Table 3.

Table 3. Unitary CO_2 emissions by mode group (Source: adapted from Caserini and Baglione, 2018)

Mode	*g/pkm of CO_2*	*Notes*
car	123,1	Average car occupancy: 1,3
local PT	20	Intermediate value between 26 (bus) and 15 (tram&metro)
train	18,6	Regional 11, HS 15, generic 13. We assume generic, with load factor 70%
train+PT	18,6	Same as train
train+car	18,6	Same as train (we assume car marginal for first or last mile only)
boat	18,6	No info: same as train
boat+TP	18,6	No info: same as train
air, below 1500 km	121	
air, below 4000 km	92	
air, above 4000 km	52	

3. Current travel patterns at Polimi

In this section, an in-depth analysis of the travel patterns observed during the year 2019 was performed.

3.1 Destinations and modal share by country

The following Table 4 and Figure 1 enlist and illustrate respectively the destinations of Polimi trips by country and by Italian regions. Italy is, of course, the main destination with over 11000 trips, followed by Germany with 757 trips. Overall, all non-Italian destinations account for approx. 6300 trips. Looking at regions, the number of trips to Lazio is significant: while Lombardy and Emilia-Romagna include many very short-range trips, Lazio (primarily Rome) is by far the main destination in terms of distances travelled, with nearly 1 million km.

Table 4. Top-20 destination countries and Italian regions

Top-20 countries	*Trips 2019*
Italy	11577
Germany	757
France	597
United States	574
Spain	476
Switzerland	470
Belgium	466
United Kingdom	466
Netherlands	341
Austria	236
China	187
Portugal	153
Greece	134
Sweden	121
Finland	102
Poland	100
Canada	98
Denmark	85
Japan	66
Hungary	58

Italian regions	*Trips 2019*
Lombardia	3945
Lazio	1628
Emilia-Romagna	1320
Piemonte	978
Veneto	685
Toscana	617
Campania	384
Liguria	375
Trentino-Alto Adige	375
Puglia	282
Sicilia	223
Marche	193
Friuli-Venezia Giulia	131
Sardegna	111
Umbria	111
Abruzzo	82
Basilicata	64
Calabria	45
Valle d'Aosta	25
Molise	3

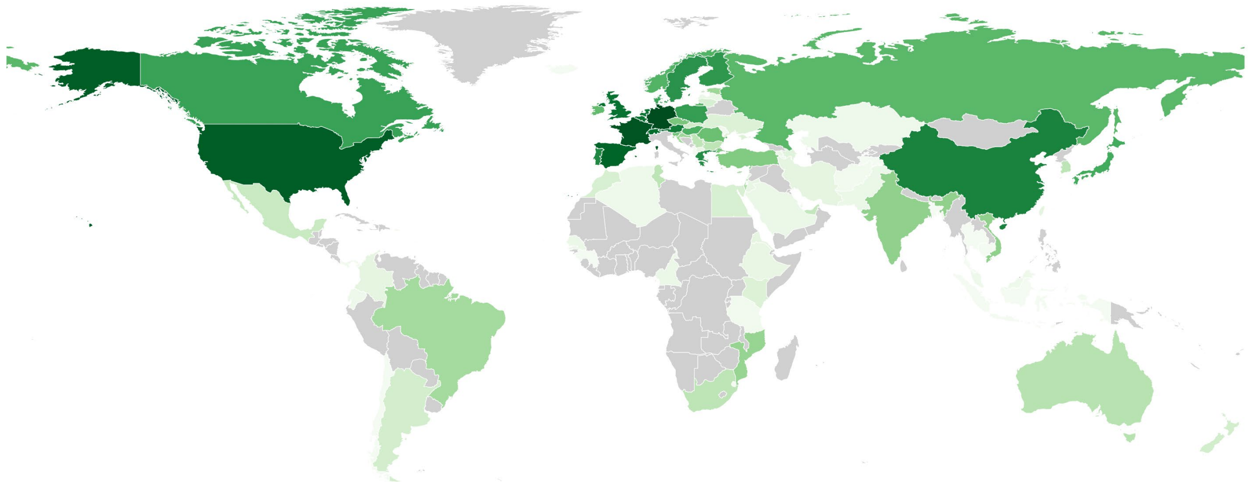

Figure 1. Map of international destinations from Polimi, year 2019

We can detail the modal share by distance class by associating, as described in Section 2.4, a distance and a prevalent mode to every destination (Figure 2). As expected, the **modal share of car** is largely relevant for short trips, especially considering the dispersion of industrial attractors typical of Northern Italy. The share of car drops to 28% only beyond 200 km and then plunges even more beyond 500 km after which its contribution is only 7%.

Train initially rises at about 35% for short distances and goes upwards to 77% for 500-600 km trips, which represents the "ideal" distance for train travelling. However, above 600 km train share goes down to 31%, except for the range 700-800 km (up again to 49%) that is the distance of Naples, where an effective high-speed service exists.

We observe the transition from train to **plane for distances greater than 600 km**, with a justifiably increasing trend with distance (up to 85% for 800 – 900 km and 98% above 1200km). Interestingly, we observe a local maximum of air share at 600-700km, which correspond to southern Germany.[8]

An important inference from these results with respect to the *flygskam* policies can be drawn. It would be reasonable, in fact, to focus on **eliminating air trips could for distances lesser than 500 km** (where there are real life examples of the trains being effective, both with respect to time and comfort) and **reducing it for distances between 600 and 800 km** (just where trains are effectively providing satisfactory service).

[8] In Italy, the distance of 6-700 km from Milan is quite an "empty" area, with l'Aquila being the first destination (35 trips, 74% by train) and Fiuggi the second (just 9 trips/year). As a comparison, the first international destination in the same distance range is Frankfurt, that receives 33 trips/year, 78% by plane.

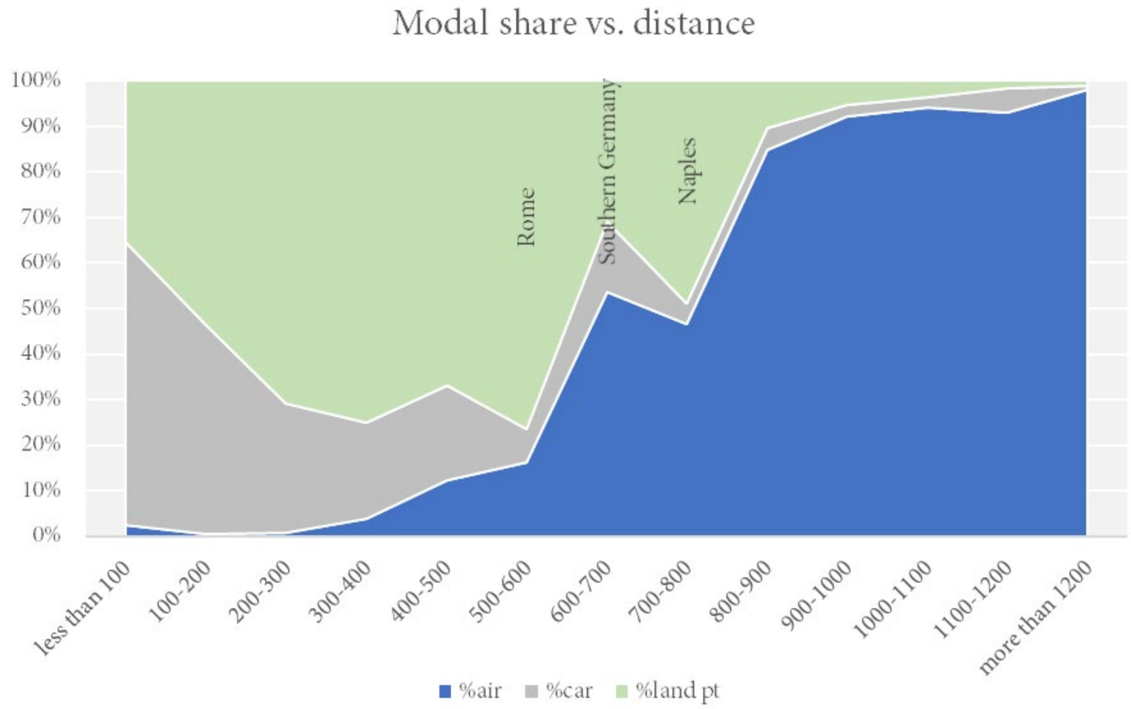

Figure 2. Modal share by distance

These figures, however, hide important differences among specific destinations, that demand a more detailed examination as seen below. Figure 3 illustrate the expected differences in terms of consistency of trips and modal share.

Northern Italy is out of scale, but also out of papers' scope. Because of the distances involved, central Italy and Campania are, expectedly, the domain of train (82%). Car gets a residual 9% (of course, some travels may require carrying materials or destinations be particularly inaccessible via public transport) and plane is only 10%. In southern Italy and Sardinia, the proportions are reversed: 86% by plane, just 9% by train.

The neighbouring countries of Switzerland, Austria and Slovenia are **comparable in distance to Central Italy, but the modal share is completely different.** Switzerland, which is the only country well connected with international trains, has a good 63% share of trains. Slovenia is even higher, because of the longer distance mix and lack of air connections. To Austria, whose main destinations are farther and barely connected, train falls to 22%. We will further investigate these differences in the following.

Due to the order of distances, **international trips to Germany and France have a relatively higher air transport** share (68% to 82%) that is comparable to Southern Italy. To Germany, in particular, the contribution of train does not go beyond 7%.

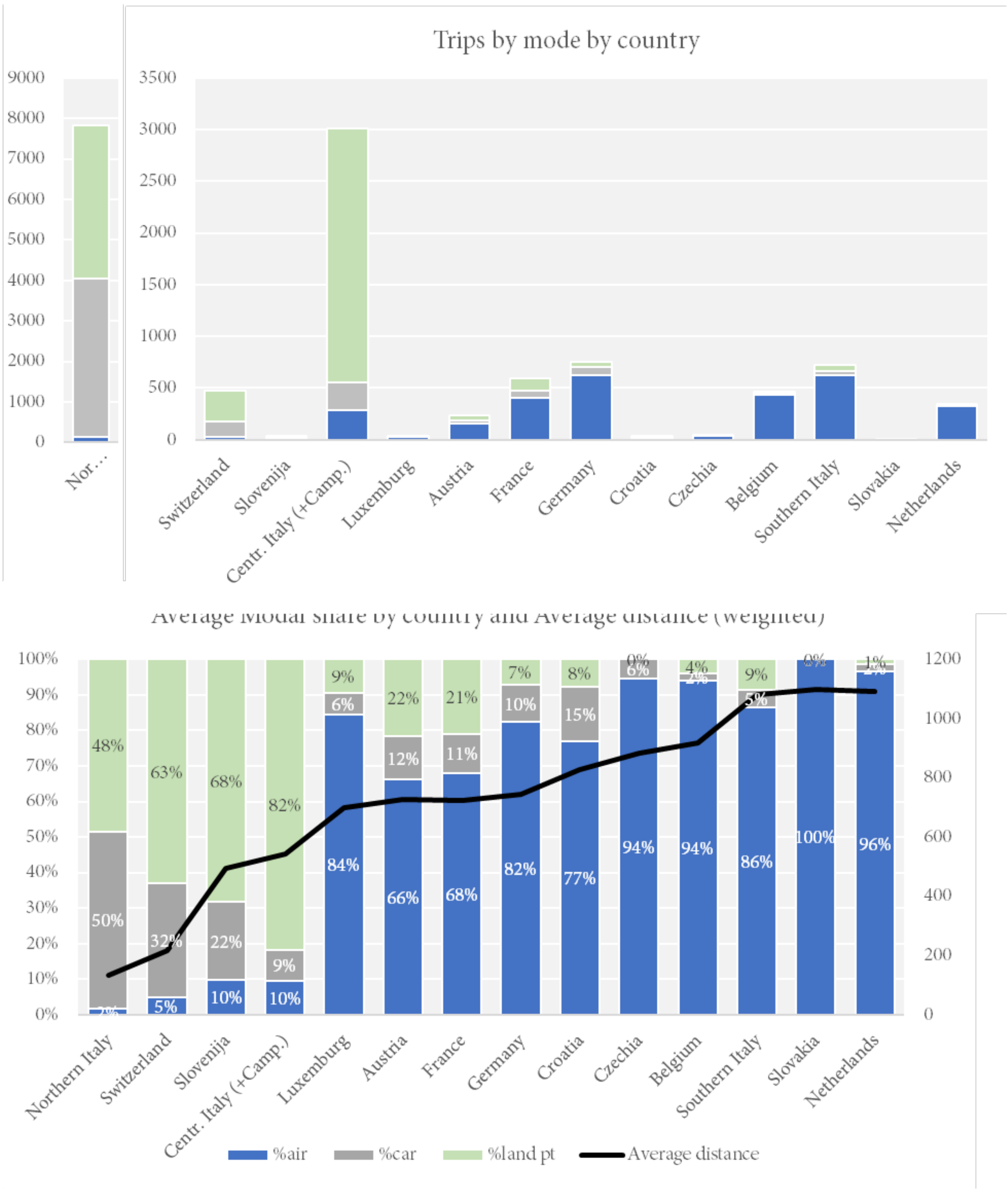

Figure 3. Total trips and modal share by destination group

3.2 STUDY AREA DESTINATIONS AND RELATION WITH TRAIN ACCESSIBILITY

The analysis by groups of countries is realistically hiding significant differences in terms of modal share. For this reason, **we geolocated all travels directed to Italy and abroad below 1200 km**, for a total of 14272 observations out of 17957. This also allows to **calculate a precise distance**, with the exception of observations for which association of a precise place was impossible.[9] These unknown destinations have been assigned the average distance of the other geolocated destinations of the country.

Figure 4 evidently shows that air transport is irrelevant (0% to 10%) for reaching destinations of Switzerland, Tyrol, Slovenia, eastern France and Italy up to Roma and Chieti/Pescara. Air transport share gains significance (above 30%) in specific cities that do not correspond to a specific distance threshold. For example, air transport is preferred for destinations such as Lyon (450km) or Marseille (528 km) than to Naples (772 km) because the latter is well connected with train services while the French cities are not. Interestingly, we observe some minor destinations around Rome or Naples where air transport is proportionally higher. In these cases, the destination is not a city centre and air transport can be integrated with a rented/shared car for completing the last mile more conveniently than by train.[10]

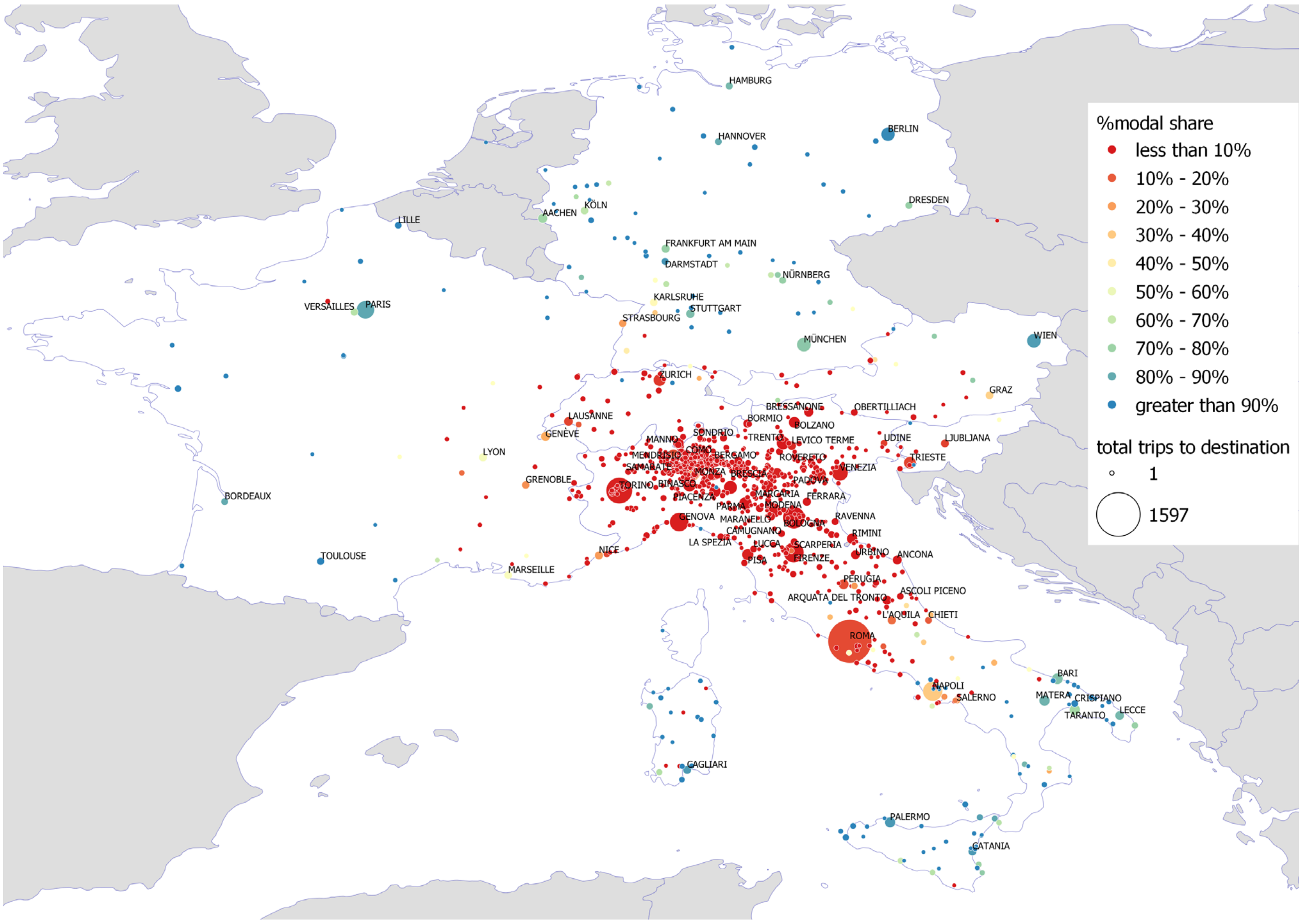

Figure 4. Localisation of travels in the study area (dot size) and modal share of air transport (colour).

The "reign of air" is quite evidently demarcated (Figure 5). In Italy, destinations south of Naples and the islands of Sardinia and Sicily, where the air transport share is always above 80%. Most of city destinations in Puglia, for example, take more than 6-7 hours to reach. Out of the cities the percentage of air transport is even higher because of the inconvenience of interchange.

In France, cities that are farther than Lyon, Marseille and Strasbourg towards the west and the north are dominated by air. In Austria, air transport is exclusively used for far north and east destinations, with Graz as a

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[9] For example, those described as "University" or "meeting with professor Müller" without city details.

[10] For example, reaching the area south of Rome by train and suburban bus could be complicated in some hours of the day and air plus car can be preferred.

reference where modal share of air transport is 20-30%. The capital Vienna in the far east is connected to Milan by a couple of night trains/day, but considering the duration, the nature/motive of the trips, and even comparable prices with flights, air transport contributes to more than 90%. Germany seems to be the most interesting case in terms of *flygskam* policies because even towards cities like Munich and Stuttgart that are at a doable distance from Milan (500 km) by train, the air transport is dominant because of long time and few connections. Basically, any destination north of Basel is dominated by air trips.

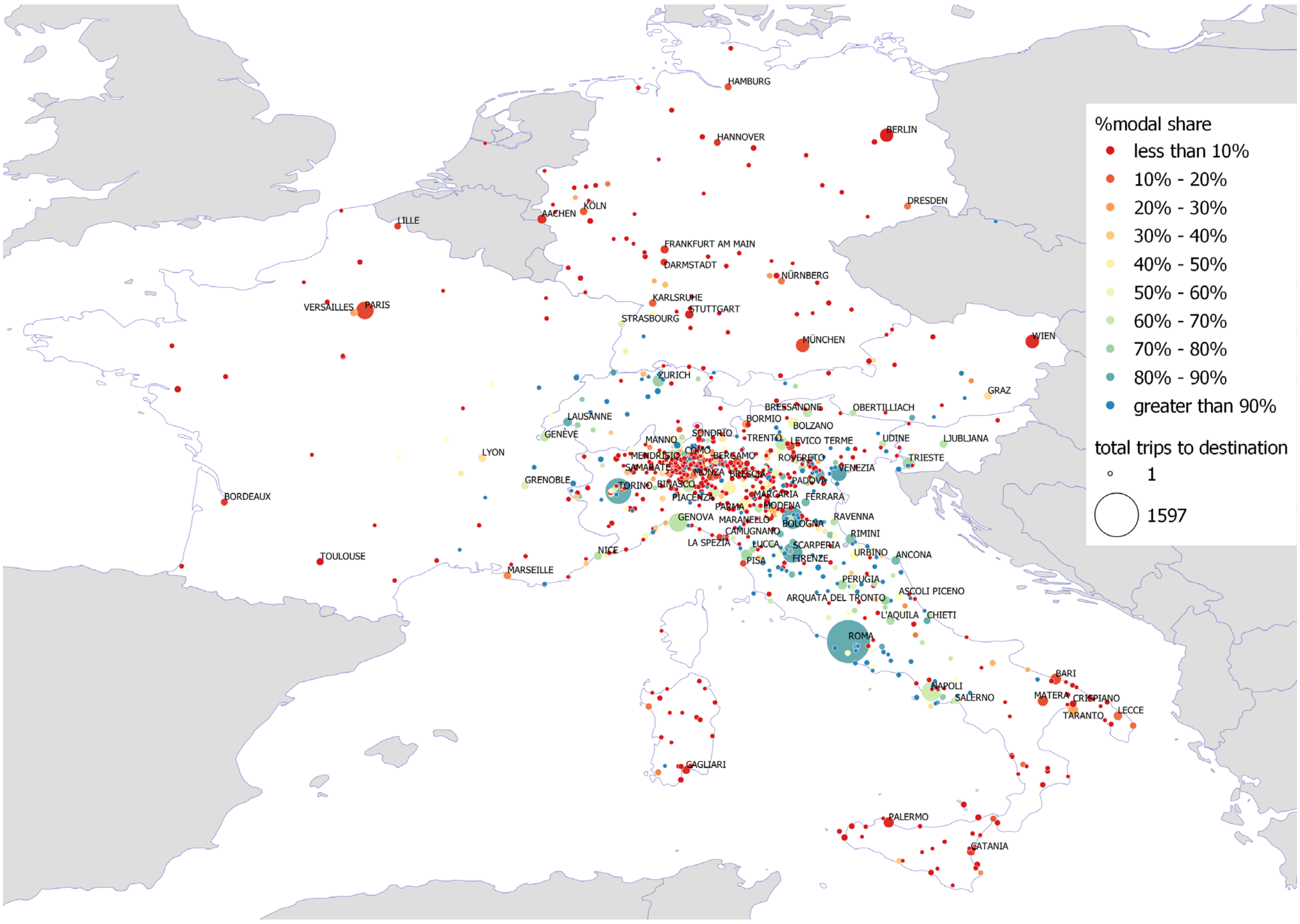

Figure 5. Localisation of travels in the study area (dot size) and modal share of land public transport (colour).

No unique distance–dependency function is observed for near European countries, as seen in Figure 6. In the case of France, Austria and Hungary the percentage of air transport is lowest for nearer destinations and increases more or less quickly with increasing distance, with the shape of the decay depending on direct transport options. In the case of Switzerland, with its ideal proximity range and connectivity, train is the dominant mode of transport. However, a slight increase in air transport share is observed with distance and seems somewhat linear with an extremely mild slope. Germany displays outlier behaviour because even though the share of air transport increases from Munich (500km – 80%) to Berlin (1000km – 100%), airplane usage is more or less static and seems to be irrespective of the distance for the cities between these extremes. The difference with France, still not particularly well connected by rail, is clear.

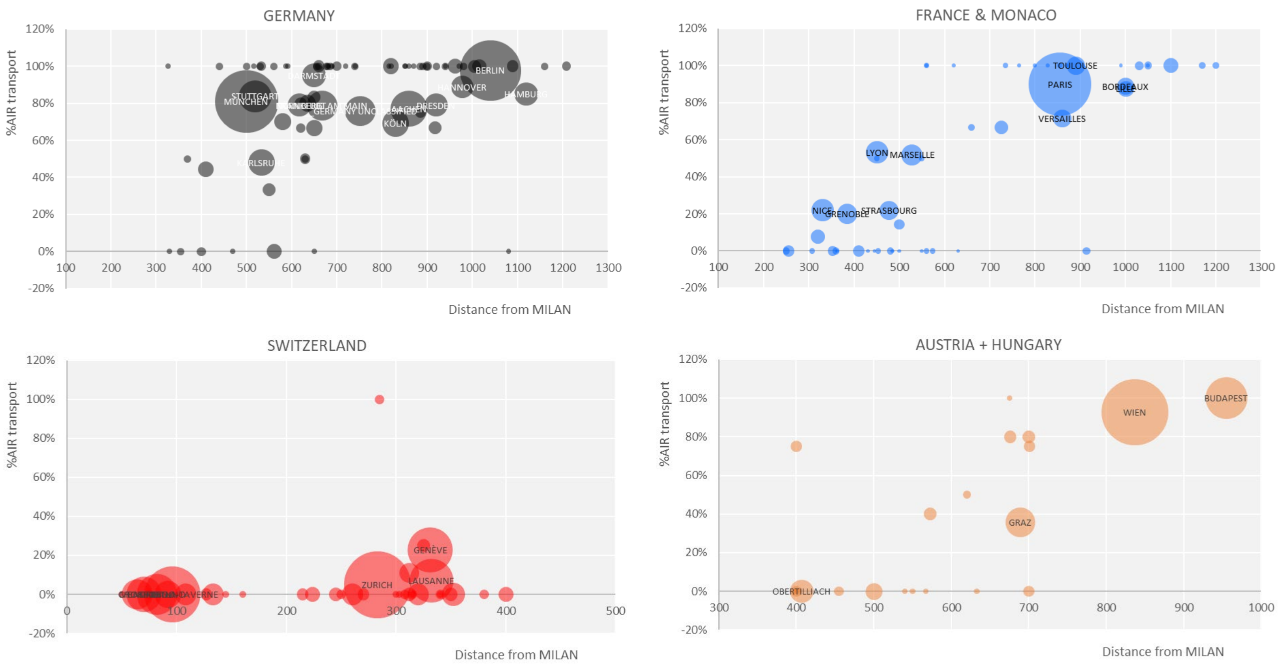

Figure 6. Modal share of air transport in function of distance from Milan.

It is beyond the scope of this report to analyse the **usage of car**. However, Figure 8 confirms that car is preferred for trips to destinations (towns and villages that are also typical of industries) that are sparse and relatively near to Milan. This is primarily to avoid unnecessary time losses for interchanges in short trips. In this context, cities are instead always preferred to be reached with train or air transport depending on the distance, but seldom by car.

Figure 7 Average modal share Vs Distance for the different groups

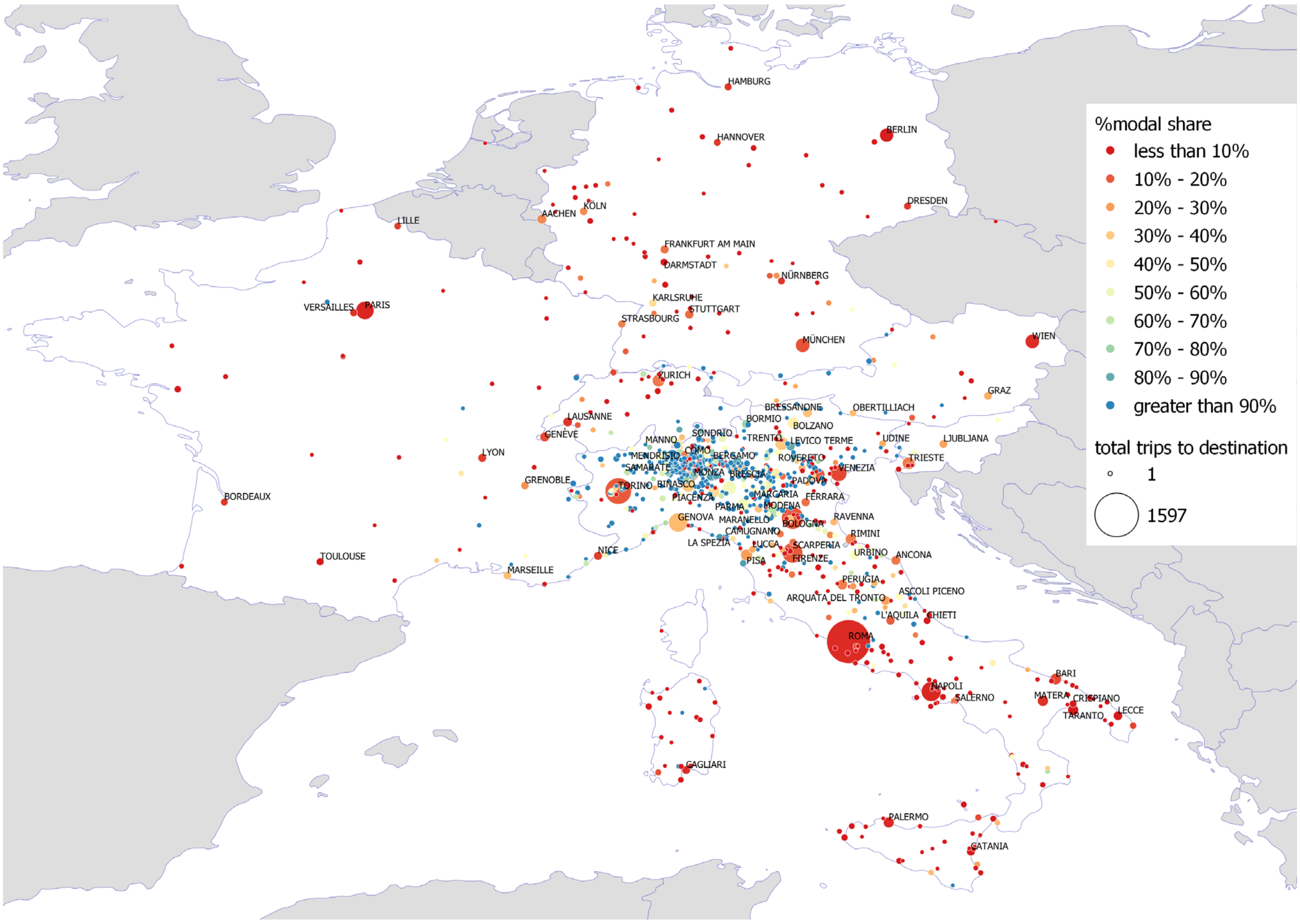

Figure 8. Localisation of travels in the study area (dot size) and modal share of private transport, including rental and lifts (colour).

In conclusion, **where reasonably fast and frequent connections with Milan exist (larger towns and cities in most of Italy and Switzerland), the train is almost always preferred, even if distances are very long (800 km)**. Car is abundantly used around Milan (radius of a 50-100km). Relatively close foreign destinations, such as Lyon or Graz, represent the marginal situations with concurrent presence of both train and plane in which some colleagues prefer the plane while others prefer the train according to trip characteristics. For other destinations within doable distances such as Munich and Stuttgart, low frequency of direct connections and travel time reduces the propensity to use train.

The problem when implementing *flygskam* policies is that **contestable destinations** (defined in Figure 9 as those where the minimum of modal share of either plane or train is 20%), **such as Lyon or Naples, are few and consequently the actual CO2 reduction effect obtainable with non-draconian policies is extremely limited.**

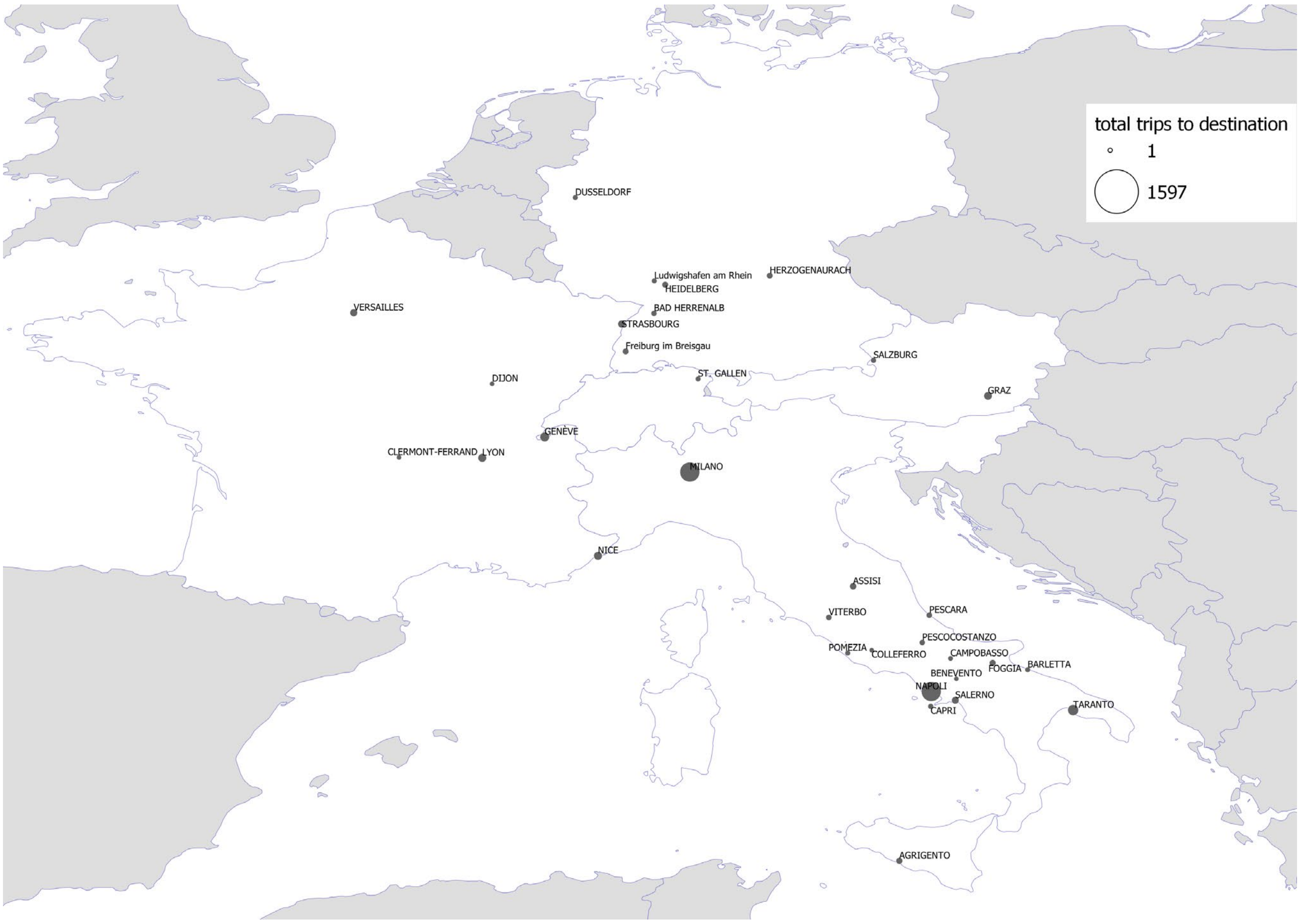

Figure 9. Contestable air / train destinations, defined as those where each of the two options has 20% of modal share or more.

3.3 DISTANCES TRAVELLED

Since CO_2 emissions are proportional to distances travelled, we introduce this variable to have a realistic size of potential effects of emissions reduction.

Table 5. Overall modal shares and destination shares.

Overall modal shares and destination shares

	modal share (#trips)	modal share (distance)		destination share (#trips)	destination share (distance)
car	26%	5%	ITA_nord	44%	6%
local PT	1%	0%	ITA_cent+Campania	17%	9%
train	24%	8%	ITA_sud	4%	4%
train+PT	13%	4%	CH+AU+SL	4%	2%
train+car	0%	0%	DE+FR	8%	6%
air	17%	64%	EU_far	16%	20%
air+PT	18%	18%	WORLD	7%	53%
air+car	1%	1%			
boat	0%	0%			
boat+TP	0%	0%			

As visible in Table 5, considering distances in the equation totally reverses the importance of destination groups. While northern and central Italy and the region of Campania, where train services are predominant, account for 60% of total Polimi travels, these trips contribute to only 15% of all distances travelled. Aggregating Southern Italy and the neighbouring European countries, they contribute to 16% of the trips and account for just 12% of distances. The remaining 24% of long-distance trips (far Europe and rest of the World) aggregate to 73% of all travelled distances. As already established that **short and long-distance travels are out of the target distance ranges, the group of trips that are actually compatible with the *flygskam* policies accounts for as low as 12% of all travelled distances. Moreover, in this group, the destinations that are contestable (because train options are realistically comparable to air ones) are not all, and thus potential emission reduction is a subgroup of this 12%**.

Considering the actual modal share, Table 6 clarifies that **total distances travelled by air in the four regions of interest represent just the 10.2% of all travelled km by Polimi people** and this value comprises **destinations where air cannot in any case be reasonably substituted with train**, such as Palermo, Berlin or Bordeaux.

Table 6. Total distances travelled by destination group.

Total distances travelleb by destination group (km)

	ITA_nord	ITA_cent+ Campania	ITA_sud	CH+AU+SL	DE+FR	EU_far	WORLD	
car	440.893	114.465	38.337	44.011	86.081	96.090	-	819.877
local PT	5.568	14.624	3.801	4.664	6.871	1.870	-	37.398
train	384.264	862.532	29.994	59.895	37.933	24.995	982	1.400.596
train+PT	192.066	429.754	20.329	49.962	49.420	37.080	-	778.611
train+car	4.034	11.915	-	-	1.820	3.300	-	21.069
air	9.308	**73.683**	**263.347**	**39.828**	**249.020**	1.225.602	9.519.806	11.380.595
air+PT	10.558	**111.320**	**339.217**	**93.830**	**537.756**	2.073.983	12.652	3.179.316
air+car	-	**4.920**	**82.940**	**1.875**	**27.652**	81.255	-	198.643
boat	-	-	4.539	-	-	-	-	4.539
boat+TP	12.818	9.346	3.579	615	4.029	5.013	-	35.399
	1.059.509	1.632.560	786.084	294.680	1.000.582	3.549.188	9.533.440	**17.856.043**

4. Shift-to-rail scenarios

The opposite of *flygskam* is *tågskryt*: shame to flight, proud to travel by train. However, **travellers – and in particular business ones that must consider the trade-offs between travel time, working productivity and working comfort – cannot easily be forced to choose a predefined travel behaviour that is significantly worse than the best option**. While individuals can spend a month to reach New York by a cruise, it is easy to believe that this is not a reasonable option for a business traveller. That is why in this section we define four simple scenarios of modal shift that are compatible with business trips and quantify their actual effect in terms of emission reduction.

4.1 Simulations

As already clarified, we limit the analysis to the study area defined above: Italy and the five neighbouring countries. We considered also Belgium, Netherlands, Croatia, Czech Republic, Slovakia and Hungary to have a precise picture of travels, but the distances involved are too long and/or there is a lack of direct or reasonably indirect train connection.[11]

The scenarios we test in the study area are:

1. All trips below 500 km shift to rail;
2. All trips below 800 km, excluding Sardinia, shift to rail;
3. All trips below 800 km, excluding Sardinia, shift to rail if the trip is longer than 3 days;
4. All trips by air towards destinations where train modal share is already higher than 50%.

The third scenario is more realistic than the second, since forcing the traveller to 6 or more hours of train (plus first and last mile) probably requires spending one or two nights out more and consequently this option becomes incompatible with short missions, daily ones in particular. The last one indirectly takes in consideration the actual travel conditions, assuming that if the majority of travellers use the train, all "could" use it.

Table 7. Scenarios impacts

	Total trips	*Impacted trips*	*%impacted trips in study area*	*Total emissions (ton CO_2)*	*Delta emissions*	*%total emissions*
All trips	17957			1190.51		
Study area	6828			343.45		
scenario 1		84	**1.2%**	340.46	**-2.99**	**-0.3%**
scenario 2		769	**11.3%**	305.70	**-37.75**	**-3.2%**
scenario 3		425	**6.2%**	322.48	**-20.97**	**-1.8%**
scenario 4		311	**4.6%**	327.40	**-16.05**	**-1.3%**

Table 7 summarises the results of the analysis. The study area comprises 6828 trips, generating 343.5 ton/CO_2 calculated with the coefficients described in Section 2.5. These trips represent the 38% of all Polimi trips, but just 29% of total travel related CO_2 emissions.

[11] Just two examples: going to Prague takes at least 13 hours and three trains from Milan. Brussels is nearly 10 hours far, with one or two changes.

Scenario 1 has the least impact and induces a shift of only 84 trips, that is 1.2% of trips in the study area. **The effect of this shift is however negligible in terms of total emissions, just 3 tons (-0.3% of all Polimi travel-related emission)**. Scenario 2 is more draconian: any trip shorter than 800 km must go by train, including Amsterdam, Reims or Koln, irrespective of the duration of the mission. **The scenario cuts 38 tons of CO_2, or 3.2% of total Polimi travel emissions, even if forces a change to 11.3% of all trips in the study area**. Relatively softer scenario 3 excludes the trips shorter than 3 days from the forced shift defined in Scenario 2, and this **cuts nearly half of the emission reduction: 21 tons or 1.8% of total**. Finally, **Scenario 4 cuts 1.3% of travel emissions (16 tons of CO_2) by shifting 4.6% of trips.** This scenario is more realistic in terms, because prevents the inclusion of destinations that are in the travel range, but practically unreachable.
The differences between scenarios are clearly visible in Figure 10. Scenario 2 passes to train every trip within 800 km, including places (all Germany, for example) where the train option is so uncomfortable that today less than 20% uses it. To the contrary, Scenario 4 is more plausible, as shifts only trips that reach places where train is "feasible", but they're mostly in Italy. The main addition to Scenario 2 is the area of Salerno, which is above 800km, but where train is a good option already used now.

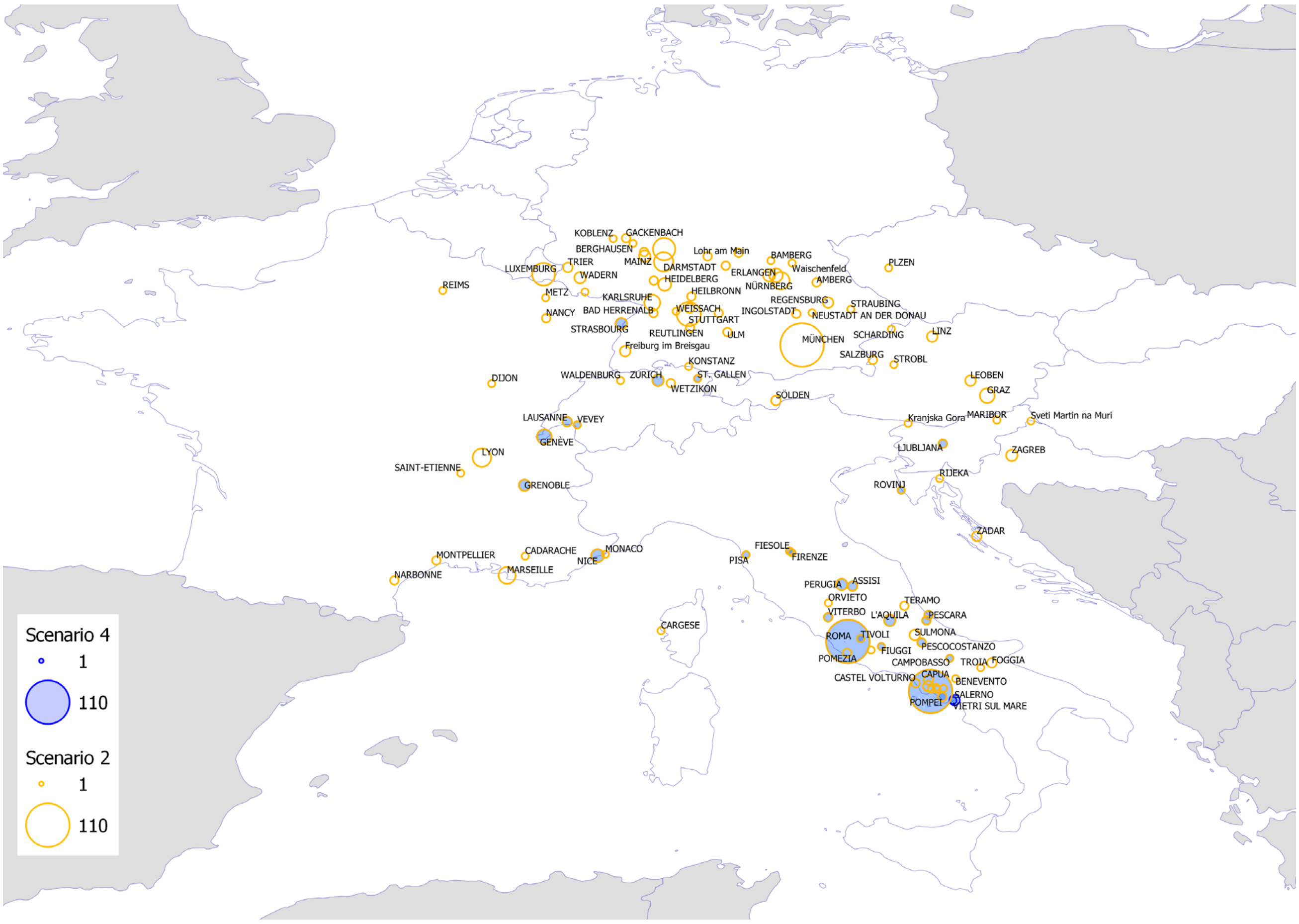

Figure 10. Trips shifted from air to train in Scenario 2 and Scenario 4.

These results may appear unexpectedly low. But Figure 11 clarifies the reasons. As we can notice, current air trips below 500km are so few and short, that their contribution to emissions is negligible, the above mentioned 3 tons/year. In the second distance range, 800 km, air transport becomes visible, but remains a fraction of total emissions. Air transport CO2 contribution starts rising above 900 km (in the range there are Paris, Vienna, Bari, Prague, Brussels, Amsterdam, etc., all important destinations in terms of trips). However, in terms of total emissions, the main slice of the cake is above 1000km. For example, intercontinental travels above 3000 km (1250 trips out of 18000) generate 490 tons of CO2, which is nearly 50% of all emissions.

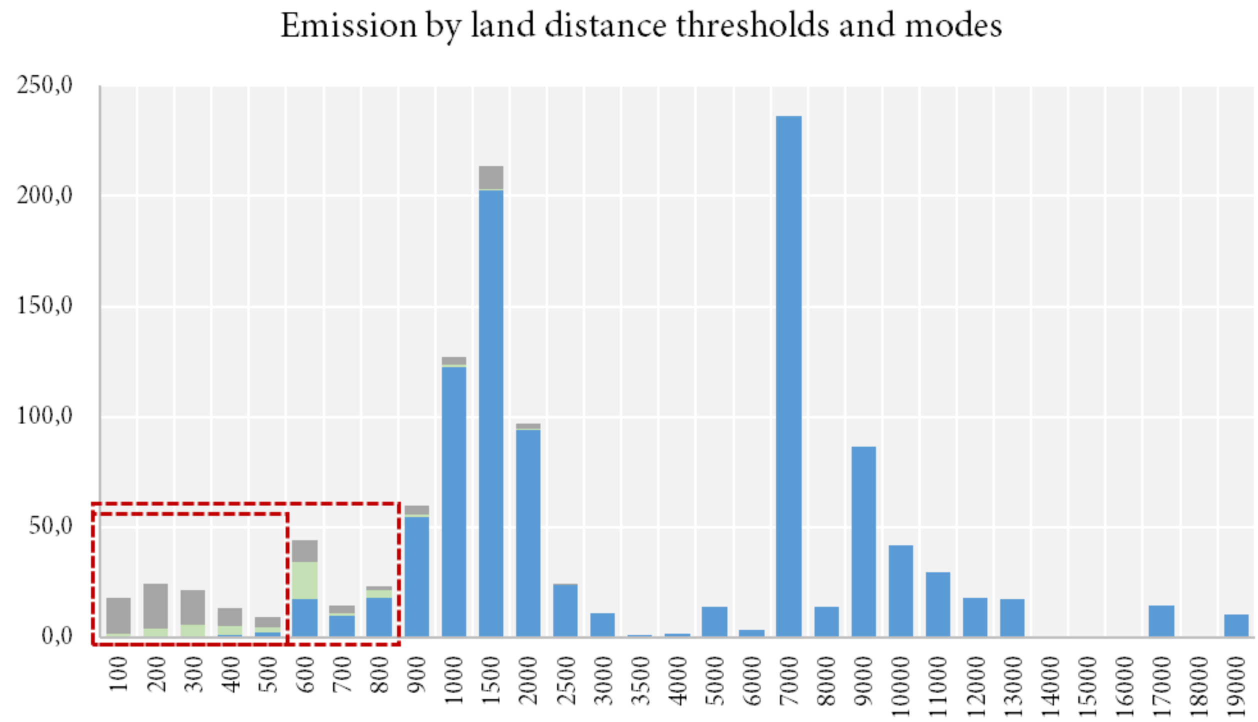

Figure 11. Emission by mode and distance classes, with the indication of the emissions involved in the *flygskam* scenarios.

4.2 Sensitivity analysis

In the previous section we defined thresholds that we consider realistic in terms of policy applicability and acceptability. In this section we relax these assumptions and calculate the effect using the same rules but extending the ranges.

In Figure 12 we see the effect of different distance thresholds. Preventing trips up to 500km gives zero result: people is already not using planes. The 800km threshold we chose in the main scenarios according to travel conditions makes a second step in emissions saving. Savings become more relevant from 900 km on, up to 200 ton/year at 1200 km. The problem is that at 1200 km the impact on travel conditions is severe: 40% of trips in the core of Europe is impacted and the impact is hard in terms of much longer travel time. Relaxing the rule to trips that take more than 3 days limit the inconvenience to ¾ of travellers but "costs" up to 50 ton/year.

In Figure 13 we test the approach of Scenario 4: we define a threshold of actual train usage and above that level, we shift all air travels to train. A 0% threshold means that *any* travel by air in the study area must become a train travel. This saves more than 200 ton/year. Already a 10% threshold is abating enormously the effect: considering as doable by train any destination where at least 10% of trips occur already by train, gives just 41 tons of CO2 and impact 10% of all trips in the study area. The effect shrinks progressively and at 90% is zero. Again, the indication is that where train is doable, it is already used.

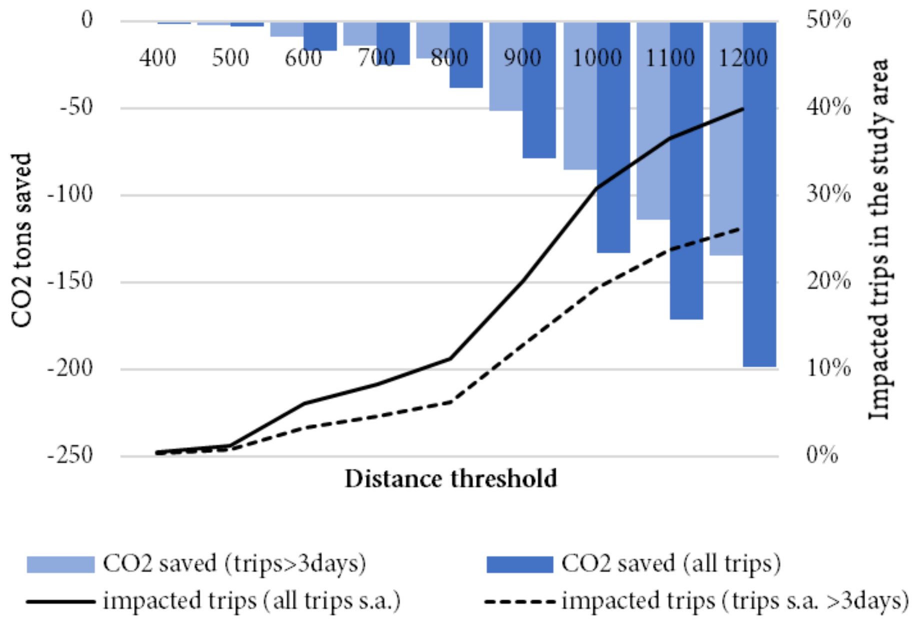

Figure 12. Sensitivity analysis of scenarios, effect of the distance threshold

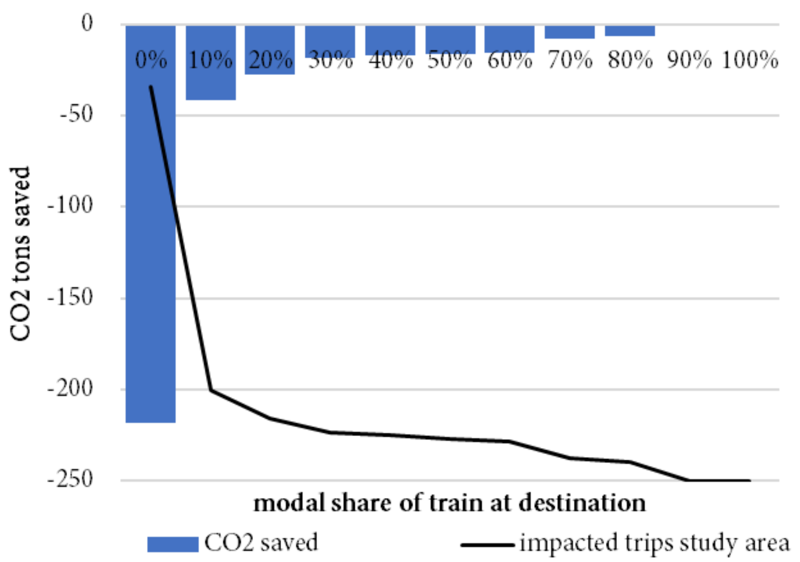

Figure 13. Sensitivity analysis of scenarios, effect of the convenience threshold

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