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MIMOSA

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D.3.1.4. - Development Scenarios

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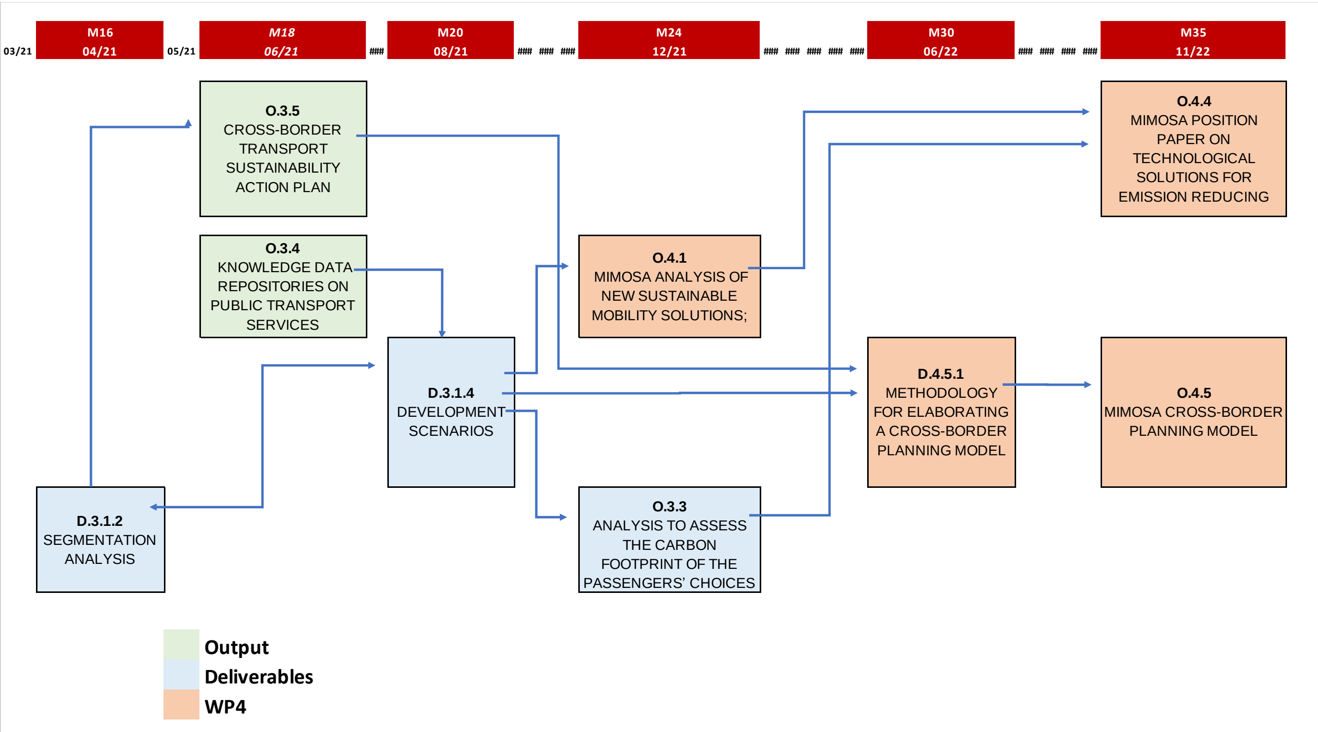
1. Aim and scope of this document

The goal of the MIMOSA Project is to provide significant advances in knowledge and in experience of what is necessary to improve the sustainability of cross-border and coastal passengers' mobility between Italy and Croatia. WP3, in particular, has the role of providing and disseminating the state-of-the-art knowledge-base on travels' demand & offer, and related environmental impact, including predictions about their future possible developments. In the overall framework of the MIMOSA project and of WP3, this document is aimed at providing predictive scenarios on the development of travel demand between Italy and Croatia, as well as the impacts in terms of emissions per passenger. In the framework of the general goals of the project, the scenario analysis stems from the qualitative and quantitative analysis of demand, and is a crucial input for the assessment of passengers' carbon footprint and for the definition of a cross-border planning model (fig. 1).

Figure 1. The relevance and relatedness of D. 3.1.4. with other Outputs and Deliverables of Crossmoby project



The analysis presented in this paper inevitably suffers from the major discontinuity represented by the Covid-19 pandemic. In general, when it comes to forecasting travel demand between certain origins and destinations, the main reference points are represented by historical data series and correlations between the propensity to travel and the main socio-economic and demographic parameters (e.g. GDP, demographic curves, disposable income, etc.). Whichever method of prediction is used, these are based directly or indirectly on the assumption that future manifestations of the studied data are somehow related to past observations. Such an assumption makes sense when the evolutionary dynamics of the phenomenon are somehow inertial and characterised by specific links with the explanatory variables. For instance, under normal conditions, tourist flows between foreign countries exhibit both of these characteristics. But the Covid-19 pandemic has not only altered these flows, almost bringing them to zero and thus creating a discontinuity in the historical series. It has also had an impact on the individual determinants of travel choices (habits, perceptions, values, etc.) to such an extent as to change the reference framework on which to base the forecasts.

At the time of writing, pandemic restrictions are less cogent than in the past, but the situation is still evolving, and data for the first 9 months of 2021 are not available, which would have been useful to verify the degree of return to 'normality' in the first at least partly non-panedemic summer. The choice of forecasting method was inevitably affected by this situation. As explained later in the methodological section, past data were taken into account to forecast travel demand, applying both autoregressive interpolation and correlation methods, but also qualitative considerations and evaluations expressed by other researchers who have tackled similar problems in other contexts. From the forecasts made in this sense, the trend of the carbon footprint was then deduced as a function of possible technological and modal shifts.

Of course there is room for errors in the predictions of absolute values of demand and emissions. However, we believe that the role of this deliverable is above all to highlight the relative values of possible improvements, and on this front we are confident in the validity of the models used. Therefore, this document should be read in the logic of providing support on how to govern travel demand and supply between the two countries, and it would be a mistake to accept the predictions made as an inevitable future.

The document is organised as follows: section 2 presents the premises for the analysis, including the method description and a brief overview on terminology and data sources. Section 3 shows the present situation with the data that represent the starting point for the forecasts (in fact, the situation in 2019, assumed as last reliable situation for the predictive model, given the discontinuity caused by the pandemic: this will be explained later). The scenarios and related forecasts are presented in Section 4.

2. Premises to this analysis

2.1 Terminology and data sources

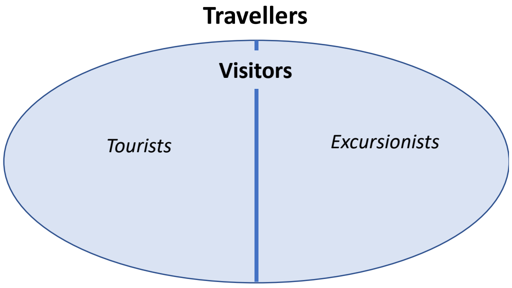
This document takes into consideration the passenger transport demand, with a focus on outbound travellers, i.e., on people who undertake travel outside the country of their residence, from Italy to Croatia and vice versa.

According to [DESA2010], travellers can be organized in different subsets (see, Fig. 1):

- **Visitors**: a visitor is a traveller taking a trip to a main destination outside his/her usual environment, for less than a year, for any main purpose (business, leisure or other personal purpose) other than to be employed by a resident entity in the country or place visited. These trips taken by visitors qualify as tourism trips.
- **Tourists**: a tourist (or overnight visitor) is a visitor whose trip includes an overnight stay.
- **Excursionists**: an excursionist (or same-day visitor) is a visitor whose trip does not include an overnight stay.

It is important to note that the distinction adopted by statistical agencies does not consider the motivation for travel. Therefore, the connotation of the terms "tourist" and "excursionist", which in both cases common parlance associates with leisure travelers, actually includes possible trips for business, health, shopping, visiting friends and relatives, etc. The only distinction noted by the statistic agencies is whether or not to spend at least one night in the foreign country. As we'll see later, exposing the data, the proximity of Italy and Croatia makes same-day travel a common phenomenon not only for business reasons but also for leisure and shopping reasons, both by land and by sea, via high-speed passenger vessels.

Figure 2: Travellers, visitors, tourists and excursionists relationship in statistical survey definitions.



This report crosses the data collected by the national and international bureaus of statistics or organizations with the ones presented in the Deliverables 3.1.2 and 3.2.1. The first set of data are typically obtained by consulting official records, the second sets through questionnaires submitted to a sample of the population of the Italy- Croatia Programme Area. Hereinafter, by Croatian (respectively Italian) we understand Croatian (respectively Italian, travellers/visitors/tourists/excursionists who undertake a travel to Italy (respectively Croatia).

Data on the different kinds of travellers have intrinsically different levels of detail and accuracy. As an example, both the Croatian[1] and Italian[2] bureaus of statistics record in detail with a good level of accuracy the number of tourists, as tourists must register their presence at the facilities of their overnight stays. On the other hand, neither country imposes any form of registration to excursionists, so it is apparently more difficult to count them. Excursionists estimations are usually carried out, for instance, through, a) visitor surveys (as suggested in [DGEI2013]), b) analysis of digital traces of mobile phones or credit cards, c) counting sensors, d) analysis of the mode of transportation.

Many data sources have been used for emissions values, above all: [EMEP2019] EMEP/EEA. (2019). *EMEP/EEA air pollutant emission inventory guidebook - 2019.* European Environment Agency (EEA). And [IMO2020] IMO. (2021). *Fourth IMO Greenhouse Gas Study*. International Maritime Organization.

2.2 Method

The formulation of possible scenarios for the evolution of the carbon footprint of travellers between Italy and Croatia was carried out by first considering the probable evolution of the overall travel demand, then cross-referencing it with the trends considered realistic in terms of modal shift and transport technologies. This process is roughly summarised in figure 3. Each of those stages presents distinctive complexities which have been addressed by reference to the models considered most reliable on the basis of the data made available by the official survey bodies.

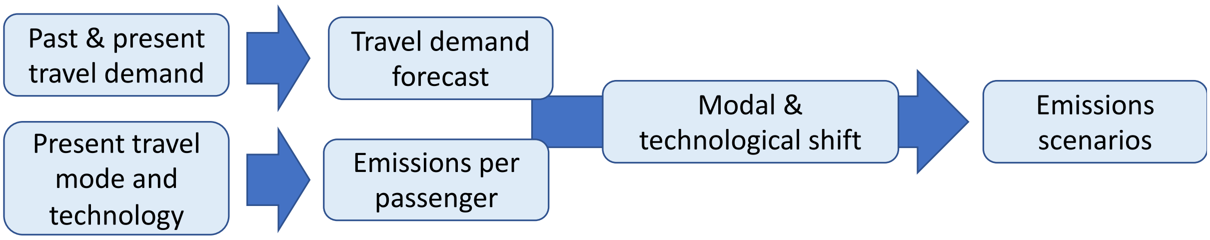
Travel demand forecast can be estimated on the basis of the typical predicting method adopted for market demand. The main data at the basis of such predictions are historical series of travellers' flows in previous years, and the main socio-economic and demographic parameters that are normally

[1] Državni Zavod za Statistiku - DZS: dzs.hr

[2] Istituto Nazionale di Statistica - ISTAT: www.stat.it

considered to be significantly correlated with travel demand (i.e.: population and GDP). Various methods can be used for this purpose.

Figure 3: overall process for the identification of scenarios



In this work forecast are based on two main methods: the time series-based forecast (TSBF) and the correlation (or econometric) -based forecast. Both of them are, in fact, labels including several different techniques sharing a common logic, that is briefly explained below.

The first method (TSBF) evaluates past data trends by extrapolating coefficients of variation which, it is assumed, will be the basis for future changes in demand, over a range that is greater the larger the changes in demand in the past. In essence, it is assumed that the pattern in which the phenomenon occurs does not change in the future. In quantitative terms, the following hypotheses hold: a) “weak stationarity”, i.e., mean and variance of the observed process doesn’t change over time, at least after having detrended and seasonally adjusted it; b) ergodicity, i.e.,the statistical properties of the observed process can be deduced from a single, long enough, random sample of the process. Given these hypotheses, such method works properly only for short/medium-term forecasts, since it relies on a simplistic assumption about the future. Presently, both stationarity and ergodicity are denied by the Covid pandemic. To overcome this obstacle, the TSBF has been developed assuming 2020 and 2021 data are not affected by the pandemic. In other words, data for these two years have been “predicted”, while the real data have been discarded. This is equivalent to assuming that from 2022 the effects of the pandemic will have ceased impacting travel choices.

The second method (correlation-based forecast) assumes that there exist explanatory variables whose current values are linked to the future value of the response variable to forecast (for instance, GDP and travel demand). This is possibly a very reliable and least biased method, fitting the needs of long term forecasts, to the extent the correlation between the explanatory variable and the phenomenon is robust and enduring. For this reason, to be reliable such method require a large number of observations and a large amount of data are needed to understand the relations between explanatory and response variables.

These two methods were used together to get an overview to 2030 of the range of estimates of the number of travellers that can reasonably be expected. A judgmental correction was then applied based on factors that will be indicated later and concerning possible scenarios of pandemic evolution.

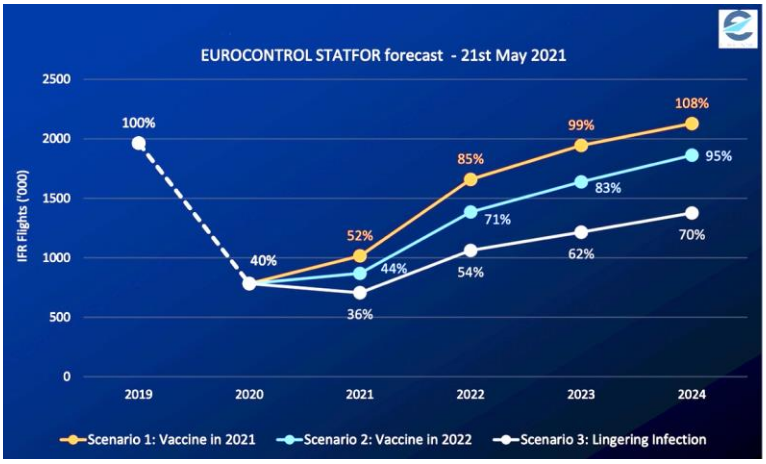
2.3 Previous studies

Passengers' flows development scenarios between Italy and Croatia have been investigated also in previous projects, including:

- **CHARGE** - Capitalisation and Harmonisation of the Adriatic Region Gate of Europe – Italy-Croatia programme, D.4.1.2 "Analysis on potential market flows " of the Port of Venice / of the Port of Ploče"; D.4.1.3 Comprehensive report on the future scenarios of traffic flows between Italia-Croatian ports
- **MOSES** - Maritime and multimOdal transport Services based on Ea Sea-way project. D.3.3.1 Updated passenger flow analysis In both those cases, however, the COVID-19 situation could not have been taken into consideration. Moreover, our study has the goal to provide a support to the carbon footprint reduction and for this reasons we will also consider possible changes in the technology of transport means, as well as possible modal shifts, both not being considered in previous studies.

Another important contribution is represented by Eurocontrol's air traffic forecasts between 2021 and 2024, which are based on various pandemic scenarios (figure 4, source: [ECNM2021]). Such document correlates the upturn in air traffic to the vaccination trends; such approach has been taken into consideration for defining the scenarios outlined in this deliverable.

Figure 4: Air traffic forecast for Italy according to Eurocontrol (Source: [ECNM2021])



3. Analysis of the present situation

3.1. Estimates of present travel flows

The analysis of the existing (and past) situation focused on the three main factors that determine the carbon footprint of travellers. These are, in a nutshell: a) number of travellers, b) length of trip, c) mode of travel (as a proxy variable for emissions depending on the technologies in use).

From 2014 to 2019, the number of overnight travellers ("tourists") between Italy and Croatia grew continuously at an average rate of 3.3%, but with very variable annual rates (between 0.3% and 5.1%) underlining the relative volatility of demand. The average length of stay is stable at 4 nights, with the exception of 2020 which saw an average length of stay of 5 nights (table 1).

Table 1: passenger flows between Italy and Croatia 2014-2020 (Sources: ISTAT, DZS)[3]

Year	Total Italy-Croatia tourists		
	Arrivals	Nights	Avg nights
2014	1.245.518	5.021.679	4,0
2015	1.308.978	5.347.967	4,1
2016	1.343.891	5.558.805	4,1
2017	1.351.416	5.573.041	4,1
2018	1.420.562	5.721.624	4,0
2019	1.469.894	5.900.425	4,0
2020	301.895	1.509.541	5,0

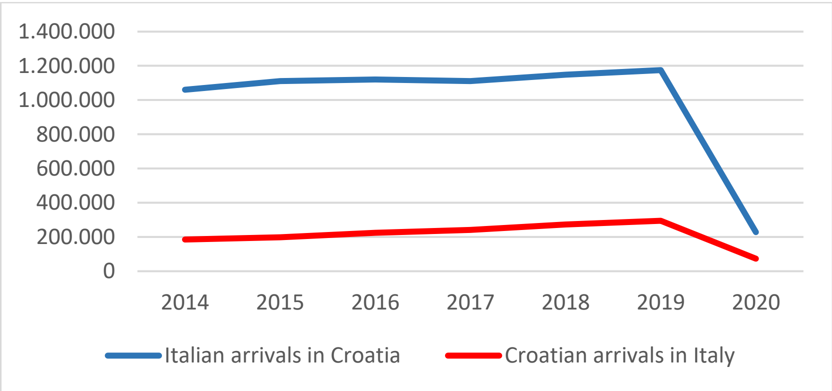
[3] It should be noted that other sources provide different data and in some cases the deviation is significant. For example, the data published by [OECStat2021] differ by up to 30% from those of DZS. However, DZS was chosen, being the official Croatian statistical source.

The ratio between the populations of the two countries[4] is about 14,7:1 in favour of Italy. Consequently, also the data on passenger flows show a preponderant number of Italians compared to the number of Croats, but with a much lower ratio: on average 4,6:1 in the period 2014-2020, decreasing from 5,7:1 in 2014 to 4:1 in 2019 and 3,1:1 in 2020[5]. Obviously, the sharp decrease of absolute number of travellers in 2020 is the effect of the pandemic (table 2, figure 5).

Table 2: passenger flows between Italy and Croatia 2014-2020 by Country of origin (Sources: ISTAT, DZS)[6]

Year	Italians towards Croatia			Croatians towards Italy		
	Arrivals	Nights	Avg nights	Arrivals	Nights	Avg nights
2014	1.060.912	4.466.221	4,2	184.606	555.458	3,0
2015	1.111.428	4.800.153	4,3	197.550	547.814	2,8
2016	1.119.932	4.960.583	4,4	223.959	598.222	2,7
2017	1.110.219	4.915.170	4,4	241.197	657.871	2,7
2018	1.148.078	5.023.959	4,4	272.484	697.665	2,6
2019	1.175.069	5.141.064	4,4	294.825	759.361	2,6
2020	228.458	1.231.506	5,4	73.437	278.035	3,8

Figure 5: passenger flows between Italy and Croatia 2014-2020 (Sources: ISTAT, DZS)



[4] The actual population of the Italy-Croatia programme area is about 12,5 million, but the data available for estimating travellers between Italy and Croatia do not distinguish whether the origin is from the population of the Italy-Croatia programme area or from other parts of the two countries. For this reason, the populations referred to in the data are those of the whole of Italy (about 60.4 million) and the whole of Croatia (about 4.1 million).

[5] Of course, the 2020 figure cannot be considered significant as it is affected by the Covid-19 pandemic.

[6] It should be noted that other sources provide different data and in some cases the deviation is significant. For example, the data published by [OECStat2021] differ by up to 30% from those of DZS. However, DZS was chosen, being the official Croatian statistical source.

The demand for travel from Italy compared to that from Croatia has different structural characteristics, highlighted above all by the different seasonality and average stay. More than 73% of Italian demand is concentrated in the three summer months (against 24.7% from Croatia to Italy), while Croatian travellers are distributed relatively evenly throughout the year (figure 6).

A further element of structural diversity is the average length of stay. This is generally longer for Italians (on average 4 or more days for Italians in Croatia, about one day less on average for Croatians in Italy; fig. 7). In addition, the length of stay have a similar seasonality to that seen for overall flows (fig. 8).

Figure 6: seasonality of demand shown as distribution of arrivals during the year in % of total yearly arrivals (2019)

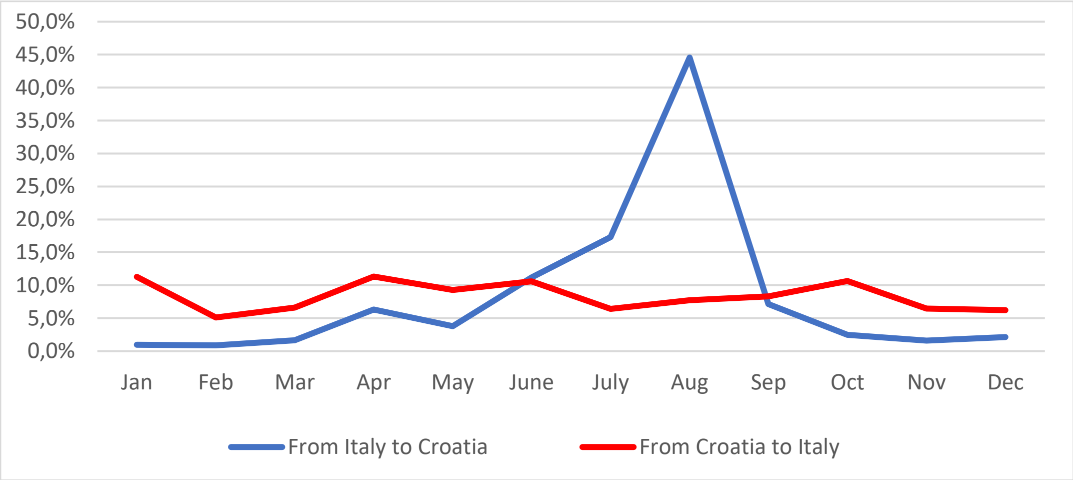


Figure 7: average stay of tourists between Italy and Croatia 2014-2020 (Sources: ISTAT, DZS)

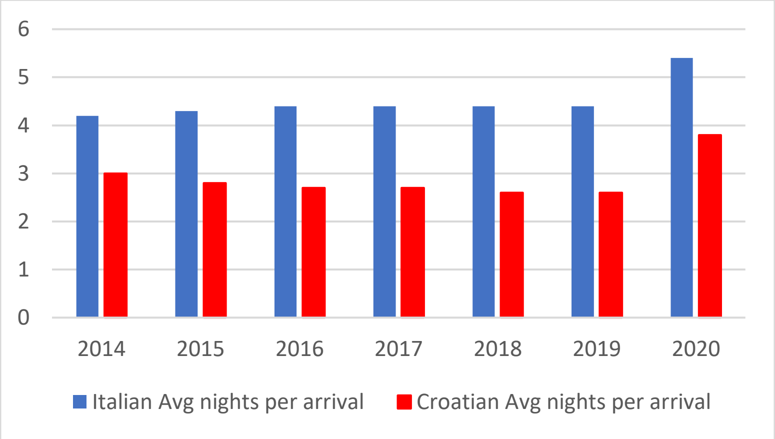
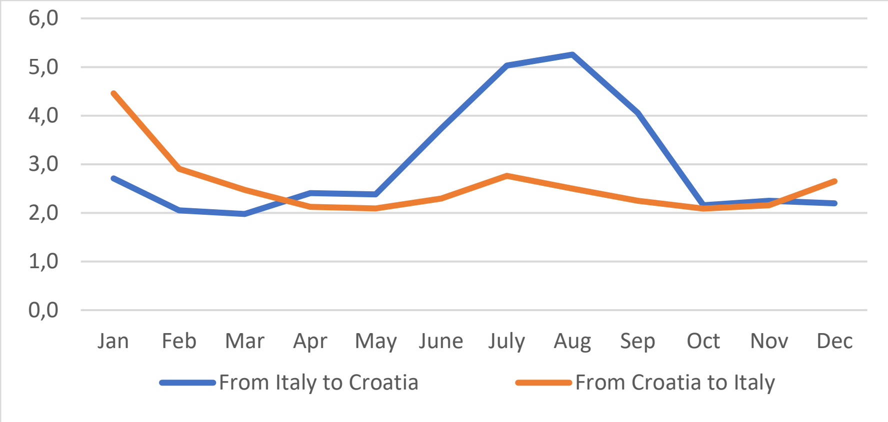


Figure 8 seasonality of demand shown as distribution of length of stay during the year in number of days (2019)



The difference in length of stay is also due to the higher percentage of excursionists on the Croatian side. It has to be said that the estimation of the number of hikers out of the total number of travellers is quite complex. As there are no specific surveys, in this document we have estimated the demand for travel by excursionists on the basis of percentages of global traveller statistics for each of the two countries.

As for Croatian travellers, the Croatian Ministry of Tourism document [MTHR2020] reports that 25%, respectively 28%, of same-day trips of excursionists in organisations of travel agencies have Italy as a destination in 2019, respectively 2016.

Table 3 shows the estimated values of the number of Croatian excursionists on the basis of the overall Croatian visitors in the World [OECStat2021] in the hypothesis that: the same-day trips of Croatian excusrsionists are similarly distributed regardless the destination, the number of Croatian excursionists in Italy seems to be between 1,5 and 3 times greater than the number of Croatian tourists in Italy.

Table 3: Estimated number of Croatian excursionists in Italy

Year	Croatian tourists (World)	Croatian Excursionists (World)	E/T ratio %	Croatian excursionists in Italy	
				Low estimate	High estimate
2015	4.355.000	2.578.000	59%	515.600	773.400
2016	2.581.000	1.614.000	63%	322.800	484.200
2017	2.597.000	1.923.000	74%	384.600	576.900

2018	2.980.000	2.058.000	69%	411.600	617.400
2019	3.500.324	2.254.931	64%	450.986	676.479

Applying the same procedure to Italian travellers/excursionists gives the results in table 4, with the corresponding estimates of the number of Italian excursionists in Croatia.

It is worth noticing that the number of Italian excursionists appears to be between 2 and 3 times greater than the number of Italian tourists. This certainly has a significant impact on the carbon footprint, all the more so as it is to be expected that the journeys of these hikers are predominantly by car, favoured by the relative proximity of many Italian and Croatian destinations.

Table 4: Estimated number of Italian excursionists in Croatia

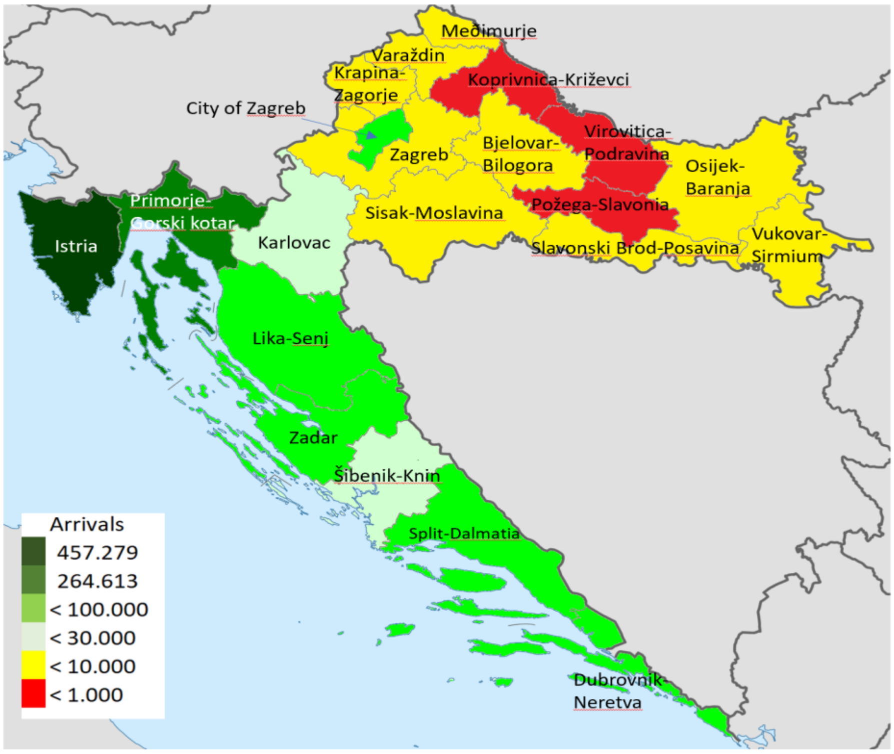
Year	Italian tourists (World)	Italian Excursionists (World)	E/T ratio %	Italian excursionists in Croatia	
				Low estimate	High estimate
2015	27.493.537	29.924.527	109%	2.992.453	3.590.943
2016	29.066.901	28.412.727	98%	2.841.273	3.409.527
2017	31.805.451	28.236.936	89%	2.823.694	3.388.432
2018	33.347.082	27.847.560	84%	2.784.756	3.341.707
2019	34.702.570	27.504.822	79%	2.750.482	3.300.579

As for the overall travel flows, historical data show that total cross-border demand is just under six million travellers, 75-80% Italian and with the latter staying in Croatia about 1.5 times longer than Croatian travellers in Italy. The carbon footprint of travel from Italy represents by far the largest share of overall emissions. Since such impact is also a function of (among other things) the length of the trip, the distribution of Italian travellers on Croatian territory was investigated. As expected, data available for DZS show that over 90% of Italian travellers head to the coastal area of Croatia, while over 61% head for only two counties (Istria and Primorje-Gorski Kotar; Table 5 and figure 9) .

Table 5: distribution of 2019 Italian tourists by destination (source DZS)

Destination (city / county)	Arrivals	Quote %	Nights	Avg num of nights per arrival	%
Croatia	**1.175.069**	**100%**	**5.141.064**	**4.4**	**100%**
Istria	457.279	39%	2.184.851	4.8	42%
Primorje-Gorski Kotar	264.613	23%	1.263.801	4.8	25%
Split-Dalmatia	92.941	8%	392.085	4.2	8%
Lika-Senj	86.895	7%	362.129	4.2	7%
Zadar	72.040	6%	360.315	5.0	7%
City of Zagreb	66.170	6%	131.506	2,0	3%
Dubrovnik-Neretva	60.920	5%	218.488	3.6	4%
Šibenik-Knin	28.060	2%	138.377	4.9	3%
Karlovac	26.198	2%	46.363	1.8	1%
County of Zagreb (other than city)	5.835	0%	10.914	1.9	0%
Krapina-Zagorje	2.414	0%	6.214	2.6	0%
Varaždin	1.973	0%	4.429	2.2	0%
Slavonski Brod-Posavina	1.759	0%	2.853	1.6	0%
Osijek-Baranja	1.677	0%	3.695	2.2	0%
Sisak-Moslavina	1.559	0%	3.610	2.3	0%
Vukovar-Sirmium	1.236	0%	2.596	2.1	0%
Bjelovar-Bilogora	1.224	0%	2.831	2.3	0%
Međimurje	1.101	0%	3.213	2.9	0%
Virovitica-Podravina	508	0%	1.272	2.5	0%
Požega-Slavonia	407	0%	942	2.3	0%
Koprivnica-Križevci	260	0%	580	2.2	0%

Figure 9: distribution of 2019 Italian tourists by destination (source DZS)



Unfortunately, we do not have a similarly analytical survey for Italian visitors to Croatia. The website on Foreign Markets of the Italian Ministry of Foreing Affairs and International Cooperation [IME2019] reports the data shown in Tab. 6.

Table 6: Most popular destinations for Croatian visitors - year 2017 (source [IME2019])

Positions	Destinations	Quote %
1	Great cities of art	45
2	Winter mountains	25
3	Small centers	15
4	Lakes	10
5	Nature and parks	5

Culture, often combined with shopping, is the segment most appreciated by Croatian tourists followed by winter mountains, thanks to a better value for money than our competitors such as

Austria, Switzerland and France. In recent years there has been an increasing interest in the cities of Southern Italy [IME2019]. There are also many daily trips, without overnight stays, by Croats to Italy made just for shopping or skiing. Finally, there is an increase in religious tourism [IME2019]. This last information, together with the distribution of cities of art in Italy, suggests that the destinations of Croatian travellers are less territorially concentrated than those of Italians. We will return to this theme later, when we discuss the possible modal shift in the scenarios.

3.2 Transport Mode

Various sources report the number of travellers passing through Italy to Croatia (and vice versa), by ship and by air (no rail route is currently available).

[OSN2020] estimates 75.000 seats on line flights from Italy to Croatia in 2019 (source: elaboration of data from [OSN2020], which is about 2,6% of round trips of all travellers in the same year. However, in % terms, the incidence of air travel is much higher among Croatian travellers (between 6 an 9%) than among Italian travellers (1-2%), due to a wider dispersion of destinations on the Italian territory and their greater distance from the origin of the trip.

Estimates of ship passengers available from various sources (DSZ, [PAAN2019] [PABA2019] [PATS2019] [PAVE2019], Deliverable 3.2.1), and are coherent with a 5-6% incidence of ship use for Italian travellers, compared to around 1% or less for Croatian travellers.

Road transport is the one on which most travellers travel, and the most used means of transport is certainly the car (although bus use is, according to some sources, increasing). The choice of car is largely justified by the proximity of origin and destinations for a large part of the travellers. Tab. 5 and Fig. 7 show how the Italian tourists spread over the Croatian counties. The ones closest to the north border attract more than the 50% of the Italian tourists and, probably, a much bigger fraction of the Italian excursionists. Analogously, reports [IME2019] e [IME2016] suggest that Croatian visitors mainly spread over the Italian regions closest to the north-east border for visiting cities of arts, skiing in the Alps, and shopping.

In order to estimate the number of travellers using the car, the number of foreign cars, buses, and passengers crossing the Croatian-Slovenian border during 2019 were taken into account. Assuming that visitors reach their destinations following the most direct route, it is reasonable to assume that this border is crossed mainly by visitors coming from Germany, Slovenia, Austria, Czechia, respectively, the first, the second, the third and the seventh country for the number of tourists visiting Croatia. The values reported in Tab. 7 are compatible with a number of (almost) 3 passengers per car and about fifty passengers per bus.

Table 7: Entry of passengers vehicles on road border crossing points in 2019 (source DZS)

Month	Cars	Buses	Passengers
Jan	403.025	4.864	1.293.238
Feb	436.567	4.224	1.182.707
Mar	535.563	5.664	1.436.891
Apr	764.714	8.039	2.323.927
May	719.380	8.617	2.096.881
June	1.089.192	9.268	3.919.538
July	1.464.201	8.936	5.527.547
Aug	1.489.112	8.993	5.602.490
Sep	824.869	9.375	2.655.617
Oct	692.467	7.975	2.048.218
Nov	475.936	5.226	1.357.839
Dec	608.192	6.201	2.055.632
Total	9.503.218	87.382	31.500.525

Assuming an average of 3 foreign passengers per car and fifty passengers per bus, our estimation of the present modal split is as shown in table 8.

Table 8: Mode of transportation for Croatian and Italian visitors in 2019

	Italian travellers	Croatian travellers
Car	90-91%	75-77%
Bus	1%	16-17%
Plane	1-2%	6-9%%
Line ships	5-6%	<1%
Private vessel	1-2%	0%

3.2 *Transport modes emissions*

In order to estimate the carbon footprint of travellers, the pollutant emissions of the various means of travel were measured from the various available sources according to consumption (i.e., distance) and type of means. As it is obviously not possible to reconstruct every possible means of transport analytically, we concentrated on standard measures whose average values can be considered acceptable approximations of the "average" type of trip, considereing that they depend on many contingent factors, such as weather conditions, speed, etc. A summary of these data are presented in table n. 9. All the emission emission factors per kg of fuel are taken from [EMEP2019][7].

[7] Please, notice that different sources often reports different values for emissions and other relevant parameters. In particular, vessel emissions are controversial among different sources. values reported in table 6 do not differ significantly, if Marine Gas Oil (MGO) is considered instead of Low Sulphur Heavy Fuel Oil (LSHFO). Differently, the emissions factors reported in Table 9 differ significantly from the ones proposed by IMO [IMO2020] as regards the SOx emissions for MGO. This last document reports 1,56-2,74 SOx kg/tonne MGO fuel, whereas [EMEP2019] suggests 20 SOx kg/tonne MGO fuel. This difference of an order of magnitude may be partially explained by the fact that [EMEP2019] makes references to values reported in 1995 Lloyd's Register, that is long before more stringent rules were enforced by the EU. The two documents also differs for the emission factors of CO and NOx but within a range of error compatible with the measurement errors in this field. See, for instance [Beecken2015].

Table 9: Sample list of estimated emissions per journey elaborated on the basis of [EMEP2019] data (assuming MGO fuel for vessels) and from CAMI analysis (as for cars consumption).

Origin	Destination	Mode of transportation	Distance (Naut. miles for sea and air travels, Km for ground travels)	Passenger capacity	Fuel burn (kg for ships and vessels, lt per cars and buses)	CO2 (kg)	NOx (kg)	CO (kg)	SOx (kg)	CO2/pax (kg)
Milan	Dubrovnik	Airbus A320-200	451	180	3.497	11.049	55	15	2,95	61,4
Venice	Dubrovnik	Airbus A320-200	311	180	2.772	8.758	46	14	2,34	48,7
Rome	Dubrovnik	Airbus A320-200	272	180	2.570	8.120	43	13	2,17	45,1
Milan	Split	Airbus A320-200	348	180	2.963	9.364	48	14	2,5	52,0
Venice	Split	Airbus A320-200	206	180	2.201	6.954	38	13	1,85	38,6
Rome	Split	Airbus A320-200	207	174	2.206	6.972	38	13	1,86	40,1
Milan	Zagreb	Airbus A320-200	309	174	2.761	8.726	46	14	2,33	50,1
Venice	Zagreb	Airbus A320-200	157	174	1.923	6.077	32	12	1,62	34,9
Rome	Zagreb	Airbus A320-200	289	174	2.658	8.398	44	14	2,24	48,3
Ancona	Split	Bus	992	56	238	748	0,49	0,15	n.a	13,4
Bari	Dubrovnik	Bus	1.634	56	392	1.232	0,81	0,25	n.a	22,0
Trieste	Porec	Bus	78	56	19	59	0,04	0,01	n.a	1,1
Venezia	Pula	Bus	285	56	68	215	0,14	0,04	n.a	3,8
Milan	Dubrovnik	Bus	1.147	56	275	865	0,57	0,17	n.a	15,4
Venice	Dubrovnik	Bus	840	56	202	633	0,42	0,13	n.a	11,3
Rome	Dubrovnik	Bus	1.392	56	334	1.050	0,69	0,21	n.a	18,8
Milan	Split	Bus	911	56	219	687	0,45	0,14	n.a	12,3
Venice	Split	Bus	604	56	145	455	0,3	0,09	n.a	8,1
Rome	Split	Bus	1.155	56	277	871	0,57	0,17	n.a	15,6
Milan	Zagreb	Bus	684	56	164	516	0,34	0,1	n.a	9,2
Venice	Zagreb	Bus	377	56	90	284	0,19	0,06	n.a	5,1
Rome	Zagreb	Bus	929	56	223	701	0,46	0,14	n.a	12,5
Milan	Dubrovnik	Euro 6 med. Diesel car	1.147	5	190	195	0,61	0,1	n.a	39,0
Venice	Dubrovnik	Euro 6 med. Diesel car	840	5	161	143	0,82	0,0	n.a	28,6
Rome	Dubrovnik	Euro 6 med. Diesel car	1.392	5	137	237	1,09	0,0	n.a	47,3
Milan	Split	Euro 6 med. Diesel car	911	5	116	155	1,45	0,0	n.a	31,0
Venice	Split	Euro 6 med. Diesel car	604	5	99	103	1,94	0,0	n.a	20,5
Rome	Split	Euro 6 med. Diesel car	1.155	5	84	196	2,58	0,0	n.a	39,3
Milan	Zagreb	Euro 6 med. Diesel car	684	5	71	116	3,45	0,0	n.a	23,3
Venice	Zagreb	Euro 6 med. Diesel car	377	5	61	64	4,59	0,0	n.a	12,8

Rome	Zagreb	Euro 6 med. Diesel car	929	5	52	158	6,13	0,0	n.a	31,6
Ancona	Split	Euro 6 med. Diesel car	992	5	44	169	8,17	0,0	n.a	33,7
Bari	Dubrovnik	Euro 6 med. Diesel car	1634	5	37	278	10,89	0,0	n.a	55,6
Trieste	Porec	Euro 6 med. Diesel car	78	5	32	13	14,52	0,0	n.a	2,7
Venezia	Pula	Euro 6 med. Diesel car	285	5	27	48	19,36	0,0	n.a	9,7
Milan	Dubrovnik	Euro 6 med. Petrol car	1.147	5	76	241	0,07	0,71	n.a	48,2
Venice	Dubrovnik	Euro 6 med. Petrol car	840	5	55	176	0,05	0,52	n.a	35,2
Rome	Dubrovnik	Euro 6 med. Petrol car	1.392	5	92	292	0,08	0,86	n.a	58,4
Milan	Split	Euro 6 med. Petrol car	911	5	60	191	0,06	0,56	n.a	38,2
Venice	Split	Euro 6 med. Petrol car	604	5	40	127	0,04	0,37	n.a	25,4
Rome	Split	Euro 6 med. Petrol car	1.155	5	76	242	0,07	0,72	n.a	48,4
Milan	Zagreb	Euro 6 med. Petrol car	684	5	45	144	0,04	0,42	n.a	28,8
Venice	Zagreb	Euro 6 med. Petrol car	377	5	25	79	0,02	0,23	n.a	15,8
Rome	Zagreb	Euro 6 med. Petrol car	929	5	61	195	0,06	0,58	n.a	39,0
Ancona	Split	Euro 6 med. Petrol car	992	5	65	208	0,06	0,62	n.a	41,6
Bari	Dubrovnik	Euro 6 med. Petrol car	1634	5	108	343	0,1	1,01	n.a	68,6
Trieste	Porec	Euro 6 med. Petrol car	78	5	5	16	0	0,05	n.a	3,2
Venezia	Pula	Euro 6 med. Petrol car	285	5	19	60	0,02	0,18	n.a	12,0
Venezia	Pula	Hydrofoil/Pax ships	80	330	3.454	11.075	271	26	69	33,6
Trieste	Porec	Hydrofoil/Pax. Ships	36	210	1.388	4.450	109	10	28	21,2
Ancona	Split	Medium hybrid car	992	5	34	107	0,01	0,43	n.a	21,4
Bari	Dubrovnik	Medium hybrid car	1634	5	56	177	0,02	0,7	n.a	35,4
Trieste	Porec	Medium hybrid car	78	5	3	8	0	0,03	n.a	1,6
Venezia	Pula	Medium hybrid car	285	5	10	31	0	0,12	n.a	6,2
Milan	Dubrovnik	Medium hybrid car	1.147	5	39	124	0,01	0,49	n.a	24,8
Venice	Dubrovnik	Medium hybrid car	840	5	29	91	0,01	0,36	n.a	18,2
Rome	Dubrovnik	Medium hybrid car	1.392	5	47	151	0,02	0,6	n.a	30,2
Milan	Split	Medium hybrid car	911	5	31	98	0,01	0,39	n.a	19,6
Venice	Split	Medium hybrid car	604	5	21	65	0,01	0,26	n.a	13,0
Rome	Split	Medium hybrid car	1.155	5	39	125	0,02	0,5	n.a	25,0
Milan	Zagreb	Medium hybrid car	684	5	23	74	0,01	0,29	n.a	14,8
Venice	Zagreb	Medium hybrid car	377	5	13	41	0	0,16	n.a	8,2
Rome	Zagreb	Medium hybrid car	929	5	32	100	0,01	0,4	n.a	20,0
Ancona	Split	Ro-Ro/Pax ships	139	2.280	37.870	121.410	2.973	280	757	53,3
Bari	Dubrovnik	Ro-Ro/Pax. ships	116	1.300	33.055	105.975	2.595	245	661	81,5

4. Scenarios

4.1 Key factors in determining upcoming scenarios

The definition of the scenarios was formulated taking 2030 as the reference year[8] and taking into account two main sets of elements. The first is the overcoming of the pandemic situation, which at the time of writing is still relevant although apparently on the way to a downward trend thanks to the spread of the vaccination campaign among the population. The second factor is the evolution of demand under "normal" conditions, in relation to the main determinants of travel demand (GDP, population). As mentioned above, the evolution of the post-Covid situation was based on the forecasts made by Eurocontrol in relation of European air traffic. Such scenarios are as follows:

Scenario 1 – Vaccine 2021, recovery 2024

From mid-2021: Vaccine roll-out progressing within Europe and globally. Effective test & trace programme. Relatively good passenger confidence. Coordinated interregional approach. Savings glut/Pent-up demand. Lingering hit to business travel. Airlines, especially LCCs, are reasonably well able to invest and re-hire once demand returns. Some long-haul flows restarting quicker than others (e.g. North Atlantic, Oceania and Asia).

Scenario 2 - Vaccine 2022, recovery 2025

From late-2021:Vaccine roll-out reaching herd immunity levels within Europe. Effective test & trace programme. Relatively good passenger confidence. Coordinated European approach. Savings glut/Pent-up demand. Permanent lingering hit to business travel. Airlines, especially LCCs, are reasonably well able to invest and re-hire once demand returns. A few long-haul flows restart quicker than others (e.g. North-Atlantic first).

Scenario 3 - Lingering infection, recovery ~2029

Persistent restrictions due to vaccine not effective against new and more transmissible coronavirus variants. Patchy uptake of vaccine. Difficult for airlines to operate as preCOVID-19: some regions are experiencing renewed outbreak phases, not at the same time, not with the same severity. Demand is bouncing back for 60-70% of travelers but reluctance to fly for rest (fear and/or alternatives); permanent drop in propensity to fly.

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[8] Forecasts beyond 2030 are of course possible but the degree of uncertainty increases critically as the period lengthens.

The recovery period of the first two scenarios above was considered, while the third, which considers a much longer recovery period, was not considered likely. In our forecast, the recovery period is shorter than that of Eurocontrol, for two reasons. Firstly, for the years 2020 and 2021, we did not use the actual figure but used a forecast, since as pandemic years, we assume that the actual figure represents a non-significant discontinuity. Second, Unlike general air traffic, which grew steadily prior to Covid, the total number of passengers on trips between Italy and Croatia had an irregular trend, so that with the same forecast, interpolation of past data determines a shorter recovery period for Italy-Croatia tourism.

Additional Risks

- The risk behind Brexit: is assumed that continued transport connectivity will be ensured. Businesses and individuals operating in the UK should therefore see no change to existing conditions after the transition period.
- Future airspace and network changes (e.g. unexpected closures, new routes) and airlines' changing choice of routes are not modelled by the forecast.
- The economic recovery remains fragile. Current forecast includes different economic forecasts (Sc1: Rapid upturn, Sc2: Baseline, Sc3: Limited Vaccine Effectiveness) but a further deterioration of the economic situation (e.g. financial crisis) is a downside risk.
- The volatility in oil and fuel prices: A surge in oil prices could lead to an increase of fuel cost, hence an increase of the ticket prices which is a downside risk.
- Terrorist attacks, bans of one country on another one, wars and natural disasters. These are impossible to predict. Their impact on air traffic could however be a temporary one, or more significant. E.g.,2015 terrorist attacks on Egypt and Tunisia may have partially increased the interest of the Italian tourists for Croatia.

4.2 Time series-based forecast

These three scenarios provide three different forecast trends based on the different demand recovery time they imply.

The forecast for each of these three scenarios was formulated on the basis of two different model:

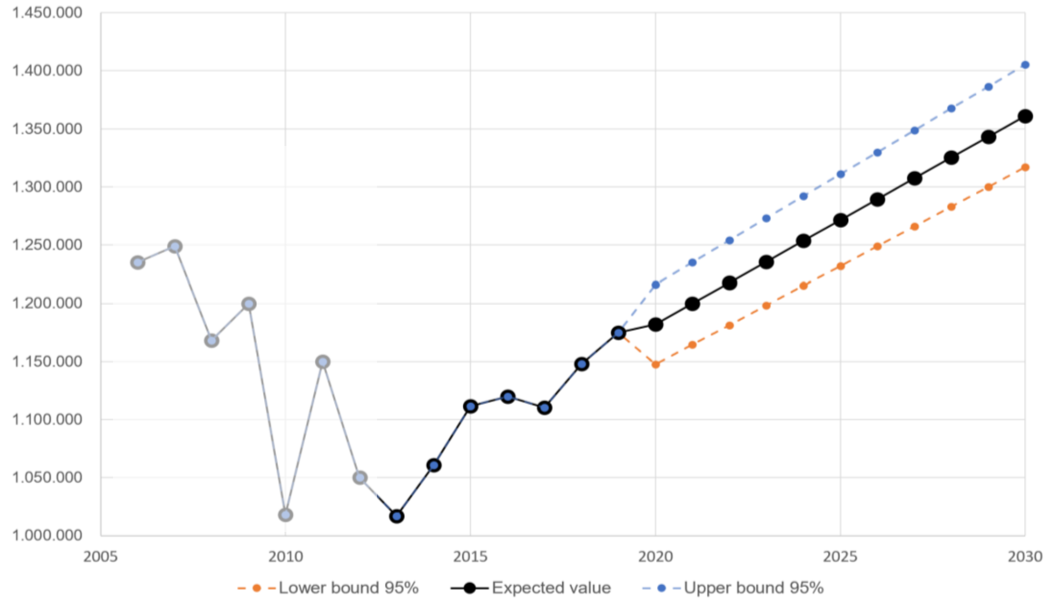
- an autoregressive model that took into account past passenger flows time series;
- an econometric model considering the degree of correlation between travel flows and the GDP of the two countries.

A judgmental correction was then applied to both forecasts, which is discussed below.

The two quantitative models mentioned above return very similar forecasts, net of differences resulting from time discontinuities in the time series. In particular, as for the time series-based forecast, with regard to the flows of Italian tourists, data are available for both countries from 2006 onwards. A significant discontinuity emerges in relation to the period 2014, from which the trend of travellers shows an almost monotonic growth trend, while in the previous period (2006-2014) there are significant yearly fluctuations. This leads to a drastically different projection of the data for future years, depicted in fig. 10 and fig. 11. The shorter time series (2014-2019) influences the subsequent period with its upward trend, providing a forecast of substantial growth that takes on different but linearly correlated values depending on the three possible Covid-exit scenarios (fig. 10). If, on the other hand, the previous period from 2006 onwards is included in the forecast, since between 2006 and 2014 the demand for travel had a decreasing trend in a fluctuating annual context, the forecast is affected in a completely different way, even with a different sign from the first case and decreasing (fig. 11). The data of the two different forecast are shown in table 10.

Note that the actual figure for 2020 is not shown, but is treated as if it were a forecast without a Covid effect, to purge the forecast of the discontinuity generated by the pandemic. This is also the case for 2021, which at the time of writing is not yet available but which is expected to still be affected by the pandemic effect.

Figure 10: Time series forecasts for Italian tourists based on historical data from 2014 to 2019*



* The 2020 and 2021 data are simulated as if it were unaffected by the pandemic

Figure 11: Time series forecasts for Italian tourists based on historical data from 2006 to 2019*

* The 2020 and 2021 data are simulated as if it were unaffected by the pandemic

Table 10: Time series-based forecasts for Italian tourists (in thousands) based on sets of historical data of different length*

	Forecast using 2014-2019 data			Forecast using 2006-2019 data		
Year	Lower bound 95%	Expected value	Upper bound 95%	Lower bound 95%	Expected value	Upper bound 95%
2020	1.148	1.182	1.216	945	1.096	1.246
2021	1.164	1.200	1.235	938	1.089	1.241
2022	1.181	1.218	1.254	930	1.083	1.236
2023	1.198	1.236	1.273	922	1.076	1.231
2024	1.215	1.254	1.292	914	1.070	1.225
2025	1.232	1.272	1.311	906	1.063	1.220
2026	1.249	1.289	1.330	899	1.057	1.215
2027	1.266	1.307	1.349	891	1.050	1.209
2028	1.283	1.325	1.368	883	1.044	1.204
2029	1.300	1.343	1.386	875	1.037	1.199
2030	1.317	1.361	1.405	867	1.030	1.194

* The 2020 and 2021 data are simulated as if it were unaffected by the pandemic

Applying the same method to the Croatian demand for travel, for which data are available from 2008 onwards, we obtain the forecast shown in Fig. 12 and Tab. 11. It should be noted that in this case, as the absolute starting numbers are much lower, the gaps generated by the three different scenarios are extremely small, to the point of being barely visible in the diagram of fig. x. In addition, unlike in the previous case, the forecast trend in this case is steadily increasing.

Figure 12: Time series-based forecasts for Croatian tourists based on 2008 to 2019 historical data

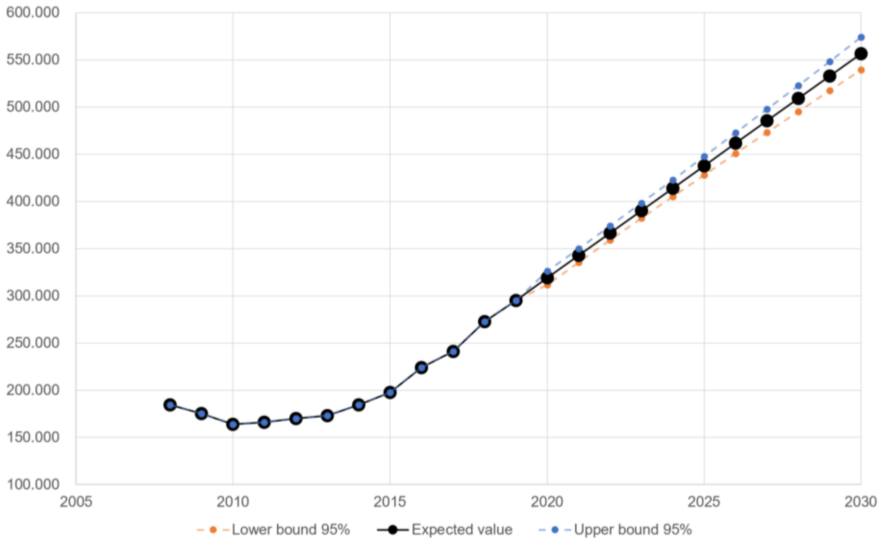


Table 11: Time series forecasts for Croatian tourists (in thousands) based on the 2008-2019 historical data*

	Forecast using 2008-2019 data		
Year	Lower bound 95%	Expected value	Upper bound 95%
2020	312	319	326
2021	335	343	350
2022	359	366	374
2023	382	390	398
2024	405	414	423
2025	428	438	448
2026	451	462	472
2027	473	485	498
2028	495	509	523
2029	517	533	548
2030	539	557	574

* The 2020 and 2021 data are simulated as if it were unaffected by the pandemic

4.3 Correlation-based forecast

Generally speaking, the logic behind econometric models (correlation-based forecast) is that it is possible to identify and assess variables whose trend are drivers of the studied phenomenon. In our case, the main drivers of the number of travellers between two countries are: GDPs, populations, education levels, and exchange rates (i.e: the wealthier, the more numerous, and the more educated are populations the more they move for tourism, business, leisure, etc.). Eurostat [ESTATp2021] measures the transport performance (in passenger-kilometers) as a function of a nation's GDP. The values for the normalized ratio between these two quantities over time are always between 95% and 105% for both Croatia and Italy.

Given a) the scarcity of data, b) the actual correlation between GDP and the other drivers, we have here considered the nations' GDPs as single driver for travel demand. Our analysis of the trends for the other variables make us confident that this will provide no significant loss of generality[9]. Figure 13 highlights an evident parallelism between the values of the number of tourists and the real GDPs over time. Figure 14 and table 12 shows the linear regression model associated with the GDP-correlation based forecast model. It can be seen that the correlation coefficients and standard error are very similar for the two countries. It is therefore considered that the adoption of a GDP correlation-based forecasting method is relatively reliable. We then consider the Croatian and Italian, GDPs to forecast, respectively, the Croatian and Italian number of travellers. Forecasts obtained through this method are shown in table 13 and 14. Please notice that for year 2020 and 2021 the same considerations as above for the time series forecast apply.

Figure 13: Number of tourists and countries' normalized real GDPs 2006-2019 (Croatian 2008 real GDP = 100, Italian 2006 real GDP = 100)

[9] In fact: a) the education (expressed as % of population that has reached a given degree of education) is correlated with the GDPs' increase; b) the currency exchange rate between Euro and Kuna has remained relatively constant in the last few years. Finally, as for the population, the Italian population below 65 years is negatively correlated with the number of Italian travellers (respectively, population below 65 is decreasing and the number of Italian touritravellers is increasing)

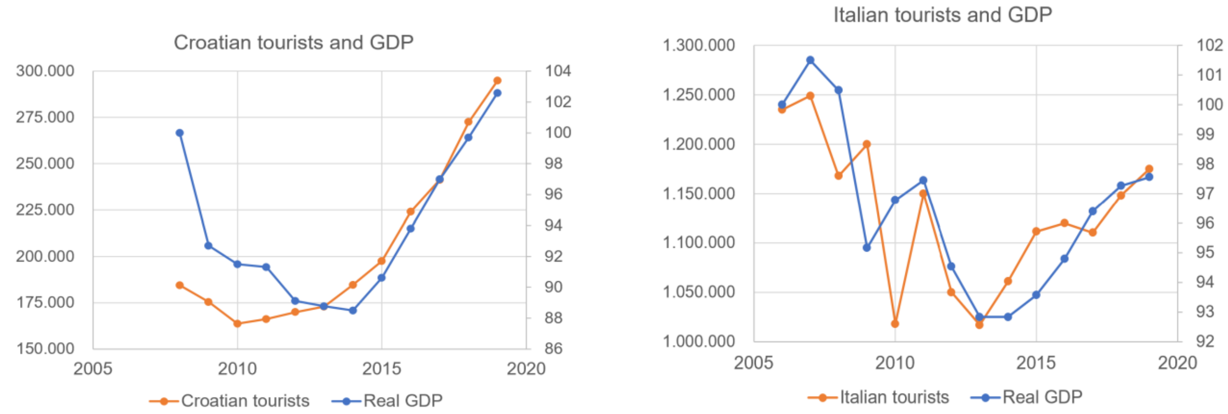


Figure 14: Number of tourists vs their countries' normalized real GDPs and associated linear regression model

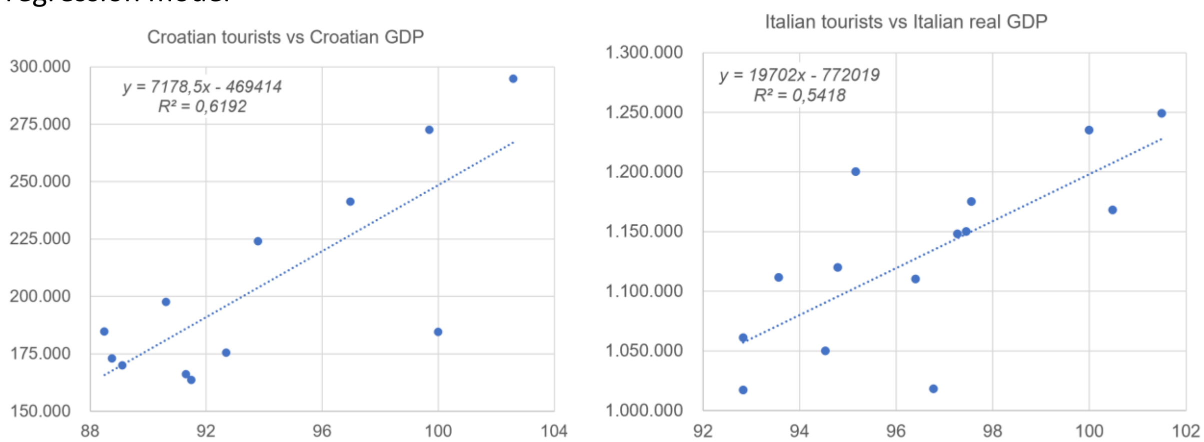


Table 12: Regression statistics for the econometric model linking the number of Croatian / Italian, tourists to their respective countries real GDPs

Regression statistics					Significance	Confidence interval	
Tourists	**Parameter**	**Value**	**Variable**	**Coefficient**	**p-value %**	**Lower 95%**	**Upper 95%**
HR	Sample correlation coefficient	0,79	Intercept	- 469.414	1,85	-841.890	-96.937
	R-squared	0,62	Real GDP	7.179	0,24	3.212	11.145
	regression standard error	28.636					
ITA	Sample correlation coefficient	0,74	Intercept	-772.019	15,22	-1.872.236	328.199
	R-squared	0,54	Real GDP	19.702	0,27%	8.307	31.098
	regression standard error	52.292					

Table 13: GDP-based econometric model forecasts for Italian and Croatian tourists (in thousands), based on the 2008-2019 historical data*

	Italian tourists (/000)			Croatian tourists (/000)		
Year	Lower bound 95%	Expected value	Upper bound 95%	Lower bound 95%	Expected value	Upper bound 95%
2020	877	979	1082	145	201	257
2021	950	1053	1155	176	232	288
2022	1016	1118	1221	211	267	323
2023	1046	1149	1251	242	298	354
2024	1063	1166	1268	269	325	381
2025	1081	1183	1286	298	355	411
2026	1096	1199	1301	323	379	435
2027	1112	1215	1317	349	405	461
2028	1128	1231	1333	375	431	487
2029	1144	1247	1349	402	458	514
2030	1160	1263	1365	430	486	542

* The 2020 and 2021 data are simulated as if it were unaffected by the pandemic

The forecasts for the number of tourists (covering years 2022 on) based on the econometric models and the ones based on time series present similar positive trends. However, the former ones appear a little bit less optimistic than latter ones. Specifically:

- Forecasts for Italian tourists: the high-end econometric forecasts overlap the expected value forecasts based on the 2014-2019 historical data (0,3% difference at 2030).
- Forecasts for Croatian tourists: the high end econometric forecasts overlap the low-end time series forecasts for year 2030 (0,6% difference at 2030), otherwise the high-end econometric forecasts remain few percentage points below the low end time series forecasts.

These results are coherent with the fact that both the two forecasting methods use data that assume that the positive trend in the value of the number of tourists, or of its main driver observed in the recent years, will start again as soon as the covid-19 pandemic is defeated.

The econometric models forecast a slightly lower increase in the number of tourists because they take into account the sudden drop of the GDPs during 2020. In the light of the above consideration, only econometric model forecasts are considered next.

As stated above, the 2020 data are not taken into consideration and substituted with econometric forecast, in order to preserve the hypothesis of the stationarity and ergodicity of the tourist demand over time. In order to take this aspect into account, in the next section we apply judgmental corrections to the econometric forecasts to take into accont of the effects of Covid pandemia not correlated to GDP, based on the above-mentioned forecast model developed by Eurocontrol for air traffic. We will also estimate the overall number of travellers on the basis of previously shown global ratios between tourists and excursionists.

4.4 Travellers estimates

The econometric model forecasts must be further correct to consider the categorical effect induced by the covid-19 pandemic. An educated guess is that the covid-19 pandemic impact on the visitor movements is similar to the one on air traffic, as both these processes are linked to the nations' GDPs and the corresponding observed decreases for 2020 are of the same order of magnitude. If this is the case, a downward correction of the forecasts should be expected at least for years between 2021 and 2024. This concerns the total number of travellers, while it is reasonable to expect that the shares of travel demand of the various modes of transport are influenced by the greater or lesser confidence travellers have in that mode of transport. In the case of air travel, for example, which is characterised by tight spaces and long stays, it is likely to take longer than other modes to return to pre-Covid shares.

Table 14 reports the expected increase in the number of visitors from 2019 to 2030. The results presented are based on the following values:

- the actual number of tourists in 2019 reported in Tab. 2,
- the estimated number of excursionists in 2019 reported in Tab. 3 and 4,
- the forecasts for the number of tourists in 2030 reported in Tab. 13;

and the following assumptions:

- There will be no further waves of pandemic infection by the year 2024
- The ratio of excursionists over tourists will remain equal to the one estimated for the year 2019.

Table 14 shows the summary of the scenarios emerging by this analysis: the overall number of visitors, and hence of the corresponding demand of transport, will increase at most by 30% in the next decade (tab. 14). From now on, these data will be taken as reference for the calculation of the change in the carbon footprint, taking into account three further factors: a) a possible change in travel habits resulting in a different distribution of passengers on the different means of transport available (modal shift); b) a technological improvement of the means of transport leading to a reduction in emissions; c) a reduction in the number of passengers on the different means of transport.

Table 14: Expected increase in the number of visitors from 2019 (as if it were unaffected by Covid pandemic) to 2030

		Italian visitors		Croatian visitors		Total	
Year	**Visitors**	**Low estimate**	**High estimate**	**Low estimate**	**High estimate**	**Low estimate**	**High estimate**
2019	Tourists	1.175.069		294.825		1.469.894	
2030		1.160.000	1.365.000	430.000	542.000	1.590.000	1.907.000
2019	Excursionists	2.750.482	3.300.579	450.986	676.479	3.201.468	3.977.058
2030		2.715.210	3.834.064	657.760	1.243.625	3.372.970	5.077.689
2019	Total	3.925.551	4.475.648	745.811	971.304	4.671.362	5.446.952
2030		3.875.210	5.199.064	1.087.760	1.785.625	4.962.970	6.984.689
2019/30 % variation		-1%	16%	46%	84%	6%	28%

4.5 Modal split

Several factors can provide changes in the distribution of travellers among the various transport modes. Car is expected to remain the most commonly used mean of transport, and it may even increase its popularity in case the pandemic persists as they guarantee a greater level of safety from infection. Differently, a shift from cars to buses can be observed in the future years above all among the youths and visitors without accompanying children, given a series of conditions, among which the following seem particularly relevant:

- there are no further waves of pandemic infection;
- diffusion of long-distance bus or minibus rental services (following the business model of, for example, Flixbus or Go-Opti, Croatia-Bus, etc.), with adequate services (e.g. luggage transfer, high-comfort equipment, etc.);
- improvement of connectivity on starting point and destination;

- new services of (fast) vessels from and to main coastal attractors (e.g. Trieste, Venice, Rovinj, Pula, etc.), especially within a logic of increasing the attractiveness of sea travels by offering improved services, such as bicycle transportation or all-inclusive packages.

Segments identified in D.3.1.2. leave room for alternative forms of tourism, oriented towards multimodal travel that does not use cars (bike + bus, bike + ship, bike + train, etc.). That analysis suggested that this type of travel is more likely to develop for segments of young and highly educated people. However, this is unlikely to change the modal shares beyond what is shown in the table 13 (See D.3.1.2, “Segmentation Analysis” for further information).

On the other hand, a possible increase of the demand for transportation by ships or flights could occur if long-distance destination increase their attractiveness, gaining higher shares of visitors. For instance, if South Italy and the main religious sites increase their attractiveness to Croatian tourists as suggested in [IME2019] and [IME2016]. Similarly, if Italian visitors would consider more frequently the Counties of Zadar, of Split-Dalmatia, and of Dubrovnik-Neretva instead of concentrating in the north-west coastal area.

Scenarios assume data coherent with those from the sample interviewed for D.3.1.2 The following assumptions are implied by those estimates:

- Differently from the Croatian tourists, the Croatian excursionists use little or no flight.
- The value of the ratio between the number of Croatian excursionists that prefers a bus than a car is equal to the value of the same ratio for the Croatian tourists.
- The value of the ratio between the number of Italian visitors that prefers a bus than a car is equal to the value of the same ratio for the foreing passengers that cross the Croatian-Slovenian border.
- The number of non-Italian passengers that boarded a ship routing from Italy to Croatia is negligible compared to the number of Italian passengers.
- Neither transit nor arrivals cruise passengers were counted as either excursionists or tourists in 2019.
- The number of Croatian and Italian visitors using the train or the bycicle for their journeys is negligible.
- Average load factor per means of transport is: 3 passengers per car, 50 passengers per bus, 90% occupation for line ship and 95% occupation for airplanes and fast ships.

In conclusion, table 15 show the likely scenario as for the share of alternative mode of transportation in 2030.

Table 15: forecast of cross-border transportation mode share in 2030* between Italy and Croatia

	2019		**2030 - High Est.**		**2030 - Low Est.**	
	Italian travellers	Croatian travellers	Italian travellers	Croatian travellers	Italian travellers	Croatian travellers
Car	90%	75%	88%	73%	85%	70%
Bus	1%	17%	2%	18%	4%	19%
Plane	2%	7%	3%	8%	4%	9%
Line ships	4,5%	1%	4%	1%	4%	1%
Fast vessels	1,5%	0%	2%	1%	2%	1%
Private vessel	1%	0%	1%	0%	1%	0%

4.6 Technological improvement

The technological improvement of means of transport can provide a significant contribution to the reduction of the carbon footprint especially for ships and flights.

Recently, the European Commission presented a legislative proposal, linked to the Green Deal Investment Plan, known as "Fit for 55" published on 14 July 2021[10]. This proposal envisages, among many other actions, a series of green transition supports for aviation and shipping fuels, as well as the achievement of a zero emissions target for passenger cars and light-duty vehicles on the market by 2035. The primary goal of all the initiatives, however, is to reduce the greenhouse gas emissions by 50% within 2030. As we write only a few weeks have passed since the publication of the "Fit for 55". Therefore, as for the forecast of emissions only documents previous to the "Fit for 55" has been taken into consideration.

The ICAO (International Civil Aviation Organization) had targeted a 2% efficiency improvement per year between 2013 and 2050. However, the report [ICAO2019] illustrates that under the most optimistic scenario the projected long-term fuel efficiency is equal to 1.37%. In addition, sustainable alternative fuels, hydrogen, and e-fuel are not going to fill the gap in the short term. The scenarios considered in this section assume a reduction of emission by planes of at most 13% by 2030. The

[10] Brussels, 14.7.2021 COM(2021) 550 final, "'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality"

IMO's (International Maritime Organization) sets decarbonization targets of international shipping by at least 40% CO_2 emissions reduction by 2030 in comparison to 2008 [IMO2021]. This strategy was set in April 2018 by Resolution MEPC.304(72) consistent with the Paris Agreement temperature goals [IMO2018]. The IMO is expected to issue a revised GHG strategy in 2023, however we have included this prediction into the scenario.

As for cars, currently in Italy 1.2% of the Italian cars are hybrid, about 0.2% are full electric ones, the remaining 98% are standard Internal combustion engines cars. Only 18,7% of Italian fleet meets the Euro 6 standard. In the most optimistic scenario, by 2030 the share of hybrid cars will be 20% and 10% for electric cars (Source: CAMI - Center for Automotive and Mobility Innovation, elaboration of data from ACEA, ANFIA. Simulation of Italian fleet composition according to the average fleet turnover rate and in case of enduring incentives). In this case, the greatest reduction in emissions would come not so much from the growth in the share of electric and hybrid cars, as from the gradual elimination of older cars up to Euro 5, which currently make up more than 60% of the Italian car fleet. An average value of CO2 emissions per car has been calculated as weighted average of standard emissions. Data for the Croatian fleet are not available, therefore it is assumed that the two fleets are similar in terms of composition ad average emissions.

As for trains, at the moment a travel by train from Italy to Croatia is not an option. Most journeys involve travelling via Zagreb. VIsitors are advised to use buses or ferries rather than trains. As pointed out in [SIPPEL2019], no positive evolution is foreseen in the short term. Consequently, the scenarios here considered assume that a negligible number of Croatian and Italian visitors will use the train as the main means of transportation in the next few years.

4.7 Carbon Footprint Scenarios

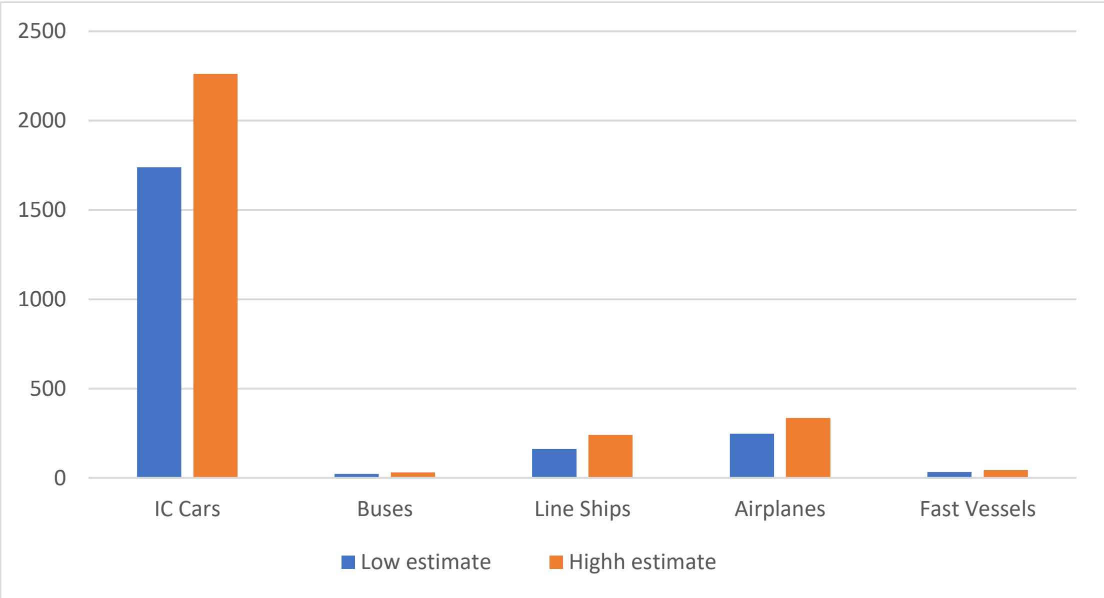
According to our estimates, the yearly amount of CO2 ascribed to cross-border travel between Italy and Croatia is 368.000 Tons., 83,5% attributable to Italian travellers. The average emissions per capita is 72,7 Kg/y. In caso of no-changes (i.e.: same technology, same modal split) the expected increase in the number of travellers by 2030 would, result in an increase in overall emissions of between 2,8% (low estimate) and 35% (high estimate) (table 16).

Assuming that technological improvement as the primary driver of emissions reductions, it emerges that at the current modal split the efficiency gain of the internal combustion (IC) car provides the greatest benefit. In fact, for every percentage point of CO2 reduction of IC vehicles, total emissions decrease by more than 1.739 tons in the low growth scenario and by 2.261 tons in the high growth scenario Planes and ships, which have much higher emissions per passenger than the car, are however much less used and therefore their improvement has a relative (i.e. per each % point of increase in efficiency of IC cars) lower impact on the overall reduction of emissions (fig. 15).

Table 16 (no action scenario): carbon footprint of travels between Italy and Croatia given present modal split, technology and distance travelled and emissions at 2030 if no modal shift and no technological improvement occur

	2019		**2030**			
			Low estimate		**High estimate**	
CO2 Emissions	**Tons CO2**	**Kg per capita**	**Tons CO2**	**Kg per capita**	**Tons CO2**	**Kg per capita**
Italian travellers	183.578	43,7	173.639	44,8	222.176	42,7
Croatian travellers	36.036	42,0	48.433	42,6	71.449	40,0
Total	219.614	43,4	222.071	44,3	293.624	42,0
			+ 1,1%		**+ 33,7%**	

Fig. 15: yearly reduction in total CO2 emissions (tons) generated by travel between Italy and Croatia (projected to 2030) for each percentage point reduction in emissions from the various means of transport



As for the modal shift, benefits and disadvantages are of course related to the average emission per passenger per distance. Table 17 shows our estimation of this parameters as for the Italy-Croatia routes.

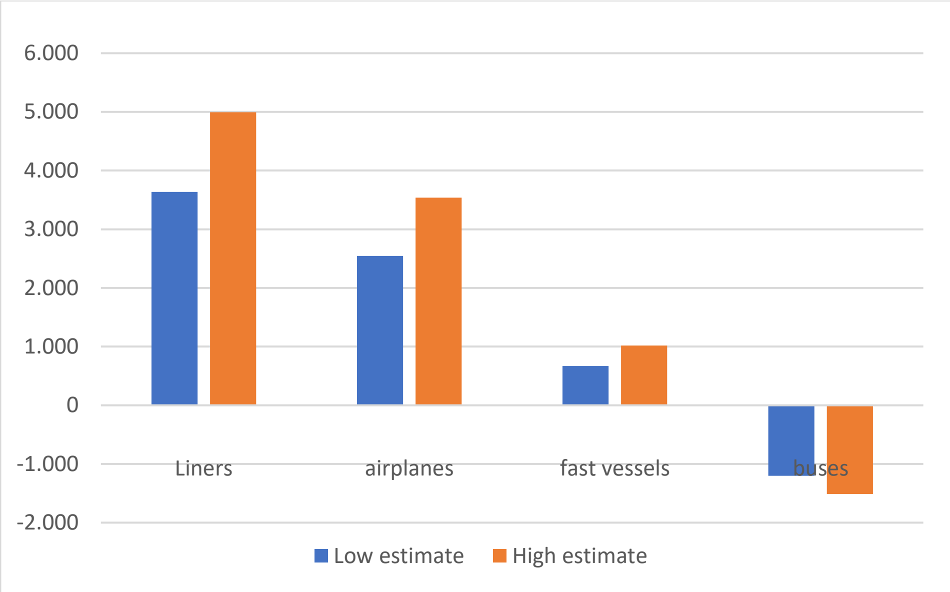
Table 17: tank-to-wheel estimated emissions per passenger per travel mode on Italy-Croatia routes[11].

Car EURO 6 - 5 seats [kg/km]	0,1328
Car Hybrid - 5 seats [kg/km]	0,0361
Car 0 emissions -5 seats [kg/km]	0,0000
Coach/Bus - 56 seats [kg/km]	0,0151
Private vessel [kg/km]	0,3768
Plane [kg/pass journey]	52,63
Line ship [kg/pass journey]	66,67
Fast ship [kg/pass journey]	28,42

Liners and aircraft have the highest consumption per passenger, and therefore the highest CO2 emissions per capita. In order to translate this data into an understanding of the advantages or disadvantages of the modal shift, figure 16 shows the annual CO2 change that would occur if one percentage point (1%) of travellers between Italy and Croatia used one of the other available means. Given the present technology, shifting from cars to others than buses would increase emissions instead than reducing them.

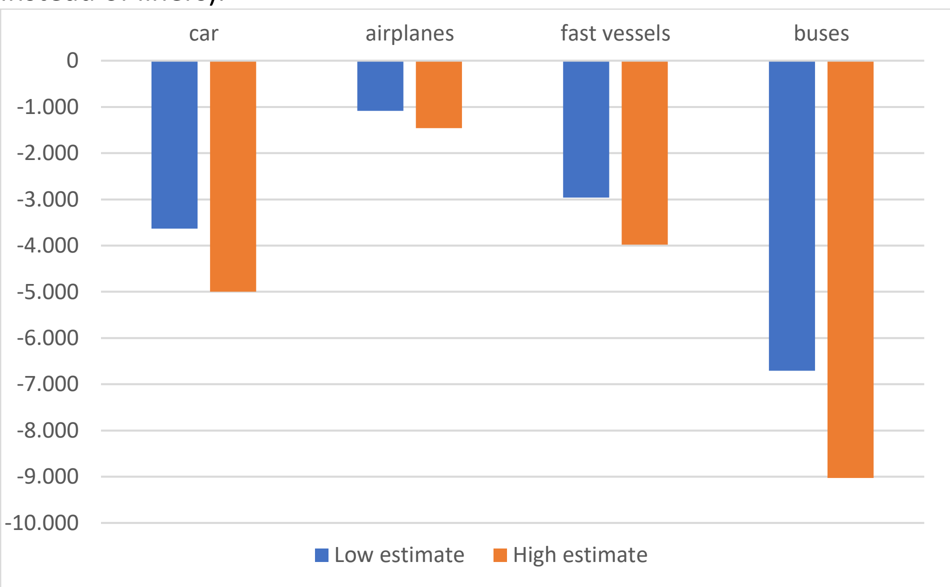
Fig. 16: yearly variation of CO2 (in tons.)expected for 1% Italy-Croatia travellers shifting from cars to other means of transport at 2030 travellers flows (e.g. 1% travellers use ships/airplanes/buses instead of cars).

[11] It was not possible to find well-to-wheel emission data for the programme area.



A similar measurement was carried out with regard to the modal shift from liner ships to other vessels. Liner shipping being the mode with the highest emission rate per passenger, the CO2 changes per percentage point are all negative in this case, reaching over 9,000 tonnes of CO2 in the high growth scenario for each percentage point of passengers using the bus instead of the liner (fig. 17).

Fig. 17: yearly variation of CO2 (in tons.) expected for 1% Italy-Croatia travellers shifting from liners to other means of transport at 2030 travellers flows (e.g. 1% travellers use cars/airplanes/buses instead of liners).



However, in the case of liners, ships and airplanes, the reduction is hypothetical since it would actually occur discontinuously, only to the extent the the number of travels of a ship / airplane devreases. Such improvement would therefore be related to the average saturation rate of vessels / airplanes capacity, and this is an information that is presently not available to us. However, this data is useful to visually understand the carbon impact of different means of transport, given current technologies.

Of course, it is possible to depict as many scenarios as many possible variations of each parameter can be conceived. Here we outline three scenarios, which we label "conservative", "realistic" and "optimistic" depending on variations in the various parameters described so far that seem realistic to us, net of the inevitable uncertainty of any forecast. Beyond the labels, all scenarios share optimistic assumptions about improved technology over time and a less unbalanced travel mode distribution. However, the introduction of new shipping lines using old ships would be enough to overturn these scenarios. Moreover, although all the changes introduced, in terms of technology and modal shift, go in the direction of reducing per capita emissions, the overall emissions are affected by the increase in the total number of travellers.

Scenario 1 ("conservative"): in 2030, emission reduction of 0,6% for airplanes and 12% for vessels operating on Italy-Croatia routes. Car fleet composed by 12% hybrid cars, 2% zero-emissions cars. 18% improvement in average emissions from the internal combustion car fleet (due to replacement of older cars), 10% improvement in average emissions of hybrid cars and 8% improvement in average emissions for buses. Modal shift as depicted in table 15 – High estimate.

Scenario 2 ("realistic"): in 2030, emission reduction of 0,9% for airplanes and 15% for vessels operating on Italy-Croatia routes. Car fleet composed by 16% hybrid cars, 3% zero-emissions cars, 22% improvement in average emissions from the internal combustion car fleet (due to replacement of older cars), 11% improvement in average emissions of hybrid cars and 10% for buses. Modal shift as average of the two scenarios (high and low estimate) depicted in table 13. Modal shift as average of the high and low estimate depicted in table 15.

Scenario 3 ("optimistic"): in 2030 emission reduction of 1,1% for aviation and 22% for vessels operating on Italy-Croatia routes. Car fleet composed by 20% hybrid cars, 5% zero-emissions cars, 25% improvement in average emissions from the internal combustion car fleet (due to replacement of older cars), 13% improvement in average emissions of hybrid cars and 12% improvement in average emissions for buses. Modal shift as depicted in table 15 – Low estimate

Emissions forecasted for each scenario are shown in table 18, according to the minimum and maximum number of travellers expected in 2030 (see table 14)[12].

As can be seen from table 18, the 30% emission reduction target for 2030 is only achieved under the 'optimistic' assumption of improved vehicle technology and modal shift, and only if passenger flows are close to the minimum prediction. In the 'realistic' scenario 2, if the number of travellers is kept to the minimum values, the overall reduction is close to 23%, but if the number of travellers is the same as in the highest growth scenario, the reduction in carbon impact would be negative (+2,8% emissions). If the growth in travellers were to be at the maximum values predicted, the CO2 reduction would be 17,7% 'optimistic' scenarios, and would even increase in the 'conservative' scenario (+8,4%). Basically, as the most likely scenario sees an increase in the number of travellers, a 30% reduction in emissions from each mode of transport would not be sufficient to reduce overall emissions by the same amount.

Against this less-than.positive backdrop, a legitimate question is: what objectives (a) for technological improvement, (b) for modal shift, should be set to achieve at least a 30% reduction in emissions by 2030, given the travel flows forecast?

According to our simulation, in the event that the number of travellers between Italy and Croatia in 2030 corresponds to the forecast of higher growth, the target of an overall 30% reduction in emissions can only be reached by achieving about 40% reduction in emissions from both land vehicles and vessels.

As for vessels, table 19 reports GHG emissions per kg of the most common fuels for ships: Heavy Fuel Oil (HFO), Low Sulphur Heavy Fuel Oil (LSHFO), Marine Gas Oil (MGO), Liquefied Natural Gas (LNG), Methanol (MeOH) (source: [IMO2020]). Table 20 compares CO2 emissions per unit of energy produced by diesel engines using different fuels.

Table 19: CO2 emissions per kg of fuel (source [IMO2020])

Fuel	CO2 emissions (kg)	Index
Marine Gas Oil (MGO)	3,206	100,0

[12] Data in table 18 are obtained from the calculator model developed by the Center for Automotive and Mobility Innovation (CAMI) of the Dept of Management of Ca' Foscari University specifically for the MIMOSA Project.

Heavy Fuel Oil	3,114	97,1
Low Sulphur Heavy Fuel Oil	3,114	97,1
Liquefied Natural Gas	2,75	85,8
Methanol	1,375	42,9

Table 20: CO2 emissions per unit of energy produced by different types of engine (g/kWh) (source [IMO2020])

	g/Kwh				Index			
Engine	**HFO/ LSHFO**	**MGO**	**MeOH**	**LNG**	**HFO/ LSHFO**	**MGO**	**MeOH**	**LNG**
SSD - Slow-Speed Diesel	545	529	481		89,8	87,1	79,2	
MSD - Medium-Speed Diesel	576	561	509		94,9	92,4	83,9	
HSD - High-Speed Diesel	607	594			100,0	97,9		
LNG-Otto (dual fuel, medium speed)				429				70,7
LNG-Otto (dual fuel, slow speed)				410				67,5
LNG-Diesel (dual fuel)				388				63,9

Although a 40% reduction at the moment seems a more ambitious target than the current technical possibilities, the use of LNG (Liquified Natural Gas) seems the most promising route to a substantial reduction in greenhouse gas emissions from shipping fleets. In particular, if there were incentives for this type of development, we could expect to see greater investment in improving the efficiency of this technology which, according to [IMO2020] data, already offers emission advantages per unit of energy of more than 30% compared to traditional fuels, with peaks 36% (table 20).

As far as emissions from passenger cars are concerned, the share of average emissions is currently high due to the age of the fleet. It should be noted that: a) about 50% of Italian cars on the road have been registered before 2008, this meaning that they don't comply with emissions standard Euro 5 introduced in 2008. Such cars comply with CO2 emissions standards that are more than twice as much those of most recent cars. B) the average rotation of Italian car fleet is 22,6 years (i.e.: cars on the road are, on average 11,3 years old). (data at 2019, source: ANFIA). In 2030 about half of the fleet will have been replaced (presumably the older part) by new cars with much lower emissions. The scrapping of older cars and the gradual growth of hybrid and zero-emission cars will certainly improve average emissions, but unless an intensive policy of forced or incentivised scrapping is deployed, the 40% reduction target seems unrealistic.

5. Italy-Croatia travel demand scenario and carbon footprint

The scenarios described in this study show that in 2030 the carbon footprint of passenger travel between Italy and Croatia is likely to decrease, but only if very specific conditions occur with regard to:

a) the development of travel demand,

b) the technological improvement of means of transport, firstly ships, secondly cars,

c) the growth of the share of multimodal and sustainable modes of travel, i.e. alternatives to journeys made entirely by car or ship.

Given the current estimated average emissions from cars and ships, a modal shift from cars to means other than buses would only make emissions worse. Fleet renewal and a shift to alternative/low impact fuels (particularly LNG) emerges as the key technological priority for overall emissions reduction.

The renewal of the car fleet, with the gradual introduction of hybrid and zero-emission cars by 2030, will contribute to reducing the carbon footprint, but to a lesser extent than might be thought. Despite the growth in the market share of hybrids and zero-emission cars, the car fleet will continue to be made up mainly of conventional cars for at least the next 12 to 13 years, unless there are particularly incisive scrappage or ban policies. Finally, the improvements expected from technology risk being cancelled out by the significant increase in the number of travellers.

In the most 'optimistic' scenario, CO2 emissions in 2030 could be reduced by around 32% compared to today provided the following conditions:

- annual travellers remain below 5 million (not far from today's figures);
- average emissions reductions are 1,1% for aviation, 22% for vessels operating on Italy-Croatia routes, 25% for the internal combustion car fleet, 13% for hybrid cars and 12% for buses;
- car fleet will be composed by 20% hybrid cars, 5% zero-emissions cars;
- bus use for travel increase significantly (2-3 percentage points), at the expenses of cars and liners.

In our view this is an "optimistic" scenario as technological improvements and the modal shift considered is at the highest limit of what can reasonably be considered possible/feasible, but with a limited increase in travel demand.

The scenario we consider realistic is the intermediate one described in the previous section, which envisages an average reduction in overall emissions of 10-11% by 2030, with an increase in travellers of up to one million (tourists and hikers).

On the other hand, emissions per passenger, seem set to fall in any case due to the effect of technological improvements and the fact that demand is expected to be less concentrated on different modes of travel (currently around 90% use cars).

In conclusion, it is worth remembering that these scenarios have been formulated on the basis of currently available data and trends and do not represent a necessary future, but rather an indication of what will happen based on measures that may or may not be taken. Given that the expected technological development and modal shift, taken separetely, are not likely to significantly reduce emissions by 2030, radical changes for the better could occur with severe policies in the short term (within two to three years at most), combining restrictions (e.g. bans on the most polluting marine fuels and older cars) and new multimodal travel combinations (e.g. bus + bike with luggage transfer, fast ships + bike, etc.).

This should be accompanied by an awareness and communication campaign aimed at those segments that are more inclined to alternative travel formulas, as emerged from the study on demand segmentation (Deliverable 3.1.2 of the MIMOSA project). These segments were found to be already relatively large and are expected to become even more important in the future.

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