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How to cite:

Warren, James and Ieromonachou, Petros (2013). Can rail/sail compete with air travel to Cyprus? A comparison of emissions. *Transportation Research Part D: Transport and Environment*, 18 pp. 86–90.

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Version: Accepted Manuscript

Link(s) to article on publisher's website:
<http://dx.doi.org/doi:10.1016/j.trd.2012.09.003>

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Can rail/sail compete with air travel to Cyprus? A comparison of emissions

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ABSTRACT

Rail and sea voyage journeys to Cyprus from a variety of origins are constructed to derive the travel emissions and travel time per person to compare popular aviation routes. The hypothetical 'slow travel' routes are approximately eight to ten times longer than flying. Emissions are lower from certain origins by about 100kg CO₂ per person per round trip under reasonably high occupancy conditions when compared to current direct air services. Emissions from the sea voyages are derived from a sample of 162 marine vessels using the energy efficiency design index for European ships running at 20 knots.

KEYWORDS slow travel; greenhouse gas emissions; ferries

1. Introduction

The recent development of the Cyprus' tourist sector has largely relied on air transportation to bring 2.2 million visitors per year. This, however, poses problems of CO₂ emissions. Whilst more fuel efficient aircraft have the potential to bring about some reductions in emissions, consumer demand the growth in tourist demand will outweigh at least part of this. Here we consider rail travel combined with sea (rail/sail) travel as a less environmentally damaging alternative to air.

2. Methodology

Larnaca and Paphos are taken as the final tourist destination in Cyprus, and we consider trips originating from the UK (52.3% of arrivals in Cyprus), Russia and the Ukraine (6.9%), and France and Italy (2.3%); Germany and Sweden also provide large tourist inflows, and Berlin, Hamburg, Frankfurt and Munich provide a variety of services but we treat these German origins as originating from Berlin. Flights are assumed to be direct, non-stop services. Rail emissions from major German cities to seaports are of the same magnitude; Berlin to Naples return is 145.2kg/passenger whilst Munich to Naples is 103.4kg/passenger.

A variety of internet resources are employed to calculate the 'slow' mode overland emissions; rail emissions are derived from Ecopassenger (2010). For flight emissions both JP Morgan Climate Care (2005) and standard UK Department for Environment, Food and Rural Affairs (DEFRA) values are applied along with those from the International Civil Aviation Organisation (2011)¹.

We use a large sample of ferries and apply their average value to various sea-going journeys to estimate maritime emissions that differ according to: route distance, vessel capacity, service speed, engine power, fuel used and fuel consumption (Baird and Pedersen, 2011). We use a large body of engine based data, extracted from Shipping Efficiency (2011) to derive an average value for ro-pax ferries for longer journeys.

'Fast routes' by aviation to Cyprus

The 'fast travel' aviation routes to Cyprus are considered the standard mode of travel. For many passengers airports are some distance from seaports in the country of departure. We do not calculate door-to-door emissions, but rather departure gate (or departure station) to arrivals hall or destination point. This is termed point-to-point and there will be a slight increase in emissions due to access and egress from seaports or airports. The fast routes, by air, chosen for consideration are listed below as origin and destination city pairs:

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¹ There are debates about the appropriate values to attribute to aviation for CO₂ (Gössling and Schumacher, 2010) *Transport Research Part D*, 18 (2013) 86-90

- London (any airport) to Larnaca (LCA) direct, for tourists from mainly southern England, London area, and perhaps the Midlands.
- Paris (Charles de Gaulle) to Larnaca (LCA) direct, for tourists originating mainly from France.
- Rome (Fiumicino) to Larnaca (LCA) direct, for tourists mainly from Italy.
- Moscow (SVO, Sheremetyevo) to Larnaca (LCA) direct for tourists based mainly from Russia and Kiev (Boryspil – KBP) from Ukraine.
- Berlin (SXF) to Larnaca (LCA) as an example of any major air hub within Germany.

For the aviation routes, it makes only a minor difference in emissions and time if the destination airport of Larnaca is substituted by Paphos, the second largest airport, because of the relatively small distances involved compared to overall flight lengths. This is also true for UK routes from southern England, where all of the airports can be reasonably interchanged. In reality however it is expected that travellers' choice of airport is important (Hess, 2010) and this could be modelled based on stated preferences. German air routes are more complex because Frankfurt, Munich, Berlin and Hamburg all serve tourist destinations in Cyprus; we use Berlin as a single representative origin.

'Slow routes' by rail and sea to Cyprus

The slower routes are composed of a rail journey, or set of rail journeys, linked to a longer sea crossing:

- London to Marseille by rail, departing from Marseille to Valetta, Malta and finally Valetta to Limassol by sea.
- London to Rome and then Napoli by rail, and to Heraklion and Limassol by sea.
- Moscow to Odessa by rail, followed by Odessa to Limassol direct by sea, with the possibility of one Aegean Sea stop en route.

For the sea-going segments of the first two slow routes, it is assumed European passengers would board in France or Italy and travel via Malta and/or Crete. The stop-over from the origin of Odessa is specified as Syros Island (Greece) as it is approximately at the half-way point of the sea travel. Travellers from the Former Soviet Union (FSU) are expected to come from many origins, but we model Moscow and Kiev as popular origins and then onward to Odessa.

All sea routes travel times are expected to increase significantly if the port-of-call is extended, and is dependent on exact arrival times and departure times. We do not attempt to operationally link all of the departure/arrival times to derive the most coherent itinerary or schedule as some of the services do not exist.

Ship emissions are derived from the beta version of the Shipping Efficiency (2011) database. The database contains information on approximately 980 car-carrying ferries, and 390 cruise ships. These values agree well with the findings of Howitt et al. (2010) who finds that in 2004 there were 255 cruise ships over 100 gross tonnes, and in 2007, 499.

Emissions from Rail

Emissions from rail are taken directly from Ecopassenger (2010) for all European trips. All European emissions were then checked with DB Bahn using the Environmental Mobility Check (DB Bahn, 2012). Distances were taken from the European Rail Timetable (Thomas Cook, 2011). Russian rail emissions were estimated using a single value for emissions based on that used in the UK from DEFRA. This estimate for the Russian train emissions has a higher level of uncertainty due to the complexity of the Moscow to Odessa routing. This route passes through various geographies each with a different energy feedstock and level of emissions. Association of Train Operating Companies (2007) stated many diesel units in the UK emitted 61g/pass-km, but UK Department for Environment, Food and Rural Affairs (2011) revised the figure to 53.4g/pass-km

to account for an increased number of trains drawing energy from the national grid via overhead electrical systems.

Distances for Moscow to Odessa are 1450 to 1590 km depending on the route taken and emissions from the trip calculated using the lower emissions value for 1477 km results in about 79kg CO₂; this could be as low as 22 to 26kg CO₂/person if one applies the Eurostar rail emissions factor².

Ship emissions

The UK Department for Environment, Food and Rural Affairs (2011) gives the typical values for ferry emissions, at the average occupancy loading factor for the UK of 70%, as 115.2g CO₂/pass-km. The allocation of emissions to passengers is assumed to be one-third for all types of ro-pax ferries, regardless of the various deck layouts and lane-metres available for cars and freight vehicles, as an initial approximation for the 165 ferries modeled. These included ships from 21 major ro-pax ferry lines.

Emissions per passenger-distance are calculated following LIPASTO (2010). An energy efficiency design index (EEDI) is extracted from the database for each vessel³; there are about 46,000 vessels in the database. The EEDI rating (grams of CO₂/tonne-nautical mile) is multiplied by the dead weight tonnage (DWT) and divided by the actual maximum passenger capacity. This value is multiplied by the passenger allocation, held constant at one-third for typical ro-pax ferry car and passenger deck configurations. Maximum passenger (P_{max}) are taken from the various ferry operators' websites. This study assumes 70% occupancy for all ferries and per passenger emissions are calculated using.

$$\text{CO}_2\text{g/pass-km} = [(\text{EEDI} \times \text{DWT}) / P_{max} \times 0.7_{(\text{occupancy})}] \times 0.333_{(\text{passenger emissions allocation})} \quad (1)$$

Average sailing distances and sailing times are extracted from a ship operators navigation aid (Dataloy, 2011), by applying a standard speed of 20 knots. The sample represents 17% of ferries available within the database. Average dead weight tonnage was 4,300 tonnes with a typical main engine power of about 24,000 kW.

Overall ferry emissions are 67g/pass-km and 96g/pass-km at 100% and 70% occupancies as derived from the average EEDI rating of 159g/tonne-km for all ferries. Similar emission values are observed in Finland (LIPASTO, 2010) and the UK (UK Department for Environment, Food and Rural Affairs, 2011), and were somewhat higher for New Zealand cruise ships (Howitt et al., 2010).

3. RESULTS

The results of the fast routes are presented in Table 1. In the cases of lower overall travel time for air, it is assumed that tourists come mainly from the country of departure. We do not include an estimate for travel time from home to airport, or emissions for this part of the journey. The emissions values are shown for three calculators (JP Morgan, DEFRA and ICAO). A second higher value is also shown that includes both CH₄ and N₂O and indirect emissions. The DEFRA 2 total of equivalent GHGs (greenhouse gases as CO_{2e}) uses indirect emissions including extraction, transport, refinement and distribution of the finished fuel (UK Department for Environment, Food and Rural Affairs, 2011) as prescribed in Scope 3 regulations.

² As Eurostar's feedstock energy mix relies on nuclear energy from France, it may be appropriate for certain parts of the FSU. The lower DEFRA CO₂ value is, however, utilized.

³ The EEDI is an estimate of grams of CO₂ per tonne nautical mile.

Table 1: Emissions, travel times and passenger arrivals to Cyprus from six countries.

Origin and distance (km)	CO _{2e} (kg/passenger) (one way)	Average Flight Time (hr, min)	Passengers per year*	Minimum and Maximum CO _{2e} (kg/passenger) (round trip, values)
London (LHR) 3276 km	JPM: 358.2 ICAO: 246.5 DEFRA: 326.0 DEFRA 2: 390.0	4'50"	1,219,856	493-780
Paris (CDG) 2980 km	JPM: 325.9 ICAO: 216.5 DEFRA: 297.0 DEFRA 2: 355.0	4'25"	36,847	433-710
Berlin (SXF) 2522 km	JPM: 280.0 ICAO: 187.8 DEFRA: 251.0 DEFRA 2: 300.0	3'40"	146,060	376-600
Rome (FCO) 2010 km	JPM: 222.3 ICAO: 157.7 DEFRA: 200.0 DEFRA 2: 239.0	3'05"	17,061	315-478
Kiev (KBP) 1733 km	JPM: 193.4 ICAO: 184.3 DEFRA: 173.0 DEFRA 2: 206.0	2'55"	8,139	369-412
Moscow (SVO) 2361 km	JPM: 259.3 ICAO: 179.2 DEFRA: 235.0 DEFRA 2: 281.0	4'10"	153,846	358-562

*Arrival of tourists by air by country of usual residence, annual average for 2005 to 2010 (Republic of Cyprus, 2011).

As many inbound passengers currently come from both Ukraine and Russia, this table shows both major origin airports. These six origin countries account for nearly two-thirds of all tourist arrivals to Cyprus.

The results of the slower overland and sea routes are seen in Table 2. The tourists' origin is always from their usual country of residence with onward travel to a departure point of their choice. There are more segments to each of the slower routes, and for simplicity each route describes segments separately to aid the reader. No further travel time is added for 'stop-overs' (e.g. Valetta, Syros Island or Heraklion) as the hypothetical routes focus on trip emissions, rather than operability or commercial feasibility.

Average ship emissions are calculated using the lower occupancy value (70% occupancy) resulting in an average overall pass-km emission of about 96g CO₂/person; at 100% occupancy this value would drop to about 67. We assume occupancy being fairly constant at 70% and somewhat similar to that of aviation loading; this may be an optimistic assumption, but given that the 'slow travel' framework aims for potentially lower carbon emissions, it seems applicable.

Table 2: Distances, emissions and travel times for slow travel

Origin	Destination (distance, km)	CO ₂ (kg/passenger)	Time (hr' min'')	Emissions (kg/passenger on a return trip basis)
London	Lille (267)	3.7	1'21"	
Lille	Marseille (1009)	3.7	5'35"	
Marseille	Valetta (1214)	116.5	29'	
Valetta	Limassol (1723)	165.3	41'	

<i>Total</i>	4213 km	289.2	~77	578.4
London	Paris (492)	3.7	2'21''	
Paris	Milan (821)	14.9	9'05*	
Milan	Rome (568)	18.7	2'59''	
Rome	Naples (222)	6.7	1'01''	
Naples	Heraklion (1271)	121.9	31'	
Heraklion	Limassol (754)	72.3	19'	
<i>Total</i>	4128 km	238.2	~65	476.2
Berlin	Munich (892)	23.0	5'56''	
Munich	Bolzano (320)	15.8	3'56''	
Bolzano	Naples (841)	33.8	12'*	
Naples	Heraklion (1271)	121.9	31'	
Heraklion	Limassol (754)	72.3	19'	
<i>Total</i>	4078 km	266.8	~72	533.6
Moscow [†]	Odessa (1477 km)	78.9	23'	
Odessa	Syros (1260 km)	120.9	31'	
Syros	Limassol (843 km)	80.9	22'	
<i>Total</i>	3580 km	280.7	~76	561.4

Notes: [†]Kiev results in reductions of 621 km, 32.9kg, about 14 hr. * are night or sleeper trains

Summary values for the two routes originating in London in terms of time and emissions show trends towards the maximization of rail distances in favour of sea distances results in lower emissions and faster times. For most origins in Germany there are a variety of rail routes that can favor either Naples or Marseille, however the routes from Berlin and Munich go via Switzerland to Naples. The route through Italy reduces the emissions burden by about 50kg CO₂, and there are time savings of about 12 hours. Rail time savings and overall time values need to be treated with care, as actual travel schedules were not used, but based on operational services at that time. The sea travel times, under fairly constant ship speeds, do result in scenarios where either two to three nights at sea would be required. Both Moscow to Odessa and to Naples rail routes would normally require one night on a sleeper-train.

Overall round-trip values are depicted in Figure 1, for the various routes. In some cases rounding has resulted in the final value displayed being different by approximately 1 to 2kg per return trip but these are within reason given that the majority of rail emission calculators assume relatively high occupancies per train carriage. In the overland routes, rail accounts for 1 to 28% of rail/sail emissions depending on which route is chosen and the overall configuration.

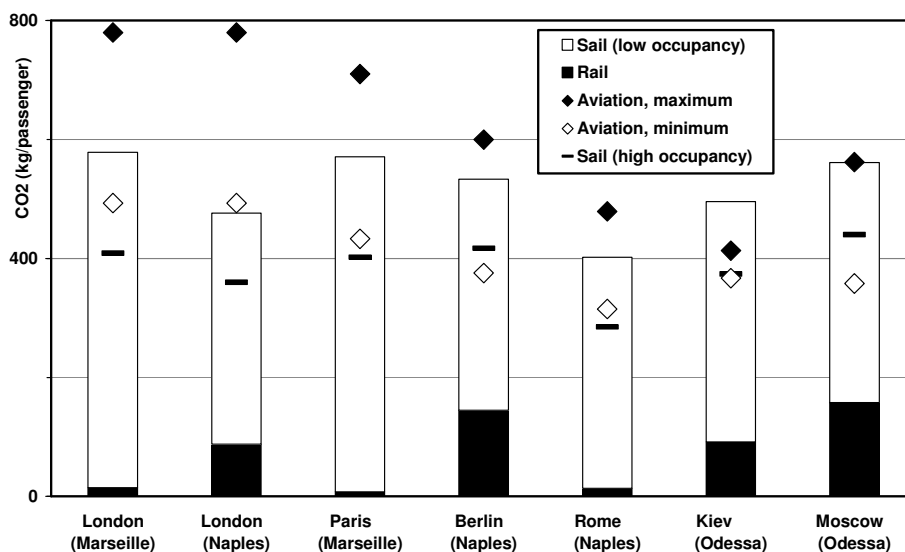


Figure 1: CO_{2e} emissions per passenger as a function of origin and route

Figure 1 shows a variety of origins and pathways for arriving in Cyprus, with departure point for seaports shown in parentheses. There is little difference in emissions when traveling by air from London regardless of whether it is via Marseille or Naples, but for rail/sea overland routes Naples produces 117kg less CO₂ than Marseille. Further, for round trips starting in London, air involves 202kg or 304kg of CO₂, compared with rail/sea emissions of 139kg for Paris and 77kg for Rome. Those from Moscow have identical emissions for slow and fast travel under these conditions. For Kiev, although the overall distance is shorter than for Moscow, the emission results are higher because the rail portion when combined with a relatively long sea crossing, compares poorly with aviation emissions; a difference of about 84kg per person.

For UK tourists, the best combination of rail/sail routes, in terms of time and emissions, seems to be the London via Naples route with rail distance maximized, and the sea voyage minimized under low occupancy conditions. This value can be further reduced by another 116kg, if occupancy is 100%. The high occupancy rail/sail totals are shown by the black dash in Figure 1 and these could represent the peak season case.

4. CONCLUSIONS

We have modeled various fast and slow travel routes to Cyprus and find that fast routes are slightly higher in emissions for specific origins, by 70-300kg/person per round trip. For those originating from Moscow there is no emissions saving overall, and for Kiev the scenario shows that slow travel emissions are some 85kg higher. Slower overland and sea routes take much longer in time, with average one-way travel times of 65 to 78 hours. The slow travel route is seven to ten times longer than the estimated travel time of 6 to 9 hours for the aviation based routes. For the tourist from London, the overland route to Naples results in a lower overall impact due to the relatively low emissions of rail systems when compared to the average ro-pax ferry.

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Link to this paper directly <http://dx.doi.org/10.1016/j.trd.2012.09.003>