Australasian Transport Research Forum 2011 Proceedings
28 - 30 September, Adelaide, Australia
Publication website: http://www.patrec.org/atrf.aspx

Potential reduction in energy use from a High Speed Rail network in Australia

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Abstract

High Speed Rail or HSR with electric passenger trains using steel wheels on steel rails with maximum operating speeds of 250km/h or more is now operational in 12 countries. It is now under review in Australia. The paper considers energy use on the 10 top routes of the Melbourne-Sydney and Sydney-Brisbane corridors and finds that HSR was in place by 2020, HSR could reduce the use of aviation fuel by over 450 million litres each year.

External costs are also considered as are Sydney airport issues. Based on European estimates, the potential reduction of external costs resulting from diversion from planes to HSR in Eastern Australia could be $540m per annum by 2020. On 2009 data, if HSR had been operational between Sydney and Melbourne, between Sydney and Brisbane, and between Sydney and intermediate points on each corridor, and attracting at least 50 per cent of aviation passenger numbers, then 198 slots would have been released at Sydney Airport.

Areas for further research in an Australian context include liquid fuel savings from diversion from cars and buses to HSR on shorter corridors, the potential reduction in carbon dioxide emissions, and external costs.

1. Introduction

In this paper, High Speed Rail (HSR) will designate electric passenger trains using steel wheels on steel rails operating at maximum speeds of 250km/h or more. This recent definition is due to the International Union of Railways (2008, p2) and Railway Gazette International (RGI, 2009, p2). High Speed Rail requires dedicated track, special trains, and in-cab signalling as per the Tokaido Shinkansen and the French TGV. These trains commenced commercial operations in 1964 and 1981 respectively with good results (The Economist, 1998). By 2001, Spain, Italy, Germany, and Belgium also had HSR.

By December 2009, a total of 12 countries had HSR trains (RGI, 2009, p2); the 6 further countries since 2001 being Britain, Korea, Taiwan, China, Turkey and Russia. Of these 12 countries, 8 had HSR trains that did not exceed 300 km/h.

High Speed Rail is now under close examination in the United States and has been the subject of ongoing government supported HSR studies in Canada on two corridors. In early 2010, and again in July 2011, proposals were made by government to extend HSR in Britain.

In June 1984, CSIRO (Wild et al., 1984) outlined the concept of a Very Fast Train (VFT) linking Sydney, Canberra and Melbourne via Gippsland. It included a then ambitious Sydney Melbourne transit time of three hours using French technology. The proposal was developed by the private sector (a VFT consortium), and later augmented to include an inland option through Albury (Black, 1989). After a somewhat negative approach by government to the concept of a VFT concerning key questions, concessions relating to taxation and land development, the proposal lapsed in 1991. Various VFT publications (including VFT, 1989) gave consideration to energy use.

By 1994, a Speedrail Consortium including Alstom and Leightons had been formed to promote a Sydney-Canberra high speed rail proposal. In 1998, following an invitation by the Australian, NSW and ACT governments that led to four detailed proposals (an electric tilt train, a diesel-electric tilt train, Speedrail and a Maglev), Speedrail was invited to prepare and submit a full proposal that would be at "no net cost to the tax payer." This bid was made on a commercial in confidence basis. The amount of information in the public domain about the Speedrail proposal is quite limited but does include Budd (1996), Aerospace Publications Pty Ltd (1997) and two presentations (King, 2000 and Quantm, 2003).

In December 2000, the Federal government announced that it would not proceed further with the Speedrail proposal, and commissioned an East Coast Very High Speed Train (VHST) Scoping Study (Department of Transport and Regional Services, 2001). Further information is given by Cortis-Jones (2004) and a 2010 HSR strategic information report (von der Heidt et al., 2010) prepared for the CRC for Rail Innovation as part of Project R1.109. The CRC report concluded that an in-depth concept study of High Speed Rail in Australia was warranted and that even if HSR doesn't go ahead in the immediate future, there should be a move towards corridor preservation to reserve future options.

In August 2010, the Australian Government announced that it would proceed to a two phase study of HSR options for Australia. A Phase one report was released in August 2011. In September 2010, HSR reports were released by Infrastructure Partnerships Australia (2010) and the Bureau of Infrastructure, Transport and Regional Economics (BITRE - 2010a).

This paper draws on a CRC for Rail Innovation project R1.114 (Laird, 2010) that is complementary to the above CRC R1.109 project. Section 2 of this paper is concerned with energy use by aviation and potential HSR options between Melbourne, Canberra, Sydney, Newcastle and Brisbane. Section 3 examines questions about external costs, whilst Section 4 looks at some issues affecting Sydney airport. The conclusions follow in Section 5.

2. Energy use and emissions

This section will examine energy use by HSR and competing modes of transport. A recent reference on HSR energy use is that of Smith (2010). It is of note that this topic proved controversial during 1990 in the assessment by government of the former Sydney Canberra Melbourne VFT proposal. Here, estimates of likely energy use of a VFT, planes and cars between Sydney and Melbourne were then contested before a Very Fast Train Review Panel (1990) by a Society for Socially Responsibility in Engineering (SSRE).

The VFT Consortium then responded to SSRE estimates disputing assumptions leading to high energy use (including low seat occupancy and power station efficiency), and produced data including aggregate energy use for Sydney-Melbourne travel with all modes; with or without a VFT. This was also contested by SSRE and an independent assessment (by the Greenhouse Unit of the Victorian Department of Conservation and Environment) was sought by the Review Panel. The VFT Review Panel (1990, 76) cited overseas data including that of Suda (1985) along with Wayston and Bowlby (1989) and concluded that resolution of the greenhouse (and energy) issue could only advance if agreement was reached on factors including occupancy rates, secondary energy efficiency, conversion factors and increased traffic; also attention was needed to emissions during both the construction and maintenance phases. The Senate Standing Committee on Transport, Communications and Infrastructure Committee (1991) also examined both energy use and carbon dioxide emissions from the VFT and other transport modes.

High speed trains invariably use electricity. Conventional trains now mostly use either electricity or diesel. Larger passenger planes use aviation turbine fuel whilst cars mostly use petrol. Each of these liquid fuels has a different energy content (at a given temperature) for which the standard unit of measurement is a Mega Joule (or MJ) of end use energy. Taking into account the energy used to produce the fuel (extraction, refining and transport) as well as the fuels energy content gives Full Fuel Cycle (FFC) or primary energy.

Average energy intensity of many freight and transport operations has been given by the Apelbaum Consulting Group and in recent years, this data has been published by the Australasian Railway Association or ARA. This includes ARA (2007, 2009) which suggests a conversion factor of 38.6 MJ end use energy for a combustion of a litre of diesel which equates to 41.58 MJ (FFC).

For electrical energy conversion factors from coal fire power stations or other sources, there is a significant difference between end use energy and FFC factors. For end use energy, one kilo Watt hour (kWh) is 3.6MJ whilst the FFC factor and hence emissions depends on factors including the quality of the coal (poor in Victoria), and the extent, if any, of the use of natural gas, hydro, nuclear, solar and/or wind to generate power.

Carbon dioxide equivalent emissions per kilowatt hour for NSW and Victoria are given by the Department of Climate Change and Energy Efficiency (2011) as respectively 1.07 kg and 1.37 kg. On an allocation of Sydney Melbourne HSR using say 67.5 per cent of its power requirements in NSW and 32.5 per cent in Victoria the overall emissions factor is 1.17 kg CO2-e per kWh. On this basis, Sydney Melbourne HSR electricity use of 1 kWh equates to 10.98 MJ FFC of energy.

2.1 Aviation fuel use

Australian aggregate data for energy use in moving passengers by plane is conflicting with at least two different sources. These include data (ARA, 2009) for aviation turbine fuel, at 36.8 MJ per litre content and a FFC factor of 1.131, an energy intensity of 2.38 MJ (FFC) per passenger km (pkm). This allows for a calculation of 5.72 litres of aviation turbine fuel per 100 pkm. However, Qantas (2008) has claimed aviation fuel use at 3.5 litres per 100 pkm. which is 39 per cent lower than an average of 5.72 litres per 100 pkm.

The fuel use of 3.5 litres per 10 pkm is in accord with system wide data given in the Qantas 2008 Annual Report, and various assumptions. This includes an average mass of 90 kg per person (as used in BITRE statistics). In brief, a 2007-08 passenger task of 102.5 billion pkm (p146) equates to 9222 tonne kilometres. Moving passengers and freight used some 4849 million litres of aviation fuel, at a rate of 38.7 litres per Revenue Tonne Kilometre (RTKs – p148) giving 12,530m RTKs. Allocating fuel use to passengers by the proportion of RTKs (73.6 per cent) gives 28.7 pkm per litre, or an average 3.48 litres per 100pkm.

This average (which equates to an energy efficiency of about 0.69 pkm/MJ (FFC) is subject to many qualifications. Given equal load factors, and the extra fuel used in take-off and landing, one would expect international flights to use appreciably less fuel per 100 pkm than domestic flights.

One source of estimates for fuel use for various flight sectors is given by an International Civil Aviation Organisation (ICAO) Carbon Calculator. This calculator, and a background paper on the methodology used (including an allowance for freight load factors, seat occupancy, and prevailing types of aircraft used) with relevant conversion factors may be found at www.icao.int

TABLE 1: Aviation data in 2009 for various top routes in Eastern Australia

Sector	**Length GCD km**	CO_2 **emissions kg**	**Fuel use kg**	**Passenger Numbers million**	**Aggregate** CO_2 **000 tonnes**	**Fuel Use ML**
SYD-MEL	705	89.13	28.2	7.09	632	250
SYD-CBR	251	46.07	14.6	1.02	47	19
CBR-MEL	452	67.79	21.5	1.05	71	28
SYD-WGA	367	53.19	16.8	0.18	9	4
SYD-ABX	452	61.9	19.6	0.24	15	6
Subtotal				**9.57**	**774**	**306**
SYD-BNE	740	94.01	29.8	4.30	404	160
SYD-OOL	678	88.04	27.9	2.15	189	75
SYD-CFS	441	64.68	20.5	0.30	19	8
BNE-NTL	603	81.62	25.9	0.56	46	18
NTL-OOL	539	72.87	23.1	0.14	10	4
Subtotal				**7.45**	**669**	**265**
CBR -BNE	959	116.42	36.9	0.61	71	28
BNE- MEL	1370	150.3	47.6	2.71	407	161
Subtotal				**3.32**	**478**	**189**
Total				**20.34**	**1921**	**760**

Reference: Length (GCD = great circle distance), CO2 emissions and fuel use are from data given by the ICAO Carbon Calculator, for a one way flight in economy. Passenger numbers are for 2009 are from BITRE (2010). Conversion of weight of aviation fuel to volume assumes a density of 0.8 kg/litre and the combustion of 1kg of aviation fuel releases 3.157 kg of CO2. Airport codes include ABX for Albury, CFS for Coffs Harbour, NTL for Newcastle, OOL for Coolangatta, and WGA for Wagga Wagga.

Table 1 gives distances and passenger numbers for 12 origin-destination 'top routes' for the Sydney-Melbourne corridor, the Sydney-Brisbane corridor, and two longer routes (Melbourne-Brisbane and Canberra-Brisbane). This table also gives estimates of average CO_2 emissions per passenger for one flight, fuel use per passenger, passenger numbers in 2009, and for that year aggregate emissions and fuel use for each route.

It can be seen from the data in Table 1 that during 2009, regular domestic passenger services on the 12 top routes between Melbourne, Canberra, Sydney and Brisbane, and intermediate points, conveyed over 20 million passengers. This passenger task used an estimated 760 million litres of aviation fuel. In addition, aggregate emissions for these services was about 1.92 million tonnes of carbon dioxide.

2.2 JR Central energy and emissions data

The Central Japan Railway Company (JR Central, 2005, 2008) publishes data on energy use and emissions that demonstrates increasing energy efficiency for its HSR operations. In summary, based on simulated test runs between Tokyo and Shin-Osaka with trains running at a maximum of 220 km/h, the N700 series of trains consumes just 51 per cent of the energy that the original series 100 trains did; also, for a maximum of 270 km/h, a Series N700 train uses 68 per cent of the energy that the Series 100 trains used.

This suggests that along with the new trains improving energy efficiency, the lifting the maximum speed of a Series N700 train from 220 km/h to 270 km/h uses 33 per cent more energy.

The various measures outlined in JR Central report to have improved energy efficiency include reducing tare mass and air resistance and the use of regenerative braking. For comparisons of train use with cars, buses and planes, the JR Central 2005 Environmental Report notes energy use data as given in Table 2.

From Table 2, it may be calculated that the energy efficiency of the Tokaido Shinkansen is then an impressive 2.86 passenger km per MJ (FFC). It is of note that this energy efficiency is higher than that of JR Central's conventional trains (2.35 pkm per MJ).

Table 2 also gives carbon dioxide emissions for various passenger transport modes. Note that with the use of more Series 700 trains and the introduction of the Series N700 trains, energy use and emissions per pass- km will have fallen despite the higher average speeds.

TABLE 2: Energy intensity and CO_2 emissions

	MJ (FFC) per pass km	CO_2 Emissions grams per pass. km
Trains (Railway)	0.425	18.3 (18)
Car (Automobile)	2.730	183 (172)
Plane (Airplane)	1.664	112 (111)
Coach (Bus)	0.804	55 (51)
Tokaido Shinkansen	0.349	14

Reference: JR Central (2005, p15) citing Ministry of Infrastructure, Land and Transport (MILT) data (with 2008 Environmental Report on page 15 citing MILT data in brackets).

JR Central published data on energy use and emissions, which is appreciably more than that of some other sources, and despite some minor discrepancies, demonstrates high energy efficiency for its HSR operations. In addition, the main claim (JR Central, 2008 p 4) that “the Tokaido Shinkansen has overwhelming environmental superiority” is a substantial one. This is supported by noting that a Series 700 train between Tokyo an Osaka emits about one tenth of an airplane (B777-200) with the respective emissions being 5.1 and 51 kg of CO_2 per seat.

JR Central (2008) also notes that each day there is an average of 58 plane trips made each day each way between the Tokyo and Osaka areas, and that if the trips by plane were to be replaced by Shinkansen, there would be a reduction of CO_2 emissions by about 511, 000 tonnes per annum. To put it another way, if all of the many people using the Tokaido Shinkansen were to transfer to air, there would be a large increase in emissions.

2.3 Simulation results for the Sydney Melbourne corridor

The East Coast VHST study (DOTARS, 2001) in outlining transit times for the various route and train options only gave limited attention in its report to energy questions. For the CRC for Rail Innovation project R1.114, simulation was undertaken by Mr Alex Wardrop to get a better appreciation of energy use by HSR in potential Australian contexts, and for this purpose, some more powerful trains were simulated. The results are indicative only and apply for a hypothetical route from Sydney’s Central station through Goulburn, Canberra Airport, Yass, Wagga Wagga, Broadmeadow, and Melbourne’s Southern Cross Station.

Five different standard train types were considered. These were: Hunter cars (code HVCT with 292 seats) that are modern outer suburban diesel multiple unit (DMU) trains with the potential to run up to 160 km/h, a DMU train (code ICT with 334 seats) that was offered in 1997 for the Sydney - Canberra service by Siemens, the X2000 train (code XNEC with 287 seats), as offered to Amtrak for the US Northeast and based on the Swedish 210 km/h X2000 train, the TGV-Réseau train (TGVR with 377 seats) or classic French HSR train with articulated passenger cars sandwiched between two power cars; and, a postulated uprated version for higher speeds (code TGVM also with 377 seats).

These five trains were simulated with respective maximum speeds of 160, 200, 250, 300 and 350 km/h to produce estimates of transit times and energy use. Note that the first two trains use diesel and the faster three are electric trains. The respective FFC energy efficiencies for each train, were found from the simulations and the conversion factors above to be 2.97, 2.11, 1.28, 1.34 and 1.15 passenger km per MegaJoule (pkm/MJ).

The simulation demonstrates that in general, a higher maximum speed comes at the expense of less energy efficiency (the one exception being the X2000 (NEC) train that has the least number of seats). Note that the energy efficiency of the fastest train at 1.15 pkm per MJ (FFC) compares favourably with aviation energy efficiency of 0.69 pkm per MJ (FFC) for domestic aviation derived from Qantas data and very favourably with the ACG estimate of 0.42 pkm per MJ (FFC).

2.4 Potential reduction of aviation fuel use from HSR

As noted above, Australian data for energy use in moving passengers by plane is conflicting. We shall use data from the ICAO Carbon Calculator which gives an intermediate fuel use between that suggested (ARA, 2009) of 5.72 litres of aviation turbine fuel per 100 pkm, and Qantas (2008) noting 3.5 litres per 100 pkm.

In 2009, there were 7.09 million journeys by regular scheduled air services between Sydney and Melbourne. If HSR was now operational (at speeds up to 350 km/h) and as per von der Heidt et al (2010), HSR could attract 50 per cent of air traffic (citing Hall (2009) re European experience) on this corrridor. Based on this traffic and assumption and from the data in Table 1, the reduction of use of aviation turbine fuel would be 125 million litres.

The data in Table 1 also suggests that if HSR served Canberra, and if HSR took 90 per cent of Sydney-Canberra (a relatively short length corridor-see Hall (2009)) and 70 per cent of Melbourne-Canberra 2009 air traffic volumes, fuel use would fall by a further 36 million litres per annum. To this may be added other traffic such as Sydney-Wagga Wagga and Sydney-Albury. The total reduction in aviation fuel use on the Sydney Melbourne corridor, on 2009 data as above, is then estimated to be at least 175 million litres per annum.

For Sydney-Brisbane with its 4.3 million journeys in 2009 by regular scheduled air services, if HSR was operating and took 50 per cent of mode share, there would be an annual saving in aviation turbine fuel of 80 million litres. If we also assume that HSR would attract a 50 per cent mode share on the other four top routes on this corridor, fuel use would fall by an additional 52 million litres per year.

Under these assumptions, the diversion of about 11 million passengers from regular domestic air services on the 10 top routes between Sydney and Melbourne, and, between Sydney and Brisbane, there would be a total reduction of use of aviation fuel by 307 million litres per year on 2009 passenger numbers.

From a Sydney Airport (2009, p49) Master Plan (SAMP) an average growth rate of 3.9 per cent per annum is projected from 2007 to the year 2029 for domestic passengers. At a 3.9 per cent per annum compound growth rate, domestic passenger numbers through Sydney Airport would increase from 2009 to 2020 by a factor of 1.523, and to 2030 by a factor of 2.233. Although energy efficiency of aircraft is expected to increase over the next two decades, this could to some extent be offset by increased congestion at airports.

Assuming these growth factors, and diversion as above of some passengers from aviation to HSR as above, there could be a total reduction of use of aviation fuel by 468 million litres per annum by 2020 and 685 million litres per annum by 2030.

Further research is needed to estimate the likely reductions from either the many shorter flights on this corridor, or the longer flights of Melbourne - Brisbane and Canberra - Brisbane, being diverted to HSR.

A further factor in calculating the potential of HSR to reduce aviation fuel use is the ability of HSR to carry high value freight in the way the domestic planes carry freight. The SAMP notes (p50) that 471,000 tonnes of air freight moved through Sydney in 2009.

The fuel savings likely transfer of intercity travel from journeys by car to any operational HSR is a further subject for examination. Here, it should be noted that the dominant method of transport between Sydney and Canberra is by car. The Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2006) has data including that in 2003-04 about 4.59m Sydney-Canberra intercity passenger movements by car (as against 0.43m by air, 0.21m by bus and only 42,000 by rail). BITRE (2006) also gives data for journeys for intercity travel with projections out to 2030.

The BITRE (2006) projections are based on past trends (to 2003-04). These projections would no longer apply in an environment where international oil prices trend upwards.

Oil vulnerability is a topic that has received attention by the Senate Rural and Regional Affairs and Transport References Committee (2007) and the Garnaut Climate Change review. Further information on oil vulnerability in an international context and how this may be addressed is given by Gilbert and Perl (2010).

In an Australian context, Garnaut (2008, Chapter 21 'Transforming transport') noted, inter alia, that "Governments have a major role in lowering the economic costs of adjustment to higher oil prices, an emissions price and population growth, through planning for more compact urban forms and rail and urban public transport. Mode shift may account for a quarter of emissions reductions in urban public transport, lowering the cost of transition and delivering multiple benefits to the community."

Garnaut (2008) also noted that "Now may be a good time for [Government…] to examine why intercity passenger train services in Australia are inferior to those in European and high-income Asian countries, with a view to removing barriers to the emergence of high-quality inter-regional rail services in Australia."

2.5 Potential reduction of emissions from HSR operations

As noted in Table 1, the average emissions (from the ICAO carbon calculator) for a one way flight between Sydney and Melbourne are about 89 kg per passenger. If a longer HSR route, similar in length to that of the 960 km existing track (with its excessive length and curvature) was used for a Sydney Melbourne journey with the fastest TGV type train carbon emissions approaching this amount could result. The resulting lack of reduction of carbon emissions, in this least favourable scenario, in part reflects the fact that the train would be using electricity produced mainly by coal fired power stations.

However, if one assumes use of a shorter 820 km HSR route between Sydney and Melbourne (identified in the late 1980s as part of the VFT investigations, see Compton, 2010) and the Shinkansen emission factors noted in Table 2 of 14.7 grams of CO_2 per passenger kilometre (pkm), then the CO_2 emissions for one Sydney Melbourne passenger would amount to about 12 kg. Factors relevant to the large difference, apart from the route length, include that the French TGV having a tare mass of 1.11 tonnes per seat which is about twice as much for a Series 700 Shinkansen and the TGV having just 377 seats as opposed to over 1000 seats in a Shinkansen.

The use of International Union of Railways (2008) data of 4 kilograms of CO_2 emissions per 100 pkm for HSR over 820 km would indicate 32.8 kg of CO_2 emissions for a Sydney Melbourne journey by HSR. This UIC data also notes that planes emit 17 kilograms of CO_2 emissions per 100 pkm, which then suggests emissions of 136 kg as opposed to the 89.13 kg advised by the ICAO carbon calculator.

For travel between Sydney and Melbourne, if we assume travel by one person by HSR produces the intermediate amount of 32.8 kg of CO_2 and the ICAO estimate of 89.13 kg by air (both mid range estimates) there is a reduction of 53.33 kg of CO_2. For the 7.09 million passengers by plane in 2009, if HSR had been operational and taken 50 per cent of mode share, then there would be a net reduction of about 186,700 tonnes of CO_2 per annum.

From this, and considering aviation turbine fuel use data in Table 1, it appears that an operational HSR between Melbourne, Canberra, Sydney and Brisbane could result, on 2009 traffic levels, in a net reduction of carbon dioxide levels of at least 400,000 tonnes per annum.

Clearly, the quantification of the potential reduction of emissions (including from road congestion impacts near airports and where HSR could replace intercity road journeys) from HSR is an area where more research is warranted.

By way of comparison with HSR potential to reduce aviation fuel use by 307 million litres and CO2 emissions by 400,000 tonnes per annum, on 2009 traffic data, the upgrading of the Sydney-Melbourne-Brisbane existing track to FFT standards with rail winning 50 per cent of intercapital intermodal freight by 2014 was estimated (Laird, 2007) to save 134 million litres of diesel per annum and reduce net CO2 emissions by over 340,000 tonnes per annum.

3. External costs

The East Coast VHST study (DOTARS, 2001, Section 14, Evaluation) found that although public benefits (including airport and road decongestion, accident costs, noise and local air pollution costs) were small in comparison with user benefits and fare revenue, for each of the two major corridors, on a 'central evaluation' case with a 7 per cent discount rate, the total benefits exceeded the total costs. In this analysis, it was found that a Sydney-Brisbane VHST "produces greater economic benefit" than a Sydney-Melbourne VHST, also, (s14, p25) a "significant incremental impact ... forecast for constructing the complete Brisbane-Melbourne corridor" (with a NPV of $26 billion).

With the growing land freight task and projections for future growth, accounting for external land transport costs have been of increasing interest to government. Related reports include those of Austroads (2003), BTRE (2005), Evans (2006) and the Australian Transport Council (2006) gives various default values for various land freight and passenger tasks.

External costs for road vehicle use by passengers in Australia are outlined by Austroads (2008). Along with updated vehicle operating costs, the report includes sections on crashes and safety, environmental and other externalities.

Six external costs of road and rail freight operations in both metro and non-urban areas were identified in a major Track Audit prepared for the Australian Rail Track Corporation (ARTC-2001). These external costs are accidents, air pollution, noise pollution, greenhouse gas emissions, congestion, and incremental road damage. The ATRC Track Audit estimates were updated by this writer (Laird, 2005).

3.1 Aviation external costs

Aviation, like other modes of transport, gives rise to external costs. For aviation, these include aircraft noise, accidents, air pollution and climate change. Large airports such as Sydney act as significant road traffic generators, thus giving rise to further external costs.

In Australia, apart from accidents, there has been little qualitative information provided about estimated external costs of aviation. The cost of aviation accidents is covered in various ATSB reports whilst the question of cost recovery from providing airports and air navigation services was addressed by BTCE (1983, part 5).

The Henry Tax Review (2010, p338) also comments on recovering the costs of the Civil Aviation Safety Authority via an aviation fuel excise of $0.02854 per litre. Some submissions to this review, noting an excise rate of 38.143 cents per litre for petrol, considered that, "because aviation fuel is lightly taxed, air transport receives a subsidy from the tax system.

Some suggest that this is environmentally damaging because aviation is more energy intensive than other forms of transport."

Comment touching on aviation externalities in Australia is given in papers by Nero and Black (2000) re Sydney airport, May (2006) and May and Hill (2006) re Canberra airport. May and Hill (2006) also address aircraft noise. As noted by the Victoria Transport Policy Institute (2010): "Researchers May and Hill argue that the unchecked growth of aviation, as generally assumed by the aviation and tourism industries, and by governments, has significant risks, because aviation is a major source of global warming emissions, imposes local environmental impacts such as noise and air pollution, and the aviation industry is vulnerable to increasing fuel prices."

Although reducing carbon emissions, and minimising the impact of aircraft noise is covered in the 2009 Aviation White Paper “Flight Path to the Future” (respectively Chapters 13 and 14), the external costs of aviation are not mentioned at all.

The importance of the aircraft noise issue near major airports in Australia is highlighted by ongoing complaints leading to the Senate Standing Committee on Rural and Regional Affairs and Transport (2010) holding an Inquiry into aircraft noise. This was accompanied by a decision by the Australian government to appoint an Aircraft Noise Ombudsman. The Committee's report included ten recommendations that received a government response in February 2011.

3.2 Potential reduction of external costs from HSR

It is recognised that HSR can give rise to external costs, including noise. External costs for HSR may differ from those noted above for conventional passenger rail services. As noted by Nash (2009), in a study on HSR, there is scope for inclusion of specific noise external costs for each aircraft take-off. In the absence of any published estimates of external costs for aviation and HSR in Australia, it is proposed to use, for indicative purposes, European based estimates. These follow in Table 3.

On using the above 7.5 cents per passenger kilometre for a Sydney-Melbourne one way flight with a great circle distance of 705km plus the ICAO factor of 100km gives an estimate of external costs amounting to $60.37. For rail, using the existing railway (about 960km), the estimated external cost is $31.68, using a short 820km HSR route, it would be $27.06. For an HSR route of intermediate length of 898km (DOTARS, 2001, Annexure 2), the rail external costs would be $29.63.

TABLE 3: Average unit external costs

	Euros per 1000pkm	Aust. Cents per pkm
Private car	76	10.9
Bus	37.7	5.4
Rail	22.9	3.3
Plane	52.5	7.5

Reference: International Union of Railways (2009, p9) with pkm denoting passenger kilometre and an assumed exchange rate of $A1 = 0.7 Euros. External costs comprise accidents, air pollution, nature and landscape, urban effects and climate change.

Accordingly, on the 2009 traffic level of 7.09 million plane journeys between Sydney and Melbourne and diversion of 50 per cent of this traffic to HSR (898 km) there would be a reduction of external costs of about $109 million. Using the data in Table 1 with the accompanying assumptions for aviation, plus approximate rail distances of HSR rail link by Canberra, Wagga Wagga and Albury being respectively 270, 475 and 595 km from Sydney (DOTARS 2001, Ann. 2) the total reduction of external costs on the five Sydney-Melbourne corridor 'Top Routes' on 2009 data would be $138 million.

For the Sydney-Brisbane corridor, using again Table 1 and associated assumptions of HSR use, plus rail distances from Sydney to Coffs Harbour, Coolangatta and Brisbane being respectively 460, 745 and 845km and Newcastle-Brisbane at 575km, the estimated reduction in external costs would be $118 million.

For both corridors, the diversion of passengers from regular domestic air services on the 10 top routes between Sydney and Melbourne and between Sydney and Brisbane to HSR could lead to a total reduction of external costs of $256 million on 2009 passenger numbers. The reduction of external costs from road congestion impacts near airports and where HSR could replace intercity road journeys is a further topic for research.

By way of comparison with HSR, the upgrading of the Sydney-Melbourne-Brisbane existing track to FFT standards with rail winning 50 per cent of intercapital intermodal freight by 2014 (then expected to be 15 million tonnes per annum) was estimated (Laird, 2007) could lead to a reduction of external costs of $274 million that year.

By 2020, assuming aviation traffic growth at 3.9 per cent per annum and an average inflation rate of 3 per cent per annum, the potential reduction of external costs from diversion from planes to HSR for the 10 top routes on each of the Sydney-Melbourne and Brisbane corridors would be $540m per annum.

4. SYDNEY AIRPORT ISSUES

Sydney Airport is Australia's busiest airport, and in 2008-09 (BITRE, 2009) had 32.3 million passengers (20.1m domestic, 1.9m regional and 10.3m international). This is a more than three fold growth from the 9.5 million passengers in 1985-86. An airport passenger may be regarded as a person who arrives at or departs from an airport, or one who transfers through an airport in a given day.

By 2009, Sydney was the world's 28th busiest airport on passenger numbers. Sydney's main airport is subject to both a curfew (from 11:00 pm to 6:00 am restricting takeoffs and landings) and a "maximum movement limit" or "cap" of no more than 80 air craft scheduled movements per hour (with 'slot' management and compliance schemes). As noted by Sydney Airport (2009, section 14.2) guaranteed access for regional services is required, and noise is clearly an issue requiring runway modes of operation for noise sharing and respite. Noise near Sydney airport has long been an issue, leading to much effort over many years in locating a potential second Sydney Airport site, and much controversy in building a third runway at Mascot. A noise levy also applied for some years. Thus, the curfew and the cap are likely to stay in place for some years.

Sydney Airport (2009) notes that the current owners have first right of refusal of any new airport site within 100 km of Sydney, also military bases Williamtown and Nowra are each about 120 km from the Sydney CBD, with Canberra Airport some 290km away.

The Sydney Airport (2009) Master Plan briefly addresses future projections to 2029. These include an average annual growth rate of 2.9 per cent for all passengers from the year 2000 (25.3m) to 2007 (31.9m), and assuming an annual growth rate of 4.2 per cent (international 4.8 per cent, domestic 3.9 per cent), 78.9m passenger movements are projected for Sydney Airport in 2029 (the end of the planning period). This assumes both a decline in general aviation traffic and 'a progressive upscaling in aircraft size across the fleet' (citing a standard airbus A380 with 525 seats).

The 2009 National Aviation Policy White Paper (DITRDLG, 2009) outlines "growth" both past and projected and passenger movement through Australia's 10 busiest airports for 2008-09 are noted, including Sydney (32.4m), Melbourne (24.4m), Brisbane (18.7m), Gold Coast (4.6m) and Canberra (3.1m and the eighth busiest). The White Paper (chapter 12) outlines future aviation needs for the Sydney region.

In noting approval for the Sydney Airport 2009 Master Plan, the Australian Government (DITRDLG, 2009) did not accept that this airport "can, nor should, handle proposed long-term growth for the region." By way of contrast, the Sydney Airport Master Plan takes a contrary view, and suggests it could handle 89m passenger movements by 2028-29).

Part of the cost of operating Sydney Airport includes ongoing improvement in road capacity. Despite the completion of the M5 East in 2001, and the upgrading of roads serving Sydney airport, road congestion near the airport continues to be an issue.

The NSW government (2010) and its Roads and Traffic Authority has identified an option for a major F5 upgrade for reasons including the growth of Sydney Airport. As noted by the Sydney Airport is supportive of this upgrade which will include widening of the M5 South-West Motorway and the duplication of the M5 East tunnels. The cost has been noted as about $4.5 billion.

As noted in the 2009 Aviation White Paper (DITRDLG, 2009, Chapter 12), the Australian Government is working with the NSW Government to develop an aviation strategic plan for the Sydney region. A media release (Albanese, 2010) notes, in part that "The Aviation Strategic Plan for the Sydney Region will identify potential sites for a second Sydney airport, the additional road and rail infrastructure that will be required and investment strategies that will deliver this additional capacity."

This Sydney aviation strategic plan was initially expected to be finalised in mid 2011. The Minister's media release also notes that "Without action, Sydney's existing aviation infrastructure will struggle to cope with the continuing growth in passenger numbers which is predicted to more than double to 72.9 million by 2029-30."

4.1 Airport Slots

In airports with relatively few aircraft movements, runway access for take-off or landing can be allocated on a "first come, first served" basis. This procedure can be used as plane movements increase, but may require queuing which imposes additional costs.

Larger airports with potential excess demand for runway access often use a "slot" system where a slot is "most commonly known as a landing or take-off right at airports during a specified period of time" (Czerny et al., 2008, p41). Airports are generally operated under legislation and under guidelines issued by the International Air Transport Association (IATA – a "trade association of international airlines" (Czerny et al., 2008, p1)).

Sydney is noted by Gillen and Morrison (Czerny et al., 2008, p182) as “the only slot controlled airport in Australia” with a government control of 80 movements per hour.

The movement in 2009 of some 7.09 million passengers between Sydney and Melbourne required some 45,000 airport trips (BITRE 2010b). This is an average of about 123 plane trips per day.

If HSR was in place and attracting 50 per cent of Sydney-Melbourne plane journeys, then on 2009 traffic it would allow for the release of about 61 airport slots per day (with more during busy weekdays).

Other potential Sydney Airport slots that could be released by operational HSR include Sydney-Canberra (18,550 aircraft trips in 2009, with 90 per cent to HSR, then 48 slots released per day), Sydney-Brisbane (28,560 aircraft trips, say 50 per cent to HSR releasing 39 slots per day), plus Sydney Gold Coast (14,500 aircraft trips, with 50 per cent HSR releasing 20 slots per day).

The operation of HSR on these four major intercity routes would release an average of 168 slots per day at Sydney Airport. There would also be the release of further slots in journeys between Sydney and each of Wagga Wagga and Albury to the south and Port Macquarie, Taree, Coffs Harbour, Grafton and Ballina to the north. For flights between Sydney and each of Wagga Wagga and Albury, the BITRE data indicated a total of 12,645 aircraft trips a year; with 50 per cent released from HSR operations, this would release an average of 17 slots per day. From a count of flights for seats offered for sale on 5 May 2010 between each of Sydney and Port Macquarie, Taree, Coffs Harbour, Grafton and Ballina, there are a total of 26 flights. Again, if HSR was to gain 50 per cent of this traffic, there would be release of a further 13 slots.

In summary, on 2009 data, if HSR had been operational between Sydney and Melbourne, between Sydney and Brisbane, and between Sydney and intermediate points on each corridor, and attracting at least 50 per cent of aviation passenger numbers as indicated above, then 198 slots would have been released at Sydney Airport.

5. Conclusions

Steel wheel on steel rail High Speed Rail (HSR) has developed to a mature technology, now operational in twelve countries around the world. A well designed and operational HSR operating on the East Coast of Australia would reduce demand for both aviation fuel and airport slots at Sydney.

The reduction of aviation fuel use, based on 2009 levels of air travel, including 7.09 million passengers between Sydney and Melbourne, plus other air travel on this corridor, was found under various assumptions (including HSR taking 50 per cent of plane passengers between Sydney and Melbourne) to be about 175 million litres per annum.

On the Sydney-Newcastle-Gold Coast-Brisbane corridor, possible reduction of aviation fuel use due to an effective HSR is estimated on 2009 traffic at some 132 million litres a year.

By 2020, under various assumptions, including a projected average annual growth rate of 3.9 per cent for domestic passengers through Sydney airport, diversion of passengers from regular domestic air services between Sydney and Melbourne an between Sydney and Brisbane to HSR could lead to a total reduction of use of aviation fuel of 468 million litres per annum by 2020.

The actual electrical energy use by HSR depends critically upon the route chosen, the type of train used, the stopping patterns and operating speeds. For net energy savings, there is a trade off between higher speeds generating a larger HSR modal share and the train using more energy (with decreasing energy savings per passenger switching from air to HSR off set by more passengers). In this regard, selection of a shorter Sydney-Canberra -Melbourne route (e.g. 820km) as against a longer one (e.g. 960km) could allow for a maximum speed of 300km/h as against 350km/h for a journey time of less than 4 hours.

The potential reduction in carbon dioxide emissions depends not only on the HSR energy use factors including the track constructed and the trains used but also the source of power. Here, the estimates of emissions vary much more than possible reductions in the use of aviation turbine fuel. It was found that an operational HSR between Melbourne, Canberra, Sydney and Brisbane could result, on 2009 traffic levels, in a net reduction of carbon dioxide levels of at least 0.4 million tonnes per annum.

Based on UIC estimates of external costs in Europe, the diversion of passengers from regular domestic air services on the 10 top routes between Sydney and Melbourne and between Sydney and Brisbane to HSR could lead to a total reduction of external costs of $256 million on 2009 passenger numbers.

By 2020, assuming aviation traffic growth at 3.9 per cent per annum and an average inflation rate of 3 per cent per annum, the potential reduction of external costs from diversion from planes to HSR for the 10 top routes on each of the Sydney-Melbourne and Sydney-Brisbane corridors would be $540m per annum.

If HSR was operational between Melbourne, Canberra, Sydney, Newcastle, the North Coast of NSW, the Gold Coast and Brisbane there would be some 198 slots released at Sydney Airport on 2009 traffic levels.

The paper identifies numerous areas for further research. These include the potential liquid fuel savings from diversion of planes on minor routes to HSR and the liquid fuel savings from diversion of cars and buses to HSR travel, including on the important Sydney-Canberra and Sydney Newcastle corridors. Next, there is the question of reduction in carbon dioxide emissions, and the area of external costs, and particularly that of aviation operations in Australia. Future studies could usefully look at the costs and benefits of HSR under a range of future oil prices.

The relevance of such research is highlighted by the fact that the question of emissions can become a controversial area. This was the case with the VFT when the question of the amount of emissions was reviewed by a Senate Committee in 1990 and more recently in the United Kingdom.

Acknowledgements

The author would like to thank the School of Mathematics and Applied Statistics of the University of Wollongong (UOW) and is grateful to the CRC for Rail Innovation (established and supported under the Australian Government's Cooperative Research Centres program) for the funding of this research under Project No. R1.114 *High Speed Rail - Quantification of Non Commercial* Benefits.

He is also grateful the CRC Project Steering Committee chaired by Mr Phil Sochon of the ARA, along with Ms Sarah Schachtel of UOW for research assistance, Mr Alex Wardrop for computer simulation and for three ATRF referees for helpful suggestions. However, the responsibility for the findings and views expressed in this remains with the author.

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