Transport Infrastructure Noise: Beyond 2050

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ABSTRACT

Noise from transport infrastructure - roads, railways and airports - is usually required to be assessed as a part of the broader environmental assessment of major transport infrastructure developments. Acoustic engineers routinely make noise predictions for likely future operational scenarios of the road, railway or airport - usually 10 or more years after the proposed project opening date, which may be 12–15 years after the date of the study itself, depending on the required construction period. The key parameters driving the assessment of the future scenario are the source noise levels of the vehicles, and the vehicle flow rates. The former is usually estimated based on existing noise levels, with some (small) allowance for technological improvements. The future vehicle flow rates are usually provided to the Acoustic engineer by a Transport or Traffic Engineer, and are based on extrapolations of previously measured flow increases mixed with estimates of patronage demand. In the past, this seems to have resulted in a reasonable assessment of noise from transport infrastructure projects. However, within the next 10–20 years, there are likely to be several major 'shocks' - the primary one being oil depletion (also known as 'peak oil'), which could seriously challenge the key assumptions underlying many of the noise assessments currently being undertaken and invalidate the results. This study broadly investigates the potential impacts of technological, political and energy supply changes on noise assessments for large transport infrastructure projects. These changes are likely to result in further shifts to rail-based transportation of freight and passengers, and a softening in demand for air-travel.

INTRODUCTION

Noise impact assessments are commonly required as a part of the regulatory approval process for major transport infrastructure projects such as highways and railways. Airports are also required by the Airports Act to prepare masterplan documents outlining, amongst other things, the likely noise impact of the airport. These noise impact assessments are usually prepared by acoustic engineers who create a computer noise model of the study area to predict the noise levels from the road traffic, railway of aircraft flyovers for a range of existing and future usage scenarios.

These scenarios typically consider a 'future existing' situation and compare it with one 10-years (or more) after opening of the planned infrastructure. The 'future existing' scenario is sometimes referred to as the 'do nothing' case, and is representative of the existing infrastructure without the proposed development at some future time, and subject only to incremental increases in traffic flows. The 10-years after opening scenario is commonly used as a reasonable basis for designing and selecting noise control – since it would reasonably be considered short-sighted if the infrastructure is only designed to accommodate its day-of-opening capacity. (Nevertheless, demonstrating compliance with a 10-years after opening is difficult, in practice, and some agencies have considered adopting a 'day of opening' compliance limit, albeit with a lower initial noise level target - technically this could result in the same overall noise outcomes.)

The computer noise models created by consultants and engineers rely on many input parameters including the location of the alignment (ie where the noise source is), the source sound power levels of the source (how loud it is), the ground topography and the location of the receivers relative to the source (how much propagation loss will occur). The road or rail alignment, or aircraft flight-paths, ground topography and cadastre are usually provided as 3-dimensional CAD or GIS files by the transport agency or the design engineers. The sound power source level of individual vehicles is determined by the acoustic engineer, often based on validation measurements for the particular transport source.

The final key modelling input then, is the traffic flow rates related to each of the modelled scenarios - including predictions for the future state. This defines the overall source sound power for each source line. Future traffic flow rates are calculated by a traffic or transport engineer, based on current traffic flows scaled by a compounding per-annum percentage increase (itself based on analysis of actual increases measured over previous years) coupled with complex demand analysis which might consider population locations, transport user behaviours and preferences, and extrapolation of current trends.

Usually, the traffic flow rate is required to be defined for individual hours (to enable day and night-time noise level calculations), and may require splits between different traffic types (for example cars and heavy-goods-vehicles, or propeller or jet aircraft movements). However, the particular geometric and traffic engineering required to design the project infrastructure often only requires the peak traffic flow rates to be known – since peak flows define the required infrastructure capacity. Surprisingly then, it often falls to the *acoustic* engineer to be responsible for determining the detailed hourly traffic flow rates which feed into the noise predictions for each of the scenarios. (In some respects, this is not as problematic as it might appear, since even significant inaccuracies in the assumed traffic flow rates, say errors of 10–20%, do not result in large errors in predicted noise level, or at least, an error that is less significant than that introduced by other assumptions).

Thus the source sound power level that is used to predict noise for the future state in the acoustic assessment is based on an individual source sound power level and assumed vehicle flow rates that are both substantially based on historical information.

In the past, this has proved to provide a reasonably reliable way upon which to base transport infrastructure noise assessments. However, within the next 10–20 years, there are likely to be several shocks which will mean that the basic assumptions underlying the future noise predictions will be challenged, and simple extrapolation based on incremental increases in flows and other changes will no longer hold true.

The primary change is likely to be related to the joint challenges of oil-depletion (commonly known as 'peak oil') and climate change (particularly carbon emissions trading) and the associated technological changes necessary across our transport infrastructure to account for reduced availability and increasing cost of fuel.

This paper examines the *potential* changes that are likely to occur in Australia's transport infrastructure in the period between now and 2050, and in particular, how those changes will influence the noise emission from the road, rail and aircraft transport sectors. This analysis is necessary, as it assists acoustic engineers to understand the potential limitations of noise models being used to predict noise for future scenarios.

Since the primary transport modes (road, rail and aviation) are all linked in a network, this analysis will begin by examining the likely network-wide changes, before examining each transport mode in more detail.

NETWORK WIDE TRENDS

Ongoing population and economic growth are fundamentally likely to result in increased travel demand across the transportation network. Coupled with this, technological improvements to communications systems (such as video-conferencing, which is often thought of as reducing travel demand) create a more nationally and globally connected population, further fuelling demand.

Transportation engineering analysis typically shows that demand is relatively insensitive to fuel cost (Litman, 2012). Nevertheless previous fuel price shocks such as the 1970's fuel crisis have resulted in substantially changed behaviour and modal shifts in transport use (where other alternatives exist).

Even during the recent economic turmoil – despite lower oil costs than mid 2008 – the American Public Transport Association (APTA) has documented a shift away from short-haul aircraft travel, and the highest public transport use in the US in 52 years (APTA, 2009). APTA suggests that there is a;

> Propensity to public ridership influenced by shorter distances, security procedures causing time delays at the airport, fare, gasoline price, frequency, and overall comfort.

They note that short-haul air travel, in particular, is ripe for substitution to alternative transport modes, because it is relatively expensive and takes a disproportionally long time; due to airlines 'routinely internalising' airspace and taxiway congestion by increasing overall schedule time. International air travel is, of course, somewhat more difficult to replace with other modes.

Public transport systems in Australia - particularly Melbourne - have also recently seen increased patronage (Webb and Gaymer, 2009, BITRE, 2012), albeit limited by significant peak-hour congestion due to a lack of capacity.

Therefore, in areas that are particularly well served by existing or major new public transport systems, such as the Regional Rail Link serving western Melbourne and the North West Rail Link serving north-western Sydney, there is likely to be a significant shift away from car transportation towards public transport.

Intra-national rail transport, in particular, has the potential to replace car, aircraft and freight and passenger transport between major Australian east-coast cities. However, in terms of the development of the infrastructure necessary to achieve this change, rail is at somewhat of a disadvantage compared to aviation. Constructing railways has a very large one-off cost for the development of the basic infrastructure, although additional capacity can then be added incrementally. Aircraft routes are by their nature, ultimately flexile, and only require sufficient capacity at the origin and destination airports. Additional aviation capacity can therefore generally be added at incremental cost (eg for new aircraft) at any time that demand dictates.

The Changes Will Take Time

Changes related to the transport system, particularly those that influence noise, do not generally occur rapidly, but occur over many decades. For example fleet replacement to improve the vehicle stock, airframe replacement and major infrastructure improvements eg rail track renewal schemes, typically occur over a 20–30 year timeframe.

Changing The Way We Live

Furthermore, many of the changes to the transport network necessary to cope with oil-depletion and climate change will also demand changes to the way our cities and communities operate, and necessitate a change in urban form. For example, sprawling suburban estates (a form copied here in Australia from the US) are largely a product of cheap fuel and rising standards of living which started in the 1950's that has extended to the present day (Litman, 2006). In a low-carbon future, urban forms are likely to shift towards more higher-density developments centred closely around activity and transportation nodes.

Changes are also likely to be necessary to freight distribution, particularly food supplies, which will revert to more locally grown supplies with less importation.

From a noise point of view, these changes to the way we live will put more of us in closer proximity to both our neighbours and to the major transportation routes.

Squeezing Capacity, Pricing Use and Managing Externalities

Across each of the three major transport systems, technological advancements are likely to enable more efficient use of the existing transport infrastructure. For example, across each of the transport systems safety, noise, congestion, or amenity charges enable better ways of pricing use and managing externalities.

Congestion charges, in particular, have assisted major cities around the world (most notably London) to achieve significant reductions in private motor vehicle travel into the city (Transport for London, 2004). Notably, electric or plug-in hybrid electric vehicles are *exempt* from London's £10/day congestion charge, and are free from 'road tax' (registration fees) in the UK. (Note that typical Toyota Prius's (with the exception of some newer variants being trialled by Toyota) are not ‘plug-in’ and do not receive the exemption).

Similarly, in Europe, where rolling-stock operators from many countries use common railway track infrastructure, Noise Differentiated Access Charges (NDAC) are applied to rail freight operators depending on the measured noise levels of their locomotive and wagon fleet as a way to drive source noise level reductions.

New technologies, such as variable speed road signage, advanced railway signalling systems or GPS enabled aircraft landing systems are also likely to enable greater capacity from current infrastructure, without incurring significant infrastructure development costs.

FREIGHT

The demand for freight transportation is likely to rise significantly in the next 20–40 years, particularly due to an increased shift towards just-in-time (JIT) (low inventory) manufacturing processes coupled with the globalisation of manufacturing and transport logistics. However, this will create a manufacturing system that, while globally connected, is less resilient and has less capacity to absorb shocks. This means that it will be less tolerant of transportation delays and breakdowns in the transport system.

Already in Australia, freight movements at several major ports are limited by the local road network capacity, are plagued by complaints regarding truck noise, and are subject to curfews to maintain amenity in nearby residential areas (Lubulwa et al. 2011). In Victoria, the government is being forced to look at alternatives to existing port facilities, such as the Port of Hastings, to increase international freight capacity.

The Victorian Department of Transport is considering the development of a ‘metropolitan freight’ rail system hauled with electric locomotives to transfer freight from the central dock areas to three outer metropolitan intermodal facilities and inland freight distribution terminals. Unfortunately, such a system would necessitate many additional railway movements across the existing metropolitan passenger network which, due to peak time capacity constraints, would be limited to occupying off-peak pathways, predominantly during the night-time.

Between Melbourne and Perth, where the network capacity already exists, interstate rail-freight transport accounts for an impressive 80% of the total freight load. However, east-coast freight movements are currently dominated by road-freight (trucks), which are the cause of a significant number of noise complaints along the Pacific and Hume Highways in NSW, Queensland and Victoria. Work is already underway to improve east-coast rail-freight capacity, for example through the South Sydney Freight Line (SSFL) and North Sydney Freight Line (NSFL) projects, to remove major freight bottlenecks where it crosses through the Sydney metropolitan passenger network. Significant shifts towards the freight rail network are to be therefore to be expected, as capacity allows.

At the same time, technological improvements are likely to allow better pricing of the many externalities of road-freight, for example, allowing registration on a ‘road damage’ basis. Truck operators will also rely on technological improvements, such as remote vehicle regulation, GPS tracking and active condition monitoring to reduce costs, and maintain competitiveness against competing modes.

ROAD TRANSPORT

As investors in recent toll roads in Australia will be well aware, many recent tollway projects have not come close to reaching the traffic flow forecasts used for the economic – and presumably the acoustic – modelling. These projects have unfortunately served to lower the public credibility of all ‘engineering predictions’, including noise, associated with these types of project.

Increased public transport ridership noted earlier, while not necessarily reducing the use of private passenger cars, has at least served to mitigate ongoing increases.

For road passenger transport, there is likely to be a large shift towards Hybrid Electric and Electric Vehicles (HEV and EV, respectively). The Victorian government is currently engaged in a large-scale Electric vehicle trial. However, at the current time, Electric Vehicles are still prohibitively expensive compared to equivalent vehicles with internal combustion engines, although improving battery technology is likely to enable lower manufacturing costs into the future.

Some energy and transportation researchers are instead suggesting a large-scale shift to hydrogen fuel-celled vehicles, rather than HEV or ‘plug-in’ EV (Lovins et. al., 2005) on the basis that this technology will deliver a more usable range, and the ability to leverage of existing refuelling infrastructure.

In terms of noise level from individual vehicles, it has long been recognised that at highway speeds, the most significant source of noise is from the tyre/road interface, and not due to engine or exhaust noise. A recent US Department of Transportation Study investigating the impacts of quieter cars on the safety of blind pedestrians (US Dept. Of Transport, 2010) showed that there was no difference in noise emission between EV and conventionally powered vehicles above 32 kph (20 mph).

That inherently means that a shift to either EV or hydrogen powered vehicles is not going to result in wide-scale reductions in road traffic noise for residents living near to large collector roads or freeways.

The largest changes in road transport noise are therefore most likely to come from a shift in usage towards public transport.

AVIATION

Aviation is particularly sensitive to fuel pricing. The International Air Transport Association (IATA) estimates that fuel represents around 30% of airline costs and that a $1/barrel increase in the price of oil costs the global airline industry $1.6billion per annum (IATA, 2011).

At the same time, aircraft are not inherently suitable for substitution of alternative ‘low energy’ fuels. Nevertheless, biofuels have been successfully tested during recent New Zealand, US and European flight-trials in commercial jet engines (Air New Zealand, 2009). German airline Lufthansa is currently conducting a long-term trial of a 50-50 mix of biofuel and aviation kerosene (in one engine) on scheduled commercial flights. In the future, the Advisory Council for Aeronautical Research in Europe (ACARE, 2001) has recommended the investigation of ‘low-polluting cryogenic fuels’.

The level of uptake of alternative fuel systems in the aviation industry is destined to take decades, since production facilities are currently limited and since aviation represents less than 5% of the world's liquid fuel consumption, fuel producers may be likely to target larger markets (ICAO, 2011).

Rising fuel prices coupled with the increasing strength of competing modes (particularly as new railway infrastructure comes on line) will also serve to increase airlines other costs, such as gate costs at airports, as airport owners seek to maintain revenue with fewer domestic flight movements.

In terms of future technologies which are expected to reduce fuel use, and allow for capacity increases (or at least maintenance), the key improvement is likely to be the introduction of lighter aircraft manufactured largely out of composite materials (eg. the Boeing 787 'Dreamliner'), and higher capacity aircraft such as the A380. These are expected to have 20% greater fuel efficiency, per passenger, than current aircraft, and result in fewer flight movements for the same level of capacity.

Overall, these changes are likely to result in either a reduction in aviation movements or a much lower level of growth in the next 30 years, resulting in *reduced* noise levels around airports. Already, the UK plans a significant reduction in short-haul aircraft travel in order to reduce greenhouse gas emissions, and meet their carbon reduction policy targets.

The aircraft industry has also made significant reductions in aircraft noise emission since the 1960's particularly through the introduction of high-bypass turbofan engines. Achieving significant further noise reductions is likely to be considerably more difficult. A wide range of noise reduction techniques are noted in the literature (Casalinoa et al., 2008).

Noise from aircraft was first regulated by the introduction of the US Federal Aviation Authority's (FAA) aviation regulations FAR Part 36 and ICAO Annex 16 Chapter 2 in 1971. More stringent noise requirements came into force under 'Chapter 3' restrictions in 1981, and 'Chapter 4' restrictions in 2006.

Unfortunately, the level of noise reduction these restrictions require can be difficult to understand, as shown by Figure 1, reproduced from public consultation documentation prepared for the proposed Brisbane Airport New Parallel Runway project (BAC). Although it has a caveat stating that 'the graph does not provide information about the absolute noise levels that people hear', readers unfamiliar with acoustics could be led to believe that newer 'Chapter 4' compliant aircraft, such as the A380, are 15–20 dB quieter than current 'Chapter 3' compliant aircraft such as the B737-300.

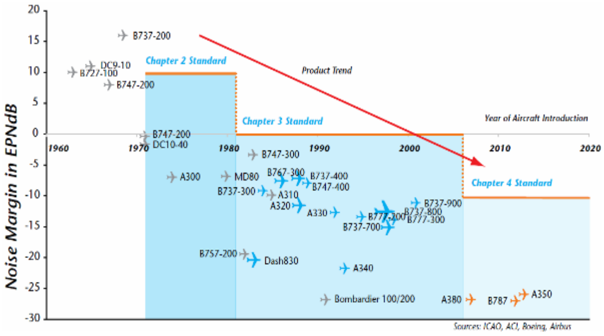

Figure 1. Noise Reduction Trend diagram, ref: Brisbane Airport 'Managing Aircraft Noise Impacts'.

Airbus's own documentation factually states that the A380 has 'a 17-EPNdB (Effective Perceived Noise in Decibels) cumulative margin to the ICAO Chapter 4 standard'. However, since the Chapter 4 requirement is the cumulative *arithmetic sum* of effective perceived noise levels from three flight modes (lateral (take-off), flyover and approach), the actual reduction in noise level for each individual mode is much less. A 10 dB *cumulative* margin is required between Chapter 3 and Chapter 4 aircraft noise levels - around 3.3 dB on average for each flight mode.

Furthermore, since the 'Chapter limits' are also based on the Maximum Take Off Weight (MTOW) of the aircraft, an A380, which has a MTOW of around 560 T, has a much higher allowance than a 60 T B737 aircraft. The actual lateral Effective Perceived Noise levels for typical 737-200 (Chapter 2), 747-400 (Chapter 3) and A380 (Chapter 4) aircraft have been determined based on the European Type Certificate Data Sheet for Noise (TCDSN) for each individual aircraft (EASA), and are shown in Figure 2. The ICAO Annex 16 Chapter 2 and Chapter 3 lateral noise limits have been calculated based on Annex 16 (ICAO) and are also shown in Figure 2 for reference.

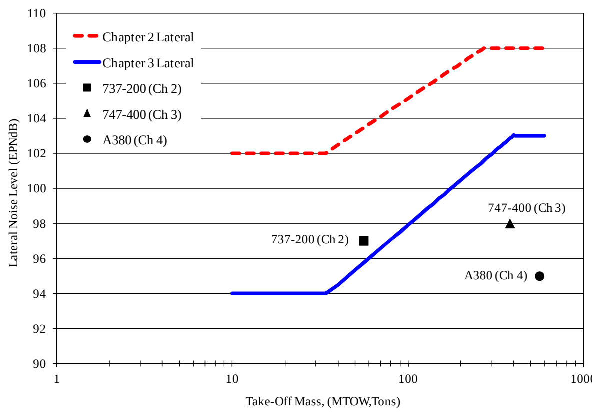

Figure 2. Lateral noise levels (EPNdB) for typical Chapter 2, Chapter 3 and Chapter 4 aircraft. Chapter 2 and Chapter 3 lateral EPNdB noise limits are shown for reference.

Clearly, while the A380 aircraft produces remarkably little noise for its size and passenger capacity, it is actually only about 2–3 dB quieter, in absolute terms, than earlier generation aircraft.

Apart from further incremental reductions to engine and airframe noise, additional noise reductions are most likely to come from the adoption of 'low noise' flight operations. Already many airports require the use of 'noise abatement' flight procedures, such as PANS-OPS NADP (Noise Abatement Departure Procedure), although the requirement to operate safely usually over-rides any requirement to adopt low-noise operating modes.

There are also several new 'on-board' technologies available to airlines, such as Required Navigational Performance (RNP) and Continuous Descent Approach (CDA) flight management systems which use advanced GPS systems to allow more accurate aircraft positioning and higher approach flight paths which result in fewer 'noisy' manoeuvring movements.

RAIL TRANSPORT

Rail transport is set to see the greatest increase into the future, as it displaces short-haul aircraft movements, interstate freight, and metropolitan vehicle trips.

While proposals for an east-coast Very Fast Train have been around for decades with no sign of governmental support, a recent review again recommended development of a High-Speed Train network to link Melbourne, Sydney, Canberra and Brisbane at a cost of approximately $100bn over 10 years.

A high speed train has the opportunity to provide improved city-to-city travel times over competing short-haul air travel, and would be likely to result in significant modal shift towards rail travel. Again, the high initial cost of railway infrastructure is likely to continue to burden the project. However, fast rail networks tend to become more connected as additional infrastructure is completed, and build on themselves, creating more flexible trips.

For metropolitan rail systems, more underground rail lines are likely, as this is often the only remaining option to create new corridors in constrained, inner-city environments. These have the potential to generate groundborne (sometimes called regenerated) noise in properties above the alignment, and depending on their depth, may require substantial vibration isolating trackfroms.

Similarly to the other transport modes, new technologies are likely to allow greater capacity on the existing infrastructure at incremental cost. For example, new signalling systems will enable reduced headway between trains and rolling stock with a greater number of doors (eg 'metro' type rolling stock) allows shorter dwell times at stations since it is quicker to load and unload passengers. Finally, changing from diesel to electric traction (as is being undertaken in Adelaide) acts to increase capacity and improve travel times due to faster vehicle starts and stops at stations.

DISCUSSION

In 2050 we expect that there will be a reduction in use of personal vehicle trips, coupled with a significant rise in the use of public transportation – particularly metropolitan railway patronage. However, despite the widespread introduction of electric and hybrid vehicles, road traffic noise is unlikely to see significant reductions compared to the present.

From a noise point of view, this substitution is likely to place greater demand on railway system capacity, and concentrate trips – and therefore noise - on major railway corridors.

Domestic air-travel is likely to have fallen – substituted with increased inter-city high-speed rail services. Noise from airports is likely to decrease, as older, noisier aircraft are replaced with newer, quieter aircraft. These also have a greater passenger capacity which is able to absorb additional demand while maintaining absolute flight schedules.

Hopefully, there will be much less road-truck freight on the eastern seaboard and at ports, displaced by greater rail freight usage. However, as a consequence of the anticipated reduction in noisy truck movements on roads, it is inevitable that noise will be concentrated more onto major freight railway corridors.

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