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1. INTRODUCTION TO AUSTRALIAN HIGH SPEED RAIL

High speed rail (also commonly known as HSR) is highly regarded as one of the most significant innovation for mass passenger transportation to travellers willing to pay for shorter trip time and convenience. They are increasingly attracting public attention as a sustainable and ubiquitous alternative to medium range air transportation system (300km-1000km distance or 1hr-3hrs travel time range) around the world. However, the investment in HSR system is a complex decision that includes economic, social, environmental, technical and political trade-off considerations.

Proposals for HSR in Australia (also known as Very Fast Train or VFT, Very High Speed Train or VHST, High Speed Train or HST) have been under active investigation since the early 1980s. Various studies and recommendations by prospective operators, government departments and advocacy groups have asserted that a HSR system between four Eastern Capitals (Sydney, Melbourne, Brisbane and Canberra) in Australia could compete air travel and will be able to put some cars off the interstate highways (Hume and Pacific Highways). Although these HSR studies have generated much interest from the private sector and captured the imagination of the general public upon their release, to date no private-sector proposal has been able to demonstrate financial viability without the need for significant governmental assistance. The long distances between major population centres, low population density of the intervening regions, and present affordability of air travel make it difficult for such proposals to demonstrate their economic viabilities. Although none of the previous proposals cited environment as an important issue for their failures, it is clear
that coastal route from Canberra to Melbourne via Cooma, Orbost and Latrobe Valley is being abandoned due to strong opposition from environmentalists.

Despite major financial roadblocks, HSR system in Australia has always been in the centre of discussion as a potentially better investment for future sustainable mobility for expected increase in travel demand. While many economic, social, environmental, technical and political battles loom, the HSR in Australia has the potential to reduce long-distance transportation energy consumption and emissions, provided measures are taken to encourage high ridership, minimise construction impacts, and establish clean energy future. Out of several alternative alignments under active investigation, a potential alignment can be narrowed down to the one as shown in Figure 1. The alignment follows inland route from Melbourne to Canberra, highland route from Canberra to Sydney and then coastal route from Sydney to Brisbane.

![Figure 1: Australian HSR alignment](image)

Australian Bureau of Statistics (2006) has projected that the population in three Eastern States—New South Wales (NSW), VIC (Victoria) and QLD (Queensland)—and Australian Capital Territory (ACT) will reach about 25 million (approx. 1.5 times) in 2036 and about 30 million (approx. 1.8 times) in 2056 from 17 million in 2011 Census. This amounts
approximately 80% of the total Australian population. The significant urban areas where the HSR stations are proposed cover approximately 75% of the population in NSW, 75% in VIC, 60% in QLD and nearly 100% in ACT. Current long distance travel demand (more than 50 km) in this corridor amounts approximately 105 million trips (in 2012) and is expected to reach 180 million in 2036 (at a rate of 2.2% per annum) and 260 million by 2056 (at a rate of around, 1.8% per annum). Currently in the East Coast of Australia, cars account for roughly 74% of trips, air 15%, conventional rail 10% and other 1% (e.g., coaches) (AECOM, 2011). The proposed HSR in Australia is expected to accommodate 54 million trips in 2036 and will reach 92 million trips at a rate of 2.7% per annum by 2056. This is equivalent to 22.5 billion passenger kilometre of travel (PKT) in 2036 and will reach 37 billion PKT by 2056 at a rate of 2.5% per annum. Approximately, 62% of this travel (14 billion PKT) is expected to be shifted from air and 22% from road (4.8 billion PKT). The remaining 16% of the travel (3.7 billion PKT) is expected to be generated by the introduction of the HSR system itself (Edwards, 2012).

In this chapter, the environmental impacts of the proposed HSR system are first discussed based on international studies and experience (Chester and Horvath 2010, UIC 2010, Persons Bringckerhoff 2011, Ryan and Sochon 2010, UIC 2010a). A list of environmental impact types are then generated and assessed with reference to Australian HSR geo-environmental conditions. As with any large scale transportation projects, HSR does not bring positive environmental impacts by itself but indirect environmental benefits could potentially outweigh the negative environmental impacts. It can be realised through sustainable construction practices, modal substitution effects, ridership generation effects, high HSR occupancy levels and future clean energy generation achievements. It depends on, for example, the amount of cement used in HSR infrastructure construction, the amount of patronage demand shifts from aircrafts and road cars, the amount of new trips generated or induced by HSR, the operating frequency and occupancy of HSR services and the mix of sources used to generate electricity to supply power consumed by life-cycle components of HSR system including its supply-chain components.

2. ENVIRONMENTAL ASSESSMENT APPROACH

Often, the environmental impacts of HSR are assessed based on impacts during HSR operations without considering life-cycle and supply-chain components. This approach considers the direct electricity use and corresponding power plant emissions from train active-operation energy requirements. This will certainly portray HSR system as one of the most environment friendly transport alternative, compared with aircrafts and cars (Campos and de Rus, 2009; Givoni, 2006). However, comprehensive environmental impacts of HSR are not negligible. Like any other transportation projects, HSR system contributes directly, indirectly and cumulatively to environmental problems (Rodrigue, 2013) during its life-cycle, only a few of them are temporary impacts. Direct impacts are the immediate
consequence of HSR on the environment where the cause and effect relationship is generally clear and well understood, for example, land take by HSR infrastructure system. *Indirect and wider impacts* are the secondary (or tertiary) effects of HSR on environmental systems. They are often of higher consequence than direct impacts, but the involved relationships are often misunderstood and difficult to establish, for example, local area pollution in the vicinity of power plants away from the HSR system. *Cumulative impacts* are the additive, multiplicative or synergetic consequences of HSR system. They take into account of the varied effects of direct and indirect impacts on environment, which are often unpredicted. *Temporary impacts* include, among other, construction noise, construction emissions and energy consumption during construction. Following the best practices, these temporary impacts can generally be kept at manageable levels.

To understand the comprehensive environmental impacts of deployment and adoption of a new HSR system, it is important to consider emerging alternative transport modes such as future aircrafts and future cars as well as environmental assessment of life-cycle and supply-chain components of HSR system itself (Chester and Horvath, 2009; Chester and Horvath, 2010). The supply-chain impacts can be far fletched but usually difficult to go beyond the electricity generation. It is also necessary to take into account the fact that the other transport modes are getting cleaner and more energy efficient. Moreover, the HSR system itself is becoming more sustainable due to technological innovation in fuel efficient train designs and the increasing amount of clean electricity used to power HSR system. Vehicle manufacturing and maintenance energy and emissions are important, as are those resulting from infrastructure and electricity generation. The environmental trade-offs of the HSR system should be evaluated from supply-chain life-cycle perspective so that total environmental assessment and its associated impacts are transparent in policy and decision-making. It is possible that when using the life-cycle assessment framework, greenhouse gas footprints may increase significantly and human health and environmental damage potentials may be dominated by indirect and supply-chain components. Passenger kilometre of travel (PKT) of such total environmental assessments on energy consumption and efficiency, greenhouse gas emissions, air and noise pollutions are compared against the alternative transport modes (particularly cars and aircrafts). This will help to quantify the environmental trade-offs. For example, HSR may lower energy consumption and greenhouse gas emissions per PKT but may create more SO₂ emissions (for a typical electricity mix) leading to environmental acidification and human health issues. The impacts on natural and built-up environments, particularly the land take, due to HSR system can be very significant.

To assess the full range of environmental impacts of a HSR system through life-cycle and supply-chain perspective, Chester and Horvath (2010) grouped the HSR components into three categories: vehicle components, infrastructure components and fuel components. HSR *vehicle components* include running (propulsion), idling, auxiliaries (heating, ventilation,
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Air conditioning and lighting, train manufacturing, train cleaning, flooring replacement, crew health and benefits and train liability. Infrastructure components include, station construction, track construction, station lighting, escalators, train control, station parking lighting, station miscellaneous (e.g., other electrical equipment), station maintenance, station reconstruction, station cleaning, track maintenance, station parking, non-crew health insurance and benefits and infrastructure liability insurance. Similarly fuel components include infrastructure and operational electricity generation upstream requirements and transmission and distribution losses. During the life time of a HSR system, these components produce some sort of environmental impacts in both ‘natural’ and ‘built’ environments.

3. ENVIRONMENTAL IMPACTS OF HSR IN AUSTRALIA

3.1 Energy consumption and efficiency

Substantial amount of energy is consumed during construction, maintenance and operation of vehicle, infrastructure and power production (electricity generation, transmission and distribution) components of HSR system. Energy consumption can be expressed in power required per passenger kilometre of travel (Wh/PKT). It can be measured at pantograph level (intake to the train), substation level (intake to the HSR system—this takes into account the distribution losses) or power plant level (this takes into account the losses from intake power plant to train wheels).

There are a wide range of accounts on energy consumed by HSR system compared with other transport modes. It is because of a wide range of vehicle and infrastructure types within each transport mode. A supply-chain life-cycle energy requirement has been established by Chester and Horvath (2010) and is significantly different than other literature as shown in Figure 2. UIC (2010) data shows that HSR is about 4 times more energy efficient than car and 8 times more energy efficient than flying. This is not the case when life-cycle components of HSR are included. Depending on the vehicle occupancy, HSR may consume as much energy as car and aircraft per PKT.

Australian HSR system will consume in the range of 1500 to 4500 GWh of electricity in 2036 depending upon whether the energy consumed by its life-cycle and supply-chain components are considered. This energy consumption may be significantly higher if the HSR cannot maintain a certain level of occupancy during its operations. For example, it may consume 10 times more energy if the occupancy is very low (say, 10%) per PKT. However, there is always a room for energy savings through energy efficient HSR vehicle and infrastructure designs.

3.2 Climate change and greenhouse gas (GHG) emissions

Coal-burning electric plants which are the major source of electricity consumed by the
components of HSR system in Australia release several million tons of gases each year into the atmosphere. These include lead (Pb), carbon monoxide (CO), carbon dioxide (CO₂), methane (CH₄), nitrogen oxides (NOₓ), nitrous oxide (N₂O), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), silicon tetraflouride (SF₆), benzene and volatile components (BTX), heavy metals (zinc, chrome, copper and cadmium) and particulate matters (ash, dust) (Rodrigue, 2013). There is an ongoing debate to what extent these emissions are linked to climate change and the role of anthropogenic factors. Some of these gases, particularly nitrous oxide, also participate in depleting the stratospheric ozone (O₃) layer which naturally screens the earth’s surface from ultraviolet radiation.

As HSR system consumes electricity to construct, maintain and operate its life-cycle system components, the amount of GHG emissions associated with HSR system depends on the sources used to generate electricity. As the electricity to HSR system is generally supplied
through national grid, the GHG emissions due to electricity can be traced back to the electricity generation mix and beyond. Figure 3 and Figure 4 show the share of electricity to Australian CO₂ equivalent GHG emissions and sources used to generate electricity during the last 10 years. Electricity generation has contributed about 36% of CO₂ equivalent GHG emissions whereas transportation contributed to about 15% during the last decade. It is clear that to use electricity as an energy source to transport system in Australia may not reduce the GHG emissions but may shift pollution from transportation sector to electricity sector. The higher the level of renewable sources and nuclear power used to generate electricity, the lower the level of GHG emissions associated with HSR system.

![Figure 3: CO₂ equivalent GHG emissions by industry sector](image)

As more than 90% of the electricity generated in Australia is from non-renewal energy sources such as burning of coals and petroleum products, the electricity consumed by HSR will is not be a clean energy. However, there is an opportunity to propel Australian HSR system through renewable electricity sources as the Australian Government has developed a comprehensive plan to move to a clean energy future. The Government is planning to drive innovation and investment worth billions of dollars in renewable energy. Under the Renewable Energy Target (RET) scheme that combines both Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (SRES), Australia is expected to generate at least 20% (45,000 GWh) of its electricity from a variety of renewable sources by 2020 (Parliament of Australia, 2013). This equals to 1,900GWh per year until 2015 and 4,600GWh per year to 2020 and beyond. Australian Government expects around 40% of the electricity generation by renewable energy sources by 2050. Even this target of renewable
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Electricity generation is achieved; 70%-80% (during construction), 65%-70% (during the first year of operation in 2036) and around 60% (in 2056) used by HSR in Australia comes from non-renewable energy sources such as burning coals and natural gas.

Many existing literature put HSR travel over driving or flying as a green alternative in terms of GHG emissions. This may be because some of these estimates are based only on the direct electricity use and corresponding power plant emissions from HSR active-operation energy requirements. Chester and Horvath (2012) estimated the life-cycle CO₂ equivalent GHG emissions of transport alternatives, including supply-chain, using California’s electricity generation mix and they pointed out that this is not always the case. Australian HSR (60-80% from non-renewable sources) will be less green to its Californian counterpart (about 45% from non-renewable sources) because of the higher share of coals and natural gas to produce electricity. To put these numbers in context, Figure 5 shows the comparison between alternative transport modes.

Depending upon whether the GHG emissions associated with life-cycle and supply-chain components are included in the comparison, Australian HSR will emit in the range of 0.5-5.0 million tonnes of CO₂ equivalent GHG gasses in 2036 for the 18.8 billion PKT diverted from car and air trips. It may or may not reduce GHG emissions as the total emissions by
other transport modes substituted by HSR may fall within this range (0.2-1.2 million tonnes by car and 1.5-2.4 million tonnes by air). However, there is always a room for reducing GHG emissions by powering HSR system through renewable electricity generation.

### 3.3 Air pollution emissions

HSR is also a source of air pollution in the form of gases (SO₂, NOₓ) and particulate matters (PMs) emissions that affects air quality causing damage to human health. Toxic air pollutants are associated with cancer, cardiovascular, respiratory and neurological diseases. Carbon monoxide (CO) when inhale affects bloodstream, reduces the availability of oxygen and can be extremely harmful to public health (Rodrigue, 2013). An emission of nitrogen dioxide (NO₂) reduces lung function, affects the respiratory immune defence system and increases the risk of respiratory problems. The emissions of sulphur dioxide (SO₂) and nitrogen oxides (NOₓ) in the atmosphere form various acidic compounds that when mixed in cloud water creates acid rain. Acid precipitation has detrimental effects on the built environment, reduces
agricultural crop yields and causes forest decline (Rodrigue, 2013). The reduction of natural visibility by smog has a number of adverse impacts on the quality of life and the attractiveness of tourist sites. Particulate emissions have an impact on air quality. The physical and chemical properties of particulates are associated with health risks such as respiratory problems, skin irritations, eyes inflammations, blood clotting and various types of allergies (Rodrigue, 2013).

HSR affects the environment predominantly by contributing to the local area pollution. The levels of local area pollution depend mainly on the share of coal used to generate electricity. Hence, there will be substantial pollution associated with HSR system in Australia as coal-burning electric plants are expected to contribute 60%-80% (currently about 90%) of the electricity to HSR during its construction and the first 20 year of operation. However, fossil fuel (black coals, brown coals and natural gas) power plants in Australia are located away from the densely populated areas; actual pollution impact is lower as fewer people are directly exposed to emissions.

3.4 Sound pollution: noise and vibrations

Noise and vibrations represents the general effect of irregular and chaotic sounds. It is traumatising for the hearing organ and may affect the quality of life by its unpleasant and disturbing character. Long term exposure to noise levels above a certain threshold seriously hampers hearing and affects human physical and psychological wellbeing.

Noise nuisance from construction (temporary impacts) of HSR vehicle and infrastructure and operation of HSR lines can be considerable. It may also adversely impact on the wildlife along the HSR line. There may be substantial adverse effects on endangered and threatened species from noise, barriers and direct kills. Increasing noise levels have a negative impacts on the urban environment reflected in falling land values and loss of productive land uses.

The level of noise depends on the technology adopted and speed. At speeds between 50 and 300km/hr, rolling noise is the most important noise source (Brons et al., 2003) and it depends on the smoothness of the wheel and rail. Only at speeds above 300km/hr does aerodynamics become the main source of noise. Figure 6 shows the expected speeds of the proposed Australian HSR (Nepal, 2013). For Australian HSR, rolling noise is the most dominant source of noise. The overall impact of noise pollution is lower in built-up areas as speed of HSR in density populated areas near Melbourne, Sydney and Brisbane will be lower than 300km/hr. It is also possible to protect people from HSR noise by barriers and tunnels.

3.5 Land take and land-use impact

Since the development and operation of HSR system involves the construction of new
infrastructure tracks, land take is the most prominent environmental impact related to HSR. Land take includes, among others, taking of houses and businesses, farmlands and grazing fields, reserve areas (forest, natural conservation, water supply) and indigenous lands and, natural vegetation and cultivated areas. Land take leads to other environmental impacts such as habitat loss of endangered communities, fragmentation, loss of access to urban and rural parcels and community severance (Commission for Integrated Transport, 2001). Land take is inevitable but land-use impact can be minimised by proper choice of HSR alignment and right-of-way. Indirect or secondary impacts on land take can also be important such as, induced growth and change in the value of lands.

3.6 Impacts on natural environments

The proposed HSR alignment crosses border ranges between QLD and NSW, which is one of the 15 national biodiversity hotspots announced by Australian Government in 2003.
This sub-tropical and temperate hotspot is one of Australia’s most diverse areas - and it is the most biologically diverse area in NSW and southern QLD. It has a variety of significant habitats: subtropical rainforest, wet sclerophyll forest, mountain headlands, rocky outcrops and transition zones between forests. These habitats support a huge variety of bird and macropod species. Many are rare or threatened: the Richmond Bird-wing Butterfly, Fleay’s Frog, Hastings River Mouse, Spotted-tailed Quoll, Eastern Bristle Bird, Rufous Scrub-bird and the critically endangered Coxen’s Fig parrot. Notable birds such as Albert’s Lyrebird and the Paradise Riflebird make their home here, and in the south-east Queensland rainforests live a rich variety of primitive plant species.

The entire Australian HSR alignment frequently passes through national parks, water supply catchments and sensitive coastal environment. Following existing right-of-way, elevation or undergrounding the HSR infrastructure can avoid or minimize adverse impacts on natural environments.

### 3.6.1 Geology and soils

The environmental impacts on geology and soils are the direct result of construction of the HSR infrastructure. These include landslide, soil erosion, soil contamination and loss of fertile and productive soils during and after construction. Soil contamination can occur through the use of toxic materials by the HSR system. Chemicals used for the preservation of HSR tracks may enter into the soil. HSR may encroach into the areas of highly erodible or otherwise sensitive soils.

As the proposed Australian HSR passes through the Great Dividing Range and major built-up areas in Sydney, Melbourne and Brisbane, its geological impacts should not be overlooked (Figure 7). Topographical challenges are eminent in the HSR legs between Wagga Wagga and Canberra and between Sydney and Newcastle. Sydney to Newcastle leg has the severe topographical constraints and considerable proportion of which is likely to be in tunnel. There are frequent patches of topographical issues elsewhere.

### 3.6.2 Endangered communities

Many animal species are becoming extinct as a result of changes in their natural habitats and reduction of ranges. The following are few examples of endangered communities and their habitats in the vicinity of the Australian HSR corridor:

- Large areas of endangered flora are located to the north of Wangaratta and are likely to include the Box Ironbark communities.
- Other endangered species known to occur near Chiltern are the Box Ironbark, Regent Honeyeater, various amphibians and gliders.
- The section of the corridor south of Sydney and north of Bargo is characterised by
frequent pockets of low to medium quality Cumberland Plain Woodlands.
- Majority of the Sydney to Brisbane corridor is located in the buffer zones in which
  endanger and migratory species are likely to occur. White Box, Yellow Box, Blakely’s
  Red Gum, Grassy Woodland and Derived Native Grassland are possible in this
  part of the HSR corridor.

### 3.6.3 Native vegetation

The need for construction materials for HSR may lead to the destruction of natural vegetation.
Maintaining right-of-way and stabilising slopes along HSR infrastructure may result in
restricting growth of certain plants or may produce changes in plants with the introduction
of new species different from those which originally grew in the areas. Native vegetation
extends through the entire length of Australian HSR corridor as shown in Figure 8.

### 3.6.4 Cultivated areas

In addition to other farmlands, the proposed Australian HSR alignment passes through
the patches of cultivated areas (orchard and plantation) as shown in Figure 9. It is important
to align the HSR route in such a way that the adverse impacts in these cultivated areas are
minimised.
3.6.5 Hydrology, water resources, wetlands, nearshore ecosystem

Construction of HSR system has an impact on hydrology, water resources, wetlands and nearshore ecosystems, especially coastal lagoons and inlets. It modifies the hydrology by creating turbidity that can affect the biological diversity and by disturbing water paths and channels.

As Australian HSR passes through many water course lines and nearshore environments as shown in Figure 10, its impacts on hydrology and water resources are substantial. The HSR corridor is located along the Great Dividing Range and it crosses a number of perennial and non-perennial watercourses along the way. Perennial rivers that HSR would cross include:

- **VIC**: Goulburn river, Ovens river, Murray river
- **ACT**: Murrumbidgee river
- **NSW**: Murray river, Murrumbidgee river, Wingecarribee river, Georges river, Hawkesbury river, Wyong river, Hunter river, Karuah river, Myall river, Coolongolook river, Wallamba river, Manning river, Camden Heaven river, Hastings river, Macleay river, Nambucca river, Bellinger river, Clarence river,
Figure 9: Cultivated areas along HSR corridor

Figure 10: Water course lines along the HSR alignment
Richmond river, Wilsons river, Tweed river
  - QLD: Nerang river, Coomera river, Logan-Albert rivers and Brisbane river

As Australian HSR requires draining land, it reduces wetland areas driving-out water plant species. A network of wetlands exists throughout the proposed HSR corridor. Examples of wetlands and biologically sensitive habitat areas affected include Myall Lakes Ramsar wetlands and Everlasting Swamp.

3.6.6 Reserves: parks, recreation and open space

Australian HSR passes through a number of reserve areas as shown in Figure 11. It frequently intrudes parks, recreational areas and open spaces. They include:

- Natural conservation reserves:
  - VIC: Craigieburn grassland, Wandong regional park, Rowan swamp state game reserve, Warby Range state park, Chiltern Box-Ironbark national park, Mount Pilot regional park, Baranduda regional park
  - NSW: Benambra national park, Burrinjuck nature reserve, Alpine region west of Canberra, Brindabella national park, Bargo state conservation area, Garigal national park, Kuringai national park, Brisbane water national park, Lake Macquarie state conservation area, Kuragang nature reserve, Hexam Swamp nature reserve, Monkerai nature reserve, The Glen nature reserve, Yoorigan national park, Crowdy Bay national park, Queens Lake nature reserve, Lake Innes nature reserve, Rowdan Creek nature reserve, Limburners nature reserve, Cooperabung Creek, Mariya national park, Clybucca historical site, Bongil Bongil national park, Ulidarra national park, Sherwood nature reserve, Tallawudjah nature reserve, Nightcap national park, Mount Jerusalem national park, Mooball nature reserve, Cudgen nature reserve,
  - ACT: Canberra nature park reserve, Molongo nature reserve

- State forest reserves: patches state forest reserves are located throughout the HSR corridor.
- Water supply reserves:
  - VIC: Lake Mokoan, Lake Hume
  - NSW: Lake Burrinjuck, Lake Nepean, Manly Dam

Impacts on most of these reserve areas can be minimised by suitably selecting the HSR alignment.

3.7 Built-up environment and urban growth areas

Visual impacts of elevated structures, sound walls, and other elements for HSR can affect
property values, enjoyment of open space in big cities such as Sydney, Melbourne and Brisbane. Noise and vibration effects on built environment can sometimes be significant. However, except in the vicinity of large cities and regional towns, proposed Australian HSR system will not impact significantly for urban growth and urban environment. Establishing HSR alignment along the existing transport corridors and tunnelling in large cities would help reduce the impacts on urban environment.

4. DISCUSSIONS

Many environmental impacts (mostly negative) are the result of construction, operation and maintenance of HSR and its system components. These impacts, among other, include energy consumption, GHG emissions, air pollution and land take. HSR system results in adverse impacts on the environment, mainly by affecting local area pollution in the vicinity of coal burning power plants and by affecting natural and built environment by consuming considerable amount of land. There is a very significant up-front GHG emissions associated with the construction of infrastructure. Some of these impacts are the result of operating HSR trains, whether or not they attract passengers such as noise, a good part of the energy and emissions. Still others depend on whether ridership materialises and extent to which it is diverted from other modes such as air quality, energy, CO$_2$ emissions avoidance. To summarise:
Some environmental impacts are negative and unavoidable results of construction of HSR vehicle, infrastructure and power plants. Some depend on attracting patronage to HSR from air and road traffic (i.e. car). Relative impact in part depends on how the other modes—aircrafts and cars—develop in future. Relative impact also depends on whether cities and regional towns coordinate land use strategies with HSR investment.

HSR does not provide positive environmental impacts by itself but indirect environmental benefits could potentially outweigh the negative environmental impacts. It can be realised through sustainable construction practices, modal substitution effects, ridership generation effects, high occupancy levels and future clean energy generation achievements. International evidence shows that HSR demonstrates significant benefits in terms of energy consumption and GHG emissions than the aircraft and car when the sufficient occupancy is maintained on HSR and renewable energy is used to generate electricity used by HSR system. Nonetheless, HSR has the potential to reduce passenger transportation impacts to the environment, but must be deployed with process and material environmental reduction measures and in a configuration that will ensure high adoption and occupancy. HSR occupancy, infrastructure construction and electricity generation are the dominant hotspots. By identifying low and high adoption outcomes, the potential benefits can be discussed. Given the dominating HSR life-cycle effects from electricity generation and infrastructure construction, strategies can be identified to reduce the system's footprint, prior to its construction and use. However, it is very hard to quantify these impacts discussed in this chapter and real environmental benefits could be very difficult, if not impossible, to estimate to a reasonable accuracy.

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