High Speed Rail and Sustainable Mobility: a Life Cycle Assessment of the Spanish AVE network

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Overview

Spain remains as the world's second longest network of high speed rail lines built and in service. High-Speed Rail (HSR) is usually presented as a sustainable means of transport with huge potential to reduce greenhouse gas (GHG) emissions and energy consumption. However, most of the literature has focused on analysing and estimating these savings in terms of network operation, but sometimes ignore the burdens associated with the construction of the infrastructure. This is crucial when framing these investments in the Paris Agreement on climate change. This paper evaluates the contribution of the Spanish HSR network to reducing environmental impacts and energy consumption using Life Cycle Assessment (LCA) methodology. It concludes that the construction of two out of four corridors is not justified in terms of energy savings and emission reductions and that, more importantly, the modest emission reductions found in the overall network are far from the efforts needed to fulfill with the Paris Agreement on climate change. In line with the literature in cost-benefit analysis, we find that the decision to build new HSR sections should be based on an analysis of demand so that only corridors with high transport demand are built. Furthermore, policymakers should consider other measures related to transport that would lead to considerable and rapid reductions in environmental impacts without the burden of building new infrastructures: e.g. reducing the demand for transport, increasing the occupation of private vehicles, promoting electric traction and the use of electricity from renewable sources.

Methods

The analysis carried out in this work is based on the Life Cycle Assessment (LCA) methodology. This methodological tool is used to assess environmental impacts associated with all the stages of the life-cycle of a product or service, from raw material extraction to the processing of materials, infrastructure construction, use, maintenance and end-of-life treatments, based on a "cradle-to-grave" approach. LCA relies on the collection and analysis of all inputs (energy and materials consumption) and outputs (emissions, waste and by-products) of the system under study. The LCA of a product or service is often based on the use of exhaustive databases that compile the inventory of the life cycle of other products and processes already analysed.

All the scenarios examined in this paper consider a fixed technological and socioeconomic context during the entire infrastructure's life cycle. This implies that important variables, such as transport demand, diverted traffic, vehicle occupation rates, energy intensities or electricity mix were considered invariable. The calculation period is established in 60 years, as it is the expected useful lifetime of most of the components of a railway network (Stripple and Uppenberg, 2010).

Results

The main factor behind the net environmental balance of the Spanish HSR network is clearly the density of total demand as long as it is capable of diverting traffic from more polluting modes of transport (air or road) rather than inducing new demand. Vehicle occupancy rates, electrification of road transport and electricity mix have also been found to have a significant impact on the environmental balance of the network.

In line with the findings of many economic analyses (e.g. Albalate and Bel, 2011; Betancor and Llobet, 2015; De Rus, 2011), the performance of the Spanish HSR network is clearly hampered by its low passenger demand. In 2016 the Spanish HSR network transported the equivalent of just 4.17 million passengers over the complete infrastructure; significantly lower than the transport density supported by other networks in the world.

The Spanish HSR network is also hampered by the fact that it allows only for passenger transport, which prevents attracting potentially more polluting traffic from road freight transport. As argued by Akerman (2011, p. 208), “HSR investments may not be justified for the passenger markets alone.”

The LCA of Spanish HSR is quite robust in showing that the launch of the Catalonia and Andalusia corridors of the Spanish HSR network has led to a net environmental benefit in CO_2eq after nine-twelve years of operation. However, it also shows that results worsen as the network expands to corridors with lower demand (Levante or Northern corridors). This also coincides with transport economics literature (see e.g. Albalate and Bel, 2011).

Conclusions

Climate change and oil scarcity have received increasing attention in transport policy. In this context, HSR has often been presented as a sustainable mode of transport, having a leading role in the European Commission’s environmental goal of net-zero GHG emissions by 2050, due to its potential contribution to energy savings and GHG emissions reductions. In this paper, it is assessed the environmental performance of the Spanish HSR network by means of LCA under 2016 traffic conditions. Results show that the construction loads of the Spanish network are not disproportionate, as they remain within the lower limit of the range of construction burdens found with other HSR lines. Although these construction loads are not excessive, the net environmental balance of the entire network in the Baseline Scenario, without being detrimental in almost all indicators, is modest: an annual emission reduction of 610 kt CO_2eq, of 7 031 TJ of CED, of 2 879 t NO_X and of 627 t NMVOC, together with an annual increase of 88 t PM_{10}, of 17 t SO_2. This modest balance means that the infrastructure requires a minimum number of years of operation to offset the initial loads associated with the construction: between 9 and 16 years in all the environmental categories studied except for SO_2 (62 years) and PM_{10} with 87 years. In absolute terms, it means a reduction in CO_2eq emissions equivalent to less than 1% of the annual transport emissions in Spain in the base year (2016), together with a reduction in primary energy demand which is less than the equivalent of 0.5% of annual energy consumption in the transport sector.

The environmental balance varies according to the network corridor considered. The corridors of Catalonia (5.76 Mp) and Andalusia (5.36 Mp) present a slightly better balance than the total average, managing to compensate the initial construction loads in less than 7-12 years in all the analysed categories except for PM_{10} and SO_2. The Northern corridor (1.31 Mp) would not be able to compensate the initial loads in the whole time of operation, and the Levante corridor (2.71 Mp) would need around 14-21 years (except for SO_2 with 80 years and PM_{10} which would not be compensated). According to these results, the construction of the Levante and Northern corridors is not justified in terms of energy savings and emission reductions. Thus, in line with the findings on cost-benefit analysis, the decision to build new HSR sections should be based on the analysis of demand in order to build only those sections that ensure a high demand, that is, to build only those corridors that connect centres with high demographic density (De Rus, 2011).

References

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