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Efficient solutions for passenger transport*

Investing public money in High-Speed Rail

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Executive Summary

As with other ways of spending public money, the key question with high-speed rail (HSR) is not whether people want to travel faster and more comfortably, but whether they value these benefits highly enough to compensate for the huge investment costs of constructing the line, its environmental impact and its operating and maintenance costs.

The point is whether society is willing to pay the opportunity cost of HSR. This is of course an empirical question, and the answer is context-specific. There is nothing intrinsically good or bad about this railway technology and economists do not have any other a priori position with respect to the construction of new HSR lines, beyond the suggestion of the importance of comparing social benefits and costs of the project under consideration before taking any irreversible decision.

HSR performs very well in terms of market share in corridors of 400-600 km but this success is in many cases the result of rail users not being charged the infrastructure costs. A high-speed line requires high volume of demand to share the investment costs associated with its construction. Many lines are heavily subsidized, so high load factors and market share are compatible with a poor social return. It is not surprising that HSR investment is more popular among politicians and the general public than among economists.

The standard medium-length line where HSR develops its full potential is around 500-600 km with two big, densely populated cities at each end. Some of the lines in operation or under construction are far from having the volume of passengers needed to justify the investment. In some existing HSR lines, the majority of passengers were already traveling by conventional rail or by air, meaning that the time benefits of diversion are modest.

A potential benefit of HSR investment is the reduction of environmental externalities, though this depends on the volume of demand deviated from less environmentally-friendly transport modes and whether demand is high enough to compensate for the negative externalities during construction, the barrier effect, noise and visual intrusion. Analysis shows that in order to balance the annualised emissions from high-speed line construction, traffic volumes of more than

10 million annual one-way trips are usually required. It is only in a case of high diversion of passengers from aviation in combination with low CO₂ emissions from the marginal electricity production that substantially fewer trips suffice (but still more than 7 million).

Building a completely new high-speed line means traffic will be diverted from the pre-existing rail network. Thus excess capacity on the old tracks may be allocated to other types of trains. But for this to happen, there must be demand for transport by rail that could previously not be met for lack of capacity. However, there may be other responses to a growing imbalance between supply and demand that give rise to fewer emissions, e.g., rail track congestion charges and incentives to improve the utilisation of inland waterways and/or short sea shipping routes, or the partial replacement of business travel by telecommunication.

The economic evaluation of permanent infrastructure requires a careful construction of the counterfactual and there are many assumptions that might seriously bias the results. This is the case for transport pricing during the lifespan of the project. Pricing policy needs to be explicitly addressed. We need to consider how the alternative transport modes are going to be charged. For example, the government could charge for air and road transport below social marginal costs and then justify a massive rail investment as a second-best policy to change the modal split, or it could optimally price all transport modes and then evaluate the best way to expand capacity. The final result may be quite different.

There is considerable pressure on governments to build new high-speed lines as if the investment were a kind of 'now or never' decision. This does not seem to be the case with this technology, however. The construction of HSR infrastructure is irreversible and there is uncertainty associated with costs and demand. In these conditions, the question of the right moment to invest is critical as the investment can be postponed in most cases. Hence, the optimal timing of the investment should be addressed even in the case of a positive net-present value.



Efficient solutions for passenger transport

1.

Introduction



Transport infrastructure and services do not follow the same long-term planning criteria. Private operators, including car owners, decide how much and when to invest in new capacity (and this also includes technology). Private airlines decide which type of aircraft to buy depending on their demand expectations and business strategies. There is strong evidence that competitive air transport services work reasonably well (Morrison and Winston, 1995; 2005). This is also true of bus transport services, at least under a scheme of competition for the market (Nash, 1993; Mackie and Preston, 1996; Preston, 2004).

On the contrary, roads, airports, ports and railway tracks and stations ultimately belong to the public sector (with some exceptions). Although many crucial transport decisions are in the hands of private operators subject to market discipline, the public sector can heavily influence future modal split and the configuration of transport networks through investment, pricing and regulatory decisions affecting capacity. This is the case with high-speed passenger trains operating largely within the public sector, both in the areas of infrastructure and services. The endorsement of railways by the European Commission, and especially of the development of a high-speed rail (HSR) network, has provided this rail technology with public funds and political support.

The future of interurban transport is expected to be dominated by strict budgetary constraints and the introduction of efficiency-oriented policies affecting pricing and investment decisions, such as the application of polluter-pays and user-pays principles, and the planning of infrastructure on a strict economic basis. The ultimate objective is to have an “integrated and sustainable transport system” that promotes economic growth and social cohesion (European Commission, 2009). What is the role of HSR infrastructure in this context?

ECONOMIC ANGLE

From an economic perspective, the question is quite simple. Like any other technology, HSR is not inherently good or bad. Its social value resides in its ability to solve transport problems that are significant enough to justify its opportunity cost. Cost-benefit analysis can help answer this crucial question, but we do not need to go any further to maintain that the economic case for HSR investment depends on the prevailing conditions in the intercity corridor where the construction of the new line is planned, in particular the level of demand, the degree of congestion, value of time, expected time savings from diverted traffic, generated traffic and the net external effects.

An economic evaluation of projects would, in principle, lead to the best ones being selected, but there is overwhelming evidence that this is not happening. The context in which the social appraisal of projects is carried out cannot be ignored in the economic assessment of major infrastructure projects. The institutional design is a key element for understanding public decision-making when different levels of government are involved, as is the case in the EU or generally when the national and regional governments of the same country do not necessarily share the same objectives, particularly with regard to where public investment should be made.

This report is organised as follows: Section 2 provides an overview of the costs and benefits of HSR investment. Governments promote HSR construction as an instrument for a better environment. The environmental benefits and costs of HSR construction and operation are analysed in Section 3. The opening of new HSR lines changes the modal split in intercity corridors and Section 4 addresses the important consequences in terms of intermodal competition, pricing and investment. Section 5 covers the positive question of why governments invest in HSR infrastructure with special attention to the consequences of institutional design on long-term investment decisions. Section 6 concludes with a summary.

2.

Investment in High-Speed Rail infrastructure



Some facts on HSR infrastructure investment

- Sunk costs represent more than 50% of HSR investment. This implies huge costs for poor decisions due to irreversibility.
- HSR investment develops maximum potential at medium length corridors (400-600 km).
- To be socially profitable, HSR requires high-demand to compensate costs.
- Environmental benefits rarely justify the investment because of emissions during construction period.
- Right design of the institutional framework is necessary to resolve information problems and conflict with interest groups. Project appraisal is essential in this setting to take decisions about transport investment.

All over the world, governments of different political orientations are investing in HSR infrastructure. In some countries the enthusiasm is more intense than in others.

There is no single pattern. The UK and the US are now closer to building HSR lines, though they have been reluctant to give definitive approval until now, and the money allocated to HSR has not gone beyond financing the cost of the evaluation of economic and financial viability. Other countries, like France and Spain, have been keener on HSR, in contrast to such European countries as Norway or Sweden, for example, whose governments are still studying whether this type of investment is socially worthy. Spain is a unique case because, with much less traffic density than other countries (and much less congestion) in the conventional rail network, it is one of the first countries in the world measured in HSR kilometres.

Other countries have chosen alternative ways of improving intercity passenger rail services. The UK and Sweden, for example, upgraded their conventional rail using their conventional network, increasing speeds on existing tracks up to 200 km per hour, using tilting trains where necessary because of the curvature of the track (Nash, 2010). Now, the so-called HS2, between London and Edinburgh, is under study to introduce a new HSR track.

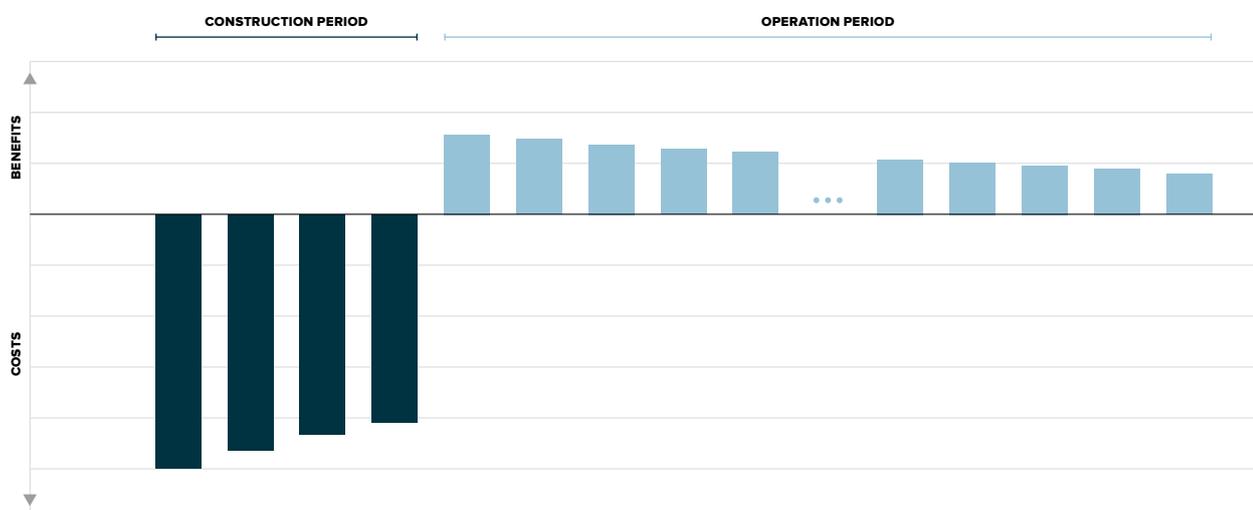
The European Commission's White Paper on Transport Policy (2011) envisages an important extension of the European high-speed rail network by 2050, tripling the length of the existing high-speed rail network by 2030 and maintaining a dense railway network in all Member States. By 2050, the majority of medium-distance passenger transport should go by rail, according to the Commission.

HSR performs very well in terms of market share in corridors of 400-600 km, but not as good with other key parameters that do not reach some minimum threshold to offset the high investment costs associated with the construction of this rail infrastructure. Many lines are heavily subsidized, so high load factors and market shares are compatible with a poor social return. It is not surprising that HSR investment is more popular among politicians and the general public than among economists (Levinson et al., 1997; de Rus and Nombela, 2007; de Rus and Nash, 2007; Nash, 2010).

OPPORTUNITY COST

Investment in infrastructure requires significant public funds. The type of assets invested in transport infrastructure are essentially irreversible and subject to cost and demand uncertainty, so the optimal timing is a key economic issue, since the investment decision can be delayed in most cases (Dixit and Pindyck, 1994). These characteristics give a significant value to the option to invest, which is in the hands of governments that own the land or can expropriate it. In the case of intercity transport, most of the corridors are already in operation and investments in large projects, such as high-speed rail infrastructure, can be viewed as a change in the generalised cost of travelling (time and cost savings, reliability, comfort and safety, etc.) with respect to the prevailing situation prior to the project (de Rus and Nash, 2007; de Rus, 2008).

Figure 1 Time profile of environmental costs and benefits including the period of construction



Efficient solutions for passenger transport

The investment in HSR infrastructure is one of the feasible 'do something' alternatives to deal with transport-capacity problems in intercity passenger corridors, but is not the only one. The economic case for HSR option is more likely when there are capacity constraints in the conventional rail network, roads and airports; and the release of capacity generates additional benefits for freight, long-haul flights and other side effects of the marginal capacity that avoid major investments. Another potential benefit of HSR investment is the reduction of environmental externalities, though this depends on the volume of demand diverted from less environmentally friendly transport modes and whether the demand is high enough to compensate for the negative externalities during construction, the barrier effect, noise and visual intrusion (Kågeson, 2009).

Some critics of HSR investment point to the high investment costs associated with the construction of a new high-speed line. However, the point is not whether the passenger prefers to travel with this technology instead of the conventional modes, nor the high cost of the HSR, but whether society is willing to pay its opportunity cost. This is of course an empirical question and the answer is context-specific. There is nothing intrinsically good or bad about this railway technology and economists do not have any other a priori position with respect to the construction of new HSR lines, beyond the suggestion of the importance of comparing social benefits and costs of the project under consideration before taking any irreversible decision.

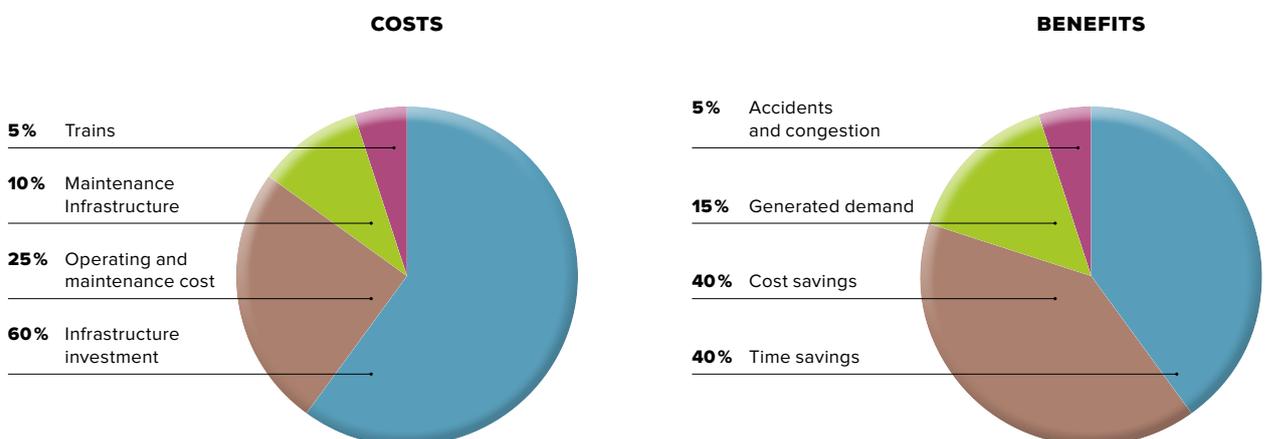
COSTS AND BENEFITS

The direct benefits of HSR in terms of time savings, generated traffic and avoidable costs in terms of competing modes, are usually not enough to compensate for the construction, maintenance and operating costs. The magnitude of direct benefits depends on the prevailing conditions before the project. The benefits also depend on whether there is an upgraded conventional railway able to run above 150 km/h and convenient air services. If this is the case, it is difficult to find a socially profitable investment based exclusively on time savings, generated traffic and cost savings in the conventional modes, unless demand is above 10 million passenger-trips in the first year of operation and grows at a significant annual rate (de Rus and Nombela, 2007; de Rus, 2010).

Investment in HSR modifies the equilibrium in intercity passenger transport. Most of these corridors in developed countries are already in operation and HSR projects entail no more than the introduction of faster trains, changing the generalised cost of travel with respect to the prevailing situation before the project (de Rus and Nash, 2007; de Rus, 2009).

An interesting issue related to intermodal competition in intercity corridors is the asymmetry between the different operators. Although this is case specific, the separation between infrastructure and services that characterises road, bus and air transport puts the airlines at some disadvantage. Vertical unbundling may create some problems for

Figure 2 Costs and benefits of a standard medium distance corridor



NOTE Net present values computed at 5% for a 50-year project life. The size of figures represents actual magnitudes.

the airlines that lose control of the service as a package. In theory, vertical unbundling should not affect the final product supplied in the market but, in practice, this is far from being true, as travel time has a strong component within airports, even where the airlines lose control of the process. On the contrary, high-speed railways operate as if the infrastructure and services were integrated, controlling the access to the station and waiting time in the station. This fact has its consequences in terms of modal split, since access-egress, waiting time, and the disutility of going through congested airports may determine, at the margin, the user's choice.

THE PRICING IMPERATIVE

The construction of a new HSR line in a particular medium distance interurban corridor changes the modal split, and this change will occur regardless of the social value of the HSR project. The final impact will depend heavily on the pricing policy of the government with respect to the railways. The economic evaluation of HSR investment cannot be carried out without first determining what prices are going to be charged for HSR services. This is a key issue in general, but decisive in this case, where the market shares are very sensitive to pricing decisions taken in the public sector that affect the playing ground for intermodal competition. The public pricing decision regarding construction and maintenance costs of HSR infrastructure is crucial to the competitiveness of the railway operators, the intermodal equilibrium and eventually the result of the cost-benefit analysis of new lines. Therefore, this is an issue that the economic evaluation of new projects should not overlook. Investment and pricing decisions are interdependent.

There is considerable pressure on governments to build new high-speed lines as if the investment were a kind of 'now or never' decision. However, this does not seem to be the case with this technology. The construction of HSR infrastructure is irreversible and there is uncertainty associated with costs and demand. Under these conditions, the question as to the right moment to invest is critical, since the investment can be postponed in most cases. Hence, the optimal timing of the investment should be addressed in the case of a positive net present value. Even the idea of 'all or nothing' is false, as it could be profitable to build a line today and another in the future. Moreover, it is feasible to build an HSR rail track on parts of the overall line and use it for traditional trains at the same time as it is prepared for high-speed services that would operate once demand motivates building new tracks on missing links. There exist several 'do something' alternatives.

3.

The environmental impact of HSR infrastructure



Transport affects the environment in numerous ways. The most important parameters are exhaust emissions, noise, and climate change. Land use, including intrusion and barrier effects, may also be important.

Some governments promote HSR believing that it may become an important instrument for curbing CO₂ emissions. They may have listened to environmentalists and interest organisations of the rail sector that claim that HSR is environmentally beneficial, despite high-speed always coming at the price of rising energy consumption. Proponents think that a shift away from aviation, being an even faster mode, will balance any potential negative side effects. Generally, they also believe that substituting car travel with train services is highly beneficial, thus neglecting the impact of such a shift on the emissions from electricity production (Banverket, 2008, UNIFE 2008, UIC 2008).

However, independent research has concluded that the climatic benefits of HSR may not be particularly significant. Studies suggest that the socio-economic benefit of reducing traffic emissions through HSR may typically amount to a small percentage of the overall benefits produced (de Rus, 2008, Nilsson and Pydokke, 2009, Kågeson, 2009).

Pros and cons of high-speed rail

- HSR consumes less energy and emits fewer emissions per seat-km than aviation or cars
- However, the difference compared to road transport is modest when indirect emissions from marginal electricity production are accounted for
- HSR, being a fast mode, generates new traffic
- HSR causes noise, intrusion and barriers

Investigating the environmental pros and cons of HSR requires a number of methodological difficulties to be addressed. One of them concerns how to deal with the long life span of new infrastructure. Comparing the environmental impact of different modes based on today's differences does not make sense as they are expected to diminish over time when all modes become cleaner and more energy efficient. Making estimates of future technologies decades ahead is, on the other hand, hardly feasible. One way around the problem may be to base the assessment of the long-term environmental performance of different modes on what could be expected to be the best available technology in, say, 2025.

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The assumption would then be that these technologies will dominate transport at mid-term of the depreciation period of the new infrastructure and may be taken as a proxy for the environmental impact of a mode over an entire period of 50 years.

Based on this methodology, Kågeson (2009) found that investing in a new 500 km HSR line would result in a net annual reduction of CO₂ emissions of about 9,000 tons per 1 million one-way trips. Traffic on the new line was in this case assumed to consist of 20 per cent of journeys diverted from aviation, 20 per cent diverted from cars, 5 per cent from long-distance coaches, and 30 per cent from pre-existing trains. The remaining 25 per cent is newly generated traffic.

FACTORING IN ELECTRICITY PRODUCTION

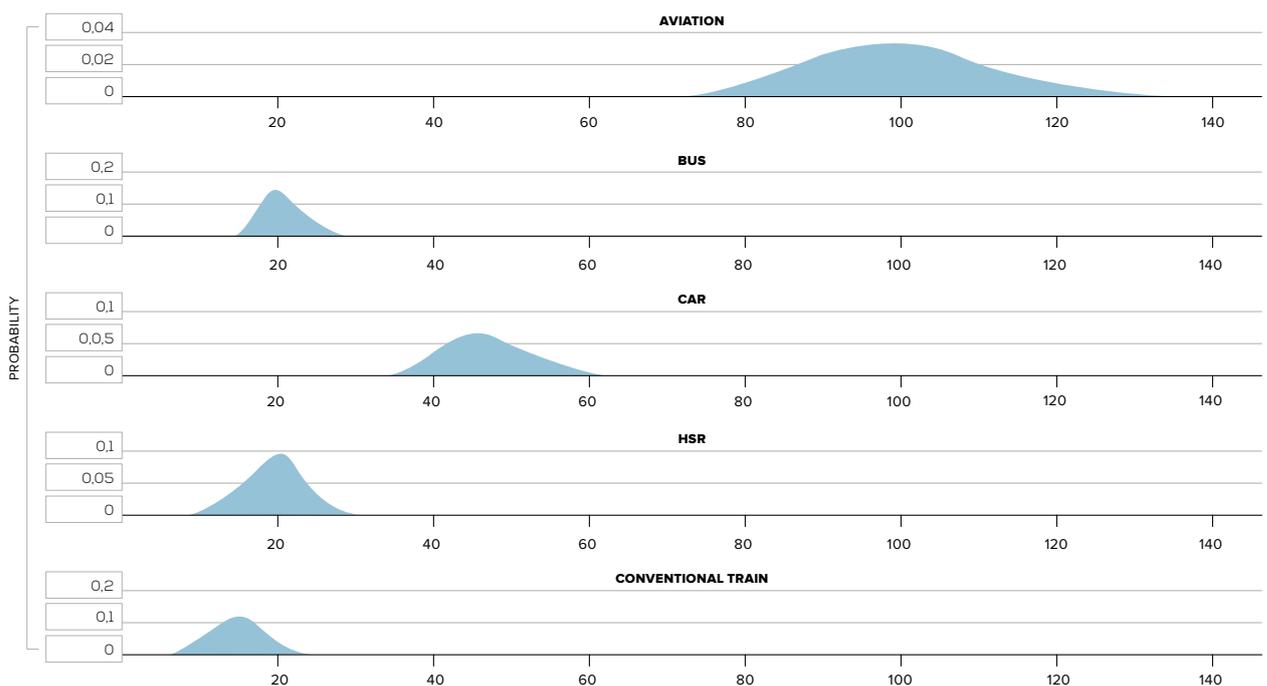
Another methodological problem is how to account for the emissions from the electricity production required for satisfying a growing demand for rail transport. More than 50 per cent of current European power production is based on the combustion of fossil fuels. Under dynamic circumstances, such as when investment in high-speed rail results in modal shift and newly generated traffic, average figures cannot be used for calculating the climate effect.

Instead the marginal effect on emissions of greenhouse gases of rising demand for electricity is what matters. The marginal power production may differ somewhat between countries as well as over the months of the year and between day and night. The differences between national European markets, however, are gradually diminishing as a result of the emerging common electricity market and improved transmission of electricity. Kågeson (2009) assumed the marginal effect of growing demand for electricity in Europe to be on average 530 grams per kWh over the next 50 years.

Even in Scandinavia, where the average CO₂ emissions from power production are less than 100 g/kWh, the average effect on emissions from marginal demand is between 660g and 700 g (Vessia and Byskov Lindberg, 2008; Sköldberg and Unger, 2008). All else being equal, rising demand for electricity will make it more difficult to phase out power plants that burn hard coal or lignite.

In this context, it may also be relevant to note the outcome of shrinking demand for electricity on CO₂ emissions. In the short term, the power plant with the highest variable production cost would be the unit to close first. This will mostly be plants that use lignite or hard coal. Windmills and hydro power stations would not reduce production in a situation of

Figure 3 Simulated emission per passenger-kilometre (g CO₂/passengerkm)



diminishing demand. For this reason, the European Union's Directive on Energy End Use Efficiency and Energy Services (2006/32/EC) recommends that the effect of electricity efficiency improvements should be multiplied by 2.5 to reflect the reduction in primary energy consumption.¹ It would be very strange, indeed, to use marginal figures when demand is shrinking, and average figures in situations of increasing demand.

Based on the above, it is obvious that from a systems perspective a shift from aircraft, cars and buses to electric trains would predominantly reduce demand for kerosene, diesel and gasoline and increase the use of coal and gas.

Some argue that carbon dioxide emissions trading means that taking the marginal effect of electricity production into account has become obsolete. The emissions will not be allowed to exceed the cap of the European Emissions Trading Scheme (EU ETS) no matter how much demand for electricity increases. If so, this is equally true for emissions from aviation, which became subject to the EU ETS in 2012. A shift from aviation to trains following investment in high-speed rail would thus, by definition, have zero impact on the overall emission of greenhouse gases.

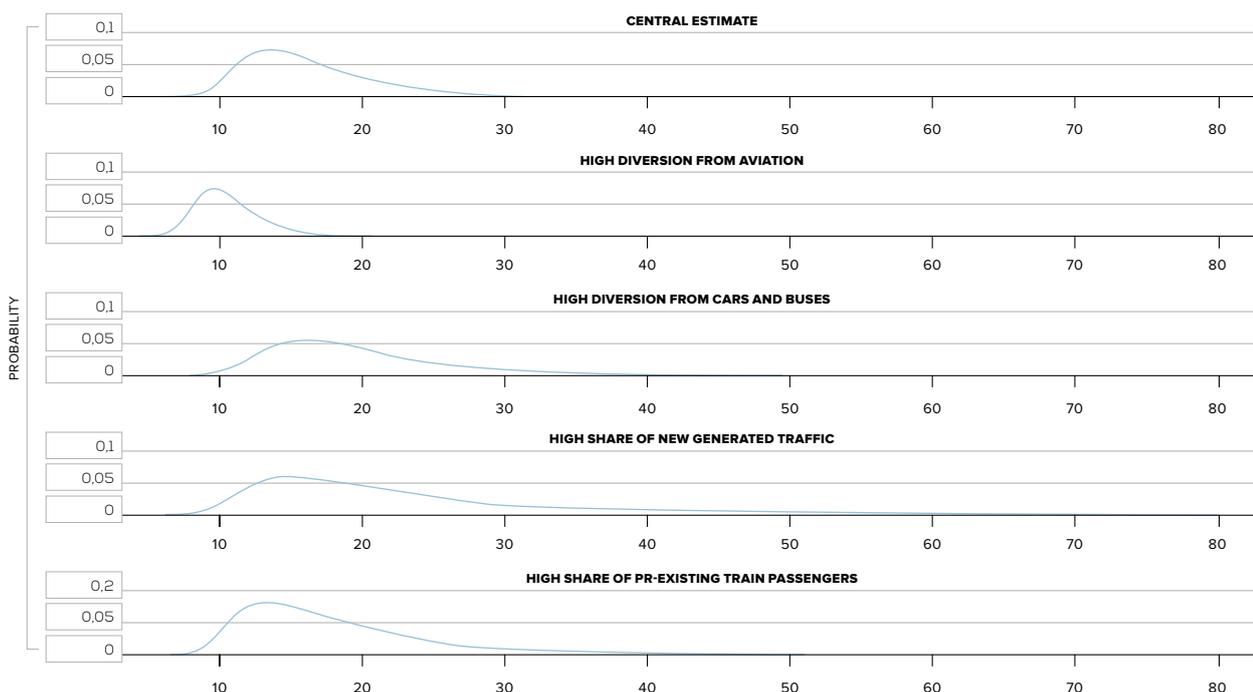
EMBEDDED EMISSIONS

To take account of the fact that airplanes emit several other gases and substances that contribute to global warming, the estimated CO₂ emissions per seat kilometre from aviation may be multiplied by a radiative forcing factor to get a total estimate of the greenhouse gas emissions. The total effect varies with time horizon and altitude. The factor is significantly smaller for short-hauls that do not involve flying at high altitude than for long-distance flights. For a distance of 500 km there are reasons to believe that the value falls within the range of a factor of 1.0–1.3 of the radiative forcing of the CO₂.

The embedded CO₂ emissions from constructing a high-speed link are often substantial, partly because of extensive use of steel and concrete (Network Rail, 2009). For a new investment in high-speed rail to make sense from a climate perspective, these embedded emissions must be offset by the reduction in greenhouse gases that results from traffic shifting from high-emitting modes to rail.

Westin and Kågeson (2012) determined the amount of annual passenger trips and the magnitude of shift from other modes that are required for compensating for the embedded emissions from the construction of a reference high-speed

Figure 4 Million annual trips required for offsetting construction emissions



1. 2.5 equals an electricity efficiency of 40% which is normal in coal-fired condensing power stations.

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rail project, when depreciated over the lifetime of the infrastructure. The specific emission numbers were taken from Network Rail (2009). Since the expected lifetime of the components differ, the embedded emissions were calculated using a steady-state approach where all components were assumed to be continuously replaced and recycled at the end of their lifetime. The authors therefore chose to calculate the carbon annuity based on a 50-year analysis period.

NET CARBON CALCULATION

The size of the net carbon benefit from a future high-speed train link depends on a number of parameters, among them: the energy per seat kilometre needed for moving different vehicles; the carbon dioxide emitted from the combustion of fossil fuels used for vehicle propulsion; the origin of the electricity; the average rate of occupancy for different transport modes; and the distribution of diverted traffic from other modes of transport, newly generated traffic and pre-existing train passengers. The future values of all these parameters are associated with uncertainty.

Westin and Kågeson used a parametric model to calculate the change in CO₂ emissions per passenger kilometre from a person shifting to high-speed rail from another travel mode. To capture the uncertainty of the input estimates, the Monte Carlo simulation was used with a probability distribution over likely future values of each parameter. In the simulation, the change in emissions per passenger kilometre and the resulting net emissions for five scenarios were calculated using random draws from the parameter distributions. The process was repeated a million times until stable simulated distributions for the resulting net emissions were obtained for the competing transport modes.

Westin and Kågeson focus on a few parameters for which the choice of value is highly influential. These are: the marginal electricity production; the total radiative forcing factor of short-haul aircraft; and the assumed occupancy rate of the various vehicles and vessels. Assumptions on how generated traffic is attributed to shifts from other modes and on newly generated traffic are also important. The central values for all other parameters were taken from Kågeson (2009). The highest and lowest values in the distributions were selected in order to provide estimates that significantly differ from the central value without being completely unrealistic.

The analysis shows that in order to balance the annual emissions from high-speed line construction, traffic volumes of more than 10 million annual one-way trips are usually required. It is only in a case of high diversion of passengers from aviation in combination with low CO₂ emissions from

the marginal electricity production that substantially fewer trips suffice (but still in the order of 7 to 9 million trips).

NOISE CONSIDERATIONS

Problems associated with noise from vehicles and vessels are location-specific. It is therefore difficult to calculate average noise costs for different modes. However, a few general observations can be made. Intercity journeys by car or bus usually take place on motorways or other high-quality roads that allow speeds of 90 km/h or more. These roads are often built so as to avoid crossing through minor towns and other settlements. That means fewer people are victims of such noise compared to noise from traditional railway lines, which were often designed to go through the heart of towns. However, new high-speed lines may avoid crossing through smaller towns where no stop is made anyway.

A 50 per cent future reduction of external noise from road vehicles, trains and aircraft appears to be technologically possible. Additional improvement can be achieved by using noise-absorbing road surface materials or installing absorbents close to the railway track. Shielding by noise-protection walls may significantly reduce the impact, but only relatively close to the barrier. People living further away will be affected by the diffuse background noise that barriers cannot stop. Where aviation is concerned, the only way of shielding is by improved insulation, particularly of windows.

The noise created by large carriers amounts to less per passenger kilometre compared with an equally high-decibel sound from a smaller vehicle or vessel. Trains that can seat hundreds of passengers therefore create less noise per passenger kilometre than cars even when making much more noise when passing by. However, on motorways, trucks are the dominant source of noise. The marginal contribution of an additional car to an already busy highway is minimal.

The conclusion is that the social marginal cost caused by traffic noise cannot be included in a generalised comparison of the different modes. A shift from one mode to another may increase or decrease the impact of noise on human health depending on local circumstances.

LAND USE AND INFRASTRUCTURE

The use of land and the impact on landscape is also to a large extent site-specific. However, some general observations can be made. Aviation, for obvious reasons, consumes much less land per passenger kilometre than other passenger transport modes. An additional flight generally does not cause any extra damage in this sense, while growing traffic

volumes may, after a while, require an additional runway or even a new airport.

Intercity traffic by car, bus or traditional intercity trains share infrastructure with vehicles bound for other destinations and to some extent with local traffic. The marginal impact on land use is usually zero. It is only when congestion calls for additional infrastructure capacity to be built that more intercity traffic will make a difference. If new capacity is created simply by adding a new lane or track, the marginal effect on land use is limited and no new barrier is formed (Kågeson, 2009).

Introducing high-speed trains where no previous infrastructure for such trains exists requires a new railway especially designed for this type of traffic. High-speed traffic necessitates a layout with large radius curves and limited gradients. The horizontal curve radius must be at least 5.5 kilometres to accommodate speeds of 300 km/h, and should ideally not be less than 7 kilometres (UIC, 2008). For these reasons, high-speed lines are often built in new corridors although partial location within existing railway or motorway corridors is sometimes possible. This means new land is occupied and new barriers are created.

OTHER CONSIDERATIONS

Regulated exhaust emissions occur from all types of internal combustion engines as well as from the combustion of fossil fuels and biofuels in power plants. The tailpipe emissions from cars and buses have been drastically reduced over the last two decades and will continue to decline. Within 10-15 years, new vehicles may be expected to emit so little that the aggregated impact from the entire new fleet would be almost negligible.

The marginal electricity used by trains is usually produced in coal-fired power plants, and some of them still emit huge quantities of sulphur, particles and NO_x. However, by 2025 the dirty power plants will either have been decommissioned or have had to clean up their operations. Therefore, in the longer term, the regulated emissions from power plants will also have been reduced to sustainable levels. Thus, with respect to exhaust emissions, any remaining differences between the modes are likely to be small and the impact on such emissions from modal shift could be expected to be insignificant.

An aspect not considered above is the possibility that, in the absence of investment in high-speed lines, growing demand for rail services would require investment in other kinds of additional capacity where construction would also affect climate change. However, there may also be other types of responses to a growing imbalance between supply and

demand that give rise to fewer emissions, e.g., congestion charges and incentives to improve the utilisation of inland waterways and/or short-sea shipping routes, and the partial replacement of business travel by telecommunication.

Building a completely new high-speed line means traffic will be diverted from the pre-existing rail network. Thus excess capacity on the old tracks may be allocated to other types of trains. However, for this to happen there must be demand for transport by rail that could previously not be met for lack of capacity. A further shift from road to track would, of course, reduce the overall climatic impact of passenger and freight transport.

THE CASE OF SWEDEN

Åkerman (2011) believes that it would be possible within five years of the creation of HSR corridors in Sweden to more than double freight transport by trains in the otherwise congested pre-existing railway system. However, before taking this as a reason for investing in an otherwise unprofitable high-speed rail line, there is cause to investigate whether capacity problems in the rail freight sector can be overcome by other, less expensive measures. Improved signalling systems and investment in passing siding may substantially increase the capacity of existing track (Nilsson and Pydokke, 2009). Another option, in the case of Sweden, may be to increase the average length of the country's freight trains, which by international standards are rather short.

A third measure in Sweden could be to level the playing field by enforcing the same principle of liability for external costs on all modes. Currently, short-sea shipping is restrained by the enforcement of fairway dues on all ships calling at Swedish ports, and these fees recover not only the short-term marginal costs, but also the fixed infrastructure costs. Freight trains, on the contrary, enjoy the European Union's lowest track fees that do not even cover the short-term marginal cost, much less the costs associated with expanding the infrastructure. Levelling the playing field implies reducing the fairway dues and raising the track fee for trains as well as introducing kilometre-charging on heavy trucks (Kågeson, 2011).

In other countries, alternative solutions may be more relevant, for instance increasing the use of inland-waterways or pipelines. EMS* combinations fuelled by grid electricity might be an option in regions where the motorways are not overcrowded.

From a climate as well as an overall point of view, there is cause to consider whether the objectives of heavy investment in new transport infrastructure can be reached

* European Modular System (EMS) according to Directive 96/53/EC

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by measures that imply using fewer resources. For precisely this reason, the Swedish government requires the four-stage principle to be applied in the assessment of all proposed new infrastructure projects.² The Swedish Transport Administration must carry out its assessment of potential projects in the following four steps:

- 1 Measures that affect transport needs and choice of transport mode;
- 2 Measures leading to more efficient utilisation of the existing network;
- 3 Minor investment in road or track improvement;
- 4 Major investment in new capacity. If the first steps are sufficient in providing the required capacity, the fourth step should not be considered.

Conclusions

- HSR is likely to reduce greenhouse gases from traffic
- The reduction is modest and it may take many decades for it to compensate for the emissions caused by construction
- Traffic noise is likely to increase as passengers shift from aviation and road transport to HSR
- A new HSR line will cause intrusion and barriers which, depending on local circumstances, may be more or less serious

4.

Intermodal effects, pricing and investment assessment



Medium-distance intercity corridors (around 500 km) with road, air and rail transport in open competition have a modal split equilibrium that is very sensitive to small changes in the generalised prices of the alternative modes of transport. The differences between these modes of transport are quite obvious, but they have several things in common. On the supply side, they all need infrastructure to provide services combining vehicles, labour and energy under private or public ownership, with infrastructure and operations vertically integrated or unbundled; on the demand side, they all involve a transport service carrying passengers who have to pay different generalised prices in terms of money, time, quality and safety.

Air, maritime and road transport are vertically unbundled and different operators use a common infrastructure, sometimes with free access and sometimes with payment of an access fee. Usually the operators are private and the infrastructure is public or privately operated under a concession contract. Road, air and maritime transport services are vertically separated from the infrastructure operator, and railways are unbundled in some cases and vertically integra-

ted de facto in the case of high-speed trains operated by a single firm with the exclusive use of dedicated infrastructure. Buses and cars share the same roads, competing airlines share airports and high-speed rail is technically operated as a single business, even if, from an organisational standpoint, the maintenance and operation of the infrastructure are separated from service operations.

HSR has other advantages over airlines beyond vertical integration (with subsidized prices), reflecting some structural differences. Airports and airlines would still serve a large number of markets using the same airport capacity, and it is not clear that airport congestion management would be better with vertical integration. The HSR advantage in this case is that capacity is used to serve a very small number of markets (O-D pairs), and this makes it possible to reach very high levels of reliability.

These differences on the supply side have a significant impact on the demand side. The vertical integration of infrastructure and operation in the case of HSR is a significant advantage with respect to air transport in terms of the generalised costs of travel. HSR is more reliable than air transport, and access and waiting time much less cumbersome. Airport and airlines managers do not necessarily have the same objectives and, as a matter of fact, the generalised cost advantage of HSR lies outside the travel-time segment of the trip. In the case of roads, the differences are even clearer. Road infrastructure and operations are vertically separated. In contrast with the single operator of HSR, there are many users driving their own cars with free access (sometimes paying a toll) to a limited-capacity infrastructure. Road transport has the advantage of reducing access and waiting time to almost nothing and the cost disadvantage appears in the travel-time segment.

Time savings are not the only consequence of HSR investment. The reduction in the generalised cost of travel generates new trips, and the diverting of traffic from other modes of transport may contribute to a reduction in congestion, accidents and environmental externalities. Unfortunately, the net impact on the alternative modes is not necessarily positive. The reduction in congestion is one effect on those who continue to use the previous mode of transport, but the reduction in operations in response to lower demand volumes negatively affects the adjustment to travel preferences of those users.

GENERALISED COST

The generalised cost of travel includes three basic components: time, quality and money, with "quality" understood in a broad sense to include comfort and safety. The

² However, this principle was not observed by a recent Swedish government committee that investigated the feasibility of two high-speed railway lines.

time component is far from being homogeneous. It includes access-egress, waiting and in-vehicle time. In medium-distance corridors like the ones evaluated in de Rus (2012), we have seen how close the time component may be between HSR and the alternatives, and this concedes a key role to the pricing policy of the public sector regarding the access to HSR infrastructure.

Investment in HSR changes the equilibrium in the inter-urban corridor through its impact on the generalised cost of rail travel. Compared with conventional rail, HSR services barely affect access, egress and waiting time. The main impact is on travel time with a magnitude depending on the prevailing operating conditions of the conventional rail. Passengers shifting from road transport benefit from travel-time reductions but lose in terms of access, egress and waiting time. Those shifting from air transport may benefit from lower access-egress and waiting time, but lose in terms of in-vehicle time. When the whole door-to-door time is considered and weighted with the values of the time of each component, we have found that, given the actual differences in the time-cost component, the modal choice may be highly dependent on the money component.

Moreover, not all travellers want or need to go from city centre to city centre. They may have points of departure and/or destination that are in a suburb, which, together with other circumstances such as personal cargo and number of persons travelling together, may make it reasonable for them to travel by car.

According to de Rus (2012), some consequences of pricing on modal split and eventually on the social profitability of HSR projects. In some cases, the generalised cost is lower for HSR compared with the air alternative, though the total value of travel time is higher. The price component explains the negative differential in the generalised cost. In other words, the average user loses time benefits with the change, but he is compensated with taxpayers' money. This is apparently the case in some corridors where the differential in the generalised costs is quite low, which indicates that the success of HSR in competition with air is dependent on the low prices charged by the railways in the corridor. This also leaves the problem of intermodal competition and pricing unresolved.

SOUND PRICING POLICY

It seems clear (equity issues aside) that for the user's choice to be socially optimal, prices should reflect the opportunity costs of his choice. Efficiency requires a sound pricing policy that not only allows the transport user to choose the

best option within a transport mode, but also when choosing between air, rail or road transport.

Let us assume that supplier-operating costs and external costs are already included in the generalised cost. How much should a rail operator be charged for the use of the infrastructure under particular time or demand conditions? In principle, the answer is the 'marginal social cost' of running the train in that particular situation. Given the presence of economies of scale, significant indivisibilities and fixed and joint costs, pricing according to marginal social costs is far from being an easy task.

Charging according to short-run marginal cost is incompatible with cost recovery when the infrastructure rail network is built and there is excess capacity, as is the case with some HSR lines in Europe. Some critics argue that the natural alternative is long-run marginal costs. Short-run marginal cost is equal to the change in total costs when new demand is added, given a constant network capacity. Long-run marginal cost accounts for the change in total cost allowing for an optimal adjustment of capacity.

Long-run and short-run marginal costs are equal assuming perfect demand forecasting and perfect divisibility of capital, but both assumptions are unrealistic in transport and the consequences of choosing a pricing principle are quite important in practical terms. In the case of HSR investment, short-run marginal cost pricing means prices below average costs and the need for public funds to cover infrastructure costs (see Rothengatter, 2003; Nash, 2003).

With a fixed capacity, any additional demand willing to pay in excess to the additional cost imposed on the system increases welfare. In the extreme case, when capacity is well above demand (forecasting error, indivisibilities or both), short-run marginal costs can be very low compared to average cost. Many argue that passengers should only pay the short-run marginal costs, but there are other reasons to charge above the strictly avoidable cost. The first reason is the problem of financing the infrastructure costs. Additional taxation needed to cover the gap has an additional cost in terms of the distortion imposed on the rest of the economy. The second is related to incentives, as subsidization usually reduces effort to minimize costs. Another drawback comes from the way in which capacity costs are covered, as users only pay variable costs and non-users pay capacity costs. In addition to the equity side (it is difficult to think of HSR passengers as equity targets), we face a dynamic efficiency question: are users willing to pay for capacity? In the corridors where this is not the case, the government would be providing more capacity than optimal.

Efficient solutions for passenger transport

SHORT-TERM MARGINAL COST

The consequences of charging according to the short-run marginal cost on the expansion of HSR lines are significant. Low prices favour the reallocation of demand from the competing modes and encourage demand generation, with a feedback on the future expansion of the network. Pricing according to short-run marginal cost leaves a key question unanswered: are rail users willing to pay for the new HSR capacity? Unless this question is answered before investment decisions are taken, marginal-cost pricing is not a guarantee for an efficient allocation of resources.

The social marginal cost of a passenger trip by a particular mode of transport, in a particular place and time, has three different parts: the user marginal cost (user cost and the share of the producer cost, including infrastructure and vehicles), the cost to other users and the rest of society (congestion, external cost of accidents and environmental externalities) and to taxpayers (the share of the producer cost that has been subsidized).

In many lines, HSR revenue is far from covering total costs. It might be argued that economies of scale and strong indivisibilities justify the deficits, but the question is whether users would be willing to pay for the HSR infrastructure before new lines are built. HSR prices act as signals that transport users take as key information for their decisions on where, how and when to travel, or even whether or not to travel.

When infrastructure costs are not included in transport prices, according to the rationale of short-term marginal social cost, the problem is that the price signal is telling consumers that it is efficient to shift from road or air transport to rail transport. This, of course, could be true in the short-term when optimal prices are not affected by the fixed costs of the existing HSR network, but the world is dynamic.

The problem is that prices that do not include fixed infrastructure, which act as long-term signals for consumers in their travel decisions, and consequently in the future allocation of resources between transport modes or between transport, education or health. An extensive HSR network can be developed based on suboptimal prices decided by the government that are not linked to the opportunity costs of its existence, but once the network is built, bygones are bygones, and speculation on the counterfactual with a different allocation of resources and their effect on welfare is not very useful.

The role of cost-benefit analysis in these circumstances is important. Even if we accept that short-term marginal cost is the right pricing policy, investing in a new HSR line would

require that the willingness to pay for capacity be higher than the investment costs or any other demand unrelated to cost during the lifetime of the infrastructure. This does not solve the problems of fair competition between different transport modes or the equity issue of taxpayers paying HSR fixed costs, but at least it puts a filter on the most socially unprofitable projects.

Given the record of economic evaluation of projects in Europe, cost-benefit analysis provides no guarantee against the construction of white elephants. It is therefore crucial to examine the institutional design under which the investment decisions are taken.

5.

Public funding of transport infrastructure in Europe

National and supranational governments support the implementation of this new rail transport technology with public funds. To understand the impact of this public support on investment decisions, it is useful to distinguish between two levels in the process of funding major infrastructure projects. The first relates to the institutional design, in which supranational and national governments (or national and regional governments) agree on the projects to be financed. The second is related to the selection of contracts for the construction and operation of the infrastructure. This level includes the relationship between the national (or regional) government benefitting from the project and the operator(s) responsible for the construction and operation of the project.

The co-financing system in the EU is the so-called "funding-gap" method consisting of a type of cost-plus financing mechanism in which the difference between the investment costs and the discounted revenues (net of operating costs) of the project are partially covered by the supranational organisation. The European Commission finances a percentage (the co-funding rate) of this financial gap. The incentive embedded in this mechanism is perverse, since the subsidy increases with total investment costs and decreases with net revenues. This financing mechanism penalizes the internalisation of externalities and congestion, leads to excessive demand and biases the capacity size and the choice of technology.

The fixed cost/total cost ratio in HSR projects can be 50 per cent or higher (Campos et al., 2009), so these projects are always candidates for supranational funding. In a world of perfect information, the supranational agency would

maximize social welfare by forcing the national government to exert the maximum level of effort, thereby minimizing project costs and introducing marginal social cost pricing. In the real world, efforts and marginal costs are not observable and the behaviour of the national government will respond to the incentives of the financing mechanism.

With the present funding gap mechanism (as with any other cost-plus financing system), it is costly to be efficient. Governments have no incentive to minimize investment costs or to introduce optimal pricing. There is a bias in favour of expensive, latest technology mega-projects and pricing will depart from user-pays or polluter-pays principles, since the higher the price for the use of the new national infrastructure, the lower the consumer surplus of voters will be, and the lower the probability of re-election. Consequently, the politician will choose maximum number of users and will not charge for the external costs.

The evidence supports these conclusions. It is remarkable that member countries have promoted the construction of some HSR lines when the demand was too low to pass a strict cost-benefit analysis, as well as other transport infrastructure such as roads or ports. An ex post evaluation of a sample of projects co-financed by the Cohesion Fund in the period 1993-2002 concludes that national governments have been focusing primarily on timely commitment of the available funding, paying less attention to the technical content and economic priority of projects (ECORYS Transport, 2005). The evaluations generally fail to assess the quantitative contribution of the project to the declared objectives. Problem descriptions and analyses are sometimes lacking.

Moreover, it was generally impossible to determine whether projects were technically sound, and this deficiency led to problems such as improper designs; technical changes after the project was approved but before construction was started; late changes to design/tender dossiers; late beginning of implementation; cost overruns due to additional activities for the contractor, who was then in a good position to claim additional payment; longer implementation periods than foreseen; and too many requests for extension of the implementation period. The document concludes that, “the evaluators have found only pragmatic criteria for the co-financing rate. In addition, some basic dilemmas exist between general policy objectives and the rules applied for calculation of the co-financing rate. In particular, the polluter-pays principle is only partially adopted since increasing user charges is discouraged by the present system of determining the co-financing rate” (ECORYS Transport, 2005).

FIXED-PRICE MECHANISM

These disappointing results are not completely unexpected. As we have already discussed, national governments are in general better informed than supranational planners about the costs and benefits of the infrastructure projects to be constructed in their own regions, and they do not necessarily share the same objectives. Governments may have incentives to manipulate project evaluations in order to obtain more funds from the supranational planner. In a context of asymmetric information and different objectives, the relationship between national governments and supranational planners cannot be modelled in a conventional cost-benefit analysis framework.

The existence of information asymmetries and conflicting interests requires a different approach in which incentives are explicitly accounted for. Florio (2006) proposes to move away from the current low-powered incentive EU co-financing mechanism, essentially a partial reimbursement of investment cost scheme, towards a more incentive-based system.

As argued in de Rus and Socorro (2010), a fixed-price financing mechanism may provide the necessary incentives to reduce costs and charge the socially optimal price. Moreover, with the funding-gap method, cost-benefit analysis is simply a bureaucratic requirement to enable national governments to obtain supranational funds. However, with the fixed-price financing mechanism, cost-benefit analysis is a very useful tool for governments to allocate the supranational funds in the most efficient way.

The fixed-price mechanism, in this context, is an ex ante fixed quantity of external funding unrelated to costs or revenue. The idea of the fixed-quantity financing mechanism is to make national governments responsible for insufficient revenue and cost inefficiencies, since they receive a fixed amount of funding and are the residual claimants for effort. The incentive to introduce optimal pricing is now high as the costs of inefficient pricing will also be suffered by the politician.

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6.

Conclusions

Consumer preferences and producer costs reflected in market competition between firms and modes of transport, subject to the minimum regulation required both to internalize externalities and guarantee a basic level of accessibility, are far from being the only forces shaping transport networks in the years to come. Deregulation of transport services has not meant the end of government intervention. Infrastructure construction with public funds and price regulation can exert a remarkable influence on the future form of interurban transport corridors. Whether the future networks are the best option is difficult to answer a priori but there are some indications that this might not be the case.

The high-speed rail investment decisions taken and the subsequent infrastructure pricing policies set by the public sector have a profound impact on the allocation of resources in the transport sector and the rest of the economy. It seems obvious that high-speed rail infrastructure is an appropriate option for some corridors, but a very expensive one in low-traffic areas where alternative modes of transport can satisfy demand at much lower cost.

All over the world, investment in high-speed rail infrastructure has dramatically modified the position of the railway within the set of transport alternatives the passenger faces in his travel choices. Although the decline of the market share of railways has not changed, high-speed trains have contributed to a substantial recovery in rail market share in medium distance corridors where they compete with road and air transport.

High-speed rail generates social benefits, which come from time savings, increased reliability, comfort and safety, and the reduction in congestion and accidents in alternative modes. Releasing capacity in the conventional network, which can be used for freight transport, is an additional benefit of the investment in the construction of new lines.

Investment in high-speed rail is likely to reduce greenhouse gases from traffic compared to a situation where the line is not built. The reduction, though, is small and it may take many decades for it to compensate for the emissions caused by construction. In cases where anticipated journey volumes are low, it is not only difficult to justify the investment in economic terms, it is also hard to defend the project from an environmental point of view. Under such circumstances, it may be better to upgrade an existing line to accommodate somewhat higher speeds as this would minimize emissions from construction and reduce emissions from train traffic compared to HSR.

Traffic noise is likely to increase marginally as passengers shift from aviation and road transport to HSR. Building a new high-speed railway line will cause additional intrusion and barriers, which, depending on local and regional circumstances, may be more or less serious.

KEY QUESTIONS

There is no cause to refrain from investing in HSR on environmental grounds so long as the carbon gains made in traffic balance the emissions produced during construction and the noise and intrusion caused by the new line are not significant. However, investment in infrastructure for modal shift should only be considered when traffic volumes are high enough to carry the cost. The principal benefits of high-speed rail are time savings, additional capacity and generated traffic, not a reduction in greenhouse gases.

The key question is to determine whether these social benefits are greater than the costs incurred by society due to the construction and operation of high-speed lines. In other words, the question is not whether we like high-speed rail or not, but whether we are willing to pay its costs.

Why have some countries decided to invest in HSR? This last question leads directly to the institutional design and set of incentives of each country. This is really important in practical terms, because the public nature of these investments, along with the separation of decision-making and financing, as happens to be the case in the EU with the co-financing of HSR projects, can explain investment decisions that would not have been taken without supranational funding. A similar game is played between national and regional governments in countries where these projects are supported by the national budget.

It is convenient to reinforce the role of the economic appraisal of new high-speed rail projects, co-financed with European Union funds, instead of using the rhetoric of regional development to support the expansion of the network. High-speed rail infrastructure is not good or bad in global terms. There are socially profitable projects and others which are not. Economists can help to identify those projects which are socially worthy and whose benefits justify the sacrifice of leaving other social needs unattended. This research project hopes to contribute to this aim.

THE CHALLENGE

The challenge is to design an institutional framework that helps to find the best options for society, beyond the special interests of industry groups and politicians. To reinforce the use of cost-benefit analysis as a requirement for approving new infrastructure is clearly insufficient. Because of asymmetries of information and conflicting interests, there is a need for a new incentive mechanism that will help overcome the current situation in which the member country-supranational government relationship (or that of regional and national governments) creates a bias in favour of the most expensive and modern technology over more efficient and less expensive solutions, new construction over maintenance and upgrading, and free access over the introduction of efficient pricing based on the polluter-pays and user-pays principle.

There is a dynamic aspect worth considering. Socially profitable or not, once the HSR infrastructure is built, the fixed costs are sunk, and this irreversibility affects more than half of the total costs (even higher for low density lines). Once the line is built, the marginal cost of additional traffic is quite low compared with the ex ante marginal cost. Prices much lower than total average costs are common for many HSR lines around the world, fostering demand and the expansion of a network in regions or countries where there were better transport solutions for their accessibility and mobility needs.



References

Åkerman, (2011), "The role of high-speed rail in mitigating climate change – the Swedish case Europabanan from a life cycle perspective". *Transportation Research Part D: Transport and Environment* 16, 208–217.

.....
Banverket, (2008), Svenska Høghastighetsbanor. Banverket Rapport 2008-005-30, Borlänge, Sweden. (National Rail Administration).

.....
Campos, J., G. de Rus and Barrón, I. (2009), "The Cost of Building and Operating a New High Speed Rail Line" in G. de Rus (eds.) *Economic Analysis of High Speed Rail in Europe*. Fundación BBVA.

.....
de Rus, G. (2008), The Economic effects of high-speed rail investment, OECD-ITF Transport Research Centre. Discussion Paper, 2008-16. OECD, International Transport Forum, Paris.

.....
de Rus, G. (2009), Interurban passenger transport: economic assessment of major infrastructure projects. 18th Symposium on Transport Economics and Policy. Joint OECD ITF Transport Research Centre. Discussion Paper n° 2009-18.

.....
de Rus, G. (2010), "The BCA of HSR: Should the government invest in high speed rail infrastructure?". *The Journal of Benefit-Cost Analysis*, 2 (1).

.....
de Rus, G. (2012), *Economic evaluation of the high speed rail*. The Expert Group on Environmental Studies. Ministry of Finance, Sweden.

.....
de Rus, G. and C.A. Nash (2007), In what circumstances is investment in high-speed rail worthwhile?, Working Paper 590, Institute for Transport Studies, University of Leeds.

de Rus, G. and G. Nombela (2007), "Is investment in high speed rail socially profitable?", *Journal of Transport Economics and Policy*, 41 (1): 3-23.

de Rus, G. and M.P. Socorro (2010), "Infrastructure investment and incentives with supranational funding", *Transition Studies Review*, 11 (17): 551-567.

Dixit, A.K. and R.S. Pindyck (1994), *Investment under uncertainty*, Princeton University Press.

ECORYS Transport (2005), Ex post evaluation of a sample of projects co-financed by the Cohesion Fund (1993-2002), Synthesis Report for the European Commission, DG Regional Policy.

European Commission (2011), *White Paper. Roadmap to a Single European Transport ACEA*. Brussels, 28.3.2011.

European Commission (2009), The future of transport, Focus Groups' Report, Brussels.

Kågeson, P. (2009), Environmental aspects of inter-city passenger transport. In: 18th International Transport Research Symposium, Madrid, November 16–18, OECD/ITF Discussion Paper No. 2009/28, OECD, International Transport Forum.

Kågeson, P. (2011), Vad skulle likabehandling av alla transportslag innebära för kustsjöfarten, miljön och behovet av infrastrukturinvesteringar? CTS Working Paper 2011:14. Centre for Transport Studies, Royal Institute of Technology, Stockholm.

Levinson, D., J.M. Mathieu, D. Gillen and A. Kanafani (1997), "The full cost of high-speed rail: an engineering approach", *The Annals of Regional Science*, 31: 189-215.

Mackie, P. and J. Preston (1996), *The local bus market: A case study of regulatory change*, Avebury.

Morrison, S.A. and C. Winston (1995), *The evolution of the airline industry*, The Brookings Institution, Washington, D.C.

Morrison, S.A. and C. Winston (2005), "What's wrong with the airline industry? Diagnosis and possible cures", Hearing before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, United States House of Representatives.

Nash, C.A. (1993), "British bus deregulation", *The Economic Journal*, 103 (419), pp.1042-1049.

Nash, C. A. (2003), "Marginal cost and other pricing principles for user charging in transport: a comment", *Transport Policy*, 10 (2): 345-348.

Nash, C.A. (2010), Enhancing the cost benefit analysis of high speed rail. Paper given at the symposium on the environmental and other co-benefits of developing a high speed rail network in Berkeley California.

Network Rail,(2009), Comparing Environmental Impact of Conventional and High Speed Rail. Network Rail, London.

Nilsson, J.E., Pyddoke, R. (2009), Höghastighetsjärnvägar – ett klimatpolitiskt stickspår. Report to the Expert Group for Environmental Studies 2009:3. Swedish Ministry of Finance, Stockholm.

Preston, J. (2004), *The deregulation and privatisation of public transport in Britain: twenty years on*, Transportation Research Foundation.

Rothengatter, W. (2003), "How good is first best? Marginal cost and other pricing principles for user charging in transport", *Transport Policy*, 10 (2): 121-130.

Sköldberg, H., Unger, T. (2008), Effekter av förändrad elanvändning/elproduktion – Modellberäkningar. Elforsk Report 2008:30, Elforsk, Stockholm.

UIC (2008), *High speed rail. Fast track to sustainable mobility*. Union Internationale des Chemin de fer, Paris.

UNIFE (2008), More rail = Less CO₂. The European Rail Industry.

Vessia, Ø., Byskov Lindberg, K. (2008), Vi lavere kraftforbruk i Norge gi lavere CO₂ – utslipp fra europeisk kraftproduksjon? Published in *Kvartalsrapport for kraftmarkedet 1 kvartal 2008*, Norges vassdrags- og energidirektorat, Oslo.

Westin, J., Kågeson, P. (2012), Can high speed rail offset its embedded emissions? *Transportation Research Part D* 17 (2012) 1–7.



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