Sustainability of HSR-Comparative Study

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Abstract. There has been an increasing need for a sustainable High-Speed Railways (HSR) as a result of the rapid increases in world population coupled with a growing global trade of goods over long distances. The transport industry is 95% dependent on fossil fuel and therefore is responsible for the majority of Greenhouse Gas (GHG) emissions. The HSR can move passengers and goods quickly, safely and cost-effectively in the most sustainable way. However, there is a need to consider the objectives of the development of HSR systems and analyse the eventual public benefits in order to minimise the economic risk. Currently, there are three major HSR systems in the development stages, namely; Rail Baltic, Californian HSR (CAHSR) and High Speed railway-2 (HS2) in the UK. This research paper investigates the benefits of investment in these three projects and evaluates possible consequences and expected outcomes. It considers the key influencing factors of the HSR sustainability such as changes in population, density of population, ability to pay, type of energy that will power the HSR and the existing railway networks. The expected outcome of this research will contribute to better understanding of the drives for demand of railway services and evaluate economic, social and environmental sustainability of the Rail Baltic, the CAHSR and the HS2.

Keywords: HSR, Sustainability, Emissions

1. Introduction

The high cost of developing railway infrastructure and related environmental issues mean that it is important to carefully compare and evaluate the proposed development to fully understand the key drives for demand of railway services and to evaluate the economic, social and environmental sustainability of the project. According to Bueno et al. (2017) there is a necessity to evaluate the entire life-cycle environmental impact of developing HSR. The reduction of carbon dioxide emissions from developing HSR depends on the future passenger demand which must be over 10 million passengers annually, on the amount of diverted traffic from other modes and on how extensively tunnels will be used. HSR will lead in reducing the environmental impact only after the deficit associated with building HSR infrastructure is compensated. Bueno et al. (2017) pointed that for CAHSR, carbon dioxide emissions can be balanced between 6 to 20 years of service depending on the level of train occupation. HSR lifetime is estimated to be 60 years, but following the EU vision (European Commission, 2013) it seems that over this time the road transport will be electrified and power production will be gradually decarbonized. Because of these changes, it is uncertain how much carbon footprint reduction can be achieved from developing new HSRs in Europe.

Kamga (2015) found that since 2004 in USA the number of miles in vehicle per capita gradually fell, but there was a growing demand in public transportation, increases in rail and bus ridership. This was partly linked to the increased travel time by air due to the tightening of security at airports, increased congestion at airports and roads, and the wide spread of digital technologies. Wang et al. (2017) concludes that CAHSR will improve the mobility and accessibility and will change the current urban and regional transportation systems. Matute and Chester (2015) highlighted that there is a continuous uncertainty surrounding the future of CAHSR, and to achieve the reduction of carbon dioxide emissions there is a necessity to have a substantial shift from other modes of transportation to CAHSR. Bueno et al. (2017) and Nash (2015) pointed that the size of the catchment area and large populations are crucial for HSR. To be successful, HSR needs to connect megapolises such as Tokyo-Osaka, Paris-Lyon, Beijing-Shanghai or link in a chain a few large cities. Bueno et al. (2017) conclude that arguments such as GHG reduction and energy savings cannot be crucial in decisions in developing HSR, as environmental benefits may not be cost-efficient.

Cornet et al. (2017) admit that there will not be any carbon dioxide emission reduction until HS2 is opened, but even then, there will be uncertainty about the level of modal shift and the level of freight and passenger demand. The total global environmental costs will be increased, but the local environmental costs will be reduced. For instance, Nash (2015) noted that significant factors that influence the cost of a project and carbon dioxide emissions are the length of tunneling that is needed for the HSR. The major issues of developing new HSR lines are environmental impact, such as GHG footprint from infrastructure construction, noise, land taking and visual impact. Cornet et al. (2017) report that the construction of HSR not only affects the global climate, but also destructs the local environment. Nash (2015) concluded, that due to the limited number of access points to HS2 the total journey distance is likely to be longer which will increase the total carbon dioxide emissions.

There are few key factors that attract commuters to HSR and Nash (2015) pointed out some of them. They are journey time and HSR fares. HSR fares are competitive with airlines, but much higher than that of using a bus. Tomes (2017) noted that ridership of HSR is related to the levels of employment in the country. Willingness to pay to use HSR services is lower in low-income countries. Nash (2015) stressed that the benefit from shifting passengers to HSR from other modes can reduce the externalities of transportation, but only if it is a very large diversion from air on routes where previously air travel dominated. Regarding HS2 it was projected that it would only make a 4% shift from roads and 1% from air. Cornet et al. (2017) pointed that the benefit of switching from other modes of transportation to HS2 has unresolved issues such as: the scale of the modal shift, the time over which a benefit saving in carbon dioxide will accrue and the scale of carbon dioxide emissions from the construction of infrastructure.

Nash (2015) concludes that CAHSR will support agglomeration and centralization of economic activities in major cities. Kamga (2015) noted that the increase in population density reduces the car use. The development of CAHSR can support increasing the density in urban areas by concentrating economic and social activities near multimodal stations. Creating high density communities that reduce the needs for travel by car and encourage the commuters to use public transport is the way to achieve a sustainable society.

Vaiciunas and Steisunas (2017) found that the Rail Baltic project is most significant for Estonia followed by Lithuania and last is Latvia. Hilmola and Henttu (2015), noted that in recent years the total transit traffic through Estonia has decreased by shifts to Russian seaports. There is a strong competition with road and sea transport, as in many cases it is cheaper than transporting by railways. Hilmola and Henttu (2015) reported that the rail freight volume in the future will maintain its current level as Russia is focused on increasing transit through its own seaports. Railway transportation in Estonia has a lack of cargo to be profitable whilst

Latvia and Lithuania are in the same position. According to Bulis and Skapars (2014), free capacity of the seaports of Riga is around 0.5 million containers. Bulis and Skapars (2013) had found that 97% of freight transported by railways is transited from Russia and Belarus to the seaports of Latvia.

This research aims to compare and analyse the economic, social and environmental aspects of the Rail Baltic, CAHSR and HS2.

The remainder of this paper is organized as follows. An overview is given in Section 2 concerning the current railway systems of the Baltic State countries and a detailed analysis of the Rail Baltic project. Section 3 and Section 4 report on the CAHSR and HS2 respectively. The main findings and key conclusions are shown in Section 5.

2. The Rail Baltic Project

The Rail Baltic project intends to improve connectivity between Poland, Baltic countries, Finland and to link this area to Central Europe and Germany (Vaičiūnas, and Steišūnas, 2017). The Rail Baltic railway design will start in 2018 with a projected start of construction in 2020 and a planned opening for operation in 2025 (Railbaltica.org, 2011). The EU will provide 85% of funding for Railway Baltic whilst the remaining 15% will be provided by the Baltic countries (Railbaltic.info, 2015).

Figure 2.1 The main routes of Rail Baltic (Source: xxxx, 20…)

Figure 2.1 shows the proposed 870-km long route of Rail Baltic. The railway from Tallinn to Poland is part of the Trans-European Network (TEN-T). The electrified railway will provide a mix-traffic with a maximum speed of up to 120 km/h for freight trains and up to 240 km/h for passenger trains (Railbaltica.org, 2011). This is the maximum design speed, but the operational speed will be 170km/h for passenger trains and 68 km/h for freight trains (DELFI, 2011). Freight trains from Tallinn to the Polish border will travel for more than 10 hours. The railway will be preliminary designed as a double track with a standard gauge of 1435mm and an axle loading of 22.5 ton and equipped with ERTMS and ETCS Level 2. For a passenger train, it will take over 4 hours to travel from Tallinn to the Polish border. There will be up to 15 freight trains per day between Tallinn and Vilnius and rising to 22-31 trains between Kaunas and the Polish border (Briginshaw, 2017). Preliminary estimation of the costs in 2011 was €3.8 billion but by 2017 it had risen to €5.8 billion (The Baltic Course, 2017). It was predicted that 80% of freight will come from road and 20% from sea transportation. In the last twenty years, over 97% of the total freight between the Baltic States and Poland was transported by road (Rail-baltica.lt, 2017).

Table 2.1 Changes in population in the Baltic State Countries between 1990 and 2017 and forecast for 2080 (in millions) (Source: Stratfor, 2017; Ec.europa.eu, 2017b)

Country	**1990**	**2011**	**2017**	**2080**
Lithuania	3.6	3.0	2.85	1.842
Latvia	2.6	2.0	1.95	1.351
Estonia	1.5	1.3	1.32	1.030
Total	**7.7**	**6.3**	**6.12**	**4.223**

Table 2.1 shows the decrease in population in the Baltic States from 1990 to 2017 and forecast for 2080. Population decreases are substantial as there will be 25% shrinkage in population. It will not only shrinking but also ageing as by 2025 the median age will be more than 10 years greater than it was around 2011 (Railbaltica.org, 2011). The density of population in Estonia is 29 persons/square km, 31 in Latvia and 46 in Lithuania (Ec.europa.eu, 2017b). The density of population is very low, compared with countries that have HSR systems such as Spain, France and Germany. High density of population is one of the critical factors to have an economically sustainable HSR.

Table 2.2 Growth of GDP and Labor Market in the Baltic State Countries in 2017 (estimated) (Source: Tradingeconomics.com, 2017; Railbaltica.org, 2017)

Country	**GDP**	**Minimum Wages**	**Full Time Employment**
Lithuania	2.9%	380 EUR/Month	1184.70 Thousand
Latvia	2.8%	380 EUR/Month	782.60 Thousand
Estonia	2.2%	470 EUR/Month	557.90 Thousand

Table 2.2 shows the growth in GDP, minimum wages and employment in the Baltic countries. Another critical factor of having economically sustainable HSR is the willingness to pay, or in this case the ability to pay. With average minimum wages between 470 and 380 EUR/Month, it is difficult to predict substantial demand for Rail Baltic. The majority of the population may not afford traveling by the Rail Baltic. There would be a strong competition with bus services. Also, there is a need to take into consideration the increased number of car ownership.

Figure 2.2 shows the increased car ownership in the Baltic countries between 1997 and 2014.

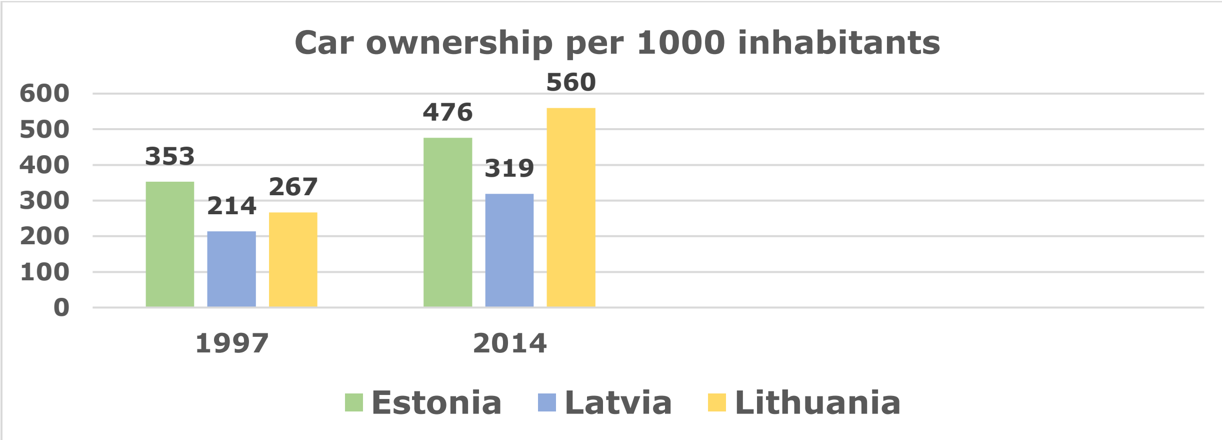

Figure 2.2 Car ownership in the Baltic state countries (Source: Data taken from Nationmaster.com, 2017)

Table 2.3 Distance and prices of using the HSR on selected routes for the Rail Baltic, Spain, France and Germany (Source: Data taken from various resources)

Route	**Distance (km)**	**Ticket price (in €) on HSR**
Riga-Tallinn	318	35
Riga-Vilnius	291	35
Berlin-Bremen	315	69.90
Berlin-Hamburg	256	85
Paris-Nantes	341	88
Paris-Nancy	282	60
Madrid-Zaragoza	274	43
Madrid-Puente Genial	349	86.90

Table 2.3 shows the distances and prices of using HSR on selected routes. The predicted price of tickets on Rail Baltic is substantially lower than that of the HSRs in Europe. The price of a single ticket shown in Table 2.3 is a one-way ticket which is bought one week in advance. Rail Baltic will be powered by electricity and the price of electricity in the future will only increase. In the Baltic countries, the majority of their electricity is imported. This will increase the price of electricity for Rail Baltic. Also, it will affect the predicted price of tickets on trains. There is a decision among all the three Baltic countries to have only one railway operator which may mean that there will not be any serious competition as such operator can dictate the ticket prices.

Table 2.4 Monthly net income average wages in selected countries in 2015 (Source: Reinis Fischer, 2015)

Country	**Average Monthly Salary, EUR NET**
Latvia	601
Estonia	832
Lithuania	544
Spain	1734
France	2180
Germany	2155

Table 2.4 shows the difference in the average salary in selected countries in the EU. The one-way ticket on Rail Baltic will cost approximately 5.5% of the monthly income of the residents of Baltic countries whilst it costs approximately 3.7% of the monthly income in Germany. The tickets on Rail Baltic will be too expensive compared with the average income of residents in the Baltic countries.

Table 2.5 Number of Tourist visited Baltic State Countries in 2014-2015 (Source: E-unwto.org,2017)

Country	**2014 (million)**	**2015 (million)**	**Rank in 2014**
Lithuania	2,063	2,296	80
Latvia	1,843	2,024	83
Estonia	2,918	2,989	67

Table 2.5 shows the number of tourists who visited the Baltic countries in 2014 and 2015. The number of tourists increased by approximately 10% and the majority of them came from neighboring countries. A substantial percentage of tourists came from countries with a track gauge of 1520 mm (Russian gauge), such as Finland, Belarus, Ukraine and Russia.

Table 2.6 Tons of freight carried annually by railways of Baltic state Countries 2013-2015 (Source: Litrail.it, 2014; Evr.ee, 2017)

Country	**Company**	**2013 (in Mil tons)**	**2014 (in Mil tons)**	**2015(in Mil tons)**
Latvia	LDz Cargo Ltd	55.9	57.1	55.7
Lithuania	Lietuvos Gelezinkeliai (LG)	47.0	49.0	n/a
Estonia	Eesti Raudtee (EVR)	24.4	19.22	15.39

Table 2.6 shows that the annual amount of freight transported by railways in Baltic countries is falling where the majority of the freight is flowing from East to ports on the Baltic Sea coast. The fall in the amount of transported freight has a few reasons. Firstly, the adverse political environment and economic sanctions that the EU imposed on Russia. Because of this, there has been a substantial reduction in transit through the ports of the Baltic Sea to and from Russia. Another reason is that Russia built the Ust Luga port for which the volume of freight loading through Ust Luga in 2015 was 87.8 mill tons (railbaltica.org, 2017). Also, Russia significantly improved the ports of Bronka, the deep-water port of Saint-Petersburg and Primorsk. This substantially affected the transit through ports in the Baltic countries. For example, Estonia has losses of almost 20% of freight transit by railways in 2015. Finland and Russia have the same railway gauge of 1520mm and this will attract Finland to use the Ust Luga port. Also, in many cases transportation by sea or by road is more efficient and less expensive (Hilmola and Henttu, 2015).

The Rail Baltic project will affect around 2000 businesses and private properties in Latvia alone. Prices of properties along the railway will drop by 10%-30% (LVPORTALS, 2016). It was estimated that in the construction period of five years, the number of full time jobs that will be created is 3,283 in Estonia, 4,199 in Latvia and 4,419 in Lithuania. After opening the operational services, 331 full time jobs would be created, by 2030 another 160 full time jobs and 244 by 2040 (Railbaltica.org, 2017). This number of new jobs does not look substantial enough for the investment of €5.8 billion needed to develop the Rail Baltic.

The environmental impact of building the Rail Baltic is evaluated only as a saving in carbon dioxide emissions from shifting transport from road to rail but it does not show the amount of carbon dioxide that would be produced from building the Rail Baltic. Also, there is no clarity about energy resources for the Rail Baltic. Furthermore, CBA estimated the noise reduction by shifting traffic from road to rail, but did not estimate the increases in noise levels during the construction and operation of the HSR. Also, CBA considered the current condition of road and air transport, but as railways will be built to last for the next 60 years, it actually needs to take into consideration the technological changes in road and air transport which will reduce the current carbon dioxide emission levels and increase the efficiency of road and air transportation. For example, EasyJet could be flying electric planes within the next ten years for flights under two hours (Monaghan, 2017).

3. Californian High-Speed Railway (CAHSR)

Figure 3.1 The main routes of CAHSR (Source: xxxx, 20…)

The USA has the busiest roads in the world with one of the highest car ownerships. In 2016 only 8.7% of householders in USA were without cars whilst in California it was 4.9%. On average, the USA has 1.8 vehicles per household but in California it is 2.32 (Governing.com, 2018). California is the most populated state in the USA with a population near 40 million and it was predicted that by 2020 this will increase to 41 million but by 2050 the population will reach 59 million (Mtc.ca.gov, 2009). Two third of households have upper or high income of more than $40 000 annual salary (Wang, Chen and Chan, 2017). The density of population in California is 97 people per sq.km compared with the average of 35 people per sq.km (Worldometers.info, 2018b). The increase of population by 0.9% every year and the rising number of trips (Worldpopulationreview.com, 2018a) may increase the concentration of businesses in high density nodes and increase the tourism. All of this makes roads and airports more congested and infrastructure experiencing difficulties to cope with the increased demand for travel. The development of CAHSR will cut carbon dioxide emissions by 40% compared with the level of 1990 (Tlnoco, 2017). The maximum operational speed will be 200 mph and the average speed will be 170mph with 20 passenger trains per hour in each direction (Railway Technology, 2018). Originally a one-way (1287 km) ticket was estimated to be $55 (Railway Technology, 2018). The Two-line track will have 20 times more capacity than existing roads and railways (Stern, 2017). It was predicted that a third of all air trips will shift to HSR and around 6% of the road trips. Building the HSR will increase the accessibility and connectivity and will create new jobs. It was estimated that $1 billion investment in infrastructure in the USA would create 30,000 jobs (Mtc.ca.gov, 2009). Implementing the HSR will reduce the number of accidents on roads and reduce the congestion costs which is approximately $20 billion per year (Railway Technology, 2018). The construction of HSR will raise economic activities in the region. 94% of the $2.3 billion investment in the construction of CAHSR went to local businesses (Hsr.ca.gov, 2016). Construction began in 2015 and it was planned that Phase 1 will be open for train traffic in 2029. The estimated cost of the project grew substantially from $40 billion in 2008 to $64 billion in 2016 (Tlnoco, 2017). The cost increases are due to delays in construction, the needs to build more barriers along the track to separate HSR line from conventional lines and the high cost of bridges (Capradio.org, 2018). The CAHSR will operate with 100% renewable energy and all 24 CAHSR stations along the route will be designed to the highest environmental standards as energy self-sufficient stations. CAHSR has a recyclability between 99% and 100%. In order to improve the safety of HSR and accessibility to local communities, the CAHSR funded several grade separation projects (Hsr.ca.gov, 2017). This not only improves the safety, reduces traffic jams, but also reduces the noise and pollution from cars that stop and accelerate near level crossings.

It was predicted that HSR will carry 115,000 passengers per day with an annual passenger flow of around 117 million. Such prediction looks very optimistic as Shinkansen yearly passenger ridership is approximately 155 million (CJRC, 2018) with a density of population in Tokyo of approximately 6,000 person/sq.km (Worldpopulationreview.com, 2018a). For Paris-Brussels/London services the 2002 forecast of passenger flow was 20.5 million, but it was only 7.3 million with a 64.5% forecast error (Vickerman, 2015). Predicted future passenger flow quite often does not reach the expectation.

4. HS2 in the UK

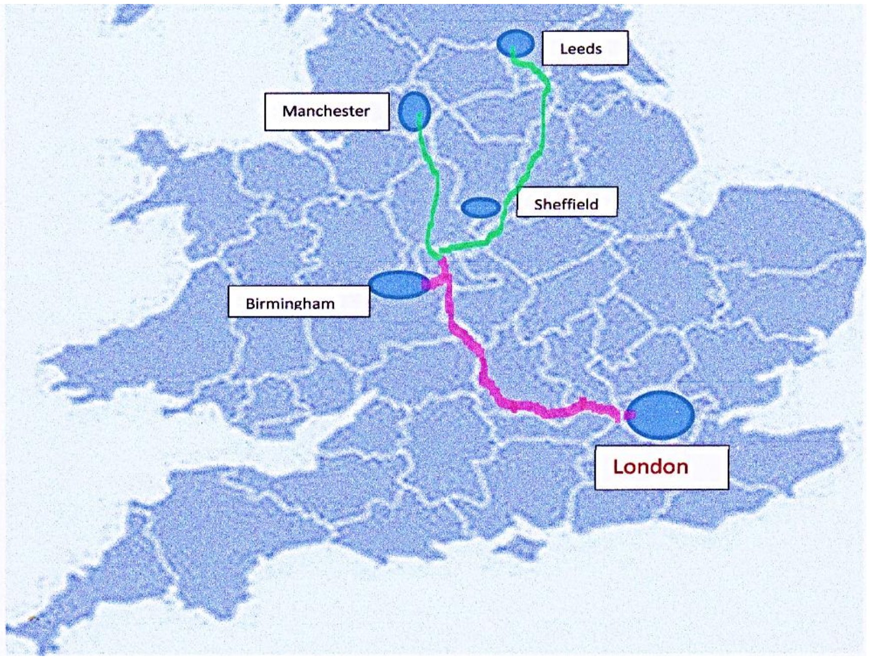

Figure 4.1 The main routes of HS2 (Source: xxxx, 20…)

HS2 is planned to be built in the UK between London Euston and Birmingham, which will be 225km long (Phase 1), with future expansion to Manchester 150km and Leeds 185km (Phase 2) and potentially to Scotland later. Four major cities will be connected by the new line: London, Birmingham, Manchester and Leeds. The construction of HS2 began in 2017. Phase 1 will be completed in 2026 and Phase 2 in 2032. The initial cost was £43 billion but by 2017 it increased to £56.5 billion, unofficial sources estimate that the final cost will be at £104 billion (HS2 Facts, 2018). Most of the large infrastructure projects failed to meet expectation of society in terms of the promised benefits and in terms of exceeding the initial estimation. On average, the initial cost of railways is normally exceeded by 44.7% whilst that of bridges and tunnels is exceeded by 33.8% (Nunen et al., 2011).

The maximum operational speed of HS2 from day one of operation would be 360km/h with a maximum of 14 trains/hr in each direction and with a capacity of 1100 seats per 400mtr long train and a projected passenger flow of approximately 90 million trips per year (Gov.uk, 2011). There are some examples from France or China when the introduction of HSR negatively affects conventional railways. These become less frequent with increases in travel time in addition to not serving some destinations at all (Zhang et al., 2016). The development of the HSR leads to the detriment of the conventional railway (Zembri and Libourel, 2017), widens the gap between different territories (Watson et al., 2017a) in addition to having a strong influence on increasing agglomeration (Vickerman, 2018). Without extensive integration, it can only strengthen major centres and weaken areas between them. Cities with HSR stations have a higher growth rate of population, high employment and higher economic activities (Wang et al., 2017).

Developing HSR will create thousands of direct jobs to construct and operate the railway, but it will also create many indirect jobs and large numbers of new jobs around the railway stations. It was predicted that by only redeveloping the Old Oak Common to the interchange station 20,000 new jobs would be created (BBC News, 2017). The West Midlands could have 50,000 additional jobs (Birmingham.gov.uk,2018). Approximately for each 10 new direct rail jobs at least 14 new indirect jobs will be generated (Jehanno et al., 2011). Currently there is a large difference in labour cost around the UK. For example, in 2012, in London it was £51,351 per employee per year compared with £34,502 in the West Midlands (Gov.uk, 2017a). The experience of Germany shows that after introducing HSR the labour market had a 3% rise in wages in that area (Guirao et al., 2017). Most likely, the knowledge-based employment is the one that will take advantage of the increased accessibility offered by HSR (Vickerman, 2018). This can increase regional disparities (Guirao et al., 2017). Developing HS2 will support businesses and have access to cheaper labour forces and to cheaper office rents. There is a huge difference in office rents between London (£68.59 per sqm) and Birmingham (£30.00 per sqm) (Gov.uk, 2017b).

Table 4.1 The cost of building 1km of HSR in selected countries (Source: Williams, 2017; Feigenbaum, 2013; Muldowney, 2016)

Route	Cost per km (in millions)
Tokyo-Osaka	$3.1
Paris-Lyon	£4.7
LGV Mediterranee	£16.9
HSR in China	$17-21
HSR in California	$56.0
HS2 (UK)	£78.5

Table 4.1 shows the cost of building 1 km of HSR in selected countries. HS2 was classified as the most expensive HSR in the world (Pasha-Robinson, 2017). As it is more expensive to build an HSR, it will be more difficult to recover the construction cost and therefore HSR will never pay back the investment (Muldowney, 2016). Most of the railways worldwide need government subsidies not only for construction, but for operation and maintenance as well (Feigenbaum, 2013). HSR will be sustainable only if benefits exceed the costs. It is difficult to predict future modal shift from roads and airplanes. In the case of HS2 Phase 1, there will only be a shift from roads as there is no direct flight from London to Birmingham (Cornet et al., 2017). The environmental benefit of developing HS2 depends not only on how much traffic shifts from roads and planes but also on the future carbon dioxide emissions from producing the electricity to power the HS2. The increased noise and vibration level along the HS2 route is another environmental concern. Embankments will reduce noise and visual impact, but it incurs a large area, reinforces the separation effect and reduces the available living space (Watson et al., 2017b). It is difficult to predict how HS2 will affect the economy of North-West England, but it looks very promising, because they have what is needed for cities to be able to prosper: a strong economy and vacant land (Wang et al., 2017).

5. Main Findings and Key Conclusions

The Rail Baltic project will duplicate the existing railway network that the Baltic countries have. In order to operate and maintain two railway networks with different gauges there will be a need for substantial funds, but this may be quite difficult for countries with low population density where populations continuously decrease and without remarkable industrial concentration. Two types of rolling stock will need to be kept and maintained which may mean two types of maintenance machines, etc. Modernizing and upgrading the existing railway system based on 1520mm gauge would be more economically appropriate. Currently there are no railway connections between Estonia and Latvia. It was closed approximately 10 years ago as it was not economically viable. If there is not enough demand to operate a railway at the present time then why would it be different in 10 years' time when the population is continuously decreasing in all of three Baltic countries? It was found that higher public subsidies have little or no effect on shifting passengers to railways (Tomeš, 2017). The new Rail Baltic can shift only a limited number of journeys from road and air as it is more expensive than bus services and it does not give sufficient time saving compared to flight.

The reasons to build the Rail Baltic may not be influenced only by the increased traffic flow and the lack of capacity but by political considerations. Rail Baltic has a strategic and military significance for the EU. It is difficult to recover the cost of HSR construction, but in the particular case of Rail Baltic it does not look that easy as it may need government subsidies to cover the operational and maintenance costs. The projected ridership is expected to be only 5 million in the opening year, but the European Commission stated that only in exceptional circumstances HSRs can be built if the ridership in the first year is less than 6 million whilst the minimal ridership thereafter must be 9 million per year (Muldowney, 2016). Overall, the Rail Baltic will improve connectivity and reduce travel time, but the main aim of building new HSR is the increasing capacity. In the case of Rail Baltic, Estonia, Latvia and Lithuania have enough capacity on the existing railway network. The majority of passengers travelling on the existing railways in the Baltic state countries are satisfied with the quality of services.

CAHSR has a strong positive impact on social sustainability. Apart from creating thousands of new jobs, a positive impact on tourism, improving accessibility, it raises economic activities in the region. From the $2.3 billion invested in CAHSR, 94% went to local businesses. Trains will be powered by 100% renewable energy and all 24 HSR stations along the route will be energy self-sufficient. CAHSR has a recyclability between 99% and 100%. It was projected that by 2030 there will be a reduction in carbon dioxide emissions between 2.1 to 2.8 MMT (million metric tons) per year. It is equivalent to taking half a million cars off the road. CAHSR has a potential to be profitable as the route goes through high density areas where the majority of the population have a high income.

It was forecasted that HS2 annual passenger flow will be around 90 million. However, as HS2 has been classified as the most expensive HSR in the world it is difficult to see that the construction costs will be recovered. HS2 will take some cars from roads and reduce the number of internal flights. The environmental benefit of developing HS2 depends not only on how much traffic will shift from roads and airplanes, but on the future carbon dioxide emissions from the production of electricity for HS2. HS2 will create thousands of new jobs in the range of 10 new direct rail jobs and at least 14 new indirect jobs. The development of HSR stations may increase the population and employment rate in cities may and open more opportunities for regeneration and fostering of regional development (Watson et al., 2017a). The major objectives of developing HS2 are to increase capacity and rebalance the economy of the UK, but these will depend on the integration of HS2 with the local and regional network.

Table 5.1 Data related to HS2, CAHSR, Rail Baltic (Source: xx, 20..)

Country	Population In Million	Density of Population Ind/Sq.km	Income/ Annually	Ticket Price	Annual pas. Flow (in Millions)	Energy resources for HSR
UK (England)	55.04 (2016)	407	Between £34.000 in West Midlands and £51.000 in London	N/A	90	between 15% and 40% of electricity will be generated by low carbon sources
USA (California)	39.35 (2016)	97	2/3 of householders over $40.000	$83 (2012)	115	100% Renewable
Baltic State Countries	6.1 (2018)	29-46	€6480-€9960	€70	5	N/A

Table 5.1 shows the selected data for the UK, USA and Baltic countries. HSR reduces travel time, but higher ticket prices may turn away low-income passengers. Profitability of newly constructed HSR heavily depends on the expected volume of demand, but such demand depends on the willingness-to-pay and density of population.

Table 5.2 Unemployment rate in selected countries (Source: Data taken from different sources)

Country	Unemployment Rate in 2017
Latvia	8.5%
Lithuania	8.2%
Estonia	8.2%
California (USA)	7.5%
UK	4.9%

Consider Table 5.2 which shows the unemployment rate in selected countries. With a high rate of unemployment, it is impossible to have a high ridership on HSR. It will be difficult not only to recover the construction cost of Rail Baltic, but to collect enough revenue to cover the operational and maintenance costs. In case of Rail Baltic, there may be a need to assess political decisions regarding a better allocation of public investments.

Table 5.3 Economic, environmental and social sustainability of HS2, CAHSR, Rail Baltic (Source: xx, 20..)

HSR	Sustainability		
	Economic	***Environmental***	***Social***
HS2	Weak case	Moderate case	Moderate case
CAHSR	Moderate case	Strong case	Strong case
Rail Baltic	Weak case	Weak case	Weak case

Table 5.3 shows the comparison in economic, environmental and social sustainability of HS2, CAHSR and Rail Baltic. Building railways, operating and maintaining them is an expensive business and governments heavily support and contribute to the development of HSR. In order to cover the costs of building, operating and maintaining a profitable HSR, it must not be very expensive to build and maintain and to have a high occupancy.

HSRs will be sustainable only if the benefits exceed the costs, otherwise they will need substantial government subsidies.

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