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ENERGY CONSUMPTION OF RAIL BALTICA PROJECT: REGIONAL ASPECTS OF ENVIRONMENTAL IMPACT

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Abstract

Research purpose. The high-speed railway (HSR) construction project in the Baltic States is the largest joint infrastructure project since the restoration of independence of Latvia, Lithuania and Estonia. Rail Baltica (RB) is considered as the most energy-efficient project having the lowest environmental impact. However, the issue of energy consumption of the project was not sufficiently addressed either in the investment justification of the RB construction or in the relevant research works regarding the project. The aim of the current research is to determine the indicators of energy consumption and carbon dioxide (CO_2) emissions intensity of the Latvian section of RB, since they are the key factors of the quantitative assessment of sustainability.

Design/Methodology/Approach. Critical analysis of the academic research works and reports of the official international organizations dedicated to the topic of energy consumption and CO_2 emissions of HSR was conducted prior to the calculation of the above-mentioned indicators. The method of calculation based on International Union of Railways (UIC) was used in order to conduct the cluster analysis within the framework of current work. The main points considered are electricity consumption, carbon dioxide emissions, and level of passenger and freight demand. Statistical databases of UIC and International Energy Agency were used.

Findings. The calculations carried out by the authors of the given article demonstrate substantial figures of CO_2 emissions intensity for Latvian section of the project related to the train load rate and traffic intensity which is evened out only by the CO_2 emissions factor in Latvia.

Originality/Value/Practical implications. On this basis the authors present the directions for future research required for the development of the effective strategy for the Latvian Republic with the aim of achieving the increase in the RB project's ecological efficiency.

Keywords: Energy consumption; Environmental impact; Rail Baltica; Sustainable development.

JEL Classification: L98; Q51; R42.

Introduction

Nowadays, even though sustainable development is considered as focal point in a huge number of memorandums and strategies, the reality clearly envisages that the whole relationship between economic activity and environmental stability is based on the principles of net profit interests. This is clearly reflected in the fact that main strategic decisions being made in respect of the high-speed railway (HSR) network development have been formulated before the assessment of the environmental impact of such project.

The key factors for carrying out the quantitative assessment of sustainability are yet to be standardized. In addition, such factors are not considered to be mandatory for the purpose of infrastructure projects' evaluation. In case they are applied, more often than not, it is done in improper manner even though the minimum lifespan of the project is 30 years. Hence, the indicators used for such projects need to be linked to all long-term sustainable development strategies starting from the initial planning stage.

The carbon footprint caused by the construction of railway infrastructure is often ignored when considering the content of carbon in the transportation of passengers and cargo. Only in 2016 (UIC, 2016) a qualitative comparison of 10 existing methodologies was carried out. It was the first step to investigate how to develop a coordinated approach towards the inclusion of carbon dioxide (CO_2) emissions deriving from infrastructure construction, as well as the rolling stock production process and its further utilization at the end of the lifecycle, into the overall results of carbon efficiency assessment for the HSR project. As a result, it was suggested to include the embedded emissions of CO_2 from the construction into the overall carbon intensity estimate in order to increase the transparency and consistency of the results.

At the same time, it was noted that density of the traffic is a key factor for the quick payback of emissions from infrastructure construction. Therefore, it is necessary to conduct a rigorous traffic assessment while planning a new railway infrastructure.

According to the official documents (i.e. Regulation (EU) No. 1316/2013 of the European Parliament and of the Council of 11 December 2013 establishing the Connecting Europe Facility, amending Regulation (EU) No. 913/2010 and repealing Regulations (EC) No. 680/2007 and (EC) No. 67/2010) of Rail Baltica (RB), it is emphasized that the common objective of the project is to develop it for the common good of the people, meaning that it has to be of a considerable strategic and economic importance to the EU citizens and economies.

HSR does not have the same characteristics across the regions. In the RB project, trainload indicators also vary depending on the region (Ernst & Young Baltic, 2017). Yet, in the investment justification of the project, due attention was not paid to this aspect.

The purpose of this article is to determine the regional indicators of the energy consumption of the Latvian section of the RB project based on the analysis of the actual electricity supply ability, the pricing policy of Latvia and the potential traffic figures for this region.

For the analysis of energy consumption, the calculation method of International Union of Railways (UIC) was used. The calculation of the carbon footprint payback period from infrastructure construction and rolling stocks production is based on the technique which is similar to determining the time value of money, using discounting of the investment ratio for the project. Discounting was used on a simple basis, since the intensity of emissions from construction affects the environment significantly at present, and the positive effect of reducing emissions is too remote from the moment of construction to the lapse of time.

The study identifies the energy consumption level of the RB project for Latvia, the carbon efficiency of the project in the region, and puts forward recommendations on how to improve the project's conformity assessment in accordance with the requirements of sustainable development, as well as gives further research directions to clarify the project's passenger and cargo traffic flow.

The article is logically organized in five sections. The next section is literature review, in which different points of view of the ecological impact and carbon footprint of railway infrastructure, including HSR projects, by various specialists in the field and organizations concerned about the issue are illustrated. The third section highlights the methodology and other details of the research conducted for the purposes of identifying the energy consumption of the project and its ecological footprint. The next section presents the assessment results of energy consumption of the Latvian section of the RB project, illustrates the main determinants of the carbon footprint of this section of RB and presents the future trends. The conclusions are presented last.

Literature Review

In the majority of the reports issued by the European and international official entities, HSR is being considered as the most energy-efficient mode of transportation having the lowest environmental impact. However, the examples provided in these reports are usually taken either from a small part of the European projects with a high degree of air transportation replacement (United Kingdom–Paris) or from projects of Japan, Korea and China, which were implemented as a necessary tool for meeting the mobility needs of the population in the regions with high density.

At the same time, important factors leading to the success of these projects' implementation such as the use of cheap nuclear power for the operation and subsequently low carbon dioxide emission are mentioned only briefly. The comprehensive analysis of the results of the HSR project's construction, development and operation has not been presented yet.

Anticipating the ex ante analysis of the energy consumption by the Latvian section of RB and its carbon footprint, it is advisable for the reader to become familiar with different research works conducted in the field. The authors did not focus on the analysis of the HSR projects performances in China due to the following reasons: the significant differences in many aspects of the HSR projects, such as the initial aim behind the projects together with the lack of the need for land acquisition, as well as the scale of construction, contributing to the standardization of the project documentation and the production of railway equipment and rolling stock.

In Garcia Alvarez and Cañizares (2010), the relationship between the speed of high-speed passenger trains, their energy consumption and greenhouse gas emissions is analysed. The authors compare the amounts of energy being consumed by the conventional and high-speed passenger rail systems. It is shown that, on average, high-speed rail systems consume 29 percent less energy than the conventional rail systems.

Jurado (2012) provides a detailed analysis of the energy consumption by trains in the Spanish HSR network, emphasizing that in many cases, rail services with low demand are installed without a vision of competitiveness or complementarity with other types of transport, which leads to a small traffic volume with an ever smaller number of passengers. In too many cases, lines of medium or low traffic offer trains with large capacity, when, on the contrary, it is necessary to increase the number of trains and reduce their individual capabilities.

In respect of carbon dioxide emissions, the previous research illustrated that HSR CO_2 emissions intensity varies between 4.0 and 32.9 g CO_2/PKT in the major European countries (Bueno et al 2016; Seguret, 2014).

The reason for difference in HSR CO_2 emissions among the states is the variation in numbers of such parameters as occupancy levels and the source of train electricity. For example, the French HSR has low CO_2 emissions per passenger-km (pkm) mainly due to the high share of nuclear power in French electricity supply to rail operators (Seguret, 2014). Nevertheless, there is a chance that investments into the rail industry may end up with much less environmental benefits than was expected during the stage of planning, because of several factors. It was argued by Miyoshi & Givoni (2012) that the CO_2 mitigation impact of possible HSR investments in the United Kingdom has become relatively minor in light of the low demand and the high current carbon intensity of electricity in that country is 0.5 kg CO2 per kWh. Their analysis shows relatively limited potential of HSR for reduction in CO2 emissions. In 2033, the overall CO_2 reduction due to HST operation on the London–Manchester route is estimated at 100,000 t CO_2 per annum, which is less than 0.1 percent of the total U.K. domestic transport emissions in 2007. Thus, they demonstrate the train energy consumption (21.45 kWh per km) in cases where the U.K. electricity carbon reaches intensity (0.45 kg CO_2 per kWh).

In the research conducted by Von Rozycki *et al.* (2003) the CO_2 emissions figures for German HSR network is much worse (69.4 g/pkm), which can also be explained by the fact that the demand is relatively low with a very high level of CO_2 emissions.

Another group of studies criticized the impact analyses of HSR systems for being focused solely on vehicle operation stage (Chester & Horvath, 2009). The point of view taken up in these studies is that significant amount of energy use and CO_2 emissions originates from non-operational aspects of HSR systems, such as construction of stations and infrastructure in general, manufacturing of the vehicles, its maintenance and fuel production. The conclusion is based on a comprehensive life-cycle energy and emissions inventory of different modes of transportation and indicates the fact that the operational energy use and CO_2 emissions of rail systems are nearly two times less than the non-operational one.

Westin & Kageson (2012) went even further in their conclusions on ecological benefits of HSR:

To be able to balance the annualized emissions from the construction of the line, traffic volumes need to be large, and the diverted traffic should primarily come from aviation. An important aspect that was disregarded in the considerable number of researches conducted is the time lag between construction and the years when its emissions will gradually be paid back. Even if emissions from the construction are balanced in the longer term by reduced emissions from traffic, they do have a short-term impact on the atmospheric concentration of greenhouse gases. There is thus an obvious risk that investing in high speed rail will add to the difficulties of keeping the atmospheric content of greenhouse gases at a level that prevents the mean global temperature from exceeding its pre-industrial level by more than 2 degrees Celsius.

The research by Bueno *et al.* (2016) also shows that even in the most optimistic scenarios, the reduction in emissions from a modal transition from other modes of transport will not compensate CO_2 emissions associated with the construction of HSR infrastructure and its operation (2.71 Mt CO_2), and it will not contribute to the net energy savings of up to 55 years of operation. As an example, the research provides the figures available after the calculation of CO_2 emissions and reduction of energy consumption over the life of HSR infrastructure (60 years) in the Basque region. The validity of these results suggests that reducing carbon dioxide emissions and energy savings should not be used as a general argument for investing in high-speed rail infrastructure.

In the report provided by Jehanno (2011), the emissions from the construction of the high-speed rail lines were estimated. In the range of 58 t–176 t of CO_2 per km of line and year. Lines with a moderate space and relief constraints (for example in France) emits around 60t of CO_2. By comparison, the carbon footprint of the construction of a 2×3 lane motorway is 73 t CO_2 (with similar transport capacity under the same geographical conditions)... The construction, maintenance and disposal of the rolling stock lead to emissions of 0.8 CO_2 to 1.0 g CO_2 per pkm. Compared with the construction of a car (20.9 g CO_2/pkm), the construction of a HSR-Train is 20 times lower. The construction of an airplane (0.5g CO_2/pkm) is in the same order of magnitude as HSR.

However, all the researchers agree on one thing: in order to reduce the emissions and increase the energy efficiency of the HSR, it is necessary to extend the passenger and cargo traffic to the maximum capacity by attracting riders from air travel, use of cleaner electricity sources and comprehensive planning. The plan of operation for the existing railway system has to be considered as well, because it will be subjected to partial substitution by the newly created one.

Considering the RB project, it is important to mention the lack of research works available, which include analysis of the energy consumption and CO_2 emissions of the future project. Only Humal *et al.* (2018) have noticed that authors of the investment justification have ignored the requirement of 'Guide to Cost-Benefit Analysis' (EC, 2014) regarding the CO_2 emissions arising out of the project's new infrastructure construction.

According to the authors of this article, the discussion of this issue had to start in advance, because at the present moment two out of the three state participants in the project import electricity rather than generate it. Furthermore, new large power plants are not planned to be built in this region preceding the start of RB operation.

Methodology

The methodological scheme of the given study for the Latvian section of RB consists of three major steps which include the determination of

1. energy consumption and emissions from passenger flows (Ernst & Young Baltic, 2017) scenario;
2. energy consumption and emissions from freight flows (Ernst & Young Baltic, 2017) scenario;
3. total energy consumption and emissions, including annualized emissions from infrastructure construction.

The total amount of CO_2 emissions will be an amount of the required reduction of emissions from other modes of transport, cargo and passengers, which will have to switch to a new railway.

In case of further research, the results of this study can serve as the boundary indicators of the net environmental effect of the RB project for the Latvian section of the route.

The study uses these definitions (Union of Railways, 2012):

- One train-km is one train travelling for 1 km. Total train-kms are calculated by multiplying the number of trains by the number of km they travel.

- One gross tkm (tonne-km) is 1 tonne (including weight of wagons, locomotives and cargo) travelling for 1 km. The gross tkm of one train is calculated by multiplying the total weight of the train by the distance it travels.
- One seat-km is one seat travelling for 1 km, calculated by multiplying the number of seats in a train by the distance travelled.
- One passenger-km (pkm) is one passenger travelling for 1 km. The number of pkm is the number of passengers multiplied by the distance travelled per passenger.
- Occupancy (loading) factor is the relation between the number of places occupied and the maximum number of places offered. It can be calculated by dividing the passenger-km by the seat-km.
- Average electricity use pass (kWh/seat-km) is the required amount of energy to transfer one seat travelling for 1 km. This indicator was considered by Jehanno (2011), Jurado (2012) and IEA & UIC (2017) based on the electric consumption of an Alstom AGV (0.033 kWh/seat-km).
- CO_2 emission factor of traction electricity is the well-to-wheel CO_2 emission factor of the electricity used by railway (in kg CO_2-eq/kWh). In this study, this indicator is assumed to be equal to the country coefficient, due to the lack of data on future electricity suppliers for the project. Detailed information on the methodologies, assumptions and data sources, as well as recommendations, for using this factor is found in Koffi et al. (2017).

Energy consumption of freight transport is influenced by logistical, technical and operational factors. Energy consumption per tkm is strongly related to the maximum net tons carried. Total consumption relates to the vehicle's mass because almost all the energy losses of the vehicle (rolling resistance, aerodynamics, gravity and kinetic energy) depend on the vehicle tare.

In estimating the energy consumption of freight flows of Latvian RB section, supposedly representative average values are used (with many limitations).

It should be noted that the calculated values of some indicators of freight rail transport presented in global surveys of international organizations often do not correspond to the primary statistical country data or regional research data. Hence IEA ETSAP (2011) estimates global averages for carbon intensity of freight rail to be 15 to 40 g CO_2-eq/tkm (compared with 190–300 g CO_2-eq/tkm for long distance trucking), whereas, according to the methodology proposed in García Álvarez *et al*. (2013), electric trains are overall as efficient as megatrucks ((0.05 kWh/tkm and 13 g CO_2/tkm) vs. (0.28 kWh/tkm and 73 g CO_2/tkm) over flat profiles. This author's data is taken as the average value of the electric power consumption for freight trains of the Latvian RB section.

In Europe there is a lack of data which describe the trend of energy consumption in the freight sector. EuroStat, one of the largest collectors of those sorts of data, has no such detailed (split) data available as yet.

Electricity consumption and CO_2 emissions for passengers traffic according to the location-based method of the GHG Protocol Scope 2 Guidance are calculated using the following equations:

Annual Electricity Use = Avg. Electricity Use × Train Capacity × Line Length × 365 × Number of train/day (1a)

[kWh]= [kWh/seat-km] × [seats] × [km]

Annual CO_{2eq} Emissions = Annual Electricity Use × CO_{2eq} Emissions Factor (1b)

[kt CO_{2eq}]= [kWh] × [kg CO_{2eq}/kWh]/10^6

Electricity Intensity = Avg. Electricity Use/Occupancy (1c)

[kWh/pkm]= [kWh/seat-km]/[%]

CO_2 Emissions Intensity = Electricity Intensity × CO_2 Emissions Factor (1d)

[g CO_{2eq} pkm]= [kWh/pkm] × [kg CO_{2eq}/kWh]/10^3

The production data collected regarding Latvian RB are given in Tables 1 and 2.

Table 1. Passenger flow data (Source: Ernst & Young Baltic, 2017; Koffi et al. 2017; Jehanno, 2011; Jurado, 2012; IEA & UIC, 2017)

Indicators of RB		**Unit**	**Total section**	**Riga-RIX**
Line length		km	262.42	13.3
Number of trains		Pairs/day	8	36
Train capacity		Seat	402	228
Passenger flow		Thous. pass		
2026	Base case		869	1852
	Low case		690	1470
2035	Base case		930	2085
	Low case		734	1643
2045	Base case		991	2347
	Low case		780	1841
2055	Base case		1050	2628
	Low case		826	2056
Average electricity use		kWh/seat-km	0.033	0.033
Emissions factor for electricity consumption (LCA approach)		kg CO_{2eq}/kWh	0.183	0.183

LCA, life circle assessment.

Electricity consumption and CO_2 emissions for cargo traffic according to the location-based method of the GHG Protocol Scope 2 Guidance are calculated using the following equations:

Annual Electricity Use = Avg. Electricity Use × Train Capacity × Line Length × 365 × Number of train/day (2a)

[kWh]= [kWh/tkm] × [tonnes] × [km]

Annual CO_{2eq} Emissions = Annual Electricity Use × CO_{2eq} Emissions Factor (2b)

[kt CO_{2eq}] = [kWh] × [kg CO_{2eq}/kWh]/10^6

Electricity Intensity = Avg. Electricity Use/Loading (2c)

[kWh/tkm] = [kWh/tkm]/[%]

CO_{2eq} Emissions Intensity = Electricity Intensity × CO_{2eq} Emissions Factor (2d)

[g CO_{2eq}/tkm] = [kWh/tkm] × [kg CO_{2eq}/kWh]/10^3

Table 2. Freight flow data (Source: Ernst & Young Baltic, 2017; Koffi et al. 2017; Jehanno, 2011; Jurado, 2012; IEA & UIC, 2017)

Indicators of RB		**Unit**	**Total Latvian section**	
			Border EST–Salaspils	**Salaspils–Border LT**
Line length		km	126	77.4
Freight train capacity, net		Tonnes	1098	1098
Average electricity use		kWh/tkm	0.05	0.05
CO_{2eq} emission factor		kg CO_{2eq}/kWh	0.183	0.183
Number of trains		Pairs/day		
2026	Base case		1	2
	Low case		1	1
2027	Base case		2	3
	Low case		2	2
2028	Base case		4	5
	Low case		3	3
2029	Base case		6	9
	Low case		5	8
2030	Base case		9	10
	Low case		7	9
2040	Base case		11	13
	Low case		9	11
2050	Base case		12	15
	Low case		10	12

The data on the distribution of carbon dioxide emissions by years of operation arising during the construction of the railway infrastructure were adopted by the authors on the basis of the report (UIC, 2016). For corridors that have a share of tunnels and bridges below 30%, a common, conservative and realistic value of around 50–70 tCO_2/km/year would be adopted following the values and the results using the IFEU/Tuschchmid methodology; on a case by case basis, lower emission factors could be used if railway operators could justify such lower values.

However, due to the fact that, according to this methodology, the emissions are distributed by linear depreciation, the authors of the study conducted a procedure for compounding the built-in CO_2 emissions at construction at a rate of 5 percent, similar to the socio-economic discount rate of 5 percent adopted in the investment rationale for the project.

Results

The results of the calculations presented below are based on the methodology described in the previous section.

Table 3 shows the results of the electricity consumption assessment, CO_2 emissions of the passenger traffic flow in the Latvian section of RB and their intensity according to the periods referred to in the investment justification of the project.

Table 3. Performance of passenger flow on the Latvian section of RB (Source: author's compilation)

Perspective		Total section				Riga-RIX			
		Annual Electricity use, MWh/year	**Annual CO_{2eq} emissions** kt CO_{2eq}/year	**Electricity use per 1 pkm**, kWh	**CO_{2eq} emissions intensity,** g CO_{2eq}/pkm	**Annual Electricity use,** MWh/year	**Annual CO_{2eq} emissions,** kt CO_{2eq}/year	**Electricity use per 1 pkm,** Wh	**CO_{2eq} emissions intensity,** g CO_{2eq}/pkm
2026	Base case	20 330.6	3 720.5	0.089	16.31	2 629.8	481.3	0.107	19.54
	Low case	20 330.6	3 720.5	0.112	20.55	2 629.8	481.3	0.135	24.62
2035	Base case	20 330.6	3 720.5	0.083	15.24	2 629.8	481.3	0.095	17.35
	Low case	20 330.6	3 720.5	0.106	19.32	2 629.8	481.3	0.120	22.02
2045	Base case	20 330.6	3 720.5	0.078	14.31	2 629.8	481.3	0.084	15.42
	Low case	20 330.6	3 720.5	0.099	18.18	2 629.8	481.3	0.107	19.65
2055	Base case	20 330.6	3 720.5	0.074	13.50	2 629.8	481.3	0.075	13.77
	Low case	20 330.6	3 720.5	0.094	17.16	2 629.8	481.3	0.096	17.60

Based on the calculations provided above, it can be concluded that passenger traffic in the Latvian section of the RB highway has a low energy efficiency level. Energy intensity of one pkm in the first year of entering the railway operation is 89 Wh in the baseline scenario and 112 Wh in the low demand scenario. The intensity of carbon dioxide emissions in the same period will be 16.31 and 20.55 g CO_2-eq/pkm, respectively.

These indicators are somewhat in the middle of the HSR emission intensity range for the EU as a whole. Yet, it is necessary to take into account that Latvia's emissions factor is one of the lowest in Europe and, mainly due to that factor, the emission intensity in the Latvian section of RB does not exceed European indicators (Bueno et al. 2016; IEA & UIC, 2017).

However, if we compare the results obtained with the emission rate indicator in the Lithuanian section of RB in the first year of operation (6.6 g CO_2-eq/pkm), then it becomes obvious that low passenger demand for highway services in Latvia creates a significant negative environmental effect.

The results (Table 3) also show the emissions generated by the shuttle to Riga Airport (RIX). Due to the need for high frequency of traffic, train load will be not more than 18 percent, which leads to an increase in CO_2 emissions in this area to 481.3 kt CO_2-eq/year in the first year of operation. It should be noted that all the airplanes of Air Baltic for 2017 created less CO_2 emissions – 321 kt CO_2 (AIR BALTIC

CORPORATION, 2017) – than a 13.3 km railway section from the centre of Riga to the airport would create.

The calculations of electricity consumption, CO_2 emissions of freight flows in the Latvian sector of RB, as well as their intensity over the periods specified in the investment justification of the project, are given in Table 4.

Table 4. Performance of freight flows on the Latvian section of RB (Source: author's compilation)

Perspective		Border Estonia–Salaspils				Salaspils - –Border Lithuania			
		Annual Electricity use, MWh/ year	**Annual CO_{2eq} emissions,** kt CO_{2eq} /year	**Electricity use per 1 tkm,** KkWh	**CO_{2eq} emissions intensity,** gCO_{2eq} /tkm	**Annual Electricity Use,** MWh/ year	**Annual CO_{2eq} emissions,** kt CO_{2eq} /year	**Electricity use per 1 tkm,** Wh	**CO_{2eq} emissions intensity,** g CO_{2eq} /tkm
2026	Base case	5 049.7	924.1	0.057	10,.48	6 203.9	1135.3	0.100	18.34
	Low case	5 049.7	924.1	0.067	12.23	3 101.9	567.7	0.057	10.43
2027	Base case	10 099.4	1 848.2	0.057	10,.48	9 305.8	1703.0	0.071	12.99
	Low case	10 099.4	1 848.2	0.073	13.33	6 203.9	1135.3	0.057	10.43
2028	Base case	20 198.8	3 696.4	0.073	13.33	15 509.7	2838.3	0.077	14.10
	Low case	15 149.1	2 772.3	0.071	12.94	9 305.8	1703.0	0.057	10.48
2029	Base case	30 298.2	5 544.6	0.063	11.58	27 917.6	5108.9	0.080	14.67
	Low case	25 248.5	4 620.5	0.067	12.22	18 611.7	3406.0	0.089	16.30
2030	Base case	45 447.3	8 316.9	0.077	14.04	31 019.5	5676.6	0.067	12.22
	Low case	35 347.9	6 468.7	0.074	13.51	27 917.6	5108.9	0.080	14.67
2035	Base case	45 447.3	8 316.9	0.062	11.38	31 019.5	5676.6	0.057	10.48
	Low case	35 347.9	6 468.7	0.061	11.16	27 917.6	5108.9	0.064	11.79
2040	Base case	55 546.7	10 165.1	0.074	13.46	37 223.5	6811.9	0.069	12.71
	Low case	45 447.3	8 316.9	0.074	13.46	34 121.5	6244.2	0.069	12.71
2050	Base case	60 596.4	11 089.1	0.074	13.46	46 529.3	8514.9	0.069	12.71
	Low case	50 497.1	9 241.0	0.074	13.46	37 223.5	6811.9	0.069	12.71

As presented in Table 4, freight traffic indicators for the Latvian section of RB are more efficient than for passenger traffic: the energy intensity of 1 tkm and the emission intensity will be 57 Wh and 10.48 g CO_2-eq/tkm, respectively, in the first year of operation of the project.

After the year 2035, upon reaching the estimated maximum load on the whole section of the Latvian part of RB, the above figures, on average, will constitute 59 Wh and 10.94 g CO_2-eq/tkm, respectively.

It is possible that the project management will still reconsider its views on the combination of passenger and freight traffic in the Latvian section and will consider the possibility of replacing part of passenger traffic by freight or introducing regional passenger trains to replace part of high-speed trains going all over the main line. This would improve both the energy characteristics of the project and the environmental ones. The change in the proportions of the total volume of the organization of traffic on high-speed highways, as one of the strategies for increasing the energy efficiency of HSR, was proposed (Akerman, 2011) for Sweden.

On the basis of the presented calculations, the conclusion regarding the energy intensity of the project of the new railway line could be drawn. The total need for electricity for the Latvian section of the RB can range from 34.2 GWh in 2026 to 130.1 GWh in 2050 and beyond.

Table 5. IEA Key Indicators for Latvia (Source: IEA ,2017)

Indicator	Latvia
Electricity generation, by fuel, GWh	
Gas	2944
Biofuels	823
Hydro	2530
Wind	128
Total	6425
Electricity consumption, TWh	6.98
Deficit (–)/surplus (+), TWh	–0.56
CO_{2eq} intensity of energy mix, t CO_{2eq}/t OE	1.6
CO_{2eq} emissions per capita, t CO_{2eq}/capita	3.47
Electricity prices for industry, Euro/kWh	0.093

As can be seen (Table 5), already in 2017, electricity consumption in Latvia exceeded production by 560 GWh. Therefore, the issue of power supply of a project with high energy intensity (approximately 2 percent of the total energy consumption of Latvia) should now be addressed at the state level.

Infrastructure manager maintenance costs for traction costs are assumed (adopted from Atkins 'Rail Baltica Cost Estimation, Renewal & Maintenance and Benchmarking' study, 2017) to be the following: 15 538 EUR/km/year from total operating expenses of 69 402 EUR/km/year. That is, the cost of electricity will be more than 20 percent in the operating costs of the project.

It should be borne in mind that in Latvia electricity prices are the highest among all the project member states. Furthermore, over the last 5 years, Latvia has been experiencing a rise in electricity prices, even though, most of the energy sources are renewable, which means the cost of production should be quite low. This tendency appears to be odd in comparison to a steady decline in electricity prices in Lithuania and Estonia.

Such a high component of the share of electricity costs, combined with a high price for it in Latvia, can lead to an even greater drop in demand for passenger services for the RB project in the Latvian section.

General results of CO_2 emissions calculations are presented in Table 6.

Table 6. Total CO_2 emissions level of the Latvian RB section (Source: author's compilation)

Perspective		**Emissions from constructions,** kt CO_{2eq}/year	**Emissions from passenger flows,** kt CO_{2eq}/year	**Emissions from freight flows,** kt CO_{2eq}/year	**Total,** kt CO_{2eq}/year
2026	Base case	16.5	4 201.8	2 059.41	6 277.69
	Low case	16.5	4 201.8	1 491.75	5 710.03
2030	Base case	20.1	4 201.8	13 993.45	18 215.29
	Low case	20.1	4 201.8	11 577.60	15 799.44
2035	Base case	25.6	4 201.8	13 993.45	18 220.84
	Low case	25.6	4 201.8	11 577.60	15 804.99
2040	Base case	32.7	4 201.8	16 976.95	21 211.43
	Low case	32.7	4 201.8	14 561.10	18 795.58
2050	Base case	41.8	4 201.8	19 604.03	23 847.54
	Low case	41.8	4 201.8	16 052.86	20 296.37

The results (Table 6) are the starting point for the subsequent calculations of the environmental effects of the new railway line that results from the modal replacement. The level of modal replacement needs to be specified in accordance with several governmental programmes for the development of more sustainable road transport infrastructure. Moreover, it is necessary to determine the induced demand for the services of the new highway and take into account the need for the state to finance the transport infrastructure, which will supply the new highway with the cargo and passenger flow, maintaining it in proper condition.

Conclusions

The purpose of this research was to assess the energy consumption and CO_2 emissions of the Latvian section of RB project in order to be able to evaluate the environmental contribution of the project in ensuring sustainable mobility.

The information provided in this research allows us to draw several conclusions. First, the Latvian section of the RB highway will require to supply the line with a maximum share of generation from renewable sources or import electricity from nuclear power plants to ensure a low proportion of the cost of electricity in the total operating costs, hence in the tariffs for services. For instance, in Poland a number of nuclear powers are expected to be built by the time the operation of RB starts.

In addition, the use of low-emission electric power will minimize the total CO_2 emissions in the event of low demand for line services in the first years of its operation.

The second important conclusion is that in order to assess whether there will be a significant reduction in emissions from a modal shift from regimes with a higher environmental impact, it is important to conduct a proper life circle assessment using the IFEU/Tuchschmid methodology recommended by UIC. It needs to be done in order to consider not only the operational period, but also the period of construction, maintenance and disposal of RB, which was not done in the investment justification of the project, despite the requirements of the 'Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020'.

This would allow monitoring the carbon footprint already at the stage of procurement of construction works and equipment for the project. Applying a scientific approach and creating a financial incentive would reduce carbon emissions at the construction stage by allocating part of the budget for the construction of RB infrastructure for the purpose of reducing emissions.

Existing carbon arbitrage funds are already offering a powerful incentive to reduce the carbon content of the infrastructure using the most cost-effective solutions.

The introduction of the procurement requirement for low CO_2 emissions in the proposed works and equipment, as well as the encouragement to use carbon arbitration funds during construction, will allow Latvian representatives interested in the development of the project to play a leading role in discussing sustainability and environmental issues of the RB. It will also encourage other project participants to use the tools for the improvement of environmental performance of the new railway line.

One of the directions of future research determined by the results of this work will be the determination of the induced demand for RB services and the variables on which it depends. The investment rationale for the project states that the induced demand is 0 percent throughout the project. On the one hand, this has improved the environmental performance of the project, but on the other hand, this assumption creates high risks of not loading a new line. Furthermore, the awareness of the percentage of new cargo traffic is important for an adequate assessment of both energy consumption and CO_2 emissions, because the energy required for the transportation of new passengers and cargo represents a net increase in energy demand, which partially reduces the benefits derived from the modal transition from road and air transport.

In this context, arguments regarding energy that are put forward in favour of investment in RB may already be controversial: RB can both contribute to sustainable mobility through a major transition from road and air transport to rail, but it can also increase overall mobility, which will result in the net effect being negative.

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