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The Emissions Reduction Potential for Freight Transport on a High-speed Rail Line Along the 'European Silk Road'

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Abstract

This report estimates the CO_2 emissions of freight transport on a hypothetical high-speed rail (HSR) line along the northern route, from Lyon to Warsaw, of a 'European Silk Road' (ESR). Using a methodology consisting of predictions regarding the freight-carrying capacity of the future HSR, and the freight modal shift, our results indicate that a best-case scenario, at a project lifecycle of 60 years, in which all trains run with 257 tonnes of load, provides for a reduction of 176.2 Mt of net CO_2 emissions compared with current levels. These lifespan savings are comparable to a reduction of net emissions by close to 24% of the overall EU transport sector emissions (excluding air transport) of one year (as measured by the net emissions in 2018). The net negative emissions in the optimistic full-capacity scenario will compensate for the construction costs in 13 years. Thus, the potential for emission reduction along the northern route of the ESR is quite substantial, given that this is just one line, with limited capacity. This hints at the importance that bold missions, such as the construction of a pan-European HSR network, could have for the definition of a European Green Industrial Policy that is capable of supporting the fulfilment of the goals of the Paris Agreement on climate change.

Keywords: Climate change, ecological efficiency, European Silk Road, European Union, green growth, green transition, high-speed rail (HSR), infrastructure, intermodal competition, life-cycle analysis (LCA), logistics, modal shift, train networks, transportation

JEL classification: H54, L91, L92, Q42, Q50, Q51, Q55, Q56, Q58, R40, R41, R42

Executive summary

- Holzner et al. (2018) proposed the construction of a 'European Silk Road' (ESR) for high-speed rail for Europe. This report focuses on the CO_2 emissions of the freight component of the project along its northern Lyon-Warsaw corridor.
- It builds on earlier work by Weber et al. (2022), who focused on the emissions of passenger transport via high-speed rail (HSR) on a similar transit corridor.
- Using methodology centred on cargo differentiation, we provide a means of calculating the potential emissions reductions associated with a transition to HSR for freight transport on the Lyon-Warsaw corridor.
- The model we use for estimating the avoided CO_2 emissions consists of two elements: the prediction regarding the freight-carrying capacity of the future HSR and the freight modal shift prediction.
- Our results indicate that a best-case scenario, at a project lifecycle of 60 years, in which all trains run with 257 tonnes of load, provides for a potential freight HSR capacity of 147,574 million tonne-kilometres per year. The best-case scenario results in a reduction of 176.2 Mt of net CO_2 emissions in total.
- The results of the HSR construction ultimately present an opportunity to reduce net emissions by close to 24% of the overall EU transport sector emissions (excluding air transport) of one year (as measured by the net emissions in 2018) over an assumed lifetime of the project of 60 years.
- By comparison, the net 176.2 Mt of CO_2 emissions avoided (with the construction cost taken into account) is broadly equivalent to 20 years of emissions from one large city with over a million inhabitants, the emissions from the Bitcoin industry since its launch, or the whole sum of the emissions that the Netherlands produced in 2021.
- The net negative emissions in the optimistic full-capacity scenario will compensate for the construction costs in 13 years. Under a more pessimistic scenario, this time period might double.
- The yearly 3.76 Mt of avoided emissions is equal to the annual emissions from more than nine natural gas-fired power plants, or one coal power plant, or almost half a million homes, or to the annual avoidance effect from 1,000 wind turbines.
- Thus, the potential for emission reduction along the northern route of the ESR is quite substantial, given that this is just one line, with limited capacity. It also demonstrates how important the reduction of emissions in the transport sector is in the overall fight against the climate crisis.
- In addition, it hints at the importance that bold missions, such as the construction of a pan-European HSR network, could have for the definition of a European Green Industrial Policy that is capable of supporting the fulfilment of the goals of the Paris Agreement on climate change.

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1. Introduction

Freight transport in Europe currently occurs predominantly via truck, water, standard rail and air, depending on the type of good and the locations it is being shipped to and from. Many goods are transported via intermodal means (via two or more modes of transportation). Transitioning some of this freight to high-speed rail (HSR) has the potential to reduce carbon emissions associated specifically with the movement of goods, as HSR is considered to result in lower emissions than other forms of transportation. This potential emissions reduction can play a role in the EU's goal of reducing carbon emissions by 55% by 2030 and of becoming carbon neutral by 2050. Using the methodology detailed in the body of the report, we will illustrate different scenarios that present varying opportunities for emissions reductions in HSR freight transport in Europe.

It is important to note that transport has the highest reliance on fossil fuels of any sector and accounted for 37% of CO_2 emissions from end-use sectors in 2021 (IEA, 2023). The UN's Agenda 2030 specifically states that 'more freight should be transported by rail' (EC, 2019). Moreover, apart from investment in wind and solar energy generation, cheap and effective policy options for managing the energy transition as suggested by IPCC (2022) include measures in the building and transport sectors. In a study proposing the construction of a 'European Silk Road' (ESR), Holzner et al. (2018) provided a possible solution for this envisaged shift to rail, suggesting inter alia an HSR network for Europe. In the original plan, it was to extend around 11,000 km on a northern route from Lisbon to Uralsk on the Russian-Kazakh border, and on a southern route from Milan to Volgograd and Baku, also including other modes of transport and a string of logistics centres and ports.

The original idea was, on the one hand, centred around the aim of linking the industrial centres in the west and the deindustrialised but populous regions of the east of Europe with a traditional infrastructure-based developmental agenda. And, on the other hand, the hope was that this would also support European unity in a changing world after a global populist shift that included the election of Donald Trump as US president and the problematic outcome of the UK's Brexit referendum, both in 2016, as well as the removal in 2018 of term limits for the presidency of China's Xi Jinping. Much like the failed 'Wandel durch Handel' (change through trade) policy, the idea of connecting the EU with Russia via new transport infrastructure received the death blow on 24 February 2022, when Russian president Vladimir Putin ordered the full-scale invasion of Ukraine. Although one might consider the possibility of a reconnection with a new (post-Putin) Russia, even the medium-term prospects of such an outcome are clouded, at best. It is our view that, under the circumstances of the ongoing war, even a line to Lviv and Kyiv would be a more realistic project. Thus, in the present study our geographical focus is on the most central part of the originally suggested northern route of the ESR from Lyon to Warsaw (Figure 1).

Figure 1 / The core of a northern route of the 'European Silk Road' high-speed rail network

Source: GEOATLAS.com, own route design.

In another note, Holzner (2019) suggested a specific, extra-budgetary financing model for the ESR. In order to conduct and finance the project, he suggested establishing a 'European Silk Road Trust', owned by the euro area countries, other EU countries and third countries that wish to join in the construction of the ESR. The trust could rely on a public guarantee for the issuance of long-term bonds. It would formally be part of the private sector, especially as it would have sufficient income of its own from private customers (through tolls). As a strong core guarantor of the trust, the gradual development of a European Sovereign Wealth Fund by euro area member states was suggested, along the lines of the structure of the Norwegian oil fund, sourced for example from part of the profits of the European Central Bank (ECB). Other options that would make use of existing institutions could include, for instance, a substantial increase in the European Fund for Strategic Investments and/or a larger capital injection into the European Investment Bank (EIB), in order to finance the ESR.

More recently, the proposal by Holzner et al. (2018) has gained significance as the idea of a European HSR network is also being considered as a mechanism for economic recovery after the Covid-19 pandemic. The Macroeconomic Policy Institute (IMK) in Düsseldorf, the Observatoire Français des Conjonctures Économiques (OFCE) in Paris and wiiw have jointly proposed dedicating a part of the EU's Recovery Fund inter alia to the development of a pan-European HSR network – an 'ultra-rapid' train connecting EU capitals (Creel et al., 2020). Apart from the economic recovery, an HSR network could also be an important step towards achieving the announced goal of reducing greenhouse gas (GHG) emissions set out in the Paris Agreement and Agenda 2030.

Finally, in a first co-operation between students from Central European University's School of Public Policy (now the Department of Public Policy) and wiiw, Weber et al. (2022) have published a report complementing the earlier economic feasibility analysis of the ESR by determining the environmental impact of the northern route, focusing on the net GHG emissions, in carbon dioxide equivalent (CO_2-eq) in the passenger transport segment of the suggested HSR. The study used a life cycle assessment (LCA) for the analysis of construction, maintenance, operation and disposal of the passenger transport HSR, to provide an estimate of how many tonnes of CO_2-eq can be saved over the span of 60 years. In generating a modal shift from road and air passenger transport, the construction of an HSR line provides the potential for saving up to 10% of net CO_2-eq emissions in the EU27 for one year.

Thus, the proposed HSR line contributes to the current targets and goals of the EU to reduce emissions and present smart, sustainable and inclusive economic solutions. Moreover, in the new geopolitical era of the *Zeitenwende*, the global energy crisis and the related upsurge in inflation, green industrial policy is seen as a way to deal with the political, economic and ecological problems of the dependency of Western democracies on fossil fuels and its omnipresent use in our societies. As a reaction to the 2022 US Inflation Reduction Act (IRA), which aims to invest massively in clean energy, the European Commission presented a Green Deal Industrial Plan in February 2023 (EC, 2023). Many of the suggested measures are based on refocusing, streamlining and simplifying earlier initiatives and on changes in framework regulations, but there are also a few new ideas, such as the plan to implement a European Sovereignty Fund.

Although it is important to pick all the low-hanging fruit, as suggested by IPCC (2022) – such as, for instance, in the transport sector the support of fuel-efficient light and heavy-duty vehicles, the more general shift to public transport and bikes, and higher efficiency and optimisation in shipping and aviation, all of which can be done at relatively low costs – it becomes increasingly clear that this will not be enough to reach the climate goals. It appears that Europe also needs to implement costly missions, maybe even bolder than those suggested by Mazzucato (2018). A European HSR network could be one such mission and encompass passenger as well as freight transport. So far, the environmental effects of constructing an HSR freight transport network in the framework of an ESR have not been examined. This study closes the gap by conducting an environmental impact evaluation of the core route of the proposed HSR network, specifically with regard to freight transport.

2. Literature review

Much of the existing literature on HSR networks focuses on passenger rail. The existing research pertaining to freight HSR is dominated by China, with some contributions from North America and Europe. Across the European continent, there are only a few HSR networks, with the highest concentration of lines in Spain, France, and Italy, although these are primarily for passenger travel. A 2011 report by the European Commission stated the goal of shifting 30% of road freight travelling more than 300 km to transition to modes such as rail or water transport by 2030, and 50% by 2050 (Islam et al., 2015). This report suggests that a shift to HSR presents one method of working towards this goal, but obstacles remain, which are discussed below.

The proposed project includes two components. The study by Holzner et al. (2018) seeks to investigate a dedicated European HSR network in the framework of its ESR initiative that includes both passenger and freight components. The critique of HSR feasibility by the European Court of Auditors (2018) serves as a guiding framework to address potential shortcomings and develop a roadmap for development. The Court found that, based on one audit, the development goals of HSR suffer in feasibility analysis for several reasons. These include the frequency of delays, the lack of an EU-wide approach and centralised operations, and the fact that so far co-funding from the EU constitutes only a small proportion of the total costs for HSR development.

An important trend that emerged in the literature is the importance of goods differentiation. Freight has significant differences by type of good or goods category. The potential for a transition to HSR will vary for different goods and goods categories. Based on the literature, there will likely be no noticeable shift from air freight because of the characteristics of their usual cargo – for example, urgent mail, and specialised items such as zoo animals or components of nuclear-power plants (Eurostat, 2020). The share of water transport is highly variable by country, depending on their water access and existing infrastructure; many countries in our catchment area have negligible reliance on water transport. For that reason, we have omitted this from the study but propose it as an area for future study. Transport by truck remains the favoured method in many cases, given that trucks can go almost anywhere and are often required for the first or last sections of a cargo journey to get goods to and from their destination outside air, rail or ship hubs. The use of multiple methods is common and referred to as intermodal transport (Eurostat, 2020).

Reliability in rail infrastructure came up multiple times in the literature. A study in the United States found that, while HSR is of interest for shippers and those affiliated with the industry, greater reliability in existing rail infrastructure may have more of an impact in engaging shippers to expand their use of rail for freight transport. Concerns raised by existing rail users included delays, while mid-size producers expressed concern about how their products were handled in transit. Many research participants stated a preference for rail that stayed on schedule and handled goods with care, irrespective of the speed of the type of rail itself (Holguín-Veras et al., 2021). Our research proposes that reliability must be a cornerstone of future HSR development. We suggest further research on intermodal transport for greater efficiency and sustainability in the European freight transport system in the future.

The Basque Y HSR line is a relevant example to consult in conducting the LCA for freight transportation in Europe. Bueno et al. (2017) calculated the emissions of passenger and freight transportation through an LCA, considering diverted traffic as well as construction costs from sources such as tunnels. The result was not positive. Only 8.5% of air traffic diverted, and construction and maintenance costs ensured that net emissions were not reduced because 60% of the Basque Y line consisted of tunnels, owing to the Basque Country's mountainous terrain. Fortunately, the route from Lyon to Warsaw is not as mountainous as that of Basque Y. Although Basque Y serves as a cautionary tale of simplified understandings of net emissions reduction potential in HSR, it does not show that HSR development fails to reduce emissions in all cases.

The state of freight transportation along the route from Lyon to Warsaw should be considered. The literature shows a patchwork of situations with minimal consistency. Mitusch et al. (2014) emphasise, for example, that the Betuweroute from the Netherlands to Germany is a pure freight line. The most significant of German corridors is the East-West corridor No. 8. The Eurasian Rail Alliance Index has indicated that Poland's freight load must increase its market share to survive, but that the Covid-19 pandemic led to the transfer of 25% of total freight volume to railway freight in Poland.

The following sections will illustrate our methodology and research findings regarding the emissions reduction potential of the freight conversion to HSR in the Lyon-Warsaw corridor. They will also discuss limitations and areas for future study, to enable future researchers the opportunity to efficiently elaborate on the existing research from this paper and beyond.

3. Methodology and data

3.1. HSR CAPACITY

The distance of the line was calculated upon consideration of the previous passenger report (Weber et al., 2022, pp. 20-21), but an important distinction is that, because of Russia's full-scale invasion of Ukraine, we have omitted the Belarusian and Russian railway stretches that were in the original plans of the ESR. Based on the data from the 2018 ESR study (Holzner et al., 2018), the total length of the HSR subject to this modification will be 2,185 km, which is the sum of the stretches Lyon-Paris-Crespin (704 km), Crespin-Brussels-Maasmechelen (212 km), Maasmechelen-Herungerberg (79 km), Herungerberg-Duisburg-Berlin-Frankfurt/O (694 km) and Frankfurt/O-Warsaw (496 km). Looking ahead to a time after presidents Putin and Lukashenko have left office, the Warsaw-Minsk-Moscow line could easily be reintegrated into the capacity and construction calculations.

The train used in the model is Mercitalia Rail's modification of the passenger train ElettroTreno Rapido 500, which has a maximum speed of 360 km/h and is one of the few high-speed locomotives in Europe, and the most popular one (Smart Rail, 2018). This is a relatively new project, suggesting that future HSR trains will have similar specifications. ETR 500 was chosen specifically because it is already used on the Italian cargo HSR. Unlike French high-speed trains, ETR 500's capacity is not limited to mail and parcels, and it is more suited than Chinese high-speed trains for European geographical and technical requirements. ETR 500s can carry around 257 metric tonnes of cargo (equivalent to two Boeing 747 cargo planes) in the 12-car trainset, with emissions '80% lower than in road transport' (Smart Rail, 2018). The cargo truck emission level is around 75 grams of CO_2 per tonne-km (van Essen et al., 2003, p. 43), with ETR 500's emission equal to around 15 grams of CO_2 per tonne-km. The cargo capacity of trains varies and therefore we review two scenarios: the first and most optimistic, where all trains run with the 257 tonnes of load, and the second, where trains run at 50% capacity.

As speedier trains need more time for braking, the headway between two trains is an important consideration for the model of the HSR. In ideal conditions and with trains that move faster than 250 km/h, four minutes of headway is 'a good approximation of the highest capacity performances' (UIC 2018, p. 56). This means that one line of HSR can support 15 trains per hour moving in the same direction. Although we expect this number to be lower in practice, owing to possible incidents and weather conditions, the capacity evaluation model works with figures that are close to ideal, thus making it possible to take a step back and review the results more sceptically.

The final consideration regarding capacity is the number of HSR lines – and therefore the number of hours per day that the trains can run. We analyse four scenarios: one passenger line at night – eight hours; two passenger lines at night – 16 hours; one cargo-dedicated line – 24 hours; two cargo-dedicated lines – 48 hours. The number of lines and their use influence construction costs, which are the main benchmark against which avoided CO_2 emissions are measured. The night-time-only models presuppose that on HSR lines passenger trains run from early morning until night (e.g. from 8am until midnight), while cargo is transported at night. In this way, management and logistical difficulties because of train interferences can be minimised. Obviously, the four scenarios proposed are not exhaustive, and different mixes can be envisaged – for example, it is possible to build one cargo line and simultaneously use the two passenger lines at night. For the sake of simplicity, we cannot review all these combinations.

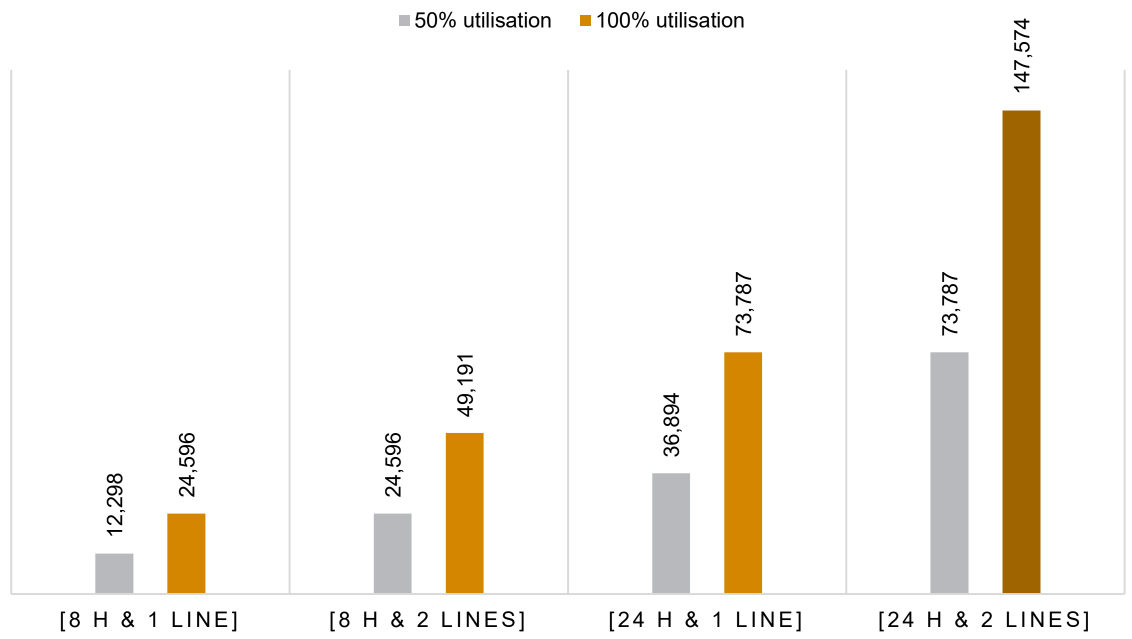
The specifications of distance, train capacity, headway and number of lines give us the opportunity to estimate the total capacity of the line. We multiply them together to get daily capacity, and further multiply the resulting number by 365 to produce the total annual capacity of the network.

Table 1 / HSR capacity scenarios

Annual capacity (million tonne-km)		[hours per day] x [number of tracks]			
		8 x 1	8 x 2	24 x 1	24 x 2
% of load per train	50	12,298	24,596	36,894	73,787
	100	24,596	49,191	73,787	147,574

The 48 hours per day and 100% load scenario is treated as the most optimistic, with 147,574 million tonne-km (tkm) per year. Building two lines would provide the most capacity but would also involve the highest construction costs. We will treat CO_2 avoided emissions under this capacity as the ideal outcome, with other outcomes being suboptimal but more likely.

Figure 2 / ESR's core northern route HSR capacity, million tkm



Source: Own elaborations.

3.2. MODAL SHIFT AND MODAL SPLIT

After computing the gross capacity of the HSR, it is crucial to analyse how these numbers will be distributed across different modes of transportation, as each mode has its own CO_2 emission figures, with differing emission reduction potential.

Aircraft emissions are higher than for other types of transport. For example, the emissions of passenger planes are approximately ten times higher than emissions of regular passenger trains on the same route (Seat61, n.d.). Although reducing aircraft emissions via the introduction of HSR would be a desirable scenario, air transport accounts for a minimal share of overall cargo transportation, with a total of around 14m tonnes transported in 2018 in the EU (Eurostat, 2020, p. 67). To put air freight into perspective, it is insignificant in comparison to the 300m tonnes of water freight in 2018 in France alone, or to the 53m tonnes of textile and leather – the smallest category – transported via roads in the EU as a whole (Eurostat, 2020, pp. 59-63). Air is mostly used for mail and highly specific – urgent or unique – goods. Because of these considerations, we omit air freight from the analysis.

Water transport is also omitted. Inland waterways account for 5% of total cargo transportation in the EU in terms of tonne-km. Their share of inland transport for the countries where the proposed HSR would go is mostly under 10%, with Belgium topping the list with around 18% (Eurostat, 2020, p. 52). There are several factors that made inclusion of waterways in this research challenging, including variability by country, variation by region (given inbound vs outbound and river vs ocean transport), and the assumption that transoceanic shipments cannot be replaced by HSR. These three considerations underpin the difficulty of accounting for river and ocean cargo transport modal shift in any meaningful way (Eurostat, 2020).

We are left with trucks and conventional trains. The highly aggregated estimates for these two types of transport report CO_2 emissions of 75 grams per tkm for trucks and 25 grams per tkm for trains respectively (van Essen et al., 2003, p. 43). These figures were predictions for 2010, which are based on 2000 emission levels and their subsequent trends, and so using them is an effective way to account for the age of the average vehicle in use. As a reminder, the emissions from the baseline HSR train ETR 500 are around 15 grams of CO_2 per tkm. Because of these differences, accounting for the future modal split is crucial, as truck emissions are five times higher than those of high-speed trains, while the difference between conventional and high-speed trains is only around 10 grams per tkm.

In their study, Böhm et al. (2021) simulate the results of the modal shift for Europe in 2030, predicting that HSR can replace 62% of lorries in the optimistic scenario. This does not consider the future capacity of the line. Additionally, it does not consider conventional rail as the third element of the modal shift. This consideration is crucial, as lorry load can switch over to conventional rail rather than to HSR, and conventional rail can take up the capacity of the HSR by itself, leaving truck modal shift significantly less than the equivalent of the 62% of the total truck load. In turn, this would bias the quantity of emissions avoided.

We take the estimate from Böhm et al. (2021, p. 4) as a reference point, but also aim to account for the respective likelihoods of modal shifts by considering the inherent characteristics of the goods that are transported via each mode. For the final calculations, we take only the categories of goods that are found to be likely to switch from truck to conventional rail based on their innate qualities. The list of the categories under review can be found in Table 2, and the discussion as to why these specific goods are more likely to shift from trucks to rail can be found in the study by Holguín-Veras et al. (2021). To generalise, some goods require more spatial flexibility in terms of their delivery and would not shift to rail, as rail is less flexible than road transportation. The loading points of some goods are scattered (for example, fields), while others are concentrated in one location (such as a mine), which defines the choice between rail and road. Finally, some goods need timeliness in delivery and/or additional conditions such as refrigeration. These and other issues underscore how the choice is made and whether there are enough opportunities for shifting from higher-emitting trucks to lower-emitting conventional rail. We extend this analysis from conventional to high-speed rail, as it has the same characteristics as conventional rail but offers greater timeliness and would therefore be likely to attract urgent or quickly perishable goods from trucks. Substantively, accounting for these and no other categories does not change the resulting figures, as the total sum of cargo belonging to these categories is larger than the HSR's capacity, even in the most optimistic scenario. Still, the crucial methodological point was to check whether there is enough truck-transported cargo that can shift, given that it does so under specific conditions.

Table 2 / Cargo categories that are likely to switch from trucks to conventional rail

›	Coal and lignite; crude petroleum and natural gas
›	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
›	Chemicals, chemical products, and man-made fibres; rubber and plastic products; nuclear fuel
›	Other non-metallic mineral products
›	Basic metals; fabricated metal products, except machinery and equipment
›	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
›	Furniture; other manufactured goods n.e.c.

Source: Eurostat (2022); categories based on Holguín-Veras et al. (2021).

The 62% modal shift estimate is halved, to account for the presence of conventional rail rather than just trucks in the input cargo figures. The resulting dedicated shares are 31% for trucks and 69% for rail, which we believe is a functional approximation of how the HSR's capacity can be split between the two modes. We were unable to locate any studies that would give credible evidence on a similar note, and therefore we had to resort to downsizing the estimate given by Böhm et al. (2021, p. 7). The more than twofold difference between the two shares seems to be a credible depiction of how likely trucks and conventional rail are to switch. For trucks, the categories of rail-inclined goods must fulfil certain conditions as discussed above: timeliness, geographical concentration, need for specific facilities etc. The HSR can fulfil the timeliness criterion as it is faster than conventional rail, but the other criteria will hardly be affected sufficiently. The story is different for the modal shift from conventional rail to the HSR: it is essentially the same mode of transportation, but with substantially improved speeds and different costs. Therefore, the 31-69% predicted split overestimates rather than underestimates the future share of truck cargo shifting, but is the most relevant approximation at this point. The model in this paper is lean enough for the equation to incorporate any future findings regarding the distribution.

4. Results

4.1. EMISSIONS AVOIDED

This section sums up the previous points and puts them into a single model capable of predicting the amount of emissions avoided through the introduction of the northern HSR route of the ESR, with specific issues considered. First, we calculate the capacity of the future HSR line(s), based on: the total length of the Lyon-Warsaw route, equal to 2,185 km; the tonnage of the reference train model ETR 500, with either a full load or a half load; the number of rail lines (one or two dedicated freight lines, or one or two passenger lines on which freight high-speed trains run for eight hours at night); and with the assumed ideal headway of four minutes between trains. This overall capacity on the route is then distributed over the train-truck ratio according to the estimations above, with 31% of the total taking up the truck cargo traffic, and the remaining 69% as conventional rail. The net negative emissions from these two cargo shares are calculated through the multiplication of a respective cargo share by the difference of the ETR 500's fuel efficiency and the respective mode's fuel efficiency, and summed up thereafter. This gives us a negative number which is the total sum of the emissions avoided yearly with the HSR in place under the assumed conditions (train model, number and length of the lines, fuel efficiency and so on).

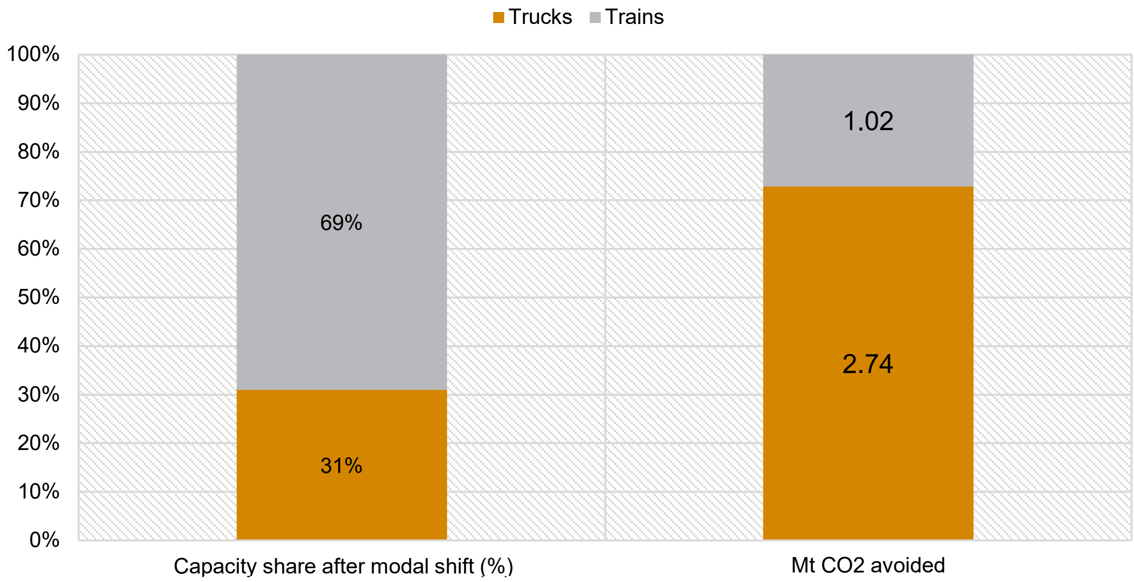
The sum of the two avoided emission volumes per mode is how much CO_2 the HSR will save. The components of the equation are subject to different scenarios. We have shown eight (out of many) potential line/load variations and discussed the lack of clarity around modal splits. The CO_2 emissions from fuel per mode can also vary. The baseline scenario that comes into the model is the one we see as the most optimistic in terms of capacity and the most likely in terms of the modal split, with highly averaged fuel emission figures taken at the highest level of estimation.

The most optimistic two-lines, full-load scenario gives us the potential capacity of 147,574 million tkm per year. We split it into 45,748 million tkm (31% of total) diverted from trucks, and 101,826 million tkm (69% of total) from conventional rail, respectively. The fuel emission difference between trucks and ETR 500 is 60 grams of CO_2 per tkm, which results in 2.74 Mt of CO_2 emissions avoided annually for trucks. The fuel emissions difference between conventional electric trains and ETR 500 is 10 grams of CO_2 per tkm, which results in 1.02 Mt of CO_2 emissions avoided annually for conventional rail. These two figures sum to 3.76 Mt of net negative CO_2 emissions per year of operation and under the conditions assumed.

With the project's lifecycle of 60 years, the total amount of the emissions avoided through the HSR will be around 225.6 Mt of CO_2. After factoring in the construction emissions, the HSR will provide 176.2 Mt of negative CO_2 emissions in its projected lifetime. In terms of financial cost of the project, based on the methodology of the 2018 report, and corrected for inflation, we estimate that the overall costs for construction of a Lyon-Warsaw two-track railway line with tunnel systems would stand at about EUR 164bn at 2021 prices. The current episode of high inflation might yield in the end a much higher nominal figure. In terms of the EU's GDP in 2021, the construction costs are only slightly above 1%. In the long term, the cost to avoid emissions through the construction of the HSR is therefore EUR 0.93 per kg of CO_2 in 2021 prices. It is crucial to note that this analysis looks at the direct positive effect of the HSR on the environment, assuming that there is going to be no profit/losses from the operation of the HSR and leaving out the outcomes that are relevant for the development of businesses, logistical chains, and the EU and national economies at large. Thus, realistically we expect a somewhat different avoidance price as a consequence of these factors. The current price of emissions allowances in the EU (as at end-February 2023) is about EUR 0.1 per kg of CO_2.

By comparison, the net figure of CO_2 emissions avoided, 176.2 Mt, is broadly equivalent to more than 20 years of emissions from one large city with over a million inhabitants (BMW Group, 2021), the emissions from the Bitcoin industry since its launch (Sparks, 2022), or the whole sum of the emissions that the Netherlands produced in 2021 (Statista, 2022). The figure of 3.76 Mt of emissions avoided on a yearly basis is equal to the annual emissions from 9.4 natural gas-fired power plants, or one coal power plant, or 473,621 homes, or the annual avoidance effect from 1,000 wind turbines (EPA, 2023).

Figure 3 / Modal share vs emissions avoided



Source: Own elaborations.

4.2. CONSTRUCTION COSTS, YEARS TO OFFSET

The earlier report on the viability of an HSR for passenger transportation claimed that the construction costs would most likely amount to 38 Mt of CO_2 (Weber et al., 2022, p. 20). We use the same figures for construction emissions, as we believe that the claims made in the previous study are sufficiently persuasive to rely on their inferences (Weber et al., 2022, pp. 19-20). Using the same methodology regarding the geospatial characteristics of the line, we nonetheless expect that the Warsaw-Minsk-Moscow section will not be built in the foreseeable future. Therefore, the total emissions from constructions for our model are smaller, as the line itself is shorter by 1,150 km, or by 35% (Weber et al., 2022, p. 21). The carbon product of construction can therefore be expected to lie somewhere around 24.7 Mt, or 49.4 Mt for two lines.

With net negative emissions of 3.76 Mt yearly, the two-line full-capacity set-up will compensate for the construction costs in 13 years and one and a half months. The same is true for the one-line full-capacity set-up, with only half the avoided emissions but only half the construction costs. Underused load capacity of the trains could diminish the offset time: if the average load factor is 50%, it will take a minimum of 26 years for the construction costs to be compensated.

The findings of this report are close to the earlier paper on the passenger HSR variant: assuming a medium scenario for both substitution rates and construction costs, the authors found that the ecological costs would be offset in 11.8 years (Weber et al., 2022, p. 19). This is similar to this paper's estimation of the offset period of around 13 years. The most conservative scenario in the passenger HSR case foresaw a maximum of 37 years for the construction cost to be offset, which is a longer time period than the pessimistic scenario in this report.

4.3. POLICY RECOMMENDATIONS

On the ecological side, the freight HSR will offset its construction costs in just over 13 years under the ideal full load and full utilisation scenario, or in just over 26 years if the HSR train load is utilised only up to 50% on average. Therefore, good co-ordination is key. Co-ordination also is a cornerstone for short and efficient headways – of, ideally, four minutes – between trains. Finally, co-operation of state authorities, scientists, rail companies and businesses is required for the HSR to be a worthwhile investment to reduce carbon emissions. These tasks are not simple ones, but the estimations of the two reports on the HSR viability demonstrate that the ecological benefits can be reached within a reasonably short timespan.

It is crucial to note that freight dynamics are constantly shifting in terms of volume, modal splits, innovations and so on (Ferrari, 2014). One of the major changes that may come with implementation of an HSR is additional demand for transportation, induced by the availability of new capacities. A shift from a higher-emissions to a lower-emissions mode of transport can decrease the CO_2 emissions from a specific cluster of goods, but the new capacity may lead to more CO_2 emissions in total. HSR can be useful for some categories of goods, including high-value and/or time-sensitive ones, especially in suitable structural and business conditions (Watson et al., 2019, p. 103). A more integrated HSR network along with a major shift from more traditional modes of transport towards HSR can ensure that the load factor per train is sufficient to cover the ecological costs more quickly, also making the HSR system more profitable for the owners (Watson et al., 2019, p. 103).

Therefore, co-ordination, cost-benefit analysis and structural expertise are crucial in creating a workable HSR solution, but HSR is a suitable response to achieve a more ecological and faster cargo delivery. It will not take much time for HSR to reach a zero-emissions point, even with some of the assumptions for this model being relatively restrictive.

4.4. LIMITATIONS

We faced two main limitations in the research and analysis of this topic. The first limitation was the lack of peer-reviewed data, aggregate substitution rates and conversion rates for freight transport modes. Without applicable data, substitution rates or conversion rates for regular rail, air, truck and marine transport, it was difficult to make reliable estimates for an HSR based on our methodology. The most extensive research in this field has been done in China, which has significant HSR coverage compared with the rest of the world. However, the geographical, socio-political and cultural context of China differs from the EU in significant ways. These differences make it difficult to reliably use the existing China-based research as the applicability or replicability in a European context varies significantly. In the European context, there is a lack of consistency in the availability of data by region, or by transit mode.

A second limitation was the technical and complex nature of the project itself. Multiple considerations are required (transport modes, intermodal transport, types of goods, regional requirements, existing infrastructure etc.) and it was difficult to sufficiently narrow our scope, while also ensuring that the research was suitably comprehensive to ensure its future utility. Given the complexity of the project, we recommend further study on the topic. We have suggested some areas for further study below which may support future researchers in continuing to develop a nuanced understanding of this important and rapidly evolving topic.

4.5. AREAS FOR FUTURE STUDY

Through this research, we were able to identify several areas for complementary future study, elaborated upon below. These topics may provide opportunities for deeper analysis of the current topic or present a new area of research that we were unable to cover within the scope of the existing analysis.

An issue that currently exists across the EU is the presence of varying rail systems, with different infrastructure requirements that can make cross-border transport a challenge. Given these varying requirements, research into local requirements by country, and opportunities for cross-border unison would be beneficial in enabling expansion of HSR.

As discussed previously, transit from rail, air and water hubs to further or final destinations presents a challenge in reducing emissions, as this is an area where trucks are often the most efficient or convenient option. In some cases, trucks are the only option, given existing transportation infrastructure and geographical contexts. Transitioning from one mode to another also presents a challenge, as this is one of the areas where delays occur most often. Research on ease of use, expansion of connecting rail lines, or other options to reduce transportation emissions from this area would help to gain a full perspective on HSR possibilities in Europe. In a wide-reaching study in the US, Holguín-Veras et al. (2021) were able to provide a comprehensive analysis of the current state of freight transport and opportunities for future improvements in that country. A similar study, with co-operation from implicated jurisdictions and freight rail users, could be highly beneficial in a European context.

Freight differs significantly from passenger rail in that what is being transported can have substantially different requirements, depending on the item. For example, many types of food require refrigeration and speed, thus necessitating transport by refrigerated truck. Most fertiliser, however, is already transported by rail – it is a good that does not require rapid service, it is bulky and there are existing systems in place to ensure ease in moving it effectively via rail. Further research to understand the needs of different goods and goods categories can better enable infrastructure designers to create HSR lines that meet the needs of manufacturers and producers.

The existing research often does not include pipelines within its scope. Pipelines constitute a separate transportation method, which – given the nature of the lines themselves and the nature of the goods being moved via this method – requires further study. Similarly, we have omitted aircraft and ships/boats, owing to the needs of goods types being transported, wide variation in use of these transit methods depending on region, and lack of data in a European or international context. However, these are also important transportation methods worthy of further study.

Induced demand, wherein the introduction of new infrastructure increases its use and therefore its associated emissions, is an issue identified in this research. Although we have acknowledged the issue, more research is required to fully understand the possible emissions associated with this.

5. Conclusion

To estimate the CO_2 emissions reduction potential of a transition for freight transport from truck and conventional rail to HSR along a hypothetical northern 'European Silk Road' route from Lyon to Warsaw, this report used two elements: the prediction regarding the freight-carrying capacity of the future HSR and the modal shift prediction. Our results indicate that a best-case scenario, at a project lifecycle of 60 years, in which all trains run with 257 tonnes of load, provides for a reduction of 176.2 Mt of net CO_2 emissions. This is comparable to a reduction of net emissions by close to 24% of the overall EU transport sector emissions (excluding air transport) of one year (as measured by the net emissions in 2018). Under this scenario, construction emissions would be offset in 13 years, however underused line capacity (in a scenario of 50%) would extend the offset time to 26 years. Cross-border co-ordination and reliability in service were identified as paramount in ensuring that the HSR can achieve its full emissions reduction potential. Thus, in principle, the potential for emissions reduction along the northern route of the ESR is quite substantial, given that this is just one line, with limited capacity. This hints at the importance that bold missions, such as the construction of a pan-European HSR-network, could have for the definition of a European Green Industrial Policy that is capable of supporting the fulfilment of the goals of the Paris Agreement on climate change.

Bibliography

BMW Group (2021), 'Over 200 million tonnes: BMW Group sets ambitious goal to reduce CO2 emissions by 2030'. https://www.press.bmwgroup.com/global/article/detail/T0332273EN/over-200-million-tonnes:-bmw-group-sets-ambitious-goal-to-reduce-co2-emissions-by-2030?language=en

Böhm, M., M. Arnz and J. Winter (2021), 'The potential of high-speed rail freight in Europe: how is a modal shift from road to rail possible for low-density high value cargo?', *European Transport Research Review,* Vol. 13(4). https://doi.org/10.1186/s12544-020-00453-3

Bueno G., D. Hoyos and I. Capellán-Pérez (2017), 'Evaluating the environmental performance of the high speed rail project in the Basque Country, Spain', *Research in Transportation Economics*, Vol. 62, pp. 44-56.

Creel, J., M. Holzner, F. Saraceno, A. Watt and J. Wittwer (2020), 'How to spend it: A proposal for a European Covid-19 recovery programme', wiiw Policy Note/Policy Report, No. 38, The Vienna Institute for International Economic Studies (wiiw), Vienna, June. https://wiiw.ac.at/publications-all-all-all-all-10-year-desc-0-how+to+spend+it.html

EC (2019), 'Sustainable mobility – The European Green Deal', European Commission. https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6726

EC (2023), 'The Green Deal Industrial Plan: putting Europe's net-zero industry in the lead', European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_510

EPA (2023), 'Greenhouse gas equivalencies calculator', United States Environmental Protection Agency. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results

European Court of Auditors (2018), 'A European high-speed rail network: Not a reality but an ineffective patchwork', Special Report No. 19, Publications Office of the European Union. https://data.europa.eu/doi/10.2865/105814

European Environment Agency (2020), 'Greenhouse gas emissions from transport in Europe'. https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-12

Eurostat (2020), 'Energy, transport and environment statistics: 2020 edition', *Statistical Books* [accessed 20 March 2022]. https://ec.europa.eu/eurostat/documents/3217494/11478276/KS-DK-20-001-EN-N.pdf/06ddaf8d-1745-76b5-838e-013524781340?t=1605526083000

Eurostat (2022), Transport database [accessed 25 April 2022]. https://ec.europa.eu/eurostat/web/transport/data/database

Ferrari, P. (2014), 'The dynamics of modal split for freight transport', *Transportation Research Part E: Logistics and Transportation Review*, Vol. 70, pp. 163-176. https://doi.org/10.1016/j.tre.2014.07.003

Holguín-Veras, J., L. Kalahasthi, S. Campbell, C.A. González-Calderón and X. Wang (2021), 'Freight mode choice: Results from a nationwide qualitative and quantitative research effort', *Transportation Research Part A: Policy and Practice*, Vol. 143, pp. 78-120.

Holzner, M., P. Heimberger and A. Kochnev (2018), 'A "European Silk Road" ', wiiw Research Report, No. 430, The Vienna Institute for International Economic Studies (wiiw), Vienna, August. https://wiiw.ac.at/a-european-silk-road-dlp-4608.pdf

Holzner, M. (2019), 'One trillion euros for Europe. How to finance a European Silk Road with the help of a European Silk Road Trust, backed by a European Sovereign Wealth Fund and other financing instruments', wiiw Policy Note/Policy Report, No. 35. The Vienna Institute for International Economic Studies (wiiw), Vienna, November. https://wiiw.ac.at/one-trillion-euros-for-europe-how-to-finance-a-european-silk-road-with-the-help-of-a-european-silk-road-trust-backed-by-a-european-sovereign-wealth-fund-and-other-financing-instruments-p-5106.html

IEA (2023), 'Transport – Topics'. https://www.iea.org/topics/transport

IPCC (2022), 'Climate change 2022: Mitigation of climate change. Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf

Islam, D.M.Z., R. Jackson, T.H. Zunder and A. Burgess (2015), 'Assessing the impact of the 2011 EU Transport White Paper – a rail freight demand forecast up to 2050 for the EU27', *European Transport Research Review*, Vol. 7. https://etrr.springeropen.com/articles/10.1007/s12544-015-0171-7

Mazzucato, M. (2018), 'Mission-oriented research & innovation in the European Union: A problem-solving approach to fuel innovation-led growth', European Commission, Directorate-General for Research and Innovation.

Mitusch, K., G. Liedtke, L. Guihery and D. Bälz (2014), 'The structure of freight flows in Europe and its implications for EU railway freight policy', *Working Paper Series in Economics*, No. 61. Karlsruher Institut für Technologie. https://econpapers.wiwi.kit.edu/downloads/KITe_WP_61.pdf.

Seat61 (n.d). 'Cut your CO2 emissions by taking the train, by up to 90%...' [accessed 10 April 2022]. https://www.seat61.com/CO2flights.htm

Smart Rail (2018), 'High speed trainset to be converted for freight', *Railway Gazette,* April 6, 2018 [accessed 2 April 2022]. https://smartrail-project.eu/railway-gazette-high-speed-trainset-to-be-converted-for-freight/

Sparks, M. (2022), 'Bitcoin has emitted 200 million tonnes of CO2 since its launch', New Scientist, September 28, 2022. https://www.newscientist.com/article/2339629-bitcoin-has-emitted-200-million-tonnes-of-co2-since-its-launch/.

Statista (2022), 'Carbon dioxide (CO_2) emissions in the European Union in 2000, 2010 and 2021, by country'. https://www.statista.com/statistics/1171389/co2-emissions-european-union/

UIC (2018), 'High speed rail: Fast track to sustainable mobility', International Union of Railways, Railway Technical Publications, Paris.

van Essen, H., O. Bello, J. Dings and R. van den Brink (2003), 'To shift or not to shift, that's the question: The environmental performance of the principal modes of freight and passenger transport in the policy-making context', CE, Delft. https://cedelft.eu/wp-content/uploads/sites/2/2021/04/4360_eindrapportHvE_1244546518.pdf

Watson, I., A. Ali and A. Bayyati (2019), 'Freight transport using high-speed railways', *The International Journal of Transport Development and Integration*, Vol. 3(2), pp. 103-116. DOI: 10.2495/TDI-V3-N2-103-116.

Weber, K., M. Zangl, M.U. Zahid and M. Holzner (2022), 'Environmental impact evaluation of a European high speed railway network along the "European Silk Road" ', wiiw Research Report, No. 459, The Vienna Institute for International Economic Studies (wiiw) and Central European University School of Public Policy, January. https://wiiw.ac.at/environmental-impact-evaluation-of-a-european-high-speed-railway-network-along-the-european-silk-road-dlp-5837.pdf

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