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Better Integrating Finland's Rail Network

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Abstract

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With a continually changing Europe and growing internationalisation, the need for strong cooperation in the form of infrastructure projects connecting countries is becoming more apparent. With Finland having a rail system built to be compatible with the former Russian empire, there has been increased desire to create a compatible connection to the European Rail Network.

This Thesis will explore potential new connections to Finland's European neighbours and how various technologies currently available could change the way Finland's rail network currently operates. Sea bearing freight for the transportation of goods is by far the most dominant method for international trade in Finland, but with the growing concern on the environment, fossil free alternatives are being sought after. With Rail being the most environmentally friendly mode of transport if using green electricity, it's important to explore how rails benefits can be exploited for their environmental advantage. This paper examines how by avoiding complex technologies that may bring more complexity and potentially reduce the desire to utilise rail, but by bringing a standard gauge line to Finnish soil and integrating it with the existing infrastructure.

Keywords: Railways, Logistics, Freight, Economics

The originality of this thesis has been checked using Turnitin Originality Check service.

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Glossary

AC	Alternating Current
DC	Direct Current
MoU	Memorandum of Understanding
NATO	North Atlantic Treaty Organisation
RTO	Rostered time off
TEN-T	Trans-European Transport Network
USSR	Union of Soviet Socialist Republics
VTT	Teknologian tutkimuskeskus VTT Oy

1 Introduction

With international trade constantly on the rise and the ever-increasing concern over emissions, rail transport has often been viewed as an obvious choice for environmentally friendly bulk transportation. However, even though rail technology has been around for almost 200 years, beginning at the start of the Industrial revolution, some regions today have incompatible systems due to various factors such as Government policies and changes of borders.

Finland is one of these countries that still deals with the legacy of being part of the Russian Empire, because of that legacy the rail network in Finland today does not fit the current geopolitical situation. Recent developments have changed the Finnish rail network, as the only country it connects with is now under severe trading sanctions. Since then, other than for some small trade with Russia, the network now finds itself effectively isolated from the rest of Europe.

What this paper will explore is the current state of Finland's rail network and potential options on how to increase its integration with the European network. With an increase seen in international trade, especially with a growing need for renewables such as wood derived products. A large part of this research will be looking at what goods make up the Finnish economy, and how could a potential Standard gauge rail connection to Finland from a European country change the way Finland's imports and export are transported.

One of the biggest challenges facing the world currently is the climate, and rail as a method of transportation can be very environmentally friendly, compared to ocean or sea going vessels the difference is unquestionable, pertaining to certain requirements. With Finland's reliance on using the Baltic Sea for the transportation of goods, and emissions requirements becoming more strict, a need for a more appropriate and climate friendly mode of transport is becoming more apparent. Geographically, it made sense that in the past Russia could be part of Finland's international trade, and a reliable road and rail transportation route, however the importance of an alternative have become clear.

An important aspect to this Thesis will involve looking a project known as Rail Baltica. This project currently under construction in the Baltic states brings a new potential link for Finland, and with construction technology continually improving as well, as past projects such as the Channel Tunnel proving it possible to build long, undersea tunnels shows it is possible to change the way freight moves. Additionally, there is also potential in the North, where previous attempts at creating a link to Europe on the border of Sweden have gone no further than now cancelled trials and test.

2 Rail in Finland

2.1 The importance of context and History

To understand why Finland's rail network is built the way it is, context is required regarding its past, and the general history of Rail. The first railway was constructed in England and was known as the Stockton and Darlington Railway (S&DR) which was a passenger railway built between the Cities of Stockton and Darlington. Construction was completed and the line commissioned in 1825 and operated until its closure in 1863 (ICE, 2024). However, the idea of the railway soon quickly spread over the globe, with the world industrialising at an exponential rate, railways were being built just as fast. According to the American Railroad Society (2024), between 1865 and 1916 approximately 219,000 miles (352,446) of new railways were built in the United States of America by numerous railroad companies, making what is today still the largest freight rail network in the world (Railway technology, 2014).

In 1862, the first rail line was constructed in Finland between Helsinki and Hämeenlinna. Importantly, the gauge chosen to be built was what is now known as the Russian Gauge, or with a width between the rail heads of 5 feet, or 1,524mm, the vision of eventually connecting to St. Petersburg, the capital of the Russian Empire, was the main contributing factor to choose this gauge as by the end of the decade, a new line had been constructed and reached Viipuri, a mere 135km away from St. Petersburg (Lahti Historical Museum, no date).

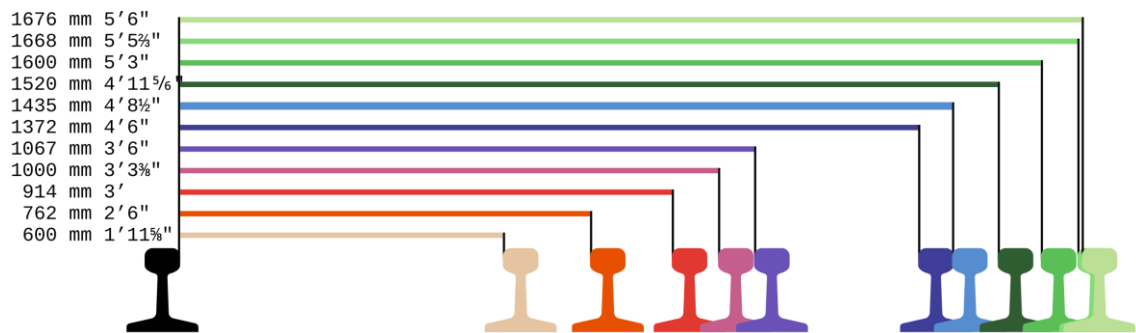


Figure 1: A visualisation of railway gauges (Wikipedia, 2016)

The gauge chosen at least at the time made sense, given that the Grand Duchy of Finland was part of the Russian Empire, and that the countries are geographically close. However, a majority of the industrialising world at that point had been chosen 1,435mm or 4 Feet 8 and a half inches as their standard (1,435mm), the differences can be seen in Figure 1 above. As time went passed the rail network eventually reached the Russian capital. This railway, today known as the Riihimäki – Saint Petersburg line and at an original travel length of 371km, according to I.J. Inberg (1875).



Figure 2: Different rail profiles introduced over time. (Kämäräinen, 2012)

With technological advancements continuing throughout the years the desire to improve railway efficiency came about, one of these involved increasing the rail

weight, usually described as kilograms per metre. These new 'larger' rails allowed heavier trains to run, achieve faster speeds and run more smoothly. The rail used in the first railway in Finland, was built at a specification of 33kg per meter (pictured as number 3 in Figure 2). Today, the rails are even larger, according to the Finnish railway agency (Väylävirasto, 2021, p.7) 60kg/m allows a speed of up to 300km/h and 54E1 allows a maximum speed of 160km/h.

The Finnish National railway network at the end of 2022 was 5,918 km in length, with 5,645 km of it being in operational condition. Most of the network is single track, with only 713 km being double tracked or greater. The total length of the network that is electrified is 3,449 km.



Figure 3: Finnish rail network and surrounding countries (Väylävirasto², 2021)

As previously mentioned, the railway network in Finland was mainly constructed during the time it was part of the Russian Empire, and that can still be seen today in its design. As seen above in Figure 3, there are 4 separate points where rail connections are made across the border to Russia, being in Vainikkala, Imatrankoski, Niirala and Varitus (Väylävirasto, 2024). The only

other rail connection Finland has to another country is with Sweden. This connection however is problematic, as Sweden's rail system is quite different to Finland, not only in rail gauge but also in operating voltage for electric locomotives.

In this region of the network, multiple rail gauges are used in both countries. In 1919 the Tornio River Railway bridge linked Tornio in Finland to Haaparanta in Sweden. This bridge however utilises two track gauges, with Finland's 1,524 mm gauge reaching the yard area in Sweden, whereas the European Standard gauge of 1,425mm, which Sweden uses, reaches as far as the Tornio railway goods yard (Väylävirasto, 2019).

2.2 Recent developments in the Finnish network

In February 2023, almost a year after the war between Russia and Ukraine started, a renewed possibility for the transportation of freight between Finland and the rest of Europe was completed. Although basic in Design, a 130m long dual gauge track section within the rail yards of Tornio was built (Destia, 2023). The company chosen for the project, Destia Oy, detailed its construction and purpose. Whilst the construction has ended, it may only be used for testing purposes and has not been given operational permission from the Finnish Railways agency, Väylävirasto.

It's difficult to estimate how much of a success this testing operation will bring, however it is still a method conducted today and numerous parts of the world.



Figure 4: Bogie exchange hydraulic lifts in the railyards of Chop, Ukraine (Kozlenko, 2010)

The operation for the gauge changing track is simple, in that rail cars are taken to the track and hydraulic lifts, as seen in Figure 4, are used to raise the wagons off the rails to a suitable clearance. The bogies are then changed out for ones with the different gauge, with the wagons then lowered again to continue on their journey.

Whilst this method has been used for over a century, it is time consuming, with a 1977 (Bureau of Transport Economics, p. 67) study in the activity calculating the average time for freight wagons as 362 seconds, or around 6 minutes.

Activity	Assumptions	Time (Sec)
Beetle moves out to queueing wagons	36m @ 2m/sec	18
Beetle drags all wagons forward 1 wagon length	27m @ 1m/s	27
First wagon is uncoupled		5
Beetle moves wagon into position (sic) in dept	36m @ 1m/s	36
Jacks are positioned		15
Wagon raised to allow access to brake rods	0.3m @ 1.5m/min	12
Uncouple brake rods		10
Wagon raised to full height	0.75m @ 1.5m/min	30
Beetle moves bogies	28m @ 2m/sec	14
Wagon lowered partially	0.75 @ 1.5m/min	30
Couple brake rods		15
Wagon lowered fully	0.3m @ 1.5/min	12
Check for level		30
Beetle moves wagon out of depot	63m @ 1m/sec	63

Beetle returns to start	90m @ 2m/sec	45
	Total	362 sec

Table 1: Analysis of wagon transfer time (Bureau of Transport Economics, 1977)

As seen in the above table, there are quite a few steps involved, and this is for one wagon. With the average time calculated, it is known that with a gang of 4 individuals in an 8 hour shift, an assumed rate of 56 wagons is to be expected. However, this rate would only be achievable if all other variables do not cause issues, such as the supply of wagons for the gangs, issues occurring with equipment or wagons themselves or the safety block, which is a part of a rail line reserved a specific wagon(s) or train, for the converted wagons runs out of space.

The rate in the report is for a proposed facility and when the report was written in 1977, the current productivity of wagon conversion was as follows. One gang consisting of 7 men could theoretically convert 32 wagons per shift, with a shift being 8 hours, 11 of said shifts being worked per fortnight and an assumed 6 weeks lost through holidays, sick leave, Rostered Days Off (RTOs), etc, the calculation being $32 \times 11 \times 23 = 8096$ wagons per annum. The report concluded with a cost saving calculation showing that with an assumed average of 50,000 wagons per year, the new process would save 29.1 man years per annum with the labour calculated with the new process at 14.1 man years per annum.

To put this in modern perspective, and assuming similar equipment and the same number of workers are required, the minimum salary cost per employee in Finland today would most likely be around 30,000 euros, not including any overtime penalty rates (Vaskiri 2024). However, according to Osuuspankki (2022) the rule of thumb regarding salary costs in Finland is 1.75 times the gross salary paid to the employee, due to insurance premiums, sick leave pay and retirement funds, for example. This comes with the estimate that a more

realistic amount is at least 52,500 euros per employee or at least 210,000 euros per year for one gang.

2.3 Finland in Nato

With Finland becoming the 31st member of the political and military alliance, the North Atlantic Treaty Organisation (NATO), it brought with it a new era, ending Finland's long stance of military nonalignment (NATO, 2024). As a member of NATO, Finland is now confidently not alone in its threats received from Russia over the course of the last few years, and of course Finland has reason to be worried, with Russia already caught crossing a number of its neighbouring countries such as Moldova's Transnistria, Abkhazia and South Ossetia in Georgia and finally in Ukraine: Crimea and parts of Luhansk oblast, Donetsk Oblast, Zaporizhzhia Oblast and Kherson Oblast. The only difference between Finland and the other countries Russia has invaded is that unlike Ukraine, Moldova and Georgia, Finland was never part of the USSR. Nevertheless, due to these countries' past, they all have the same railway gauge that all former Soviet Socialist republics have (Donski-Lesiuk 2022, p.9).

Now after over a year as a member of NATO, and with the war still raging, attention is being paid to the region in and around Finland from a military perspective. Logistical operations within the military are one of the most important aspects of its operations, with the need to transport everything a military, Navy or Airforce needs, accounting for approximately 75 percent of the United States army budget (National Research Council, et al. 2015 p 109). It is clear that without good logistical planning, a military will soon find itself in trouble. and its meaning became better known in a report from the United States army originally published shortly after World War 2 in 1947:

The word "logistics" has been given many different shades of meaning. A common definition is: "That branch of military art which embraces the details of the transport, quartering, and supply of troops in military operations." As the word is used in the following pages, its meaning is even broader. It embraces all military activities not included in the terms "strategy" and "tactics." In this

sense, logistics includes procurement, storage, and distribution of equipment and supplies; transport of troops and cargo by land, sea, and air; construction and maintenance of facilities; communication by wire, radio, and the mails; care of the sick and wounded; and the induction, classification, assignment, welfare and separation of personnel. (Center of Military History, United States Army, 1993)

With the importance of military logistics acknowledged, it comes as no surprise that focus has increased on the subject, and especially within the NATO alliance.

At the time of writing, the war in Ukraine is still ongoing. Certain aspects inside and outside of Russia and Ukraine are changing regularly. One point that seems to be evolving is the tone of Governments throughout the European Union, including Finland. The following is one example of a U turn during the period of a less than 2 years. In April 2023, the Government (Valtioneuvosto, 2023) along with numerous news outlets (Tekniikka & Talous, 2023; HS, 2023), had reported that Finland would not convert its rail gauge to the European standard, mainly due to the quite high estimated cost of 15 Billion euros and the Transport and Communications minister of the time, Timo Harakka saying “Finland does not accept changes to the track width, and I believe that our views will be listened to during the further preparation.” (Liikenne- ja viestintäministeriö, 2022)

All of this was in response to the Europeans Commission’s Trans-European Transport Network, also known as TEN-T. The proposal was initially meant to cover all current EU countries, as well as other ‘third party’ countries such as Ukraine, Belarus and Russia. However 5 months after the Russia and Ukraine war began, revisions started entering the policies that had planned improvements with Russia and Belarus, specifically they are to be no longer a priority and should in fact be discontinued (Council of the European Union, 2022).

During the year 2024, the tone began to change markedly within the Finnish Government, and once again the Ministry of Transport and Communications

had requested that the Finnish Railway Agency prepare another report, this time focusing on a European gauge (or standard gauge of 1,435mm) rail connection at the only current rail link to another EU country, being on the border with Sweden in Haaparanta. This aligns with the fact that both Sweden and Finland are now both part of the NATO alliance, and in a signed statement on April 30, 2024 (Ministry of Transport and Communication, 2024). The transport minister of Finland Lulu Ranne, Transport Minister of Norway Jon-Ivar Nygård and the infrastructure minister of Sweden Andreas Carlson stated that recent changes in the security situation of Finland, Sweden and Norway require cross border transport to be more resilient and effective, particularly for Military mobility.

2.4 Military uses of railways

All over the world, rail has played a vital role in terms of logistics for military operations. The earliest known use of a railroad for this purpose is generally accredited to the Prussian military (Brophy, J. M., 2008) however, the first well known conflict that utilised railroads according to the US Army Transportation Corps (2024) was during the American Civil War, which occurred during the years 1861 – 1865. Railways, being a relatively new technology at the time, brought new unparalleled abilities to transport the military personnel, supplies, heavy equipment, for example, at a previously unknown pace. At the time of the Civil War the only alternative would have been, at least on land, carts and wagons pulled by animals that moved at 3 miles per hour, whereas with new railways the speed possibilities increased to 10-15 miles per hour, assuming the rail was already laid and in usable condition. It's widely accepted (National Park Service, no date) that the superior and more cooperative railway companies in the North were a large contributing factor to the North's victory in the civil war.

In more recent times, World War 2 saw the railroads play a wide role in the European theatre, as by the time of the invasion of Poland in 1939, many European countries had expansive and well developed for the time rail networks. Even in 1939 the standards for railroads regarding the transportation

of freight did not vastly differ much compared to the present day in terms of speed and the load capacity, with today the maximum speed limits being 100-120km/h, and by looking at the specifications of the well known locomotive DRB Class 52, it would be likely freight and military trains within the Third Reich and occupied countries never went above their rated speed of 80km/h (Military Intelligence, 1943) under normal war time circumstances.

With rail well developed, roads on the other hand were not nearly as close to the standard as they are today, only cities and town centres were sealed with asphalt, with the rest being dirt or gravel. This posed logistical challenges throughout World War 2 for both the allies and axis powers, meaning railways were the only reliable mode of transport that could meet the needs of militaries.



Figure 5: A railway gun in Suursaari, Finland (Jokinen, 1942)

During World War 2, trucks and other motorised means of transport were not as powerful as they are today, and moving heavy artillery and weapons was not easy by road. Rail, on the other hand, allowed large guns, known as rail guns, as seen in Figure 5, to be transported with relative ease within a preexisting rail network. According to Zaloga (2016) although Railway guns had lost their effectiveness since World War 1 due to the technical advances of other technologies such as aeroplanes, they still held importance as the most powerful land artillery of their time. After the Second World War ballistic missiles had become the mainstay for long range heavy fire, mainly due to lower weight and could be moved on roads and through fields with specialised trucks.

As important as railways were for one country, it was vital infrastructure that an enemy could use. Towards the end of the second world war, the German Army used a rail car known as a railroad plough. This car used a large hook at the end which would be lowered into the ground between the rails and destroyed the wooden railroads sleepers as it was dragged along, rendering the line being it useless until repaired (Nevington War Museum, 2024), this was one tactic known as 'scorched earth' used by the Germans whilst retreating.

Today, and most relevant for Finland's national security, requires looking at the contribution of railways in Ukraine and Russia with respect to their conflict. Ukraine borders the Russian Federation and was once part of the larger Soviet Union. Because of this past, there were many transport routes between the two nations with 38 separate crossing road points between the two nations according to the Humanitarian Data Exchange (2024), as well as 8 active rail border crossings in 2015 (State Border Guard Service of Ukraine, 2015). As the war began in Ukraine, and Russian forces had entered the Country, a focus began on the importance of railways in the conflict. Early on, Ukrainian forces destroyed all rail links between the Russian Federation and Ukraine shortly after the beginning of the war to prevent their use by Russian Forces, as reported by Trains magazine (2022). This most likely proved to be a well calculated move, as according to Emily Ferris, an expert on Russia at the Royal United Services Institute (RUSI), who commented that, Russia has historically relied on its vast

rail network for military operations and even in Ukraine, it was seen that ground forces did not get too far from the end of their rail supply line and ground vehicles got stuck, meaning the all important supply chain had a fail point (Ferris, 2023, p. 8).

Russia had also seen the importance of the Ukrainian rail network for the Ukrainians, and begun a campaign of bombing railway stations, rail yards, as well as electrical infrastructure both relating and not relating to the rail network. An article written by Latschan (2022a) titled '*Ukraine: Will the railroad decide the war?*' discusses the aspect of the railways at the start of the war. It became clear early on how important the rail network would be. Before the war, it was mainly for the transportation of some commodities such as grains and passenger services. However, when Russia began its blockade of the Black Sea, the only other options were by road or rail, with the latter being chosen. The strength of the network came from multiple factors, with the network having a 700 million euro investment on improvements and modernisation mainly for the 2012 European soccer championships, according to the International Rail Journal (2012). This involved track, electrical and rolling stock upgrades to bring the network to a more European standard compared to its Soviet past. According to Oleksandr Pertsovskiy, CEO of the Ukrainian national railway company, the network had proven itself to be quite the asset and even during wartime is mostly fully operational, partly thanks to having quite a few routing options. If, for example, a certain line is bombed, an alternative route can be made with relative ease (Latschan, T. 2022b).

In 2024, we are still seeing the importance of the rail network in the conflict. With the passing of time, it has given Russia the ability to construct a new rail link to the occupied territories in Ukraine. Early in the war, the most important transportation link between Russia and the occupied territories was the Kerch Bridge, also known as the Crimean Bridge. With construction starting in 2016, it is two separate bridge structures, one for road, which was completed in 2018, and a second rail bridge with two lines, completed in 2019.

In summary, the Russian military does still heavily rely on rail to support its operations (Engqvist 2022, p.5) and the Russian rail network does in theory pose a threat to not only to Ukraine, but every country that shares its unique broad-gauge system. However, the idea of Russia being so attached and reliant on railways for the purposes of invasion does have the advantages for countries like Finland, in that the rail network is a vulnerable type of infrastructure system and can delay enemy attacks with the employment of sabotage.

3 Finland's Economy, imports and exports.

3.1 What drives the economy.

If Finland is to make investments in its rail network, particularly for the purpose of freight transportation, it is important to understand the structure of the economy, how it operates and especially what products are imported, exported, the types of products, and which countries are the largest importers, essentially the flow of goods. Any large investment in infrastructure should in theory help with economic development. Like many Nordic countries, Finland's economy was fairly agrarian up until the 1950s, shortly after the end of World War 2. Immediately afterwards, manufacturing and industry started to grow and was quickly rebuilt after losses during the winter war, continuation war and the land losses that followed, partly helped by the fact that Russian war reparations were paid in goods and these goods accounted for up to four percent of Finland's GDP in the period of 1946 to 1952 (Statistics Finland, 2007).

Today, with few exceptions, the Finnish economy is based on free enterprise, meaning the government does not have much control, virtually the opposite of administrative-command system of the former Soviet Union, and private ownership with many large manufacturers and other businesses being publicly listed on stock exchanges.

Business	Turnover 2023
Stora Enso Oyj	25,114,318
Nordea Bank Abp	22,100,553
UPM-Kymmene Oyj	14,168,207
Nokia Oyj	13,692,548
Neste Oyj	13,401,731
Sampo Oyj	12,908,489
Metso Oyj	7,585,668

Table 2: Some of the top corporations in Finland by Turnover (Nasdaq, 2024)

Looking at Table 2 above, consisting of the top 7 largest businesses in Finland by turnover in euros, 2 corporations are in the forestry industry. UPM-Kymmene Oyj has 5 paper mills in Finland, located at Jämsänkoski, Kaukas, Kymi, Rauma and Tervasaari with many other locations producing plywood, timber and other products requiring wood. Stora Enso has 11 locations in Finland mainly producing sawn timber and pulp. The next largest group in the forest industry is Metsä Group, whose parent company Metsäliitto Cooperative owned by 90,000 plus forest Finnish owners (Metsä, 2024) has 4 Mills located in Äänekoski, Punkaharju, Suolahti and Lohja.

3.2 The Industries

The forest industry, according to Metsäteollisuus (2023), or the forest industry association, is an important resource for Finland, covering over 70 percent of the land, meaning a total of 20.3 million hectares, and is continually growing as

the growth of wood stock exceeds that of felling. Much of the forests are privately owned by around 620,000 individuals, meaning around one in 9 Finns owns some portion of land that is designated as forest, with the rest owned by the State of Finland, companies and other entities. Around 75 million cubic meters of wood that is used in the industry for further processing comes from private forest owners.

Distribution of export market for Finnish forest industry products in 2023



Figure 6: Finnish wood export markets and their share in percentage (Metsäteolisuus, 2020)

In terms of economic value, the Finnish ministry of Agriculture and Forestry states that the industry is key to the Finnish economy (Ministry of Agriculture and Forestry of Finland, 2023). In 2022 the forest industry production value was estimated at 20 billion euros; this total considers not only the value of the timber alone, but also the related services and employment in timber production as well as berry and mushroom picking. Wood is a large employer in Finland, as many of the trees that are felled go to further manufacturing and processing to create a large range of products. The more simple of these are various types of timber used especially in construction such as: Plywood, made of multiple thin layers bound together with glue; Impregnated timber, which is a type of timber impregnated with copper compounds increasing its longevity outdoors; and

glued sawn timber, which is a combination of two or more sawn timber pieces which is then further processed to create furniture fittings and interior decorations such as wooden window frames and shaped cladding (Puuinfo, 2020). From the more traditional uses of wood comes an increase in more sustainable packaging, due to what consumers want. According to numerous studies (Ng & Obbard, 2006; Zbyszewski, Corcoran & Hockin 2014; Martins & Sobral, 2011), microplastics have found their way into parts of the environment not previously considered. One of the greatest contributing factors for plastics ending up into the environment is from single use packaging used with food products, one notable example is the simple plastic drink straw, with Finland banning the use of some single use plastic products such as straws, plates and cutlery in 2021 (Yle, 2021). This decision brought in new innovations and alternatives, with many of these new options being derived of wood products and other natural materials. This general shift from plastics to renewable products alongside the general decline of printing paper due to digitalisation also has the effect on the forestry industry in, with large players such as Metsä Group, UPM, and the VTT (Tech Research Centre of Finland) investing heavily into research and development for new wood derived products such as a cellulose wood derived clear film to replace transparent plastic food wrap (VTT, 2022). These new innovations and commitment from the industry show that whilst the industry is changing as a whole, it is far from declining, and we can see this in the requirement of longer trains carrying wood, such as reported by Rintamaa (2023), where the now longest wood trains have around 18% more capacity with 30 carriages, up from the previous 25. In addition to the increased size, a new way of railway operation has been introduced where the same set of carriages are used for the same customer to collect and deliver wood, reducing lead times and increasing efficiency.

Other important industries in Finland are in the Chemical, mining and metal processing. The chemicals industries account for a large portion of the Finnish economy and employment, with a turnover of 36.4 billion euros and exports valued at 17.7 million euros in 2022 according to Kemianteollisuus (2023), it also brings other benefits with its research and development spending at 450

million euros annually. Some of the industry's largest players are Neste Oyj, Yara and Terrafame. Neste, being the largest with a market capitalisation of 16.8 billion Euros, is an Oil refining corporation producing fuels such as Diesel, Petroleum, Aviation fuels as well as other petroleum derived products for chemical industry uses, combined.

4 Freight flows of Finland

4.1 Volume and method of transportation.

Being the developed country that Finland is, there is a variety of freight transportation methods available with the main modes being road, rail and inland waterways. Air transportation is also used for freight transport, but it is such an insignificant amount at 175,561 tonnes (International and domestic) for 2023 according to Statistics Finland (2024), that it will not be included in the discussion. According to Traficom (2024a) the amount of freight transported within Finland is related to the demand on goods, mainly going to Finland consumption by the end user, this includes household demand, public demand and company investments. The input demand combined with the final consumption then equals the total demand of the Finnish economy.

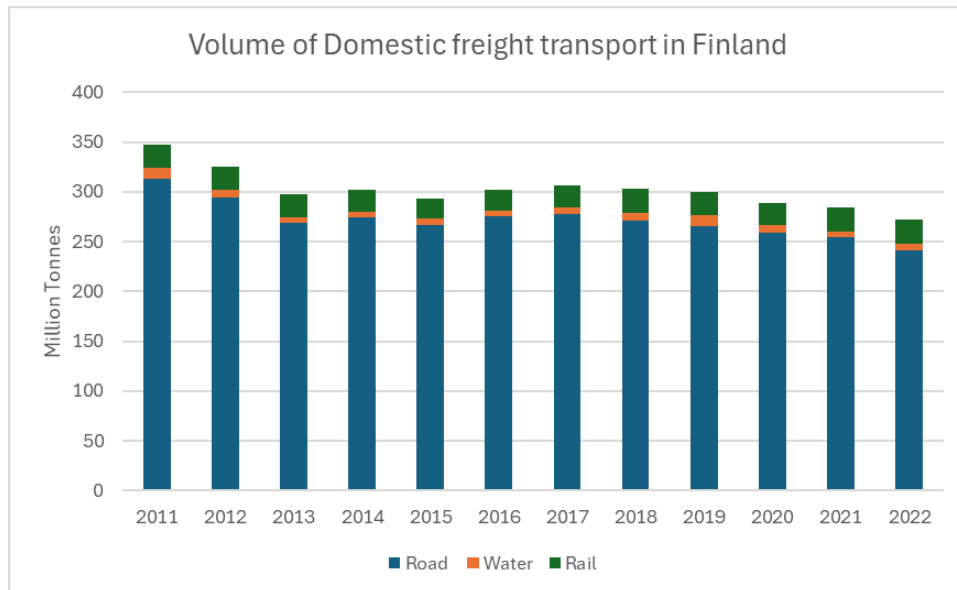


Figure 7: Domestic freight transport volume in Finland by Mode (Traficom, 2024b)

Looking at the years 2011 to 2022 in Figure 7 the domestic transport average volume has been between 289-347 million tonnes with road having a huge role in the transportation of goods with Rail and water having a smaller share of the volume. However, it doesn't give a full picture of the transportation story, as another statistic is important to get an understanding on how each mode of transport contributes to freight movement.

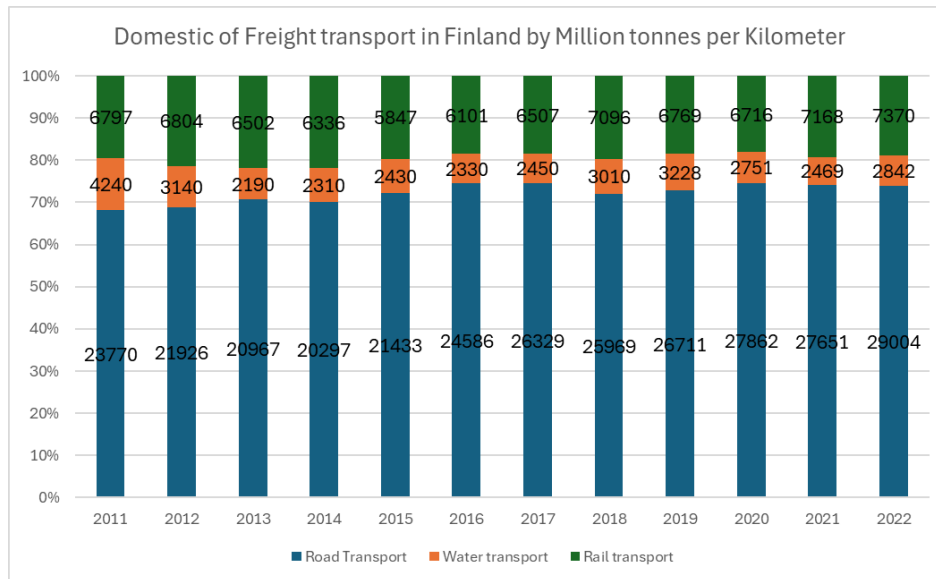


Figure 8: Volume of domestic freight transport in Finland by modes share per km (Traficom, 2024c)

Over the decade of the 2010s the share of the three modes of transport began to shift, with inland water ways, which once dominated the transport of wood within the country, shrinking. Rail has also gained a share with an increase of roughly 8.4 percent, but the main transportation method, being road, has risen 22 percent as seen in Figure 8. These statistics do correlate to the increased demand on the forest industry as according to Traficom (2024d), rising development in the forest industry has brought along with-it additional need for road freight, which it is heavily reliant on, additionally in the past decade legislation changes have allowed heavier and longer trucks on the road (Poikela and Venäläinen, 2023, p.4).

4.2 How is rail involved

In Finland, rail freight reaches almost all corners of the country. With the exception of the North East of Finland, freight is transported to and from major cities, as well as from smaller towns where wood is harvested or where paper mills can be located. Recent investments have been made for this commodity, and rail, combined with other transport such as truck for the last mile delivery, is

sanctions in detail we can find that rail transport is in fact not part of the sanctions (European Union, 2024) as the list only contains mention of road transportation, its related equipment such as semi-trailers, trucks and the import of those goods being transported, even if they are only transiting the EU.

Using data from 2021 the total rail transport in Finland was a total of 40.2 million tonnes which 15.8 tonnes were between Finland and Russia, or in percentage terms 39.3%, which is certainly substantial.

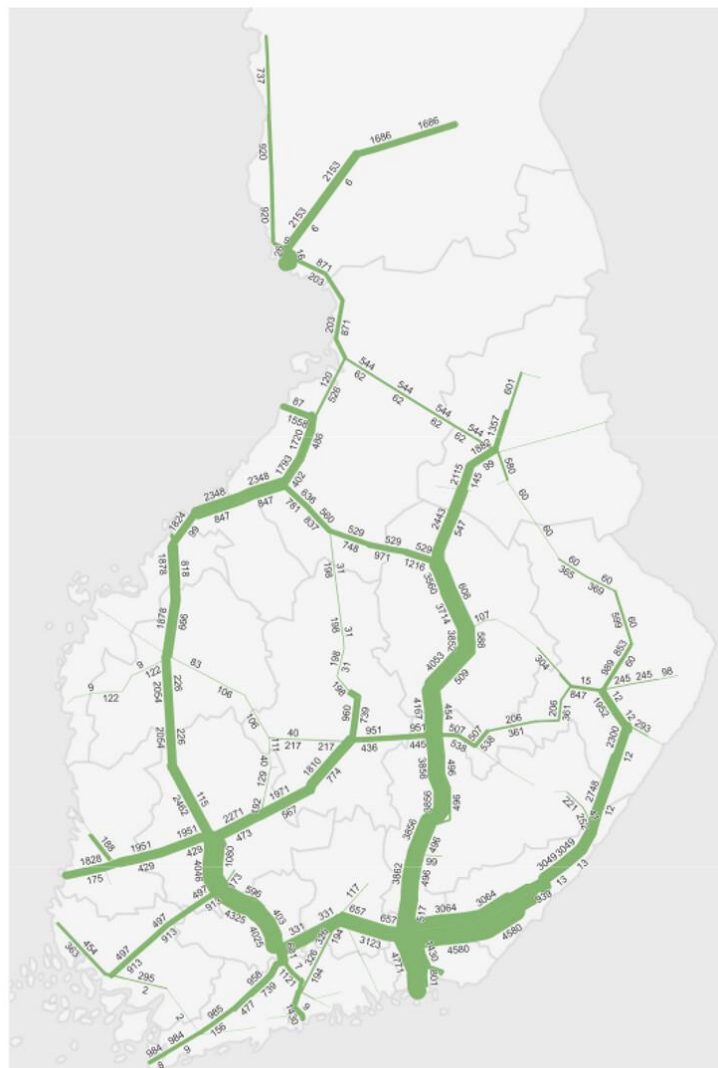


Figure 10: Rail freight traffic forecasts in the year 2030 (Traficom, 2024b)

Keeping into account the fact that Finland-Russian rail traffic has reduced and constantly changing, Traficom has released a forecast of rail traffic for the year 2030, this has been visualised in Figure 10, which shows the direction of freight

travel, in addition to weight (in 1000 net tonnes). These forecasts however do not take into account some variables, such as the additional paper board manufacturing line which opened in Oulu in 2022, which was estimated to double road and rail traffic volume in the area (Degerman, et al. 2022). It is also difficult to accurately ascertain other investments the forest industry will make in the coming years, the choice of rail routes made and other rail infrastructure investments that are only just being commissioned, such as such as the Ylivieska-lisalmi line electrification. This electrification project is the largest in Finland since 2006, being roughly 162km long (Ratatek, 2024) at an estimated cost of 66 million euros (cost including a short electrification section between Siilinjärvi-Ruokosuo) (Väylävirasto², 2024), and in a way fixes a missing electrified east west link in the core of the country as it was the busiest non electrified rail line in Finland. According to a report by Kauppakamari (2018) it's also stated that this project will bring annual savings starting at 2.76 million euros in the first year of electrification, to an estimate of 14.7 million euros a year after 10 years as traffic volume increases. This project is already being utilised by companies such as Yara Suomi, a manufacturer of fertilisers, which stated in a press release that rail traffic between their factories can now be 100% electric traction and additionally save time by not having to change locomotive types (Yara Suomi, 2024).

4.3 Rail Baltica

Rail Baltica is a project which is currently under construction in the Baltic region, designed to connect all three Baltic states, Poland, and eventually Finland with the European standard gauge rail network via the countries of Poland, Lithuania, Latvia and Estonia.

To get a better understanding of how this project has the potential to radically change the way freight moves to and from Finland it's important to evaluate Rail Baltica in detail. The project's basic specifications are that it is a double track

rail line, meaning that its capacity is more than double that of single track, built on the European standard gauge of 1,435mm, allowing access to the rest of Europe without any additional equipment, cost or delays such as the earlier mentioned bogie changes. Maximum design speed of 249km/h for passenger service and 120km/h for freight services, allows for maximum train lengths of 1050m, which is longer than the current European standard of 750m to 835m (UIRR, 2022). This is still far shorter than for example the regularly running BHP Billiton iron ore trains of Australia which are 2.4km long (Railtarget, 2023), have an axle load of 25 tonnes, and use the ERTMS L2 traffic management system which multiple European countries use, allowing easier cross border traffic (Railbaltica, 2024).

What makes this project important for the Baltic region, as well as for the wider European community is that it is a key part of the Trans-European Transport Network TEN-T, which is a key European union policy which covers railways, inland waterways, roads (including motorways) and airports with the main goals of promoting better integration of countries within the union in the context of society and economics including trade. The TEN-T policy is based on Regulation (EU) 2024/1679 (European Parliament, 2024) which states that rail freight traffic should see an increase of its market share to 50% by the year 2030 and then double over the next 20 years to the year 2050. With this in mind, it can be predicted that Rail Baltica will have a strong focus on increasing rail freight use in the region.

A tunnel connecting Tallinn, Estonia and Helsinki, Finland has been mentioned as far back as 2009 (Helsingin Sanomat International Edition, 2009) when both cities were wanting to continue planning the connection with an undersea railway or a ferry that would transport railway carriages but were denied funding by Interreg, a programme that focuses on intra EU cooperation. The funding was for 800,000 euros for the first planning stages of the proposed tunnel. Not much had happened until the tunnel proposal came back into the spotlight following feasibility studies commissioned in early 2017 (Railway Gazette, 2017).

Finland formally became part of the project after the former Finnish minister of transport and communication, Timo Harakka, and the Estonian Minister of Economic Affairs and infrastructure signed a Memorandum of Understanding (MoU) in 2021 (MoU, 2021). The objective of the MoU is to begin cooperation between the two countries on a Helsinki-Tallinn Railway project taking into consideration the Rail Baltica project, the North Sea- Baltic Sea core network corridor as well as multiple other relevant projects in and outside of the Trans-European Transport Network. The 3 core points of the MoU are that the proposed Helsinki-Tallinn tunnel connect to the Rail Baltica project seamlessly, which in reality would most likely mean it would have to be standard gauge (1,435mm) as well as an electrification voltage of 25kv AC, which is already the standard in Finland. The second point, a seamless connection from the tunnel to the countries' existing infrastructure in the context of social and economic benefits. Lastly the third point of the connection being for both freight and passenger transport with the tunnel being considered critical infrastructure.

This report, which is now available, comprehensively assessed the feasibility of the project using multiple proposals, looking at economic impacts, cost estimations, Financing of the project and more. Regarding freight transportation with the tunnel, assuming the current average price of transporting cargo on the current ferries between Helsinki and Tallin are 15.6 euros per tonne, the average fixed link price would average 10.3 euros per tonne. This average is because of two ways cargo can utilise a rail link. The first option is where trucks drive onto the train at platforms into carriages which are designed to accommodate semi trailer trucks, with this option costing 12.3 euros per tonne. However, the second option is a typical freight train consisting of, for example, shipping containers loaded onto regular carriages designed to carry them. In this case, the trains would technically be able to start their journey anywhere in Finland, Estonia, or another country and run through the tunnel. This method costs only 5.8 euros per tonne, substantially cheaper than ferries and the first option (Finest Link, 2018). Additionally, it is estimated the freight would only account for 30% of the tunnel's revenue.

Other challenges with building this tunnel are its length: at 102.3km it would become the longest rail tunnel in the world, and the longest tunnel under water, as currently the second longest rail tunnel, which is currently under construction, is the Mont d'Ambin base tunnel connecting France and Italy through the Mont d'Ambin mountain range. The Helsinki-Tallinn tunnel also comes with a mean estimated cost of just over 16 billion euros, with numerous possible funding options and with the assumed EU grant of covering 40% of the cost, making the project feasible.

However, the future of a Helsinki Tallinn tunnel is uncertain, with Finland's current Transport and Communication minister Lulu Ranne reported by Estonian news outlet, Maailm (2024), saying that due to Finland's national debt being so high, money must be used thoughtfully and that while she wants to have better connections with Estonia, she currently sees the tunnel project as unrealistic.

4.4 Transport Emissions

According to Suomen Varustamot (2024) maritime traffic accounts for 96% of all imports and exports of Finland. This is unsurprising as many of Finland's largest cities have access to the Baltic Sea, where vessels can easily reach other countries within the EU, as well as access to the North Atlantic Ocean. With a total of 94.8 million tonnes of cargo sent and received internationally, that leaves only an estimated 9 million tonnes through other means such as air, rail and road. With Finland's emissions goals based on the Climate Change Act, such as being carbon neutral by 2035, and a 90 to 95% reduction from 1990 levels of CO₂ (State treasury of Finland, 2024) it should be considered that these figures of maritime transport being so large is a cause for concern. Although cargo ships can be low emissions when equipped to use greener fuels, there is a better alternative, that being rail. Using tables from the *Guidelines for Measuring and Managing CO₂ emissions from Freight Transport Operators* (ECTA, 2011), we can roughly compare CO₂ emissions of various transport methods. For large container vessels of around 20000 tonnes, their

grammes of CO₂ per tonne km are roughly 11.5, with larger deep sea vessels being around 8.4 gCO₂/tonne-km. Rail freight on the other hand can be much lower in emissions with 1.8 gCO₂/tonne-km. However, there are many variables that can heavily influence the emissions of rail, such as if the locomotive is diesel, or electric powered, and whilst electric locomotives are emissions free, their energy may be produced using heavy CO₂ emitting sources such as coal.

In Finland, the newest locomotives in mainline use for both passenger and freight transport are the Siemens Vectron model, known locally as the Sr3 Model. Beginning delivery in 2017 (Railway News, 2017) with a total of 80 ordered, these models are slated to replace the older Sr1 models from the Soviet Union. By using the specifications of the Siemens Vectron locomotive used in Finland, the estimated g CO₂/tonne-km can be calculated. According to one Siemens Vectron customer in Poland, their Vectron locomotives are consuming 0.029 kwh of electricity per tonne kilometre (Orlen, 2023). With one locomotive able to pull 2,000 tonnes of cargo, this would mean a fully loaded freight train with one locomotive consumes 58kw/h of electricity. In Finland, the average amount of CO₂ from producing electricity was 66 g CO₂/kWh (Statistics Finland³, 2024) so a Finnish Siemens Vectron freight train of 2000 tonnes would be producing an estimated 1.138 grammes of CO₂ per tonne km. This calculation however is just an average, and there are other factors which could change said average, such as the fact that the Vectron locomotive model used in Poland operates on a 3kv DC network. Compared to Finland's 25kv AC network, there are larger losses of electricity due to the lower voltage over distances in accordance with Ohm's law ($V = IR$), which in simple terms means a higher voltage has a lower resistance across for example a conductive wire. Additionally, freight traffic may be lower in the summer in Finland due to industry slowing down for the holiday season, which coincides with cheaper electricity in the summer months.

To see the environmental impact of a rail transport link between Tallinn and Helsinki over the proposed distance of the tunnel of 102.3 km, we can now see how much of a potential emission reduction could be made. Knowing this, and

the earlier estimated carbon emissions electric trains would produce, we can roughly estimate that transporting goods between Estonia and Finland via a rail tunnel would be 116.4 grammes of CO₂ to transit the tunnel. In comparison, using a large container vessel which uses an estimated 11.5 grammes of CO₂ per tonne km, and from Tallinn to Helsinki being 43 nautical miles, or 79km apart, means that 908.5 grammes of CO₂ is produced to transport the same amount of cargo by weight from Finland to Estonia. In 2023, the total import and export of goods with Estonia was 8,445,997 tonnes (Statistics Finland², 2024), this of course is only with goods originating in Estonia and goods with their destination in Finland and does not include other goods transiting through one country, for example goods going from Finland to Germany via Estonia. Knowing this allows us to estimate that in 2023 7,673 tonnes of CO₂ was produced, whereas rail would have only produced 983 tonnes. With Finland continually investing in green energy and the average CO₂ per kw/h of electricity constantly falling, it seems sensible to assume that in the future the emissions of trade between Finland and Estonia will become lower, if a tunnel link becomes a reality.

4.5 Other alternatives

There are other technologies that exist to help interoperability of trains to run on different rail gauges. The most well known of these is to run a third rail alongside the usual second rail to accommodate a train with a narrower or wider gauge. Secondly there is the option of bogie changeout, which involves a lengthy and labour-intensive job of changing the bogies, or wheel sets of every carriage and lastly a more modern solution of self changing bogies, which automatically adapt to a different rail width by slowly driving through a special track section.

In Finland, having a dual gauge line is more complex and costly compared to other parts of the world due to the sizes of the gauges that would need to be accommodated. For example, in the state of Victoria in Australia, it is possible

to accommodate both standard gauge and broad gauge (Also known as Irish gauge) being 1,600mm making the difference in rail width is 165mm, this leaves a sufficiently large gap between two rails to have a three-rail dual gauge system. In comparison due to Finland's gauge being 1,524mm, this leaves only 89mm of space. Due to this technical issue, the only way to have dual gauge track is with a four-rail system by having the different gauges offset (Inventing Europe, 2024). As mentioned earlier, This method is used at the border with Sweden and Finland at the Tornio-Haaparanta section between the yards of the aforementioned towns. Converting a single gauge line to dual gauge with a third rail has been done before in Europe, when it was announced in 2012 that the rail line between Barcelona and Valencia would convert to dual gauge at a cost of 1.4 Billion Euros (Puente 2012). The distance between the two cities is approximately 301km meaning the cost per kilometre was around 4.65 million. If we adjust the cost per kilometre to include the inflation, it would be 5.73 million per kilometre and with an estimated distance by rail from Tornio on the border with Sweden to Helsinki (via Ylivieska, Seinäjoki and Tampere) being 885km the bare minimum cost of converting is around 5 billion Euros. This of course does not take into account that any dual gauge track in Finland must use 4 rails, so the cost is likely higher and gets close to around half the cost of the earlier mentioned Helsinki – Tallinn Tunnel.

An alternative to having a dual gauge track section for the entirety of the Tornio-Helsinki route could be a completely new rail line that is only standard gauge that runs the length of the route. This could be done in numerous ways, such as running parallel along existing rail routes that go directly north and constructing new line where required. This is currently being done in Australia, a project called Inland Rail is a 1,600km route that comprises of both upgrading existing rail line and new construction. At a now increased cost of \$31 Billion AUD or 18.75 Billion Euros, it is now at a cost of 11 Million euros per Kilometre, using this projects cost per kilometre as an example, a similar project in Finland to go from Helsinki to Sweden would be around 8.55 Billion Euros. However, it is important to note that large construction projects in Australia are notorious for

huge budget overruns and according to Campbell (2023) cost more than other countries.

Another method to achieve interoperability is automatically adjusting rail bogies. According to the Rautatietekniikka lehti (2022) the first real attempt at making the break of gauge easier between Finland and Sweden began in 1998. A device, known as a 'gauge changer', manufactured by Germany's National Railway company Deutsche Bahn, was installed in the Tornio yard on a trial basis. However, after a decade of on and off testing, the equipment was booked out of use, with a fire eventually destroying the electrical measuring components in 2017 (Yle, 2017).

However, the track record of technology on trains with complex mechanical systems have proven to be difficult in Finland due to the challenging weather conditions during winter. Examples of this include the VR passenger trains known as Pendolino, they had problems with their tilting mechanism as well as coupling system, simply due to the snow and frost freezing components, reducing reliability (VR Group, 2011).

5 Conclusion

This study has shown that up until recently, Finland's rail network has operated as effectively designed, a network that mainly serves the domestic freight and passenger market, with its existing connections with the Russian Federation due to historical ties used for freight and passenger services. However, recent events due to the war in Ukraine and the following political fallout have shown that the Finnish rail network is now virtually isolated from Russia, as well as technically Europe due to the gauge difference.

Due to the increasing attention paid to emissions, and the environmental effect on the transport industry, it does seem that Finland can improve in this area by reducing its dependence on sea freight for its international trade. With wooden

based products become increasingly sought after, and Finland's abundance of raw wood, combined with the ban of raw wood from Russia, it does seem appropriate to look at better ways for these products to be shipped abroad, ideally with rail.

The main options that have been discussed all bring with them different issues. The cost to convert Finland's entire network to standard gauge would be an extreme undertaking, with the cost alone previously being the main cause to rule out that option. Additionally, in the long term, it may be beneficial to keep the rail network mostly the way it is, the reason being that Russia is Finland's neighbour geographically, and that is something unlikely to change and hopefully in the future full trade will resume with the populous and natural resource rich neighbour. To rule out this future looking vision could cause headaches in the future, and bring the current problem that Finland has with the European rail network and effectively transfer it to Russia.

Other technologies, such as variable gauge systems which have known to cause problems in Finland's winter environment, and additionally would not require the purchase and installation of the (current) nonstandard equipment on rolling stock, locomotives and track. For example, this would create a tiered and non ideal situation where only special equipment can run on both gauges. The method of changing rail bogies on rolling stock is time consuming and costly over time, requiring equipment and training of staff, meaning it is not a real seamless connection.

Considering the above, the most appropriate decision would be for Finland to invest in ways to allow easier access to the European standard gauge rail network whilst maintaining its current network at the current gauge of 1,524mm. The most appropriate action to take would be to have a dedicated standard gauge rail line either from Sweden, or via the proposed tunnel linking to Rail Baltica. Once that link has been established, it would then be possible to create a multimodal transport hub, which has connection to both the Domestic Finnish, and EU wide standard gauge rail networks, as well as good road connectivity.

By using this well-known method used around throughout the globe in developed countries, it would bring better access to EU and international markets. However the cost is the biggest roadblock, and it would be wise for Finland to closely investigate the cost benefit ratio of such endeavour.

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Appendices

Appendix 1. Data extract of carbon Dioxide Emissions

12.3.2.2 Sähkön ja lämmön tuotannon ominaishiilidioksidipäästöt ja liukuvat keskiarvot (energiamenetelmä, g CO₂ / kWh)

12.3.2.2 Glidande medeltal för specifika koldioxidutsläpp inom el- och värmeproduktionen (energi metod, g CO₂ / kWh)

12.3.2.2 Moving averages of specific carbon dioxide emissions in electricity and heat production (energy method, g CO₂ / kWh)

	Sähkön tuotanto Elproduktion Electricity production		Kaukolämmön tuotanto Fjärrvärmeproduktion District heat production				Teollisuushöyryn tuotanto Industriångarproduktion Industrial steam production	
	Liukuva keskiarvo 5 vuotta Glidande medelvärde 5 år Moving average 5 years	Liukuva keskiarvo 10 vuotta Glidande medelvärde 10 år Moving average 10 years		Liukuva keskiarvo 5 vuotta Glidande medelvärde 5 år Moving average 5 years	Liukuva keskiarvo 10 vuotta Glidande medelvärde 10 år Moving average 10 years		Liukuva keskiarvo 5 vuotta Glidande medelvärde 5 år Moving average 5 years	Liukuva keskiarvo 10 vuotta Glidande medelvärde 10 år Moving average 10 years
2000	174	..	291	..	..	124	..	..
2001	218	..	302	..	..	133	..	..
2002	241	..	297	..	..	129	..	..
2003	309	..	293	..	..	123	..	..
2004	260	244	286	294	..	120	126	..
2005	162	241	274	290	..	121	125	..
2006	268	251	281	286	..	108	120	..
2007	239	251	289	285	..	112	117	..
2008	176	223	267	279	..	107	113	..
2009	189	209	267	275	284	115	112	119
2010	230	222	261	272	281	110	110	118
2011	189	205	253	267	276	104	110	115
2012	131	164	241	257	270	96	106	112
2013	167	183	204	228	250	87	102	108
2014	141	173	192	217	240	86	97	105
2015	105	147	186	204	229	87	92	101
2016	114	132	170	204	219	81	87	99
2017	100	126	156	195	209	72	82	95
2018	113	115	150	194	202	70	79	91
2019	87	104	140	181	195	66	75	86
2020	68	97	122	155	186	63	71	81
2021	75	89	110	138	172	56	65	76
2022	66	82	104	143	162	56	62	72

Tietoja taulukosta - Uppgifter ur tabellen - About the table

Ominishiilidioksidipäästöillä tarkoitetaan päästöjen suhdetta energiämäärään.

Med specifika koldioxidutsläpp avses utsläppens förhållande till mängd energi.

Specific carbon dioxide emissions refers to the ratio of emissions to the amount of energy.

Taulukko sisältää fossiilisten polttoaineiden ja turpeen poltosta aiheutuneet hiilidioksidipäästöt sähkön ja lämmön tuotannossa. Päästötietojen pohjana ovat polttoainetiedot perustuvat Energiateollisuus ry:n ja Tilastokeskuksen kyselyihin. Lämmöntuotannon osalta tietoa ei ole täysin kattava, sillä mm. pienten lämpökeskusten ja teollisuuslaitosten tietoja puuttuu jossain määrin.

Tabeller innehåller koldioxidutsläppen vid förbränningen av fossila bränslen och torv av el- och värmeproduktionen. Bränsleuppgifterna som ligger till grund för utsläppsuppgifterna baserar sig på enkäter som genomförts av Finsk Energiindustri r.f. och Statistikcentralen. För värmeproduktionens del är enkäten inte heltäckande, utan bl.a. de små värmecentralernas och industrianläggningarnas uppgifter saknas delvis.

The table includes CO₂ emissions from combustion of fossil fuels and peat in heat and power production. Emissions are based on data on fuels obtained with inquiries of the Finnish Energy Industries and Statistics Finland. The inquiry is not comprehensive as regards production of heat. Data from e.g. small heating plants and industrial plants are partly missing.

Appendix 1. Moving Average of specific carbon dioxide emissions in electricity and heat production (energy method, g CO₂/ kWh). (Statistics Finland, 2024)

Appendix 2. Data extract of International Sea Transport

International sea transport by Country, Commodity group, Direction, Month and Information											
				Tons							
Estonia	Total	Total	2023M01	618587							
			2023M02	645293							
			2023M03	824783							
			2023M04	777629							
			2023M05	862430							
			2023M06	767431							
			2023M07	645365							
			2023M08	726440							
			2023M09	661275							
			2023M10	656332							
			2023M11	665935							
			2023M12	594497							

Appendix 2. International sea transport by Country, Commodity group, Direction, Month and Information. (Statistics Finland², 2024)