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Comparing the Sustainability of Multimodal Transportation Between China and Europe

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Abstract: The China-Europe trade trend and sustainability issues are rising the global attention. This paper will explore six alternative routes for sending goods from Shenzhen, China to Budapest, Hungary; analyze the current and future sustainability issues of these routes under the Paris Agreement. The core of this paper is the calculation of carbon dioxide emissions of each route, summarized the policies of countries along the routes and predicts the future carbon dioxide emissions of the routes. based on these policies, the modeling in this paper improved the original method in the 2016 IPCC Guidelines for National Greenhouse Gas Inventories to do calculations. This paper produced three conclusions. Firstly, CER express can definitely reduce the CO2 emissions of the China Europe international transport. Secondly, if the current policies of countries along the route are implemented smoothly in the future, the carbon dioxide emission reduction of transport between China and Europe has been calculated. Thirdly, calculation based on current proportion of each route, forecast the future China- Europe shipments could be at least doubled under the Paris agreement.

Keywords: CER express, The China-Europe Land Sea Express Line (CELSEL), CO2 emission, Sustainability of multimodal transportation.

1. Introduction

This paper will explore various alternative routes for sending goods from Shenzhen, China to Budapest, Hungary; analyze the current and future sustainability issues of these routes under the Paris Agreement. Among these routes, there are two hotly discussed routes: The China Europe railway express (CER express) and The China-Europe Land Sea Express Line (CELSEL). The CER express as an important part of the Belt and Road (BRI) cooperation has drawn the attention of countries along the route to make economic and trade cooperation since the CER express was built up in 2011. At the same time, The CELSEL is also attracting the relevant countries to propose the “Three seas initiative” which aims to explore the possible extension of the railway, connection the Belgrade-Budapest railway with the Albanian, Croatian, Montenegrin and Slovenian Ports.

The China-Europe trade trend and sustainability issues are rising the global attention. The United States and China have been at trade war since April 2018. This issue affects not only the Chinese and American economies, but the stability and balance of global economic development(Goulard, 2020). China has been the third largest export partner for EU (10.5 %) and the largest import partner for EU (22.4 %) in 2020 (eurostat, 2021b). Barua said that the trade between China and the EU will continue to grow (Barua et al., 2020). At the same time, the upcoming Glasgow Climate Conference is the most important meeting since COP21 in 2015, where nearly 200 world leaders signed the Paris climate agreement; people are looking forward to their carbon emissions reduction plan effect on transportation in the future. Some politicians claim that national policies and the future development of science and technology can support the growth in global trade and pursue a more sustainable living environment(OECD).

It is important to pay attention to the current and future CO2 emission because of the global warming. Some scholars think if carbon dioxide emission continue to increase at it current rate, global temperatures might rise by as much as 4.4°C by the end of this century (UNs). while the global transportation volume is keep increasing, the corresponding international transportation and the carriage CO_2 emission will also magnify. Therefore, as a huge proportion of global transportation, it is essential to calculate CO_2 emissions between China and the EU freight transportation, as well as combine the published policies and potential technological popularization to prospect the future CO_2 emissions reductions. It is a timely topic to further extrapolate how much trade transport between China and the EU could be increased or reduce under the Paris Agreement, give a clear guidance for the countries to balance their emission reduction target with their global transportation volume.

2. Literature Review

2.1. The current trade situation between China and Europe

The bilateral rade volume between China and Europe maintained a continuous growth since 2013, Despite the severe COVID-19 pandemic in 2020, China-EU trade still grew by 3.5 percent(eurostat, 2021a). Obviously, the trade relationship between China and Europe is year on year closer, however, there are still many differences between them, such as in political, economic, cultural and other fields, and some serious issues blocked their win-win ways, especially on trade protectionism, anti-dumping and other issues. In addition, Brexit had great impact on China's further access to the European market, but on 30 December 2020, leaders of China and the EU jointly announced the completion of the China-EU treaty(BIT) as scheduled(Brussels, 2021), which has provided a greater market access, a higher level of business environment, a stronger institutional safeguards and a brighter prospects for China-EU mutual investment(Chi, 2019).

2.2. The comparison of chosen routes

After review, most comparison criteria between the routes were about economic, timeline and reliability. As Yin used the method of simulated annealing algorithm have found that carbon emissions, transportation expenses, and time costs all have varying degrees of impact on the CER Express operation plan, the highest is the carbon emissions, and then the transportation costs, last is the time costs(Yin et al., 2020). However, Larranaga used the Stated Preference approach to estimate the parameters of numerous Logit models and studied the competition relationship between road, intermodal considering rail, and intermodal considering inland waterway transport. The results showed that the transportation reliability was the most important contributing element, followed by transportation cost(Larranaga et al., 2017). Zhao used the method of novel multi-criteria decision-analysis has discovered that the most critical feature of CRE express have to focus on is reliability, this key element helps expand the market (Zhao et al., 2018). On the contrary, Seo used the total transport cost, total transit time and confidence index to comprehensive evaluation the competitiveness of transport routes between China and Europe(Seo et al., 2017), in this paper, the main advantage for the airline freight between China and Europe was the speed and safety. Yang built a performance evaluation system, used a questionnaire survey and Fuzzy Multi-Criteria Decision Analysis (MCDA) got some managerial implications. He concluded that all respondents strongly favor parameters based on economic factors, other factors have small difference between government and industry groups, so traditional Sea-Land Line outperforms the CESEL and CER express in his study.

2.3. The research on the CER express and CESEL

Yang built a performance evaluation system to understand the relative performance of these trade routes. The criteria were divided into five categories: technology, economics, the environment, governance, and commodity nature, He concluded that the trip frequency, freight pricing, and travel time take precedence over other factors(Yang et al., 2018a). Therefore, it was understandable that the current researches were mainly focused on the CER express, it had the advantage of short distance, fast speed, high safety and less affected by nature. As Fardella reviewed that the establishment of the CELSE line and the CER express has made other European countries realize the importance of taking advantage of the Belt and Road Initiative potential, voluntary connect ports with railway network can maintain market share (Fardella and Prodi, 2017). However, Kuzmicz pointed out that there are still some problems in the operation of CER express, such as basic function dislocation, unclear market positioning, inefficient coordination mechanism, overseas infrastructure and other fundamental problems restricting the development, and derived from subsidy dependence, line duplication, operation congestion and other problems. (Kuzmicz and Pesch, 2019). Feng devoted to modelling and solving the issue of optimal subsidy amount in the operation of the China Railway. In a case study of the Wuhan to Hamburg section of CER express line, the validity of the proposed model is examined. The results were between 2000 and 2500 USD per Forty-Foot Equivalent Unit (FEU)(Feng et al., 2020a).

The second group of researchers focused on CRE logistics hubs and facilities, including connections, routes, related hinterland, and logistics centers. Lu found that the reasonable connection of roads and railways, particularly the optimization of consolidation, was a significant link in the intercontinental multimodal transport system that impacted the system's carbon emissions. Lu established a two-layer mixed integer linear problem (MILP) model to solve the problem of connecting between roads and railways (Lu et al., 2019). Although Song' studies had long proved that railways are the least polluting for China(Song et al., 2016), and the CER Express line had played a role in promoting transnational trade between China and Europe, but the CER express lack of systematic top-level design gives rise to competition between each of the CER Express line.

The third group of scholars researched the consolidation network and consolidation routes for China-Europe various transport modes. Intensive comprehensive development can solve the problem of homogeneous competition, but collaborative legislation will inevitably reform and unify the old mechanism, which will cause losses to some enterprises(Ali, 2019). According to Tuusjärvi and Möller wrote(2009), if self-interests were not preserved as part of the relational norm, cooperative connections might dissolve and coexistence could return(Tuusjärvi and Möller, 2009), so the hardest part was to establish a cooperation mechanism and improved subsidy policy. Accordingly, Feng model calculated the optimal subsidy in the operation of China Railway Express, he had taken into account the China Railway Express operator's level of operational effort, the actual freight rate, and the greatest freight charge that the shipper was ready to pay to build the Optimal subsidy model(Feng et al., 2020b).

2.4. Research on sustainability issues

One is policy sustainability. Few researchers have sought to look at research trends and determine future research priorities. Although the CELSE Line is under construction, short distance, fast speed, convenience route, goods from non-EU countries can remain in the bonded area indefinitely, reduction for VAT, have an advantage of free customs formalities. However, The uncertainty of the current situation in Macedonia can lead to political and economic risks, the geopolitical and political stability of the countries along the route is also significantly concerned by relevant stakeholders(Yang et al., 2018a), associate with the development of these routes. At the same time, the participating countries of the Belt and Road Forum for International Cooperation are all supporting the CER express construction. but faced the force political of the countries along the route(Summers, 2016) and tensions between neighboring countries, the further expanding of CER express may face to sticking the original farther route.

2.5. Highlight gaps and the research fits in

Previous studies have summarized and analyzed various transportation routes between China and Europe, and the evaluation of these routes has been followed up, found the existing problems and proposed the solutions. The main problems that haven't been solved yet are function dislocation, unclear market positioning, inefficient coordination mechanism, overseas infrastructure discontinuity and other fundamental problems, derived from subsidy dependence, line duplication, operation congestion, lack of consolidated network and other operational problems restricting the development.

Although some scholars have paid attention to environmental problems, but the sustainability is only a small factor when they evaluating the routes. With the proposal and formulation of the Kyoto Protocol, China's awareness of environmental protection has gradually increased, until 2020, Chinese President Xi announced that China will adopt more forceful policies and measures to increase its contributions on reduction of greenhouse gas (GHG) emissions. Strive to peak China GHG emissions by 2030 and achieve carbon neutrality by 2060, which means China commitment to halt the growth of GHG emissions by 2030 and to slow down after a peak, all GHG produced after 2060 should be offset by planted trees(huaxia, 2020). But there are still many problems to be solved in order to meet the climate Council's standards and the President Xi's announcement. The goal of sustainability multimodal transportation, therefore, focuses on reducing CO_2 emissions. At the same time, The meeting of the UNFCCC in Glasgow in November 2021 will be COP26, it will bring together over 200 countries to further solve the problem of climate change. There are 73 Countries Commit to Net Zero CO_2 Emissions by 2050, and no academic studies have been published undertaken on the change of CO_2 emission of these transport routes in the future. Combine the countries' green policy along the routes and the technological developments in freight transport in the coming years to calculate the CO_2 emission of various routes of multimodel transportation between china and Europe. Depend on the 2016 IPCC Guidelines for National Greenhouse Gas Inventories issued by the Intergovernmental Panel on Climate Change can estimate carbon emissions of various routes of China-Europe transportation(Li et al., 2019). But now many countries are focusing on renewable power generation and rail electrification, the IPCC Guidelines calculations method needs to be improved.

The prediction of future trade and transportation between China and Europe is still blank. Combined with the policies of countries along the route, the carbon dioxide emissions between China and Europe can be preliminary predicted. Combined with the constraints of the Paris Agreement, the gap in the prediction of future environmental protection of transportation between China and Europe can be filled in this dissertation.

3. Methodology

This chapter will choose the representative freight routes from China to Europe based on the summarized criteria from last chapter, then collect the policies of countries along the routes, find useful data sources. Finally, build the digit model to calculate the current and future carbon dioxide emissions of each representative route.

3.1. Overview the representative China-Europe routes

As reviewed before, consider the freight volume, choosing Shenzhen as the place of departure, consider the geographical and policy advantages, choosing Budapest as the place of destination. As Seo said the Rail, road, inland waterways, and air are the primary forms of transportation, each mode has technological and economic restrictions, the decision maker should carefully assess the transport mode for each segment based on traffic conditions, the features of the goods, and the consignor's needs(Seo et al., 2017). As summarized criteria reviewed in chapter two, this studies will keep including China-Europe shipping Line, China-Europe Railway Express, added competitive aviation transportation, railway and shipping combined transport, as well as the cross in the land transport, concluded six representative routes. The first route is the CER express, the whole railway transport. Route 2 is an upgraded version of route 1, with a shorter distances and less time. Route 3 is the CESEL which is shipping from China to Paris then change to the railway. Route 4 is the whole air transport. Route 5 and 6 are traditional shipping ways but the last part which reaches to destination provides road transport and rail transport two ways. Chart 1 shows the geographical location of each route.

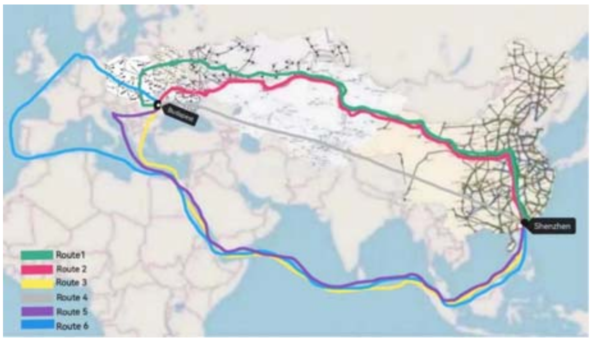

Figure 1. Routes layout(own work)

3.2. Status quo and development trend of each route

3.2.1. Routes through CER express(railway route1)

Recently, the CER express line has been extended to forty-three cities across China. The stock of goods in Shenzhen can be transshipped through Alashankou, go through Kazakhstan, Belarus, Poland, arrived at their destination Budapest. Therefore, Route 1 has been chosen because it represents an emerging rail link between China and Europe. As Chinese Foreign Minister Zhao Lijian said on Foreign Ministry Regular Press Conference that the first China-Europe railway express service departed in March 2011, over the past decade, more than 40,000 freight trains have been running between China and Europe. Only in 2020, the number of freight trains run between China and Europe had exceeded ten thousand, with the total cargo value was more than 200 billion US dollars. Seventy-three routes have opened, connecting more than 160 cities in 22 European countries(Lijian, 2021).

3.2.2. Routes through New route (railway route2)

Route 2 is an extension of the CER express line. According to cnR.cn, Route 1 from China to Hungary via CER express has opened since 2017, and has become a regular and fixed weekly service now. In 2017, China's first brand new line of CER express enter the EU via Ukraine by route 2, the whole journey is from Xi 'an, China to Hungary, arrived at BILK station in Budapest only took 11 days(Liu, 2017), setting a new time-lapse record for the Budapest line of CER express platform, this not only means that having a new time-saving route but also proved the CER express can bypass Belarus and form a closed loop of the Belt and Road to southern Europe. However, the political relationship between Ukraine and Russia is a serious factor in smooth operating this corridor, because of different gauges problem between Kazakhstan and Russia, and Russia is in enough control of flatbed trucks, containers and other transportation equipment, so the cooperation between Ukraine and Russia is essential for running route 2 smoothly. According to statistics, this route has not been normalized due to its small cargo volume(statista, 2021), but it can indeed reduce the time traveled and carbon dioxide emissions, so the future of route 2 is still uncertain.

3.2.3. Routes through CESEL (Sea+railway route3)

According to China Central Television news, the Budapest-Belgrade Railway is a flagship project of China-CEEC cooperation and an important part of China-EU connectivity cooperation. It is of great significance to the Belt and Road Initiative and the further China-Europe cooperation(Zhang, 2020). The CESEL line runs from the Greek port of Piraeus in the south to Budapest in Hungary in the north, passing Skopje in Macedonia and Belgrade in Serbia on the way. The traditional route would go through the Strait of Malacca, the Bay of Bengal, across the Indian Ocean, around the Cape of Good Hope, longitudinally across the entire South Atlantic, along the coast of West Africa, and finally into the heart of Europe.

3.2.4. Routes through airline（route4）

Air transportation is an important part of modern logistics, which provides safe, fast, convenient and high-quality service, greatly shorten the delivery period. But air transportation is only suitable for cargoes that small batch and low cost sensitivity with high timeliness requirements and long transit distance. As Wu said, according to the perspective of the development of air cargo in the world, the market share of China's air cargo industry in the world is still relatively low, and the development potential is great(Wu and Man, 2018).

3.2.5. Routes through Sea connected with road (route5)

The traditional shipping from China to Europe mostly starts from the southern coast of China to the southern coastal countries of Europe, and then reaches the inner hinterland of Europe by rail or road. Based on the plans of several freight forwarding companies, the shipping route from Shenzhen to Hungary is normally ends at Koper, Piraeus and Hamburg port. For Koper port in Slovenian, The Beltinci-Lendava-Rédics railway has been suggested by the Slovenian border municipality of Lendava, this 20-kilometer line will connect Lendava to Slovenia's railway network as well as Hungary's border, and the freight services will be available between Slovenia and Hungary when the new railway route finished(Zasiadko, 2019b), but now the transport between Slovenia and Hungary are still depend on truck. Considered the cost advantage of rail, prospect that there will be more people choosing route five compared with now.

3.2.6. Routes through Sea connected with railway (route6)

Hamburg port is the second largest container port and the most important transit seaport in Europe, China has become Germany's most important trading partner since 2016(Shakeel et al., 2020). The number of shipping flights between China and Germany is huge and their operation is mature and stable. But now, apart from the impact of the global shipping recession, Hamburg port is also facing more and more competition among other homogeneous ports(Hurtienne, 2018). Since 2010, the cargo volume of Hamburg port has stabilized and decreased slightly(Xie, 2018), but its container business and inland train transport business with China were kept growing steadily. In order to enhance the competitiveness of ports, the Hamburg port also began to explore the "smart port" focusing on smart energy and smart transportation in 2013, had made remarkable results. Besides, The railway connects Hamburg port with Budapest has been mature, the train timetable is stable. So in general, route six transit volume would keep stable or slightly increase.

Table 1 has concluded six representative routes that balance the various demands of decision makers and satisfied the competitive prospects of market.

Table 1. Six representative routes from China to Europe(own work)

routes	Intermodal Transportation Path
CER express (railway route1)	Yiantian Port-Alashankou-Oktyabr'sk-Brest-Marashevich-Budapest
New route (railway route2)	Yiantian Port-Alashankou-Oktyabr'sk-Guriyev-Astrakhan-Lugansk-budapest
CESEL (Sea+railway route3)	Yiantian Port-waterway-singapore-piraeus-railway-budapest
Airline (route4)	Shenzhen airport-budapest airport
Traditional (Sea+road route5)	Yiantian Port(Shenzhen)-waterway-Koper-road-budepest
Traditional (Sea+railway route6)	Yiantian Port(Shenzhen)-waterway-hamburg-railway-warsaw-budepest

3.3. Energy in the countries covered by each route

With the Glasgow UN Climate Change Conference meeting (COP26) fast approaching, various countries have now set relatively ambitious targets for GHG emissions reduction, including of course emissions from the transport sector. In order to think more precisely about the future sustainability development of these routes, review the policies and implementation advice of the countries through which these routes. At the same time, the development of science and technology in the future will also reduce the negative impact of freight transport on the environment, so review the scientific and technological development achievements which expected to popularity in the world.

3.3.1. The green policies impact

3.3.1.1 China

At the 75th SESSION of the UN General Assembly, Chinese president Xi said that China will Strive to peak China’s GHG emissions by 2030 and achieve carbon neutrality by 2060(huaxia, 2020). With a particular focus on the rail freight sector, the latest implementation advice of the Ministry of Transport on comprehensively strengthening ecological and environmental protection states that: China will reduce road freight volume and increase rail freight volume in future fifteen years, increase the use of new energy and clean energy vehicles in railway freight yards(Transport, 2018). China's railway is working towards an era of electrification, electric traction has the advantage of high horsepower, high speed, high efficiency, low energy consumption, and environment friendly, but it needs to invest a lot of manpower, material and financial resources (Lin. Z, 2018).

3.3.1.2 Kazakhstan

The majority of Kazakhstan's electrified lines are in the north, middle, and south. Diesel locomotives service the western and eastern sections of the region now. To meet with the electrification plans, Kazakhstan is developing two electrification projects which are part of the state development program"Nurly Zhol" ('Bright Path' in Kazakh), name Moyynty-Aktogay railway in northwestern Kazakhstan and the Tobol-Nikeltau line in the eastern part of the country between 2021-2025(Zasiadko, 2019a), so if all goes well, the Kazakhstan section of the CER express line will be electrified by 2025.

3.3.1.3 Russia

In Russia, electric traction already transports over 86 percent of cargo volumes. When it comes to integrating green technology in the future, Russian Railways(RZD) prioritizes electrification of railway lines, according to Kobzev(Papatolios, 2020). RZD has announced plans to increase about 1000 new electric locomotives to expand its electrified rolling stock over the next three years(Lobyrev et al., 2018). As of 2021, hydro, solar and wind power account for 21.47 percent of total installed power capacity. But in the Russia's Energy Strategy-2035, the Russian government wants to maximize the contribution of the hydrocarbon industry and boost the country's position in the global energy sector, cut down the investment in renewable power generation(Alekseev, 2019).

3.3.1.4 Belarus

The railway connects Belarus, Russia and Poland has been electrified(wikipedia, 2021a). Between 1963 and 1983, the railway sections Russian border-Orsha-Minsk-Brest which involved in the route two had been electrified. Electrified portions of the Belarusian railway system accounted for about 900 kilometers, or around 16% of the overall length of the country's railways(BELARUS.BY, 2020). In 2018, natural gas provided nearly all of the electricity production(IEA, 2020a), but the Comprehensive Development Plan for the Electricity Sector provides the aim of reducing the share of gas in heat and electricity production to 60% by 2025(iea, 2020b).

3.3.1.5 Europe

According to the "Green Deal" issued in December 2019, the European Commission aims to net-zero emissions for the entire EU before 2050, Germany, Poland and Hungary are belong to Europe, only Poland refused to commit to European Commission execution. The transport sector is being considered to be included in the CO2 carbon trading scheme, so the obligation to curb pollution would apply to trains, which means the EU would have to stop using coal-fired powered train. In fact, a considerable portion of the European railway network has also been electrified. Almost 60 percent of railway tracks in Poland and Germany are fitted with electric traction now. The Polish Railway Market 2020-2021 report shows that EU funds have been set aside 6 billion euros for the development of rail transport in Poland. In the near future, the railway between Germany, Poland and Hungary will be electrified(2020a).

As the data shown in the Port of Hamburg website, the Hamburg port and Budapest terminals are connected by regular freight trains. there are 24 block trains to and from Budapest every week, rail transport accounts for about 85 percent of all products handled in Hamburg(Kovács, 2021). According to Siemens Mobility head Albrecht Neumann, "freight train has to switch to diesel powering on stretches without overhead electricity lines, while the majority of Germany's railroad network is already electrified, but many cargo train journeys will encounter the circumstance that forcing locomotives to rely on their combustion engines". So the type of locomotives are unstable for each shipment, in this article, the proportion of rail transport driven by electricity is determined by the proportion of electrification of the national rail network. Germany had a railway network of 33,331 kilometers (20,711 mi), of which sixty-one percent were electrified, the Polish railways network of 18,510 kilometers (11,500 mi), of which 65 percent were electrified.

3.3.1.6 Ukraine

Ukraine's passenger and freight rail transportation is owned by the Ukrainian government, it manages a total of 22,300 kilometers of railways with 44.3 percent has been fully electrified(wikipedia, 2015). In order to adapt to EU regulations, Ukrainian Railways will receive 130 heavy electric locomotives by Alstom as part of a fleet renewal project. By 2025, it intends to buy at least 50 new electric locomotives, and by 2033, it wants to buy 265 new electric locomotives(Papatolios, 2021a).

Ukraine's onshore wind segment is predicted to rise by 20% in 2030, while biopower and solar PV capacity are expected to grow by 16% and 13% respectively, and now Ukraine's pollution-free electric generation has reached to 63%(Kucher and Prokopchuk, 2018).

3.3.1.7 Macedonian

The transform of Budapest-Belgrade Railway is going to add two lines, form a double - line electrified passenger-freight express railway(2020b). The plan for the Macedonian government is to open the entire modified electric railway line which runs from Tavanovci on Macedonia's border with Serbia to Gevgelija on Macedonia's border with Greece between 2025 and 2027.

As Papatolios said the freight terminal which could facilitate transshipment and multimodal transport are not very easy to find in Greece(Papatolios, 2021b). While the Ocean rail currently lobbies to electrify the rail section between the Ikonio terminal in Piraeus and Idomeni border crossing with North Macedonia, but the tender hasn't been made yet(Wikipedia, 2021b), but it can be seen that the rail transshipment between Greece and Macedonian could be easier and the rail sections of the CELSE line will be electrified in the future.

3.3.1.8 Slovenian

As Zasiadko reported that when the Beltinci-Lendava-Rédics railway finished, the route from Hungary to Koper will be totally electrified(Zasiadko, 2019b).

Euro VII is Europe's new emissions standard blueprint for heavy duty vehicles, designed to eliminate pollution from road transport, reclaim technological and regulatory leadership(Squaiella et al., 2013), and align standards with the European Union's new "Zero Pollution Ambition," which aims to achieve net-zero greenhouse gas emissions by 2050. This standard will be announced in 2021 and will most likely take effect in 2025(Grigoratos et al., 2019).

But DG Climate Action has proposed CO2 emission targets for 2025 and 2030, The Vehicle Energy Consumption Calculation Tool (VECTO) (Fontaras et al., 2013) was created and adopted in the European regulation as the principal instrument for estimating the standard CO2 emissions of heavy duty vehicle(Hofer et al., 2020). The

European Parliament and the Council adopted Regulation (EU) 2019/1242 setting CO_2 emission standards for heavy-duty vehicles, The goal is that a relative CO_2 emission reduction of 15% from the baseline until 2029, 30% reduction from the baseline from 2030 onwards(Union, 2019). In order to meet these goals, a significant amount of each manufacturer's fleet would have to be zero-emission vehicles, such as electric or hydrogen-fueled trucks. If it works out like this, future carbon dioxide emissions from road transport would be reduced by 15% by 2029.

3.3.2. Shipping and Air transport

The Paris Agreement is a landmark UN climate agreement that was adopted in 2015 and came into force in November 2016. However, the agreement does not cover shipping or air transport, leaving emissions-reduction targets for those sectors to the relevant specialized agencies. For air transport, now, information from the China Cargo Airlines LTD can know that the current cargo aircraft taking off from China is still the aviation fuel driven(LTD, 2021), however, The International Civil Aviation Organization (ICAO) assembly adopted Resolution A40-18 at its 40th Session in 2019, which reaffirmed the two global aspirational goals for the international aviation sector, which were established at the 37th Assembly in 2010, of 2 percent of annual fuel efficiency improvement through 2050 and carbon neutral growth from 2020 onwards. ICAO is exploring a variety of measures, including advancements in aircraft technology, operational improvements, sustainable aviation fuels, and market-based measures (CORSIA)(ICAO, 2019).

In order to pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals, International Maritime Organization (IMO) has agreed on draft new mandatory measures to cut the carbon emission of existing ships, which aims to reduce the carbon emission of international shipping by 40% by 2030, compared to 2008, pursuing efforts towards 70% by 2050(Joung et al., 2020). Countries could achieve this by slowing the growth of seaborne trade (tonnage nautical mile), limiting speed and improving ship fuel structures. Now, all ship company are working hard on the “IMO 2020” published by IMO and had came into force at 1 January 2020, the rule limits the sulphur in the fuel oil used on board ships operating outside designated emission control areas to 0.50% m/m.

In order to actively promote the green development of global shipping, China put forward the "Chinese plan" for the IMO global sulfur limit in 2020. Major Chinese oil companies have all launched production plans and countermeasures for low-sulfur fuel oil. In 2019, Sinopec announced that the production capacity of low-sulfur heavy clean Marine fuel oil would reach 10 million tons in 2020 and more than 15 million tons in 2023. which has shown china are working on producing LSO and have a strong positive attitude on keeping up with the demands of the world. However, as a study conducted by Lloyd's Register and University College London observed that the lowest uptake of LNG, and a sustained outlook for Heavy Fuel Oil (HFO), which maintains a high share of nearly 60% of the marine fuel mix in Competing Nations by 2030. HFO is slowly replaced by MDO/MGO (and LSHFO from 2025) but to a smaller degree compared to the Status Quo scenario(Smith et al., 2014).

All ports involved in this paper are developing toward smart and green ports. According to the destination port layout plan, China promotes the construction and upgrading of LNG-powered and electrically powered ships, increase the intensity of ships by electric facilities construction and retrofit, improve ship port facilities construction of harbor electricity, making electric facilities serve electrically powered ship, efforts to make the pearl river delta emissions control area shore power electricity prices have supported policy, gradually improve the shore power facilities usage(Transport, 2018). According to the Green Port Programme, Singapore is promoting ocean-going ships which calling at Singapore's port to reduce polluted gas emissions, local maritime companies can apply for up to 50 percent of eligible expenditures in grants to develop and adopt green technological solutions together(Newman, 2010).

As shown in the last chapter, Hamburg's marine commerce has created several environmentally friendly technologies in order to meet the goal of balancing commercial goals with environmental concerns several years ago. Now, Hamburg's port can boast extremely efficient global transportation chains as well as environmentally friendly, long-term port operations(Nitt-Drießelmann and Wedemeier, 2021). In order to enhance the competitiveness of the port of Hamburg, the "smart port" focused on smart energy and smart transportation was launched in 2013. As the information provided on the Port of Hamburg website, the landside cruise liner power supply sourced from renewable energies has significantly reduced the CO_2 emission; The cloud-based system optimizes the movement of empty containers between packing companies. reduced unnecessary empty trips to the depot. Now, Hamburg port is reviewing ways of extending e-Mobility to passenger and freight traffic in the harbor area. focusing on innovative technologies, including wind and solar power and bio-energy(2021b). All these efforts show that docking in Hamburg's port is more and more environmentally friendly. Table 5 has taken into account this factor when calculating the overall CO_2 emissions.

Table 2 and 3 have summarized the environmental protection status of each route and the policies which affect the routes' future carbon dioxide emissions. In tables, the column of country are the countries that we analyzed above, represented the countries involved in these six representative routes, the modes column is the modes of transport which involved in the “country”, the section represent the end and the beginning station, showed the trajectory in the “country”, Drive energy explained that the kind of energy is used to drive this “modes” of transportation in this “country”, the last column is focus on the pollution-free electric generation, the percentage of electric are generated by pollution-free power in this “country”, The pollution-free power is different from renewable power, since renewable power concluded the wind power, photovoltaic power station(Dawn et al., 2019), biomass power station, geothermal power station and marine power station, but Nuclear power is a non-renewable energy source, but the nuclear power generation process does not produce carbon dioxide(Hewitt and Collier, 2000). These data will be used to calculate in section-3.5 CO_2 emission model below.

Table 2. Summarized the current policies of the countries though the routes(own work)

country	modes	section	Drive energy	% of pollution-free power generation
China	railway	Yiantian--Alashankou	Diesel +electric	27.32%
	shipping	Yiantian-- port of transshipment/Koper/hamburg/Piraeus	LSO	
Kazakhstan	railway	Oktyabr'sk--Guriyev	Diesel +electric	13.6%
Russia	railway	Kartaly--Krasnoye	Diesel +electricDiesel +electric	81%
Belarus	railway	Brest--Marashevich	Diesel +electric	99%
Poland	railway	Marashevich--Budapest	Diesel +electric	11%
Ukraine	railway	Rostov--Budapest	Diesel +electric	63%
Slovenian	railway	Beltinci-Lendava-Rédics	Diesel +electric	68.8%
	road	Koper--Budapest	Oil+electric	
Germany	railway	Hamburg--warsaw-budepest	Diesel +electric	76%

Table 3. Summarized the future policies of the countries though the routes(own work)

country	modes	section	Drive energy	% of pollution-free power generation
China	railway	Yiantian--Alashankou	Diesel +electric	66%
	shipping	Yiantian-- port of transshipment/Koper/hamburg/Piraeus	LSO	
Kazakhstan	railway	Oktyabr'sk--Guriyev	Diesel +electric	50%
Russia	railway	Kartaly--Krasnoye	electric	83%
Belarus	railway	Brest--Marashevich	Diesel +electric	40%
Poland	railway	Marashevich--Budapest	electric	23%
Ukraine	railway		Diesel +electric	63%
Slovenian	railway	Beltinci-Lendava-Rédics	Diesel +electric	68.8%
	road	Koper--Budapest	Oil+electric	
Germany	railway	Hamburg--warsaw	electric	100%
Hungary	railway	warsaw-budepest	electric	46%

4. Finding

4.1. Calculation of the current and future CO2 emissions

This chapter will summarize the characteristics of each route, point out the current and future one time freight volume of each route. use the methodology introduced in chapter 3 to calculate the current and future carbon dioxide emissions of each route. As a result of the requirement of the Climate Summit, countries have state the targets and policies, which could be used to predict future CO_2 emissions from these routes.

In the following table, which summarizes carbon dioxide emissions from each route. Added the "status", because the problem of changing gear caused by different gauge is a big disadvantage of international train operation, other studies have looked at this issue at the point of wasting time or time efficiency(Wieslaw, 2012, Sampson and Wu, 2003), but in this paper we focused on the environmental aspect, so loading process is also taken into account in the calculation. The "distance" is the running distance between the sections, the unit of distance is kilometers. The "energy" in this chapter is the electrification percentage of the railways involved in each "country", in order to ensure the accuracy of the data, the electrification percentage of the railways involved in the calculation of some countries is unknown. In this case, maximum likelihood method is used to determine the electrification level of each section, if there is no clear evidence that the section has been or will be electrified then this section of railway electrification percentage will be counted as zero. "Now" and "future" represent the current and future CO_2 emissions when finish recently policy from each "country". The result in the last row "total" is the sum of the data in the same column, is the final result of the current and future CO_2 emissions from each route, the unit of CO_2 emission is tons.The traditional 1-ton/5-ton/10-ton containers were displaced by 20'GP (general purpose)/ 40'GP/ 40'HQ (high cube)containers(Edirisinghe, 2018). The following calculation results are based on one container(20'GP) as the standard unit to calculate.

4.1.1. Route 1

The transportation time of railway is between sea and air, which is a supplement to the traditional sea and air transport market, while the transportation volume is limited and the price is very high for using aviation to deliver goods, due to the lengthy delivery time of sea transportation. But now, The CER express line can not only carry high value-added products such as cars and laptop computers but also attract many low value-added bulk goods(Tjia, 2020). Affected by the epidemic, shipping and airline prices continue to rise, the time of arrival is uncertain, making enterprises more and more dependent on the export of CER express line, however only 41 TEU goods can be carried at one time, therefore, the demand for CER express line is gradually exceeding supply, the phenomenon of empty container gradually disappeared. Because the scenario of The CER express line is bright and there will be more and more users.

Table 4. Carbon dioxide emissions from route one(own work)

Route 1	country	status	Distance(km)	energy	Now (kgCO2/TEU)	energy	Future (kgCO2/TEU)
Yiantian - Alashankou	China	loading	0	Electric	16.8	Electric	5.7
	Ex：DF7	Rail transit	4844	Diesel	13493.14	Diesel	5520
Alashankou-Oktyabr'sk	KZ	reloading	19 5d	Diesel	53.34	Diesel	53.34
	KZ8A	Rail transit	2980	Diesel	4859	Electric	632.95
Oktyabr'sk-Brest	Russia	Rail transit	2235.6	Electric	483.8	Electric	459.61
Brest-Marashevich	Republic of Belarus	reloading	0	Electric	0.32	Electric	0.27
		Rail transit	745.2	Diesel	1215	Electric	523.46
Marashevic-budapest	Poland	Rail transit	630	Diesel	1027.25	Electric	442.54
Total					21148.65		7637.87

4.1.2. Route 2

Route 2 has obvious short distance, high efficiency and green logistic advantages, gradually attract shippers' attention. But due to political reasons, fewer merchants are selected for route 2, so the operation is not stable, however, Ukraine is also working on ease relations and reach business deals. Overall, it is a route that develops at a low speed, but still optimistic(Pop-Eleches and Robertson, 2018), so this calculation is based on the optimal full load 41 TEU per train.

Table 5. Carbon dioxide emissions from route two(own work)

Route 2	country	status	Distance (km)	energy	Now (kgCO2/TEU)	energy	Future (kgCO2/TEU)
Yiantian - Alashankou	China	loading	0	Electric	16.8	Electric	5.7
		Rail transit	4844km	Diesel	13493.14	Diesel	5520
Alashankou-Oktyabr'sk	KZ	reloading	19	Diesel	53.34	Diesel	53.34
		Rail transit	2980	Electric	3062.47	Electric	2429.52
Oktyabr'sk-Guriyev-Astrakhan	Russia	Rail transit	326	Diesel	531.56	Diesel	531.56
Astrakhan-Záhony-Eperjeske	Ukraine	reloading		Electric	0.2	Electric	0.2
		Rail transit	978	Diesel	1594.68	Diesel+ Electric	970.66
Total			9128		18752.19		7081.46

4.1.3. Route 3

Although route 1 has developed well in recent years, and many scholars have praised its environmental performance as reviewed. However, According to many case studies, one container ship can carry 4300 containers at one time(Wan et al., 2018, Liu and Kronbak, 2010), which carries 100 times more than CER express line does. Therefore, CER express line cannot replace sea transportation, and the shipping industry needs to find a more environmentally friendly way, Route three is a representative attempt by China(Zhao et al., 2020). Recently, due to the COVID-19 pandemic, the international logistics capacity has been reduced, which has led to the overflow of container ships, but as Goulielmos persistent mathematical analysis of data from 1741 to 1945 found that shipping cycles lasted an average of 6 years(Goulielmos, 2020), so it is not stable whether the container ship is full. But shipowners will always pursue full ship, this paper is calculated according to the shipment of 4300 TEU.

Table 6. Carbon dioxide emissions from route three(own work)

Route 3	country	status	Distance (km)	energy	Future (kgCO2/TEU)
Yiantian -singapore	china	loading	0	Electric	5.7
		water transit	2630nm	0.50% sulphur in the fuel oil	8494.77
Singapore-piraeus	Singapore	water transit	10795	0.50% sulphur in the fuel oil	34867.33
piraeus-railway-budapest	Piraeus MZ 443	Rail transit	≈320	Electric	181.98
total					43549.79

4.1.4. Route 4

International air transport is mainly suitable for electronic products, small parcels of e-commerce, and other goods requiring high timeliness. The china Civil Aviation Authority data shows that the growth rate of international airlines fluctuates greatly(Li et al., 2008). At present, China's international civil aviation logistics business has not formed a stable and sustainable development pattern. But as the number of containers transported worldwide and its annual growth demonstrates that specialized container planes can supplement fast sea intermodal containerized commodities transit(Zhang and Figliozzi, 2010). According to the traditional case study, there are weight and height restrictions in air freight, the largest cargo plane 747 air freight about 8 tons, equivalent to half the marine 40'HQ weight limit. Now, New container aircraft have fulfilled both sea transport and aviation requirements, and 2 TEU goods can be carried at one time(Jeziorek, 2020). For the current stage of the calculation, this paper is calculated according to the air shipment of 0.5 TEU, and for the future, 2 TEU one time. Use the unit emission and Fuel consumption per unit of the largest cargo plane 747 air freight to calculate the CO2 emission, 3150 grams per liters of fuel, 12 liters per kilometer(Langton et al., 2009).

Table 7. Carbon dioxide emissions from route four(own work)

Route 4	country	status	distance	energy	Now (kgCO2/TEU)	Future (kgCO2/TEU)
Shenzhen airport-budapest airport	china	loading	0	electric	16.8	7
		air transit	8302.52	Aviation fuel	156917628	78458814
total					627670528.8	156917633.7

4.1.5. Route 5

Now from the view of logistics company's quotation, shippers generally choose road freight transport to finish the last leg from Koper port to Budapest . European emission standards for new heavy-duty diesel engines can refer to as Euro I ... VI, all these standards have not mentioned the CO2 emission standard. The oil is based on the rules of Euro V/Ecological Class 5 (ECE R49.04-B2C), the co2 emission of the road transport keep using the method introduced in section 3, the final result has shown in table 4.

As reviewed the Beltinci-Lendava-Rédics railway has been suggested by the Slovenian border municipality, so for the future CO2 emission, the calculation will be based on the use of electric trains throughout the journey.

Table 8. Carbon dioxide emissions from route five(own work)

Route 5	Country	Status	Distance (Km)	Energy	Now (kgCO2/TEU)	Status	Distance (Km)	Energy	Future (kgCO2/TEU)
Yiantian - Koper	China	loading	-	Electric	16.8	loading	-	Electric	7
		water transit	16540.2km	LSO	53424	water transit	16540.2km	LSO	32054.4
Koper-Budepest	Slovenian	reloading		Electric	11.73	reloading		Electric	10.9
		road transit	408km	Fuel oil	49123.2	Rail transit	338km	Electric	209.2
total					102575.7				32280.2

4.1.6. Route 6

Hamburg port as the second largest container port in Europe, receives goods from all over the world to Europe, ships are relatively easy to full load because of the large number of shippers and various voyages(Hein and Schubert, 2021). Shippers can gather different volumes of ordinary goods together into one container for deliver. one container ship can carry 4300 containers at one time, while one block train can carry 41 containers.

Table 9. Carbon dioxide emissions from route six(own work)

Route 6	Country	Status	Distance (Km)	Energy (kgCO2/TEU)	Now	Energy	Future (kgCO2/TEU)
Yiantian -hamburg	china	loading		Electric	16.8	Electric	5.7
		water transit	19533.04km	LSO	63090.8	low sulfur oil	63090.78
Hamburg-budepest	German	reloading		Electric	4	Electric	4
		rail transit	300	Diesel	122.56	Electric	109.76
Brest-Marashevich	Poland	reloading	0	Electric	12	Electric	8.4
		Rail transit	745.2	Diesel	1215	Electric	523.46
Marashevich-budapest		Rail transit	630	Diesel	1027.25	Electric	442.54
Total					65488.41		63793.66

4.2. Freight volume between China and Europe

From an environmental point of view to compare the result in table 10. Horizontal comparison, all routes are reducing carbon dioxide emissions accordingly. Air international transport has the best emission reduction effect, that is to say, under the same economic input, aircraft emission reduction could have the best repay. Second, the results show that railway electrification would perform well, Route 5 land section of transportation transfer from truck to rail has reduced the CO2 emission significantly. Route 1 and 2 results have shown that the world is focusing on railway electrification, and the policies of relevant countries have helped to reduce the pollution of international railway transportation by more than half. By contrast, the traditional shipping route 6 would done a poor job, IMO should attach importance to it and accelerate the formulation of corresponding carbon dioxide emission reduction policies. Vertical comparison, Route 2 releasing the least CO2, is the best for the environment now. In the future, Route 1 was predicted to be better at reducing CO2 emissions, as a result, the environmental advantages of route 2 are reduced, but Route 2 will still release the least CO2. As a complement to traditional shipping, rail transport is the best choice for international freight transport from an environmental aspect. On the other side, even air international transport would perform well on emission reduction in the future, but it still the most polluting modes, reduce the air international transport using proportion can be effective in alleviating global warming.

Table 10. Projected future CO2 reductions for each route(own work)

Route	Now CO2 emission	Future CO2 emission	Reduced
Route1	21148.65	7637.87	13510.78
Route2	18752.19	7081.46	11670.73
Route3	-	43549.79	
Route4	627670528.8	156917633.7	470752895.1
Route5	102575.7	32280.2	70295.5
Route6	65488.41	63793.66	1694.75

Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C, even just for limiting global warming to below 2 °C, CO2 emissions should decline by 25% by 2030 and by 100% by 2075(Stocker et al., 2014). Total greenhouse gas emissions in the European Union until 2019 is 4067 million metric tons, account for 12.8% of total greenhouse gas emissions in the world(Roser, 2019). Transport (including aviation and shipping) was responsible for 27 % of total greenhouse gas emissions under the EU-28 in 2017(2021a), China was the third largest partner for EU exports of goods (10.5 %) and the largest partner for EU imports of goods (22.4 %)(eurostat, 2021b). so total greenhouse gas emissions between China-Europe transport are 361.3 million tons. 2010 total greenhouse gas emissions in the world is 33.13 billion tons, while 2020 is 36.44 billion tons, in order to decline the CO2 emissions by 25% by 2030, assuming a 25% reduction in emissions from all sources of generation, the CO2 emissions between China to Europe transport should at less reduced to 270.98 million tons.

Table 11. Current using proportion of each route(own work)

Route	Now CO2 emission (kgCO2/TEU)	Future CO2 emission (kgCO2/TEU)	Reduced	percentage
Route1	21148.65	7637.87	13510.78	3
Route2	18752.19	7081.46	11670.73	1
Route3	-	43549.79		
Route4	627670528.8	156917633.7	470752895.1	26
Route5	102575.7	32280.2	70295.5	25
Route6	65488.41	63793.66	1694.75	33

Combined with the trend of future international transportation and expected trade quantity, the freight volume between China and Europe would continue to increase(Barua et al., 2020). Min analyzed the trade data between China and Europe in the first half of 2018 by trade gravity model, he found that China-EU trade will accelerated growth(Min and Yiming, 2019).

Assume the percentage of different transport modes from china to EU keep stable(Zhang, 2021b), the CO2 emissions between China to Europe transport would be reduced to 90.37 million tons. So when all mentioned countries' policy smoothly implemented, there is room to at least double the number of goods shipped between China and the EU by 2030.

As OECD states that increase global commerce, on the other hand, can contribute to a stronger capacity to manage the environment effectively by supporting economic growth, technology development, and social welfare. More importantly, free markets can increase access to new technologies that reduce the consumption of energy, water, and other environmentally hazardous elements in local production processes(OECD).

5. Conclusion

This thesis use an innovative ways of using data to give sustainable advice to countries, focus on the CO2 emission since the urgent global warming issue, concentrate on the central European region, speciality in freight transport field. This thesis have answered three research questions in section-1.3, found that the two hotly discussed routes have the common advantage that the transportation time and distance are shorter than the traditional sea transportation, which can reduce the emission of CO2 in transportation, the disadvantages vary, but beyond the superficial cost, the underlying hard problems are the decentralization of management, the homogenization competition and the complicated political relations. The overall volume of CO2 emission between China to the EU freight transportation will be reduced, because the corresponding countries along each route have environmental protection guarantees, and some technologies are likely to be put into production in commission. As a complement to traditional shipping, Route 2 and Route 1 are the best choice for international freight transport from an environmental aspect. In the future, if the countries along the routs fulfill their guarantees, large-scale use of technology applications that have mentioned in previous chapters, then the trade volume between China and the EU have a space to increase by twice.

I highly recommend similar studies involving more about the routes comparison of the corresponding environmental protection index, the starting point and destinations could be freely changed. It is worth paying attention to the diversity of routes options when decide the representative routes. When consider the development of science and technology, include more update environmental innovation of cutting-edge on transportation. When combine the progress of the nations, deeper analyze the expected completion degree of the policies.

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