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What are the possible alternative routes to the Black Sea for Ukrainian wheat exports?

Analysis of rail and inland waterway options

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Executive summary

On 24 February 2022, Russia invaded Ukraine. As a result of this invasion, exports of Ukrainian wheat via the Black Sea came to a halt, jeopardising food security in certain countries as well as the affordability of wheat on the market.

In this work, possible wheat export alternatives will be studied.

Solutions by rail and inland waterway will be considered. We will detail the routes and analyse the possible costs and export volumes. Finally, the limitations of these routes will be discussed.

We will finish by concluding which of the alternatives is the best and raise the questions that still need to be answered in order to complete this model.

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List of Abbreviations

BSGI: Black Sea Grain Initiative

mm: millimetres

m: metres

CEMT: European Conference of Transport Ministers

TEN-T: Trans European Transport Network

Ro-Ro: roll-on/ roll-off

Ktons: Kilotonnes

Km/h: Kilometres per hours

OEM: Orient/East-Med

UNCTAD: United Nations Conference on Trade and Development

Unece: United Nation Economic Commission for Europe

t: tonnes

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1. Introduction

1.1 Motivations

Ukraine is nicknamed the granary of Europe. Thanks to its fertile soils and favourable weather, its agricultural exports are constantly breaking records (Carré, 2022). Goujon (2023) reports that in 2019, the agricultural production and the agri-food industry accounted for 15% of Ukraine's GDP.

According to Da Sois (2022), the main countries importing Ukrainian wheat are North African countries such as Egypt, Libya, Tunisia, Morocco and Algeria. The figure below (Figure 1: Dependent countries of Ukrainian and Russian wheat) shows the countries that are most dependent on Ukrainian and Russian wheat.

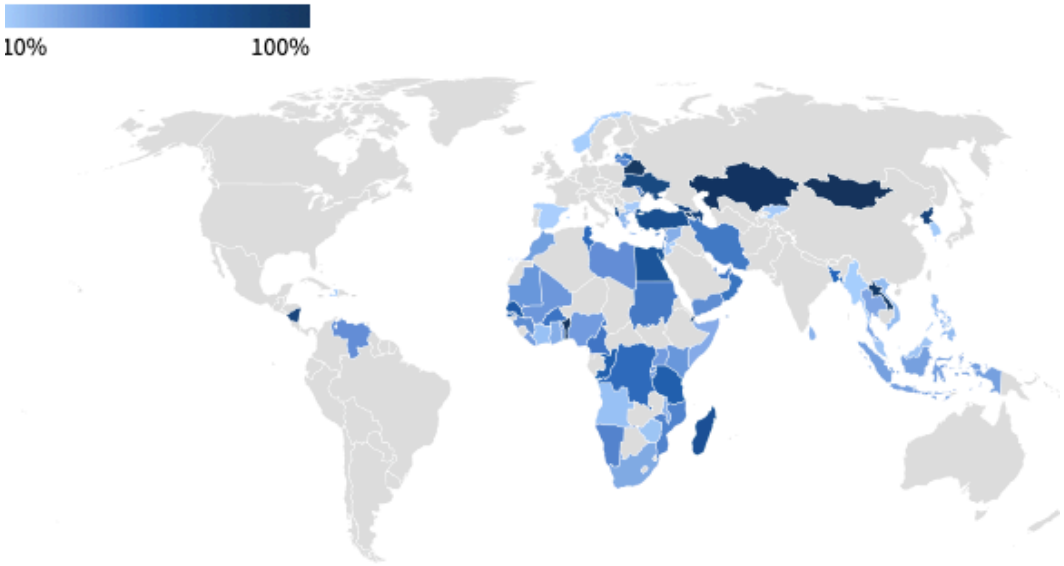

Figure 1: Dependent countries of Ukrainian and Russian wheat.
Source: OEC (2019)

Ukraine, former member of the Soviet empire, has complex relations with Russia. They sharply deteriorated with the rise to power of Petro Poroshenko in 2014 and the election of Volodymyr Zelensky in 2019. Both were in favour of Ukraine joining NATO and the EU (Orcier, 2022).
On 24 February 2022, Russia invaded Ukraine. Since that date, as explained by the Council of the European Union (2023), Russian military vessels have blocked access to Black Sea ports.

According to the Council of the European Union (2023), the blockade of Black Sea ports has had a direct impact on food security and the affordability of foodstuffs worldwide. On the one hand, there has been a significant increase in price of wheat, making it less affordable, and on the other, North African countries have been at risk of famine due to their heavy dependence on Ukrainian wheat.

In response to these food security problems, Ukraine and Russia reached an agreement, the Black Sea Grain Initiative (BSGI), to continue exporting Ukrainian wheat. As it will be explained, this agreement has made the wheat export possible, but it has a number of limitations.

Ukrainian grain is currently exported via the port of Constanta in Romania (Ilie & al, 2023). However, as Ben Hassen and El Bilali (2022) underline the fact that there are capacity problems at the port of Constanta to handle the influx of Ukrainian grain.

Not knowing how long this conflict will last and what the outcome will be, it is interesting to find a new sustainable export route for Ukrainian wheat.

The research question is therefore formulated as follows:

What are the possible alternative routes to the Black Sea for Ukrainian wheat exports?

This is an exploratory question, the aim of which is to propose possible new routes for exporting Ukrainian wheat. The feasibility of these alternatives will be analysed in terms of costs and export volume.

1.2 Limits

It is important to underline that several limitations were encountered during the writing of this master thesis.

Firstly, the conflict is recent and still ongoing, having started in February 2022. This conflict limits the information available and can lead to rapid changes in the situation. The Kakhovka dam explosion on 6 June is one example among other (Hajdari, 2023).

Although it is possible to find a lot of information on future infrastructure projects, there is little information on the current state of the infrastructure, whether it be the rail network or the river network.

Furthermore, the current global economic instability makes it difficult to estimate transport costs. In recent months, huge fluctuations in fuel and energy prices have been observed.

2. Methodology

The structure of this master thesis is as follows. The first part will be an introduction that sets the context for the research question and the limitations encountered. We then move on to the literature review which aims to gather a range of information about Ukraine and its transport infrastructures. The study that we are carrying out is then strictly qualitative. This literature review is completed by a section, named data collected, containing figures for the ports mentioned in the report.

It is then followed by a comprehensive presentation of the various alternative export routes. Details of the routes followed, their costs, volumes and limitations will be given. Some of the difficulties encountered by the BSGI will also be highlighted.

Finally, it will be important to shed light on interesting points of each scenario presented, and to conclude with questions that will be of interest for the implementation of these scenarios.

It should be added that during the writing of this master thesis, two short interviews were carried out to support certain points in the study, which are available in the appendix (Appendix B & Appendix C).

3. Literature Review

A literature review is a collection of information whose aim is to communicate knowledge and ideas on a subject to the reader (Taylor, 2020).

The purpose of this section is to detail the transport networks within Ukraine. However, the air and road networks are not examined as they are not relevant to this study. Transporting large volumes of low-value goods by air is not an option. Moreover, road transport is only interesting for short distances.
This literature review describes the situation of the networks in Ukraine before the conflict with Russia.

Firstly, Ukraine has 18 seaports spread across the Black Sea and Sea of Azov basin (Karpenko & Al, 2013). These include major ports such as Mariupol, which plays a significant role in the industrial world, and Odessa, which, according to the Searates platform (2023) has an annual traffic capacity of 40 million tonnes.

Ukraine also has a well-developed rail network, as it can be seen on the following map (Figure 2: Ukraine and Moldova railway network)

Figure 2: Ukraine and Moldova railway network

Source: Railway Gazette International: Ukraine & Moldova: national rail network map. https://www.railwaygazette.com/maps-and-data/ukraine-and-moldova-country-map/54025.article

In the newspaper Les Echos, Fainsilber (2021) informs us that the Ukrainian railway network is 23,000 kilometres long, making it the third longest railway network in Europe. In this article, the author also points out that the main part of the network is 19,800 kilometres long, of which only 9,320 kilometres are electrified.

The track gauge, which is the distance separating two rails on a railway line, as Bouron (2021) explains, and the load gauge, which corresponds to the height, width and length that trains have to fit into to be able to run on the network (de Kemmeter, 2020), are specific to Ukraine.

On the one hand, the track gauge of its network is 1,520mm (millimetres), as in Russia and Moldova, whereas the European gauge is 1,435mm (Lamming, 2020). On the other hand, the load gauge of a train in Ukraine is larger than that in Europe, as explained by Gravisse (2022). The Ukrainian gauge follows the ex-Soviet train gauge shown in the comparison table below (Table 1: Comparison of gauge) (Gravisse, 2022). So, a Ukrainian train cannot therefore travel safely on European railways.

	Height (m)(metres)	**Width (m)**
Ex Soviet	5,3	3,4
Europe	4,28	3,15

Table 1: Comparison of load gauge

Finally, it is important to take a look at Ukraine's river systems. Ukraine is crossed by a number of different waterways, including the Dniestr, the southern Boug, the Danube and the Dnieper which can be seen on the map below (Figure 3: Ukraine Inland Waterway). The analysis will be focused on the two main ones, the Danube and the Dnieper as shown on Figure 5 (Figure 5: Danube and Dnieper in Ukraine)

Figure 3: Ukraine Inland Waterway

Source : https://fr.wikipedia.org/wiki/Géographie_de_l%27Ukraine

First of all, Ougartchinska (2000) reports that the Danube, which is 2850 kilometres long, rises in Germany in the Black Forest. It then flows through Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria and Romania before ending its course in the Black Sea. The Danube delta forms the border between Ukraine and Romania, stretching for around 140 kilometres (Eckert, 2018). It includes the ports of Reni and Izmail, which are the main ports on the Danube in Ukraine, as stated on the Danube Commission website.

Boats ranging from CEMT (European Conference of Transport Ministers) class V to CEMT class VII can navigate on the Danube, as shown on the map on the Euris website (details of the CEMT classes can be found in appendix (Appendix A: CEMT List). Navigation on the Danube is not possible when the water level is low and when it is too high, as waves could damage infrastructure and large vessels could have difficulty passing under bridges (Scholten & Al., 2016).

Figure 4: Barge class map

Source: https://www.eurisportal.eu/reseau/ouvrages

Then, the Dnieper, 2200 kilometers long, which rises on the Valdai plateau in Russia (Larousse online, 2023). It continues its course in Belarus and crosses Ukraine, from north to south, before flowing into the Black Sea (Carrière, 2017).

Navigation on the Dnieper is possible from the beginning of March until December, as the Dnieper is icebound at that time of the year (Carrière, 2017).

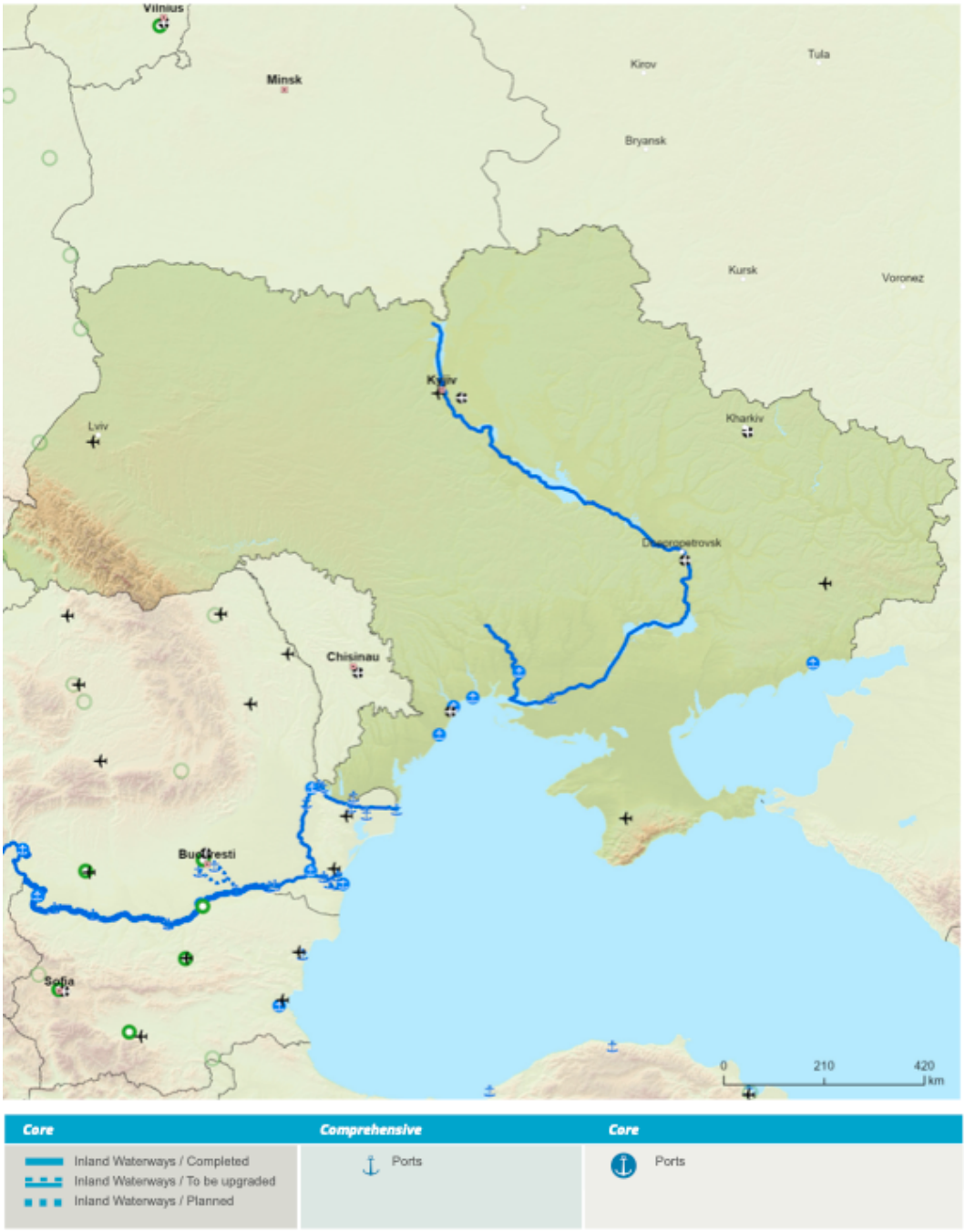

Figure 5: Danube and Dniepr in Ukraine

Source : https://transport.ec.europa.eu/system/files/2022-06/Indicative%20Maps%20Ukraine%202022_04_06.pdf

4. Data Collected

The aim of this section is to provide some figures on the various ports that will be discussed in this report.

4.1 Port of Thessaloniki

The port of Thessaloniki, located in the Aegean Sea basin, is important to the economic activity of its region, as well as to Central and Eastern Europe, thanks to its connection to the TEN-T (Trans- European Transport Network). Although it is a passenger port, it is also a cargo port. There is container handling on the one hand, and general cargo handling on the other. General cargo includes solid bulk such as cereals, ore, coal, etc. The port is equipped with various storage facilities, including a 20,000-tonne silo. In 2022, the turnover of the port was €80,561,000 (ThPA S.A., 2023).
The MarineTraffic (2023) website informs us that the port of Thessaloniki is a large-sized port, as it can accommodate ships 335 metres long, with a draught of 15.7 metres and a maximum weight of 165209 tonnes.

4.2 Port of Koper

The port of Koper, located on the Adriatic Sea, is Slovenia's only seaport (Beyer & Al, 2008). Like the port of Thessaloniki, it is connected to the TEN-T. It has 12 different terminals, including a container terminal, a Ro-Ro (roll on/ roll off) terminal and a silo terminal. The latter handles various types of cereals and fodder. It has a silo storage capacity of 60,000 tonnes and a flat has a storage capacity of 55,000 tonnes (Lula Koper, 2023).
The largest vessel to ever enter the port was 366 metres long. The maximum draught is 15 metres, and the deadweight is 18,2820 tonnes, as stated on the MarineTraffic website.

4.3 Port of Reni & Izmail

The ports of Reni and Izmail are Ukrainian ports located on the Danube delta. They are both medium-sized ports, according to the MarineTraffic website. They both have access to the Black Sea and are connected to the railroad network.

The port of Izmail has the infrastructure needed to handle cereals. The monthly grain transshipment volume is 43Ktons (Kilotonnes) (Danube Commission, 2022). According to MarineTraffic, the maximum size of ship that can enter the port is 330 metres, with a draught of 7.1 metres and a deadweight of 24,306 tonnes.

The port of Reni also has the infrastructures for the transshipment of grain. The port is capable of handling 560.9Ktons of grain each month (Danube Commission, 2022). As far as the dimensions of ships entering the port of Reni are concerned, the current maximum length is 289 metres, with a maximum draught of 7 metres and a deadweight of 26,467 tonnes.

4.4 Port of Rotterdam

The port of Rotterdam is located on the North Sea. It is accessible by train, road, river. It is Europe's leading port, ahead of Antwerp and Hamburg (Barday, 2022). In 2022 its revenue was €825.7 million. The port of Rotterdam offers infrastructure and equipment for the storage and transshipment of cereals, soya beans and corn. In 2021, 468 700 000 tonnes of goods transited through the port of Rotterdam (Port of Rotterdam, 2022).
The largest ship to enter the port was 340 metres long. The maximum draught is 17.3 metres, and the maximum deadweight is 32,300 tonnes (MarineTraffic, 2023).

4.5 Port of Gdansk

The port of Gdansk is Poland's largest port on the Baltic Sea. It has river and rail connections. It also has 7 terminals, one of which handles cereals, as stated on the Eurisles website (2022), and has infrastructure for storing cereals.
With regard to the dimensions of the ships that come to the port of Gdansk, they can be up to 400 metres long with a draught of 15 metres and a deadweight of up to 319,000 tonnes.

5. Analysis

Before starting the study of the different scenarios, we assume that goods are easily transported within Ukraine, and should therefore not be taken into account in the study.

5.1 Rail

In order to draw up the rail export scenarios, the map (Figure 6: TEN-T map) which represents the European rail network to TEN-T standards will be used. The criteria for this standard are set out by Mathieu Grosch (2022): "Electrification", "Line speed ≥ 100 kilometers per hours (km/h)" (freight), "Axle load ≥ 22.5 tonnes" and "Track gauge = 1,435 millimetres (mm)".

The TEN-T corridors were created by Europe in order to bring together all the industrial basins as the rail network is not unified and it is not possible to imagine that it will ever be. (de Kemmeter, 2022).

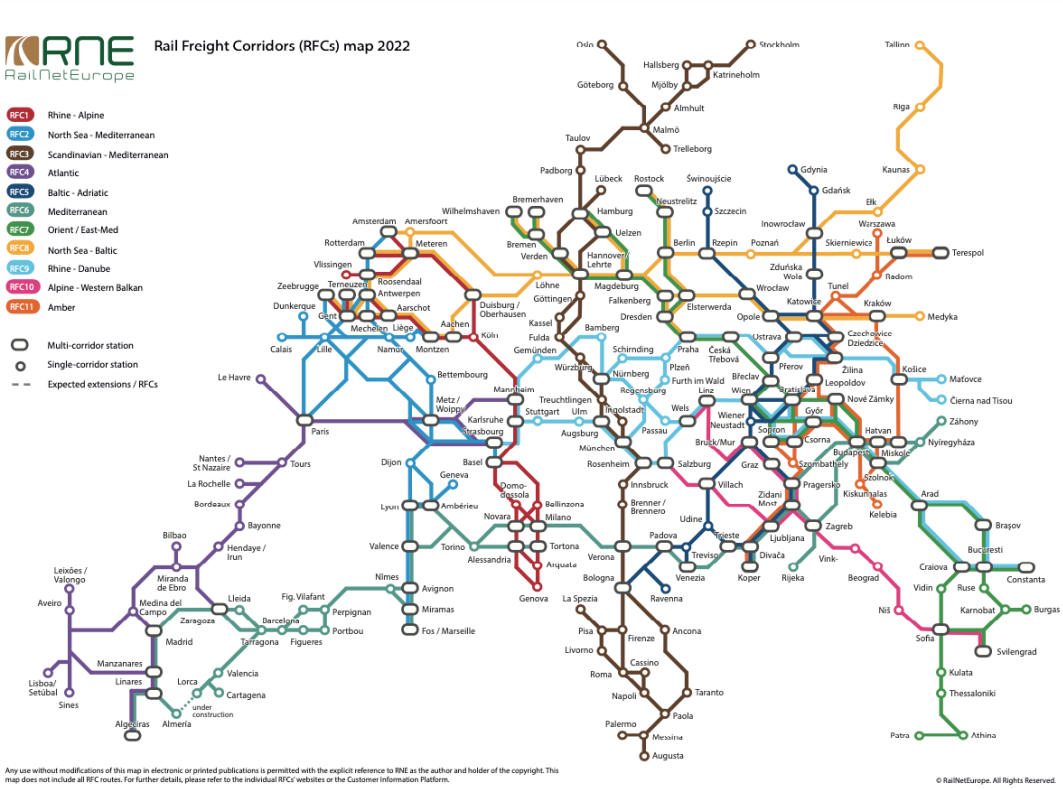

Figure 6 : TEN-T map

Source : Rail Net Europe. RFC Network Map.

https://rne.eu/wp-content/uploads/2022/12/2022_RNE_RFC_Map_A0.pdf

Scenario 1: Ukraine – Greece

The aim of this first scenario is to reach the Mediterranean via Greece. Greece's rail network is underdeveloped, with only 2,240 km of tracks in 2019 (Lamming, 2019). However, as can be seen on the map of the TEN-T network (Figure 6: TEN-T map), European rail freight corridors link three Greek ports, namely Piraeus, Thessaloniki and Patras.

The port of Piraeus is the largest port in Greece and has a strategic position. However, an analysis of the terminals available in the port of Piraeus reveals that there is no grain terminal ("Piraeus Port", 2023). The same applies to the small port of Patras. ("Patras Port", 2023).

For these reasons, it is more interesting to focus the port of Thessaloniki. This is the second largest port in Greece after Piraeus (Vanidis, 2008) and the main commodities handled there are grain, iron, tin, rice, tobacco, ore, fertiliser timber, cement, chemicals, crude oil and refined products ("Thessaloniki (Greece)", 2023). The port of Thessaloniki has a grain terminal, as shown in the figure below (Figure 7: Thessaloniki Terminals).

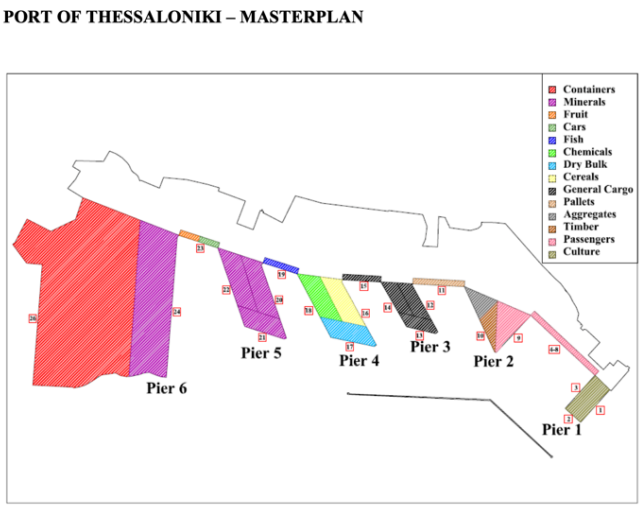

Figure 7 : Thessalonique Terminals.

Source : http://resolver.tudelft.nl/uuid:ef97dcda-07cf-4af7-a930-598e06f36267

To get from Ukraine to the port of Thessaloniki in Greece, the Orient/East-Med (OEM) corridor will be used, which can be joined in Bucharest in Romania.

To complete this journey, it is first necessary to go to Galati station in Romania via Guirguilesti in Moldova, as Moldova has the same track gauge as Ukraine. Between Guirguilesti and Galati, as can be seen in Figure 2 (Figure 2: Ukraine and Moldova Railway Network), there is an old disused Soviet gauge line (1520mm) that Romania wanted to refurbish. In April 2022, Romania started the process of rehabilitating this line, with work scheduled to last 2 months (Sauvage, 2022).

At Galati, the change of track gauge implies a change of train. Goods then need to be transferred from 1520mm gauge trains to 1435mm gauge trains. It will also be compulsory to switch from a diesel locomotive to an electric one, as we're moving from a non-electrified track to an electrified one.

Then, the towns of Faurei, Buzau and Ploiesti are crossed to reach Bucharest (Figure 9: Romania Rail Network). Once in Bucharest, we continue on the OEM corridor, which offers us a connection to Thessaloniki (Figure 6: TEN-T map).

As far as the Orient/East-Med corridor is concerned, it can be noted that a large part of the route is non-compliant. As a reminder, the TEN-T criteria are as follows: "Electrification", "Line speed ≥ 100 km/h" (freight), "Axle load ≥ 22.5 tonnes" and "Track gauge = 1,435 mm").

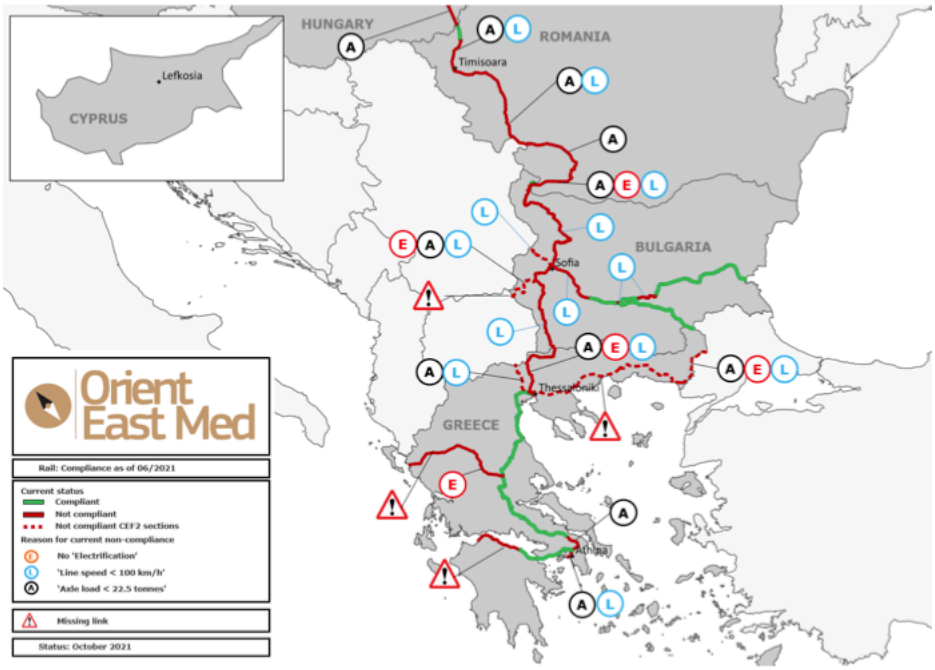

Figure 8: Rail Compliance South OEM

Source : https://transport.ec.europa.eu/system/files/2022-09/oem_wp_v.pdf

Firstly, in Romania, the route between Bucharest and Craoiva is not compliant with the TEN-T requirements because it does not meet the 100km/h speed criterion (Grosch, 2022).

Secondly, the passage from Craoiva in Romania to Vidin in Bulgaria does not comply with any of the TEN-T criteria, as can be seen on the compliance map (Figure 8: Rail Compliance South OEM). Furthermore, on this map, we can also observe that the entire route in Bulgaria is not compliant. The main problem is once again the speed limit.

Finally, the route in Greece is also not compliant as it does not meet any of the TEN-T criteria.

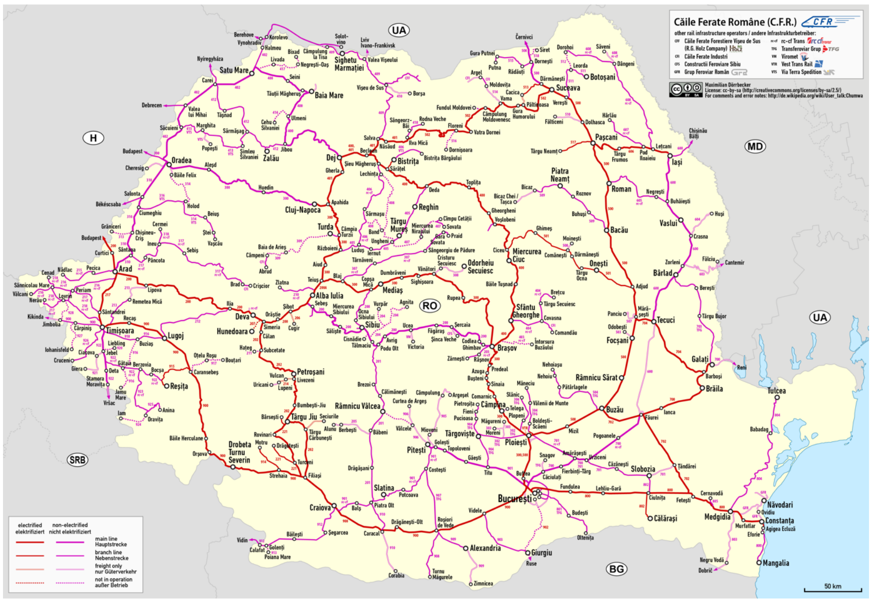

Figure 9: Romania Railway Map

Source: https://upload.wikimedia.org/wikipedia/commons/4/46/Railway_map_of_Romania.png

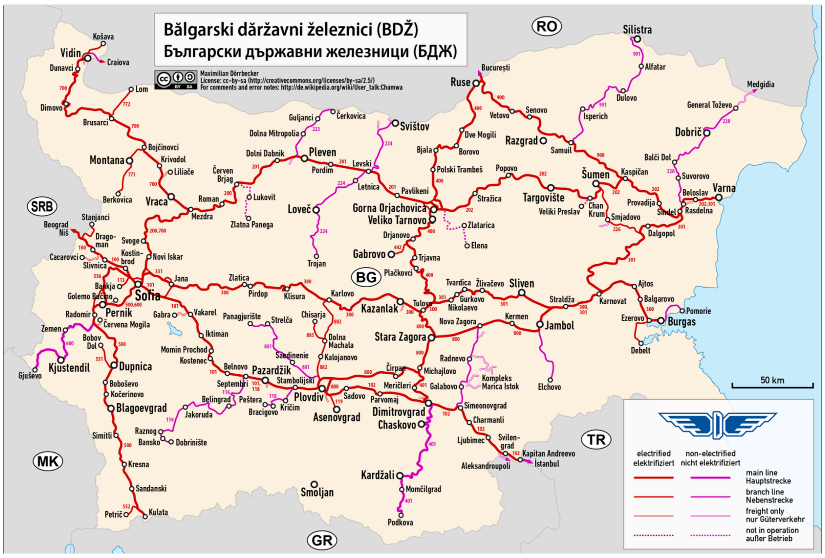

Figure 10: Bulgaria Railway map

Source:

https://en.wikipedia.org/wiki/List_of_railway_lines_in_Bulgaria#/media/File:Railway_map_of_Bulgaria.png

Figure 11: Greece Railway map

Source : https://fr.wikipedia.org/wiki/Transport_ferroviaire_en_Grèce#/media/Fichier:Railway_map_of_Greece.png

This route from Ukraine to Greece has an interesting advantage. We arrive directly in the Mediterranean Sea without having to cross the Bosphorus Strait, which is a bottleneck. However, there are several problems along the way. The biggest is at Galati, where we have to change trains because of the track gauge. The next challenge is that it is required to change locomotives 3 times. The change of locomotive is favoured for ecological and economic reasons. And finally, it will not be possible to load the wagons to their maximum capacity over a large part of the route, nor to travel at 100km/h.

In the future, using this track will require major investments. Firstly, they would need to bring the OEM corridor up to standard. The map below shows the 2030 project for this corridor (Figure 12: Overview of Rail compliance by 2030 - OEM South). Secondly, they would also need to develop infrastructure and storage capacity at the grain terminals in Thessaloniki.

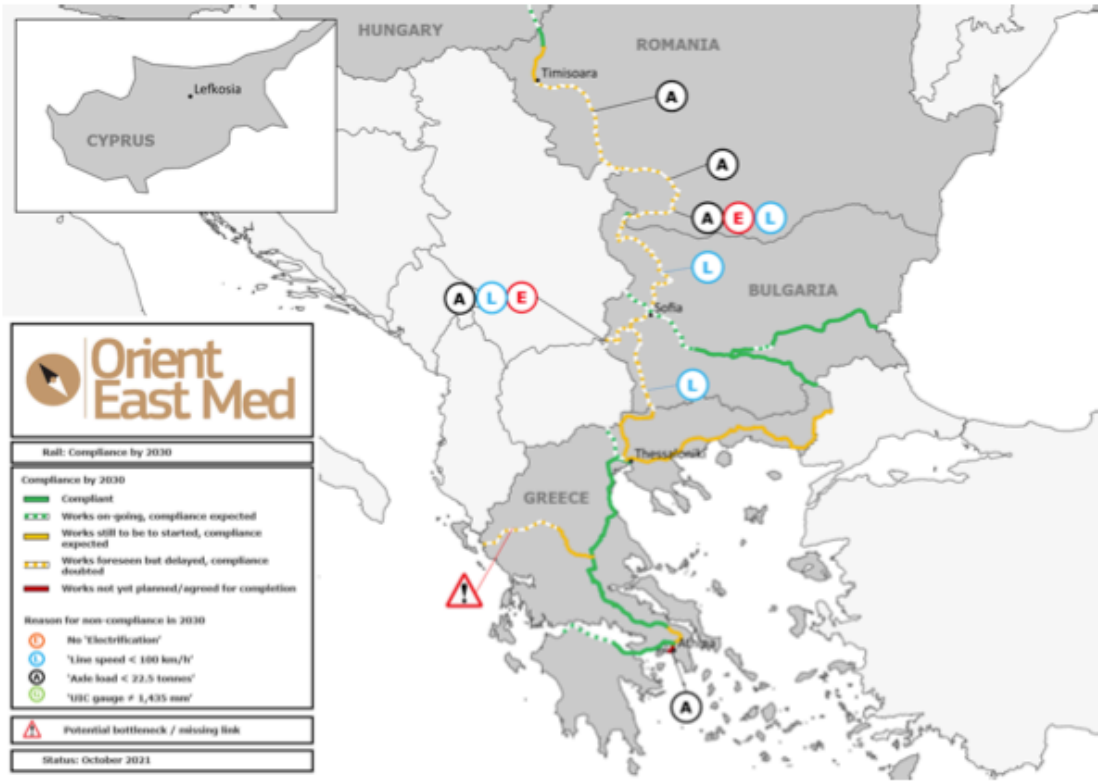

Figure 12: Overview of Rail compliance by 2030 – OEM South

Source: https://transport.ec.europa.eu/system/files/2022-09/oem_wp_v.pdf

Scenario 2: Ukraine – Slovenia

This second scenario by train aims to reach the port of Koper in Slovenia from the town of Tchop in Ukraine. The port of Koper is Slovenia's only seaport. It is dynamic and active in agricultural product traffic (Beyer & Al, 2008).

To get to the port of Koper by rail, we will follow another rail freight corridor, the Mediterranean. As it can be seen on the map of European corridors (Figure 6: TEN-T network), the Mediterranean corridor runs from Hungary through Slovenia to Spain.

The route starts in Ukraine at the Tchop station, which is equipped with infrastructure for changing bogies (de Kemmeter, 2022). As mentioned above, the track gauge in Ukraine is not the same as in other European countries. According to Dreyfus (n.d.), bogies are "*carriages on which the chassis of a wagon pivots to enable it to negotiate curves*". This feature, which is an advantage in this case, makes it possible to run a train on a new gauge without unloading it. In addition, changing bogies only takes around two hours (de Kemmeter, 2022). So, it takes less time than transferring goods from one train to another.

After the bogie change, the map below (Figure 14: Hungarian Railway) shows that the town of Zahony in Hungary can be reached directly, but this railway line is not electrified. Once in Zahony, we are on the Mediterranean corridor, which runs directly to Koper in Slovenia.

Figure 13: Bogie Exchange.

Source : https://academic-accelerator.com/encyclopedia/bogie-exchange

Figure 14: Hungarian Railway

Source: https://www.railwaygazette.com/maps-and-data/hungary-country-map/53990.article

Figure 15: Slovenia Railway map

Source: https://commons.wikimedia.org/wiki/File:Railway_map_of_Slovenia.png

With regard to the Mediterranean corridor, we can see from the map in Figure 16 (Figure 16: Rail compliance - Mediterranean corridor) shows that here too part of the route taken is non-compliant too. Although the entire route is electrified, the problems encountered are speed limits and loads of less than 22.5 tonnes per axle. In fact, the European Commission's document (2022) states that Hungary has the most problems, with only 27% of the route in Hungary permitting loads of 22.5 tonnes, and 67% of the route permitting trains 740m long. Slovenia, on the other hand, is only blocked by speed limits. Only 41% of the route indeed allows a speed of 100km/h. By 2030, 100% of the rail on the route should be compliant (Figure 17: Overview of Rail compliance by 2030 - Mediterranean corridor).

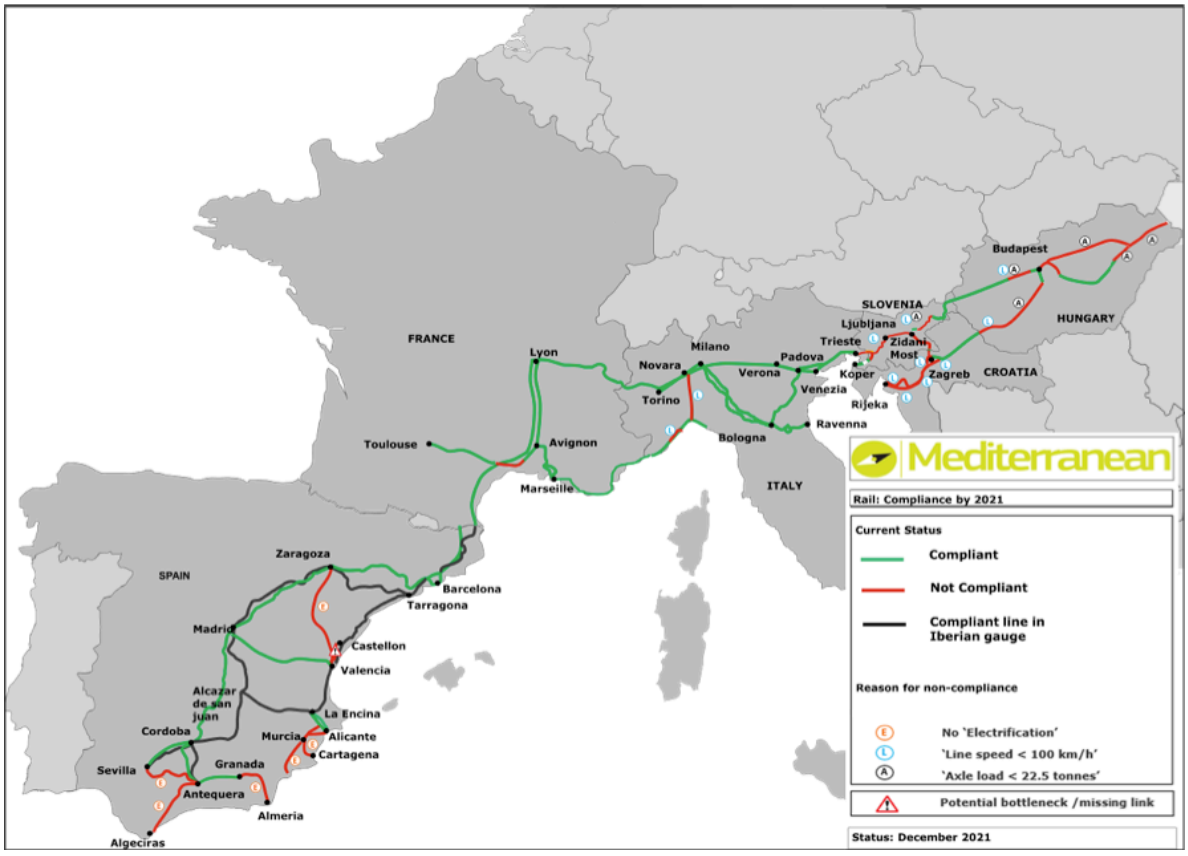

Figure 16 : Rail compliance - Mediterranean corridor

Source : https://transport.ec.europa.eu/system/files/2022-10/5th_workplan_med.pdf

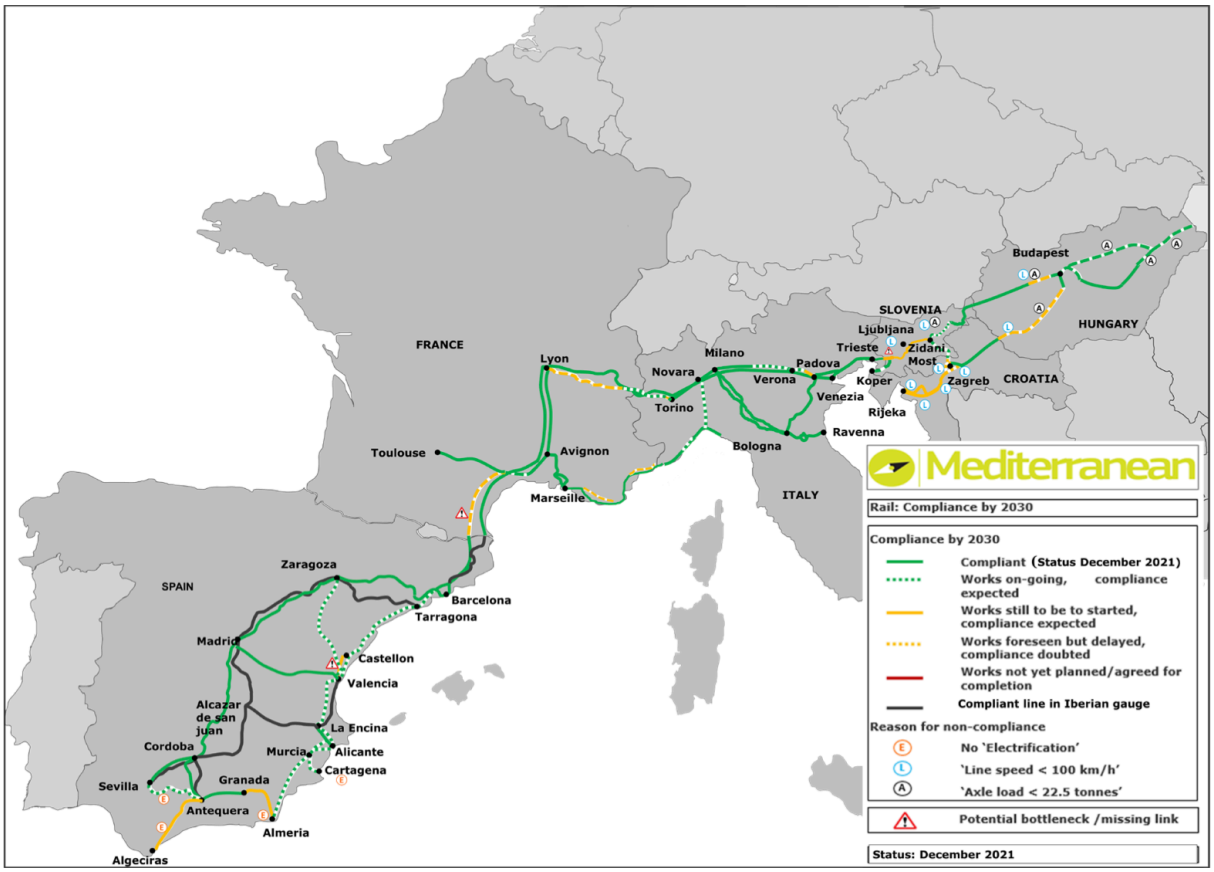

Figure 17: Overview of Rail compliance by 2030 - Mediterranean corridor

Source : https://transport.ec.europa.eu/system/files/2022-10/5th_workplan_med.pdf

This route has its advantages, as it goes directly in the Mediterranean Sea, and the port of Koper is very active in grain traffic.

However, we are limited by the weight of the load and by the maximum speed. In addition, it is necessary to plan for a change of locomotive between the Tchop station in Ukraine and Zahony in Hungary.

5.2 Inland Waterway

Scenario 3: Ukraine – Netherlands

This first scenario, by river, will take us to the Netherlands. The Netherlands has well-developed ports which have enabled the country to become the second largest exporter of foodstuffs (Lyddon, 2021). We are going to the port of Rotterdam, as it is easier to reach by river and has a lot of development potential (Huin, 2023).

Reading the map (Figure 4: Barge class map) on the Euris website, the following route can be imagined. The barges are loaded with wheat in the ports of Reni or Izmail, which are Ukrainian ports on the Danube. At Kelhiem in Germany, they take the Main-Danube canal. Arriving at Bischberg, they sail on the Main and then continue on the Rhine past the town of Mainz. Once they cross the Dutch border, they transport the wheat on the Waal. After the Waal, they sail successively on the Boven-Merwede, on the Noord, and finally on the Nieuwe Maas, which has easy access to the accommodations of the port of Rotterdam.

From the boat class map (Figure 4: Barge Class Map) we can see that the journey between the ports of Reni and Izmail and Romania can be made with a class VII boat (details of the classes can be found in the appendix A). However, from Beogradski in Serbia class VI barges need to be used, with a section in Germany, between Regensburg and Frankfurt, where class V barges are opted for.
Therefore, there are two options. Either we join Rotterdam using class V barges to avoid a change of barge in Germany. Or we use class VI barges with the idea of exporting the wheat along the route before arriving in Regensburg in Germany.

As it can be seen on the map of the European Inland Waterway (Figure 18: European Inland Waterway map), the problem with this reduction in class in Regensburg does not come from the draught and air draught but from the number of locks present on this section.

Figure 18: European Inland Waterway map

Source: https://unece.org/DAM/trans/main/sc3/AGN_map_2018.pdf

This route offers a number of advantages. The importance of the port of Rotterdam means that it can handle some of the Ukrainian wheat. In fact, it is already active in the wheat trade and there is scope for further development (Huin, 2023). What's more, this route is already operational and does not require any major investment.
Nevertheless, it is a slow network that doesn't allow cereals to be exported quickly, although wheat keeps very well.

Scenario 4: Ukraine – Poland

In this scenario, the barges sail on the Dnieper in Ukraine to the Polish ports on the Baltic Sea. Two Polish ports stand out and there are Gdynia and Gdansk.
The port of Gdynia is the most interesting, as it is larger for shippers of grain and feed (Sounds of Change, 2019). However, there are no inland waterways (Jerzylo & Al, 2018), so we will choose to reach the port of Gdansk. To reach that port, the barges will follow the E40 route shown on the map below (Figure 19: E40 Map).

Figure 19 : E40 Map

Source : https://euromaidanpress.com/2020/05/15/the-e40-waterway-economic-and-geopolitical-implications-for-ukraine-and-the-wider-region/?fbclid=IwAR0ec0hyY-Xh_TkvNpbR2MW15TGIwiw1w5P1gLlxJowM-9Z-leKACJPTDag&__cf_chl_tk=tOFg0nVxsQE2_9U6R4cy8SiP6jVDtHZxw1iZs.S0QTc-1686925752-0-gaNycGzNDdA

Sailing starts at any port on the Dnieper in Ukraine. It continues on the Pripyat in Belarus. At the Polish border, the barges sail on the Bug and then on the Vistula, which flows into the Baltic Sea near the port of Gdansk.
At the moment, this route is only a project, but it is known that most of the route is navigable in Ukraine (Hurska, 2020). However, as shown on the map in Figure 18 (Figure 18: European Inland Waterway map), the Bug is not accessible to boats above class I because of the shallow draught. Nevertheless, there is no information about navigation on the Pripyat and the Vistula, apart from the authorised draught.
Unece (United Nation Economic Commission for Europe) informs that development work is underway on this project.

The major advantage of this project is that the route directly starts from the center of Ukraine, in the regions where the wheat is produced, where it can be easily transported to the Dnieper.
However, the wheat would have to be exported to the Baltic Sea countries, which do not currently import Ukrainian wheat. Moreover, not all of the route is accessible by cargo barges. Above all, it is important to bear in mind that the war is still going on. Which can cause problems. For example, on 6 June 2023, there was an explosion at the Kakhovka dam, which lowered the water level in the Dnieper, making it difficult to navigate (Hajdari, 2023).
This route will not be further analysed in this for a number of reasons. It is not interesting from the point of view of exports to the Baltic Sea. In addition to that, the network is currently impassable.

5.3 Black Sea Grain Initiative

On 22 July 2022, an agreement was signed between Ukraine, Russia, Turkey and the United Nation to open a security corridor on the Black Sea to allow wheat to be exported from Ukraine. In exchange, Russia has obtained commitments to facilitate food and fertiliser exports, despite the sanctions imposed on Russia by Western countries (Azemard, 2022).
This agreement was valid for 120 days, automatically extended at the end of the period (Rashevska, 2023).

Since August 2022, 655,000 tonnes of wheat have left the ports of Chornomorsk, Odesa and Pivdennyi, mainly bound for developing countries. (European Council, 2023).
Although this agreement allowed wheat to leave Ukraine, the number of ships leaving the ports has been lower than before the war, as we can see from the UNCTAD (United Nations Conference on Trade and Development) website and the following graph (Figure 16: Number of departures of all cargo ships by week).

Figure 20: Number of departures of all cargo ships by week

Source: UNCTAD: https://unctad.org/press-material/black-sea-grain-initiative-offers-hope-shows-power-trade

The limits of this agreement are numerous. Firstly, Deiss (2023) says that Russia is limiting ship inspections in order to renegotiate certain restrictions that were imposed by the United Nations. Secondly, there is also a constant threat from Russia to leave the agreement. On several occasions, Russia announced that it would withdraw from the agreement. As example, on 29 October it was because Russia accused Ukraine of a drone attack, as we read in 'Le Point' (2022) writing by AFP, while on 4 July 2023 it was simply because there was no reason to extend the agreement, as Agence Belga (2024) states in RTL Info. Each time, it is the uncertainty hanging over Black Sea cargo traffic that unsettles the agreement. It is important to keep in mind that this agreement was signed between two countries in conflict. In addition, we should add that the price of insurance for ships in the Black Sea has risen, as the Euriles site informs (2022).

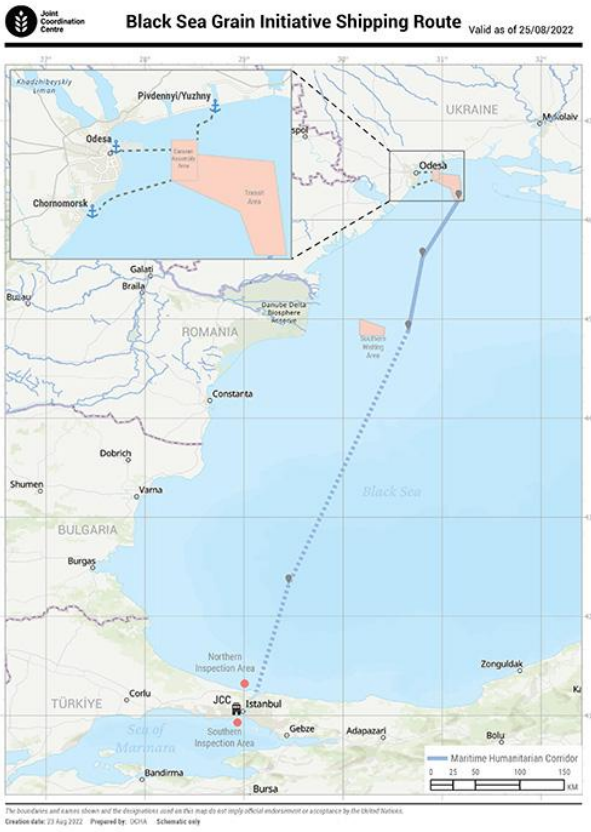

Figure 21: BSGI Shipping Route

Source: United Nation: https://www.un.org/en/black-sea-grain-initiative/resources

5.4 Volume analysis

Rail

To export cereals by train, hopper wagons will be used as they are special wagons for transporting cereals, fertilisers, ore, coal and cement.
The On-Rail (2023) website gives details of the different sizes of hopper wagons and their payload of each.

In order to study export volumes by rail, we will first make an initial assumption: the route taken complies with European TEN-T criteria (length: 740 m, load: 22.5t (tonnes) /axle, 100km/h). So, with a train 740m long and a load of 22.5t per axle, it will be possible to load a minimum of 2,087,966 tonnes onto a train (27,200t per wagon) and a maximum of 4,431,527 tonnes onto a train (68 tonnes per wagon). To estimate export volumes, it can

be assumed that our train has priority on the route, which is not actually the case. It will have to fit into an existing flow.
As far as loading and unloading times are concerned, an interview with H. Thiébaut highlights that the output of a crane is 125 tonnes/hour and that loading and unloading wheat with a redler is 150 tonnes per hour.
There is no information on the equipment available in the key points of this scenario, it can be assumed that all loading and unloading is done using a crane.
If a crane has an output of 125t/hour, then it will take around 16 hours to load and unload a train of 2,087.966 tonnes to 35 hours for a train of 4,431.527 tonnes.

Ukraine – Greece

The distance between Ukraine and the port of Thessaloniki is 1134 kilometres. If we assume that the train can run at 100km/h from start to finish, it will take over 11 hours to get to Thessaloniki. However, loading and unloading times. For this route, 4 loading/unloading operations need to be completed due to train changes at Galati.
If we use trains of 2,087.966 tonnes with a loading time of 16 hours, we will be able to make around 8 journeys per month and therefore export 16,703 tonnes/month with one train.
If we use trains of 4,431.527 tonnes with a loading time of 35 hours, we will be able to make around 4 journeys per month and therefore export 17,726 tonnes/month with one train.

Ukraine – Slovenia

The distance between Ukraine and the port of Koper is 897 kilometres. Assuming that the train can travel with a speed of 100km/h, the journey takes around 9 hours. In this case, only one loading and unloading operation needs to be completed. With all this information, we can determine that a train of 2,087.966 tonne with a loading time of 16 hours will be able to perform around 14 journeys per month, and therefore export 29,231 tonnes per train per month.
If we opt for trains of 4,431.527 tonnes with a loading time of 35 hours, they will be able to performs around 8 journeys per month and therefore export 35,452 tonnes/month with one train.

Inland waterway

Ukraine – Netherlands

For exports by barge via the Danube, two options can be considered.
Either we go as far as Rotterdam, in which case type V barges need to be used, which can load between 1,500 and 3,000 tonnes, or we don't go as far as Rotterdam and export some of the cereals on the way, which means larger type VI barges will be used, which can load between 6,400 and 12,000 tonnes.
In the first case, the journey will take 312 hours 15 minutes, which was estimated using the Euris website. The loading and unloading time are estimated to last between 12 and 24 hours. It will therefore be possible to make one trip per month, exporting between 1,500t and 3,000t.
In the second case, the barges do not cover the entire route. We will therefore assume that they sail half the route and therefore half the time, i.e., 156 hours. In this case, the loading time is estimated to last between 51 and 96 hours. It will therefore be possible to complete two trips per month with a barge, representing between 6,400 tonnes and 12,000 tonnes.

5.6 Cost analysis

For the analysis of the cost, the report "*Réalisation d'une étude sur l'évaluation des coûts de la chaîne logistique céréalière française*" carried out by FranceAgriMer (2020) will be used as a basis.
This report details all the costs covering the transport of wheat from the field to the port. For their study, they contacted people in the industry and transport operators. On the basis of this information, here is an estimation of how much it would cost to use waterways and railways:

	River	**Rail**
Lower bound	€0,032 t/km	€0,049 t/km
Upper bound	€0,042 t/km	€0.055 t/km

Table 2 : Cost Table

It should be added that river networks are generally always cheaper. Furthermore, the study shows that the longer the train journey, the cheaper it is.
However, the data from this study needs to be qualified as the study was carried out in 2020, but, since then, there have been many fluctuations in fuel and energy costs.

Ukraine - Greece			
Bound	**Tonnes**	**Distance (km)**	**Cost**
Lower	2 087,96	1134	€ 115 516
	4 431,52	1134	€ 245 174
Upper	2 087,96	1134	€ 130 670
	4 431,52	1134	€ 277 336
Ukraine – Slovenia			
Bound	**Tonnes**	**Distance (km)**	**Cost**
Lower	2 087,96	897	€ 91 374
	4 431,52	897	€ 193 934
Upper	2 087,96	897	€ 103 360
	4 431,52	897	€ 219 374
Ukraine – Netherlands			
Bound	**Tonnes**	**Distance (km)**	**Cost**
Lower	1 500	3 307	€ 154 577
	3 000	3 307	€ 309 154
Upper	1 500	3 307	€ 206 739
	3 000	3 307	€ 413 478
Lower (Midway)	3 200	1 653	€ 167 210
	6 000	1 653	€ 313 519
Upper (Midway)	3 200	1 653	€ 220 522
	6 000	1 653	€ 413 478

Table 3: Cost per volume per alternative

6. Conclusion

The aim of this report was therefore to study the various possible ways of exporting Ukrainian grain, mainly to North African countries. After analysing the different scenarios, export volumes and costs, it is possible to draw some significant conclusions.

6.1 Managerial and Theoretical findings

The first solution considered in this report is the Ukraine-Greece route. It is the shortest by ship to get to the importing countries of the Middle East, and has a well-equipped port, namely Thessaloniki, but will, on the one hand, face some difficulties before the European rail network is brought into line by 2030, and, on the other, will face significant bottleneck at Galati with the change in rail gauge. Concerning the cost for this route, they vary between €115 516,77 and €277 336,59 for a load of between 2087,96 and 4431,52 tonnes.

The second solution investigated in the study is the Ukraine-Slovenia alternative. The route is shorter by train, around 897 kilometers, but is also waiting for its route to be brought into line with TEN-T standards.
It is clear that connecting Ukraine to Europe by train will automatically involve a change of equipment due to the change in rail gauge. Using the Tchop route will avoid the need for transshipment, saving time compared with the alternative via Greece, because we just change the bogie instead of transferring goods from one train to another. On top of that, the journey to Slovenia is the cheapest in terms of train travel costs. Export costs vary from €91,374.37 to €219,374.71 for exports of between 2087.966 and 4431.527 tonnes.

For the inland waterway solution on the Danube, we will either be using class V barges to Rotterdam, or we will be leaving with big boats. However, it will be necessary to unload at the town of Regensburg in order to reload on the class V barges unless, as proposed in the second solution, class VII barges are used with the idea of exporting the wheat to the countries located between Romania and Germany.
Nevertheless, this idea is irrelevant for several reasons. Firstly, the countries of Central Europe are not importers of Ukrainian wheat, and the arrival of Ukrainian wheat on their territory would disrupt the whole market. Secondly, we are moving away from the objective of exporting to North African countries, which is the main objective in order to avoid a food crisis.

The port of Rotterdam is a well-developed port capable of handling Ukrainian cereals, but we have to bear in mind that once we arrive in Rotterdam, we still to complete the journey to reach the countries of North Africa. This journey is much longer than the sea journey of the two rail alternatives. In fact, the two rail alternatives arrive directly at the Mediterranean Sea, whereas with the inland waterway alternative arrives at the North Sea.

The last solution that is considered, which is the route Ukraine – Poland leads to a port on the Baltic Sea, far from North Africa, and leads to a region already supplied with wheat. In addition, navigation remains uncertain on the Dnieper and the barges need to be limited in size. This route is thus not feasible.

It is for all the reasons mentioned above that the alternative of joining Slovenia is the most interesting. That is to say, changing bogies at Chop station saves a considerable amount of time compared with changing at Galati, which requires goods to be transferred from one train to another. What's more, as the train journey from Ukraine to Slovenia is shorter, rail transport costs are lower. Finally, Slovenia has access to the Mediterranean Sea, which brings us closer to our goal of exporting wheat to North African countries.

6.2 Critique

It is difficult to draw a definitive conclusion. Although Slovenia's solution is the most favourable, the conflict is still ongoing and involves many actors, so any of the alternatives proposed could be affected at any time.
In addition, these different alternatives will take time and money to implement. Before the war, Ukraine based its trade essentially on its Black Sea ports and had not developed its transport infrastructure, such as rail and inland waterways.

6.3 Further work

After carrying out my study, several questions remain unanswered.
What about the return journeys? In rail transport, the most expensive part is usually the empty return journeys. In order to make the most of the chosen alternative, what are the possibilities for return journeys?
Furthermore, this new traffic will have to be integrated into existing traffic. What is the current occupancy rate on the route and what new traffic can be integrated?

Finally, how will these new export routes influence wheat markets? We know that Poland has limited exports of Ukrainian wheat, as this has had a negative impact on the price of wheat in Poland. What about the other countries concerned by the solutions presented?

To answer these questions, we first need more literature and information on infrastructures and their occupancy, so that we can integrate our alternatives into existing traffic.
In addition, a more in-depth field study is needed to investigate the possibility of return journeys.
Finally, in order to avoid deregulation of the wheat market in the countries crossed by the different scenarios, we need to think about the rules to be implemented in this context.

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