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The South Caucasian Transport Corridor: A new Eurasian Transport Option

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Introduction

This paper highlights the transformative potential of the New Eurasian Landbridge initiative and answers several questions regarding possible strategic endeavour that can bolster transcontinental infrastructure, enhance trade dynamics, and foster cultural exchange between Europe and China. It is a known fact that the geopolitical landscape of Eurasia has undergone significant transformations in recent years that positions the region at the heart of global trade and economic development [1]. Central to this evolution is the New Eurasian Landbridge initiative, a strategic endeavour aimed at bolstering transcontinental infrastructure, enhancing trade dynamics, and fostering cultural exchange between nations involve [2].

The classical concept of the Eurasian Landbridge placed Russia in the centre of the transcontinental transport links with a focus on the railway system, especially the Transsib railway, from China via Mongolia or Kazakhstan to Moscow and further towards Europe. This concept developed during the last 30 years and regular logistics links were established that needed about two weeks to transport goods between Europe and China [3]. A central role in Europe was taken by the Duisburg in Germany representing one of the biggest inland container ports in the world. Even though the transported cargo volume had never exceeded 1% of the total cargo volume between Europe and the Far East, the success of this version of the Eurasian Landbridge was very promising to the extent that many logistical side concepts and extensions were developed and implemented to strengthen connectivity and accessibility and to improve the service quality of the transcontinental transport system.

These Russia-centred activities ended with the start of the Ukraine-Russian war in 2022 and the geopolitical turbulences around the crisis. Now, the short way through Russia, Belarus and Ukraine was blocked and new ideas had to be developed. One new approach puts the Caspian Sea and the Black Sea in the centre of the New Eurasian Landbridge by try to find a new transport route around Russia. This new transcontinental transport link between China and Europe is now going from China via Kazakhstan, Caspian Sea, South Caucasus, Black Sea to European Black Sea countries and further to central Europe.

The railway link between China and Aktau, Kazakhstan especially, epitomizes this initiative’s vision, serving as a critical conduit in the New Silk Road framework [6]. This connection not only links China's Xinjiang region with Kazakhstan's Aktau port but also facilitates access to European markets, thereby promoting regional cooperation in Central Asia.

In their work, Dia et al. [7] described China's extensive and efficient railway network, which includes pivotal routes like the Longhai and Lanzhou-Xinjiang Railways, shows its indispensable role in global freight movement. However, the journey toward a possible seamless connectivity could be marred by logistical challenges, particularly at border crossings such as Alashankou/Dostyk, where differing track gauges and infrastructure inefficiencies pose significant hurdles. Addressing these challenges is imperative for realizing the full potential for a transcontinental link and is the reason why the latest proposals for a new "Central-Asia" Landbridge designed to bypass Russia, is crucial at this time. This is because this “new” landbridge has the potential to serve as a strategic solution that can enhance infrastructure, the incorporation of advanced technologies, and the diversification of trade routes that are essential to foster economic growth and regional development to create robust and efficient logistical networks.

The strategic importance of the Caspian Sea as reported by Zhekenov [8] comes into play here. The Caspian Sea, the world's largest inland water body, plays a pivotal role in connecting Asia and Europe, facilitating trade along the Trans-Caspian International Transport Route. Ports like Kazakhstan's Aktau and Azerbaijan's Baku/Alat are vital hubs in this network, because they link Central Asia with global markets. To unlock the Caspian Sea's full potential riddle with challenges such as limited port capacities, outdated infrastructure, and logistical bottlenecks despite the significant increased traffic

along the Middle Corridor due to geopolitical shifts in recent years, comprehensive infrastructure upgrades, regulatory improvements, and regional cooperation are crucial. These enhancements should be aimed towards streamlining cargo movement and optimizing efficiency, with the ambitious goal of significantly boosting trade volumes by 2030.

On another hand, as a crucial transit hub, the South Caucasus region, comprising Azerbaijan, Georgia, and Armenia, plays a critical role within the Eurasian transportation network that links Europe and Asia. There are reports i.e. [9, 10] of efforts by Azerbaijan and Georgia to modernize railways, roadways, and port facilities, notably through the Baku-Tbilisi-Kars (BTK) railway and the Middle Corridor, to substantially bolstered the region's role in global trade. Despite these advancements, political challenges, such as the closure of the Zangazur Corridor and regional instability, continue to impede the region's full potential [9]. Having a sustainable cooperation and investment are vital for enhancing connectivity, economic growth, and to maintain regional stability because the South Caucasus has a great potential to facilitate smoother cargo movement and attract substantial foreign investment that can leverage technological advancements and sustainable practices in the region.

Similarly, there are more opportunities for development of multimodal transport routes and integrating digital technologies. Although regional conflicts pose significant threats to maritime security and trade, the Black Sea is a strategically placed maritime corridor in this regard, connecting Europe and Asia. The security situation, influenced by geopolitical tensions such as Russia's annexation of Crimea and increased militarization especially, significantly affects maritime transport although various ferry routes still operate between key ports like Poti (Georgia), Constanta (Romania), and Batumi (Georgia), despite the disruptions from the conflicts. As whole, ports such as Varna, Constanta, Poti, and Batumi are crucial for this particular route and technological advancements, such as IoT, autonomous vessels, and green shipping initiatives, are crucial for to improve its operational efficiency and sustainability.

Still, Europe's heavy reliance on road transportation for hinterland services particularly for transportation corridor between Central Europe and the Black Sea faces rising costs, traffic, and environmental regulations, that makes multimodal solutions able to integrate rail and waterways increasingly essential. While the definition of hinterlands is continually evolving due to various factors such as cargo types, seasonality, business cycles, technological advancements, and transportation costs [11, 12]. According to these works, active measures that include the development of intermodal transportation options, infrastructure investments, and strategic alliances the measures will contribute to a more effective and resilient supply chain. As the strategies of shippers and logistics service providers are increasingly influenced by the dynamic nature of hinterlands, particularly regarding seaports and hinterland corridors, concerns about land scarcity and the reliability of transportation emphasises the importance of enhanced efficiency and connectivity in these areas.

Again, as the ongoing conflict between Russia and Ukraine has unfortunately disrupted traditional trade routes, Eurasian countries are prompted to explore alternative connections of routes that extend beyond mere logistics, but embodies a renaissance in Eurasian trade that promises economic growth, regional stability, and enhanced connectivity across continents. The intricate network of routes and corridors spanning Eurasia is vital for global trade that necessitates continual investment and cooperation to address existing challenges and to unlock possible potential.

Aforementioned, the Middle Corridor, stretching from Turkey through Central Asia and China via Georgia and Azerbaijan emerge as competitive alternatives to traditional routes through Russia. This new corridor offers a promising pathway for trade between China and Europe that is supported by the Trans-Caspian International Transport Route (TITR). Deliberate investments in ferries infrastructure on the Caspian Sea and expanded railway networks in Central Asia and the South Caucasus, will enhance the route's efficiency and reliability. Moreover, the strategic utilization of Turkey's developed

transportation networks and Black Sea ports will further strengthen this corridor, positioning it as a vital link in the Eurasian trade network.

The work advocates sustainable investment and cooperation to harness the full benefits of Eurasian region and serves as a comprehensive guide for stakeholders aiming to foster economic growth, enhance global trade, and ensure regional stability across the Eurasian continent. In terms of global trade enhancement, the studied opportunities are set to improve connectivity. By developing robust transcontinental infrastructure, the initiative significantly enhances connectivity between Asia and Europe, facilitating smoother and more efficient trade routes. The streamlined logistics and diversified routes suggested are expected to boost trade volumes, thereby contributing to global economic growth. Specifically, regional economic integration is fostered across Eurasian nations, encouraging investment and economic collaboration. The infrastructure projects and increased trade activities will generate employment opportunities and bolster local economies.

In terms of technological advancements, the authors promote modernized infrastructure and incorporating advanced technologies such as IoT, autonomous vehicles, and green shipping initiatives revolutionize logistics and transportation efficiency for sustainable practices that align with global climate goals. If Europe can reduce its over-dependence on traditional routes and develop alternative trade routes, reliance on geopolitically sensitive areas will decrease, improving global supply chain resilience. Lastly, the book emphasises importance of the Black Sea as a strategic maritime corridor especially in efforts to improve maritime security and efficiency.

These are all regulatory recommendations for policymakers and investors, guiding strategic investments in infrastructure to unlock the full potential of the Eurasian trade network and ensuring smoother cargo movement and logistical efficiency.

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Chapter One

1. Overcoming Logistical Hurdles to Enhance China-Europe Trade

1.1. The Belt and Road Initiative (BRI)

From the second century BCE to the eighteenth century, a large network of land and marine trade routes connected Europe, Asia, and Africa, promoting commercial and cultural interactions. One of such was the Belt and Road Initiative (BRI) dubbed as the New Silk Road in 2013. At the time, it was one of the largest infrastructure projects in history, highly financed by China, involving over US$900 billion in investments in port, gas, oil, and road infrastructure to connect the entire Eurasian continent and Africa [13]. Indeed, the BRI presents enormous and important trade routes for logistics and global trade.

China boasts a highly developed railway network spanning over 150,000 kilometres, with 40,000 kilometers dedicated to high-speed rail that has become the busiest globally for both freight and passenger transport. It moves 4,773 billion tons of freight in 2021and approximately 59% of these routes were double-tracked in 2019, where nearly 72% of them were electrified, using the standard gauge of 1,435mm [14]. This project has been highly successful, with over 140 countries participating in the Belt and Road Initiative (BRI) by 2024 [15].

The International Port Station, Xi'an Guojingang, located in the Xi'an International Trade and Logistics (ITL) Park, is central to containerized traffic. The park, spanning 120 square kilometres, is positioned near major roadways, the international airport, and the high-speed railway station [16]. With enhanced freight lines and facilities, the station supports extensive China-Europe train routes, boosting the efficiency of goods transport. The Longhai Line is another crucial railway segment running from Lianyungang to Lanzhou, covering 1,759 kilometers and is one of China's busiest lines, supporting both passenger and freight trains. Lanzhou, an industrial hub in Gansu Province, is connected by rail, road, and air. The city's major railway station, a key transportation hub, handles significant passenger and freight traffic, integrating several major railway lines [17].

The Jinghe-Khorgas Railway, operational since 2009, is a border-crossing railway at Altynkol-Khorgas that majorly transports goods between China and Kazakhstan via the Alashankou/Dostyk border crossing to the Port of Aktau, Kazakhstan [18]. This electrified line, presents the Khorgos Gateway as a Special Economic Zone, and a modern transshipment terminal that supports diverse cargo handling and utilizes advanced terminal operation systems [19].

This section of the new Silk Road from Xi'an, China to the Port of Aktau, Kazakhstan primarily relies on land transport, as water transport is not feasible. Xi'an, located on the Wei River, is not connected to major international seaports, and the Yellow River, despite its length, is unsuitable for shipping due to silt accumulation and fluctuating water levels [20]. The implications of these modal are explained as follows:

1.2. China-Aktau Transportation Modes

Rail Transport

Railways are a major mode of transport from China to Aktau due to their efficiency in carrying large volumes of freight over long distances. This is good because trains use less energy per ton compared to trucks and can be powered by electricity, potentially reducing CO2 emissions if renewable energy sources are used.

Road Transport

Trucks are also used especially following the Belt and Road Initiative. The "Western Europe-Western China Highway" allows for road transport from China to Europe through Kazakhstan, Russia, and Belarus to Poland, completing the route in about 13 days. Road transport offers flexibility in departure times, various cargo options (full and part truck loads), GPS tracking, and reduced waiting times. However, road transport is less efficient over long distances and contributes more to CO2 emissions. The route through Russia is faster but requires an international transport license and faces moderate road conditions in Kazakhstan and a ferry crossing of the Caspian Sea.

Overall, while road transport provides certain logistical advantages, rail transport is generally more efficient and environmentally friendly for long-distance freight movement from Xi'an to Aktau. In this regards, the Longhai Line, will be a crucial rail segment from Lianyungang to Lanzhou, and the Lanzhou-Xinjiang Railway (Lanxin Railway), extending to Ürümqi for China's freight movement. Lanzhou, an industrial hub, and key railway junction, connects several major lines, facilitating regional development [21]. Although, the Northern Xinjiang Railway and its extension to Alashankou improve connectivity in Northwestern China although transporting goods between China and Kazakhstan it faces challenges of differing track gauges at border crossings like Alashankou/Dostyk. These crossings are critical for the China-Europe trade route, require infrastructure improvements to reduce delays and enhance efficiency. Modernization efforts that include better sorting tracks and automated systems to streamline operations will be welcome development [22].

1.2.2. The New “Central-Asia” Landbridge

Modern technologies like blockchain, AI, and IoT are being explored to enhance supply chain security and logistics management. These technologies can improve transparency and efficiency, aligning infrastructure development with international sustainability goals, such as eco-friendly construction and green energy practices [23].

The initiative to create the "Central-Asia" Landbridge reflects a strategic response to shifting geopolitical dynamics, aiming to build a resilient and flexible trade network. By diversifying trade routes, the “Central-Asia" will likely foster economic growth and regional development that will ensure the steady flow of commerce in the complex global marketplace sustaining international commerce especially in the reduction of its reliance on politically sensitive areas.

The "Central-Asia" Landbridge would, however, require significant infrastructure development that includes port expansions in the Caspian and Black Seas, in all its rail and road networks, and in its border and customs procedures. As advanced intermodal facilities are crucial for smooth cargo transfers, maintaining the integrity of goods during transit would also require modern technologies like blockchain, AI, and IoT to enhance supply chain security and logistics management to align with international sustainability goals [24].

1.3. Border Crossings

1.3.1. The Alashankou/Dostyk Crossing

Transporting goods between China and Kazakhstan proves difficult due to differing track gauges this is because the Soviet Union adopted a wider track gauge to prevent enemies from using their tracks, resulting in a gauge difference at the border. For example, China's rail gauge is 1,435mm, the standard for Western European rail systems, while Kazakhstan uses the Russian gauge system of 1,524mm seen in Figure 1.1.

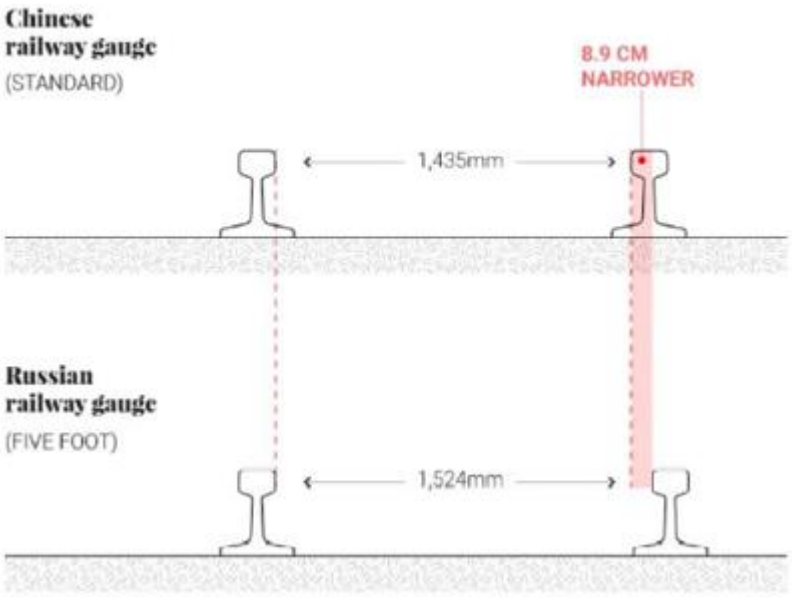

Figure 1.1. *One rail, two systems: the China's rail gauge.* Source: Adrianople Group, (2023) [25].

Therefore, at the border, all cargo must be reloaded onto wagons with a wider wheelbase, a laborious and cost-driving operation. The border crossings between Kazakhstan and China have the most developed infrastructure on this route, enabling multimodal operations; however, there are infrastructural limitations in terms of throughput between eastbound and westbound trains because the Alashankou/Dostyk border crossing has a capacity of 18 trains in each direction per day, which is fully used, making it a major bottleneck. This result to increase waiting times for transshipment that can be up to 60 hours due to the inadequate number of sorting tracks, particularly in Dostyk. Furthermore, the absence of a unified automated system for preliminary notification about the expected arrival time poses another significant challenge that necessitate a more efficient shunting locomotive management and that can address the shortage of locomotives [25].

In 2022, 6,211 China-Europe trains were handled at the Alashankou/Dostyk border crossing and by 3 November of the same year, 223.84 million tons of goods with a trade volume of 43.61 USD billion were transported through the inland port. This depicts the unique challenges being faces by the port regularly, particularly from exposure to strong winds that spans over 180 days a year. The ongoing modernization measures at the port have improved the situation, including the introduction of new indoor transhipment bays.

1.3.2. The Altynkol-Khorgas Crossing

The Khorgos Gateway Special Economic Zone is a newly established transhipment terminal shown in Figure 1.2. The dry port covers about 129.8 hectares, including logistics and industrial zones, with a capacity of 18,000 containers where three RMG gantry cranes operate to move containers between six different tracks. The zone also includes facilities for storage, production, textile manufacturing, chemical, and metal treatment. The dry port utilizes the modern N4-NAVIS-Terminal-Operation-Systems, making it better equipped than many seaports and can handle containers, motor vehicles, break bulk, and palletized cargo.

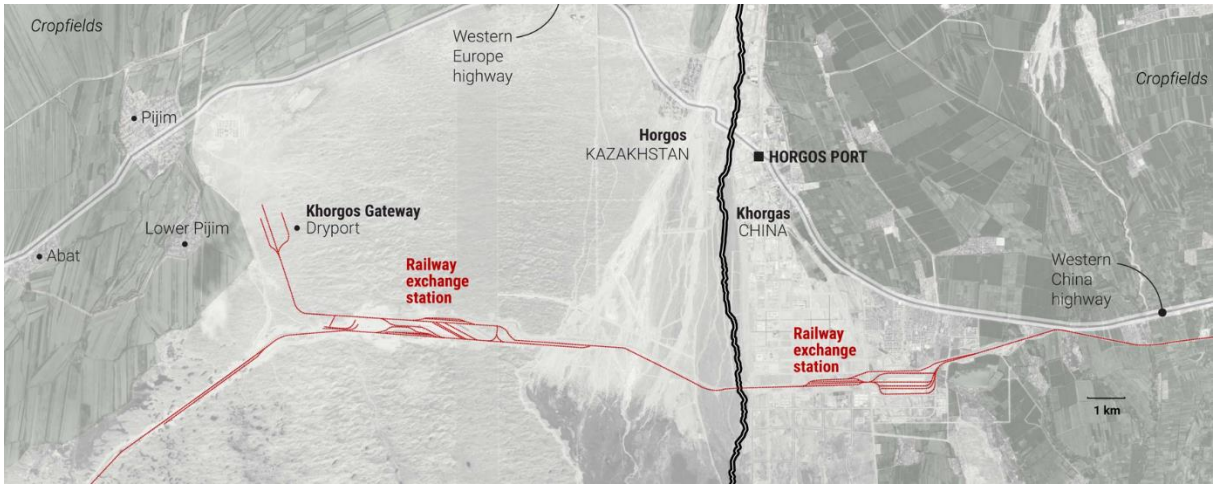

Figure 1.2: Railway exchange stations at the Khorgos Gateway Special Economic Zone
Source: Khissimova, (2021) [26].

Two railway exchange stations are located close to the border, one on each side, providing an initial exchange capability of around 15 million tons of freight per year, with the expectation of reaching 30 million tons of cargo in the future. Since the project began focusing on Chinese trains, over 12,000 complete train compositions have been deployed to 49 locations in 15 European nations, according to the People's Republic of China (PRC) Ministry of Commerce.

Altynkol/Khorgos has a capacity of 17 to 18 trains per day. A large array of overhead gantry cranes can transload all containers from one train to another in just 47 minutes. However, there are only two tracks in the transit park on the Chinese side, making it impossible for several trains to pass simultaneously and compared to Dostyk, the infrastructure at this crossing on the Kazakh side is better, but transit times are almost the same.

One significant challenge contributing to prolonged transit times is the absence of a marshalling yard at the station. Sorting operations are currently carried out in the reception and dispatch park on narrow-gauge tracks using pull-out tracks. This approach is less efficient compared to a dedicated marshalling yard. Inadequacy of reception and dispatch tracks further compounds transit time challenges and limited tracks for incoming and outgoing trains hinder the seamless flow of railway traffic, causing bottlenecks. Additionally, the insufficient availability of sidings for empty wagons has been quite challenging due to inefficient coordination of the movement and distribution of trains within the station that further contribute to idle time and delays in transit. More so, there are evidences of absence of electronic data interchange between stakeholders because the reliance on manual exchange of information that hampers coordination efforts and delays decision-making processes, affecting overall transit efficiency. These are many more affect the coordination and planning of rolling stock flow between the railways of China and Kazakhstan [26].

1.3.3. New Border Crossing and Railway Link

In 21 December 2023, Kazakhstan started the construction of a new railway line to China to connect the Bakhty border crossing with the city of Ayagoz over a distance of 272 kilometers. In this regards, the Bakhty-Chuguchak border crossing was intended to relieve the southern border crossings, enable more transit traffic, and increase the throughput capacity between Kazakhstan and China from 28 to an estimated 48 million tons. The double-track line is scheduled to be operational by 2027. The extensive construction program includes the building of 11 railway stations and 47 bridges [27].

1.4. Aktau

1.4.1. The Aktau Port Overview

Aktau Port, located south of the Mangyshlak Peninsula on the eastern coast of the Caspian Sea, is Kazakhstan's only ice-free port. This strategically significant port sits at the intersection of several international transportation corridors and primarily handles dry cargo, crude oil, and petroleum products, serving routes to and from Iran, Turkey, Russia, Turkmenistan, and Azerbaijan. The port features 11 berths, with four dedicated to oil products, and has an annual cargo handling capacity of up to 17.7 million tonnes. It also offers a 2,000 m² warehouse and 79,700 m² of outdoor storage space [27, 28].

1.4.2. Container Transshipment Growth

From 2019 to 2021, container transshipment at Aktau Port grew by an average of 38.9% annually, reaching 27,600 TEUs, of which 17,700 TEUs were along the Trans-Caspian International Transport Route (TITR). In 2022, 30,700 TEU containers were transported through Aktau Port, marking an 11.2% increase compared to 2021. The port currently has the capacity to ship up to 70,000 TEUs annually, with plans to upgrade handling equipment by 2025, which is expected to increase this capacity by 43% to 100,000 TEUs per year. Major port facilities include a ferry complex, oil terminal, grain terminal, dry bulk terminal, and multipurpose terminal [23].

The port's development is driven by container transportation, with volumes expected to reach 35,000 TEUs by year 2024. Additionally, Aktau Port plans to create a container hub within two years, significantly increasing cargo flow along the TITR [24].

1.4.3. Current Transhipment Capacity

Currently, Aktau Port’s total cargo transhipment capacity stands at approximately 4.8 million tonnes per year. Although exact figures for rail-to-sea transhipment are not readily available, the port aims to enhance its container handling capacities significantly. The development includes creating a container hub to boost transshipment capabilities and distributing trains through multiple Kazakh ports to reduce delays. Other ports, such as Kurk-Port, are also being developed to handle train ferries year-round and include new facilities like a grain terminal (Figure 1.3) [22].

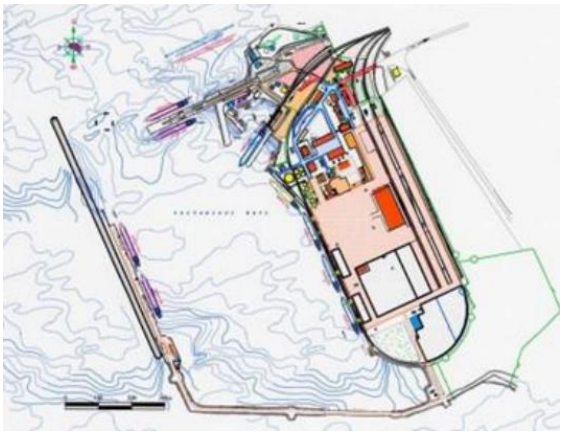

Figure 1.3: *Aktau Port. Source: [29].*

1.4.4. Aktau Port Capacity Utilization

The overall capacity of the Port of Aktau is estimated at 18 million tonnes per year, indicating a current utilization rate of only 26% at an aggregate level. For dry cargo, the rate of use is 37%, while the specific container segment, with an estimated capacity of 130,000 TEUs per year (ASCP & AMNT), shows a rate of use of 34%. ASCP has seen significant growth in container flows and is in the process of developing a new terminal dedicated to containers, projecting an increased port capacity of 215,000 TEUs per year. Based on 2022 volumes, Aktau port does not appear congested. Container flows in 2022 were distributed with 74% on the Aktau-Baku route (MC) and the remaining portion between Aktau and Iranian ports. The port is served by two shipping companies, Kazmortransflot (KMTF) from Aktau and ASCO from Baku. Container handling tariffs in Aktau port amount to US$104 for a 20-foot container and US$148 for a 40-foot container (inclusive of yard dues and ship dues for a 350 TEU capacity vessel). The dwell time for a container in the Port of Aktau is estimated to be between 5 and 12 days, excluding dwell times in port yards and ship waiting times outside the port. This estimate provides an average dwell time from the port gate to the navigation channel's outer end or vice versa [30].

Chapter Two

2. Boosting Trans-Caspian Trade through Strategic Enhancements to Aktau and Baku Ports

2.1. The Caspian Sea's Coastline

The Caspian Sea, the largest inland water body on Earth, lies between Asia and Europe. It is bordered by the Caucasus Mountains to the west and the vast region of Central Asia and its coastline is shared by five countries—Kazakhstan, Russia, Azerbaijan, Iran, and Turkmenistan. The sea a critical waterway for transporting goods along the Trans-Caspian International Transport Route, offering a shorter and more cost-effective alternative to traditional overland routes through Russia [31].

Figure 2.1 shows route of goods heading west along the Middle Corridor traverse the Central Asian steppes before arriving at the Port of Aktau in Kazakhstan and from there are shipped across the Caspian Sea to the Port of Baku/Alat in Azerbaijan.

Figure 2.1: *Trans-Caspian International Transport Route (TITR). Source* [middlecorridor.com].

Before the war in Ukraine, the Middle Corridor had gained popularity with cargo traffic along the route increasing by 52% between 2020 and 2021 [32] and despite the Ukraine-Russian war, transport volumes on the Middle Corridor have risen significantly. For instance, in the first eight months of 2022, the transport volume tripled to 970,400 tonnes compared to the same period of the previous year (Figure 2.2) [33]. In short, on average, the throughput capacity of the largest ports on the Caspian Sea ranges from 5 to 17 million tonnes per year [31]. Still, despite the seemingly relatively small capacity of the Caspian Sea ports, this infrastructure has still not been maximally utilized to its full capacity. Maximizing the logistic potential of the Caspian Sea is foremost important and requires a comprehensive approach that addresses infrastructure, regulatory frameworks, and regional cooperation of the Port.

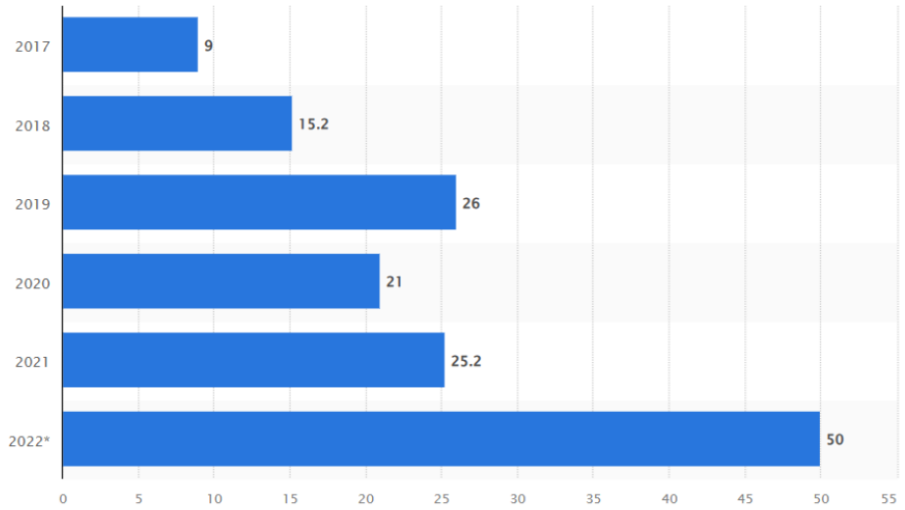

Figure 2.2: *Container traffic through the Trans-Caspian International Transport Route in thousand TEU. Source:* Walter (2022) [3].

2.2. Port in Kazakhstan

The Aktau Port, located on the eastern coast of the Caspian Sea, plays a crucial role in Kazakhstan's transportation infrastructure. It is strategically positioned in the Mangystau Region and serves as a significant intersection for the Trans-Caspian International Transport Route (TITR) and the Middle Corridor bearing a location facilitates the connection of East-West and North-South trade routes, making it a vital node for regional and international trade [34].

2.2.1. Geographical and Strategic Importance

Aktau Port is located on the eastern shore of the Caspian Sea in Kazakhstan's Mangystau Region. Its strategic position is crucial in connecting Eurasian trade and transportation networks. The port's geographical location enables it to serve as a vital hub for international trade corridors, emphasizing its significant contribution to regional and global logistics as further discussed.

Geographical Position

Aktau Port is strategically located on the Caspian Sea's eastern coastline, providing a natural gateway for Kazakhstan to the sea. This position offers several key advantages:

- Proximity to Major Trade Routes**:** Aktau Port is strategically located at the convergence of the Trans-Caspian International Transport Route (TITR) and the Middle Corridor. These transport routes are pivotal in connecting China, Central Asia, and Europe. Aktau Port's significance as a transshipment hub cannot be overstated, as it serves as a crucial link in the transportation network that enables the efficient movement of goods and resources between these regions [34].
- Natural Access to the Caspian Sea: The port provides Kazakhstan with direct access to the Caspian Sea, facilitating maritime trade routes connecting to Azerbaijan, Iran, Russia, and Turkmenistan. This connectivity is particularly significant for landlocked Kazakhstan, enabling the country to engage in international maritime trade and benefit from a broader range of economic opportunities [35].
- Favourable Climate and Year-Round Operation: Aktau benefits from a relatively mild climate, allowing for year-round operation without significant disruptions from severe weather conditions.

This reliability is crucial for ensuring consistent trade flows and maintaining efficient shipping and trade activities [36].

Strategic Importance

Situated on the Caspian Sea, Aktau Port is vital to Kazakhstan's economic aspirations. It functions as a crucial link on the "New Silk Road," facilitating the movement of goods between Europe and Asia. The Kazakh government actively supports the port's development through initiatives such as "NURLY ZHOL," underscoring its significance for national economic progress. As the primary commercial seaport on the Caspian Sea in Kazakhstan, Aktau serves as the central hub for the country's maritime trade in the region. This strategic location enables Kazakhstan to engage with other Caspian nations and access global shipping routes. In addition to its advantageous location, the port's capability to handle a wide range of cargo, including dry goods and oil products, enhances Kazakhstan's position as a versatile trading partner [37]. Furthermore, Aktau's involvement in international transport corridors like the Trans-Caspian International Transport Route extends its influence and connects it to broader trade networks. Aktau Port's strategic importance is diverse and cements Kazakhstan's role as a significant player in global trade.

2.3. Infrastructure Capacity of Aktau Port

Aktau Port, a key logistics hub on the Caspian Sea, boasts robust infrastructure designed to handle a diverse array of cargo types efficiently. Its comprehensive facilities and advanced handling equipment ensure it meets the growing demands of international trade [38]. Here’s a detailed look at its infrastructure capacity:

2.3.1 Berths and Terminals

Aktau Port has 12 operational berths, each tailored for specific types of cargo [37]:

Oil and Petroleum Products: Several berths are dedicated to the export of oil and petroleum products, leveraging Kazakhstan's vast energy resources. These specialized terminals are equipped with modern facilities to handle large volumes of liquid cargo efficiently.
Dry Cargo: The port features berths for bulk cargo, including grain, metals, and other raw materials. These berths are equipped to manage high volumes of dry goods, ensuring quick and safe loading and unloading processes.
General and Container Cargo: Aktau Port includes berths designed for general cargo and containerized goods. These facilities support the handling of a wide range of products, from manufactured goods to consumer items.

2.3.2 Storage Facilities

Aktau Port offers extensive storage capabilities to accommodate various types of cargo [39]:

Covered Storage: The port offers 16,000 square meters of covered storage space, providing a secure environment for sensitive goods. This protective measure shields the goods from adverse weather conditions, guaranteeing their safety throughout the transit process.
Open Storage: Aktau Port boasts 1.8 million square meters of open storage areas, enabling it to manage substantial volumes of bulk cargo efficiently. These vast storage facilities are critical for providing temporary storage for goods prior to their loading onto vessels or inland transportation.

2.3.3 Handling Equipment

The port is equipped with state-of-the-art handling equipment [40], including:

Cranes: Aktau Port operates numerous cranes with lifting capacities ranging from 5 to 40 tons. These cranes facilitate the efficient loading and unloading of various cargo types, from heavy machinery to containerized goods.
Specialized Machinery: Additional equipment, such as conveyor systems and bulk handling machinery, ensures the smooth handling of specific cargo types like grain and minerals.

2.3.4. Rail and Road Connectivity

Aktau Port is seamlessly integrated into Kazakhstan's national transportation network [38]:

Rail Infrastructure: The port features 10 rail sidings, enabling direct transfers of cargo from ships to trains. This integration reduces handling times and costs, enhancing overall logistical efficiency. The compatibility of rail gauges between Kazakhstan and Azerbaijan further facilitates seamless rail ferry services across the Caspian Sea.
Road Access: Aktau Port is well-connected to major highways, allowing easy access for trucks transporting goods to and from the port. This connectivity supports the efficient movement of cargo within the region and beyond.

2.3.5. Capacity, Tariffs, Waiting Time, Travel Time

The ports of Aktau and Kuryk in Kazakhstan have a combined capacity of 24 million tons per year and the National Railway Company (KTZ), with private capital participation, owns the ports. Aktau has two sub-ports, with the traditional public port in the south and a new public-private terminal in the north. In 2022, the ports handled 4.7 million tons of traffic, with the majority attributed to oil, followed by containers and cereals [37].

The Port of Aktau has an estimated capacity of 18 million tons per year, with a current utilization rate of 26%. The specific container segment has a utilization rate of 34%. The port is served by two shipping companies, with container handling tariffs amounting to US$104 for a 20-foot container and US$148 for a 40-foot container. There have been issues with border crossings that include delays due to shortages of vessels or rolling stock, congestion, extended handover times for rolling stock, control procedures, document-related problems, governance issues, and capacity shortages in China [36].

The round trip from Aktau to Baku and back took approximately seven days, with a one-way journey from Aktau to Baku lasting 3.5 days in 2022. Kazakhstan's National Maritime Shipping Company, Kazmortransflot (KMTF), exclusively handles commercial cargo transportation and owns several vessels with varying transport capacities [37].

2.3.6. Operational Efficiency

Aktau Port’s infrastructure is designed operational efficiency [40]:

- *Modern Terminals:* The port's terminals are equipped with advanced technologies to streamline cargo handling processes. This includes automated systems for tracking and managing cargo movements, reducing delays and improving accuracy.
- *Multimodal Operations:* The integration of maritime, rail, and road transport systems allows for seamless multimodal operations. This capability is crucial for handling complex logistics chains and ensuring the efficient movement of goods across different transport modes.

2.3.7. Developments

A landlocked country is constrained by its lack of direct access to the ocean and Kazakhstan, known as the world's largest landlocked nation, faces the challenge of being the furthest from the oceans among landlocked countries. Approximately 90 percent of global trade relies on maritime routes, which are usually not available to landlocked states. However, Kazakhstan has effectively addressed this challenge by implementing a pragmatic policy framework that is focused on multi-mode corridors and transportation routes. Since gaining independence in 1991, Kazakhstan has worked to develop a transportation network encompassing railways, highways, airways, and marine routes and corridors, connecting both internal and external markets [36].

Bordered by the Caspian Sea, Kazakhstan shares its coastline with Russia, Turkmenistan, Iran, and Azerbaijan. Recognizing the significance of marine trade, Kazakhstan is modernizing its ports, including the Aktau port, which handles nearly one-third of the turnover in Caspian Sea trade. Kazakhstan is also upgrading the Kuryk and Bautino ports with multipurpose terminals and railway access, essential for the Middle Corridor or Trans-Caspian International Transport Route (TITR), facilitating multi-modal cargo movement between the European Union, Baku, Kazakhstan's Aktau port, and China [34].

Kazakhstan has strategically developed foreign port assets, diversifying its port infrastructure to maximize marine trade. The country has also witnessed the construction of nearly 2,700 kilometers of railways, with sections connecting Kazakhstan-Turkmenistan-Iran and Zhetygen-Korgas designed to expedite goods delivery between China and Europe. The ongoing infrastructure development program, Nurly-Zhol 2020-2025, with a $3.9 billion investment, focuses on building, repairing, and renovating local roads, prioritizing international corridors running through the country.

Over the years, Kazakhstan has managed to position itself as a global transit power with international maritime trade, extensive transport routes, major ports, and gateways linked by overland transport corridors and continental footholds. Economically, Kazakhstan has become a key intersection point for the east-west rail, pipeline, and highway system linking China and Europe, as well as South Asia and Europe. Thus, Kazakhstan has successfully transitioned from being a landlocked country to a land-linked nation [36].

2.4. Caspian Sea: Shipping Routes and Navigation

The Caspian Sea, the largest inland body of water globally, spans a significant portion of the Earth's surface and is bordered by Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. The Sea is divided into the Northern, Middle, and Southern regions, and boasts of diverse geological features, from shallow shelves in the North to depths exceeding 1,000 meters in the South [41]. This geographical diversity impacts freezing patterns, with the northern section typically freezing in winter [42].

The Caspian Sea is crucial for transporting energy resources, particularly oil and gas, from landlocked nations to global markets. Estimates suggest vast untapped reserves, making the Caspian Sea a pivotal link in the global energy supply chain. Additionally, it supports local economies through fishing and tourism, offering scenic beaches and recreational activities like sailing and fishing.

Goods traveling along the Middle Corridor face challenges at ports due to limited shipping capacity and infrastructure deficiencies. Wait times, ranging from three to ten days, underscore the need for improvements. While efforts have been made to enhance transhipment capacities, more substantial investments are necessary to efficiently move petroleum products and containerized commodities across the Caspian [43].

2.4.1. Infrastructure and Ports

Five nations surround the Caspian Sea, a unique landlocked body of water with many ports essential to regional communication and trade. Among them, significant ports like Baku in Azerbaijan, Aktau in Kazakhstan, and Turkmenbashi in Turkmenistan serve as hubs for the region's marine activity. These ports are crucial in the larger Eurasian logistics network, serving coastal states and landlocked Central Asian countries by providing vital access to international trade routes [36].

However, the Caspian Sea's ports face several issues that hinder their competitiveness on the global commerce scene. The main problem is their limited capacity, restricting the amount of cargo they can handle and process. This is exacerbated by outdated infrastructure that has not kept pace with the rapid developments in technology and maritime logistics. Many ports lack the sophisticated container terminals and automated handling systems needed to efficiently manage large-scale international freight [44].

Existing Ferry Connections

According to the official Azerbaijan Caspian Shipping Company (ASCO) [45] website, the following vessels operate between Azerbaijan, Kazakhstan, and Turkmenistan ports.

Table 1.1: *List of existing ferry connections. Source:* ASCO [45]

Route	Vessel Name	Operator	Frequency
Baku - Aktau, Kazakhstan	Professor Gul	ASCO	Weekly
Baku – Kuryk or Turkmenbashi.	Merkuriy-1	ASCO	Weekly
Baku – Kuryk or Turkmenbashi.	Barda	ASCO	Weekly
Baku – Kuryk or Turkmenbashi.	Dagistan	ASCO	Weekly
Baku – Kuryk	Nakchivan	ASCO	Weekly
Baku - Alat, Azerbaijan	Shaki	ASCO	Weekly
Baku - Kuryk or Turkmenbashi.	Zarifa Aliyeva	ASCO	Weekly
Baku - Kuryk	Azerbaijan	ASCO	Weekly
Baku - Kurik, Turkmenbashi.	Agdam	ASCO	Weekly
Baku - Turkmenbashi.	Balakan	ASCO	Weekly
Baku - Turkmenbashi.	Karabachos	ASCO	Weekly
Baku - Kuryk, Turkmenbashi.	Shaki	ASCO	Weekly
Baku - Turkmenbashi.	Fikrat Amirov	ASCO	Weekly

There are 15 RORO vessels and two ferries regularly operating between ports in Azerbaijan, Kazakhstan, and Turkmenistan. A single sea voyage Baku-Kuryk-Baku typically takes five days. The exact schedule for the vessels varies, but based on observations of actual vessel routes, it is estimated that the ferries can complete one trip per week between these ports. ASCO does not own any container ships and carries containers on ferries as well as on conventional dry cargo ships.

Rail Ferries Suitable for the Landbridge

Roll-on/roll-off (RORO) ships play a crucial role in intermodal freight transport, facilitating the efficient movement of goods across various modes of transportation. Their ability to accommodate wheeled cargo, such as trucks, trailers, and machinery, directly onto and off the ship significantly streamlines loading and unloading processes, reducing transit times and costs. Currently, ASCO operates two RoRo and ten ferry vessels on the route.

The Republic of Kazakhstan owns a shipping company devoted to the commercial transportation of cargoes, the National Maritime Shipping Company Kazmortransflot (KMTF), which operates three specialized vessels between Caspian ports. An average round trip Baku-Aktau-Baku is estimated at five days, two days shorter than via Kazmortransflot. The average time for a round trip Baku-Aktau-Baku

(about 560km) is estimated at five days on a ferry and 4.3 days with a roll-on roll-off passenger vessel (ro-pax) (for one way, respectively 2.5 days and 2.1 days) [46].

The Ro-Pax-type ferry vessel "Zarifa Aliyeva [47]. owned by the Azerbaijan Caspian Shipping Company (ASCO) and built in Baku Shipyard in 2021, is a key player in this transport network. The ship, with 30 permanent crew members, is 154.50 meters long, has a gross tonnage of 8,523, is 17.7 meters wide, and 7.5 meters high. It is larger than other ferries in the Caspian Sea, with a carrying capacity of 100 passengers, 56 railcars of T-1 gauge with a length between auto replacers of 12020 mm (four-axle), or 50 Euro Trucks of 16.5 meters in length. Given the ports' shallow depths in the Caspian Sea, the vessel's 4.5-meter draft is ideal for all proper ports in this area.

2.4.2. Shipping Routes and Navigations

Developing efficient shipping routes is critical for enhancing maritime logistics in the region. Trans-Caspian shipping routes connect Caspian ports to international waters, providing access to markets in Europe, Asia, and the Middle East described by Security outlines [48] as follows:

Major Players

Oil and Gas Companies*:* Given the rich energy resources in the Caspian Sea region, major oil and gas companies play a dominant role. Companies involved in exploration, extraction, and transportation of oil and gas contribute significantly to maritime logistics. These include companies from Azerbaijan, Kazakhstan, and Turkmenistan.

National Maritime Authorities*:* Each littoral state has its maritime authority overseeing port operations, regulations, and safety. Coordination among these authorities is essential for smooth maritime logistics and trade activities.

Multinational Corporations: Multinational corporations involved in shipping, logistics, and infrastructure development are crucial players. They participate in port projects, invest in transportation networks, and contribute to the overall growth of maritime activities.

International Organizations: Entities like the Caspian Sea Shipping Company (CSC) and the Caspian Pipeline Consortium (CPC) play key roles in fostering collaboration and ensuring the efficient use of maritime resources. International organizations contribute to developing standardized regulations and operational procedures.

The Caspian Sea region's key ports serve as crucial nodes in global trade routes, facilitating the movement of goods and resources through collaborative efforts among energy companies, maritime authorities, multinational corporations, and international organizations to ensure the continued development and sustainability of maritime logistics.

2.5. Baku/Alat Port in Azerbaijan

The Port of Baku, located in Alat, a township 70 km south of the capital of Azerbaijan, is at the crossroads of two major transportation corridors – East-West and North-South. This is also, where Azerbaijan’s main railway and highway networks cross which facilitates the port's vision as a grand hub [49].

Known for its natural harbour, this port serves as a critical transhipment point for petroleum products and oil and gas-related industries. It also handles general cargo and timber bound for Western Europe and provides passenger services across the Caspian Sea. The port is accessible throughout the year and is not affected by weather conditions. It has seven quays equipped with 27 cranes, with hoisting capacities ranging from 5 to 40 tons. With 13 berths, the port covers 400 hectares and features 56,000

m² of open storage and 10,000 m² of warehouse space. The loading of the vessels is limited to a maximum draft restriction of 7 meters, allowing vessels with up to 5,000 MT capacity to berth [32, 50].

Figure 2.3: *Baku/Alat Port, Azerbaijan. Source:* Logistic Cluster (2023b) [49].

Furthermore, the port is directly linked to the Azerbaijan rail network through ten rail sidings. This is a huge advantage, as cargo can be shifted directly from ship to train. Additionally, trains transported on rail ferries can continue their voyage without the need for reloading, as Kazakhstan and Azerbaijan have the same track gauge.

However, the switch from land transport to water transport can become a bottleneck. Although the loading process is accelerated by the use of railway ferries, it still takes time. In particular, the process of uncoupling individual train sections in Aktau and coupling them in Alat is an important factor, as the trains are too long to be transported as a whole unit. A standard railway ferry can transport 50 to 60 wagons, distributed on rails on several decks.

Baku port is actively developing its infrastructure. In the first stage, completed in 2018, the port's nominal throughput increased to 15 million tonnes, including 100,000 TEU. The cargo throughput achieved in the first year after commissioning was 4 million tonnes. In 2022, there was a large increase in the transit of goods, which rose by 28.4 percent to 7.5 million tonnes in the first eight months. By diverting the transport of goods from the northern route to the Middle Corridor, capacity limits are expected to be reached in a few years. Therefore, active work is underway to implement a second development stage and increase throughput to 25 million tonnes, including 500,000 TEU per year [51].

2.5.1. Infrastructure Projects

The Port of Baku's development is projected in two phases:
Phase I: Following the completion of the first phase development in 2018, the Port of Baku has a total throughput capacity of 15 million tons of general cargo, including 100,000 TEU in containers. The first phase comprised a ferry terminal, Ro-Ro berths, general cargo berths, a service berth, railway lines, an administrative building, customs holding area, an open storage yard, warehouses, a container yard, rail and road access to berths, Ro-Ro ramps, a heavy lift landing area, and truck amenities area. The

completion of the first phase of development means that all intermodal operations are carried out at the Port of Baku.

Phase II: With the realization of the second phase of development, the total throughput capacity of the Port of Baku will increase to 25 million tons of general cargo, including 500,000 TEU in containers. The cargo transshipment at Azerbaijan's Baku port has increased by an average of 13.8% annually over the past few years, reaching 5.6 million tonnes in 2021. The geopolitical events of 2022 served as an additional factor in the increase in cargo transportation through the Caspian Sea. For example, in 2022, 6.314 million tonnes of cargo were transported through the Baku port, which is 13% more year-on-year. The number of wheeled vehicles transported during the year reached 51,000 units (+30.6% compared to 2021), the number of passing cars was 38,700 units (+27.2%), while the number of passenger cars transported was 12,000 units (+3-4 times) [33].

The distance from Aktau to Alat by ship is 510 kilometers, equivalent to 275 nautical miles. At a realistic average speed of 14 knots, this distance can be covered in 20 hours. Assuming we utilize the RORO vessel Zarifa Aliyeva for its ferry route, according to ASCO's tariffs, the basic cargo charge for every running meter (up to 15 meters of a wagon) is 48 dollars. For a single wagon, this translates to an estimated cost of 700 dollars. The ferry has a carrying capacity of 102 wagons, amounting to a gross cost of roughly 71,400 dollars per trip. If the ferry can make six trips per month, the total monthly cost would be approximately 428,400 dollars. It should be noted that this is a rough estimate, and the actual transportation costs of a wagon may vary [45].

The Middle Corridor (MC) saw a significant 33% increase in container traffic in 2022, but its limitations quickly became apparent. Its untapped technical capacity, logistical barriers such as slow border crossings, cargo transfers, and coordination issues caused significant delays, resulting in a 37% drop in traffic by August 2023 [52]. Definitely, the need to increase the Caspian's shipping capacity for the Middle Corridor is eminent to move cargo efficiently, going forward [43].

According to Victor Aragones, a Senior Transport Economist at the World Bank, the Middle Corridor presents significant potential for future growth, despite the current challenges. A fully operational MC could triple Caspian Sea flows to 11 million tonnes by 2030. Optimizing its operational efficiency is crucial to unlocking this potential and attracting more traffic. It is important to note that the MC is not expected to entirely replace the dominant Northern Corridor (NC). Since, the MC has already established itself as a viable option for transcontinental land trade. By improving its operational effectiveness, it can become a more attractive alternative for landlocked countries along its route, enhancing their connectivity and access to global markets. Before the Ukraine-Russia war, the Northern Corridor was the preferred route, with almost 1000 times the EU-China traffic volume via the Caspian Sea in 2021. The NC is expected to maintain a significant lead despite the projected growth of the MC. By 2030, EU-China transit volumes via the NC are expected to be six times larger than the MC. However, addressing operational bottlenecks and enhancing efficiency is crucial for it to reach its full potential [52].

Chapter Three

3. Key Eurasian Trade Hub Boosted by Modern Infrastructure and Strategic Investments

3.0. Major Transportation Routes

The South Caucasus region, encompassing Azerbaijan, Georgia, and Armenia, is a pivotal expanse in the Eurasian transportation network. This region serves as a strategic bridge between Europe and Asia because it is a transit hub for international trade and in recent times. The governments of Azerbaijan and Georgia have made substantial efforts to enhance transport infrastructure along this corridor because they understand that a seamless and efficient transportation network can significantly boost their economic prospects by attracting more trade and investment [53].

Their collaborative endeavours are driven by the mutual recognition of the economic and geopolitical benefits that come with improved connectivity, thus they focused on modernizing their transportation networks, investing heavily in railways, roadways, and port facilities through regional cooperation [54].

Figure 3.1: *South Caucasus. Source:* Tsereteli (2014). [55]

The South Caucasus is a vital transit hub connecting Asia and Europe. Significant investments in railways and roadways, particularly the BTK railway and the Middle Corridor, have bolstered the region's role in global trade. However, political challenges, such as the closure of the Zangazur Corridor (a significant point of contention between Armenia and Azerbaijan, particularly in the context of the conflict over Nagorno-Karabakh (Berg-Karabach)), continue to influence the region's full potential [56, 57]. Furthermore, the development of transportation routes in the South Caucasus is not just about building infrastructure, it is about creating a more connected and prosperous region. By addressing the challenges and leveraging the opportunities, the South Caucasus can strengthen its position as a key player in the global logistics network [58].

3.1. **Baku-Tbilisi-Kars (BTK) Railway**

The Baku-Tbilisi-Kars (BTK) railway stands as a cornerstone of the Southern Route of the New Silk Road Economic Belt. Officially operational since October 30, 2017, the BTK railway spans 826 kilometers, connecting Azerbaijan, Georgia, and Turkey. Specifically, 504 kilometers lie within

Azerbaijan, 263 kilometers in Georgia, and 62 kilometers in Turkey [59]. This railway is integral to the Middle Corridor because it facilitates a direct link between Asia and Europe to enhance regional connectivity and reduce dependence on longer, more complex routes through Russia [60]. By providing a shorter and more efficient path for freight transportation, the BTK railway is expected to boost trade volumes between the participating countries.

In addition, since its inception, Azerbaijan's Railways Company (ADY) reports that nearly 1.5 million tons of cargo have been transported, indicating a promising future for the route [61]. This railway is particularly important for landlocked countries in Central Asia, offering them a reliable gateway to European markets. It is important to note that a continued investment and cooperation among Azerbaijan, Georgia, and Turkey are essential for the railway to become a vital artery of global trade for boosted economic growth and connectivity without using Russian infrastructure [62].

3.2. Middle Corridor Railways

The Middle Corridor, also known as the Trans-Caspian International Transport Route (TITR), includes key railway systems from Kazakhstan, Azerbaijan, and Georgia using Russian railway gauge. The corridor connects to China through the Altynkol and Dostyk border crossings. Notable segments include the electrified lines between Almaty and Shymkent, and the Moiynty-Saksaulskiy section in Kazakhstan. This corridor plays a crucial role in the Belt and Road Initiative (BRI) and provides an alternative route that bypasses Russia. The Azerbaijan's ADY links the Port of Baku to the Georgian border via an electrified double-track line while the Georgian Railway (GR) continues from the Azeri-Georgian border to the Black Sea coast, serving the Ports of Poti and Batumi. A branch from Tbilisi connects to Turkey at Akhalkalaki, enhancing regional connectivity [63].

Despite challenges like transhipment at Caspian Sea ports, the system allows expedited freight movement, particularly with the development of containerized block trains. This interoperability ensures that goods can move seamlessly across different railway systems, reducing delays and lowering transportation costs. Kazakhstan especially has focused on modernizing and expanding its railway network to enhance its role in the Middle Corridor. The construction of the Zhezkazgan-Saksaulskaya-Shalkar-Beyneu railway line, completed in 2014, is an example of this commitment [56]. This 988-kilometer line, part of the "Nurly Zhol" infrastructure program, shortens the distance from western China to Kazakhstan's Caspian coast by 1,000 kilometers, improving the efficiency and competitiveness of the Middle Corridor [66].

3.3. Strategic Connectivity

3.3.1. Zangazur Corridor

When the Zangazur Corridor, a critical transit route, was closed, they were significant impact to the South Caucasus's transportation dynamics that results in indirect routing, increased transportation costs, and limited trade potential. Consequently, Azerbaijan partnered with Iran to construct a bypass road and a railway bridge that connects Azerbaijan with Nakhchivan and Turkey [65].

The new routes through Iran and Turkey offer alternative pathways that enhance connectivity and reduce dependency on politically contentious routes. This strategic shift underscores the complex interplay between infrastructure development and geopolitical considerations in the South Caucasus.

The potential reopening of the Zangazur Corridor could streamline routes from China to Europe, enhancing the Middle Corridor's attractiveness. However, political tensions between Azerbaijan and Armenia pose challenges to this development. Successful cooperation on transport projects could foster closer relations between the two nations and enhance regional stability. For example, improved infrastructure can attract foreign investment, boost trade, and create jobs; contributing to the overall

economic development of the region but these benefits can only be fully realized if the political environment is stable and conducive to cooperation [57].

3.3.2. Baku Port

To enhance Azerbaijan's transit potential, a modern facility known as the Baku International Maritime Trade Port (BMMTP) and a Free Trade Zone have been developed in Alat, 65 km south of Baku, spanning 400 hectares. The first phase of construction, set to be completed in the first half of 2018, aimed to provide the Alat port with an annual cargo capacity of 15 million tons and 100,000 TEU (Twenty-foot Equivalent Units). Future construction phases are expected to boost the port's capacity to 25 million tons and 1 million TEU, positioning it as the leading freight transport hub in the Caspian Sea [49].

Baku port is home to the oldest and largest port on the Caspian Sea, with a history dating back to the 16th century. The Baku port encompasses key terminals, including the main cargo terminal, container terminal, Dubenda oil terminal (with a capacity of up to 12 million tons), ferry terminal, and passenger terminal. The ferry terminal facilitates routes from Baku to Turkmenbashi, Aktau, and ports in Iran. The passenger terminal, with three berths totaling 340 meters, is designed for receiving passenger ships from Caspian countries. Integral to the Trans-Caspian International Transport Route (TMTM) and a significant component of the "Great Silk Road" project, the Baku International Maritime Trade Port plays a crucial role in freight transportation, serving as a vital corridor for cargo movement between China and Europe and attracting traffic from Europe to Central Asia. Its role in cargo transshipment also increased with the launch of the Baku-Tbilisi-Kars Railway (BTC) [66].

The main cargo facility, located within Baku's city limits, handles various types of cargo, including general, containerized, bulk export/import, and transit goods. Exports and imports mainly consist of steel products, machinery, equipment, and bulk cargoes, while general cargoes primarily transit through the port. The terminal can process up to 2 million tons of general and dry bulk cargo annually and has six berths totaling 866 meters in length, one of which is a roll-on/roll-off (RO-RO) quay. The quayside depth is 7 meters, and the berths are equipped with 16 portal cranes that have lifting capacities ranging from 5 to 40 tons. Additionally, the terminal includes forklift trucks with capacities from 1.5 to 10 tons, 100 roll trailers, and SI-SU type portal haulers. It can handle three vessels, up to 150 wagons, and 100 trucks simultaneously in a day. The terminal's stub railways extend over 8 kilometers, and four diesel locomotives facilitate maneuvers. Railroad and truck scales are available for weighing cargoes. Open warehouses cover around 24,000 square meters, while sheltered warehouses span approximately 10,000 square meters [66].

The main cargo terminal at the Port of Baku is crucial for servicing vessels carrying containers, bulk, and general cargoes. Most of the processed goods are general cargo, and the terminal has the capacity to handle 2 million tons of general and dry bulk cargo annually. The facility also includes a container terminal designed to handle various types of containers, including 40-foot equivalent units (FEUs), with an annual capacity of 15,000 containers. The container terminal features warehouse space extending up to 1,600 square meters [49].

The operation of the Container Terminal is managed using a computerized system with modern software that meets international standards. The terminal is well-equipped with up-to-date cargo handling equipment, including a Kalmar container forklift with a 42-ton lifting capacity, a Kalmar reach stacker with a 40-ton lifting capacity, two Terberg terminal tractors, six Plan marine trailers, and three Hyster small forklifts. Additionally, the railway branch line is directly connected to the Main Railway System that positively influence intermodal transportation [66].

3.3.3. The Baku–Tbilisi–Kars (BTK) Railway

The railway represents a strategic geopolitical tool, as it strengthens the ties between these nations [60] and serves as a crucial link between Azerbaijan, Georgia, and Turkey, serving as an alternative to the Kars–Gyumri–Tbilisi railway, which was closed in 1993 due to the first Nagorno-Karabakh War. It also offers an additional rail route between China and Europe that bypasses Russian territory. In late 2015, a goods train completed the journey from South Korea to Istanbul via China, Kazakhstan, Azerbaijan, and Georgia in just 15 days, significantly faster than by sea [67].

The railway extends 826 kilometers, with 105 kilometers of new track between Kars and Akhalkalaki (76 km in Turkey and 29 km in Georgia). The existing railway from Akhalkalaki to Marabda, Tbilisi, and Baku has been modernized. Initially, the line can transport 1 million passengers and 6.5 million tons of freight, with future capacities expected to exceed 1 million passengers and more than 15 million tons of freight [68].

Georgia and Azerbaijan use the Russian broad gauge of 1,520 mm, and the existing railway line (Akhalkalaki–Tbilisi–Baku) remains unmodified; however, new tracks from Akhalkalaki to the border station at Kartsakhi (Georgia) and from Kartsakhi to Kars (Turkey) were built to the standard gauge used by Turkey [69].

3.3.4. Batumi Port

The establishment of Georgia's seaports mirrors the evolution of the Caucasus Logistics Center, shaping Georgia's role as a pivotal transit nation. Positioned as a crucial link in the Europe Caucasus-Asia Corridor, Georgia serves as the Transcaucasian maritime gateway.

Batumi features the deepest oil pipeline, reaching a maximum depth of 58 meters, along with convenient berths, making it a strategic asset akin to Sevastopol on the Black Sea. The port contains 5 terminals, 11 berths, and a point of gratuitous filling with a total capacity of 18 million tons per year [66].

3.4. Challenges and Opportunities

The development of transportation infrastructure in the South Caucasus region presents a mixture of challenges and opportunities. While significant progress has been made in enhancing railways, roadways, and port facilities, the region still faces numerous hurdles, including political instability, financial constraints, and technical barriers [70].

Transport connectivity has become such a hot topic in the South Caucasus region with different groups involved and having numerous plans for new roads, railways, and other infrastructure. These plans are happening alongside significant political changes in the region, making it hard to predict outcomes. These countries, along with local governments, see the area's location as a key link between East and West, which they are all trying to leverage on. The Ukraine-Russian war and other conflicts have made this even more important, as global trade routes are changing [71]. The interests of larger powers, such as Russia, Turkey, China and Iran complicate efforts to develop a cohesive, influence the region’s political landscape and efficient transportation network [72]. The closure of the Zangazur Corridor, a critical transit route, further exemplifies how political disagreements can impact transportation infrastructure [73].

The situation is complicated, even though the picture is currently not so clear, it is important to consider the effects of building new transport infrastructure. The EU, for example, wants to play a major role in connecting the region, hoping to benefit from closer ties and more trade with its neighbours. This also allows the EU to spread its values and standards to these countries [74].

Thus, political instability remains one of the most significant challenges in the South Caucasus. Historical conflicts, territorial disputes, and ongoing tensions between countries in the region further hinder the development and efficient operation of transportation routes. The Nagorno-Karabakh conflict between Armenia and Azerbaijan is a prime example. This conflict has not only disrupted regional peace but also affected the stability and development of transport projects, including the potential reopening of the Zangazur Corridor [75].

On another hand, developing and maintaining transportation infrastructure requires substantial financial investment. The economic benefits of improved transportation infrastructure are clear, but the upfront costs can be prohibitive for countries with limited budgets. Creative financing solutions, including public-private partnerships (PPPs) and international cooperation, are essential to overcome these financial barriers and sustain the momentum of infrastructure development [76].

While Azerbaijan and Georgia have made significant strides in investing in their transport networks, financial constraints remain a persistent challenge. Infrastructure projects, such as the BTK railway and the East-West highway, are capital-intensive and require ongoing funding for maintenance and upgrades [77]. Even though international financial institutions, such as the World Bank and the Asian Development Bank, have provided support, more is needed to fully realize the region's infrastructure goals. Additionally, private sector investment can play a crucial role, but attracting such investment requires a stable and predictable political and economic environment [74].

Technical barriers also pose significant challenges to the development of transportation infrastructure in the South Caucasus. As the region diverse geography includes mountainous terrain and challenging climatic conditions, the construction and maintenance of transport routes are very complicated. For instance, the East-West highway in Georgia traverses difficult mountainous regions resulting to very high construction and maintenance costs and increased travel times [78].

Still, the Middle Corridor, linking China to Europe through Kazakhstan, Azerbaijan, and Georgia, presents substantial economic prospects. By offering a shorter and more efficient route, the Middle Corridor can attract more freight traffic, increasing revenue for transit countries and enhancing their strategic importance in global trade [56]. Additionally, the development of transport infrastructure can spur regional economic integration [79].

In this regards, regional cooperation is crucial for the successful development of transportation infrastructure in the South Caucasus. Collaborative efforts among Azerbaijan, Georgia, and Turkey have already yielded significant results, as seen with the BTK railway and other projects. Such cooperation can enhance the efficiency and effectiveness of infrastructure development by pooling resources and expertise [1]. Cooperation must extend beyond regional borders. Partnerships with international organizations and neighboring countries, such as Iran and Kazakhstan, are essential to create a cohesive and integrated transportation network. These partnerships can facilitate the exchange of knowledge, technology, and best practices, enhancing the overall quality and sustainability of infrastructure projects [80].

Promoting regional cooperation also involves addressing political and economic disparities among South Caucasus countries. Efforts to harmonize regulations, standards, and procedures can reduce barriers to trade and transportation, making the region more attractive to international investors and partners [81].

Technological advancements offer significant opportunities for the South Caucasus transportation network. The adoption of cutting-edge technologies can improve the efficiency, reliability, and sustainability of transportation infrastructure. For example, the implementation of smart logistics systems can optimize the management of freight and passenger flows, reducing congestion and improving service quality [82]. Innovations in construction materials and techniques can enhance the durability and resilience of infrastructure, reducing maintenance costs and extending the lifespan of transport routes. Additionally, the use of renewable energy sources and energy-efficient technologies

can reduce the environmental impact of transportation projects, aligning with global sustainability goals [83].

Embracing digitalization and automation can also enhance the competitiveness of the South Caucasus transportation network. Automated systems for cargo handling, real-time tracking, and predictive maintenance can streamline operations, reduce downtime, and improve overall efficiency. These advancements can make the region's transport infrastructure more attractive to global logistics operators and investors [84].

Lastly, environmental considerations are increasingly important in the development of transportation infrastructure. Sustainable practices are essential to minimize the ecological impact of construction and operation activities. The South Caucasus region, with its diverse ecosystems and natural landscapes, requires careful planning and implementation of environmentally friendly practices [85]. Integrating green technologies and practices into infrastructure projects can mitigate negative environmental effects. For instance, the use of renewable energy sources, energy-efficient designs, and environmentally friendly construction materials can reduce the carbon footprint of transportation infrastructure. Additionally, measures to protect natural habitats and biodiversity are crucial to preserving the region's ecological balance [86]. Sustainable infrastructure development not only benefits the environment but also enhances the resilience and longevity of transport routes and by adopting environmentally responsible practices, the South Caucasus countries can position themselves as leaders in sustainable development, attracting environmentally conscious investors and partners [87].

Chapter Four

4. Navigating Geopolitical Tensions: The Strategic Role of the Black Sea in Global Trade

4.1. The Black Sea

The Black Sea region serves as a gateway to Europe for the "Around-Russia" landbridge and over the years, the Black Sea has been a critical artery for global trade, connecting Europe with Central Asia and the Middle East [88]. It serves as a conduit for the transport of energy resources, agricultural products, and various goods. The Black Sea region's geopolitical landscape is influenced by the interests of coastal states such as Turkey, Russia, Ukraine, Romania, Bulgaria, and Georgia, as well as external actors like NATO and the European Union. This why as a vital maritime corridor, it has been a focal point for geopolitical tensions and security concerns, shaped by complex interplays of historical rivalries, territorial disputes, and strategic interests of regional and global powers [89] which has significantly impacted the maritime transport over the years.

Russia's annexation of Crimea in 2014 dramatically altered the security dynamics, leading to increased militarization and frequent military exercises by Russia. This annexation, deemed illegal by most of the international community, has heightened tensions with Ukraine and NATO member states [90] because it poses a significant threat to the security of maritime transport, creating potential flashpoints for conflict in the region [91]. For example, in 2018, Russian forces captured three Ukrainian naval vessels near the Kerch Strait, leading to international condemnation that further strained the relations between Russia and Ukraine [92]. These military activities, while intended to enhance security contributed to a heightened state of conflict currently being witnessed in the region [93].

Overall, the security situation in the Black Sea is a multifaceted issue with significant implications for maritime transport. The region's strategic importance, combined with historical rivalries and modern geopolitical tensions, creates a complex security environment. While militarization and naval incidents pose risks, international cooperation and diplomatic efforts remain crucial in mitigating threats and ensuring the safe and efficient flow of maritime commerce. The ongoing balance between military readiness and diplomatic engagement will continue to shape the security dynamics of the Black Sea in the years to come [94].

It is therefore evident that the security situation has direct implications for economic stability and maritime transport efficiency. As Astrov& Havlik [95] have noted, countries with substantial coastlines along the Black Sea have vested interests in maintaining control over key maritime routes. A prime example is the Bosporus and Dardanelles Straits, crucial chokepoints for maritime traffic entering and exiting the Black Sea, which Turkey controls under the Montreux Convention of 1936. Turkey's role as the gatekeeper of these straits adds another layer of complexity to the region's security dynamics [96].

In addition, while piracy is less prevalent in the Black Sea compared to other regions, the potential for asymmetric threats, including terrorism, cannot be overlooked. The proximity to conflict zones in the Middle East and ongoing instability in parts of the Caucasus region raises concerns about the security of maritime routes so that vigilance against potential terrorist attacks on ports and vessels remains a priority for regional security frameworks [97].

International Cooperation and Diplomatic Efforts to enhance security in the Black Sea have involved a combination of military preparedness and diplomatic engagement. NATO's presence in the region – for instance through enhanced forward presence and partnership programs with Black Sea littoral states, aims to bolster regional security and deter aggression. The EU also plays a role through initiatives like

the Black Sea Synergy to foster cooperation on various issues, including security. There are also bilateral and multilateral dialogues like the Black Sea Economic Cooperation (BSEC) that provides platforms for addressing security concerns and promoting stability. These forums have been making efforts to facilitate cooperation on maritime safety, environmental protection, and economic development, contributing to a more secure maritime environment [98].

4.2. The Black Sea Past and Present Ferry Routes

Various routes have been used to connect ports in the Black Sea with RoRo ferries and for the purpose of this section, the authors focus on ports in Georgia, Ukraine, Romania, and Bulgaria, excluding routes leading to Russian territory. The relevant ports are Poti and Batumi in Georgia, Varna and Burgas in Bulgaria, Constanta in Romania, and Chornomorsk in Ukraine (see Figure 4.1). Although Chornomorsk is close to Odessa as seen in Figure 4.1, it will not be considered due to the war in Ukraine.

Until the war in Ukraine began, there were regular ferry connections between Chornomorsk and Batumi as well as between Chornomorsk and Poti. The vessels operating on these routes were the MV Greifswald and the MV Kaunas, both of the class "Typ EGF-321." These vessels are capable of transporting rail wagons. The operator was "Ukrferry (UKR)," (see, www UKR ukrferry.com) [99]. Another route operated by Ukrferry connected Poti with Constanta. The MV Vilnius, a sister ship of MV Greifswald and MV Kaunas, sailed on this line. Although capable of carrying rail wagons, rail wagon transportation was not offered. The route Constanta-Poti is continued by the Georgian company "E60 Shipping" using the MV Vilnius. E60 Shipping offers weekly departures from Poti and Constanta. Schedules and tariffs can be checked on their webpage [100].

Figure 4.1: *Ports in the Black Sea suitable to serve "Around-Russia landbridge"*
Source: Plaske JSC (2023) [101].

Connections from Bulgarian ports are or have been operated by the companies "PBM" and "Plaske." PBM offers a weekly connection with their RoRo ferry "Drujba" from Burgas to Batumi. This ferry is not capable of carrying railroad wagons. Prices and schedules can be found on their webpage [102].

Plaske offered a connection between Varna and Batumi until June 2023. The RoRo ferries "Geroite na Sevastopol" and "Geroite na Odessa," both capable of carrying railroad wagons, were utilized on this line. Currently, the vessels are moored in the port of Varna [101]. Table 4.1 summarizes the prices for the transportation of trucks with trailers, containers, or railway wagons (suitable for a 40'-container) as at 2023.

Table 4.1: *Comparison of prices charged by different operators on existing ferry routes in the Black Sea*. Source: Based on [99; 100; 101; 102]

Operator	Route	40'-Container	Truck with Trailer (Westbound / eastbound)	Rail Wagon (40')
Plaske	Batumi-Varna	not available	1510 EUR / 2560 EUR	3350 USD / 4650 USD (probably westbound/eastbound)
PBM	Batumi-Burgas	not available	950 EUR / 2170 EUR	not available
Ukrferry	Chornomorsk-Poti/Batumi	not available	not available	2000 USD + surcharge (at least 950 USD)
Ukrferry / E60 shipping	Constanta-Poti	1050 EUR / 1600 EUR	1150 EUR / 1950 EUR (only trailer); 1750 EUR / 2300 EUR	not available

4.3. Potential Ports

4.3.1. Varna

The ferry port of Varna is located approximately 20 km inland and equipped with two ramps to handle rail ferries. In general, the port of Varna seems to be a sufficient option for our planned connection between China and Central Europe. Since Varna is one station in one of the corridors of the Trans-European Transport Network, there is a good connection from this port to Central Europe. Therefore, it is relatively easy to forward goods with a train from this port [103].

4.3.2. Constanta

The port of Constanta offers one berth for rail ferries. This berth is adjacent to the container port of Constanta and near the locks that provide access to the Danube-Black Sea canal. The port of Constanta seems to be a good starting point for the voyage from the Black Sea to Central Europe. The port offers a respectable connection to both the national rail network and the European rail network. Constanta is also one of the starting points of the Rhine-Danube Corridor of the Pan-European transport corridors; the train connection is directly available from the terminal [104].

In 2022, the port of Constanta had 4,498 calls of seagoing vessels and 10,890 inland vessels. The port handled a total of 75,537,687 tons of cargo, including 460,506 containers [105].

4.3.3. Poti

The Poti Sea Port is one of the largest ports in Georgia, handling container, liquid, dry bulk cargo, and passenger ferries. It is a multi-purpose facility with 15 berths, a total quay length of 2,900 meters, more than 20 quay cranes, and 17 km of rail track. The port serves as a European gateway for international trade in Georgia, Armenia, and Azerbaijan. It is ideally located to become a hub for Central Asia trade. The port provides direct ferry connections to the Black Sea ports of Ukraine, Russia, and Bulgaria. Additionally, it is linked to Georgia's railway network, offering connections to all major cities in the country [106].

Danish shipping company, Maersk in early 2023

announced its intention to invest heavily in the modernization of Poti. After several years of negotiations with the Georgian government, they plan to start constructing a new terminal. Recent reports in the Georgian mass media, citing government data, estimate the volume of investments in the

new terminal at $170 million. The Poti expansion project includes the construction of a 1,800-meter breakwater and a 13.5-meter deep berth. A 400-meter-long universal berth will support the loading and unloading of bulk cargo. The new berth is expected to serve container ships with a capacity of 9,000 TEU. The sea terminal will be 260 meters long with a water depth of 13 meters, allowing the port to serve larger vessels [107].

4.3.4. Batumi

The Batumi Sea Port historically represents a logistics center of the Caucasus region. Particularly, this was the very first port that enabled Georgia to function as a transit country. Today, Batumi Sea Port plays an important role in the life and development of the region. As the deepest-sea port in Georgia, it offers different types of services to its clients and partners. Incorporating several facilities, including oil-loading terminals, container berths, ferry docks, dry cargo berths, as well as berths for passenger liners, makes Batumi Sea Port multifunctional and an important facility for the region and the country as a whole.

The port contains five terminals, 11 berths, and a point of gratuitous filling, with a total capacity of 18 million tons per year [108].

4.4. Rail Ferries Suitable for the Landbridge

Since rail ferries are a very specialized ship type, typically produced for specific routes between two ports, their worldwide availability is low compared to general ship types like container vessels or bulk carriers. To receive a rail ferry, a port needs to be equipped with a ramp that fits the ferry's dimensions. Another detail is that the rail width on the ramp must match the rail width on the ferry. For the landbridge. This study utilizes block trains with 52 rail cars, the maximum allowed in the European Union. Therefore, the ferries should be capable of accommodating at least 52 rail cars. Passenger capacities are not required.

4.4.1. Typ EGF-321

The rail ferries of the "Typ EGF-321" class were five ships built in the 1980s in Wismar, Germany, for the route between Mukran, Germany, and Klaipeda, Lithuania (then Soviet Union). They are designed to carry 103 rail wagons and travel at a speed of 16 knots. The rail width is 1,558 mm (Soviet width). On their original route, they had a scheduled port stay of four hours. One of the five ships was scrapped, but the other four are still in operation. The "Vilnius," which currently operates between Constanta and Poti, is one of those four ships. The "Greifswald" operates between Europe and Libya, the "Aziz Express" in the Red Sea, and the "Kaunas" in the Strait of Gibraltar. All four ships are available on various shipbroker platforms for either sale or charter and therefore seem suitable for the landbridge [109].

4.4.2. "Geroite na Sevastopol" and "Geroite na Odessa"

The "Geroite na Sevastopol" and "Geroite na Odessa" were built in Norway in 1978. They are designed to carry railway cars but can accommodate trucks as well. Their capacity is 108 railway cars. No information could be found about the maximum speed, but it is assumed that with their main engine power of 12,944 kW, both ships can run at least 16 knots [110].

4.5. Capacity of the Route

One option to handle the block trains on the Black Sea route is by operating other ferries. This study will analyze this possibility using ferries deployed between the ports of Poti and Constanta. The authors will compare utilizing ships of the type EGF-321, which are available for charter or purchase and one of such is the Kaunas whose purchase price is €13 million [111].

The capacity of the ferry route depends on the number of ferries utilized, their speed, the turnover speed in the ports, and other factors that are difficult to determine, such as the availability of the terminal, tugs, pilots, and administrative issues (e.g., customs). Current schedule of the Vilnius is depicted with departures every four to seven days. The distance between the ports is given as 590 nautical miles, and the cruising time varies between 35 and 59 hours. According to Krüger-Kopiske [109], the speed of the ferries is 15.4 knots, meaning the distance is covered for about 38.3 hours. The shortest port stay is 13 hours.

However, when the ferries operated between Mukran and Klaipeda, the ports could organize the complete discharging and loading operations in four hours [112], thanks to loading ramps enabling operations on both decks simultaneously. It should be noted that the ferries' capacity of 103 wagons equals more or less exactly two block trains in the European Union (maximum size 52 wagons). An ambitious option would be to operate four ferries in such a way that daily departures are available. Table 2 shows an example schedule based on a port stay of six hours and a cruising time of 42 hours at a speed of 15 knots, with allowances for arrival and departure from port. Higher cruising speeds would allow for extended port durations. This option would result in two EU block trains arriving daily in Constanta, translating to 103 FEU daily. This can be considered the theoretical maximum of this route with the given equipment. Per year, the ferries would transport 37,595 FEU in each direction. The practicability depends on required vessel maintenance, weather in the Black Sea, terminal availability, tugboats, and pilots. Furthermore, the terminals will need to be converted to allow simultaneous operations on two decks.

If the fleets are reduced to two vessels (e.g., the Aziz Express and the Greifswald), then one would achieve a departure every 48 hours, leading to an average throughput of one block train per day (two block trains arriving every second day), as shown in Table 3. The annual throughput would be reduced to half of the above value, i.e., 18,798 FEU in each direction. These vessels would be operating on a tight rotation, and the feasibility of a six-hour port stay with the current infrastructure is questionable. To ease the schedule, we could operate two ferries departing at 56-hour intervals. The port stay is extended to ten hours, and the transit time is extended to 46 hours, resulting in a cruising speed of 13.4 knots (reserving two hours for pilotage). The annual throughput in this scenario is reduced to 16,112 FEU in each direction, approximately 307 block trains in each direction.

4.6. Cost

The study breaks down the total costs of one ferry operating on a 48-hour schedule to identify the cost per unit transported between Constanta and Poti. According to Stopford [113], the costs to operate a ship are calculated as follows:

$$TC = OC + PM + VC + CHC + K \quad (1)$$

where *OC* are the operating costs per annum, *PM* the periodic maintenance costs per annum, *VC* the voyage costs per annum, *CHC* the cargo handling costs per annum and K the capital costs per annum.

Operating costs are further divided as follows:

$$OC = M + ST + MN + I + AD \quad (2).$$

M is the costs for crewing and victualling, *ST* the costs for stores and consumables, *MN* the costs for routine maintenance, *I* the insurance and *AD* the administrative costs which include management fees and registration costs.

Voyage costs consist of the expenses for fuel oil for both the main engine and the auxiliary engines and the port costs.

Capital costs shall be the depreciation and the interest for buying the ship.

Assuming a utilization of 100%, the ferry will transport 103 wagons representing 103 FEU on each passage. A round voyage, starting with arrival in Poti and ending with subsequent arrival at Poti 96 hours or four days later, would transport 206 FEU (103 FEU back and 103 FEU forth). With 365 days in a year, the ferry will perform *365/4=91.25365/4 = 91.25365/4=91.25* round voyages per year. Thus, the ferry will carry *91.25×20691.25 * 20691.25×206 FEU = 18,798 FEU* per annum.

4.6.1. Utilizing a Second-hand Ship

Aassuming the acquisition the cost of the KAUNAS is €13 million. Since the KAUNAS is over 30 years old, it is logical to use costs for 20-year-old bulk carriers (the oldest provided) and additionally, benchmark values for operating costs of container vessels. Using operating costs of container vessels from the Boston Consulting Group (BCG) [114], the calculation based on the 48-hour schedule, with a comparison to the 56-hour schedule is used.

a. Operating Costs

Table 4.1. Summarizes values from Stopford [113] and BCG [114] for typical shipping operating costs.

Table 4.1: *Comparison of Opex Values.* Source: Stopford [113] & Boston Consulting Group [114].

	STOPFORD		BCG average 10-12k TEU		BCG average 13-15k TEU	
	USD/day	1k USD p.a.	USD/day	1k USD p.a.	USD/day	1k USD p.a.
Crew	2619	956	4062	1483	4358	1591
M&R	1077	393	1392	508	1518	554
Insurance	1159	423	673	246	857	313
Consumables & lubricants	953	348	1436	524	1473	538
General costs	904	330	195	71	210	77

For better comparability, the BCG values, given in USD/day, are converted to USD per annum. Based on the BCG study, a value of $1.5 million for manning costs will be assumed for our ferry. M&R costs are estimated at $0.5 million as an average of the given values. For insurance costs, we use the highest value from Stopford and increase it to $0.5 million, anticipating higher insurance costs due to the vessel's age. For consumables and lubricants, $0.5 million is used as an average of the given values. Stopford includes “management fees” in general costs, representing a significant share and not included in the BCG benchmark values. Thus, the $330,000 per annum given by Stopford is assumed. Summing these values gives total operating costs of $3.33 million per annum.

b. Periodic Maintenance Costs

Periodic maintenance costs represent a buffer built by annual cash payments to cover costs for class renewals and related drydocking. Stopford provides a value of $804/day for vessels aged 6-10 years, $1,493/day for vessels aged 11-15 years, and $1,219/day for vessels aged 16-20 years. BCG provides an average value of $909/day for 13,000-15,000 TEU container vessels with an average age of eight years. Since periodic maintenance costs rise with vessel age and our ferries are over 30 years old, we use the highest available benchmark value of $1,493/day, equating to $545,000 per annum.

c. Voyage Costs

The main engine has a power of 10,600 kW [7]. Due to its age, we assume an inefficient consumption of 230 g/kWh, leading to a consumption of 2,438 kg/h. Per round voyage, the ferry runs its engine for 84 hours, leading to a consumption of 204.8 mt of fuel oil per round voyage and 18,687 mt of fuel oil per annum. Currently, MGO is available in Constanta for $905/mt [115], totaling annual expenses of $16.9 million.

For the auxiliary engines, we assume an average power of 1,500 kW at 230 g/kWh efficiency, equating to a consumption of 345 kg/h or 3,022 mt per annum. Using the same MGO price, the annual expenses of $2.7 million for the auxiliary engines is calculated.

Next, to analyze port costs, the authors determined per port call and multiplied by 91.25 (the number of port calls per year) to obtain annual costs. For Poti, [116] summaries of tariffs based on the vessel's gross tonnage. Given the 21,890 GT [109] of the ferries, the fees amount to $14,009 per call, or $1.28 million per annum is given below:

- Channel dues: 2189 USD/call
- Tonnage dues: 4378 USD/call
- Berth dues: 4378 USD/call
- Sanitary charge: 437.8 USD/call
- Watchman charge: 437.8 USD/call
- Mooring fee (in + out): 437.8 USD/call
- Towage fee (in + out): 2189 USD/call

Constanta, [117] provides an overview of official tariffs. Given the vessel's gross tonnage of 21,890 GT and length overall of 191 m [109], the port access tariff is €1,707/call, the quay tariff €1,617/call, and the basin tariff €39/call. The total tariff would be €3,364/call, summing to €0.307 million per annum or $0.325 million. Adding $3287/call for incomplete fees like tug costs, the total annual port cost for Constanta is $0.625 million, or $1.9 million for both ports. Summing voyage costs, we get $21.5 million per annum.

d. Cargo Handling Costs

As no information could be obtained on cargo handling costs in the relevant ports. For calculation purposes, $1 million per annum is assumed.

e. Capital Costs

Next is to acquire a ferry for €13 million ($13.78 million), assume the ship will be in service for another 10 years, the annual depreciation will be $1.38 million. Assuming a 5% interest rate, the annual interest sums to $689,000. Together, total capital costs equal $2.069 million per annum.

f. Total Costs

Summing operating costs of $3.33 million, periodic maintenance costs of $0.545 million, voyage costs of $21.5 million, cargo-handling costs of $1 million, and capital costs of $2.069 million, we achieve total costs of $28.44 million. An annual transport of 18,798 FEU will result to the cost per FEU as $1,513. Utilization of 80% (15,038 FEU per annum) would lead to costs of $1,891/FEU. This value is the same for a schedule utilizing four vessels with daily departures and for a schedule utilizing two vessels with 48-hourly departures (Table 4.2).

Table 4.2: *Comparison of running costs of the ferries when deployed in different schedules – operating costs (orange), periodic maintenance costs (gold) and capital cost (grey) stay the same, voyage costs (blue) and cargo handling costs (green) are lower in the 56-hour schedule.* Source: Own Table.

	48-hour schedule	56-hour schedule
Crew	1.5 Mio. USD	1.5 Mio. USD
M&R	0.5 Mio. USD	0.5 Mio. USD
Insurance	0.5 Mio. USD	0.5 Mio. USD
Consum. & Lubr.	0.5 Mio. USD	0.5 Mio. USD
General	0.33 Mio. USD	0.33 Mio. USD
Periodic Maint.	0.545 Mio. USD	0.545 Mio. USD
Fuel Oil Main Engine	16.9 Mio. USD	12.08 Mio. USD
Fuel Oil Auxiliaries	2.7 Mio. USD	2.7 Mio. USD
Port costs	1.9 Mio. USD	1.6 Mio. USD
Cargo Handling	1 Mio. USD	0.85 Mio. USD
Capital cost	2.069 Mio. USD	2.069 Mio. USD
Sum	**28.44 Mio. USD**	**23.17 Mio. USD**

Fuel oil consumption has the largest share of total costs. Should the bunker price rise by 10%, from \$905/mt to \$996/mt, the total cost would rise by \$1.9 million per annum or \$105/FEU (7%). Conversely, consumption and related costs can be calculated accurately, whereas other values with a low impact on total costs are more variable. For instance, should insurance costs triple to \$1.5 million, the total cost would rise to \$29.44 million or \$1,566/FEU (4%).

g. Comparison to 56-hour Schedule

Increasing the round voyage duration from 96 hours to 112 hours allows decreasing cruising speed from 15.4 knots to 13.4 knots [118] provides a relation between main engine power PPP in kWh and ship speed V in knots: $P=x_1*V^{x2}$. Where x_1 is a constant and x_2 is the speed-power exponent. Using a value of $x_2=1.8$ and entering the equation with maximum power of 10,600 kWh with maximum speed of 15.6 knots, we obtain $x_1=75.5$. Therefore, the power at 13.4 knots is $P=75.5*13.4^{\{1.8\}}$ =8067kWh. $P=75.5*13.4^{\{1.8\}}$ = 8,067P = $75.5\times13.4^{\{1.8\}}$ =8,067 kWh, leading to a fuel oil consumption of 1,855 kg/h. The main engine operates 92 hours per round voyage, summing to 170.7 t/h or 13,351 t per annum with 78 round voyages. At \$905/ton, main engine fuel costs total \$12.08 million. Auxiliary engine consumption remains constant.

Port costs, assumed at \$20,820/round-voyage, lead to annual costs of \$1.6 million. Summing the new voyage costs gives \$16.38 million per annum. Cargo handling costs, estimated at \$1 million for 91 round voyages, are \$0.85 million for 78 round voyages. All other costs remain unchanged. Total annual cost equals \$23.17 million (see Table 4.2). Annual throughput per ferry is 16,112 FEU, making the cost per FEU \$1,439 at 100% utilization. At 80% utilization, costs rise to \$1,798/FEU in Table 4.3.

Table 4.3: *Comparison of annual throughput and cost per FEU for three different options of running the own Black Sea ferry route.* Source: Own Table.

Number of ferries deployed	4	2	2
Departures from each port every ... hours	24	48	56
Duration of one round-voyage	96 hours	96 hours	112 hours
Annual throughput westbound	37.595 FEU	18.798 FEU	16.112 FEU
Annual throughput eastbound	37.595 FEU	18.798 FEU	16.112 FEU
Cost per FEU at 100% utilization	1.513 USD	1.513 USD	1.439 USD
Cost per FEU at 80% utilization	1.891 USD	1.891 USD	1.798 USD

Of course, there is always the choice of building new ships, which would invariably lead to a higher initial investment but lower annual operating costs, especially for fuel and periodic maintenance, however, a detailed calculation is not provided in this study.

4.7. Relevant Technological Advancements and Innovations for Maritime Transport

Maritime transport in the Black Sea region is undergoing significant transformations driven by technological advancements. These innovations are reshaping traditional practices and paving the way for more efficient, safe, and sustainable operations.

4.7.1. Digitalization and IoT Integration

Smart Shipping Solutions: Integration of digital technologies like Internet of Things (IoT) devices, sensors, and automation systems onboard vessels enhances operational efficiency and safety [119].

Real-time Monitoring: Digitalization enables real-time monitoring of vessel performance, fuel consumption, engine health, and environmental parameters [120, 121]. This data empowers ship operators to optimize routes, reduce fuel consumption, and minimize environmental impact.

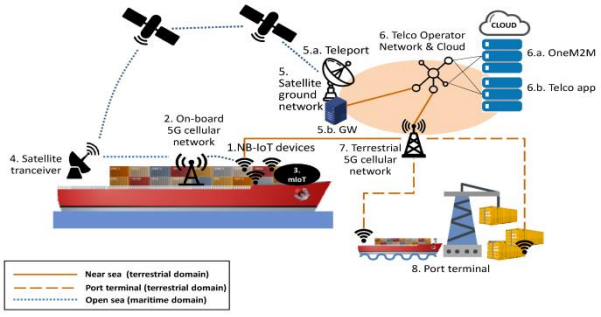

Figure 4.2: *IoT-Based Platform for Maritime Transport Services.* Source: Tijan *et al*., (2012) [121].

*Predictive Maintenanc*e: IoT sensors and data analytics enable predictive maintenance, allowing operators to anticipate equipment failures and schedule maintenance proactively, thereby reducing downtime and operational disruptions [120].

4.7.2. Autonomous Vessels and Unmanned Systems

Autonomous Shipping: Figure 4.3. Shows advancements in autonomous vessel technology that are paving the way for unmanned or remotely operated ships. These vessels offer potential benefits such as improved safety, reduced labour costs, and enhanced operational efficiency [122].

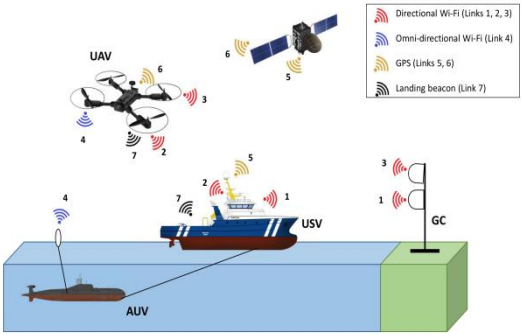

Figure 4.3*: Prototype Design and Experimental Evaluation of Autonomous Collaborative Communication System for Emerging Maritime Use Cases.* Source: DVN (2024) [122].

Remote Monitoring and Control: Remote monitoring and control systems enable shore-based operators to oversee vessel operations, navigate, and intervene when necessary. This technology enhances safety and operational flexibility [123].

4.7.3. Green Shipping Initiatives

Alternative Fuels and Propulsion Systems: Adoption of alternative fuels such as LNG (Liquefied Natural Gas) and hydrogen, along with innovative propulsion systems like electric propulsion and wind-assisted propulsion, is reducing emissions and promoting sustainability in maritime transport [124].

Emission Reduction Technologies: Implementation of exhaust gas cleaning systems (scrubbers), ballast water treatment systems, and other emission reduction technologies helps vessels comply with environmental regulations and minimize their ecological footprint [125].

4.7.4. Advanced Navigation and Communication Systems

Satellite Navigation: Global Navigation Satellite Systems (GNSS) like GPS (Global Positioning System) and GLONASS (Global Navigation Satellite System) enable precise vessel navigation, route planning, and collision avoidance, enhancing safety and efficiency shown in Figure 4.4.

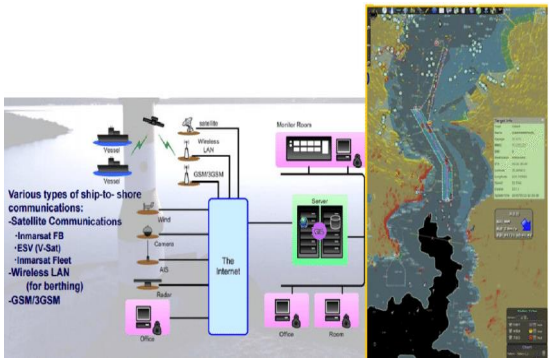

Figure 4.4: *Advanced Navigation System.* Source: Sarkodie *et al.* (2018) [126].

Vessel Traffic Management Systems (VTMS): VTMS integrates radar, AIS (Automatic Identification System), and communication systems to monitor vessel traffic, manage navigation, and ensure safe passage through congested waterways [127].

4.7.5. Digital Port Infrastructure and Smart Logistics

Digitalization of port infrastructure facilitates efficient cargo handling, berth scheduling, and port operations [127]. Smart port technologies, such as automated cranes, RFID (Radio Frequency Identification) tracking, and blockchain-based cargo management systems, optimize port throughput and reduce turnaround times.

Integration of maritime transport with other modes of transportation, including rail, road, and inland waterways, enhances supply chain efficiency [128] even the connectivity within the Black Sea region.

4.7.6. Cybersecurity and Risk Management

As maritime systems become increasingly digitalized, cybersecurity becomes paramount to protect against cyber threats and data breaches [129]. Implementation of robust cybersecurity protocols, intrusion detection systems, and employee training programs safeguards critical maritime infrastructure and data [130].

These technological advancements and innovations are poised to reshape the landscape of maritime transport in the Black Sea region, driving efficiency, sustainability, and competitiveness in the industry. Embracing these technologies can unlock new opportunities for growth and development while addressing challenges posed by evolving regulatory, environmental, and operational requirements.

4.8. SWOT Analysis on Maritime Transport in the Black Sea

Strengths: The Black Sea is a strategic corridor for maritime transportation as part of the "Around-Russia" landbridge, providing access to major markets [131]. The trade volume in the Black Sea is dramatically increasing [132] (Figure 4.5).

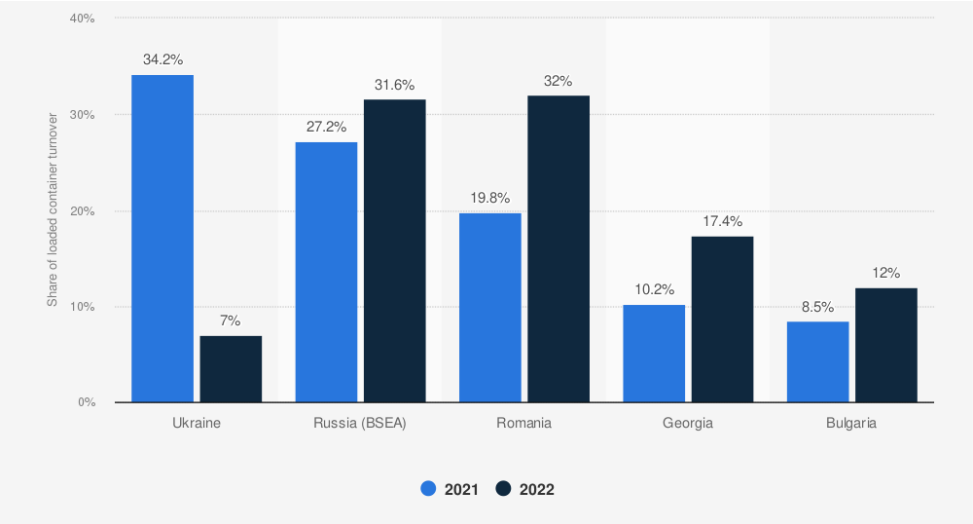

Figure 1.5: *Share of the turnover of loaded containers in the Black Sea region from 2021 to 2022 by country*. Source: Statista (2022) [132].

Additionally, there is potential for collaboration and partnerships within European and Middle Eastern countries to enhance larger logistics networks [122].

Weaknesses: The infrastructure of the potential ports mentioned in section 3.4.2 is still under development, which may lead to port congestion and delays, limiting trade potential [133]. Moreover, political tensions, conflicts, and environmental concerns affect the stability of trading routes [134].

Opportunities: There is significant potential to develop multimodal transportation routes such as the Eurasian land bridge automation systems as well as the integration of digital technologies will further enhance operations [133].

Threats: Russia's invasion of Ukraine and domination of Crimea might affect maritime transportation and security in the Black Sea [134]. In the worst case, parts of the Black Sea might become no-go areas for ships flying certain flags or managed by companies from certain countries, similar to the current situation in the Red Sea.

Chapter Five

5. Enhancing Connectivity between Central Europe and the Black Sea – a Multimodal Solution

5.1. Black Sea Hinterland

It is becoming a general knowledge that improved efficiency and connectivity seaports and hinterland corridors contribute to reducing port traffic and ensuring smoother, more reliable movement of commodities to and from interior regions. This why different countries and regions are actively involved in intermodal transportation development and option. They invest largely in infrastructure, to foster strategic alliances for a collective enhanced supply chain efficacy and resilience [135].

Port hinterlands are so dynamic and multifaceted that they change regularly based on factors such as cargo type (bulk vs. containerized), seasonality, business cycles, technological advancements, transportation regulations, and inland transportation pricing [136].

Europe's port hinterland services, primarily dependent on road transportation, face increasing challenges due to rising costs, traffic, and environmental regulations so that efficient high-volume transportation often combines rail-road or waterway-road methods. Large container ports with robust inland services can become significant loading hubs, controlling vast hinterlands and this is especially true for the transportation corridor connecting Central Europe and the Black Sea, where multimodal solutions are crucial. Successful combined transportation, which favours rail, inland waterways, or sea over roads for most of the route must demonstrate adequate competitiveness and integrate various modes to manage traffic growth and extend their hinterland influence [135].

5.1.1. Route from the Black Sea to Central Europe

"The 'pan-European transport corridors' were initiated during three conferences held between 1991 and 1997. These corridors aim to enhance the European domestic market by integrating rail, roads, seaports, inland ports, and airports along their routes [137]. One option for connecting the Black Sea with Central Europe involves trains departing from the unloading port, using the same wagons from the previous leg of the journey via the rail ferry from Poti. For the connection between China and Central Europe, while avoiding Russia, the 'Rhine-Danube Corridor' has proven particularly convenient. This corridor starts at Black Sea ports like Constanta or Varna and ends in various Central European cities, such as Dresden and Nuremberg in Germany, spanning 4,379 km of rail and 3,640 km of road, with the option of utilizing inland waterways [138]. This demonstrates that multimodal transport is a viable option when needed.

For the Eurasian landbridge revival, it is convenient to start the journey by train in Constanta, Romania, ending in Nuremberg, Germany. From there, goods can be distributed using Germany's national railway network and other Trans-European Transport Network corridors as shown in Figure 5.1:

Figure 5.1: *Map of the Rhine-Danube Corridor.* Source: EU, (2023a) [139].

A key advantage is the European standard gauge of 1435 mm that eliminates the need for gauge changes during the journey. However, to establish a train link with owned equipment the cost can be quite expensive.

5.1.2. Inland Waterways

When it comes to the inland waterways, a cost-effective alternative to rail and road for inland transportation due to their high cargo capacity can be achieved. Currently, using motor cargo vessels with up to 2000 tons capacity, operating 14 hours per day, and carrying up to 300 TEU, with the travel distance between Constanta and Duisburg, Germany that is 3036 km can take approximately 20 days and 8 hours, passing 70 locks . Also, note that the distance to Rotterdam which is 3253 km, also takes about 21 days and 5 hours, passing 70 locks.

Alhough inland container freighters present a viable alternative to road or rail, transit times are too long to be competitive, especially considering potential congestion and waiting times at locks [141].

5.2. Maritime Logistics in the Black Sea

Aforementioned, the Black Sea region is geographically favourable, connected to the Mediterranean through straits and serving as a crossroads linking Europe, Asia, and Africa. Stable political governance and international transportation networks have historically facilitated long-distance trade across the Black Sea, benefiting nearby ports [142].

5.2.1 Geographical Dynamics

The Black Sea, connected to the Sea of Marmara via the Bosphorus Strait and to the Mediterranean via the Dardanelles, spans a drainage basin covering nearly a third of Europe's territory. Major rivers such as the Danube, Dnieper, Bug, Dniester, Don, Kuban, and Rioni contribute to its water balance.

The Black Sea is bordered by six countries: Russia, Georgia, Bulgaria, Romania, Ukraine, and Turkey. It is one of the world's most landlocked seas, connected to neighbouring seas through narrow straits. Its drainage area, encompassing 20 countries, is nearly five times its surface area, contributing significantly to its unique characteristics depicted in Figure 5.2.

Figure 5.2. *Map of the Black Sea.* Source: Nationsonline.org (2023) [143].

The Danube, Dnistro, Dnipro, and Don rivers provide over 70% of the fresh water entering the sea, affecting its salinity. Various plains and mountain ranges bound the Black Sea, contributing to its geographical diversity [144].

5.2.2 Port Infrastructure and Operations

The Black Sea hosts around 65 ports, playing a crucial role in regional economic growth. Major ports include Constanta, Odessa, and Varna, each handling significant volumes of various cargo types. Figure 5.3 highlights some of its major ports:

Figure 5.3. *Major Port in Black Sea.* Source: Marineinsight.com, (2023) [145].

Port of Constanta is Romania's largest port, located on the northwest coast, handles a wide range of cargo, including chemicals, steel, timber, ore, petroleum products, coal, container cargo, and general cargo. It can manage up to 100 million tons annually. Constanta's passenger terminal welcomes cruise ships, and the port is divided into North and South Harbor, with numerous specialized terminals for different commodities [104].

Constanta's terminals include facilities for liquid bulk, dry bulk, fertilizers, cereals, cars, and containers. Liquid bulk terminals connect to major oil refineries via pipelines. Dry bulk terminals handle cement, construction equipment, phosphates, and other materials, managing over 30 million tons annually. Fertilizer terminals handle up to 4.5 million tons annually. The port has four container terminals, among the busiest globally [105].

The Port of Odessa is one of the largest ports on the Black Sea, covers 141 hectares and has 54 berths. It can accommodate ships up to 340 meters long and 100,000 tons. With a handling capacity of 50 million tonnes annually, the port manages various cargo types, including grain, oil, condensed gas, metal products, sugar, and containerized grain. The port complex comprises 17 terminals, with the container terminal handling 950,000 TEUs annually. The cruise ship terminal serves four million passengers annually, making it one of the largest among Black Sea ports. It has seven berths and can accommodate four to five ships at a time. The terminal also offers numerous restaurants and basic banking facilities.

The cargo terminal includes two warehouses and operates around the clock. It handles metal, wood, packaged food, and containerized transport. The port's shipyard can repair ships up to 40,000 DWT. The port is Ukraine's largest oil and gas terminal, with a handling capacity of 90,000 tons. Nearby, a gas terminal can accommodate 700,000 tons of liquefied gas [145].

Port of Novorossiysk is Russia's main port and is located in Tsemes Harbor on the northeastern coast of the Black Sea. In 2020, the port handled 142 million tons of cargo, making it a leading Black Sea port. As a warm-water port, it operates year-round. With a depth of 7 to 14 meters, the port has 11 berths. Four are used for containerized cargo, while the others handle goods like wine, packaged foods, plywood, lumber, metal goods, and perishable items.

The port has 51 hectares of open and closed timber storage space and 14 hectares of container space. A 14,000 square meter warehouse houses public transport, plywood, and fiberboard. The port terminals, including container terminals, are connected to 19 railway lines, facilitating loading and unloading. The container terminal handles about 350,000 TEUs annually and can accommodate Panamax container ships. The lumber terminal handles around three million metric tons annually. Additionally, the port handles 405,000 tons of general goods, including pipes, rolled iron, and aluminum, and hazardous materials [146] Penetron.

Port of Varna, Bulgaria's largest port, is located near Varna Bay on the western coast of the Black Sea. The East Terminal and West Terminal are the port's main terminals. The port can handle various cargo types, including dry and liquid cargo, heavy goods, and containerized items. When it opened in 1906, the port could accommodate ships weighing up to 25,000 tons. The port has attracted many cruise ships since becoming a popular tourist destination in the 1960s. Annually, the port handles around 8 million tons of cargo [101].

It has 32 berths, a 60-hectare open storage area, and the latest port infrastructure. The East Terminal is Bulgaria's main port for grain exports and handles molasses, sugar, metal products, and general cargo. The West Terminal handles soda, coal, fertilizer, ore, silica, phosphate, and other materials and is located near a chemical factory. The port is well-connected to the national rail and highway network.

Port of Theodosia: The Port of Theodosia, located in Theodosia Bay, has long been in use, with official facilities built in the late 1800s. The modern port opened to foreign ships in the 1990s. It provides repair services and remains frost-free year-round. Theodosia is an important port for Ukraine, primarily

handling oil and petroleum products. It can handle tankers up to 114,000 DWT and has a capacity of 11 million tons annually.

The port covers about 13 hectares and has two main areas: one for dry bulk and another for petroleum products. It also has two berths for large tankers and one for passengers. Special berths handle various types of cargo, including metals, cereals, fertilizers, and construction equipment. The port has extensive storage space, with 3,000 square meters of warehouses and 19,000 square meters of open storage, mainly for steel products, clay, and fertilizer [147].

Samsun Port is the largest seaport in Turkey and is located in the Black Sea. It serves fishing boats, ro-ro ships, oil and chemical tankers, and large bulk carriers transporting general and heavy bulk cargo. The port can accommodate ships up to 230 meters in length and 11.2 meters in draft. It handles various cargo types, including pallets, coil sheets, metal goods, pipes, marble stone, roll paper, and bagged goods.

The main terminal covers approximately 440,000 square meters, accommodating 255,000 TEU and 40 reefer points. The port features open storage yards measuring 330,000 m² and covered storage facilities measuring 45,000 m². The berths total about 1,550 meters in length. The main port area has five berths with an average depth of 10 meters, and the industrial zone has three berths with an average depth of 12 meters. The port is equipped with modern machinery, including eleven dock cranes with a capacity of 30 tonnes and mobile and gantry cranes with a lifting capability of 150 tonnes. The port also has grain silos with a capacity of 55,000 tons [148].

Batumi Port, Georgia's main Port specializes in refining fuel and other materials. Located on the southeastern coast of the Black Sea, it handles metals, grain, cement, fertilizer, corn, wood, building supplies, and sugar. With an annual capacity of 18 million tons, the port has 11 berths and 5 special terminals. Local companies producing furniture and engine parts, along with shipyards providing repair services, are nearby. Batumi Harbor is also a popular tourist destination, known for its stunning tea gardens and other features.

The port has road and rail connections to Turkey, Central Asia, Russia, and the Caucasus. One terminal, with four berths, handles oil and petroleum products and can accommodate four tankers simultaneously. The container handling facility has a capacity of 350,000 TEU. The ferry terminal has an annual capacity of 700,000 tons, delivering goods to nearby cities. A terminal specializing in dry haulage has four berths. Additionally, there is a beautiful cruise ship terminal in the harbour [149].

5.3. Trans-European Transport Network (TEN-T) and Black Sea-Mediterranean Corridor

The Black Sea is and extensive and interconnected network and crucial component of the Trans-European Transport Network (TEN-T), long recognized as a crossroads of culture and trade. The Tent-T aims to improve transport systems across the European Union, promoting competitiveness, unity, and economic prosperity. As a key maritime route connecting the Black Sea region to the Mediterranean, it forms the centre of this vast network through an interconnected network of ports, sea routes, and transport modes; this corridor links Eastern and Western Europe, vital for the flow of products.

The Black Sea-Mediterranean Corridor facilitates smooth connectivity and enhances commercial flows between the Black Sea and the Mediterranean. This corridor's efficient commodity transportation significantly boosts the economies of the regions it traverses. The corridor's interconnected modern highways, rail systems, and ports contribute to its functionality as a busy and effective commercial route. As part of TEN-T, the Black Sea-Mediterranean Corridor plays a crucial role in maximizing European transportation infrastructure. Its advantageous location influences global trade, tying the Mediterranean and Black Sea regions together. The corridor enhances Europe's access to key markets in Asia, the Middle East, and beyond, contributing to cross-continental trade dynamics [150].

Despite its strategic importance, the Black Sea-Mediterranean Corridor faces challenges such as geopolitical tensions, regulatory complications, and environmental concerns. These obstacles, however, offer opportunities for cooperative resolution, policy harmonization, and sustainable methodologies. Addressing these challenges is essential for maintaining the corridor's significance in European and international trade. Increasing awareness among European countries and international stakeholders has led to strategic partnerships and investments focusing on sustainable development of the corridor. Stakeholders aim to build a corridor that meets current trade demands and adapts to evolving international trade dynamics by establishing partnerships, improving infrastructure, and removing regulatory barriers [151].

5.4. Belt and Road Initiative and Its Transformative Impact on Black Sea Maritime Dynamics

Established in 2013, China's Belt and Road Initiative (BRI) is one of the most ambitious international infrastructure and economic development initiatives. By building a network of land and sea routes, the BRI aims to increase connectivity, encourage trade, and spur economic development across Asia, Europe, and Africa. The Black Sea region is a key focus area for the BRI's maritime ambitions, serving as a gateway for enhanced marine connectivity and trade between China and Europe [152].

The BRI has significantly altered the maritime dynamics of the Black Sea, creating alternative trade routes that complement traditional routes via the Suez Canal. These changes have heightened the region's strategic importance in international economic networks. Increased maritime traffic and trade volumes facilitated by the BRI have led to new trade routes in the Black Sea. Ports along the Black Sea coast, such as Novorossiysk, Varna, and Constanta, have become crucial transhipment centres handling the surge in goods traveling from China to Europe. This has driven economic growth and infrastructure development in these port cities.

China's investments in the Black Sea region, spurred by the BRI, offer significant economic opportunities. Infrastructure projects, including port expansion, railway enhancements, and logistics improvements, have boosted the economy and created jobs. The influx of funds has strengthened the economic resilience of Black Sea countries and improved maritime infrastructure [34].

5.5. Economic and Strategic Importance of the Black Sea Hinterland

5.5.1. Energy Transport

The Black Sea region is a pivotal corridor for energy supplies, crucial for Europe's energy security.
Oil and Gas Pipelines: Major pipelines in the region include:

- Druzhba Pipeline: Transports Russian oil to Central Europe.
- Blue Stream Pipeline: Delivers natural gas from Russia to Turkey.
- Trans-Balkan Pipeline: Facilitates gas transport from Russia to the Balkans and further into Europe.

Tanker Routes: The Black Sea is a key maritime route for tankers transporting oil and liquefied natural gas (LNG) from the Caspian Sea, Russia, and the Middle East to European markets [153].

5.5.2. Agricultural Exports

The Black Sea region, particularly Ukraine and Russia, is a major producer and exporter of grains and other agricultural products.

Grain Exports: Ports like Odessa and Novorossiysk are crucial for exporting wheat, barley, and corn. The region's agricultural output significantly contributes to global food security.

Supply Chain: Efficient transport from hinterland agricultural areas to Black Sea ports and onwards to Europe and global markets is essential, involving a combination of rail, road, and maritime transport [154].

5.5.3. Trade and Commerce

The Black Sea serves as a significant trade hub linking Europe with Asia and the Middle East. *Logistics Hubs:* Ports such as Constanța, Odessa, and Varna are developing into major logistics hubs, offering facilities for container handling, storage, and distribution. *Economic Zones:* Free trade zones and economic zones around these ports enhance their attractiveness for international trade by providing tax incentives and streamlined customs procedures [155].

5.5.4. Geopolitical Significance

The Black Sea region holds considerable geopolitical importance due to its strategic location.
NATO and EU Interests: The Black Sea is bordered by NATO and EU members (Bulgaria and Romania) and partner countries (Ukraine and Georgia), making it a focal point for Western security and economic policies. *Russian Influence:* Russia maintains a significant military and economic presence in the Black Sea, particularly through the port of Novorossiysk and the annexed Crimean Peninsula, affecting regional stability and energy route security [90]. *Conflicts and Stability:* Ongoing was, such as the one in Ukraine, impact the security of transport routes and supply chain stability in the region [134].

5.5.5. Infrastructure Development

Investment in infrastructure is crucial for maximizing the economic potential of the Black Sea hinterland. *Port Modernization:* Upgrading port facilities to handle larger ships and increased cargo volumes is essential. This includes deepening harbours, expanding container terminals, and enhancing logistics services. *Transport Connectivity:* Improving rail and road links from the hinterland to ports is vital for efficient cargo movement. Key projects include the modernization of the Pan-European Transport Corridors and the development of intermodal transport solutions. *Technological Advancements:* Implementing digital technologies for better port management, cargo tracking, and customs procedures can enhance efficiency and reduce costs [23].

5.5.6. Environmental Considerations

Environmental sustainability is a critical aspect of transport and logistics in the Black Sea region.
Therefore as done with other major water like SECA, same efforts are applicable to the black Sea. *Maritime Pollution:* Addressing maritime pollution through stricter regulations and the adoption of cleaner technologies for ships [156]. *Sustainable Practices:* Promoting sustainable practices in logistics and infrastructure development to minimize ecological impact, including the use of renewable energy sources and green logistics solutions [157, 158]. *Climate Change Adaptation:* Ensuring infrastructure resilience to climate change impacts, such as rising sea levels and extreme weather events, which can disrupt transport and trade [158].

The Black Sea hinterland holds significant economic and strategic importance, encompassing energy transport, agricultural exports, trade and commerce, geopolitical significance, infrastructure development, and environmental sustainability. Effective management and development of this region are crucial for enhancing its role as a vital transport corridor and economic hub linking Europe with the global market.

5.6. Challenges in Transport from the Black Sea to Central Europe

5.6.1 Geopolitical Issues

Conflict and Political Instability

Ukraine and Russia: The ongoing conflict between Ukraine and Russia has significantly disrupted transport routes and port operations, affecting local trade and global supply chains, especially for grain and energy exports.

Sanctions: Western economic sanctions on Russia hinder the flow of goods and complicate business operations with or within Russia.

Security Concerns: The Black Sea region is a hotspot for military activity, leading to blockades, shipping delays, and increased transport insurance costs [154].

Regional Tensions

Territorial Disputes: Disputes over territorial waters and exclusive economic zones impact maritime transport routes.

Political Alliances and Rivalries: Varying political alignments among Black Sea countries result in inconsistent regulations and policies, complicating cross-border logistics [75].

5.6.2 Infrastructure Development

Aging Infrastructure

Ports: Many Black Sea ports need modernization to efficiently handle larger vessels and increased cargo volumes. Outdated equipment and facilities lead to delays and higher operational costs.

Rail Networks: Several countries require upgrades to their rail infrastructure to meet modern standards, including better rail links and more efficient border crossings.

Investment Needs

Funding: Significant financial investments are necessary to develop and maintain transport infrastructure, which is challenging for countries with limited economic resources.

Public-Private Partnerships: Cooperation between governments and private investors is crucial for financing infrastructure projects, but political and economic instability can deter private investment.

Connectivity

Intermodal Transport: Efficient integration of rail, road, sea, and river transport is crucial. Lack of coordination between these modes leads to bottlenecks and inefficiencies.

Cross-Border Infrastructure: Differences in rail gauges, customs procedures, and regulatory standards across countries create logistical challenges and slow transport times [25].

5.6.3 Environmental Concerns

Pollution and Environnemental Impact

Maritime Pollution: Shipping activities contribute to marine pollution through oil spills, ballast water discharge, and emissions. Compliance with international environmental regulations like MARPOL is essential but costly.

Air Pollution: Transport activities, especially those relying on fossil fuels, contribute to air pollution, particularly in densely populated or industrial areas near ports and along transport corridors [158].

Sustainability

Green Transport Initiatives: There is growing emphasis on sustainable transport practices, such as using cleaner fuels, electrifying railways, and developing green ports. These initiatives require investment and technological advancements.
Climate Change: Rising sea levels and extreme weather, events pose risks to port infrastructure and transport routes, necessitating adaptation for resilience [159].

Regulatory Compliance
International Standards: Adhering to international environmental standards and regulations can be challenging, especially for countries with less developed regulatory frameworks.
Local Regulations: Varying environmental regulations between Black Sea region countries complicate compliance and increase operational costs for transport and logistics companies [119].

5.7. Short Sea Shipping Concept

The Short Sea Shipping Concept involves high-frequency liner shipping services that move standardized cargo units (like containers) over short distances along coastlines or between nearby ports, integrated with efficient inland transport connections. Some of the key aspects of the short sea shipping concept are the following:

High-Frequency Liner Services: Scheduled and frequent maritime transport services are crucial for integration into intermodal transport chains.

Short Distances: Operates over short sea routes within the same region or between nearby countries, avoiding ocean crossings.

Standardized Cargo Units: Focuses on transporting standardized cargo units like containers, facilitating efficient intermodal transfers between sea and inland modes.

Integrated Transport Chains: Highly integrated into door-to-door transport chains with efficient connections to rail, road, and inland waterways.

Modal Shift: Aims to shift freight from road transport to maritime and inland waterway transport, reducing congestion and environmental impacts.

5.7.1 Function of Short Sea Shipping in Hinterland Transport Connections

Short sea shipping significantly enhances hinterland transport connections between the Black Sea region and Central Europe:

Black Sea as a Maritime Gateway: Ports like Constanta in Romania serve as crucial gateways for landlocked Central and Southeast European countries, facilitating global maritime trade access.

Danube River Corridor: The Danube River links the Black Sea with Central European countries, integrating short sea shipping with inland waterway transport for efficient connectivity.

Rail and Road Connections: Emphasizes integrating maritime transport with efficient inland connections like rail and road networks, connecting Black Sea ports to Central European hinterlands.

Promoting Modal Shift: Integrates short sea shipping with rail and inland waterways to achieve a modal shift from road transport to more environmentally-friendly modes.

Despite significant challenges like infrastructure shortcomings, geopolitical issues, and environmental concerns, initiatives like the Short Sea Shipping Concept offer viable paths for improving connectivity, promoting modal shifts, and fostering sustainable development. Achieving the region's full potential requires strong governance, substantial investments in modern infrastructure, and cooperative stakeholder efforts, ensuring its continued prominence as a vital hub for international maritime trade.

Chapter Six

6. New Silk Road? Rising Alternative to Traditional Eurasian Trade Routes

6.1 Potential Alternative Pathways

The traditional route through Russia - a key pathway between the European Union and China for years, is facing challenges because the ongoing war between Russia and Ukraine, is continuously changing how countries in Eurasia connect. Consequently, alternative trade routes are constantantly tried and tested and are becoming more favourable. One promising option is the Middle Corridor, which starts from Turkey and passes through Central Asia and China via Georgia and Azerbaijan in the South Caucasus region (the Middle Corridor). This route offers a competitive distance between Western China and the European Union [32].

The Middle Corridor is a growing trade route because it connects China with Europe directly and provides a much-needed established alternative route. The existing Trans Caspian International Transport Route (TITR) utilizes the railway network of the New Eurasian Land Bridge (EURASIA), emerging options aim to improve and diversify this corridor's infrastructure but this can only be realised with heavy investments in ferries on the Caspian Sea and enhanced efficiency that can accommodate larger cargo volumes and reducing transit times. These ferries must also enable connections between ports on the Caspian Sea, allowing for frequent shipments. Expanding railway networks in Central Asia and the South Caucasus would further strengthen connectivity making upgrading existing rail lines and building new imperative. This would provide direct and efficient rail transport options, decrease reliance on road transportation and improve overall transit times [160].

In other words, by expanding its infrastructure and transportation alternatives, the Middle Corridor can boost its resilience, compete effectively, and cater to a variety of cargo and trade requirements. Some of these are mentioned in coming subsections.

6.1.1. The New Silk Road

The New Silk Road is a promising trade route that provides an alternative to the East-West routes through Russia. This route goes through Central Asia, the Caspian Sea, and the Caucasus Mountains, offering a connection between China and Europe without the disruptions or political tensions of the Russian path. The journey starts in China, passes through Kyrgyzstan, Uzbekistan, and Turkmenistan, and reaches Turkey via Iran. Once in Turkey, goods seamlessly integrate into Europe’s transportation network and eventually reach destinations in central and Western Europe. The journey from China to Europe typically takes 10 to 15 days by rail, depending on specific start and end points [161].

6.1.2. Central Middle Corridor

Another promising option for trade between China and Europe is the Central Middle Corridor, which bypasses routes through Russia. This alternative path goes through Central Asia, the Caspian Sea, and the Caucasus Mountains. The journey starts in China, passes through Kyrgyzstan, Uzbekistan, and Turkmenistan, and reaches the Caspian Sea. Specialized ships then transport cargo across the Caspian to Baku, Azerbaijan. From Baku, the cargo is transferred to trains that pass through Georgia or Turkey via the Caucasus Mountains to finally reach ports on the Black Sea in Romania or Bulgaria, where

goods integrate into Europe's transportation network [162]. The Central Middle Corridor typically takes around 20 to 25 days, which is faster than many maritime routes but slightly longer than the New Silk Road rail route.

6.1.3. Trans-Caspian International Transport Route (TITR)

The Trans-Caspian International Transport Route (TITR) emerges from Central Asia, connecting China and Europe through Kazakhstan, the Caspian Sea, Azerbaijan, Georgia, and Turkey. This alternative route provides a path between these two powerhouses while avoiding potential disruptions and geopolitical complexities along the traditional Russian route [63].

Like others, the journey starts in China, traversing Kazakhstan. Cargo then embarks on a voyage across the Caspian Sea, the largest inland body of water on the continent. Ships connect ports like Aktau in Kazakhstan to maritime hubs such as Baku in Azerbaijan. Upon reaching the Caspian Sea's shores, cargo transitions to rail transportation for a journey through Georgia, linking Azerbaijan's ports with Turkey's Black Sea coast. One option for reaching Europe is leveraging Turkey's land transportation network, which connects its Black Sea ports with European cities, providing a smooth link between the Middle Corridor and central and Western Europe [24].

The Marmaray Tunnel, a railway tunnel beneath the Bosporus Strait, connects Istanbul's European and Asian sides, easing rail cargo movement between continents. Additionally, existing rail bridges and ferries across the Black Sea provide efficient routes for goods between Turkey and Europe. Turkey is also investing in the Kars-Tbilisi-Baku railway line, which will directly connect China with Europe through Turkey, Georgia, and Azerbaijan. By utilizing Turkey's land transportation network and investing in infrastructure development, connectivity with Europe can be enhanced, making this route more appealing for businesses and shippers [163].

6.2. Assessment of Accessible Pathways

Assessing a trade route involves analysing factors that determine if the chosen path is feasible and efficient. Geography plays a significant role in this case, as the landscape and terrain can greatly affect transportation logistics. The logistics infrastructure, including modes of transportation and connectivity, is crucial for ensuring smooth movement of goods. Geopolitical factors, like stability and international relationships, are crucial for managing risks associated with the route. The presence of infrastructure such as roads, railways, ports, and other facilities also affects the route's capacity and effectiveness. Evaluating time and cost implications is necessary to understand if the route is economically viable and competitive [164].

6.2.1. Geopolitics

The role the geopolitical factors play in assessing the feasibility of any trade route is largely dependent on the political stability and cooperation of such region because strengthening ties and fostering collaboration among involved countries can greatly enhance the corridor's competitiveness and attract businesses. In the case of the Middle Corridor, maintaining political stability is essential to keep the route open for trade as any conflicts or disruptions could affect the flow of goods, causing delays and increased expenses. This is why the geopolitical aspects of a trade route take precedence when considering routes alternative to the Russian path especially. Regional cooperation is also vital for operating the Middle Corridor; for instance, coordinating customs procedures, developing infrastructure, and establishing logistics standards across the region are necessary for efficient operations [8].

Apart from the Russian issues, insecurity due to instability and sanctions in Iran further raises concerns about transit security along the New Silk Road. The risk of disruptions, delays, or seizures of goods due to unrest or security issues may discourage businesses from using this route. Additionally, sanctions usually create incentives for smuggling or diverting goods for illicit purposes. Worst still, international concerns persist over Iran's nuclear program, complicating the viability of the New Silk Road as a trade route [165].

In any case, despite the tensions between Azerbaijan and Georgia over the Nagorno-Karabakh conflict, both countries have improved their relations in recent years, creating opportunities for trade and transportation, including using the TITR to transfer cargo between China and Europe. Azerbaijan and Georgia have invested in upgrading their railway networks and ports and cooperating on customs procedures and border security [166].

6.2.2. Logistics

Geographical Features

Investments aimed at improving navigation and port facilities along the Caspian Sea can enhance trade opportunities and reduce reliance on land transportation through the Pamir Mountains. However, for this to actively take place, regional stakeholders need to engage in strategic planning and collaboration to overcome geographical barriers and establish a strong infrastructure network that supports economic growth and trade in Central Asia [167].

To start with, the challenging terrain of Tajikistan, especially mountainous regions like the Kunlun, Himalayan, Tianshan, and Pamir Mountain ranges, makes it difficult and expensive to develop infrastructure. With around 90% of its land at elevations ranging from 1,000 to 25,000 feet, constructing and maintaining roads, railways, and other infrastructure will be a significant undertaking. Additionally, harsh weather conditions, including extreme temperatures, heavy snowfall, and frequent storms, complicate construction activities and increase the risk of infrastructure damage.

The terrain between Tajikistan and Uzbekistan, particularly the Pamir Mountains, poses significant obstacles for infrastructure development as well. These mountains, with peaks over 24,000 feet, create barriers to building roads, railways, or any other necessary infrastructure. The rugged terrain and steep slopes add complexity and high costs to excavation and construction processes. Georgia's topography, characterized by peaks and deep valleys, makes infrastructure development challenging. However, existing routes around or through these mountains have enabled trade connections between Georgia, the Black Sea coast, and Turkish transport infrastructure.

Despite the challenging terrain, these routes have proven to be effective trade corridors due to their strategic positioning and meticulous planning. The use of tunnels, bridges, and specialized vehicles has facilitated the movement of goods across this landscape, promoting trade connectivity between Georgia and its neighbouring regions [168].

Infrastructure

Connecting China with Europe through Tajikistan, Uzbekistan, and Turkmenistan faces hurdles due to existing railway infrastructure and the regions' topography, characterized by mountains, deserts, and rivers, further present obstacles for new rail construction.

The Tien Shan Mountains, spanning Tajikistan, Uzbekistan, and Kyrgyzstan, are known for their towering heights that make railway construction costly and time-consuming. Existing railways are often narrow gauge and slow moving, which is inadequate for transporting heavy cargo. Desert landscapes like the Karakum Desert in Turkmenistan pose additional challenges, requiring specialized techniques. Existing rails within the Karakum Desert are typically narrow gauge and poorly maintained. Crossing

rivers like the Amu Darya and Syr Darya presents further challenges, requiring costly bridge construction and engineering skills [169, 170].

Still, upgrading or expanding the railways is necessary to handle the expected cargo volume along the Middle Corridor. For example, Kazakhstan has an opportunity to upgrade its railway infrastructure along the Eurasia Route to Astana that will enable the route to handle high cargo volumes between China and Europe. The country's railway network links cities like Astana and Aktau, serving as a crucial corridor for freight movement. Enhancing the connection between Astana and Aktau especially is particularly important since Aktau serves as a gateway to Europe via the Caspian Sea. By expanding and improving the Port of Aktau, Kazakhstan can facilitate the transit of goods from China to Europe through the Caspian Sea. These measures can solidify Kazakhstan's position as a transit hub for the Middle Corridor and take advantage of the growing trade demand between China and Europe [171].

Similarly, leveraging existing railway infrastructure that connects Georgia, Azerbaijan, and Turkey, alongside Turkey's developed road network, can ensure the transfer of cargo between China and Europe. With the expected surge in cargo volume from increased manufacturing in China, Georgia and Kazakhstan must enhance their port capacities [166].

Voyage Costs

In their work, Çolakoğlu [172] gave the total expense of traveling along the trade route from China to Europe through Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, Azerbaijan, Georgia, and Turkey varies based on several factors, including the type of cargo, the chosen route, and the mode of transportation. Generally, this route is more cost-effective compared to the route through Russia. Here a breakdown of the costs for transporting goods along this trade route is given:

- Railway: The average cost for railway transport ranges from $0.70 - $1.00 per ton-kilometre. In contrast, transporting goods by rail through Russia typically ranges between $1.20 and $1.50 per ton-kilometre.
- Truck: The average cost for truck transport ranges from $0.80 - $1.50 per ton-kilometre compared to $1.00 - $1.70 per ton-kilometre truck transport through Russia.
- Ship: The average cost for ship transport ranges from $0.20 - $0.50 per ton-kilometre, making it the most economical option for long-distance cargo shipments.
- Note that shipping expenses can vary based on departure and destination ports and the time of year. Additional factors that influence the cost of transporting goods along this route include:
- Cargo Volume: Transportation costs decrease as cargo volume increases because shipping companies can distribute fixed costs over more shipments.
- Customs and Duties: Fees can vary based on the specific goods and countries involved, affecting overall transportation costs.
- Insurance: Insurance to protect goods from loss or damage during transportation varies based on the value of the goods and desired coverage level [172].

The most effective way to redesign the EURASIA route involves passing through Kazakhstan, crossing the Caspian Sea to Azerbaijan, then through Georgia, and using the land route via the Marmara Tunnel in Turkey to reach Europe. This route requires infrastructure improvements between Astana and Aktau in Kazakhstan and increased port capacities in Aktau and Baku. Despite these requirements, this route remains superior to the other available two alternatives: a. constructing new infrastructure or b. facing geopolitical challenges on other routes. Leveraging Turkey's developed road network and the Marmara Tunnel assure efficiency in terms of time and cost. Additionally, using the Black Sea as a transportation hub allows shippers to optimize delivery schedules and reduce transit times, leading to improved overall supply chain efficiency.

This strategic route will establish a hub for transporting China’s mass production to markets beyond Europe, extending to Southeast Europe, the Middle East, and North Africa. This route simplifies logistical processes and positions Turkey as a crucial gateway for international trade and connectivity. Additionally, bypassing cargo-handling processes at ports in Georgia, Romania, and Bulgaria significantly improves the efficiency of the transportation network [173].

6.3. Transport Market between Turkey and Europe

Since 2020, there has been a logistics center in Kars connected to the rail network via a 7 km Long Branch line. The center has 19 tracks over 0.4 square kilometers, with container handling and storage areas. Trains designed for both Russian broad gauge and standard gauge can transfer goods between wagons at this hub. Customs clearance is also performed here. In 2019, Turkey's rail freight transport volume increased by 10% to over 38 million metric tons. A railway line runs from Kars to Ankara, passing through Erzurum, Erzincan, Sivas, Kayseri, and Kirikkale, covering 1,450 kilometers.

A high-speed railway from Sivas to Ankara has been operational since April 2023, reducing travel time from 9.5 hours to 2 hours and 50 minutes. Ankara, a key hub for the rail corridor, connects east and west Turkey with six platforms and thirteen tracks at its station. Using the high-speed line from Ankara towards Istanbul, the route from Sivas to Istanbul takes around 7 hours. This line is part of the east-west corridor from Istanbul to Baku and can also be used for freight transport [174].

The 562 kilometers from Ankara to Istanbul can be covered using either the high-speed railway or the parallel Ankara-Istanbul railway. The Marmaray line, a 77-kilometer underground commuter rail, links Gebze on the Asian side to Halkalı on the European side of Turkey. This tunnel, opened in March 2019, allows a high capacity of freight rail, integrating with the high-speed train network from Ankara for quick passage across the Bosporus Strait. However, freight trains are only allowed to pass at night between 1 a.m. and 5 a.m. due to passenger train operations during the day [173].

The first freight train passed under the Bosporus Strait in 2019, starting in Xi'an, China, and reaching the European side of Istanbul in roughly 12 days, traveling 11,840 kilometers through China, Kazakhstan, Azerbaijan, Georgia, and Turkey via the Middle Corridor. Previously, this journey took a month before the new railway lines and improvements.

6.3.1. Transport via Road

In this stance, Turkey occupies a strategic position and poise to becoming a central player in both regional and global integration. Critical energy, trade, and transportation networks link the west to the east and the north to the south, unlocking this potential. Recent economic and political shifts in neighboring regions that includes the Balkans, the Black Sea, the Mediterranean Basin, the Caucasus, Central Asia, and the Middle East, underscore Turkey's increasing importance.

Due to historical neglect of railway and maritime infrastructure, road transport has become the predominant choice for door-to-door transportation in Turkey, leading to a concentration of both freight and passenger transport on the road network.

However, overreliance on road transport introduces imbalances where issues such as congestion, environmental drawbacks, and border crossing challenges, road taxation, traffic restrictions, permit shortages, and customs limitations highlight the vulnerabilities of this dependence. To address these concerns and enhance sustainability, Turkey must implement intermodal transport solutions that offer swift results while preserving the advantages of its competitive road transport system. Turkey has significant potential, with various projects underway to advance intermodal transport initiatives. This is why in recent years the country has been seen committed to addressing this imbalance by prioritizing and investing in other modes of transportation [175].

6.3.2. Transport via RO-RO

Ro-ro transport (roll-on/roll-off) exhibits two primary characteristics. Firstly, it operates as an intermodal mode of transportation, moving goods within a single loading unit or vehicle through successive modes without handling goods during transitions. Secondly, it functions as a Short Sea Shipping (SSS) scheme, alleviating congestion on road networks [176].
Ro-ro transport stands out due to its:
Flexibility: Ro-ro vessels handle freight flexibly, transporting trailers that can be promptly moved upon reaching the destination port without special handling, leading to cost savings and reduced risk of freight damage.
Speed: Ro-ro vessels, being faster than other cargo ships, increase navigation frequency and reduce delivery time, critical for trade involving valuable goods.
Labour Efficiency: Ro-ro transport requires less labor compared to other cargo ships, as the vessels carry trailers with various commodities.
Short-Distance Shipping: Ro-ro is primarily used for short-distance shipping, distinguishing it from container ships used for long-distance shipping.
Given these features, ro-ro transport constitutes a distinct market compared to other types of maritime transport [177]. Several Ro-Ro lines operate between Turkey and Europe such as the following:

- UN Ro-Ro: Routes from Turkey (Izmir, Istanbul, Mersin) to various European ports (Trieste and Bari in Italy, Toulon in France) [178].
- Marmara Lines: Routes from Istanbul (Ambarlı Port) to Trieste in Italy [179].
- DFDS Seaways: Routes from Istanbul (Pendik Port) to Trieste in Italy [180].
- Grimaldi Lines: Routes from Istanbul (Ambarlı Port) to various European ports [181].
- EML European Seaway: Routes from Istanbul (Ambarlı Port) to Trieste in Italy [182].
- Corsica Linea: Routes from Istanbul (Ambarlı Port) to Marseille in France [183].

6.3.3. Transport via Rail

Turkey's railway network, predominantly single-tracked is concentrated on a few major routes, limiting availability to certain areas and cities. However, Turkey has prioritized railways in recent decades, resulting in significant investment and a new rail transport policy for both passenger and freight transportation.

The Ankara–Kars Railway: Extending 1,446.1 km, this is Turkey's longest railway line. Originating in Ankara, it traverses Kırıkkale, Kayseri, Sivas, Erzincan, and Erzurum, reaching Kars. While primarily single-track, sections in Ankara, Kayseri, and Sivas are multi-tracked. Notably, 652 km of the line is electrified with ongoing projects to complete the remaining sections. This railway is vital for freight, intercity, and regional passenger trains, including the Eastern Express, Southern Kurtalan Express, and Van Lake Express. The Ankara–Sivas high-speed railway runs parallel between Ankara and Yerköy, enhancing connectivity and service speed [184].

The Sivas-Erzincan-Erzurum-Kars Railway: Known as the Eastern Anatolia Railway Project, this initiative aims to improve connectivity in eastern Turkey, fostering both passenger and freight transportation. Key features include:

- Sivas to Erzincan: Improved transportation links between these two cities.
- Erzincan to Erzurum: Extending the rail network further east.
- Erzurum to Kars: Enhancing connectivity in the eastern part of Turkey.

The project boosts regional development, facilitates efficient transportation, and contributes to the overall economic growth of the eastern provinces.

Chapter Seven

7. Green Transport Corridors: An Introduction

7.1. The Role of Green Transport Corridors in Transforming European Freight Logistics

Climate change and environmental concerns have become top priorities on the public agenda, driving governments worldwide to seek new strategies to mitigate the environmental impact of economic activities [185, 186]. In the realm of green transportation for large-volume cargo, the European Commission has been promoting the concept of Green Transport Corridors (GTC). The aim is to shift substantial cargo volumes away from dominant road traffic to more efficient and environmentally friendly transport modes. As straight forward as this might sound it is actually complicated owing to the fact that in the logistics processes are not fully internal due the interconnected nature of global trade often involves multiple ports and transshipment points, requiring a combination of internal and external logistics processes to ensure smooth goods flow throughout the entire value chain [187].

The concept of GTC was first introduced in the Transport White Paper in 2001, later revised in the EU Transport White Paper in 2006, and preannounced in the Freight Transport Logistics Action Plan [e.g. 188, 189, 190]. GTC emphasizes 'an integrated transport concept where short sea shipping, rail, inland waterways, and road complement each other to offer environmentally friendly transport options.' Further details were provided in the Green Paper on TEN-T from 2009, the TEN-T Policy Review in 2011, and the EU White Paper on 'A Sustainable Future of Transport' from 2011. In these documents, the European Commission solidified the GTC concept by establishing trans-shipment routes that concentrate freight traffic between major hubs over relatively long distances. These routes are designed to reduce environmental and climate impact while enhancing safety and efficiency through sustainable logistics solutions [191].

Since the Green Transport Corridor (GTC) concept was defined at the political level, the European Union has promoted several GTC initiatives to implement different models and evaluate their performance. The Baltic Sea Region (BSR) has been pivotal in realizing these initiatives, becoming the most experienced European region for GTCs. Notable projects in the BSR include the "East West Transport Corridor" (EWTC), which links the Southern Baltic Sea and the Black Sea, and the Rail Baltica Growth Corridor (RBGC), connecting the Baltic States with Central Europe's rail system.

Despite varying interpretations of green transportation across different GTC initiatives, some common themes emerge. First, co-modality allows the choice of environmentally friendly transport options, with reduced emissions being a key objective [192, 193]. Second, essential factors for green transport include high-performing trans-shipment facilities, innovative transport units and vehicles, and advanced ITS applications. These components are crucial as customers expect both environmental benefits and economic advantages in terms of cost and time savings [194, 195].

Moreover, GTCs address broader issues such as entrepreneurial growth and cluster development, central to most projects [196]. Schröder & Prause [197, 198] explored the GTC concept under risk management, extending it to include risk assessment for transporting dangerous goods. Additionally, all GTC initiatives emphasize fair and non-discriminatory access to corridors and trans-shipment facilities so that cooperative governance and ownership models are suitable for managing GTCs [199].

The GTC initiative in the BSR has generated substantial empirical data on sustainable logistics solutions, inter-modality, ICT infrastructure, and strategically placed trans-shipment nodes. This data has laid the foundation for theoretical models of GTCs, focusing on sustainability, multimodality,

networks, and green supply chain concepts, all within the framework of common and open legal regulations [200, 201].

A landmark initiative, a Swedish Logistics Forum's green corridor project, which began in 2008 and included around 30 local green transportation projects highlighted and defined green corridors as corridors created to reduce environmental and climate impact while improving safety and efficiency. They outlined six key characteristics of a green corridor, aligning with the European Commission's definition [202]:

- Sustainable logistics solutions with documented reductions in environmental and climate impact, high safety, quality, and efficiency;
- Integrated logistics concepts that optimize the use of all transport modes (co-modality);
- Concentration of national and international freight traffic on relatively long transport routes;
- Efficient and strategically placed trans-shipment points, supported by an adapted infrastructure;
- Harmonized regulations with openness to all actors;
- A platform for developing and demonstrating innovative logistics solutions, including information systems, collaborative models, and technology.

The above points (1) to (4) pertain to the core tasks of a green corridor, while points (5) and (6) address its internal structure, focusing on business and governance models that emphasize openness, harmonization, and collaboration.

The requirements for an integrated ICT system for GTCs, drawing on major BSR initiatives must meet seven key requirements [196, 201]:

- Open architecture;
- Adherence to standards;
- Focus on interoperability and co-modality;
- Independence from specific technologies;
- Endorsement by major freight ICT system providers and logistics operators;
- Support for the European transport and logistics system's efficiency and environmental goals;
- Creation of a fair and balanced transport spot market within the corridors, facilitating interaction between market leaders and SMEs at low costs.

Openness, standards, and fairness are critical to the success of GTC initiatives. Particularly, the last point emphasizes the need for a democratic and collaborative approach in the GTC information ecosystem, ensuring that all logistics players, including global giants, integrate their closed ICT systems into a common logistics platform. This would require major logistics players to share some market power, benefiting smaller companies.

Cooperative issues are crucial for GTC success, as reflected in the literature. For example, Prause [203] developed a GTC balanced scorecard that highlights cooperation and soft logistics aspects, such as political and cultural issues, including transparency and trust as key success factors. The European Cooperative Society (SCE) legal form in this case is a promising structure for organizing GTCs, due to its democratic governance, openness, and cooperative focus, aligning well with the needs of GTCs [199]. SCEs can ensure good governance in a multi-stakeholder environment and support the strategic vision of GTC entities.

However, a significant barrier to implementing green corridor ICT systems is the political sensitivity of creating open databases with freight tariffs and contracting conditions, which are necessary to build transparent spot markets. This challenge requires specific incentives to encourage major logistics players to participate in GTCs.

Beyond technical issues, the BSR's GTC results reveal that political and cultural factors are crucial for the acceptance and success of the green corridor concept. Transparency, cooperation, and trust are essential preconditions for implementing green corridor ICT systems [203]

The governance and management format of a corridor should reflect its agenda's scope. The legal structures available for a corridor should be based on existing EU standards, as all GTC projects involve multiple EU member states. The SCE cooperative business and ownership model is particularly promising for organizing corridors due to its democratic construction, openness, and flexibility. Further benefits include easy implementation, low integration costs, and scalability. While issues associated with cooperatives and SCEs, such as non-transparent relations to national law, slow decision-making, potential financing challenges, and internal conflicts, may arise, they have only a neutral or slightly negative impact on GTCs and can be mitigated by experienced management.

GTC entities structured as SCEs can ensure financial stability and good governance, while aligning with the strategic goals of Green Transport Corridors. Public sector involvement from participating countries helps balance public good and business benefits for corridor stakeholders. Potential conflicts do not pose significant obstacles to successfully implementing the SCE as a business model for the Information Broker cooperative.

7.2. Cases of Green Transport Corridors

EWTC II – The East West Transport Corridor II: This corridor links Denmark, Sweden, Germany, Lithuania, and Russia in a network. The corridor runs from Esbjerg in western Denmark across the Great Belt Bridge and from northeastern Germany across the Baltic Sea to Karlshamn in Sweden, then via the Baltic Sea to Klaipeda in Lithuania, and further on to Moscow or Belarus, extending to Central Asia. It is mainly land-based, utilizing intermodal train solutions and sea-based options across the Baltic Sea [4].

Scandria: The Scandria corridor, adjacent to the SoNorA corridor, covers the area from southwestern Norway and southeastern Finland via Sweden (Region Halland and Region Skåne) to Berlin/Brandenburg in Germany. Currently, it is mainly a road-based corridor supplemented with ferries/bridges when crossing the Øresund and Femern, but with potential for more intermodal rail, particularly in the German section.

TransBaltic: The TransBaltic initiative focuses on improving the transport system around the Baltic Sea, involving core partners from Norway, Sweden, Denmark, Germany, Poland, the Baltic States, and Finland.

*NECL II – The North East Cargo Link II***:** This project aims to develop and promote a Midnordic Green Transport Corridor as a cost-effective and environmentally friendly transport route, involving partners from Norway, Sweden, Finland, and Russia.

SuperGreen: This FP7 project, supported by the European Commission (DG-TREN), promotes the development of European freight logistics in an environmentally friendly manner and evaluates a series of 'green corridors' covering representative regions and main transport routes throughout Europe.

BSR Transport Cluster: This Baltic Sea umbrella project for sustainable, multimodal, and green transport corridors serves as a platform for the entire Baltic Sea Region to develop a coherent concept for sustainable macro-regional transport and regional growth policies at the European level.

According to Kusch et al. [4], the East-West Transport Corridor is one of the most important GTCs in the BSR. EWTC aims to improve East-West trade routes between the Baltic Sea and the Black Sea Region by enhancing interoperability between different infrastructures, standards, and systems, as well as by removing physical and operational bottlenecks, especially at borders. The participating countries include Sweden, Lithuania, Belarus, and Ukraine, with Denmark and Germany as adjoining countries. EWTC can be considered the north-western part of the Transport Corridor Europe-Caucasus-Asia (TRACECA), attracting new freight flows from Central Asia and China to Europe, with a focus on rail transport and short sea shipping. The backbone of the corridor is the container train Viking, which

shuttles between Klaipeda and Illichevsk via Minsk and Kiev. The Viking train is linked to Karlshamn in South Sweden by a ferry line and from Illichevsk via short sea shipping routes to destinations in the Black Sea.

Integrated ICT systems that coordinate and organize activities in a GTC play a crucial role in the systems 'performance [201]. Consequently, different GTC initiatives in the BSR defined and implemented integrated ICT systems. The ICT system of the East-West Transport Corridor is called Information Broker, developed based on the theoretical considerations of Inger Gustafsson and the Swedish Logistics Forum on green corridors [204]. Based on expert interviews and surveys conducted during the EWTC II project, 15 features of the Information Broker were elaborated to ensure efficient and greener transport in the GTC, including:

1. Improving load factors
2. Using digital waybills
3. Intelligent truck parking for finding safe parking areas
4. Reduced waiting times at transfer nodes
5. Up-to-date traffic information
6. Automatic Identification System (AIS) data about ship locations and estimated time of arrivals
7. Access to up-to-date local weather data
8. Better matching of broadcasted transport information
9. Facilitation of intermodal transports
10. Easing of small cargo shipments by rail and sea
11. Reducing idle costs by sharing transport units
12. More efficient management of transnational oversized cargo transports
13. Intelligent Port Access Control
14. Implementation of data exchange between major transport hubs
15. Improved cargo tracking.

A preliminary examination of these 15 points reveals that the list includes not only the main features of classical ICT systems in logistics and supply chain management but also highlights new technical issues such as safe truck parking, sharing transport units, tracking cargo and ships, and managing oversized transports. Overall, the EWTC II ICT concept aims to provide solutions for the surface transport industry to reduce costs while ensuring system functionalities are open, standardized, secure, multi-purpose, real-time visible, scalable, and extendable. Given the investment needs and operating costs related to the implementation and operation of the Information Broker ICT system, a suitable business and ownership model is necessary to optimize its contribution to the goals of the East-West Transport Corridor.

The governance models of cooperatives should be analysed in the context of GTC requirements. Prause [203] highlighted that cooperation intensity and quality are crucial success factors for GTC performance, where cooperation quality includes soft factors such as openness, trust, and a low conflict level. These cooperation soft factors receive higher attention in the democratic environment of a cooperative than in an investor-owned company. The weak points of a cooperative business model emerge in areas such as investments, cooperative management, and production control.

In other words, GTCs require significant investments in strategic infrastructure and operating objects. Additional issues include the horizon, product portfolio, and "free rider" problems. Cooperative management for GTCs can be challenging due to the large number of tentative members from different countries, varying company sizes, and different backgrounds and aims, as GTC stakeholders consist of public and private institutions as well as NGOs. Lastly, the production control problem can create issues in a GTC context, given that different actors from various countries with different economic conditions

must be aligned. For example, in the case of EWTC, institutions from both within and outside the EU, and players from lower and higher-income countries, cooperate, potentially leading to conflicts due to incomparable price levels and quality standards.

7.3. Green Transport Corridors in Eurasia

Adapting the Green Transport Corridor (GTC) concept to the Eurasian transport system requires an in-depth analysis of the socio-economic context, existing transport infrastructure, business and ownership models, and stakeholder interests. Cross-border corridors necessitate a co-production of policy among municipalities, regional authorities, and national governments to reconcile differences in regulation and policy practices across nations [205]. This way multi-level governance, policy co-production, and multi-actor systems provide valuable frameworks for overcoming these challenges. Moreover, the rise of public-private partnerships, the growing involvement of NGOs in policy-making, and the increasing influence of market principles in public service sectors all emphasize the importance of multi-actor governance [206].

Before and following the Ukraine-Russian war, several scholars [e.g., 3, 5, 207] who explored the development and integration of Eurasian transport networks with a strategic focus on Russia concluded that identifying alternative Eurasian transport routes—particularly the Caspian Sea–South Caucasus–Black Sea route, known as the "Middle Corridor"—is a key solution to many geopolitical challenges. Thus, effective governance structures for the cross-country, multi-actor, and public-private stakeholders involved in a GTC require a regulatory framework that supports multi-level governance in a democratic environment, grounded in transnational regulations [208, 209]

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