The history of oil transportation logistics: the experience of interaction between water and rail transport

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Abstract. The paper reveals the historical aspects of the use of unique schemes for the delivery of oil cargo. The authors also consider the experience of modern transport and technological systems for oil transportation, developed by the expansion of logistics tools and principles of logistic. The study of schemes for the transportation of petroleum products in polymodal transport systems in a historical context gives the idea of the uniqueness of certain methods of cargo delivery. The modern development of logistics, technologies and infrastructure in the supply of oil and cargoes demonstrate a completely different level of industrial and environmental safety.

1 Introduction

Oil cargo is one of the main cargo classification traditionally transported by rail in land transportation and by ships in water transportatiob. In land transportation, pipeline and road transport compete with rail transportation.

However, each of the modes of transport has both its own advantages and disadvantages. The combination of various types of transport allows building efficient logistics for oil transportation.

Oil and petroleum products were originally transported in barrels, but their small volume made transporting in barrels quite expensive. In 1865 one of the first railroad vessels, the Densimore brothers' cistern (Figure 1), consisted of two large wooden barrels. In 1869, the first horizontal rail tank wagons appeared (Figure 2). Special vehicles for the delivery of goods in barrels appeared (Figure 3), but this does not yet significantly reduced the cost of transportation.

Traditional barrels had an important advantage - they were easy to handle by loaders, but they had a relatively small volume and this type of delivery was expensive.

The aggravation of interclass contradictions in capitalist countries at the end of the 19th - beginning of the 20th centuries, resulting in the increase in the number of strikes and locking of transport highways and junctions, led to a gradual transition of the transportation of oil cargo in land communication from small shipments (in barrels) using cars and railways transport to the use of special rolling stock of railway transport.

The critical vulnerability of economy and its dependence on the stability of transport, which could have been stopped by the action of a relatively small number of strikers, also pushed the industry to develop alternative transportation options and the interaction of modes of transport - polymodal logistics. In the USSR, the development of pipeline transport, due to the absence of a strike aspect, was determined exclusively by its increased productivity and efficiency of pipeline transport in comparison with other countries. However, military factors, as it is shown below, have led to an atypical use of the capabilities of various modes of transport.

The high costs of transshipment and transportation of oil cargoes in barrels pushed the transport towards the construction of special vessels - tankers.

In 1878, the Nobel Brothers Partnership built the first oil tanker Zoroastr in the world, with a carrying capacity of 242 tons. It was used to deliver kerosene from Baku to Tsaritsyn (now Volgograd) and Astrakhan (Figure 4). Onshore, the search for ways to decrease dependence on strike traffic and reduce unit transport costs led to the development of pipeline transport. However, force majeure and military needs led to the emergence of atypical forms of organization of transportation.

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Figure 1. Densimore brothers railway tank wagons, 1865 [1]

Figure 2. First horizontal rail tank wagons, 1869 [1]

Figure 3. Frenchbarreltruck[3]

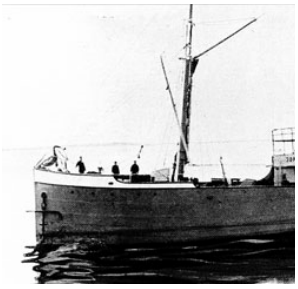

Figure 4. The first oil tanker "Zoroaster" in the world

2 Problem statement

Nowadays the bulk of oil cargo is transported by sea. The oil from the fields to the ports is delivered using both rail and pipeline transport.

In the last decade there was a decrease in the dynamics of loading in the market of rail transportation of oil cargo due to the introduction of new pipelines.For example, one of the reasons for the decrease in the loading of oil cargoes on the North Caucasian Railway (in the structure of the loading of the road the share of oil and oil products amounted to 25.8% in 2020) compared to last year is the termination of the supply of wheeled oil from the oil loading racks of PJSCTransneft to the Ilskiy Refinery in connection with the commissioning at the end of 2019 of the Novovelichkovskaya - Krasnodar pipeline for pumping medium-sulfur oil to the refinery. A significant decrease in shipments of wheeled oil has also been noted since May 2020, as a reduction in the production program of the refineries during an unfavorable price environment and a drop in demand as a result of the pandemic led to a decrease in demand for raw materials.The enterprises that use a mixed scheme of the supply of raw materials using pipeline and railroad transport (KrasnodareconeftJSC) lose the need to obtain wheeled oilat a significant drop in production volumes since the entire volume of raw materials can be supplied by pipeline transport. The same downward trend in loading is observed on other roads.For example there was a drop in the cargo base in the amount of 6 million tons due to the connection of the Khabarovsk refinery [4].

There is also a significant decrease in the production of petroleum products due to unfavorable market conditions and a decrease in the availability of light raw materials in the context of a decrease in oil production as part of the OPEC deal.

Thus, it is necessary to note that in recent years, pipeline transportation has strengthened its position in the implementation of the delivery of petroleum products and therefore competed with railway transport. According to experts, the decrease in loading was expected.Thus, in 2020 in the Russian Railways networkit amounted to 1 billion 243.6 million tons in general, which was 2.7% less than in 2019, while oil cargo occupied a fairly large share in the market ofrail transportation (Table 1).

Table 1. Dynamics of loading on the network of JSC Russian Railways

	2019	2020	Dynamics, %
Loading (million tons)	1278.2	1243.6	-2.7
Coal	372.0	353.3	-5.0
Oil and petroleum products	232.0	208.8	- 10.0
Construction cargo	124.0	131.6	+ 6.1
Iron and manganese ore	120.2	119.7	-0.4
Black metals	73.8	66.4	-10.0
Others, including cargo in containers	356.2	363.7	+ 2.1
Freightrate (billion, tariff ton-km)	2601.9	2544.4	-2.2

Wars always cause a forced burst in the development of technology including transport industry.There is no doubt that the methods used in these conditions are not safe and environmentally friendly from the point of view of modern requirements. However, the ideas themselves can be developed and used today.

It is impossible to imagine the modern development of economy without oil and petroleum products. The rhythmic and efficient operation of industrial enterprises and national economy directly depends on their timely and uninterrupted supplies. Therefore, logistics transport schemes for the delivery of petroleum products are becoming important. A number of scientific research in this area are devoted to the study of the logistics of transportation of this classification of goods,

including Chebotareva E.A., Sergeeva O.M., Annenkova A.V., Kalushina A.A., Egorova A.B., Zhitineva P.Yu., Zhuravlevoy N.A. The variety of delivery schemes and their diversification over the decades is another aspect of the ongoing scientific research.

The transport industry should be more resistant to the consequences of any economic, geopolitical shocks, since it is one of the most important, strategic sectors of economy. In this regard, it is advisable to consider the schemes and features of the transportation of petroleum products in the historical context and under various economic, political and other conditions.

3 Materials and methods

The paper presents the results of a retrospective analysis of various options for the organization of the transportation of oil cargo during the Great Patriotic War in the USSR, when the technologies of various types of transport were used as much as possible for front line missions.

From the first days of the Great Patriotic War, oil Baku had been constantly supplying the front line with oil and petroleum products. About 80% of fuel was used to refuel aircraft and Soviet tanks. During 1941, 57 enterprises and installations of oil refining, petrochemical and chemical industries restructured their work on a military basis and began to produce products for the front line (Figure 5). All possibilities were used for rail and sea transportation.

Figure 5. Transportation of oil cargo for front line missions

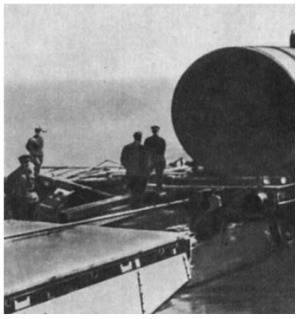

Figure 6. Shipment of railway tank wagons with oil afloat by sea

V.G. Bakaev, the Head of the Central Port Department of the People's Commissariat of the Navy, who was in Baku at that time, made the necessary calculations and proposed to send the cisterns afloat by sea [10]. Due to the interaction of oilmen and sailors, the supply of the front line through the Caspian Sea Baku-Krasnovodsk and Baku-Astrakhan was launched. The extraordinary decision was made to send railway tank wagons with oil afloat by sea from Baku to Krasnovodsk (Figure 6).

The technology was complex and unsustainable due to the turbulent Caspian Sea. On the fourth day after the start of work, the first tanks were floated. At first, seven cisterns were lowered, but they were unstable and high above the sea surface. Therefore, the tanks began to be filled with oil, only after that they rose by a fourth of the hull. Each tank was attached to the main towing cable using special clamps (Figure 7).

Figure 7. Fastening of tanks to the towing rope

Figure 8. Delivery of tanks in the Baku port

This towing method was used for the first time in world practice. It allowed getting rid of the flooded tank and saving the rest and the use of pressurized welding and reinforced fastening of tanks to the frames made them more stable under the impact of waves during the transition, which in turn allowed increasing the fleet to 12-14 tanks, and later to 35. As a result, the methods of transportation of tanks became the most convenient and their flooding was prevented.

The supply of Soviet troops was carried out through the Volga using various river vessels: boats, barges, tugs, ferries, etc. For these purposes, they even used a boat that transported personnel. A fuel tank was attached to it, which served as a cover and at the same time saved resources.

The following technology was also used: rail tank cars with fuel arriving at the Baku port were sorted into mini-trains of 10-12 pieces by the type of coupling and the number of axles. Then the tanks were filled to almost two-thirds of the volume, after which all the hatches were hermetically closed. Then the trains in the Baku port were lowered into the sea along an inclined track. They were hooked to a tug and delivered to Krasnovodsk (Figure 8).

In the port, they were lifted out of the water with the help of a crane and placed on the railroad tracks. Then, through Tashkent and Kuibyshev, the tanks

filled to their full capacity were sent to the front and to necessary industrial regions. The supply of fuels, petroleum, oil and lubricants to sieged Leningrad was carried out in the same way. Through Lake Ladoga along the water "road of life", a fuel delivery system was organized and successfully operated in semi-submerged tanks in tow and an underwater gas pipeline was also built.

Figure 9. Transportation of rail tank cars by ferryboat

According to this historical analysis it is possible to state that the role of the interaction of modes of transport in the solution of specific problems was important. It peacetime it promoted the development of polymodal and multimodal systems for the transportation of goods (Figure 9).

The front line demanded a constant supply of oil products to numerous aviation, sea, tank and mechanized formations and industry. Therefore, during the years of the war, the main task for the Caspian transport fleet was the task of State Defense Committee to bring as many different oil products as possible to the Volga. This task was given in the first days of the war On April 26, 1942. State Defense Committee issued a resolution "On the export of oil products from Baku and Grozny in 1942".

To fulfill this resolution, the "Kasptanker" team mobilized all its forces, overcoming numerous difficulties. During the first week of spring navigation, it transported 37 thousand tons of fuel to Astrakhan for the needs of the front. During the battle on the Volga and for the Caucasus, the "Kasptanker" team transported over 5 million tons of valuable fuel for the front and the country. This valuable fuel fed the military equipment of the Red Army, which defeated Hitler's troops in the fierce Battle of Stalingrad.

In 1942, due to the increase in the volume of sea traffic, the Caspian sailors began to make up "sea trains" from barges towed by motor ships. The crew of the "Turkmenistan" ship alone transported over 20 such towing trains (Figure 10).Among the ships, the crews who were distinct during the Great Patriotic War, it is necessary to mentionthe vessel "Agamali-oglu" and its fearless captain Ali balaRadjabov. Many young navigators, who later became skillful sailors, were trained under his supervision. The tanker "Agamali-oglu" was a motor ship equipped by that time with perfect equipment (Figure 11).

Figure10. Motorship"Turkmenistan"

Figure11. Tanker"Agamali-oglu"

When "Agamali-oglu" approached the oil-loading berth, its deck turned out to be several meters higher than the pier. Having taken the cargo into its holds, it sank so that only superstructures remained above the water. Barges were waiting for it at the Astrakhan roadstead. Having pumped the cargo into them, "Agamali-oglu", turned around and headed for the home port.

When the flames of war with Nazi Germany flared over the country, people had to be as powerful as possible.They did what seemed impossible during peacetime. Caspian sailors took more fuel into the holds of their ships than was required by the standards. Like other ships, "Agamali-oglu" took additional cargo - military equipment and troops.The oil conveyor on the Baku-Astrakhan roadstead line, where the Agamali-oglu tanker was a link, operated smoothly, although the nazi did everything to disrupt the delivery of fuel to the front. In general, during the period from 1941-1945 only 2393 thousand tons of gasoline was transported for the front line. With their heroic and selfless labor, the seamen and port workers of the Caspian added many significant pages to the history of the Great Patriotic War.

The study of historical facts shows that the use of schemes for the transportation of oil cargo has always been aimed at the maximum interaction of modes of transport and the use of their technical advantages. Today, the transportation of oil cargo also demonstrates unique supply schemes of logistics. For example, Gazprom Neft created a transport and technological system for the year-round transportation of oil from the Novoportovskoye field located on the Yamal Peninsula [6].

Figure 12. Terminal "The Arctic Gates" and the tanker "ShturmanAlbanov" [6]

The key element of this system is "The Arctic Gates" installed in the water area of the Ob Bay (Figure 12).

It is the only oil terminal in the world operating in fresh waters and difficult ice conditions. At the start of the project, 12 options of oil shipment were considered, including rail and pressure pipeline shipment. The delivery of hydrocarbons along the Northern Sea Route turned out to be the most effective option, which allowed developing the field, discovered in the early 1960s.

The special conditions of the Gulf of Ob required the formation of tanker and icebreaker fleets capable of operating in shallow water. In order to deliver oil to the storage tanker installed on the roadstead of the Kola Bay, six tankers of the Shturman series of Arc7 class were built by order of Gazprom Neft, which can independently overcome ice up to 2.5 m thick. In addition, in the water area of the Ob Bay there are two powerful diesel-electric icebreakers of new generation on 24 hour duty - Alexander Sannikov and Andrey Vilkitsky, which were produced in 2018 in Vyborg Shipyard.

Arctic logistics are controlled by the digital system "Captain". In real time, it conducts a comprehensive analysis of the efficiency of the fleet operation, assessing the speed of movement on the route, fuel consumption and the volume of ship loading.The system independently forms the optimal schedule for the use of tanker and icebreaker fleets, shipments from terminals and floating oil storage and synchronizes all links in the supply chain.

The Arctic logistics management system of Gazprom Neft daily processes about 7,000 input parameters and provides optimal logistics solutions, calculating more than 1 million possible options and promptly responding to possible deviations. Over the past six years, several large oil refineries, such as the Kirishsky, Volgogradsky and Samara group of plants have been connected to the Transneft trunk pipeline system.

4 Results and discussion

This research allowed forming and presenting a complete picture of the development of oil cargo transportation by both land and water transport, as well as the peculiarities of their interaction and the formation of polymodal logistics, presenting the novelty of the study.

Significant inequalities in the productivity of cargo operations with large-tonnage vessels and land transport do not allow fast and cost-effective transshipment of cargo between them using the direct option (railway / road tanker-ship). If a railway tank car was unloaded at a typical loading speed of a modern tanker (10,000 - 12,000 tons/hour), then it would take about 24 seconds to process it, while the actual unloading time of a railway tank is 1-2 hours in summer and 3-4 hours in winter.

However, despite such significant differences in the processing speed of railway and water transport, each of them has its own advantages, which determine the relevance of the use of a particular type (combinations of modes) of transport for the transportation of these goods. The considered experience of military transportation of oil cargo does not meet modern requirements. However it is a variation of lighter transportation despite its catastrophically low level of environmental safety. It is a completely viable option for transportation with an appropriate level of safety. Since the transshipment of oil and dark oil products, in most cases, requires heating the cargo in winter, which negatively affects its quality (watering), the reduction in the number of transshipments is a positive factor for the development of the considered transportation options.

The conducted retrospective analysis can serve as the basis for further scientific and practical development in the field of transportation and transshipment of oil cargo using combinations of various modes of transport, including difficult conditions, for example, in the Arctic.

5 Conclusion

The study of schemes for the transportation of petroleum products in polymodal transport systems in a historical context gives the idea of the uniqueness of certain methods of cargo delivery. The modern development of logistics, technologies and infrastructure in the supply of oil and cargoes demonstrate a completely different level of industrial

and environmental safety. The combination of the railway with other modes of transport remains a promising area to attract cargo owners. At the same time, the coordinated actions of all workers in the transportation process, the development of polymodal (multimodal) logistics schemes for the transportation of oil cargo, the development of the issues of tariff component management and other transportation parameters that affect the efficiency of each type of transport and their competitiveness in the market of transport and logistics services.

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