**Development situation and future demand for the ports along the Northern Sea Route**

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**Abstract**

Due to global warming, the ice-free time of the Northern Sea Route (NSR) is becoming increasingly longer, which increases its potential as a major international shipping route. As the key nodes, ports play an important role in the development of shipping routes, but few studies have discussed the issue of port development in the NSR. This paper presents the topic of the development situation and future demand for the ports along the NSR. The introduction of NSR and the relative ports have been introduced first. Then, the development situation and future potential of ports are analysed from different indicators; furthermore, the evaluation of the ports has been made. Finally, policy recommendations are put forward.

**Keywords:** Arctic Shipping; Northern Sea Route; Ports; Development situation

1. **Introduction**

The gradual change in Arctic sea ice conditions could potentially open up opportunities for the more frequent use of the polar route (Theocharis *et al.,* 2018). For many years, the Northern Sea Route (NSR) had been discussed as a potential new and variable route for commercial shipping between Europe and Asia (Tseng *et al.,* 2018). A number of studies on Arctic shipping have been published since the start of the continuous melting of ice in the Arctic area in recent years. There were studies on the impacts, challenges and countermeasures brought out by the opening of the Arctic routes. Some of the studies focus on the feasibility (including the political, economic and commercial aspects) of the NSR, comparing it with the Suez Canal Route (SCR) (Lasserre *et al.*, 2014; Liu *et al.,* 2010; Xu *et al.,* 2011; Halvor *et al.,* 2011; Cariou *et al.,* 2015; Zhang *et al.,* 2016; Faury *et al.,* 2016; Hua *et al.,* 2018; Zeng et al., 2019); Some focus on the development of the NSR from the point of view of shipping companies or ship owners (Lasserre *et al.,* 2011; Lee *et al.,* 2015; Pruyn *et al.,* 2016; Zhang *et al.,* 2016). These studies are mainly performed based on shipping feasibility and profitability, and most of them point out that the NSR is primarily suitable for bulk shipping rather than for liner shipping in the short term. Compared with traditional SCR, NSR will not be cost effective owing to its high icebreaker fee, limit of speed and water depth (Verny *et al.,* 2009), and the profitability of Arctic route depend on average transit speed and load factor (Lasserre *et al.,* 2014).

The above studies have investigated the attractiveness of NSR from many aspects, but there is an important factor which has been neglected: the ports. As a shipping node, a port undertakes important functions such as ship maintenance, material replenishment, and cargo distribution; thus, it is an indispensable infrastructure for the development of the NSR. At present, the basic equipment and operating conditions, such as berthing, loading and unloading, are relatively underdeveloped; approximately 2,500 nautical miles of the Siberian coast between the Bering Strait and the port of Murmansk are nearly uninhabited; thus, no stopovers are possible (Verny *et al.,* 2009). Lack of infrastructure will decrease the NSR’s attractiveness as a shipping route (Lasserre *et al.,* 2014), ship owners seem reluctant to make significant investments and plan their long-term operations using the NSR before the intended infrastructural projects are realized (Milaković *et al.,* 2018). The risk factors exert a far negative influence on the propensity to deploy vessels on Arctic routes than the supposed positive influence of economic factors (Tseng *et al.,* 2018). Therefore, the arctic routes are likely to remain risky for a long time due to the scarcity of port facilities (Lasserre *et al.,* 2011). The NSR has never really been integrated into the world’s shipping market and its scarce infrastructure struggles to meet the requirements of the modern shipping industry (Milaković *et al.,* 2018). And additional investments in infrastructure and marine services including safety and security are needed before the NSR can be subject to continuous and large-scale shipping (Roman, 2019).

Based on the above analysis, the port facilities have become one of the major barriers for the development of NSR, but the discussion on port development about the NSR is currently lacking. Thus this paper puts forward the issue of development situation and future demand for the ports along the NSR. The following questions are to be answered through this study:

* What are the main ports along the NSR?
* What are the features of these ports, including their current development situation and future development potential?
* What are the demand for the ports in the future and what should be the focus for future development?

This paper is organized as follows. In section 2, a brief introduction of NSR and the relative ports is given. In section 3, the current development situation of the ports are analyzed, including the circumstances of their cargo flow, port calls and transit traffic, throughput, infrastructures, port dues, ice-free period, and connection and distribution condition. In section 4, the future development potential of the ports is discussed, from the point view of bilateral trade, investment flow, import and export cargo type of Russia, oil and gas distribution, and development strategy of Russia. An evaluation of the ports is made in section 5, and some policy suggestions are put forward in section 6.

1. **NSR and the relative ports**

According to political perception and legal regulations in Russia, the NSR stretches from Novaya Zemlya in the west to the Bering Strait in the east (Østreng et al., 2013). But in contrast to the officially adopted maritime definition of the “NSR”, the transport-economic and regional view defines the NSR as the entire route along the Arctic Ocean from west of the Kola Peninsula to the Bering Strait (Granberg, 1998). And the scholars normally take the definition of NSR from transport-economic point of view: the NSR is a shipping lane between the Atlantic Ocean and the Pacific Ocean along the Russian coast of Siberia and the Far East, crossing five Arctic Seas: the Barents Sea, the Kara Sea, the Laptev Sea, the East Siberian Sea and the Chukchi Sea (Liu *et al.,* 2010); the westernmost end of the route is Murmansk, and the easternmost end is the Bering Strait or Provideniya on the coast of the Bering Sea (Xu *et al.,* 2011).

Considering that the traffic along the NSR not only includes intra-Russian voyage, but also includes the trans-Russian cargoes, and the intra-Russian voyages include both the intra-NSR trip and trans-NSR ones. In addition, the transit traffic passing through the NSR may play a more important role on the development of the NSR. So in this paper, we selected the ports lying along the NSR, and some Arctic Russian ports outside the NSR but active in traffic generated by the NSR are also included. The ports discussed in this paper from west to east include St. Petersburg, Murmansk, Kandalaksha, Vitino, Onega, Arkhangelsk, Mezen, NaryanMar, Varandey, Amderma, Sabetta, Dikson, Dudinka, Igarka, Khatanga, Tiksi, Pevek, Provideniya, Petropavlovsk-Kamchatskiy, Vanino, Zarubino, Posyet, Vladivostok, Nakhodka and Vostochny. There are 25 ports in total as shown in Figure 1.



Figure 1 The ports discussed in this paper

3．**Current development situation of the ports**

This section provides an analysis of the current situation of the ports, including the cargo flow, port calls and transit traffic, throughput, infrastructures, port dues, ice-free period, and connection and distribution condition.

3.1 Cargo flow

3.1.1 Transport volume

The ports located in Russian Arctic water handled 31.5 million tons of cargo in 2019, including 0.7 million tons transit cargo volumes. The cargo volume of the NSR and number of transit voyages in recent years are shown in Table 1.

Overall, shipping along the NSR has been increasing steadily; however, this increase is mainly attributed to domestic shipping and the shipping from or out of the ports in Russia; the transit shipping has not grown synchronously. The reason for this phenomena is mainly attributed to the fact that the most of cargoes passing through the NSR are oil, coal, ore, timber and LNG (the detailed figures are listed in section 3.1.2), which are Russian’s domestic resources. Owing to the sanction of western countries, the transit cargo volume has decreased from 2014. In addition, the fall of the oil price led to the freezing of offshore hydrocarbon production projects, which are accounted for a large share of the freight traffic in the NSR (Radushinsky *et al.,* 2017).

Table 1 Cargo transport volume in the NSR from 2011 to 2017

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Total cargo volume  (million tons) | Number of transit voyages | Transit cargo volume  (million tons) |
| 2011 | 3.11 | 41 | 0.82 |
| 2012 | 3.88 | 46 | 1.26 |
| 2013 | 3.91 | 71 | 1.36 |
| 2014 | 3.98 | 31 | 0.27 |
| 2015 | 5.43 | 18 | 0.039 |
| 2016 | 7.48 | 19 | 0.21 |
| 2017 | 10.7 | 27 | 0.2 |
| 2018 | 19.7 | 27 | - |
| 2019 | 31.5 | 37 | 0.70 |

Data source: Russian Federal State Statistics Service, the volume of cargo in the water area of the Northern Sea Route, <https://www.fedstat.ru/indicator/51479>; The CHNL Information Office, https://arctic-lio.com/

3.1.2 Cargo types and traffic flow

Historical cargo types in a shipping route reflect the various needs for different kinds of terminals. From the published references, only the data in 2012 and 2013 about cargo types and traffic flow of NSR are available, which are shown in Table 2.

Table 2 Cargo types and traffic flow of the NSR from 2012 to 2013

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type  Year | | Cargo volume (million tons) | Ratio (%) | West bound (million  tons) | Ratio  (%) | East bound (million  tons) | Ratio (%) |
| 2012 | Liquid | 0.89 | 70.9% | 0.23 | 26.1% | 0.66 | 73.9% |
| Dry bulk | 0.36 | 28.5% | 0.1 | 27.0% | 0.26 | 73% |
| Fishery | 0.008 | 0.7% | 0.008 | 100% | 0 | 0% |
| Total | 1.26 | 100% | 0.34 | 26.8% | 0.92 | 73.2% |
| 2013 | Liquid | 0.91 | 67.3% | 0.32 | 35.4% | 0.59 | 64.6% |
| Dry bulk | 0.28 | 20.4% | 0.07 | 26.7% | 0.2 | 73.3% |
| LNG | 0.07 | 4.9% | 0 | 0% | 0.07 | 100% |
| Break-bulk | 0.1 | 7.4% | 0.06 | 63% | 0.04 | 27% |
| Total | 1.36 | 100% | 0.46 | 33.9% | 0.9 | 66.1% |

Data source: The Arctic Resources and Transportation Information System (ARCTIS) Database (<http://www.arctis-search.com>)

From Table 2, approximately 70% of the cargoes are liquid bulk (petroleum and condensate), followed by dry bulk, break-bulk and LNG. From the traffic flow of goods, whether liquid bulk or dry bulk, the proportion of goods at eastbound (from Northwest Europe or the western NSR to East Asia or the eastern NSR) is as high as 70%. This finding shows that in the current trade pattern, the cargo flow from west to east is the main pattern. This is mainly attributed to the distribution of oil and gas resources in Russia: the main oil and gas resources are located in the western region (detailed information of oil and gas distribution in Russia is discussed in section 4.4). Therefore, when considering the layout of ports, the western ports in the NSR should be regarded as the main loading ports, whereas the eastern ports in the NSR should be regarded as the main unloading ports.

3.2 Port calls and transit traffic

Among the 25 ports, some have been visited more than others by transit vessels or have higher transit cargo flows in the past, which reflects the popularity of these ports. Thus, by the historical data, we could judge the significance of each port. We collect the statistics of the Centre for High North Logistics (CHNL) and count the number of port calls and cargo flows for the transit voyages in the NSR. The results are shown in Figure 2 and Table 3.

Figure 2 Number of cumulated transit port calls from 2007 to 2019

Data source: The ARCTIS Database(<http://www.arctis-search.com>);  The CHNL Information Office (<https://arctic-lio.com/>)

According to the statistics, from 2007 to 2019, Murmansk has the greatest number of port calls (81 times), followed by Arkhangelsk (43 times), Petropavlovsk-Kamchatskiy (37 times), Pevek (35 times), St. Petersburg (16 times), Nakhodka (13 times), Vladivostok (10times), Provideniya (11 times), Vitino (8 times), and Dudinka (7 times). The similar situation happens when we analyse the transit cargo volumes of the ports (see Table 3). It can be inferred that these ports have played important roles in the transit cargo traffic along the NSR.

Table 3 Transit cargo volumes (except for the ballast) of the ports in 2012, 2013, 2015 and 2016

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | inflow (t) | outflow(t) | total(t) | proportion |
| St. Petersburg | 19896 | 4097 | 23993 | 1.4% |
| Murmansk | 37450 | 1308396 | 1345846 | 77.5% |
| Arkhangelsk | 15850 | 73020 | 88870 | 5.1% |
| Pevek | 121420 | 0 | 121420 | 7.0% |
| Petropavlovsk-Kamchatskiy | 43288 | 39727 | 83015 | 4.8% |
| Provideniya | 263 | 10164 | 10427 | 0.6% |
| Vladivostok | 3000 |  | 3000 | 0.2% |
| Vostochny | 4097 | 6500 | 10597 | 0.6% |
| Nakhodka | 23209 | 27177 | 50386 | 2.9% |

Data source: The CHNL Information Office (<https://arctic-lio.com/>)

3.3 Throughput

Throughput of a port reflects their competence to handle the goods and their attractiveness for the goods. From the throughput of 25 ports along the NSR in 2019, there are 10 ports which throughput are over 1 million tons (as shown in Figure 3), and these ports are Vostochny, Murmansk, St. Petersburg, Vanino, Sabetta, Nakhodka, Vladivostok, Posyet, Varandey, and Arkhangelsk. The remaining 15 ports have less throughput and smaller size.

Figure 3 Throughput of the ports in 2019 (million tons)

Data source: Information & Analytical Agency Port News (IAA Port News) （<http://portnews.ru/>）

3.4 Infrastructures

The infrastructures are essential for the ports’ development. In order to identify the situation, we collect data about the maximum depth, number of berth, total length of the berths, and storage space (including open air, closed and tank) of each port (from west to east), which are listed in Table 4.

Table 4 The basic conditions of the ports

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Port | Maximum depth | Number of berth | Total length of berths (m) | Storage space | | |
| Open air (1000m2) | Closed (1000m2) | Tank (1000m3) |
| St. Petersburg | 11.5 | 102 | 17,124 | 10,970 | 439 | 354, |
| Murmansk | 15.7 | 130 | 14,441.3 | 1,590 | 340.6 | 1,758 |
| Kandalaksha | 7.2 | 7 | 794 | 80 | 8.5 | 0 |
| Vitino | 13.7 | 4 | 412 | - | - | 280 |
| Onega | 5.6 | 7 | 805 | - | - | 0 |
| Arkhangelsk | 10.4 | 146 | 16,250.3 | 3,756 | 62.9 | 8 |
| Mezen | 5 | 2 | 220 | 1 |  | 0 |
| Naryan Mar | 6 | 5 | 400 | 20 | 3.3 | 0 |
| Varandey | 17 | - | - | - | - | 325 |
| Amderma | 5 | 6 | 483 | 6.7 | 2 | 0 |
| Sabetta | 16 | 6 | - | - | - | - |
| Dikson | 14 | 7 | - | 10 | 4 | — |
| Dudinka | 11.8 | 32 | 4,142 | 285 | - | 180 |
| Igarka | 8 | 16 | 2,380 | - | - | - |
| Khatanga | 5 | 5 | - | 17.5 | - | 0 |
| Tiksi | 6.8 | 15 | 1,590 | 52.9 | 3.8 | 38 |
| Pevek | 9.4 | 4 | 500 | 147 | 2.1 | — |
| Provideniya | 10.2 | 6 | 523 | 30.5 | 3.4 | — |
| Petropavlovsk-Kamchatskiy | 10.7 | 47 | 10,237 | 1,415.5 | 200 | 17 |
| Vanino | 20 | 26 | 3,948 | 1,283 | 237 | 280 |
| Vladivostok | 15 | 66 | 11,098 | 4,839.4 | 1,326.8 | 32.5 |
| Nakhodka | 13 | 127 | 15,897 | - | - | - |
| Vostochny | 19.8 | 34 | 2,369 | 2,425.1 | 411 | 623 |
| Posyet | 11 | 24 | 3,389 | 492.7 | 351.6 | — |
| Zarubino | 9.5 | 4 | 650 | 179 | 172 | — |

Data source: the official website of the Center of the Ministry of Transport of Russia (<http://www.russianports.ru/> )

From the table, we could find that some ports have excellent water depth condition, such as Vanino (20m), Vostochny (19.8m), Varandey (17m), Sabetta (16m), Murmansk (15.7m); some ports’ total length of berths is more than 10,000 meters, such as St. Petersburg (17,124m), Arkhangelsk (16,250m), Nakhodka (15,897m), Murmansk (14,441m), Vladivostok (11,098m), and Petropavlovsk-Kamchatskiy (10,237m); some ports have very large tank storage space, such as Murmansk (1,758,000m3), St. Petersburg (354,000m3), Vostochny (623,000 m3), Varandey (325,000m3), Vanino (280,000 m3), and Vitino (280,000 m3).

In sum, among all the ports, the largest one is Murmansk, Ports with medium size are Dudinka and Arkhangelsk, the remaining ports are small or very small (Pahl et al., 2018). In addition, Russian ports require modernization to be able to host and provide service to international traffic (Gunnarsson,2016).

With the exploitation of abundant natural resource in the Arctic, the NSR will depend heavily on resource extraction, so current private port development investments are focusing on single-use oil and gas resource extraction, such as the new port of Vitolo outside of Murmansk. And in the Russian Arctic, more successful oil and gas ventures are initiating private investment in private ports (Pahl et al., 2018).

3.5 Port Dues

The ports along the NSR have different port dues, and their tonnage dues for foreign voyage vessels are charged based on the type of vessel: the first type is tanker; the second type is Ro-Ro vessels, Float-on / Float-off ships and container ships; the third type is all other vessels. From the official website of The Center of the Ministry of Transport of Russia (<http://www.russianports.ru/>), we could collect the port dues of each port along the NSR. We divide the level of charges into four grades: highest, high, medium and low. The detailed of charges for each grade and corresponding ports are listed in Table 5.

If we relate the above charges of each port to their throughput which has been discussed in section 3.3, we could find that there is a negative relationship between them. The lower the charges (such as Vostochny and Murmansk), the larger throughput, and vice versa (such as Igarka, Pevek, and Provideniya). Thus port dues could also reflect the attractiveness for the goods.

Table 5 Port dues of the ports

|  |  |  |  |
| --- | --- | --- | --- |
| Grade | The type of Port dues | Port dues  (RUB/1 GT) | Ports |
| Highest | tankers | 14-19 | Onega, Arkhangelsk, Mezen, Naryan Mar, Igarka, Pevek, Provideniya |
| Ro-Ro vessels, Float-on / Float-off ships, container ships | 9-12 |
| Other vessels | 13-17 |
| High | tankers | 9-10 | Varandey, Petropavlovsk-Kamchatskiy |
| Ro-Ro vessels, Float-on / Float-off ships, container ships | 6-7 |
| Other vessels | 9-10 |
| Medium | tankers | 6-8 | St. Petersburg, Murmansk, Kandalaksha, Vitino, Amderma, Sabetta, Dikson, Dudinka, Khatanga, Tiksi, Vladivostok, Nakhodka, Posyet, Zarubino |
| Ro-Ro vessels, Float-on / Float-off ships, container ships | 4-6 |
| Other vessels | 6-8 |
| Low | tankers | 3-5 | Vanino, Vostochny |
| Ro-Ro vessels, Float-on / Float-off ships, container ships | 2-3 |
| Other vessels | 3-4 |

Data source: the official website of the Center of the Ministry of Transport of Russia (<http://www.russianports.ru/> )

3.6 Ice-free period

Due to high latitude, most of the ports along the NSR have a freezing period. During the freezing period, ships must rely on the icebreaker to navigate them into and out of the ports and pass through the channel, which will increase the time, risk and cost of the sailing. Therefore, the length of the ice-free period is also an important indicator for the ports. The longer the ice-free period, the better the port conditions are. The number of ice-free days for the ports along the NSR are shown in Figure 4.

Figure 4 Ice-free period of the ports along the NSR (days)

Data source: official website of Russian Port Statistics Bureau (<http://www.russianports.ru/>)

As shown in Figure 5, only the port of Murmansk is ice-free throughout the year, and the ports in the Far East have a longer ice-free period, all ranging from 8 to 9 months; among the remaining ports, St. Petersburg Port has 210 ice-free days, Vitino has 180 ice-free days, and the ice-free periods of the other ports are no more than 6 months, the ports of Dikson and Tiksi only have a 2-month ice-free period.

3.7 Connection and distribution condition

The connection and distribution condition of a port refers to the conditions of the port transportation systems, including railways, highways, roads, rivers and freight stations, which are connected with the port and serve to centralize and evacuate the port goods. The connection and distribution system connects a port with its hinterland; thus, it is an important condition for the existence and development of a port. A port should have a smooth connection and distribution system to become an important hub in a comprehensive transportation network.

Table 6 Connection and distribution system of the ports

|  |  |  |
| --- | --- | --- |
| Connection and distribution system | | Ports |
| Railway+River | | Arkhangelsk (Feeder of Trans-Siberian Railway ;North Devina River), Onega(Feeder of Trans-Siberian Railway ;Onega River) |
| Railway | Far East Railway | Vladivostok, Nakhodka, Vostochny, Posyet, Zarubino, Vanino |
| Trans-Siberian  Railway | St. Petersburg |
| Feeder of  Trans-Siberian  Railway | Murmansk, Kandalaksha, Vitino |
| River | Pechora River | Naryan Mar, Varandey |
| Ob River | Sabetta |
| Yenisei River | Dikson, Igarka, Dudinka |
| Kotui River | Khatanga |
| Lena River | Tiksi |
| Mezen River | Mezen |
| None | | Amderma, Pevek, Providenja, Petropavlovsk-kamchatskiy |

As far as the connection and distribution system is concerned, Russia’s railway network is relatively dense in the part in Europe, with Moscow as its centre, but its railway network in the part in Asia, where the Eurasian Continental Bridge is the only major railway, is sparse. In addition, Russia’s rivers that flow into the Arctic Ocean (such as the Ob River, Yenisei River, Pechora River, Mezen River, Kotui River, and Lena River) can also serve as the traffic connection for the nearby ports. Detailed information on the connection and distribution system for the ports along NSR is shown in Table 6.

In summary, along the NSR, the ports with the best collecting and distribution conditions are Arkhangelsk and Onega, which have both railway and river connections. The ports with better collecting and distribution conditions are St.Petersburg, Murmansk, Kandalaksha, Vitino, as well as Vanino, Vladivostok, Nakhodka, Vostochny, Posyet and Zarubino in the Far East, because they are connected directly to the railway network (we assume that railway is better than the river because the former has faster speed normally). There are some ports that are not directly connected to the railway network but are located near the inland river that flows into the Arctic Ocean, including the ports of Naryan Mar, Varandey, Sabetta, Dikson, Igarka, Dudinka, Khatanga, Tiksi and Mezen; the remaining ports of Amderma, Pevek, Providenja and Petropavlovsk-kamchatskiy are not connected to the railway network, nor are they in the vicinity of the inland river; thus, their connection and transportation conditions are poor.

It is worth mentioning that in August 2018, the Russian government signed a concession agreement on the construction of the “North Latitude Passage” railway infrastructure(http://www.topbrain.cn/zhonghengyuance/gongsixinwen/2018-08-23/1699.html), which will become an important channel connecting Western Siberia to the Arctic Ocean. In addition, another railway from the trunk line of "North Latitude Passage" to Sabetta port on the Yamal Peninsula will be built by Gazprom and Russian Railways Group, which will be used to transport oil and gas to the NSR (<https://world.huanqiu.com/article/9CaKrnKefw6>). If these railways are finished, the connection and distribution condition of the nearby ports (such as Sabetta) will be enhanced greatly.

1. **Future development potential of the ports**

This section provides an analysis of the future development potential of the ports from the aspects of bilateral trade, investment flow, import and export cargo type of Russia, oil and gas distribution, and development strategy of Russia.

4.1 Bilateral trade

The current cargo flow through the NSR is very limited, and it has a long way to go before it becomes a real commercial shipping route like Suez Canal. Considering the sanction against Russia from Europe and the United States, the trade volume between Russia and the Far East is essential to the development of ports. In the Far East, China, Japan and South Korea are important trading partners of Russia. The bilateral trade volumes between China, Japan and South Korea have continued to grow in recent years except for the year of 2009 and 2014-2016 (see Figure 5). In terms of total imports and exports, China has been Russia’s largest trading partner since 2010 (Russian National Bureau of Statistics, http://www.gks.ru). Moreover, the advantageous industries of China and Russia are significantly different because China has advantages in the manufacturing and building industry, while Russia is strong in resources, energy and military. Thus, there are strong trade complementarities and much room for cooperation between the two countries. Therefore, the bilateral trade of China-Russia in the future will bring more freight sources for the ports along the NSR.

The Western Europe countries, including the Netherlands, Britain, Finland and France, are all among the top 10 of Russia’s import and export trade partners. In addition, the international trade volume between these countries and Northeast Asian countries, including China, Japan, and South Korea, has also continuously increased. In sum, this trading volume could guarantee the supply of transit goods for the ports along the NSR in the future.

We could further judge the development potential of each ports from Russian regional GDP, which is always positively relative to the foreign trade volume and port throughput in this area. According to data collected by website of the Russian National Bureau of Statistics (http://www.gks.ru), the ranking of the GDP of various federal districts in 2017 is as follows: the first is the Central Federal District (413.14 billion US dollars), the second is the Volga Federal District (174.12 billion US dollars), the third is the Ural Federal District (168.61 billion US dollars), the fourth is the Northwest Federal District (124.9 billion US dollars), the fifth is the Siberian Federal District (122.5 billion US dollars), the sixth is the Southern Federal District (84.67 billion US dollars), the seventh is the Far Eastern Federal District (61.23 billion US dollars), and the eighth is the Northern Caucasus Federal District (29.45 billion US dollars). The detailed information about the ports in each area is listed in Table 7.

Figure 5 Total import and export volume of China-Russia, Japan-Russia, and South Korea-Russia from 2003 to 2018 (billion dollars)

Date sources: Official website of the United Nations Trade Database (<http://comtrade.un.org/db/>)

Table 7 GDP of different district of Russia in 2017 and relative ports

|  |  |  |
| --- | --- | --- |
| District | GDP(billion US dollars) in 2017 | Ports |
| Ural Federal District | 168.61 | Sabetta |
| Northwest Federal District | 124.9 | St. Petersburg, Murmansk, Kandalaksha, Vitino, Onega, Arkhangelsk, Mezen, Naryan Mar, Varandey, Amderma |
| Siberian Federal District | 122.5 | Dikson, Dudinka, Igarka, Khatanga |
| Far Eastern Federal District | 61.23 | Tiksi, Pevek, Provideniya, Petropavlovsk-Kamchatskiy, Vanino, Vladivostok, Nakhodka, Vostochny, Posyet, Zarubino |

4.2 Investment flow

Investment flow between different countries influences the cargo flow between countries because foreign investment in an area will increase the volume of imports and exports in this area, and these import and export cargoes supply a port with loading and unloading goods; thus, investment flow reveals the potential cargo flow and port development demand in the future.

China’s investment in Russia is mainly in the mining, manufacturing and agriculture industries (SCIO, 2018). The resource industry (mining industry) has the highest proportion of this investment, and the mining industry has always been Russia’s traditional export industry; Russia’s resources (crude oil, LNG, iron ore, etc.) will cause a significant increase in exports in the future.

It is particularly worth mentioning that in the Yamal LNG project, China National Petroleum Corporation has 20% of the shares, and China Silk Road Fund has 9.9% of the shares. With the further deepening of cooperation between China and Russia in the energy industry, the construction of energy terminals, including LNG terminals (Sabetta), oil terminals (Vitino, Varandey), and coal terminals (Vanino, Vostochny, Murmansk) will become the focus, which is in line with the study of Pahl & Kaiser (2018): “current private port development investments are focusing on single-use oil and gas resource extraction”.

4.3 Import and export cargo type of Russia

Owing to the fact that in the current stage, most NSR cargo traffic is domestic or imported into and exported out of Russia, we also collect Russia’s import and export data to analyse the cargo type and then analyse the related demand for the ports in the future (we assume some of the cargoes passing through traditional route will divert to NSR in the future).

From the type of Russia’s import and export cargoes in 2016 (see Figures 6-7 for details), mineral products accounted for more than 50% of total exports, and mechanical equipment accounted for nearly half of the imported products. These two categories of goods are suitable for transport by bulk carriers (including dry bulk carriers and liquid bulk carriers) and container ships (or general cargo ships and multi-purpose vessels). Therefore, when we consider Russia’s import and export cargo types, LNG terminals (Sabetta), oil terminals (Vitino, Varandey), dry bulk terminals (Vostochny, Murmansk), timber terminals (Onega, Arkhangelsk, Igarka) and container terminals (St. Petersburg, Murmansk, Vostochny) may have higher potential in the future.

Figure 6 Proportion of Russian export goods in 2016 Figure 7 Proportion of Russian import goods in 2016

Data source: official website of the Russian Bureau of Statistics (<http://www.gks.ru>)

4.4 Oil and gas distribution

At present, Russia’s export goods are mainly resource products. In 2016, oil and gas accounted for approximately 60% of Russia’s total exports (the Russian Bureau of Statistics, <http://www.gks.ru>). According to previous analyses, the oil and gas resources in the Russian Arctic region will become the main driving force for the increase in NSR traffic volume in the future. The ports near the area with abundant resources will obtain enough goods more easily; therefore, we can analyse the potential of different ports through the distribution of oil and gas resources in Russia.

With the depletion of conventional oil and gas resources in Russia, oil and gas production in western Siberia has been decreasing year by year, and the Arctic water areas have become the strategic development focus of Russian energy (Roman 2019). Even though most of the present oil and gas projects in Russia are onshore projects after the economic sanction in 2014, these resources still reflect the development potential for the hinterland of the nearby sea ports, because the cost of oil and gas shipping is much lower than the pipeline and railway transportation, which means some oil and gas resources will divert to shipping if condition allowed.

From the distribution of the total oil and gas resources in the Russian Arctic continental shelf, the Kara Sea accounts for 39%, followed by the Barents Sea (25%), the Pechora Sea (10%), the Siberian Sea (9%), the Laptev Sea (5%), and the Chukchi Sea (5%) (Shuling *et al.,* 2017). According to the sea area that each port belongs to, the potential of the ports for oil and gas transport can be seen in Figure 8.

The main oil and gas resources of the Far Eastern Federal Region in Russia are distributed on the continental shelf of the Pacific Ocean and the Arctic Ocean, as well as some areas of the continental part. The most promising areas are the Okhotsk Sea (including the ports of Petropavlovsk-Kamchatskiy and Vanino) and the Bering Sea (including the port of Provideniya) (Yongheng et al., 2017).

Figure 8 Distribution of oil and gas resources in the Russian Arctic continental shelf and related ports

4.5 Development strategy of Russia

Russian government issued *the Integrated Development Plan for the North Sea Route 2015-2030* in June 2015, which emphasized the strategic importance of the NSR to Russian national security. The plan also pointed out that it is necessary to cooperate with Asian countries, especially China, to increase the NSR's international transit cargo transportation. This plan stated that the port of Murmansk will be built into an "Arctic transport hub", a new port of Arkhangelsk is planned, and a port of Sabetta is needed to serve the "Yamal Gas Project" (Gunnarsson, 2016).

*The Transport Strategy of the Russian Federation up to 2030* (Ministry of Transportation of the Russian Federation, 2014) states that the dry bulk cargo volume will increase by 168% from 2015 to 2030, container volume will increase by 84%, and liquid bulk cargo volume will increase by 5%. Commercial activities are turning to the fastest-growing Pacific Ocean and emerging countries in South America; thus, it is necessary to increase the throughput capacity of ports in the Far East, such as the ports of Vanino and Posyet. At the same time, the strategy notes that it is necessary to improve the infrastructure of the ports of Vladivostok and Vostochny, and the infrastructure of the port of Murmansk should be expanded.

Based on the above analysis, we can summarize that the ports of Murmansk, Arkhangelsk, Sabetta, Vanino, Posyet, and Vostochny will be the focus of future construction from the Russian government point of view.

1. **Evaluation for the ports**

Based on the analysis of section 3 and section 4, we could make an evaluation for the ports along the NSR. The evaluation is conducted from two dimensions: current development situation and future development potential. The evaluation indexes for each dimension are based on the indicators discussed in section 3 and section 4.

* 1. Evaluation for the current development situation

When setting the weight of each index for the evaluation of the current development situation, we consulted some experts in this field, including 5 senior managers from shipping companies and 5 professors in the university. We average the weights given by them and obtained the final weights. And based on their suggestions, we divide the evaluation standard for each index into four or five grades based on the analysis of section 3. The detailed division is made by experts based on the difference of the 25 ports, which is an exploratory work attempting at simulating possible development scenarios. The detailed information is shown in table 8.

Table 8 Evaluation weight and standard of each index for the current development situation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Index | Weight | Evaluation score and the standards | | | | |
| 0-2 | 3-4 | 5-6 | 7-8 | 9-10 |
| Cargo flow | 0.1 | others | Has fishery terminal | Has LNG terminal | Has dry bulk terminal | Has oil terminal |
| Port calls | 0.2 | [0,9] | [10,19] | [20-29] | [30-50] | [50-60] |
| Throughput | 0.2 | [0-1] | [1-9] | [11-29] | [30-49] | [50-70] |
| Infrastructure | 0.1 | others | depth[10,15] or length[1000,10000] | depth[10,15] and length[1000,10000] | depth[15,20] or length[10000,20000] | depth[15,20] and length[10000,20000] |
| Port dues | 0.1 | - | Highest | High | Medium | Low |
| Ice-free period | 0.2 | [0-60] | [61-120] | [121-180] | [181-269] | [270-365] |
| Connection and distribution condition | 0.1 | - | others | By River | By Railway | By River and Railway |

Remarks:

1) the unit of the index “throughput” is million tons;

2) “depth” refers to “the max depth” and the unit is meter; “length” refers to the “total length of the berths” and the unit is meter;

3) the standard of “highest”, “high”, “medium” and “low” for the index “port dues” are the same as in table 4;

4) the unit of the index “ice-free period” is “day”.

* 1. Evaluation for the future development potential

The weights of each index for the evaluation of the future development potential are also calculated based on the opinion given by the same group of experts. The evaluation score and the standard for each index is divided into four or five grades based on the analysis of section 4. The detailed information is shown in table 9.

Table 9 Evaluation weight and standard of each index for the future development potential

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Index | Weight | Evaluation score and the standards | | | | |
| 0-2 | 3-4 | 5-6 | 7-8 | 9-10 |
| Bilateral trade | 0.1 | - | Located in the Far Eastern Federal District | Located in the Siberian Federal District | Located in the Northwestern Federal District | Located in the Ural Federal District |
| Investment flow | 0.1 | - | others | Has coal terminals | Has Oil terminals | Has LNG terminals |
| Import and export cargo type of Russia | 0.2 | others | Timber terminals | Dry bulk terminals | Large oil terminals | LNG terminals |
| Oil and gas distribution | 0.3 | others | Located along the Okhotsk Sea and Bering Sea | Located along the Pechora Sea, Siberian Sea and Laptev Sea | Located along the Barents Sea | Located along the Kara Sea |
| Development strategy of Russia | 0.3 | - | others | Mentioned as to improve the infrastructure or increase the throughput | Mentioned as being served for "Yamal Gas Project" | Mentioned as arctic hub |

Remarks:

1) the evaluation standard for “bilateral trade” is given through the GDP of each port’s hinterland which is based on the analysis of section 4.1;

2) the evaluation standard for “bilateral trade” is given based on the analysis of section 4.2;

3) the evaluation standard for “import and export cargo type of Russia” is given based on the analysis of section 4.3;

4) the evaluation standard for “oil and gas distribution” is given based on the analysis of section 4.4;

5) the evaluation standard for “development strategy of Russia” is given based on the analysis of section 4.5.

5.3 Comprehensive evaluation

Based on the above setting of the indexes, weights, and standards for evaluation, we could calculate the development situation score (), development potential score (), and total score () of each port. The detailed calculation is done by the equation (2) to equation (4). The results of calculation are shown in Table 10 and Figure 9.

 (2)

 (3)

 (4)

: the development situation score of port i

: the development potential score of port i

: total score of port i

: the weight of index j, j=1,2,…,8

: the weight of index k, k=1,2,…,5

: the score of index j for port i

: the score of index k for port i

Table 10 Development potential score, development situation score and total score of each port

|  |  |  |  |
| --- | --- | --- | --- |
| Port | Development situation score () | Development potential score () | Total score () |
| Murmansk | 9.4 | 7.6 | 17 |
| Sabetta | 4.3 | 8.4 | 12.7 |
| Vostochny | 7.2 | 4.2 | 11.4 |
| Vanino | 6.6 | 4.8 | 11.4 |
| St. Petersburg | 7 | 4 | 11 |
| Vitino | 5 | 5.8 | 10.8 |
| Dudinka | 4.6 | 6.2 | 10.8 |
| Kandalaksha | 4.6 | 5.2 | 9.8 |
| Nakhodka | 6.6 | 3 | 9.6 |
| Vladivostok | 6.5 | 3 | 9.5 |
| Varandey | 4.4 | 5.2 | 9.6 |
| Posyet | 5.3 | 3.6 | 8.9 |
| Petropavlovsk-Kamchatskiy | 5.9 | 3.6 | 9.5 |
| Arkhangelsk | 5.4 | 3.4 | 8.8 |
| Igarka | 2.9 | 5 | 7.9 |
| Provideniya | 4.1 | 3.6 | 7.7 |
| Dikson | 3 | 4.6 | 7.6 |
| Pevek | 4.4 | 3.2 | 7.6 |
| Zarubino | 4.6 | 2 | 6.6 |
| Khatanga | 2.9 | 3.8 | 6.7 |
| Naryan Mar | 2.9 | 3.6 | 6.5 |
| Amderma | 2.9 | 3.6 | 6.5 |
| Tiksi | 3.2 | 3.2 | 6.4 |
| Onega | 3.3 | 2.8 | 6.1 |
| Mezen | 2.9 | 2.4 | 5.3 |

Figure 9 Evaluation results of the ports

If we set the score of 5 as a critical point, and view the scores above it as high score and the scores below it as low score, then we can find out that among the 25 ports, the ports with both high development situation score and high development potential score are Murmansk and Vitino; the ports with high development situation score but low development potential score are St.Petersburg, Arkhangelsk, Petropavlovsk-Kamchatskiy, Vanino, Vladivostok, Nakhodka, Vostochny, and Posyet; the ports with low development situation score but high development potential score are Kandalaksha,Varandey, Sabetta, Dudinka and Igarka; the ports with both low development situation score and low development potential score are Onega, Mezen, Zarubino, Naryan Mar, Amderma, Dikson, Khatanga, Tiksi, Pevek, and Provideniya.

If we further observe the location of these ports, we could find that most ports in the east area are with low development potential score. Among these ports, those located in the Far East region normally have relatively higher development situation score, and all the ports in the eastern line of NSR have both low development situation score and low development potential score, including Provideniya, Dikson, Pevek, and Tiksi. In addition, most ports near the Yamal Basin and Kara Sea have relatively higher development potential score, including Sabetta, Dudinka, Igarka, and Varendey.

1. **Results and Policy suggestions**

6.1 The main results

6.1.1 The cargo traffic of NSR is unbalanced

The data of historical cargo flow of NSR has revealed the fact that the volume of domestic cargoes dominates the route, and the transit volume is decreasing in recent years. Owing to the limit of ice extent, water depth, high icebreaking fees and bad weather in Arctic area, this phenomenon will not change in the short time. So when we plan the port infrastructure of NSR, we should put the Russian domestic cargoes as the main supply, including their export and import cargoes. In addition, the flow direction of the cargoes is also unbalanced, eastbound cargo is more than twice as much as westbound, which means most cargoes of NSR comes from the west areas and we should take the ports located in the west line as the main loading ports. On another hand, from the cargo type point of view, approximately 70% of the cargoes are liquid bulk (petroleum and condensate), followed by dry bulk, break-bulk and LNG. Considering the development of Yamal LNG project, the amount of LNG will increase in the future, so the oil and gas terminal should be paid more attention in the future.

6.1.2 The port development of NSR is unbalanced

According to the analysis of section 3, 4 and 5, we could conclude that the largest sea port of NSR is Murmansk, which has both high situation score and potential score. And most ports in the Far East has lower potential score but higher situation score; the ports along the coast of Kara Sea and Yamal Basin normally has lower situation score but higher potential score. From the infrastructural point of view, the differences between these ports are great: the ports in Far East and in the west line of NSR normally have better infrastructure and connection and distribution condition, but the situation of those ports along the east coast of NSR is not very good.

To summarize, the port development of NSR is unbalanced, which is mainly embodied by the difference between the ports in the western NSR and those in the eastern NSR. The main reason for this difference is the uneven economic development in Russia's western and eastern regions: there are higher population density, more developed economy, more advanced port infrastructures, and denser railway and road network in the western region, so there are more throughput generated by the western ports.

6.1.3 Oil and gas resources are of great significance for the future development of NSR

In short term, transit cargo volume of NSR may keep at a lower level due to the sanction of western countries and the limit of transport conditions. However, NSR cargo flow is expected to increase considerably with the further development of Russian Arctic hydrocarbon projects. Year-round export of LNG from the port of Sabetta have reached 17.5 million tons per year starting with the year 2018; crude oil from the Novoport Oil Field reached 8.5 million tons per year by 2017; and crude oil from the Payakha Oil Field should reach 7.3 million tons per year by 2024. (Gunnarsson, 2016). This is in addition to the transport of 1.3 million tons per year of nickel and other nonferrous metals from Norilsk Nickel at the port of Dudinka on the Yenisei River. Other projects in the planning stages include Novatek’s Arctic LNG-2 on Yamal and Gydan, with an estimated 16.5 million tons of LNG produced per year; transport of 5-10 million tons of coal from the Taymyr Peninsula from the port of Dikson as part of the VOSTOK coal Project; and 45 million tons per year of crude oil as part of the Transneft-Arctic Project, with the development of an offshore loading terminal for crude oil in the port of Sabetta. If all these energy projects come to fruition, then transport volumes on the NSR could reach 100 million tons per year by 2030 (Gunnarsson, 2016).

6.2 Policy recommendations

6.2.1 Prioritize the pots along NSR

When we combine the current development situation and future development potential of the ports, we could make a judgement of which ports are the most important for the development of the NSR. Based on the analysis of section 5, some ports have obtained very high total score: Murmansk (17), Sabetta (12.7), Vostochny (11.4), Vanino (11.4), St. Petersburg (11), thus, these ports are the most significant and should be given priority in future construction. In these ports, Murmansk has the highest total score and has both high development situation score and high development potential score, so it is the most important port among all the ports, which should be considered as the “hub port” in the Russian Arctic areas.

6.2.2 Pay attention to the ports with relatively higher development potential score

Among the 25 ports, there are several ports with low development situation score but high development potential score, including Sabetta, Varandey, Dudinka and Igarka. Sabetta is a relatively new port which was built in recent years, so it has lower development situation score (4.3), but it has very high development potential score (8.4), which is the highest among the 25 ports. The main reason for its high development potential is that it is a LNG dedicated terminal, and it accommodates all the LNG produced by Yamal project, which is the largest LNG project in the Arctic region. In the future, with the completion of the “North Latitude Passage” railway, Sabetta will play a more key role in the NSR. The situation of Varandey, Dudinka and Igarka are similar to Sabetta: the condition of their infrastructures, port calls, and ice-free period are not very good, but they have large oil terminal and metal ore terminal respectively and all located in the area with high GDP and abundant oil and gas resources, so they have relatively high development potential. We should pay more attention to these ports, and take them as key investment objectives to improve their infrastructure conditions in the future.

6.2.3 Recent focus on energy and resource ports

Future development of Russian resources will be the main driver for increased shipping on the NSR in the coming decades. The increase in the trade volume of energy and other resources will increase the demand for relative ports; thus, energy and resource ports should be given priority in the near future, including LNG terminals, oil terminals, iron ore terminals, coal terminals, and timber terminals. On the NSR, the main ports with such kinds of terminals include Sabetta (LNG), Varandey (oil), Vitino (oil), Arkhangelsk (wood), Igarka (wood), Dudinka (nickel-based metals), Vanino (coal), and Nakhodka (wood and oil).

6.2.4 Strengthen the construction of port connection and distribution system

The highways, railways, inland rivers and other infrastructures are equivalent to the connection and distribution systems of ports along the NSR; thus, they are very important to the ports' attractiveness for cargoes. At present, Russia’s Arctic infrastructure is relatively backward, and its transportation network is very sparse. Especially in the eastern sector, where most of the undiscovered potential resources are located, the transport and navigation infrastructures remain weak, regular navigation in the eastern sector of the NSR is almost not carried out (Radushinsky *et al.*, 2017). About half of the 25 ports are not connected to the railway network, and some of them are even not located near the inland river, so their efficiency of connection and distribution is very low, which will influence their throughput heavily. In order to build up NSR, not only should we notice the development of ports along it, but also we should care the construction of port connection and distribution system.

**7．Conclusion**

With the ice decrease of Arctic area, the commercial value of NSR has become more and more visible. Many previous studies have demonstrated that the NSR is an alternative shipping passage for the goods shipped from Northeast Asia to Northwest Europe, or vice versa, from the current seasonal shipping situation.

However, just as some researchers have pointed out that as a potential alternative shipping route, weather NSR will be accepted by shipping owners and carriers not only depends on its profitability, but also depends on its safety, service and convenience. One of the main tasks of the Arctic transport communications is the development of the port infrastructure (Radushinsky *et al*., 2017), Russian ports require modernization to be able to host and provide service to international traffic (Gunnarsson, 2016).

From present references, little attention has been paid to the development of the relative ports in the Arctic area, based on this research gap, this paper has discussed the current development situation and future development potential of 25 ports along the NSR. A lot of data has been collected to make analysis and objective evaluation of the ports. Through the comprehensive evaluation, we could observe different circumstances and characteristics of each port, and find their advantages and disadvantages. In addition, some policy recommendations have been put forward in order to provide reference or guidance for the future development of NSR.

Through our analysis, we can conclude that the development of the 25 ports is unbalanced: only 2 ports have both good development situation and development potential; there are 8 ports have good development situation but poor development potential; there are 5 ports have poor development situation but good development potential for some ports, and for the remaining 10 ports, both the development situation and development potential are poor.

Among all the 25 ports, Murmansk has the highest evaluation score, which should be considered as the “Arctic hub” in the NSR, which is also aligned with *the Integrated Development Plan for the North Sea Route 2015-2030* of the Russian government. Except for Murmansk, there are 4 ports we should also pay more attention to: Sabetta, Varendey, Dudinka, and Igarka. They are all located in the area with abundant oil, gas, wood or metal ore resources, and these bulk cargoes will provide enough loading for them in the future. These findings have verified some former study: Oil and gas transportation dominates the transits, the number of bulk transits is quite stable (Zhang *et al*., 2016); future growth in Arctic shipping will remain the preserve of bulk shipping (Tseng *et al*., 2018); bulk (Liquid, Dry) and specialised shipping (LNG, Refer) will mostly benefit from Arctic routes in the short to medium-term (Theocharis *et al*., 2018).

Just as Arctic Council (2009) has pointed out that the major source of increasing Arctic traffic will relate to bulk shipping movements associated with serving Arctic ports and the exploitation of natural resources, so in addition to Sabetta, Varendey, Dudinka, and Igarka, the construction of other energy terminals in the NSR also should be the main focus in the short run, such as Vitino, Arkhangelsk, and Nakhodka.

Most ports in the Far East are with relatively high development situation but low development potential, including Petropavlovsk-Kamchatskiy, Vanino, Vladivostok, Nakhodka, and Vostochny. These ports normally have larger throughput, better infrastructures, but they are located in the Far Eastern Federal District with low GDP and less oil and gas resources. So considering their insufficient cargo flow from cargo supply in the hinterland but enough effective infrastructures, these ports may play the role of transit ports which tranship the western ports of NSR (such as Murmansk, Sabetta, or the ports from other Nordic countries) to East Asia or vice versa in the future.

In sum, the overall situation of port infrastructures along the NSR is unsatisfied, in addition to the port facility equipment, the connection and distribution system of most ports are also relatively backward, and it will hinder the smoothness of the whole shipping route. In order to increase the attractiveness of NSR, the port connection and distribution system of the ports should be strengthened as well.

Russia is currently planning to make substantial financial investments in the future development of the NSR in terms of infrastructure development. Through the study, we can achieve a fundamental understanding of the characteristics of each port and speculate on the specific demand for various ports along the NSR in the future. All these will help us make a suitable choice in the process of building the NSR. Owing to the availability of data, we could not make a very full and complete discussion about the 25 ports, and we have not done a dynamic analysis based on the different periods, which are all our future research directions.

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