Digital Technologies in Managing Multimodal Cargo Transportation

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Abstract. Multimodal transportation via the Northern Sea Route includes several stages. First, cargoes are transported across Russia by rail or road to a port on the Arctic coast. The Northern Sea Route facilitates the transportation of cargoes, reduces delivery times and transportation costs. In addition, this route is environmentally friendly and contributes to the development of the infrastructure in the regions located along it. The "Transport Strategy of Russia Until 2030" and the adopted "Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period Until 2020" stipulate that ports should be created for the operational management of transit cargo flows. A large number of cargoes that will need to be managed requires the arrangement and digitalization of multimodal transportation. The article analyses 10 ports along the Northern Sea Route. Criteria were selected to assess their readiness for operational management.

1 Introduction

Multimodal transportation is constantly evolving and improving. It is especially important for the Northern Supply Haul, since it enables delivering cargoes to remote areas with maximum efficiency. The role of the Northern Sea Route (NSR) in this type of transportation can hardly be overestimated.

Passing through the Arctic waters, the NSR is the fastest and most cost-effective route for the delivery of cargoes in the North-East of Russia. It saves time and resources when compared to traditional ways of transporting cargoes, such as roads and railways. Furthermore, the sea route is perfect for transporting cargoes that require special storage conditions, customized equipment and frequent freezing, such as fish, marine products, oil and gas [1–4].

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In order to implement the "Transport Strategy of Russia Until 2030" and the adopted "Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period Until 2020", transport/logistics centres and hub ports should be created in the northern regions of the Russian Federation, gravitating towards the NSR, which should attract transit cargo flows and stimulate the growth of container transport [5]. The operational management of multimodal transportation in hub ports should be carried out using digital technologies.

This article will analyse the Arctic ports of the NSR and consider the degree of digitalization and infrastructure of potential hub ports ready to receive cargo flows and distribute transit traffic.

2 Materials and methods

The Arctic Basin is an area of the rapid growth in maritime traffic, where the NSR plays an important role. The structure of exports is dominated by coal, timber, oil products, non-ferrous metal ores, and equipment, while the structure of imports is dominated by food products. In our work, we relied on the methods of empirical research (observation, comparison) and methods of theoretical research (abstraction, analysis and synthesis, mental modeling). On the basis of which the following data were obtained, which are shown in table 1. Table 1 shows the ports of the Arctic Basin, indicating the location, coordinates, area, throughput of terminals, vessel dimensions and the number of berths [6–10].

Table 1. Analysis of the Arctic Basin ports.

Port	**Location**	**Coordinates**	**Area (aquatic area + territory) km²**	**Throughput Total cargo terminals (thous. t/y)**	**Vessel dimensions (length/width/draft) m**	**Number of berths (overall length)**
Varandey	Varandey settlement Zapolyarny District, Nenets Autonomous Okrug	68°49′28″ N, 58°04′08″ E	24.98 + 0.0147	12,100.4	120 / 15 / 3.5	2 units (199.86 m)
Murmansk	Murmansk Murmansk Region	68°58′25″ N, 33°03′33″ E	53.70 + 6.459	26,611.2	no limitations	1,101 units + 2 piers (13,246.48 m)
Naryan-Mar	Naryan-Mar Nenets Autonomous Okrug	67°38′48″ N, 52°59′39″ E	5.6256 + 0.225697	501.016	114 / 14 / 3.6 (combined (sea/river) navigation vessels) 90 / 16 / 3.6 (marine vessels)	6 units (730.66 m)
Arkhangelsk	Arkhangelsk, Arkhangelsk Region	64°32′04″ N, 40°30′48″ E	1,120 + 2.1526	11,772.9	190 / 30 / 9.2	75 units (8,884.14 m)
Vitino	Beloe More village Kandalakshsky	67°04′46″ N, 32°19′28″ E	11.59 + 0.1866	11,000	230 / 32,2 / 11.1	4 units (512 m)

	District Murmansk Region					
Kandalaksha	The city of Kandalaksha Murmansk Region	67°09′14″ N, 32°23′24″ E	5.09 + 0.2544	1,500	200 / 33 / 9.8	5 units (584.45 m)
Mezen	The city of Mezen Arkhangelsk Region	65°52′01″ N, 44°12′21″ E	191 + 1.91	132	120 / 20 / 4.2	3 units (215 m)
Onega	The city of Onega Arkhangelsk Region	63°55′50″ N, 38°01′57″ E	845.59 + 0.0268	261.5	242 / 32.4 / 13.6	7 units (880 m)
Pevek	The city of Pevek Chukotka Autonomous Okrug	69°41′41″ N, 170°15′32″ E	8.9 + 0.19	330	172.2 / 24.55 / 9	3 units (500 m)
Dikson	Dikson settlement Taymyrsky District Krasnoyarsk Territory	73°30′14″ N, 80°29′59″ E	0.182 + 0.0477	120	100 / 20 / 8	2 units (243 m)
Dudinka	The city of Dudinka Krasnoyarsk Territory	69°24′32″ N, 86°09′19″ E	30.22 + 0.2492	1,885	260.3 / 32.2 / 11.8	9 units (1,723.6 m)
Sabetta	Sabetta settlement Yamalo-Nenets Autonomous Okrug	71°16′00″ N, 72°04′00″ E	11,177 + 1.795	30,317.8	315 / 50 / 12	11 units (2,365.8 m)
Tiksi	Tiksi settlement Yakutia	71°37′59″ N, 128°53′22″ E	96.78 + 0.0729	67	129.5 / 15.8 / 3.9	2 units (315.0 m)
Khatanga	Khatanga settlement Taymyrsky District Krasnoyarsk Territory	71°58′49″ N, 102°27′24″ E	3.7 + 0.1062	95	136 / 16.5 / 4.17	5 units (400 m)
Anadyr	The city of Anadyr Chukotka Autonomous Okrug	64°44′11″ N, 177°30′51″ E	45.33 + 0.1189	900	177 / 25 / 7	6 units (686 m)
Beringovsky	Beringovsky settlement	63°03′47″ N,	47.07 + 0.2212	1660.4	190 / 33 / 13 (in the harbor)	4 units (269 m)

	Anadyrsky District Chukotka Autonomous Okrug	179°21′20″ E			39.9 / 12 / 2.7 (at the berths)	
Provideniya	Provideniya settlement Chukotka Autonomous Okrug	64°26′08″ N, 173°13′03″ E	13.02 + 0.127	345.4	200 / 24 / 10	4 units (350.82 m)
Egvekinot	Egvekinot settlement Chukotka Autonomous Okrug	66°14′44″ N, 179°05′03″ E	5.75 + 0.0717	174	150 / 21 / 7.5	2 units (570.62 m)

Of the Arctic Basin ports, the port of Murmansk is considered ice-free; the Arctic zone ports serving the Northern Supply Haul include Pevek, Dikson, Dudinka, Sabetta, Tiksi, Khatanga, and Provideniya.

From the list of the ports presented in Table 1, we will take the ports of the Arctic zone and the Far North regions for further research in order to analyze the degree of digitalization of the ports and their preparedness to assume the role of hub ports for the operational management of transit cargo flows. Nine ports have been selected for this purpose: Murmansk, Arkhangelsk, Pevek, Dikson, Dudinka, Sabetta, Tiksi, Khatanga, and Provideniya.

The authors determined an attempt to assess the level of digitalization of the ports of the Northern Sea Route.

We have selected the criteria to assess the preparedness for digitalization and the capabilities for multimodal transportation of cargoes:
- Information accessibility;
- Multimodal transportation convenience;
- Basic elements of digital infrastructure.

We will assess the information accessibility using the official website, which should contain basic and official information, as well as description of services, tenders, etc.

Multimodal transportation convenience is assessed using the number and quality of access roads for cargo shipment. Distance from railway stations and federal (regional) highways.

The basic elements of digital infrastructure include satellite navigation, mobile/satellite communications, telecommunications, geoinformatics, and computer equipment.

3 Theory

A digital spatial model is required for the operational management of cargoes arriving at the ports and for further shipment of cargoes for road, rail or air transportation to end users. This digital spatial model should reflect the location and specifics of the main transport infrastructure facilities. In the future, this digital model will ensure monitoring of transport during cargo transportation [11–15]. Figure 1 shows the interaction diagram for the basic elements of digital infrastructure.

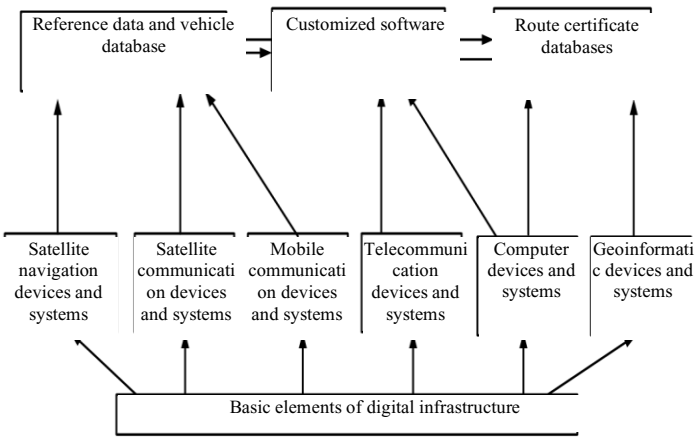

Fig. 1. Basic elements of the digital infrastructure of a multimodal transportation system.

4 Results

Table 2 was formed using the selected criteria.

Table 2. NSR ports assessment.

Item No.	Port name	Criteria		
		Information accessibility	Multimodal transportation convenience	Basic elements of digital infrastructure
1	Murmansk	80%	Railway station, E-105 highway	+
2	Arkhangelsk	100%	Railway station, M-8 highway, Arkhangelsk International Airport	+
3	Pevek	30%	Pevek Airport, long distance from a highway	+
4	Dikson	0%	Dikson Airport, long distance from a highway	+
5	Dudinka	0%	Railway station, A-382 federal highway	+
6	Sabetta	0%	Sabetta Airport, long distance from a highway	+
7	Tiksi	0%	Tiksi Airport, long distance from a highway	+
8	Khatanga	0%	Khatanga Airport, long distance from a highway	+
9	Provideniya	0%	Provideniya Bay, long distance from a highway	+

The expert assessment has demonstrated that the ports of Murmansk and Arkhangelsk have developed information accessibility at a sufficient level, while Pevek provides insufficient information, and the other ports do not have official websites.

All ports have basic elements of digital infrastructure.

Multimodal cargo transportation requires the availability of the routes leading to other modes of transportation. In our case, they include railway stations, airports and federal highways. Only 2 ports (Arkhangelsk and Murmansk) ensure the best multimodality

5 Conclusion

We consider the "Basic elements of digital infrastructure" criterion, which is necessary for operational management and the concept of port digitalization in general. The basic elements of digital infrastructure ensure [16–20]:
- Determining the location and movement parameters of monitored cargo vehicles;
- Exchange of information between monitored cargo vehicles and the dispatching system using the elements of a stationary infrastructure;
- Exchange of information between monitored cargo vehicles and the dispatching system using a constellation of communication satellites;
- Exchange of information between stationary elements of the dispatching control systems of cargo transport companies and transport infrastructure facilities;
- Data collection, storage and processing in a transport and logistics hub;
- Map visualization of the data related to the elements of digital infrastructure. Spatial data processing using GIS.

Digitalization of ports implies the "smart port" concept. A "smart port" uses innovative technologies, including artificial intelligence, big data, the Internet of Things (IoT), including the Internet of Logistics (IoL), as well as blockchain to improve the efficiency of maritime infrastructure.

Murmansk Commercial Sea Port JSC is actively implementing the "smart port" system. In particular, the company has arranged and successfully operates the "Eco-Friendly Dispatcher's Room" hardware and software suite, ILSAR information and logistics system, an automated control system for dust suppression facilities, and an automatic control system for art lighting of cranes.

Since 2022, Arkhangelsk Commercial Sea Port LLC has been implementing a digital port system to provide suppliers and cargo consumers with access to detailed real-time information from anywhere in the world, from the arrival of cargoes at the port to filling ship holds, from control of the fuel level in vehicles to distribution of stocks in warehouses. This system provides users with information on cargo handling, container filling, loading/unloading of ships, and loading of warehouse facilities. The system is available for customers and powered by 1C, thus ensuring its integration with the information systems of most companies.

Our analysis has demonstrated that it is the Arkhangelsk port that has the greatest potential for the operational management of the hub port for transit cargo traffic.

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