Information technologies as a way of port activity optimization in conditions of digital economy

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Abstract. The use of digital solutions in various fields of activity today allows you to adapt to the digital needs of customers. The adoption of information technology by the subjects of the transport complex was not quick at the beginning, but development has accelerated since then and now they allow optimizing their activities. The article discusses the current regulatory documents in the field of digitalization of seaports. An analysis of cargo turnover by Russian seaports was made, and it was noted that one of the important factors affecting the increase in this indicator is the implementation of digital solutions. Examples of information technologies in the world and in Russia used in the activities of seaports are given.

1 Introduction

The transition to the digital economy, the use of digital solutions is not only the introduction of new innovative technologies in the activities of organizations, but also the transformation of the development strategy and structure of the organization, the products and services provided, the organizational culture, etc. [1-5].

Digital transformation of the organization in the realities of the modern market allows you to adapt to the digital needs of customers, solve exactly in time of their expectations, and as a result becomes competitive in the market of services provision. Otherwise, the organization will face bankruptcy and liquidation, because they will be destroyed by new high-tech organizations.

In Russia, the introduction of digital solutions in various fields of activity began later than abroad. Nevertheless, over the past few years, we can observe a trend of active introduction of digitalization in various spheres of activity, including those related to the operation of the transport system (in particular – transport infrastructure).

The adoption of information technology by the subjects of the transport complex was not rapid in the beginning, but the development has since accelerated and now they allow:

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– choose the best methods of delivery;
– plan routes depending on the congestion of the transport infrastructure;
– track cargo location and condition;
– manage the schedule of vessels and time of cargo handling;
– optimize the work of personnel, etc.

Today, the country has many programs related to the development and implementation of digitalization. For example, according to the Decree of the President of the Russian Federation from 07.05.2018 No. 204 "On the national goals and strategic objectives development of the Russian Federation for the period up to 2024" to implement breakthrough scientific / technological and socio-economic development of the Russian Federation to ensure the rapid introduction of digital technologies in the economy and the social sphere is one of the important national development goals of the country until 2024 [28]. This includes the transformation of transport infrastructure through the introduction of digital technologies and platform solutions [28].

By Order No. 2101-r of September 30, 2018, the Comprehensive Plan for the Modernization and Expansion of the Main Infrastructure for the Period until 2024 was approved, in accordance with which the development and modernization of the sea and river infrastructure using advanced digital technologies will be ensured [18].

According to the Strategy for Spatial Development of the Russian Federation for the period up to 2025, approved by Order of the Government of the Russian Federation dated February 13, 2019 No. 207-r, the need for the development of information and telecommunication infrastructure by eliminating the “digital inequality” of the constituent entities of the Russian Federation and increasing information and telecommunication connectivity is established the territory of the Russian Federation and others in order to eliminate infrastructural restrictions and increase the availability and quality of transport infrastructure accelerate economic growth, scientific and technological and innovation development of the Russian Federation and others.

In accordance with the passport of the national project “National Program“ Digital Economy of the Russian Federation "approved by the Presidium of the Presidential Council for Strategic Development and National Projects, Protocol No. 7 of 06/04/2019 established the main targets, expressed in increasing domestic costs for the development of digital economics; creating a stable and secure information and telecommunications infrastructure for high-speed transmission, processing and storage of large amounts of data, accessible to all organizations and households; the use of predominantly domestic software by state bodies, local governments and organizations. Achievement of the set goals (referring to the transport complex) will be ensured within the framework of national projects (for example, “Development of the transport system”, “Economic development and innovative economy”, “On approval of a comprehensive plan for the modernization and expansion of the main infrastructure for the period until 2024”, “Departmental target program“ Digital platform of the transport complex of the Russian Federation ”, etc.).

2 Factors affecting the distribution of cargo turnover of Russian seaports

Seaports play an important role in the processes of globalization of production, increased access to markets and effective integration into the global economy. As a key player in international trade, we must also switch to digital management.[2, 3, 12, 24].

Russian ports process up to 80% of foreign trade cargo, which provides the country with economic and foreign trade development [12], whose cargo turnover has shown steady growth over the past few years.
A feature of the activity of Russian seaports is the uneven distribution of cargo handling across sea basins, which is due both to the distribution of goods by geographical criterion and the features of logistics routes (for example, most of the coal is handled in ports of the Far East, cargo in containers and mineral fertilizers - in mainly in the Baltic ports, grain and metals - in the ports of the Azov-Black Sea basin) [21].

Following the results of 2018, the cargo turnover of Russian seaports amounted to 816.5 million tons ((786.4 million tons) + 3.8% compared to 2017) [8]. The dynamics of cargo turnover of Russian seaports are presented in table 1.

**Table 1. Dynamics of cargo turnover of Russian seaports, million tons**

| Year     | Million tons |
|----------|--------------|
| 2003     | 286          |
| 2004     | 364          |
| 2005     | 406,9        |
| 2006     | 421          |
| 2007     | 451          |
| 2008     | 454,6        |
| 2009     | 496,4        |
| 2010     | 526          |
| 2011     | 535,6        |
| 2012     | 567          |
| 2013     | 590          |
| 2014     | 640,3        |
| 2015     | 676,9        |
| 2016     | 722          |
| 2017     | 786,4        |
| 2018     | 816,5        |
| 2020 (forecast) | 828   |
| 2025 (forecast) | 995   |
| 2030 (forecast) | 1129  |

As can be seen from the figure, a positive trend of an increase in freight turnover growth has been observed for quite some time. According to experts, in 2018, growth was achieved due to an increase in the volumes of liquefied gas (+ 57%), grain (+ 16%), and containerized cargo (+ 11%) shipment [21].

According to the Association of Commercial Sea Ports, the volume of dry cargo transshipment amounted to 387.4 million tons (+ 3.8%), and the volume of bulk cargo transshipment amounted to 429.1 million tons (+ 3.9%). Growth is observed, including for various cargo nomenclature. 623.8 million tons (+ 3.0%) were handled for export cargo, 37.3 million tons (+ 3.2%) for import cargo, 64.0 million tons for transit cargo (+ 9.8%), cabotage - 91.4 million tons (+ 6.2%) [8, 17]. Details of the data are presented in table 2.
Table 2. Volume of cargo turnover (by nomenclature) for the period 2017-2018, mln. tons

| Year / nomenclature | 2017       | 2018       | Changes   |
|---------------------|------------|------------|-----------|
| Dry cargo, including: |            |            |           |
| coal                | 154,4      | 161,4      | +4.4%     |
| grain               | 47,8       | 55,7       | +16.3%    |
| cargo in containers | 48,2       | 53,6       | +11.1%    |
| ferrous metals      | 28,2       | 30,4       | +7.6%     |
| mineral fertilizer  | 17,6       | 17,8       | +0.1%     |
| Liquid cargo, including: |        |            |           |
| crude oil           | 253,2      | 255,4      | +1.2%     |
| oil products        | 141,5      | 145,1      | +2.4%     |
| liquefied gas       | 14,7       | 23,2       | in 1.6 times |
| Export cargo        | 606,5      | 623,8      | +3.0%     |
| Import cargo        | 36,1       | 37,3       | +3.2%     |
| Transit cargo       | 58,2       | 64,0       | +9.8%     |
| Cabotage            | 86,0       | 91,4       | +6.2%     |

As for the volume of cargo handled in the basins, the highest growth is observed in the Arctic, including by increasing the volume of liquefied gas from the port of Sabetta. Details on handled volumes are presented in table 3.

Table 3. Volume of cargo turnover (by basin) for the period 2017-2018, million tons

| Basin               | Cargo turnover, mln. tons | Changes   |
|---------------------|---------------------------|-----------|
| 2017                | 2018                      |           |
| Arctic basin        | 74,2                      | 92,7      | +26.4%    |
| Baltic basin        | 247,5                     | 246,3     | -0.5%     |
| Azov-black basin    | 269,5                     | 272,2     | +0.9%     |
| Caspian basin       | 3,9                       | 4,8       | +21.6%    |
| far-East basin      | 191,7                     | 200,5     | +4.5%     |

As can be seen from table 3, of the total cargo turnover, the operators of the marine terminals of the Arctic basin handled 92.7 million tons of cargo, which is 26.4% more than the cargo turnover of the same period in 2017. The volume of handled liquid cargo increased to 62.3 million tons (+41.0%), handling of dry cargo increased to 30.4 million tons (+4.3%). The cargo turnover of the port of Murmansk increased to 60.7 million tons (+18.1%), Sabetta to 17.4 million tons (an increase of 2.3 times) and Arkhangelsk - up to 2.8 million tons (+15.5%) [8, 18]. In the ports of the Baltic basin, the volume of transshipment of cargo decreased to 246.3 million tons (-0.5%), of which the volume of liquid cargo - up to 136.5 million tons (-4.1%), bulk carriers increased to 109.8 million tons (+4.5%). The volume of cargo handled in ports decreased: Ust-Luga to 98.7 million tons (-4.4%), Primorsk to 53.5 million tons (-7.1%), the Big Port of St. Petersburg increased the volume of handling to 59,3 million tons (+10.6%), Vysotsk up to 18.8 million tons (+7.1%) and Kaliningrad - up to 14.1 million tons (+1.5%) [8, 18]. The cargo turnover of the seaports of the Azov-Black Sea basin amounted to 272.2 million tons (+0.9%), including the handling of dry cargo increased to 119.1 million tons (+0.4%), bulk - up to 153.1 million, tons (+1.3%). Operators of the terminals of the ports of Novorossiyansk increased handled cargo to 154.9 million tons (+5.0%), Rostov-on-Don - to 16.7 million tons (+11.5%). Tuapse ports reduced their handling volume to 25.6 million tons (-3.7%), the Caucasus - to 30.1 million tons (-14.9%), Taman - to 14.1 million tons (-6.0%) [8, 18]. 4.8 million tons of cargo (+21.6%) were handled in the seaports of the Caspian basin, of which
dry cargo vessels - 2.6 million m (-6.9%), bulk carriers - 2.2 million tons. The volume of handled cargo in the ports of Makhachkala increased 1.8 times to 2.5 million tons, the port of Astrakhan reduced handling to 1.9 million tons (-16.7%) [8, 18]. In the seaports of the Far Eastern basin, cargo turnover increased to 200.5 million tons (+ 4.5%), of them dry cargo vessels - up to 125.5 million tons (+ 6.8%), bulk cargo amounted to 75.0 million tons (+ 1.0%). Vanino's ports increased cargo turnover to 29.5 million tons (+ 0.9%), Nakhodka - up to 24.3 million tons (+ 0.1%), Vladivostok - up to 21.2 million tons (+24, 7%), De-Castries - up to 12.6 million tons (+ 16.7%). At the same time, the cargo turnover of the Prigorodnoye ports decreased to 17.0 million tons (-2.1%), and Posyet - up to 7.1 million tons (-7.7%). Vostochny port cargo turnover remained almost at the level of last year and amounted to 63.7 million tons [8, 18].

Considering the current situation and relying on official information from the Association of Sea Trade Ports, we can say that in 2019 an increase in the total volume of cargo transshipment is expected. In support of these words, one can cite official statistics on cargo turnover for the 9 months of 2019 according to which the cargo turnover of Russian seaports for the indicated period increased by 2.8% compared to the corresponding period last year and amounted to 626.8 million tons. The volume of handled dry cargo amounted to 280.1 million tons (-4.4%), the volume of liquid cargo handling amounted to 346.7 million tons. (+ 9.4%). As in 2018, the main increase in cargo turnover was achieved due to the activities of the shore terminals operators of the Arctic basin, in particular, due to the shipment of liquefied gas through the port of Sabetta (the increase is associated with the launch of the second and third phases of the Yamal LNG project). The growth of cargo turnover is forecasted by experts until 2030. Thus, according to the information of the Ministry of Industry and Trade of Russia, by 2020 it is forecasted that the volume of cargo handling will reach 884 million tons, by 2025 - 995 million tons, by 2030 and in the future, about 1129 million tons [6]. Such growth can be achieved due to the influence of various factors, including due to the construction and reconstruction of transport and trunk infrastructure, the introduction of digital technologies, etc.

3 Digital solutions in the activities of seaports: global and domestic experience

The digitalization of seaports began in 1993, when unmanned aerial vehicles were first used to handle containers at the port of Rotterdam. The facility works with automated unmanned RMG (ARMG) and unmanned automated controlled vehicles (AGV) for horizontal handling of containers from the berth. IBM is currently conducting a large-scale digital transformation of the port in Rotterdam (the “smart port in the world”), with the goal of receiving autonomous connected cargo ships by 2025. It is about creating a detailed digital port twin, covering the entire port area with a length of 42 km. It is an exact digital copy of port operations that tracks ship traffic, infrastructure, weather, geographic data, and depth data. Data accuracy is 100%.

The European port handles more than 140 thousand annually, so coordination of the parking of each vessel is a complex and important task. The new digital control panel of the port will be able to simultaneously view the operations of all parties, increase the volume and efficiency of shipment of goods. In turn, this will lead to a reduction in the stay time of the vessel in the parking lot, and the adoption of more vessels daily. Also, IoT sensors, augmented intelligence technology and intelligent weather data were introduced in the port to assess the availability of berths and other important parameters.

Accurate data on hydro and meteorological conditions make it possible to predict the best time to call at the port under the most favorable conditions. The system will collect information on air temperature, wind speed, relative humidity, turbidity and salinity, water
levels, tides and currents, which can be used to forecast visibility on a specific day and capability of ships port call. The system will reduce the cost of cargo delivery, reduce the consumption of marine fuel, ensure cost-effective loading of each vessel and help ensure the safe arrival of cargo.

Rotterdam Port has a Rotterdam Additive Manufacturing LAB research center, the world's first 3D printing lab dedicated to seaports and shipping companies, providing a wide range of certified metal parts for ships. Another component of digitizing the Port of Rotterdam is the introduction of sensors called digital dolphin, which are necessary for working out various scenarios of work, coordinating the traffic of incoming / outgoing vessels and controlling the actions of port crews. The system allows you to collect information about the status and use of the berth terminal, the state of water and weather conditions, which in turn will allow port operators to determine the optimal time and place for ship mooring [14, 22].

Another major European port is the port of Hamburg, which is developing with new technological trends, giving new opportunities for port operators, as well as stakeholders in the port economy. For the purpose of efficient traffic flow in the port of Hamburg, a real-time navigation system has been connected. The system allows the participant to use personalized navigation, possessing information about the traffic situation in the port, about parking and infrastructure, closing of movable bridges, etc. The port also uses the “Intelligent Railway Point” system, which allows, through the installation of sensors, to analyze the busiest points on the port railway. Sensors allow you to analyze various data, providing information about the condition and wear of the main working intersections, which in turn allows you to avoid possible downtime [https://www.hamburg-port-authority.de/en/hpa-360/smartport/]. Thanks to the ongoing digital transformation, it has become possible to reduce operating costs, reduce the load on transport routes formed by ships, trains and trucks. According to forecasts, by 2025 the port will double the port's throughput capacity to 17 million containers per year without expanding the area [22].

The Tilbury Container Terminal in London uses a fully integrated mobile vehicle reservation system application specifically designed for terminal carriers. This application allowed carriers to place orders and check the status of containers remotely from smartphones [4].

In the seaport of Montreal, the Trucking PORTAL web application has been developed to reduce pollution and increase productivity. The application optimizes truck routes, reducing traffic jams at the entrances / exits to the terminals. Information obtained using Bluetooth, RFID tags and reading vehicle numbers is transmitted to drivers in real time. This is a key tool in reducing the waiting time and greenhouse gas emissions in the port [4].

Qingdao's New Qianwan Container Terminal (QQCTN) was the first fully automated container terminal in Asia and remains one of the most advanced in the world. Operating since May 2017, it is located on the south coast of the Qingdao Qianwan port area, capable of processing 5.2 million TEU annually. It may house the world's largest container ship with 24,000 TEU [1].

The terminal is controlled by laser scanners and positioning systems, which can find the four corners of each container in order to precisely fix and transfer them to trucks without a driver. This technology allows the terminal to work in complete darkness during the night, which allows to reduce terminal labor costs by 70%, while increasing efficiency by 30% (for example, the number of employees for unloading the ship was reduced from 60 to 9 persons). In addition, the following are implemented at the terminal:

- cars with automatic control programmed for routes and tasks, as well as having artificial intelligence to recognize the need for recharging;
- automated equipment planning;
- automatic mooring of the vessel;
– fully automated container delivery;
– automatic system with a rotary lock;
– unmanned intelligent gate system.

Another interesting informational solution has a fully automated terminal, KTLB in Long Beach, California, USA. The powerful mega-crane at the quay serve mega-vessels with tremendous lifting capacity in terms of weight and ability to handle multiple containers simultaneously. Fast discharging of containers is further enabled by the fast, fully automatic portal trolley that moves containers between the crane platform and the horizontal transportation. At the yard, efficient automatic stacking cranes featuring fully automatic landing and pick-up of containers on road chassis and remote exception management from a centralized control room, ensure efficient yard operations. The automated intermodal yard cranes serve the trains on dock rail yard. All these amazing, electrically driven cranes are equipped with ABB’s Intelligent automation solutions for safer, greener and more productive container handling [9].

In the Russian Federation, issues of competitiveness and increasing the productivity of seaports, including using new technologies, increasing their level of innovation today are very relevant [27].

In Russian seaports, information technologies such as [10, 13, 22, 25]:
– electronic document management (for example, in: JSC “Rosterminalugol”, LLC “NUTEP”, JSC “First Container Terminal”, JSC “Petrolesport”, JSC “Novoroslesekport”, PJSC “Vladivostok Commercial Sea Port”, etc.) - simplifies / accelerates the activities of the seaport with interested parties, reducing downtime, reducing the costs of both the seaport and its client (for example, refusing paper media when working with orders for loading export cargo; refusing paper media when releasing cargo from the port; transfer in electronic format of the full chain of documents used in relations with customers (bills of lading / manifests, nominations / release orders, accounting documents, acceptance orders (in import), ship bookings and acceptance certificates (in export), as well as cargo plans, loading lists, applications for customs inspection, applications for approval of the import of dangerous goods, etc.)); digitalization of the financial document flow unit, etc.);
– lean manufacturing technology (lean management - which consists in optimizing processes by identifying and eliminating hidden losses, providing management infrastructure, changing the mindset of employees, which in turn increases the efficiency of the seaport) (for example, Rosterminalugol JSC);
– operational management systems in the activities of container terminals - designed to manage personnel and equipment at the container terminal in real time in order to increase the efficiency of container processing (for example, NUTEP LLC, PJSC NCSP, Vladivostok Container Terminal LLC, First JSC container terminal”, OJSC “Ust-Luga Container Terminal”, etc.);
– automated control systems in the activities of the seaport and the railway (for example, Rosterminalugol JSC, Vostochny Port JSC, etc.) - the system allows for the loading / unloading / sending of cars to the terminal in automatic mode;
– automated systems for the interaction of seaports and federal executive bodies (for example, the KPS Portal Sea Port) - a system that works on the basis of the principles and mechanisms of the Single Window. It provides electronic interaction for all participants in the process of processing goods and vehicles at sea checkpoints in order to create favorable conditions for accelerating trade through the customs border of the Eurasian Economic Union (EAEU), reducing the time it takes to complete customs operations, and increasing the efficiency of customs control;
– systems for interacting with information systems of sea vessels and with trading portals on the basis of a single window principle (terminals in Ust-Luga and Nakhodka);
specialized systems, such as security systems, recognition systems for numbers of containers, cars and railway platforms, and other systems.

In general, new technological trends that can provide new opportunities for stakeholders in port activities include: the Internet of things, artificial intelligence, 3D printing, virtual and augmented reality, digital twins, technologies for maintaining distributed accounting and credential registries, self-executing codes technologies fulfillment obligations, drones and other digital technologies.

4 Conclusion

After analyzing the existing information technologies in the activities of seaports, it can be noted that a lot of work has been done on digitalization both in the world and in Russia. However, it should be noted that the latter is lagging behind in this matter. Nevertheless, seaports are moving towards the so-called "smart ports", which will create a completely new logistics system that allows you to quickly and safely deliver goods at minimal cost. It should be borne in mind that the selection and implementation of digital solutions in the activities of seaports is a transformational and complex process, which in turn can be either destructive or transitional. The consequences of the transition will depend on the nature of the business models that may arise as a result of technology adaptation in the port sector.

Increasing the efficiency of seaports is becoming increasingly recognized as the most important factor for planning the development of their future activities, investments and their strategic positioning, as well as for achieving globally agreed benchmarks and benchmarks in the field of sustainable development.

Seaports and a wide range of stakeholders with the state, various services and infrastructures should cooperate to identify and use key levers to increase the productivity, profitability and efficiency of seaports, ensuring synchronization in various aspects (organizational, personnel, legal, financial, technological, security issues, etc.).

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