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BLOCKCHAIN AND SMART PORTS IN THE BLACK SEA BLUE ECONOMY

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Abstract. The Black Sea region has experienced significant transformation in maritime logistics, driven by the adoption of digital technologies such as blockchain, artificial intelligence (AI), and the Internet of Things (IoT). This paper examines the current state of cargo turnover in major Black Sea ports, highlighting Constanța (Romania) and Odesa (Ukraine) as regional leaders, and identifies trends in container handling and energy-efficient port operations. The study presents the "BlackSeaChain" pilot initiative, illustrating how blockchain-based solutions reduce cargo clearance times, improve document verification, and enhance operational transparency. The paper also explores the implementation of Digital Twin models, e-berth allocation systems, and energy monitoring solutions that contribute to CO_2 reduction and operational efficiency. Key challenges, including regulatory fragmentation, cybersecurity risks, and investment limitations, are analyzed alongside potential future developments, such as standardized digital governance frameworks, cross-border cooperation, and integration of blockchain with carbon accounting and green logistics. The findings demonstrate that smart port technologies are crucial for supporting the sustainable growth of the Blue Economy in the Black Sea region.

Key words: Blue economy, Smart ports, blockchain, digital transformation, maritime logistics, port sustainability, IOT, artificial intelligence, decarbonization, shipping companies.

Introduction

In 2024, the total cargo turnover of Black Sea ports surpassed 480 million tons, according to the European Maritime Safety Agency (EMSA) and the Black Sea Commission [1], growing at an annual rate of around 3.2%. Romania's Constanța Port handled nearly 92 million tons, making it the regional leader, followed by Odesa (Ukraine) and other major ports. Container traffic also recovered, with more than 2.4 million TEU processed across the region.

The Blue Economy emphasizes the sustainable use of ocean resources to promote economic growth, improve livelihoods, and create jobs, all while protecting marine ecosystems. The Black Sea, bordered by Ukraine, Romania, Bulgaria, Turkey, and Georgia, plays a key role in regional trade, energy transit, and biodiversity conservation.

One notable initiative is the "BlackSeaChain" pilot, launched in 2024 by a group of ports and shipping companies from Bulgaria, Georgia, and Turkey. By integrating

blockchain for digital document verification, the project has reduced cargo clearance times by 40% and cut up to 60% of traditional paper documentation.

Over recent years, Black Sea ports have increasingly implemented IoT sensors, AI-based predictive maintenance, and energy management systems. For example, Constanța Port's Digital Twin model enables real-time cargo flow simulation, improving berth utilization by 12% [4]. Similarly, Odesa Port's new e-berth allocation system and blockchain-based energy monitoring have reduced CO_2 emissions from port operations by 9%. The Black Sea remains a vital trade corridor, handling large volumes of grain exports from Ukraine and energy shipments from Russia. Container ship calls have reached record levels at major ports such as Constanța, Varna, Odesa, Batumi, and Novorossiysk, reflecting rerouted vessels and growing shipping volumes.

To better illustrate the current state of the Blue Economy in the region, let us take a look at the cargo throughput dynamics of the main Black Sea ports between 2018 and 2025, with a forecast up to 2030 (Figure 1).
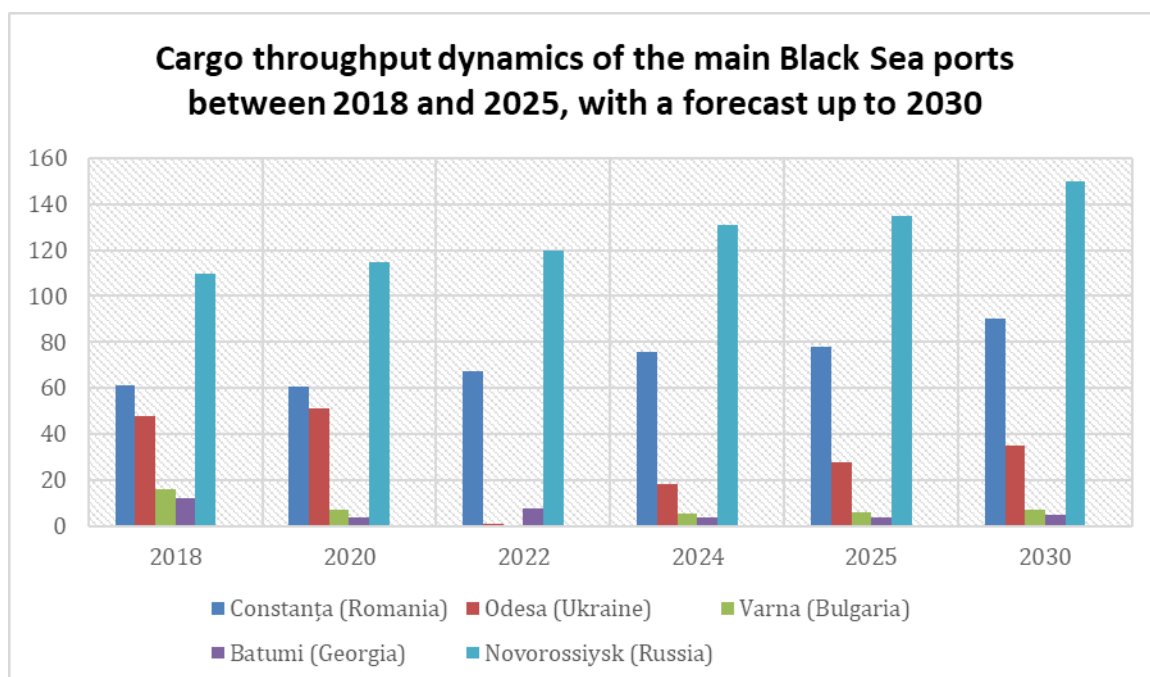

Figure 1 – Cargo throughput dynamics of the main Black Sea ports between 2018 and 2025, with a forecast up to 2030

Digital Transformation and Sustainability Trends

Digital technologies have reshaped how ports in the Black Sea operate. Smart ports increasingly rely on data-driven decision-making, automated logistics, and secure digital infrastructure to streamline operations.

Blockchain ensures data integrity and reduces costs associated with customs clearance, shipping documentation, and cargo tracking [5]. When combined with IoT and AI, blockchain provides real-time visibility of operations and predictive analytics for maintenance and energy usage.

From an environmental perspective, these innovations help achieve EU Green Deal objectives. Ports employing smart energy grids and automated lighting report electricity savings of 10–15%. Incorporating renewable energy sources, such as solar panels and onshore power supply (OPS), further supports decarbonization goals outlined by the International Maritime Organization (IMO) [3].

Blockchain and Smart Port Initiatives in the Black Sea

Blockchain offers several key benefits for the maritime sector:

− Transparency: provides an immutable record for goods and cargo origin verification.

− Efficiency: smart contracts can automatically validate and execute shipping agreements, reducing delays.

− Security: distributed ledgers minimize the risk of tampering and cyber threats.

The BlackSeaChain project highlights how regional cooperation enhances interoperability among ports. Similarly, Constanța Port is developing a blockchain-based Port Community System to synchronize data between shipping agents, customs, and terminal operators.

In Ukraine, Odesa Port has piloted blockchain solutions for tracking fuel and equipment, improving compliance and reducing procurement fraud. These initiatives illustrate a shift towards digital transparency and operational resilience, key to supporting a sustainable Blue Economy [2].

Challenges and Future Prospects

Despite promising results, some challenges remain in implementing blockchain

and smart port solutions in the Black Sea region:

1. Different digital readiness levels and regulatory fragmentation across countries.

2. Cybersecurity risks arising from integrating multiple digital platforms.

3. Limited investment capacity due to geopolitical and economic uncertainties.

Future progress will rely on harmonized digital governance frameworks, supported by EU initiatives such as CEF Digital and Horizon Europe. Regional cooperation through initiatives like the Black Sea Synergy can standardize digital documentation and create shared blockchain infrastructure for maritime data.

Looking ahead, combining blockchain with carbon accounting, smart logistics corridors, and green financing tools can create a climate-resilient, competitive, and sustainable port ecosystem in the Black Sea region.

Conclusions

The introduction of blockchain and smart port technologies marks a new phase in the Black Sea maritime economy. By enhancing transparency, lowering emissions, and streamlining operations, digital innovations support sustainable growth within the Blue Economy. Strengthening cross-border collaboration, harmonizing digital standards, and investing in technology infrastructure are essential for unlocking the full potential of smart, blockchain-enabled ports in the region.

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