ბათუმის ნავიგაციის უნივერსიტეტი

BATUMI NAVIGATION UNIVERSITY

X საერთაშორისო სამეცნიერო კონფერენცია

მდგრადი სატრანსპორტო სისტემა და საზღვაო ლოგისტიკა

კონფერენციის მასალათა კრებული

CONFERENCE PROCEEDINGS

ბათუმი – 2026

X საერთაშორისო სამეცნიერო კონფერენცია
„მდგრადი სატრანსპორტო სისტემა და საზღვაო ლოგისტიკა“

X International Scientific Conference
“SUSTAINABLE TRANSPORT SYSTEM AND MARITIME LOGISTICS”

კონფერენციის მასალათა კრებული
CONFERENCE PROCEEDINGS

ეძღვნება მეზღვაურთა საერთაშორისო დღეს
Dedicated to the International Day of the Seafarer

ბათუმი / Batumi 2026

სტატიებში გამოთქმული მოსაზრებები ეკუთვნით ავტორებს და შესაძლოა არ ემთხვეოდეს ბათუმის ნავიგაციის უნივერსიტეტის პოზიციას. სტატიაში მოყვანილი ფაქტებისა და მონაცემების სიზუსტეზე პასუხისმგებელია ავტორი.

კონფერენციის მასალათა კრებულში წარმოდგენილია ბათუმის ნავიგაციის უნივერსიტეტის მიერ ჩატარებული IX სტუდენტთა საერთაშორისო სამეცნიერო კონფერენციაზე წარმოდგენილი სტატიები.

სტატიები იბეჭდება ავტორთა მიერ წარმოდგენილი რედაქციით.

The opinions expressed in the articles belong to the authors and may not necessarily coincide with the position of Batumi Navigation University. The author is solely responsible for the accuracy of the facts and data presented in the article.

The collection of conference materials presents the articles presented at the 9th international student scientific conference held by the Batumi Navigation University.

The articles have been printed under the editorial supervision provided by the authors.

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გამომცემელი / Publisher:
ბათუმის ნავიგაციის უნივერსიტეტი / Batumi Navigation University

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ISBN 978-9941-9995-4-3

X საერთაშორისო სამეცნიერო კონფერენცია

„მდგრადი სატრანსპორტო სისტემა და საზღვაო ლოგისტიკა“

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2. **საზღვაო ლოგისტიკა და ნავსადგურების მართვა:** ჭკვიანი პორტები (Smart Ports); პორტების ოპტიმიზაცია და ეფექტიანობა; საზღვაო მიწოდების ჯაჭვის მართვა; ციფრული ტრანსფორმაცია და ბლოკჩინური ტექნოლოგიები ლოგისტიკა.
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CONFERENCE GOAL

The aim of the conference is to discuss ongoing scientific research, innovative practices, and policy development issues in the fields of sustainable transport systems and maritime logistics. The event will serve as a platform for representatives of academia, industry, and the public sector to exchange knowledge, share experience, and strengthen professional cooperation.

MAIN THEMATIC AREAS OF THE CONFERENCE

The conference will cover (but is not limited to) the following thematic areas:

1. **Sustainable Transport Systems:** Green transport and decarbonization; low-emission transport models; urban mobility and integrated transport policy; energy efficiency and alternative fuels.
2. **Maritime Logistics and Port Management:** Smart Ports; port optimization and efficiency; maritime supply chain management; digital transformation and blockchain technologies in logistics.
3. **Maritime Transport Safety and Regulations:** International conventions and regulatory frameworks; risk management in maritime transport; cybersecurity and maritime infrastructure; the human element and safety culture.
4. **Innovations and Digital Technologies in Transport and Logistics:** Artificial intelligence and data analytics; autonomous transport systems; IoT and automation of logistics operations; Digital Twin technologies.

ტრანსპორტში; კიბერუსაფრთხოება და საზღვაო ინფრასტრუქტურა; ადამიანის ფაქტორი და უსაფრთხოების კულტურა.

4. **ინოვაციები და ციფრული ტექნოლოგიები ტრანსპორტსა და ლოგისტიკაში:** ხელოვნური ინტელექტი და მონაცემთა ანალიტიკა; ავტოპორტნომიური სატრანსო ცვლილებები; IoT და ლოგიკური ოპერაციების ავტომატიზაცია; ციფრული ტვინინგი (Digital Twin).
5. **კლიმატის ცვლილება და საზღვაო გარემოს დაცვა**: MARPOL-ის წინააღმდეგ და ეკოლოგიური სტანდარტები; გარემოსდაცვითი მენეჯმენტი ნავსადგურებში; მდგრადი ლოგისტიკური პოლიტიკა; ESG მიდგომები ტრანსპორტში.
6. **საზღვაო განათლება და ადამიანური კაპიტალის განვითარება:** STCW სტანდარტები და მათი განვითარება; IMO HTW პროცესები; საზღვაო განათლების ციფრული ტრანსფორმაცია; სიმულაციური სწავლება და VR ტექნოლოგიები; აკრედიტაცია და ხარისხის უზრუნველყოფა; მწვანე და ციფრული კომპეტენციები; ადამიანის ფაქტორი და უსაფრთხოების კულტურა; Dual Education მოდელები საზღვაოში; მრეწველობა–აკადემია თანამშრომლობა.

5. **Climate Change and Maritime Environmental Protection:** MARPOL requirements and environmental standards; environmental management in ports; sustainable logistics policies; ESG approaches in transport.
6. **Maritime Education and Human Capital Development:** STCW standards and their development; IMO HTW processes; digital transformation in maritime education; simulation-based training and VR technologies; accreditation and quality assurance; green and digital competencies; the human element and safety culture; dual education models in the maritime sector; industry–academia cooperation.

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სარჩევი / Contents

IMPLEMENTATION OF SEEMP IN ORDER TO EVALUATE THE OPERATIONAL PERFORMANCE OF LNG VESSELS IN THE INDONESIAN REGION 16
Author(s): Ronald Simanjuntak; Mutarin Dewi Mustafa; Derma Watty Sihombing; Nurindah Dwi Yani; Boedojo Wiwoho

PRESENT AND FUTURE FUELS FOR SUSTAINABLE MARITIME TRANSPORTATION: A REVIEW OF OPPORTUNITIES AND CHALLENGES 28
Author(s): Aditya Kolakoti; Gargi Dangayach; Gauri Nandhana K.R

SUSTAINABLE TRANSPORT SYSTEMS AND MARITIME LOGISTICS: STRATEGIC ASSESSMENT OF THE EASTERN BLACK SEA LOGISTICS HUB 43
Author(s): Musa Gün

MODELING OF TRAFFIC FLOWS TAKING INTO ACCOUNT THE PROCESSES OF UPDATING COMPONENTS OF MARITIME TRANSPORT INFRASTRUCTURE 55
Author(s): Iryna Honcharova

STRATEGIES FOR ENHANCING THE COMPETITIVENESS AND ATTRACTIVENESS OF GEORGIA'S BLACK SEA PORTS 57
Author(s): Ruslan Verdzadze; Levan Bolkvadze; Nino Beridze

APPROACHES TO MARITIME NETWORK RESILIENCE: A STATE-OF-THE-ART REVIEW AND FUTURE RESEARCH DIRECTIONS 66
Author(s): Jinendri Prasadika; Oanh Nguyen; Wenming Shi

B2B PLACE MARKETING AND STRATEGIC POSITIONING IN SUSTAINABLE SUPPLY CHAINS: A CONCEPTUAL ANALYSIS FOCUSING ON THE IYIDERE LOGISTICS PORT 90
Author(s): Mustafa Said AKIN; Abdülkadir ÖZTÜRK

STPA-BASED SAFETY ANALYSIS IN PILOT TRANSFER OPERATIONS 92
Author(s): Muhammed Ali Dönmez; Muhammed AYDIN

TEMPORAL CHANGES AND OPERATIONAL RISK FACTORS IN MARITIME CONTAINER LOSS EVENTS 102
Author(s): Mehmet KAPTAN

IMPROVING THE INTERACTION BETWEEN SEAPORTS AND RAIL TRANSPORT 118
Author(s): Valerian Imnaishvili; Giorgi Kikvidze; Master Student Mariam Gogitidze

RISK MANAGEMENT IN GLOBAL ENERGY MARITIME LOGISTICS UNDER GEOPOLITICAL AND SUPPLY CHAIN DISRUPTIONS: A REVIEW 125
Author(s): K.M.Mahaboob Sheriff

GEOPOLITICAL RISK AND MARITIME LOGISTICS DISRUPTIONS: THE CASE OF THE STRAIT OF HURMUZ 126
Author(s): Noa Klarić; Duje Delić; Luka Vukić

IMPLEMENTING MARITIME LABOUR CONVENTION 2006 IN CADET EDUCATION: A SEAFARER RIGHTS AWARENESS MODEL AT STIP JAKARTA 137
Author(s): Dr. Capt. Tri Cahyadi; Dr. Larsen Barasa; Capt. Natanael Suranta; Titis Ari Wibowo; Dr. Markus Yando; Nurul Wahyuni; Aji Permana

სარჩევი / Contents

BLOCKCHAIN-BASED SOLUTION FOR MARITIME CREW CERTIFICATION: SUSTAINABILITY ENHANCEMENT FOR MARITIME SECTOR 139
Author(s): Thi Mai Phuong Pham; Anish Arvind Hebbar; Tafsir Matin Johansson

OBJECT DETECTION IN MARINE ENVIRONMENT: ENHANCING INDONESIA MARITIME SAFETY VIA YOLOV8 COMPUTER VISION AND KALMAN FILTER 155
Author(s): Aditya Rinaldi; Larsen Barasa; Natanael Suranta

PREDICTIVE ANALYTICS FOR SIRE TANKER INSPECTIONS USING MACHINE LEARNING: A DATA-DRIVEN APPROACH TO PROACTIVE RISK MANAGEMENT 156
Author(s): Toygar Tibet GENIS; Muhammet AYDIN

INTERNATIONAL REVIEW OF EMERGING TECHNOLOGIES IN CONTAINER PORTS AND TERMINALS: A STUDY OF ASIA-PACIFIC REGION 165
Author(s): Pavan Kumar Amarvadi; Wenming Shi; Oanh Nguyen

INFORMATION SYSTEMS FOR LOGISTICS MANAGEMENT 185
Author(s): Viktoriia Smrkovska

A MULTI-LAYER APPROACH TO EVENT PREDICTION USING SEMANTIC NETWORK MODELS 189
Author(s): Lia Shetsiruli; Natela Archvadze; Merab Pkhovelishvili

A COMBINED SALT SPRAY AND CYCLIC LOADING TEST PROTOCOL FOR CHARACTERIZING WELD ZONE CORROSION IN AH36 STEEL 195
Author(s): Anatoli Ripalevi

FORENSIC EVALUATION OF SYSTEMIC FAILURES IN THE BEIRUT PORT AMMONIUM NITRATE EXPLOSION UNDER MARITIME RISK MANAGEMENT PERSPECTIVE 202
Author(s): Kasypi Mokhtar; Chahaya Alysa Ahmad Fuad; Siti Marsila Mhd Ruslan

BIODIESEL COMPETENCY FRAMEWORK FOR ENGINE CADETS TO SUPPORT INDONESIA'S NATIONAL 203
Author(s): Dr. Larsen Barasa; Dr. Capt. Marihot Simanjuntak; Dr. Capt. Marihot Simanjuntak; Titis Ari Wibowo; Aditya Rinaldy

APPLICATION OF HAZOP METHODOLOGY FOR RISK ASSESSMENT IN CHEMICAL TANKER TANK WASHING OPERATION 205
Author(s): Batuhan İnanc Erkan; Muhammet Aydin

THE EFFECTS OF CLIMATE CHANGE ON HUMAN PHYSIOLOGY 217
Author(s): Elif ÖZDÜNDAR

PROSPECTS FOR REALIZING THE TRANSIT POTENTIAL OF THE EURASIAN ECONOMIC UNION IN THE SYSTEM OF INTERNATIONAL TRANSPORT CORRIDORS 222
Author(s): George Gabedava; Tengiz Aphkhazava; Nino Tchilaia; Master Student Giorgi Davitadze

MARITIME LOGISTICS, CLIMATE CHANGE AND HOUSING MARKETS IN CITIES 228
Author(s): Haydar KARADAG

MARITIME VALUE CHAIN TOWARDS ENVIRONMENTAL STANDARDS FOR SUSTAINABLE GROWTH FROM MALAYSIA EXPERIENCE 235
Author(s): Kasypi Mokhtar

სარჩევი / Contents

INTEGRATING IMO'S GHG STRATEGY INTO ENGINE CURRICULUM: A GREEN SIMULATION MODULE AT STIP JAKARTA 236
Author(s): Dr. Meilinasari Nurhasanah Hutagaol; Jarot Delta Susanto; Muhammad Nurdin; Mochamad Ely Ridwan; Ardiansyah; Sursina; Fitri Mulyana

DUAL AWARD MASTER'S PROGRAMME IN TRANSPORT TECHNOLOGIES: CASE OF UNIVERSITY OF PLYMOUTH AND KHERSON STATE MARITIME ACADEMY 241
Author(s): Alona Leshchenko; Alona Yurzhenko; Olena Kononova

AI LITERACY AS AN EMERGING NON-TECHNICAL COMPETENCY IN MARITIME OFFICER TRAINING: IMPLICATIONS FOR STCW AND IMO MODEL COURSES 248
Author(s): Bairamova Olena Viktorivna

CHALLENGES ECO PORT AND GREEN SHIPPING : OVERVIEW OF CURRENT AND FUTURE ACTION 258
Author(s): Vidya Selasdini; Meilinasari Nurhasanah; Naomi Louhnapessy

HUMAN FACTORS AND THEIR IMPACT ON MARITIME SAFETY AND OPERATIONAL EFFICIENCY 275
Author(s): Tamar Diasamidze

INTEGRATING AI SOFT SKILLS INTO MARITIME ENGINEERING EDUCATION 289
Author(s): Natalia Ohorodnyk

LOGISTICS AS A SCIENTIFIC TOOL FOR MANAGING FLOW PROCESSES 294
Author(s): Prof. George Gabedava, Master Student Jambul Turmanidze

THE IMPACT OF MOBILE OTG RESOURCES ON ENGLISH COMMUNICATIVE COMPETENCE ONBOARD 299
Author(s): Litikova Oleksandra

VIRTUAL REALITY FOR CONTEXTUAL MARITIME ENGLISH TRAINING: A MODEL FOR SITUATIONAL AWARENESS AT STIP JAKARTA 301
Author(s): Dr. Marudut Bernadtua Simanjuntak; Niken Sitalaksmi Widjaja; Capt. Suhartini; Ikhwanuddin

THE IMPACT OF LOGISTICS ON BUSINESS PERFORMANCE 303
Author(s): Ketevan Goletiani; Nino Tchilaia; Ekaterine Chikovani, Master Student Ana Kekelidze

OPTIMIZING EEOI TRAINING FOR DECK AND ENGINE OFFICERS: A COLLABORATIVE MODEL FOR CII COMPLIANCE AT STIP JAKARTA 313
Author(s): Pargaulan Dwikora Simanjuntak; Rosna Yuherlina Siahaan; Susi Herawati; Derma Watty Sihombing

PROBLEMS OF RELATIONS WITH THE EURASIAN ECONOMIC UNION 315
Author(s): Levan Gvarishvili; Mirza Suknishvili; Giorgi Abashidze, Master Student Bakur Kochalidze

ENHANCING ISM CODE COMPLIANCE THROUGH SIMULATION-BASED SAFETY CULTURE TRAINING FOR CADETS AT STIP JAKARTA 323
Author(s): Dr. Winarno; Capt. Natanael Suranta; Capt. Candra Purnama; Capt. Irfan Faozun; A. Nurfajri Irwan; Giovani B. Puteri

EVALUATING STCW-BASED MARITIME ENGLISH INSTRUCTION ON DECK AND ENGINE CADETS' OPERATIONAL READINESS AT STIP JAKARTA 325
Author(s): Dr. Marudut Bernadtua Simanjuntak; Capt. Suhartini; Tristanti; Yayu Nopriani Martha

საქართველოს სავაჭრო ნაკადების განმსაზღვრელები 3+3 ფორმატის ქვეყნებთან: ეკონომიკური, კულტურული და ლოგისტიკური ფაქტორების ანალიზი პანელური გრავიტაციის მოდელის გამოყენებით 327
DETERMINANTS OF GEORGIA'S TRADE FLOWS WITH THE 3+3 FORMAT COUNTRIES: AN ANALYSIS OF ECONOMIC, CULTURAL, AND LOGISTICS FACTORS USING A PANEL GRAVITY MODEL 327
Author(s): Imeda Paksadze; Ali Riza Sandalcilar

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THE IMPACT OF FOREIGN DIRECT INVESTMENT ON THE DEVELOPMENT OF MARITIME TRANSPORT AND LOGISTICS IN GEORGIA 335
Author(s): Nino Kartvelishvili

სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის ფორმირება და განვითარება საქართველოში 343
FORMATION AND DEVELOPMENT OF TRANSPORT AND LOGISTICS INFRASTRUCTURE IN GEORGIA ... 343
Author(s): Parmen Khvedelidze; Nino Beridze;

Master Student Giorgi Shainidze 343

სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის როლი ტურისტული დანიშნულების ფორმირებაში: დუბაის განვითარების გამოცდილება 354
THE ROLE OF TRANSPORT AND LOGISTICS INFRASTRUCTURE IN SHAPING TOURIST DESTINATIONS: THE EXPERIENCE OF DUBAI'S DEVELOPMENT 354
Author(s): Larisa Dolikashvili

საზღვაო ტრანსპორტის რისკების კლასიფიკაცია 363
CLASSIFICATION OF MARITIME TRANSPORT RISKS 363
Author(s): George Gabedava; Kristina Rzgoeva;

სახელმწიფო ინვესტიციების როლი პორტების ოპტიმიზაციასა და ეფექტიანობაში და გავლენა რეგიონულ ეკონომიკურ განვითარებაზე 373
THE ROLE OF PUBLIC INVESTMENT IN PORT OPTIMIZATION AND EFFICIENCY AND ITS IMPACT ON REGIONAL ECONOMIC DEVELOPMENT 373
Author(s): Daviti Grdzelishvili

საზღვაო ლოგისტიკა და ნავსადგურების მართვა 376
MARITIME LOGISTICS AND PORT MANAGEMENT 376
Author(s): Manana Laliashvili

საზღვაო ინდუსტრიის უსაფრთხოების სტანდარტები და მათი რეგულირების მექანიზმები 380
SAFETY STANDARDS IN THE MARITIME INDUSTRY AND THEIR REGULATORY MECHANISMS 380
Author(s): Nato Saginadze

DIGITAL TWIN ტექნოლოგია როგორც ტრანსპორტისა და ლოგისტიკის ოპტიმიზაციის ინოვაციური ინსტრუმენტი 383
DIGITAL TWIN TECHNOLOGY AS AN INNOVATIVE TOOL FOR TRANSPORT AND LOGISTICS OPTIMIZATION 383
Author(s): Tamila Kartsivadze

DIGITAL TWIN ტექნოლოგიის როლი თანამედროვე ლოგისტიკასა და საქართველოს სატრანზიტო პოტენციალის განვითარებაში 390
THE ROLE OF DIGITAL TWIN TECHNOLOGY IN MODERN LOGISTICS AND THE DEVELOPMENT OF GEORGIA'S TRANSIT POTENTIAL 390
Author(s): Nino Topuria; Elizbar Darchiashvili

პორტის საქმიანობის ექსპლუატაციური მაჩვენებლების ანალიზი საბაზრო პირობებში 402
ANALYSIS OF PORT OPERATIONAL PERFORMANCE INDICATORS UNDER MARKET CONDITIONS 402
Author(s): Teimuraz Gograchadze; Tariel Paksadze; Master Student Ilia Chkhaidze

საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის განვითარების პროგნოზირება საქართველოში 409
FORECASTING THE DEVELOPMENT OF THE DIGITAL TRANSFORMATION OF MARITIME LOGISTICS IN GEORGIA 409
Author(s): Irakli Gazdeliani; Tea Munjishvili

საზღვაო ტერმინოლოგიასთან დაკავშირებული გამოწვევები 422
CHALLENGES RELATED TO MARITIME TERMINOLOGY 422
ავტორ(ებ)ი/Author(s): Tatia Tsetskhladze

ადამიანური კაპიტალის განვითარების აქტუალური საკითხები საზღვაო სისტემაში ... 426
CURRENT ISSUES IN HUMAN CAPITAL DEVELOPMENT IN THE MARITIME SECTOR 426
Author(s): Nona Akhvlediani; Mariami Akhvlediani

სავაჭრო ნაკადის სტრუქტურული ცვლილების დეტერმინანტები 445
DETERMINANTS OF STRUCTURAL CHANGES IN TRADE FLOWS 445
Author(s): Givi Bakradze; Imeda Paksadze; Iago Beridze; Master Student Giorgi Chkhikvadze

სამედიცინო დაწესებულების მოტივაციის პრობლემის საერთო დიაგნოსტიკა 454
GENERAL DIAGNOSIS OF MOTIVATION PROBLEMS IN MEDICAL INSTITUTIONS 454
Author(s): Elida Khvedelidze; Ekaterine Gvarishvili

უცხოური სამუშაო ძალის გავლენა საქართველოს შრომის ბაზრის სტრუქტურულ და ფუნქციურ ტრანსფორმაციაზე 463
THE IMPACT OF FOREIGN LABOR ON THE STRUCTURAL AND FUNCTIONAL TRANSFORMATION OF GEORGIA'S LABOR MARKET 463
Author(s): Irma Tkemaladze; Teona Chachua; Nino Dokhturishvili;

Gvantsa Eristavi 463

ღვინის წარმოების ეკოლოგიური კვალი თელავის მუნიციპალიტეტში 473
ENVIRONMENTAL FOOTPRINT OF WINE PRODUCTION IN TELAVI MUNICIPALITY 473
Author(s): Magda Davitashvili; Darejan Margalitashvili; Lamara Zuroshvili

დანართი კონფერენციის პროგრამა / ANNEX – CONFERENCE PROGRAM 482

Implementation of SEEMP in Order to Evaluate the Operational Performance of LNG Vessels in the Indonesian Region

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ABSTRACT

Global warming, driven by greenhouse gas (GHG) emissions, poses a major international challenge, with the shipping industry contributing significantly through exhaust emissions from conventional fuels such as diesel and heavy fuel oil (HFO). The shipping sector is expected to account for approximately 3% of global greenhouse gas (GHG) emissions by 2025. The industry, which transports 80% of the world's goods, faces increasing pressure to decarbonize as emissions from this difficult-to-abate sector continue to rise. However, if the shipping industry is to achieve its net-zero target by 2050, significant changes will be required, as it remains heavily reliant on fossil fuels, particularly heavy fuel oil (HFO). HFO releases significant amounts of carbon dioxide (CO_2), sulfur dioxide (SO_2), and other pollutants into the atmosphere. Indonesia, a vast archipelago with programs to improve inter-island connectivity and optimize logistics, will undoubtedly require additional fleet expansion, and the private sector is also showing a trend of acquiring new ships. Although LNG is one of the main energy sources in Indonesia which is relatively more abundant, there is a high dependence on fuel that has the potential to increase energy inefficiency in the supply chain and remains a challenge of emissions, especially in the production, distribution, and use processes. IMO Regulation MEPC.213 on Ship Energy Efficiency Management Plans (SEEMP) has become a mandatory instrument since 2019 to reduce GHG by 40% by 2030 (IMO Strategy) serves as an important tool to reduce GHG and improve ship operational performance with three main interrelated parts, namely first focusing on planning, second on collecting fuel consumption data and its calculation and third practical implementation of the prepared plan and continuous monitoring through indicators such as the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII). This study focuses on the application of SEEMP by calculating the Energy Efficiency Operation-

al Indicator (EEOI) to assess the operational efficiency of LNG vessels that can help ship owners and ship operators in reducing fuel emissions in ship operations. This research methodology is quantitative with a case study approach on an LNG vessel owned by a national operator (with a gross tonnage of 109,258 GT). Primary data was collected based on EEOI calculations from 2023–2024, with a total of 24 voyages. The analysis results show an average EEOI of 27.7125 gm/ton-mile with an average carbon emission of 2.787x10^-5 t-CO_2/t-nm. Analysis of operational data from LNG vessels (2023–2024) reveals a positive correlation between carbon emission intensity and EEOI values: higher CO_2 emissions correspond to increased EEOI, indicating decreased energy efficiency. The implementation of SEEMP allows for emission evaluation and control, and can reduce greenhouse gas emissions by 30% from the specified target. These findings offer actionable recommendations for LNG operators in Indonesia to comply with IMO regulations and advance the goal of net-zero emissions.

Keywords: SEEMP, EEOI, LNG vessels, GHG emissions, operational efficiency

1. INTRODUCTION

Global warming caused by the effects of greenhouse gas (GHG) emissions has become a critical global issue, with increasing urgency across various industrial sectors. The maritime transportation sector, which accounts for approximately 80% of global trade, contributes significantly to global emissions(Ahn et al., 2023), accounting for nearly 3% of total GHG emissions and is projected to continue to increase if no mitigation measures are implemented. High reliance on fossil fuels, particularly heavy fuel oil (HFO), results in substantial emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and particulates, which contribute to global climate change and marine pollution (Abbas, 2025). The International Maritime Organization (IMO) has addressed this challenge by setting ambitious targets to reduce total greenhouse gas emissions from the international shipping sector by at least 50% by 2030 and achieve a 70% reduction by 2050 (Vaio et al., 2023) (Hanif et al., 2024). Renewable energy technologies must be introduced to support these targets. To support these targets, regulatory frameworks such as the Ship Energy Efficiency Management Plan (SEEMP) have been mandated to improve operational efficiency and promote sustainable shipping practices.

Through MARPOL Annex VI which aims to prevent and reduce air pollution from ships which includes emissions of sulfur oxides, nitrogen oxides and greenhouse gases from ship diesel engines, and also includes energy efficiency where since the 2011 amendment requires each member country to establish technical and operational measures to reduce greenhouse gas emissions including the application of the Energy Efficiency Design Index (EEDI) for new ships before they are built, the Energy Efficiency Existing Ship Index (EEXI) for ships already in operation that were not subject to EEDI regulations during their construction and the Ship Energy Efficiency Management Plan (SEEMP) for all types of ships

mandated to improve operational efficiency and promote sustainable shipping practices (Uygur et al., 2026)(Manuel José Suazo Alvarez, Mocerino Luigia, Alvaro Ignacio Gonzalez, 2026). The application of Marpol Annex VI regarding EEXI for existing ships with a gross tonnage of 400 GT and above that undertake international voyages.

Indonesia, as a vast archipelagic country, is striving to improve inter-island connectivity and optimize logistics, and possesses diverse natural resources, including coal, nickel, LNG, and other minerals. Global energy demand is increasing, with natural gas predicted to increase by almost 40 percent in 2040 compared to 2017(Eriksen et al., 2022). Its strong economic growth, driven by the growth of its public fleet and the acquisition of new vessels by the private sector, is coupled with abundant domestic natural gas resources must be accompanied by a reduction in emissions. Although liquefied natural gas (LNG) is positioned as a renewable energy fuel due to its lower carbon intensity compared to fossil fuels, its supply chain, from production to distribution, is not free from environmental impacts. Research by Sapto et al. shows that Indonesian LNG production has an environmental impact with a global warming potential of 699.31 kg CO_2-eq per ton, in addition to acidification, eutrophication, and substantial non-renewable energy consumption (Benarimo et al., 2023). Indonesia remains highly dependent on fossil fuel sources, which continues to drive energy inefficiencies throughout the supply chain. The Ship Energy Efficiency Management Plan (SEEMP) has been mandatory since 2019. The SEEMP framework consists of three integrated parts: Part I addresses specific planning for ship energy efficiency, Part II requires the collection and reporting of fuel oil consumption data for ships of 5,000 gross tons and above, and Part III was added through an amendment effective January 1, 2020. The Energy Efficiency Operational Indicator (EEOI), a key performance metric that measures CO2 emissions per ton-mile of cargo carried, is at the heart of the framework. It allows operators to track and compare operational efficiency over time (UK, 2023).

Several studies have investigated the theoretical application of EEOI on various types of ships(Park & Jung, 2023) (Ashry et al., 2024)(Chen et al., 2024), but there are still some challenges regarding how to implement it operationally on LNG carriers. This is especially true in terms of infrastructure and operations in developing countries like Indonesia. The study conducted shows that the transition from marine diesel oil (MDO) to LNG can reduce the Energy Efficiency Design Index (EEDI) by approximately 27%(Park & Jung, 2023), and the comprehensive implementation of SEEMP and EEDI measures can reduce CO2 emissions on very large crude carriers (VLCCs) by up to 66.8%(Ashry et al., 2024). However, there is still limited research on how SEEMP can be effectively applied to LNG vessels in actual ship operations, as operational variables such as boil-off gas management, voyage optimisation, and loading conditions present specific complexities.

This study addresses a quantitative analysis of the implementation of the SEEMP on a 109,258 GT LNG vessel operated by an Indonesian national operator. The study assesses the carbon intensity of LNG shipments in Indonesian waters using primary EEOI calculations derived from 24 voyages conducted between 2023 and 2024. The results show an average EEOI of 27.71 g/ton-mile, with a positive correlation between carbon emissions and the EEOI value, and a 30% reduction in greenhouse gas emissions attributable to the

SEEMP. These results provide actionable insights for LNG operators, policymakers, and industry stakeholders seeking to align national maritime growth with global decarbonization commitments.

2. LITERATUR REVIEW

2.1 IMO Regulatory Framework for Decarbonization

Technical and operational metrics were introduced in 2009 to assess ships' energy efficiency. MEPC.1/Circ.681 to MEPC.1/Circ.684 offer the Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP), and Energy Efficiency Operational Index (EEOI). SEEMP is an operational measure used to cost-effectively improve ship energy efficiency through four main stages: planning (ship efficiency management, including best practices for voyage optimization, trim and ballast management, hull and propeller maintenance, and speed optimization), implementation, monitoring, and self-evaluation and improvement. Ship owners, operators, and other stakeholders develop specific plans to ensure a continuous cycle of improving energy management. Multi-criteria decision analysis (MCDA) can be used to assess the energy efficiency of ship operations and evaluate solutions.

EEOI monitors the results of these plans to determine their effectiveness over a specific time period, based on the amount of cargo carried or the number of transportation tasks performed (Tadros et al., 2023). The framework of emissions monitoring relies on the SEEMP to run its operations. According to IMO guidelines (Resolution MEPC.346(78)), the SEEMP should be considered a ship-specific “living document” that sets out methods for continuously improving energy efficiency. Efficiency management planning is discussed in Part I. This includes best practices for voyage optimization, trim and ballast management, hull and propeller maintenance, and speed optimization. Part II describes the Data Collection System (DCS) relating to fuel oil consumption used and must be reported annually to the flag administration. Part III describes the CII Requirements, which commence in 2022 and are mandatory from January 2023. These include calculation methodologies, three-year performance projections, and corrective action plans for underperforming ships(IMO Guidelines, 2022) (Radonja, 2025)(Mouzakitis et al., 2026).

2.2 Energy Efficiency Operational Indicator (EEOI): Methodology and Applications

The main indicator for tracking operational carbon intensity is the EEOI, which is described in IMO rules (MEPC.1/Circ.684). The indicator, which is computed as follows, measures CO2 emissions per unit of transportation work:

$$EEOI = \frac{\sum_j FCj \; x \; Cfj}{m \; cargo \; x \; D} \qquad 1)$$

Where FCj is fuel consumption of type j, Cfj is the fuel-specific CO_2 emission factor, m cargo is cargo mass (in tonnes), and D is voyage distance (in nautical miles). This metric facilitates benchmarking and target setting by allowing operators to evaluate emission efficiency across particular voyages, routes, or fleet-wide operations(Bayraktar & Mollaoglu, 2025) (*Energy Efficiency Operating Indicators (EEOI) for Baltic Exchange Tanker Routes*, 2023). Recent empirical studies have demonstrated the utility of EEOI across various ship segments. Ashry et al. (2024) conducted a comprehensive field study on a super-large crude oil tanker (VLCC). The study compared the ship's operational performance across three phases: before SEEMP implementation, after SEEMP implementation, and the combined application of SEEMP/EEDI on a newly built ship. Their results demonstrated progressive improvements; the combined approach reduced fuel consumption by 82.6%, CO2 emissions by 66.8%, and EEOI by 71.5% compared to baseline conditions. It is noteworthy that, between Phases 2 and 3, ship performance improved by 46.6%. This demonstrates that operational measures alone provide significant benefits. However, to achieve the greatest reductions, a comprehensive technical and operational strategy is required (Ashry et al., 2024).

Daehyuk Kim et al., in the study GHG Emission Reduction: LNG dual fuel technology resulted in significant CO2 emission reduction, with EEDI in gas mode of 30.16 gCO2/t-nm compared to EEDI in diesel mode of 38.56 gCO2/t-nm, which is a 21.8% reduction in greenhouse gas emissions that meets IMO Phase 1 requirements. However, the average operational EEOI of LNG shows a significant reduction. Contribution to Decarbonization that the ship consistently achieves CII Grade A performance, demonstrating strong decarbonization results. Moving away from conventional propulsion, LNG dual fuel electric propulsion system is a transitional technology to reduce carbon emissions in coastal passenger ships(Kim et al., 2026).

2.3 Research Gap

Despite significant progress in maritime energy efficiency research, several outstanding issues remain. First, SEEMP and EEOI studies have largely focused on container ships, bulk carriers, and oil tankers. Despite their growing share of the global fleet and their unique operational characteristics, such as gas boil-off management and specialized cargo handling, limited attention has been paid to LNG carriers. Second, most research has been conducted in developed countries and major flag states, with little empirical evidence from developing maritime nations like Indonesia, which face significant differences in infrastructure constraints, fleet age profiles, and operational practices. Third, the observed discrepancies between design phase indices (EEDI, EEXI) and operational indicators (EEOI, CII) suggest that long-term case studies should be conducted using primary shipping data(Holovan, 2026). To address this gap, this study provides an empirical analysis of the application of SEEMP on LNG vessels operating in Indonesia. The analysis is based on 24 voyages conducted over a two-year period (2023–2024). The study offers (1) a baseline

carbon intensity metric for LNG shipping in Indonesian waters, (2) empirical evidence on the effectiveness of SEEMP as an emissions reduction tool in this context, and (3) actionable recommendations for operators and policymakers seeking to balance fleet expansion with decarbonization commitments. This study calculates EEOI values based on actual fuel consumption, payload, and distance data.

3. METHODOLOGY

The methodology in this study includes the type of ship as the object of research, data collection, calculation methodology and analysis for evaluating the operational energy efficiency of LNG ships in implementing the Sehip Energy Efficiency Management Plan (SEEMP).

3.1. Research design

This study uses a quantitative case study approach, using a single case, namely an LNG carrier operated by an Indonesian national shipping company with the implementation of SEEMP. The availability of primary data from 24 consecutive voyages allows for a robust analysis. A single-case design can be used when the case can represent a critical test of existing theory (Younas, 2025), namely the application of EEOI for LNG vessels operating in Indonesia. This study applies deductive logic with the IMO EEOI formula systematically to operational data so that this study directly observes and evaluates the operational performance of the vessel.

3.2 Characteristics of LNG vessels

Emission calculations from LNG vessels use actual operational data, including fuel consumption, cargo mass, and sailing distance over a specific period. The specifications of the LNG vessels used in the study are as Table 1.

Table 1. Ship Specification

Parameter	Value
Gross Tonnage (GT)	109.281
Kind of Vessel	LNG Carrier
Main Engine	Mitsubishi Marine Turbin One (27.700HP)
Propulsin system	Steam turbin with dual-fuel capability
Cargo tanks cubic capacity	137.012,426 m^3 (5 tanks)
Operational area	Indonesia archipelago

The selection of vessels is based on the following criteria: continuous implementation of SEEMP during the sailing period, availability of data such as fuel consumption, cargo, sailing distance and representation of LNG vessels in Indonesia.

3.3 Data Collection

Primary data was collected for the period 2023-2024, from a total of 24 voyages of shipping routes, where each voyage describes a full laden-to-laden cycle (from departure at the loading port to arrival at the unloading port followed by ballast return. The voyage of the ship is as follows: Bintuni – (Arun, Patimbang, Jakarta) and Bontang – (Arun, Lampung, Jakarta, Labuhan Maringgai).

3.4 Analysis process

The Energy Efficiency Operational Indicator (EEOI) is calculated based on IMO guidelines as in formula 1, and the CO2 emission factor is based on the fuel type according to MEPC.332(76) namely for the LNG (methane) fuel type of 2,750 and Heavy Fuel Oil (HFO) of 3,114 with the emission factor unit Cf(t-CO2/t-fuel). The results of the EEOI in grams of CO2 per tonne-nautical mile (g CO2/t-nm) are in accordance with industry standards. (Anh, 2017). The target set by the Company's DPA for LNG vessels against EEOI is 40 gm/t-mile. To see the relationship between parameters and EEOI, regression analysis is used.

1. Result and Analysis

A total of 24 voyages were analyzed in the period 2023-2024, as shown in Table 2., descriptive statistics for operational parameters such as fuel consumption (LSFO-Low Sulphur Fuel Oil, MDO – Marine Diesel Oil, BOG-Boil off Gass), Cargo, sailing distance, and calculation results of EEOI and CO2 emissions.

Table 2. Summary Data

Parameter	Unit	Mean	Std Deviation
LSFO	tons	105.28	88.44
MDO	Tons	0.197	0.78
BOG	Tons	1,059.27	311.27
Cargo	M3	128,457.65	12,384.98
Distance	Nm	3,970.46	1,030.74
EEOI	gm/t-nmile	27.708	6.0533
CO2 Emission	T-CO_2/t-nmile	2.787	0.617

The average cargo transported during the observation period was approximately 128,458 tonnes per voyage, while the average voyage distance was 3,970 nautical miles. These findings indicate that voyage distance and loading conditions significantly impact operational efficiency. Figure 1 and Figure 2 shows the results of the analysis for these parameters. The varying EEOI values indicate fluctuations in operational efficiency across voyages. A lower EEOI value indicates more efficient transportation operations. The figure shows that Cargo is the factor that most influences the emission efficiency value. The closer the vessel approaches its maximum capacity of 137,012 tons, the lower the resulting EEOI value. Based on the small number of low-load voyages (two voyages), the average EEOI value is higher than that of fully loaded voyages.

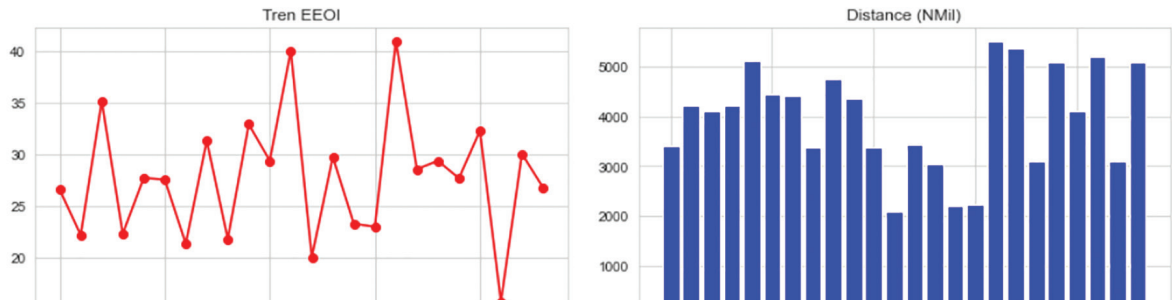

Figure 1. Value of EEOI and voyage distance

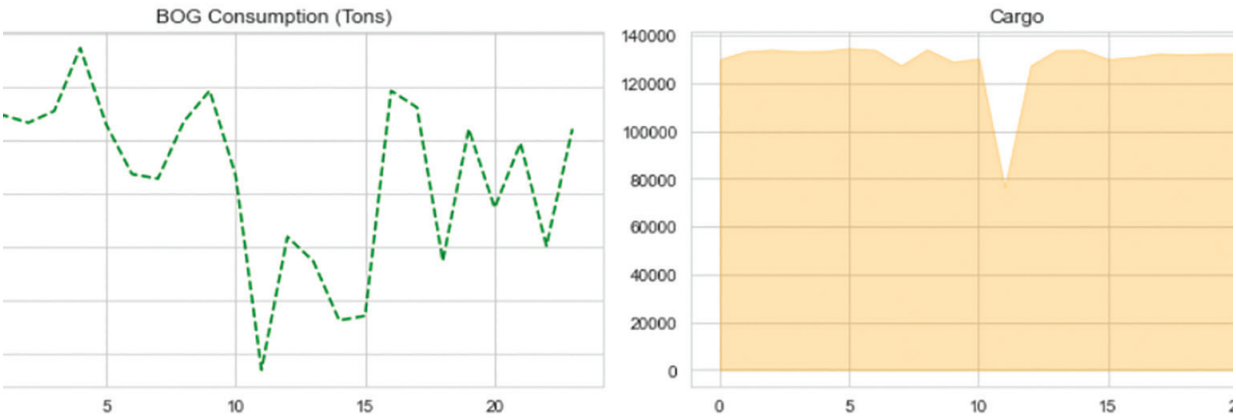

Figure 2. BOG Consumption dan Amount of Cargo

This confirms that cargo space utilization significantly determines efficiency values. Conversely, low-load voyages (such as the Bontang Labuhan Maranggai Voyage) cause an EEOI value to swell by up to 40.01, even though the total fuel consumption is lower. There is a very strong positive correlation between Distance Traveled and Total Fuel Consumption. However, this increase in fuel consumption is proportional to distance, so if the vessel is fully loaded, the long distance does not automatically worsen the EEOI value. Fuel and distance are operational and fixed variables, but cargo utilization is the key variable that determines whether fuel use is efficient. To maintain a stable emissions report below 27.0, each voyage must aim to achieve a minimum utilization rate of 95% of ship capacity. Efficiency Analysis Based on Capacity Gap, as shown in Table 2.

Table 2. Analysis gap based on cargo

Average Utilization	Rate EEOI	Analysis
Very High (>97%)	26,92	Most efficient. Vessels are nearly full.
Normal (90% – 97%)	27,15	Standard operation. Emissions per ton-mile are stable.
Low (<80%)	40,01	Critical, with utilization of only 55.8%.

Regression analysis for cargo parameters against EEOI calculations as in the figure 3, it can be seen that the larger the cargo load, the value of EEOI tends to decrease, which means that the ship's operations work more efficiently (emissions per ton mile are smaller). If it is assumed that the loading is around 95 percent, it shows that Most of the data points are gathered on the bottom right side, proving that the ship can achieve the best level of energy efficiency. The impact of a small load on the leftmost point, far below 95 percent, the EEOI value jumps drastically to 40, this shows that a voyage with a small load is very inefficient because fuel consumption remains high but the cargo moved is small.

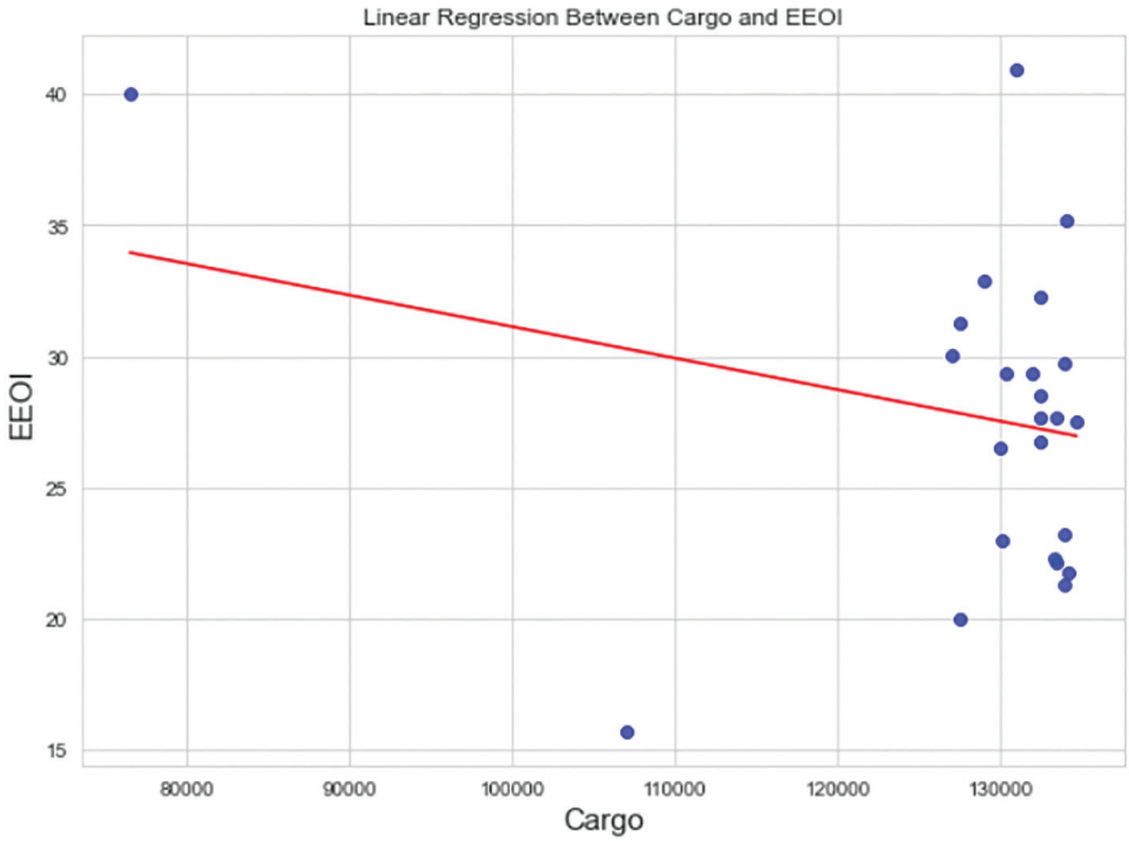

Figure 3. Analysis Regretion Cargo Vs EEOI

To see whether fuel factors also have an influence, you can look at the relationship (correlation) between variables, as in the table 3.

Table 3. Correlation Matrix

Variable	LSFO	BOG	Cargo	Distance	EEOI
LSFO	1	0.149	-0.282	0.184	0.66
BOG	0.1498	1	0.452	0.897	-0.059
Cargo	-0.282	0.452	1	0.305	-0245
Distance	0.184	0.897	0.305	1	-0.083
EEOI	0.663	-0.0059	-.0246	-0.083	1

Table 3 shows that LSFO with EEOI has a fairly strong positive correlation, the more fuel used the EEOI value tends to increase, and distance with BOG has a very strong correlation, this is because the further the journey the more gas evaporation occurs. Likewise, if it is done with a multiple regression model on these parameters, the main statistics are obtained with an r squared value of 0.47, that the variables together provide 48.7 percent of the EEOI variation, the Prob (F-statistic) value of 0.009, a value smaller than 0.05 indicates a significant model overall, and the LSFO p-value of 0.0001 is a variable that has a significant influence partially.

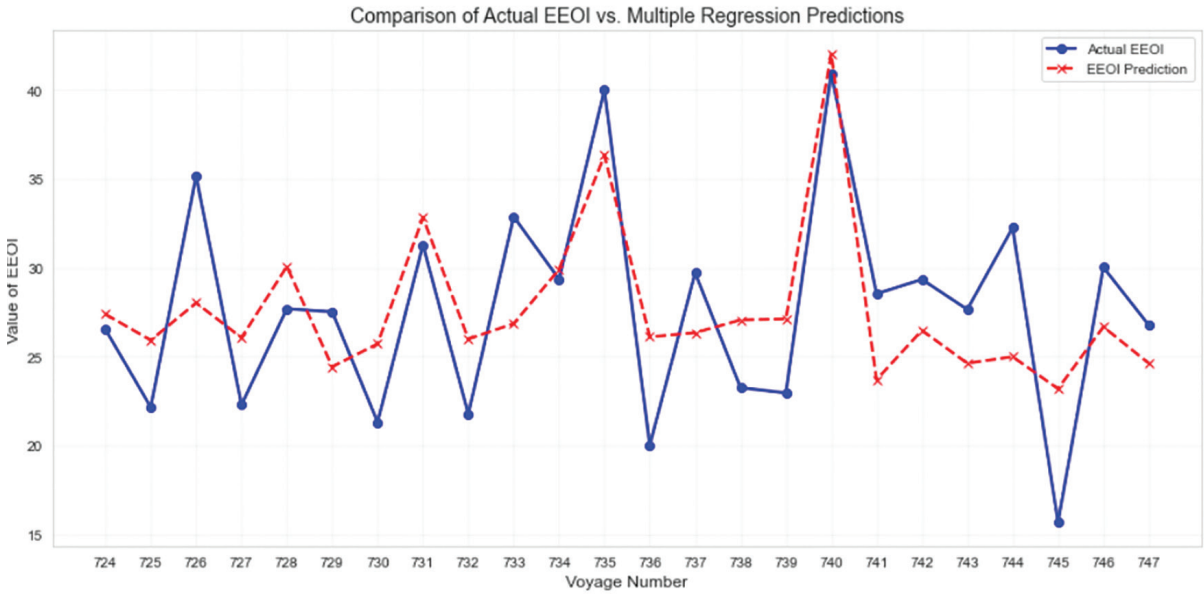

Figure 4. Comparison of Actual EEOI vs. Multiple Regression Predictions

Overall, fuel consumption (LSFO) is the main driver that determines the value of shipping energy efficiency. The visualization Figure 4, comparing actual EEOI with predictions, from the r squared value shows that the model is able to explain almost 50 percent of the data. The implementation of the Ship Energy Efficiency Management Plan (SEEMP) demonstrated measurable improvements in operational emissions control. Based on the voyage evaluation, SEEMP implementation contributed to the company's target EEOI, achieving an average EEOI of 27,708 compared to the target of 40, representing a vessel approximately 30 percent more efficient. Continuous monitoring of the EEOI enables operators to identify

inefficient voyages and optimize operational decisions. The results confirm that the SEEMP serves not only as a regulatory compliance framework but also as an operational management tool capable of improving energy efficiency.

CONCLUSION

This study evaluates the implementation of the Ship Energy Efficiency Management Plan (SEEMP) on LNG vessels using the Energy Efficiency Operational Indicator (EEOI) as the primary performance metric. An analysis of 24 operational voyages during 2023–2024 shows that LNG vessels achieved an average EEOI of 27.71 gCO_2/ton-mile, indicating relatively efficient operational performance below the target LNG fuel utilization of 40, meaning the vessel is 30 percent more efficient. EEOI variation is significantly influenced by operational conditions, particularly cargo utilization, voyage management, and fuel consumption patterns. The results indicate that loads below 80 percent significantly increase the EEOI, necessitating load optimization. Regression analysis indicates that the use of LSFO also affects the EEOI. Voyages with lower transport efficiency and unstable operational conditions result in higher EEOIs, reflecting decreased energy efficiency.

Furthermore, the implementation of the SEEMP contributed to an estimated reduction in greenhouse gas emissions of approximately 30%, confirming its effectiveness as a practical framework for emissions monitoring and operational optimization.

This study highlights that achieving maritime decarbonization requires not only alternative fuels such as LNG, but also continuous improvements in operational efficiency supported by monitoring indicators such as EEOI. These findings provide practical contributions for LNG vessel operators in Indonesia in supporting compliance with International Maritime Organization regulations and advancing the transition to sustainable and low-carbon maritime transport.

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Present and Future Fuels for Sustainable Maritime Transportation: A Review of Opportunities and Challenges

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ABSTRACT

With the implementation of decarbonization goals and the stringent regulations from the International Maritime Organization (IMO), the global shipping industry is gradually shifting towards clean-burning fuels. Conventional marine fuels such as marine diesel oil, marine gas oil, and heavy fuel oil contribute significantly to greenhouse gas emissions. To meet the challenge of a 45% reduction in emissions by 2030 and net zero emissions by 2050, industry and academic researchers are seeking possible solutions to control exhaust emissions from marine internal combustion engines. As a result, renewable and clean-burning fuels such as green methanol, green ammonia, and green hydrogen appear to be feasible options for mitigating stringent regulations. Therefore, in this mini review, the production processes and significant properties of green hydrogen, green ammonia, and green methanol are discussed, along with their challenges and opportunities.

KEYWORDS: Decarbonization Goals; Methanol; Ammonia; Hydrogen

INTRODUCTION

The global greenhouse gas (GHG) emissions are at alarming levels as a result of an increase in global warming, extreme weather, and climate change, which are witnessed by most nations. Among the different sectors, the global shipping sector accounts for ~2.8% to 3% of GHG emissions. To regulate these harmful emissions, the International Maritime Organization (IMO) came up with stringent regulations and set decarbonization goals. The goals explicitly reveal that by 2030, at least 20% or target for 30% reduction in GHG emissions compared to 2008 levels, and by 2040, at least 70% or target for 80% reduction in GHG emissions, and finally achieve net-zero emissions by 2050. The expected percentage reduction of GHG emissions and the projected years are very clear and near. However, to

achieve these targets within the timeframe seems to be challenging due to various parameters, such as the availability of infrastructure and potential sources to replace the existing hydrocarbon fuel systems.

In this study, an attempt was made to address these challenges using sustainable, clean-burning fuels. Nowadays, carbon-free fuels like ammonia (NH_3) and hydrogen (H_2) are gaining wide attention as an alternative fuel for marine internal combustion engines. In addition, methanol is competing to replace existing hydrocarbon fuels (Heavy Fuel Oil, Marine Diesel Oil, and Marine Gas Oil) due to its clean burning and safety in handling. Therefore, this study discusses the production pathways for green hydrogen, green ammonia, and green methanol, along with their challenges and opportunities.

Fuel properties play an important role in combustion chemistry; therefore, fuel properties related to energy density, octane rating, flame speed, flammability, safety, storage, and transportation are discussed. For instance, ammonia and methanol can utilize the existing infrastructure for transportation and storage due to their ability to be in a liquid state at ambient temperatures and moderate pressures. In contrast, hydrogen requires advanced cryogenic systems and high pressures. On the other hand, hydrogen has the highest energy density by weight (120 MJ/kg), followed by methanol (20 MJ/kg) and ammonia (18 MJ/kg). The flammability limits reveal the safety aspects of these fuels. Ammonia has a narrow flammability range (15% to 28%) by volume and high ignition energy (680 mJ), due to which it is safer than hydrogen (5% to 75%), and methanol is less volatile, and it is within the flammability limits (7% to 36%). As the emissions are considered, hydrogen and ammonia are carbon and sulfur-free fuels, and the GHG emissions and SOx emissions are completely under control, which is a big advantage with these fuels to achieve the decarbonization goals. Therefore, these significant physicochemical properties of these fuels are discussed, and a comprehensive comparison is provided, especially regarding safety and bunkering challenges.

Renewable, clean-burning fuels are emerging as a possible solution, and various literature studies highlight their practical implementation in existing marine diesel engines. Some of these are as follows.

Al Baity et al. in their review of green fuels for maritime energy systems present recent approaches for evaluating alternative fuels, focusing on ship power plants, fuels, optimization methods, and propulsion technologies. The study highlights the growing adoption of pure electric, hybrid, and hydrogen fuel-cell systems, especially on yachts, ferries, and research vessels, while large ships mainly rely on dual-fuel engines using MDO as a pilot fuel. It emphasizes that simultaneous optimization of system sizing and control is essential for improving efficiency and preventing component degradation. The paper also identifies major research gaps, including the need for studies on weight and space constraints, integration of multiple green fuels, and comparative analysis of hybrid propulsion configurations. Furthermore, it recommends a broader investigation of alternative marine power plants, such as gas turbines and combined systems, along with quantitative optimization methods to evaluate costs, emissions, reliability, and fuel compatibility for future sustainable maritime applications.

According to Bilgili, Alternative fuels must satisfy present and future emission regulations while being economically and technically feasible for large-scale adoption. Their implementation requires developing new production chains, raw material supply systems, and logistics infrastructure. Suitable alternative fuels should minimize engine modifications, maintain engine performance, reduce SOx and NOx emissions, and remain cost-competitive with conventional fuels such as HFO. Important evaluation criteria include safety, accessibility, renewability, environmental impact, scalability, fuel availability, and compatibility with existing technologies and infrastructure. Fuels with high energy density, low greenhouse gas emissions, and low lifecycle costs are preferred for sustainable maritime applications. Fuels that fulfill nearly all technical, environmental, and commercial requirements are referred to as "drop-in fuels."

Chiong et al. report that the tightening of shipping emission regulations and global decarbonization goals have accelerated the adoption of alternative fuels in marine propulsion systems. This review evaluates the performance of several alternative fuels, including waste plastic oil, tyre pyrolysis oil, biodiesel, ammonia, vegetable oil, and waste lubricant oil, specifically for low – and medium-speed marine engines. The study found that neat waste plastic oil and tyre pyrolysis oil showed poorer emission performance than diesel, although engine performance improved through injection timing adjustment and biodiesel blending. Preheating vegetable oil proved more effective than blending or degumming in enhancing engine performance. Ammonia emerged as a promising carbon-free fuel, but its high NOx emissions require advanced combustion technologies. Overall, the review highlights the importance of understanding the combustion behavior of alternative fuels in marine engines to support cleaner, more efficient maritime propulsion systems. **Table 1** compares Green Hydrogen, Ammonia, and Methanol as Marine fuels.

Table 1 Comparison among Green Hydrogen, Ammonia, and Methanol as Marine fuels

S.No	Parameters	H2	NH3	CH3OH
1	Fuel Type	Carbon free	Carbon free	Alcohol
2	Molecular Weight (g/mol)	2	17	32
3	Gravimetric Energy Density (MJ/kg)	~120	~18.6	~20
4	Volumetric Energy Density (MJ/L)	~8.5 (liquid H_2)	~12.7	~15.8
5	Sulfur presence	None	None	Negligible
6	Flame Speed	Very high	Very low	Moderate
7	Ignition Energy	Very low	Very high	Moderate
8	Auto-Ignition Temperature (°C)	~585	~651	~470
9	Storage Requirement	High-pressure or cryogenic tanks	Pressurized/refrigerated tanks	Conventional liquid fuel tanks
10	Compatibility with Existing Infrastructure	Poor	Moderate	Good

11	Toxicity	Non-toxic but highly flammable	Highly toxic	Toxic if ingested
12	Infrastructure Availability	Limited	Moderate	Comparatively good
13	Safety Concerns	Leakage, explosion risk	Toxicity, NOx formation	Flammability, toxicity
14	Bunkering Complexity	High	Moderate to high	Moderate
15	CO_2 Emissions	Zero at use	Zero at use	Lower than conventional fuels
16	SOx Emissions	Zero	Zero	Very low
17	NOx Emissions	Very low	Potentially high	Lower than diesel
18	Storage Difficulty	Very high	Moderate	Low
19	Ease of Adoption in Shipping	Difficult presently	Moderate	Comparatively easier

Hydrogen, ammonia, and methanol are emerging as promising alternative fuels for the maritime industry due to increasing environmental regulations and the global push toward decarbonization . Hydrogen is considered a clean fuel because it produces only water during combustion or fuel-cell operation, making it highly attractive for zero-carbon shipping. However, its low volumetric energy density and storage challenges require advanced cryogenic or high-pressure storage systems. Ammonia is another carbon-free fuel that can be produced using renewable energy and transported more easily than hydrogen. It is gaining attention for marine engines and fuel cells, although its toxicity and high NOx emissions remain major concerns. Methanol is viewed as one of the most practical alternative marine fuels because it is liquid at ambient conditions, easier to store and transport, and compatible with existing fuel infrastructure. It can significantly reduce SOx, NOx, and particulate emissions compared to conventional marine fuels. In addition, green methanol produced from renewable sources can help lower lifecycle greenhouse gas emissions. Many shipping companies are currently investing in methanol-powered vessels due to their comparatively easier adoption. Overall, hydrogen, ammonia, and methanol are expected to play important roles in the future transition toward cleaner and more sustainable marine transportation systems.

GREEN HYDROGEN PRODUCTION

Green hydrogen is considered one of the most promising clean energy carriers for achieving global decarbonization and sustainable energy development. It is produced by splitting water into hydrogen and oxygen through a process called electrolysis, using electricity generated entirely from renewable energy sources such as solar, wind, or hydropower, as shown in **figure 1**. Unlike conventional hydrogen production methods that rely on fossil fuels, green hydrogen production does not emit carbon dioxide, making it an en-

vironmentally friendly alternative fuel. The basic electrolysis reaction involves passing an electric current through water, in which hydrogen is produced at the cathode and oxygen at the anode. The overall reaction can be represented as:

$$2H_2O \rightarrow 2H_2 + O2 \quad (1)$$

Several electrolyzer technologies are used for green hydrogen production, including alkaline, proton exchange membrane (PEM), and solid oxide electrolyzers. Among these, PEM electrolyzers are gaining popularity because of their high efficiency, rapid response, and suitability for integration with renewable energy systems. Renewable electricity generated during periods of excess production can be utilized to produce hydrogen, which can then be stored and used later as an energy source. This helps solve the intermittency problems associated with renewable energy sources such as solar and wind power.

Green hydrogen can be stored in compressed gas or liquefied form, or in chemical carriers such as ammonia and methanol, for easier transportation. It has applications in transportation, power generation, steel manufacturing, fertilizer production, and marine propulsion systems. In the maritime sector, hydrogen can be used directly in fuel cells or in internal combustion engines to significantly reduce greenhouse gas emissions. Fuel cells that use hydrogen produce electricity electrochemically with high efficiency, with water as the only by-product.

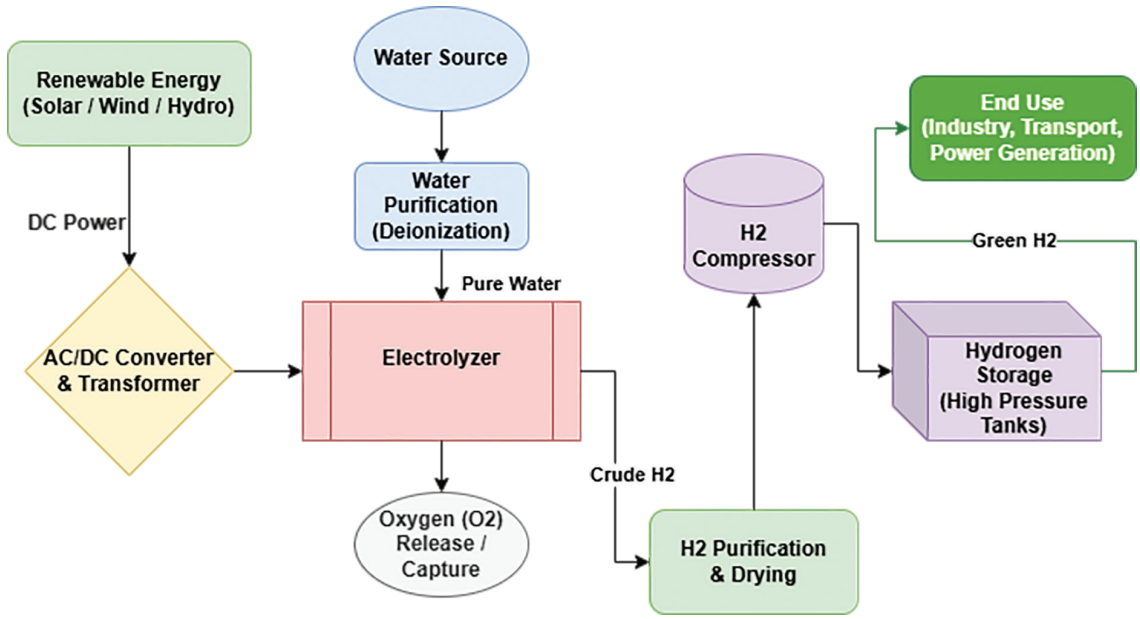

Figure 1: Green Hydrogen Production Process

Despite its environmental advantages, green hydrogen production faces several challenges, including high production costs, low volumetric energy density, storage difficulties, and infrastructure limitations. Large-scale deployment requires developing renewable energy capacity, hydrogen storage systems, pipelines, and refueling stations. Researchers

are currently working to improve electrolyzer efficiency, reduce catalyst costs, and develop safer storage technologies. Governments and industries worldwide are investing heavily in hydrogen technologies as part of their clean energy transition strategies. With continued technological advancements and declining renewable energy costs, green hydrogen is expected to play a major role in future sustainable energy and transportation systems. (See Fig.1)

OPPORTUNITIES AND CHALLENGES OF GREEN HYDROGEN

Hydrogen gas production offers significant opportunities to achieve clean, sustainable energy systems. Green hydrogen produced using renewable energy can greatly reduce greenhouse gas emissions and support global decarbonization goals. Hydrogen can be used in fuel cells, transportation, power generation, fertilizer industries, and marine applications. It also helps in storing excess renewable energy from solar and wind power, improving energy reliability and grid stability. In addition, hydrogen has high gravimetric energy density and produces only water as a by-product during fuel-cell operation.

However, hydrogen production also faces several challenges. The production cost of green hydrogen remains high due to the high cost of electrolyzers and the requirement for renewable electricity. Hydrogen has low volumetric energy density, making storage and transportation difficult. Safe handling is important because hydrogen is highly flammable and can leak easily. The lack of large-scale infrastructure, such as pipelines, storage facilities, and refueling stations, further limits its widespread adoption. Improving production efficiency, reducing costs, and developing advanced storage technologies remain major research areas for the future growth of the hydrogen economy.

GREEN METHANOL PRODUCTION

Green methanol is an environmentally friendly alternative fuel produced using renewable energy and sustainable carbon sources. Unlike conventional methanol, which is mainly produced from natural gas or coal, green methanol is synthesized using green hydrogen and captured carbon dioxide As shown in figure 2, green hydrogen is generally produced through water electrolysis powered by renewable energy sources such as solar, wind, or hydropower. The captured carbon dioxide may come from industrial emissions, biomass processes, or direct air capture systems. The main chemical reaction for green methanol production:

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O. \quad (2)$$

In this process, hydrogen reacts with carbon dioxide in the presence of catalysts under elevated temperature and pressure conditions to form methanol and water. Green meth-

anol production helps reduce greenhouse gas emissions by recycling carbon dioxide and replacing fossil-based fuels. It is considered one of the most practical alternative fuels because it is liquid at room temperature, making storage and transportation easier than hydrogen. Existing fuel infrastructure, such as tanks, pipelines, and bunkering systems, can also be adapted for methanol with comparatively fewer modifications.

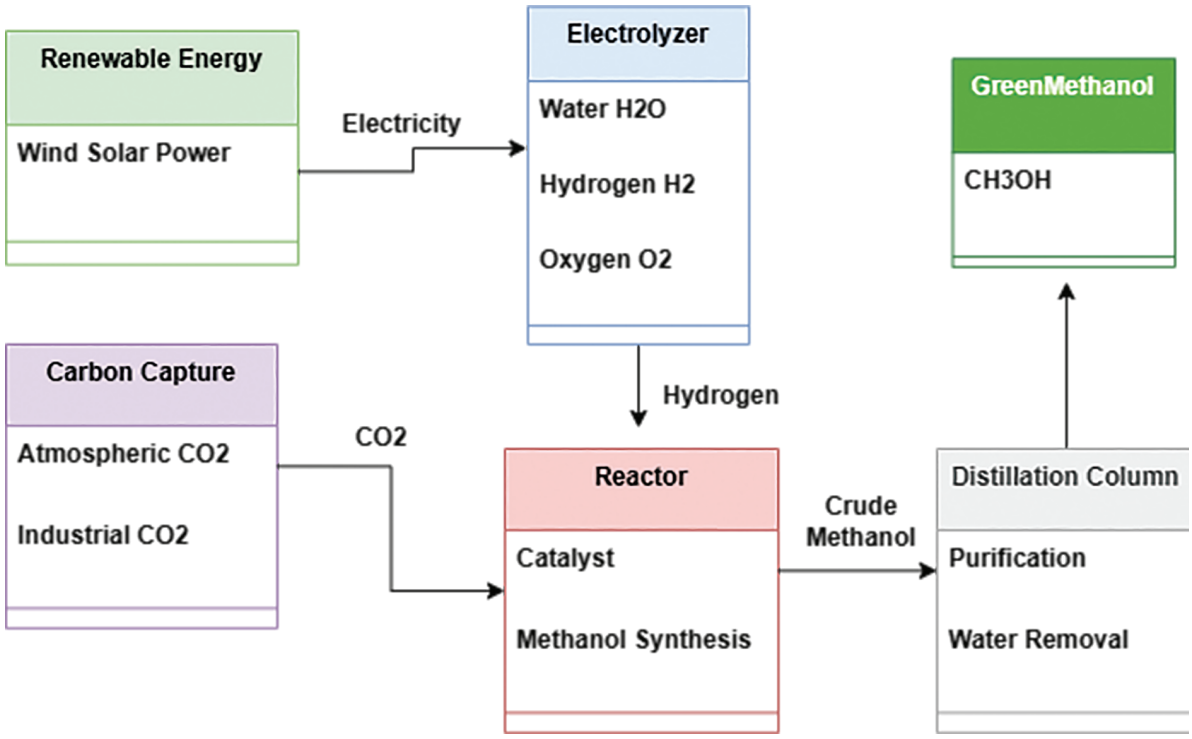

Figure 2: Green methanol production process

Green methanol has several applications in transportation, marine propulsion, power generation, and the chemical industries. In the maritime sector, it is gaining significant attention because it can reduce sulfur oxides, nitrogen oxides, particulate matter, and lifecycle carbon emissions compared to conventional marine fuels. Many shipping companies are investing in methanol-powered vessels as part of their decarbonization strategies. In addition, green methanol can serve as a hydrogen carrier for future energy systems.

Despite its advantages, green methanol production faces challenges such as high production cost, dependence on renewable electricity availability, and the need for large-scale carbon capture technologies. Researchers are working to improve catalyst efficiency, reduce energy consumption, and scale up production systems. With continued technological advancements and supportive environmental policies, green methanol is expected to play a major role in sustainable energy and low-carbon transportation systems in the future.

OPPORTUNITIES AND CHALLENGES OF GREEN METHANOL

Green methanol production offers significant opportunities to develop sustainable, low-carbon energy systems. It can utilize renewable hydrogen and captured carbon dioxide to produce a cleaner fuel with reduced greenhouse gas emissions. Green methanol is easier to store, transport, and handle compared to hydrogen because it remains liquid at ambient conditions. Existing fuel infrastructure can also be adapted for methanol with relatively fewer modifications, making its large-scale adoption more practical. In the maritime industry, green methanol can help reduce sulfur oxides, nitrogen oxides, and particulate emissions while supporting global decarbonization goals. It can also serve as a hydrogen carrier for future energy applications.

However, green methanol production faces several challenges. The production process currently requires substantial amounts of renewable electricity, which increases production costs. Efficient carbon capture technologies are also necessary to provide sustainable carbon dioxide sources. Green methanol has a lower energy density than conventional marine fuels, potentially requiring larger storage volumes. In addition, large-scale production infrastructure and renewable energy availability are still limited in many regions. Improving catalyst performance, reducing energy consumption, and lowering overall production costs remain important research areas for the future expansion of green methanol technologies.

GREEN AMMONIA PRODUCTION

Green ammonia is considered a promising carbon-free fuel and energy carrier for future sustainable energy systems. It is produced using renewable energy sources without relying on fossil fuels, making it environmentally friendly. The green ammonia production process is outlined in figure 3. The production of green ammonia mainly involves two stages: green hydrogen production and ammonia synthesis. First, hydrogen is produced by electrolyzing water using renewable electricity from solar, wind, or hydropower. Nitrogen is then separated from air using air separation technologies. Finally, hydrogen and nitrogen react in the Haber–Bosch process under high pressure and temperature in the presence of catalysts to produce ammonia. The overall reaction is:

$$N_2 + 3H_2 \rightarrow 2NH_3. \quad (3)$$

Green ammonia production reduces greenhouse gas emissions compared to conventional ammonia production, which relies heavily on natural gas. Ammonia is attractive as an alternative fuel because it contains no carbon in its chemical structure and can therefore eliminate carbon dioxide emissions during combustion. In addition, ammonia is easier to store and transport than hydrogen because it liquefies at relatively moderate conditions. Existing ammonia transportation and storage infrastructure can also support its future adoption as an energy carrier.

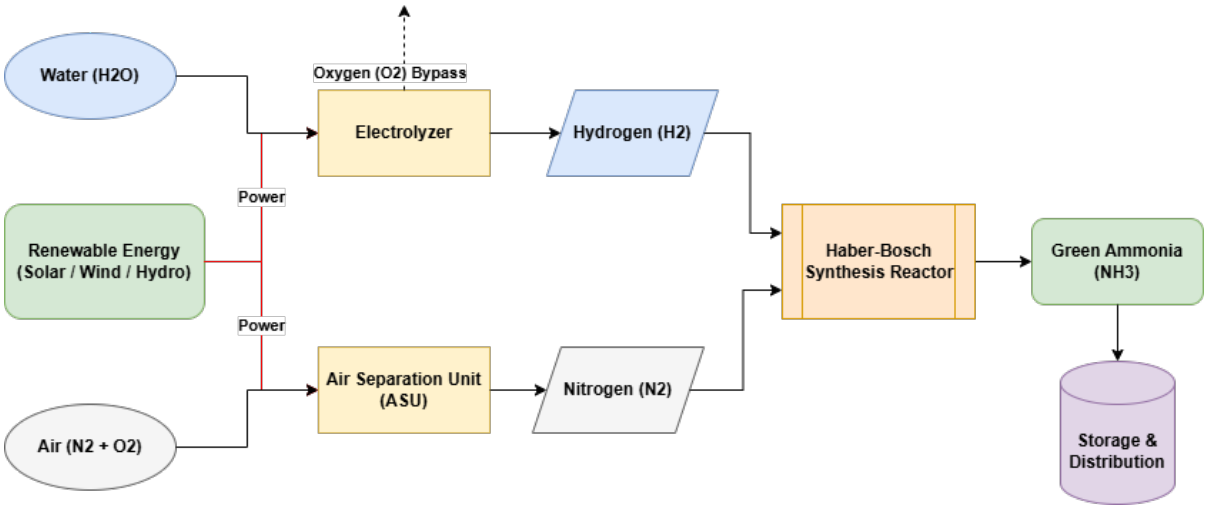

Figure 3: Green Ammonia Production Process

OPPORTUNITIES AND CHALLENGES OF GREEN AMMONIA

Green ammonia has potential applications in marine propulsion, power generation, fertilizer industries, and hydrogen transportation. In the maritime sector, ammonia-fueled engines and fuel cells are being developed to reduce ship emissions. However, ammonia combustion can produce high levels of nitrogen oxides, requiring advanced combustion and emission control technologies. Ammonia is also toxic and requires careful handling and safety measures. Furthermore, green ammonia production currently faces challenges, including high demand for renewable electricity, expensive electrolyzers, and large-scale infrastructure requirements. Researchers are actively working on improving process efficiency, catalyst performance, and safe fuel utilization technologies. With continued technological advancements and global decarbonization efforts, green ammonia is expected to become an important clean fuel for future energy and transportation systems.

HYDROGEN CASE STUDY

MF HYDRA

It is world's first Liquid Hydrogen (LH2) powered ferry, and according to Baird Maritime it uses two 200kW PEM fuel cells, two 440kW diesel generators, a 1.36 MWH battery, and two Shottel thrusters, moving at a speed of 9 knots, consisting of 80 cubic meters of hydrogen storage tank, keeping hydrogen at – 253^{0}C. The vessel is 82.4 m long and can accommodate up to 300 passengers and 80 vehicles.

While hydrogen has an excellent energy density by mass (120MJ/kg), its volumetric energy density is only 8.5MJ/L, which is roughly 4.4 times lower than that of diesel fuel. Using the internal cargo hold for fuel storage would lead to loss of revenue, as not only the cargo carrying space is compromised in this case but also some space would be lost in complying with the safety standards as stated in the IGF Code, a cofferdam would have been required

to separate the hydrogen fuel tank from Category A machinery spaces to minimize the risk of ignition in event of a leak.

To avoid losing cargo space, MF Hydra has the entire hydrogen system and its vacuum-insulated type C tank located on the top deck, the non-revenue space of the ferry. While MF Hydra uses clever design techniques, such as tank placement at the top deck, to comply with maritime regulations without compromising revenue-generating cargo space, its lifecycle sustainability is challenged by logistics, as the flaw persists in the existing infrastructure. The TTW emission on this vessel is zero, but on the downside, the WTW still introduces boil-off losses and a carbon footprint, as LH2 is produced in Germany and trucked over 1,300 km to Norway, contradicting the vessel's primary goal of full decarbonization. For true decarbonization, the production must be localized at the bunkering site.

MV Hydrotug 1

While MF Hydra uses LH2, MV Hydrotug 1 uses Compressed Gaseous Hydrogen. Hydrotug, launched in 2023, is known as the world's first tugboat powered by combustion engines burning H2 in combination with traditional diesel. Hydrotug uses two BeHydro V12 medium-speed dual-fuel engines, each rated at 2MW, and these engines can run on both hydrogen and marine diesel. The vessel uses a small amount of diesel as the pilot fuel to initiate ignition, as the auto-ignition temperature of H2 is very high (585 ?). This suggests that futuristic fuel cells are not the only option; traditional engines can be modified to burn hydrogen, providing the current industry with a realistic solution when the need of the hour is to reduce the carbon footprint. Also, the engines are capable of transitioning from dual-fuel mode to 100% diesel operation, and this flexibility is important when bunkering facilities in ports are still maturing. This tugboat is small, only 30.17 m long and 12.5 m wide, and is not conducive to storing the bulky hydrogen tank in its internal space. H2 is stored on the deck-mounted stillages (cages), which consist of Type 3 cylinders. A total of 54 individual such cylinders, grouped into 6 stillages, are installed on the deck. They hold 415 kg of compressed hydrogen. This demonstrates that hydrogen is also workable on space-constrained vessels. Unlike MF Hydra, which trucks fuel from Germany to Norway, the fuel for this tugboat is intended to be produced locally, as Antwerp is building a hydrogen Hub at the port. The WTW is hence much lower as the trucking penalty would be bypassed.

AMMONIA CASE STUDY

While H2 is great for small ferries and cruises, it is not well-suited for larger cargo ships; for longer ranges, NH3 is a better option. It has a higher volumetric energy density than H2.

NYK Line Sakigake

Sakigake, built in 2015, was Japan's first LNG-fueled tugboat, equipped with a dual-fuel – engine (LNG and diesel). Later, in 2021, due to Japan's Green Innovation Fund Project, the shift began, with NYK and IHI starting R&D to convert to NH3. The final bunkering of

LNG was in 2023, after which the vessel was taken out of service for retrofit. In 2024, the vessel was relaunched as the world's first commercial ammonia-fueled vessel. The vessel now has a 4-stroke engine that works by burning ammonia with a small amount of diesel to first ignite. In 2025, a 3-month demonstration achieved a 94.4% reduction in GHG emissions compared to HFO. Sakigake also achieved a 95% ammonia co-firing rate, which many thought was not possible for a retrofit.

Riken Keiki gas detectors are used to address ammonia's toxicity hazards. As soon as ammonia's concentration reaches 300 ppm, the safety system shuts down the fuel lines. The fuel tank and engine have been replaced to ensure compatibility with ammonia; however, as the vessel is a retrofit of the older LNG tug, the pre-existing internal tank space has been utilized to house this new system. Since ammonia is both toxic and corrosive, double-walled stainless steel pipes have been used, with the inner pipe carrying ammonia itself and the outer one either filled with inert gas or a vacuum. Leak detection sensors trigger an automatic shutdown if ammonia is detected. NYK has proved that these LNG-fueled ships are ideal for ammonia conversion and that the existing vessels can be repurposed for a sustainable future.

Anhui (The Pure Ammonia Pioneer)

Anhui is a Chinese prototype that uses an electric propulsion system. It has a 200kW high-speed gas internal combustion generator; the generator's electricity is sent to two 100kW electric-propulsion motors, which turn the twin-screw system to move the vessel. Anhui is an engineering breakthrough because it solves the issue of a fluctuating rpm, which occurs as the load on the engine of a standard ammonia ship varies. In a standard engine, varying the rpm leads to changes in the speed of air intake, and ammonia is already sensitive because of its narrow flammability limit (15% to 28% by volume in air), if the fuel and air mixture is slightly off, it may cause the flame to flicker out, leading to incomplete combustion, creating vibrations and a slip in ammonia.

Anhui uses an engine to drive the generator; the engine runs at a constant rpm and maintains steady air mixing. As the load on the propulsion motors increases, they draw more current, and the generator experiences higher torque. The governor then injects more fuel to keep the engine rpm constant. When the load on the motors decreases, they draw less current, and the generator experiences lighter load torque. The governor then decreases the amount of fuel to be injected. Either way, the engine keeps spinning at the same speed. Because the rpm never changes, the engine stays hot.

Since ammonia is hard to ignite (auto-ignition temperature of 651 ^{0}C) and thus cannot ignite with a simple spark, Anhui uses plasma ignition, which causes ammonia to burn. The drawback of ammonia's slow flame propagation is also overcome by using a catalytic cracker , which heats some of the ammonia, decomposing it into hydrogen and nitrogen; the hydrogen, when injected into the cylinder, acts as a combustion accelerator. Hydrogen, with a higher flame speed (approximately 2.65 m/s) and a wider flammability range (5% to 75% by volume in air), ignites quickly and spreads the flame front across the combustion chamber, ensuring all the ammonia burns in time.

METHANOL CASE STUDY

While ammonia and hydrogen lead to 100% decarbonization, for the time being, when the infrastructure and bunkering facilities are still in development and organizations are pushing towards targets for reducing emissions, methanol is a great drop-in fuel for the maritime sector, which is in its transition phase. Methanol, with its comparatively safer handling and better volumetric energy density compared to ammonia and hydrogen, and lower emissions than conventional fuels, offers a better trade-off for retrofit applications and has major shipping companies' eyes on it.

Laura Maersk

Laura Maersk is the first container ship powered by green methanol. This feeder vessel is said to have reduced greenhouse gas emissions by 65%. Equipped with Everllence B&W ME-LGIM two-stroke engine, the biggest advantage of this vessel is that the fuel switch is seamless; the engine can switch to diesel from methanol without any loss in engine power or vessel speed, so when a ship runs out of green methanol in a remote port, it can still finish its voyage on diesel.

Stena Connecta

1It is a newmax ro-ro vessel that entered service in 2026, operating with multi-hybrid propulsion capable of running on methanol, biofuel, and battery power. To compensate for the lower volumetric energy density of methanol compared with traditional fuels, Stena Connecta uses two 28×4 m Rotor Sails, which are capable of saving up upto 9% in fuel on its Irish Sea Route. These Rotor Sails use the Magnus Effect, providing thrust, which reduces fuel consumption, giving the ship more range without needing a larger tank.

CONCLUSION

The maritime sector is undergoing a major transition toward sustainable and low-carbon energy systems due to increasingly stringent environmental regulations and global decarbonization targets established by the International Maritime Organization (IMO). This study examined the potential of green hydrogen, green ammonia, and green methanol as promising alternative marine fuels capable of reducing greenhouse gas emissions from shipping operations. The production pathways, physicochemical properties, storage characteristics, safety aspects, and bunkering challenges of these fuels were comprehensively reviewed and compared. The study reveals that each fuel possesses unique advantages and limitations, making them suitable for different maritime applications depending on vessel type, voyage duration, infrastructure availability, and operational requirements.

Hydrogen emerged as a highly attractive zero-carbon fuel due to its exceptionally high gravimetric energy density and the complete elimination of carbon and sulfur emissions during use. However, its low volumetric energy density, high storage pressure requirements, and dependence on cryogenic systems present major technological and economic

challenges for large-scale marine applications. Ammonia, on the other hand, offers easier storage and transportation than hydrogen due to its liquid-state handling at moderate temperatures. In addition, ammonia contains no carbon in its molecular structure, enabling significant reductions in greenhouse gas emissions. Nevertheless, issues related to toxicity, combustion instability, and high NOx emissions require further advancements in engine technologies and emission control systems. Methanol demonstrated several practical advantages because it is liquid at ambient conditions, comparatively safer to handle, and compatible with existing storage and bunkering infrastructure. Although methanol is not entirely carbon-free, green methanol produced from renewable hydrogen and captured carbon dioxide can substantially reduce lifecycle carbon emissions while providing operational flexibility for the maritime industry.

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Sustainable Transport Systems and Maritime Logistics: Strategic Assessment of the Eastern Black Sea Logistics Hub

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ABSTRACT

The global maritime sector is currently undergoing a dual transformation driven by two interrelated imperatives: the need to accommodate continuously expanding trade volumes and the need to transition to sustainable, low-carbon operations. The adoption of the IMO 2023 Greenhouse Gas (GHG) Strategy at MEPC 80 represents a critical regulatory milestone, mandating net-zero emissions from international shipping by approximately 2050, with interim reduction targets of 20–30% by 2030 and 70–80% by 2040. These regulatory developments are fundamentally reshaping port investment strategies and logistics network configurations worldwide.

Concurrently, the geopolitical structure of Eurasian trade corridors has experienced a significant shift. The disruption of the Northern Corridor following the Russia–Ukraine conflict has accelerated the strategic importance of the Middle Corridor (Trans-Caspian International Transport Route), which recorded a remarkable 62% increase in cargo volume in 2024. This transformation has repositioned Türkiye's Eastern Black Sea region as a critical logistics interface between Europe and Asia, increasing the urgency of developing integrated and sustainable port infrastructure in the region.

Within this evolving global and regional context, this study provides a comprehensive strategic assessment of the Of-Iyidere Port and Logistics Hub (PLH) project. The analysis integrates financial feasibility findings derived from the Eastern Black Sea Industrial Development Zone Feasibility Report (RTEÜ, 2014) and the investment valuation study conducted by Gün (2020) with contemporary sustainability frameworks, green port principles, and current geopolitical dynamics. By combining traditional financial evaluation techniques with sustainability and strategic trade corridor analysis, the study offers a multidimensional evaluation framework for large-scale port investments.

The financial analysis demonstrates that the project maintains strong economic via-

bility, with an internal rate of return (IRR) of 18.5% and a positive net present value (NPV) under multiple cost-of-capital scenarios. In addition to its financial robustness, the project exhibits a high degree of alignment with green port development principles, including renewable energy integration, shore power infrastructure, energy-efficient operations, and digital transformation through smart port technologies. These features not only enhance environmental performance but also contribute to long-term operational efficiency and regulatory compliance.

Furthermore, the study highlights the critical role of multimodal integration in achieving sustainability objectives. The strategic connection of the Of-Iyidere PLH to the Baku–Tbilisi–Kars railway and regional transport infrastructure enables significant reductions in carbon emissions by shifting freight from road-based to rail-sea intermodal transport systems. This integration enhances both the environmental and economic competitiveness of the project within the broader Eurasian logistics network.

The findings also underline the growing importance of green finance mechanisms, including public-private partnerships (PPP), green bonds, and sustainability-linked financing instruments, in supporting large-scale infrastructure investments. The emerging global regulatory environment, particularly carbon pricing mechanisms and sustainability-oriented funding frameworks, provides additional opportunities to strengthen the financial feasibility of such projects.

In conclusion, the Of-Iyidere Port and Logistics Hub project represents a strategically positioned investment at the intersection of financial viability, sustainability transformation, and geopolitical opportunity. The study contributes to the literature by integrating port investment valuation with sustainability and geopolitical analyses, offering practical insights for policymakers, investors, and port authorities seeking to develop resilient, sustainable logistics infrastructure in emerging trade corridors.

KEEWORDS: Maritime Logistics, Port Management, Logistics Hub, Green Port, IMO 2023, Middle Corridor, Sustainable Transport, Black Sea

1. INTRODUCTION

The global maritime sector serves as the backbone of international trade, with over 80% of world trade volumes transported by sea (UNCTAD, 2022). However, this critical role comes with a substantial environmental cost: international shipping currently accounts for approximately 2.89% of global greenhouse gas emissions, a figure that could rise to 17% by 2050 without decisive intervention (IMO, 2023). The unanimous adoption of the 2023 IMO GHG Strategy at MEPC 80 in July 2023 marks the most significant regulatory milestone in maritime sustainability, establishing binding interim targets and a comprehensive net-zero framework for the sector.

Simultaneously, the geopolitical landscape of Eurasian logistics is undergoing a profound transformation. The Russia-Ukraine conflict and consequent disruption to the

Northern Corridor have accelerated cargo volumes along the Middle Corridor (Trans-Caspian International Transport Route), which grew by 62% in 2024, reaching 4.5 million tons (Daily Sabah, 2025). This shift dramatically repositions Türkiye's Eastern Black Sea coast – and specifically the Of-Iyidere basin – as a strategic gateway in the emerging Eurasian trade architecture.

This paper presents a comprehensive strategic assessment of the Of-Iyidere Port and Logistics Hub (PLH) project, integrating the financial feasibility findings of the Eastern Black Sea Industrial Development Zone Feasibility Report (RTEÜ, 2014) and the investment valuation study by Gün (2020) with current sustainability frameworks, geopolitical dynamics, and green port management principles. The study makes a dual methodological contribution: first, by updating the project's strategic context with post-2020 developments; second, by synthesising traditional port investment valuation approaches with IMO 2023 sustainability requirements and the emerging green finance ecosystem. The remainder of this paper is structured as follows: Section 2 reviews the global maritime sustainability transformation; Section 3 analyses the regional geopolitical context; Section 4 presents the financial feasibility findings; Section 5 develops the green port framework for the project; Section 6 discusses integrated strategic implications; and Section 7 concludes with policy recommendations.

2. GLOBAL MARITIME SUSTAINABILITY TRANSFORMATION

2.1. The IMO 2023 GHG Strategy: Regulatory Framework

The 2023 IMO GHG Strategy represents a decisive shift from the aspirational targets of the 2018 strategy to a binding regulatory framework with defined interim milestones. Adopted at MEPC 80 with the consensus of all 175 member states, the strategy mandates a 20–30% reduction in GHG emissions by 2030 (compared to 2008 levels), a 70–80% reduction by 2040, and net-zero emissions by approximately 2050 (IMO, 2023). Comer and Carvalho (2023) contextualise this shift, demonstrating that scientific evidence indicating the 2018 strategy's insufficiency relative to the Paris Agreement's 1.5°C pathway was a key driver of the more ambitious framework.

The operational implementation of the strategy commenced on 1 January 2023, with the mandatory calculation of the Energy Efficiency Existing Ship Index (EEXI) and annual Carbon Intensity Indicator (CII) ratings for all vessels. The IMO Net Zero Framework (NZF), approved at MEPC 83 in April 2025, completes the regulatory architecture with a carbon pricing mechanism of USD 100 per tonne CO_2 from 2028, projected to generate USD 11–13 billion annually (European Commission, 2025). Crucially, a portion of these revenues is designated for green fuel infrastructure development in developing economies, creating a new financing channel directly relevant to projects such as Of-Iyidere PLH. The EU Emissions Trading System (ETS), extended to maritime from January 2024, adds a further compliance dimension for ports serving European trade routes (Green Ports Initiative, 2025).

2.2. Green Port Management: Conceptual Framework

A green port is defined as a port that adopts sustainability as a primary operational objective, minimising the environmental impact of port activities through economic and technological measures (Zhang et al., 2024). Zhang et al. (2024), in their comprehensive systematic review of green port development strategies, identify three core dimensions: environmental performance monitoring and improvement, digital technology integration, and renewable energy transition. Key operational measures include shore power supply, renewable energy integration, energy-efficient port equipment, waste management systems, and emission monitoring infrastructure.

In the Turkish context, Uçdu and Kılıç (2022) conduct a detailed examination of Turkish ports from the perspective of green port location selection and implementation, identifying significant infrastructural gaps while highlighting the country's high geographic and strategic potential. Turkey's 2053 Transportation and Logistics Master Plan, published in January 2023, explicitly incorporates green port standards, alternative fuel adoption (LNG, methanol, hydrogen), and digital logistics corridors as national policy priorities (Sea Business, 2024). The EBRD-supported 70 million Euro project for port sustainability investment provides an institutional framework directly applicable to new port development in the Eastern Black Sea region.

2.3. Multimodal Integration and Emissions Reduction

Multimodal transport integration constitutes a critical component of maritime logistics sustainability strategy. Resat and Turkay (2019) demonstrate through quantitative analysis that railway-sea integration in multimodal networks reduces carbon emissions by 60–80% compared to road-only transport on equivalent routes. Li et al. (2023) extend this finding to cross-border intermodal hub design, showing that government-supported intermodal networks achieve both cost efficiency and significant decarbonisation co-benefits. These findings underscore the strategic importance of port-railway connectivity in the contemporary sustainability framework – a dimension particularly salient for the Of-Iyidere project, given the completed Baku-Tbilisi-Kars railway and Ovit Tunnel infrastructure.

3. REGIONAL GEOPOLITICAL TRANSFORMATION: THE MIDDLE CORRIDOR AND THE BLACK SEA

3.1. From TRACECA to the Middle Corridor

The Transport Corridor Europe-Caucasus-Asia (TRACECA), initiated by the EU Commission's Brussels Declaration in 1993 and joined by Türkiye in 2000, established a foundational multimodal connectivity framework across the Black Sea, Caucasus, and Caspian Sea to Central Asia. However, technical, economic, and administrative constraints limited

TRACECA's competitive position relative to the established Northern Corridor through Russian territory (Bárkányi and Vasa, 2023).

Russia's military operations in Ukraine from February 2022 fundamentally restructured this calculus. As the Northern Corridor lost reliability due to sanctions and security concerns, the Trans-Caspian International Transport Route (TITR) – commonly referred to as the Middle Corridor – rapidly gained strategic primacy among shippers and policymakers. In January 2023, the World Bank published a comprehensive policy and investment framework targeting a tripling of freight volumes and a halving of transit times along the Middle Corridor by 2030 (World Bank, 2023). The signing of a Roadmap agreement by Azerbaijan, Georgia, Kazakhstan, and Türkiye in November 2022, followed by the establishment of a joint logistics operator among the three countries in June 2023, provided the institutional infrastructure to support this growth.

The quantitative evidence confirms this strategic repositioning. Middle Corridor cargo volumes reached 4.5 million tons in 2024 – a 62% year-on-year increase – with over 27,000 TEU of containers transported from China via the route (Daily Sabah, 2025; CEBRI, 2025). For the Eastern Black Sea specifically, these volumes underscore the urgency of developing adequate port infrastructure to capture the transit trade flows that the completed Baku-Tbilisi-Kars railway is beginning to direct toward the Black Sea coast.

3.2. Strategic Positioning of the Of-Iyidere Basin

The Of-Iyidere basin's emergence as a strategic logistics location reflects the convergence of completed infrastructure investments and evolving trade patterns. The Ovit Tunnel, connecting the Black Sea coast to Erzurum and providing year-round passage to Eastern Anatolia and Iran's northern provinces, addresses a critical bottleneck in north-south freight movement. The feasibility analysis (RTEÜ, 2014) documents the scale of this opportunity: Iran's northern provinces conduct approximately USD 25 billion in annual imports through Dubai ports, with transit times of up to one month. The Ovit connection reduces this to days, transforming the competitive economics of the region.

The Turkish Ministry of Environment and Urbanisation's designation of the Of-Iyidere region as a Special Project Area and subsequently as an Industrial Development Zone in 2013 formally recognised this strategic potential. The combination of the Baku-Tbilisi-Kars railway, the Ovit Tunnel, and the planned Batumi-Samsun railway positions Of-Iyidere at the intersection of east-west and north-south trade corridors – precisely the locational advantage that Hanaoka and Regmi (2011) and Monios and Lambert (2013) identify as fundamental to successful logistics hub positioning.

4. FINANCIAL FEASIBILITY OF THE OF-IYIDERE PORT AND LOGISTICS HUB

4.1. Project Scope and Cargo Projections

The project envisions a port facility with a total handling capacity of 34.5 million tons across 34 hectares, structured around three specialised terminals: a container terminal (capacity 14.5 million tons / 1.1 million TEU at 75% utilisation), a general and bulk cargo terminal (3.5 million tons), and a liquid cargo terminal (7.8 million tons) (Gün, 2020). Cargo projections, based on the Ministry of Transportation's Coastal Structures Master Plan and scenario analyses across pessimistic, average, and optimistic growth trajectories, estimate annual cargo growth rates of 6%, 12.5%, and 14.2%, respectively (RTEÜ, 2014).

Table 1 presents the projected cargo handling volumes at key project milestones:

Table 1: Cargo and Capacity Projections by Year (Tons)

Year	Container (Tons)	General/Bulk Cargo (Tons)	Liquid Cargo (Tons)	Total (Tons)
1. Year	2.655.705	628.138	1.389.937	4.673.780
5. Year	3.723.468	881.243	1.972.932	6.577.643
10. Year	6.710.727	1.589.258	3.594.711	11.894.695
15. Year	14.561.348	3.449.958	7.845.125	25.856.430

Source: RTEÜ (2014); Gün (2020)

The strategic sources of cargo demand – Kazakhstan grain exports, Turkmenistan cotton and liquid cargo, Iranian transit freight, Caucasus container traffic, and Black Sea regional trade – have been further strengthened by post-2020 geopolitical developments, particularly the acceleration of Middle Corridor volumes.

4.2. Investment Cost and Operating Financials

Total fixed investment costs, determined through comprehensive technical and engineering studies by a multidisciplinary expert team from Recep Tayyip Erdoğan University, Boğaziçi University, and Karadeniz Technical University (RTEÜ, 2014), amount to USD 328,641,175. Key components include: 9 container cranes (USD 90 million), handling vehicles and forklifts (USD 70 million), breakwater construction (approximately USD 73 million), berth construction (USD 60 million), and ancillary infrastructure. All calculations are denominated in US Dollars to mitigate inflation and foreign currency exposure inherent in long-term infrastructure projections.

Projected operating revenues reach USD 47.55 million in Year 1 – derived from ship services, freight handling, terminal services, storage, and ancillary revenues – escalating to USD 265.28 million by Year 15 as capacity utilisation approaches 75%. Operating expenses,

comprising personnel costs and general administrative expenditures, increase proportionally from USD 2.78 million in Year 1 to USD 13.09 million in Year 15 (Gün, 2020).

4.3. Investment Valuation Results

The discounted cash flow valuation, conducted over a 25-year project horizon consistent with established port project appraisal practice (Dimitriou, 2018), employs three cost-of-capital rates (7.5%, 10%, 15%) to address the uncertainty inherent in long-term infrastructure investments. Table 2 summarises the core valuation results:

Table 2: Investment Valuation Results

Valuation Method	Cost of Capital 7.5%	Cost of Capital 10%	Cost of Capital 15%
Net Present Value (USD)	688.822.320	422.460.582	116.934.421
Internal Rate of Return (IRR)	18.5%		
Payback Period	7 years 8 months	7 years 8 months	7 years 8 months
Discounted Payback Period	10 years 1 month	11 years 3 months	14 years 11 months

Source: Gün (2020)

The IRR of 18.5% exceeds all three cost-of-capital rates tested, confirming robust financial viability. The non-discounted payback period of 7 years 8 months is competitive for large-scale port infrastructure. The positive NPV across all scenarios – even at the conservative 15% discount rate – indicates that the project creates value under a wide range of financing conditions. The post-2020 acceleration of Middle Corridor trade volumes provides additional upside to these projections that was not captured in the original 2014 analysis.

5. GREEN PORT FRAMEWORK FOR OF-IYIDERE PLH

5.1. Sustainable Design Principles

The contemporary port development context makes it imperative that any new port-logistics hub incorporates green port design principles from the inception stage rather than retrofitting them later at significantly higher cost. Zhang et al. (2024) identify renewable energy integration, energy-efficient quay crane systems, shore power supply infrastructure, and comprehensive waste management as non-negotiable elements of new-build green port design. The IMO NZF's carbon pricing mechanism, effective from 2028, creates direct financial incentives for port infrastructure that facilitates low-emission vessel calls, amplifying the commercial case for green design investment.

The Of-Iyidere region offers distinctive environmental endowments for sustainable port development. The Eastern Black Sea climate – characterised by high annual precipi-

tation (approximately 2,337 mm in Rize) and consistent wind patterns documented in the meteorological analysis of the RTEÜ (2014) feasibility study – presents favourable conditions for renewable energy integration. The combination of offshore wind potential and solar installations could substantially reduce the port's operational energy costs while supporting compliance with the EU ETS requirements applicable to vessels calling at ports linked to European trade routes (European Commission, 2025).

5.2. Multimodal Integration and Carbon Reduction

The Of-Iyidere PLH's multimodal connectivity – specifically its direct linkage potential to the Baku-Tbilisi-Kars railway via the Ovit Tunnel Road corridor – represents perhaps the most significant sustainability differentiator available to the project. Resat and Turkay (2019) quantify rail-sea integration's carbon reduction potential at 60–80% relative to road-only alternatives on equivalent routes. For a port primarily serving Central Asian, Caucasian, and Iranian trade flows that currently transit by road, directing this traffic through rail-sea intermodal chains would generate substantial regional emission reductions – directly aligned with Türkiye's 2024 Green Logistics Initiative targeting 10 million tonnes of annual carbon reduction (TRBusinessWorld, 2025).

5.3. Digital Transformation and Smart Port Infrastructure

Port digitalisation has become inseparable from the sustainability agenda. Zhang et al. (2024) and Dinh et al. (2024) demonstrate that IoT-based monitoring, AI-powered traffic optimisation, digital twin simulation, and blockchain-based supply chain traceability reduce port operational emissions significantly while improving throughput efficiency. Türkiye's 2024 Customs Modernisation Programme, deploying blockchain and AI for customs processing acceleration, provides a policy framework directly applicable to the Of-Iyidere PLH's digital architecture. Incorporating Terminal Operating Systems (TOS), real-time cargo tracking, and data analytics platforms from the outset would also generate additional high-margin revenue streams beyond traditional port fees – partially offsetting initial green technology investment costs.

5.4. Financing Model: PPP and Green Finance

The financing structure for Of-Iyidere PLH appropriately centres on a Public-Private Partnership (PPP) model. Ng and Gujar (2009), Bergqvist et al. (2010), and Monios and Wilmsmeier (2012) provide extensive evidence that PPP mechanisms have successfully distributed financial burdens in comparable port hub investments across multiple jurisdictions. Green finance instruments – green bonds and sustainability-linked loans – have

become mainstream capital market instruments and are increasingly accessible for port projects meeting environmental standards. The EBRD's 70 million Euro Turkish port sustainability programme demonstrates the institutional feasibility of this financing approach for Eastern Black Sea infrastructure (Sea Business, 2024). The IMO NZF's revenue allocation for green infrastructure in developing economies creates an additional, novel financing window that did not exist when the original feasibility analysis was conducted.

6. DISCUSSION: STRATEGIC ALIGNMENT AND CHALLENGES

6.1. Integrated Strategic Assessment

The multi-dimensional strategic assessment of Of-Iyidere PLH reveals strong alignment across three overlapping strategic frameworks simultaneously: at the global level, alignment with IMO 2023 GHG Strategy sustainability mandates; at the regional level, alignment with Middle Corridor growth dynamics and TRACECA network expansion; and at the national level, alignment with Türkiye's 2053 Transportation and Logistics Master Plan green port objectives. This triple-layer strategic alignment is unusual among comparable port development projects and substantially de-risks the investment from a policy-obsolescence perspective.

The sustainability-competitiveness nexus proves particularly favourable in the Of-Iyidere context. Mahmud et al. (2023), examining Asian ports, demonstrate that green port practices reduce long-term operating costs, improve port valuations, and minimise regulatory compliance risks. Castellano et al. (2020), studying Italian ports, identify a significant positive correlation between green performance metrics and economic efficiency. These findings suggest that the sustainability investments required for IMO 2023 compliance are not costs to be minimised but rather value-creating investments in the context of the contemporary port management paradigm.

6.2. Limitations and Challenges

Several challenges require transparent acknowledgement. The financial projections originate from 2014 analyses and, while the fundamental cargo demand drivers have strengthened, currency depreciation, construction cost inflation, and revised financing market conditions necessitate updated financial modelling. Green technology and renewable energy infrastructure entail significant additional capital requirements beyond the USD 328.6 million base investment, though green finance mechanisms and the IMO NZF revenue allocation partially mitigate this. The alternative fuel supply chain – critical for IMO 2023 vessel compliance – remains immature in the Eastern Black Sea region. Finally, as Gün (2020) and Pawlik et al. (2011) note, the economic impact analysis – quantifying indirect employment, regional GDP multipliers, and trade facilitation effects – remains a necessary complement to the financial valuation that is beyond the scope of this paper and requires dedicated further research.

7. CONCLUSION

This paper has demonstrated that the Of-Iyidere Port and Logistics Hub project occupies a uniquely advantageous position at the intersection of financial viability, geopolitical opportunity, and sustainability imperative. The core financial findings – IRR of 18.5%, positive NPV across all discount rate scenarios, and a non-discounted payback period under eight years – establish a sound economic foundation. The post-2020 acceleration of Middle Corridor trade volumes provides additional demand-side support not captured in the original analysis. The IMO 2023 GHG Strategy's regulatory architecture and accompanying green finance ecosystem create new tools and incentives for sustainable port development that were unavailable when the feasibility study was conducted.

The paper advances a concrete set of policy recommendations for decision-makers. First, international sustainability consultancy should be engaged from the design phase to integrate green port principles – particularly renewable energy systems, shore power infrastructure, and smart port digital architecture – into the initial engineering specifications. Second, a hybrid financing model combining PPP structures with green bonds, sustainability-linked loans, and IMO NZF revenue allocations should be developed to optimise the capital structure while minimising pure public budget exposure. Third, direct multimodal rail-port connectivity between Of-Iyidere and the Baku-Tbilisi-Kars railway should be prioritised in the transport access planning, maximising the project's carbon reduction co-benefits and its attractiveness to sustainability-conscious cargo owners. Fourth, coordinated business development activities should be pursued within the framework of the Türkiye-Azerbaijan-Georgia-Kazakhstan logistics agreements, capitalising on the institutional momentum of the Middle Corridor's expansion.

The methodological contribution of this paper lies in its integration of traditional port investment valuation with sustainability framework analysis and geopolitical assessment – an approach that responds to the growing recognition in the maritime logistics literature that large infrastructure appraisals must encompass these dimensions to remain analytically adequate for contemporary investment decisions. Future research should pursue scenario analysis quantifying the financial impact of IMO NZF carbon pricing on project economics, lifecycle assessment of the regional emission-reduction potential of multimodal integration, and updated cargo-demand modelling incorporating Middle Corridor growth trajectories.

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Modeling of Traffic Flows Taking into Account the Processes of Updating Components of Maritime Transport Infrastructure

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ABSTRACT

When modeling traffic flows to maximize the efficiency of existing maritime transport infrastructure components, various factors are considered. The most significant are factors affecting travel speed, as overall travel time depends on the speed of route sections prone to congestion. Traffic flow modeling is used to obtain a mathematical representation of key flow components, such as flow density and the speed of individual route sections. In waterway traffic management, modeling traffic flows through closed waterways is particularly important, as canals, straits, and rivers can create congestion, leading to emergency situations, thereby posing a threat to both external and internal transport security and the risk of breaching contractual obligations. Using modern modeling methods, we can consider a multitude of factors, including hydrometeorological conditions, vessel characteristics, infrastructure parameters, and traffic regulation features. This makes it possible to predict traffic flow behavior in various scenarios, optimize scheduling for bottlenecks, and improve the efficiency of waterway use. Digital decision support systems play a special role. They use modeling to provide dispatchers and operators with up-to-date information for rapid response to changing situations. However, their design and development require mathematical models of traffic flows that enable high-quality analysis. Since the key indicators used in mathematical modeling of traffic flows depend on a number of other factors, primarily technical and natural, the task of developing and optimizing a mathematical model for each individual facility is unique. However, using a standard set of components allows for the development of a common methodology for the formation, development, and evaluation of potential improvements to a traffic flow model. This study

examines a method for mathematical modeling of traffic flow in a closed system of hydraulic structures with varying component efficiencies. The study develops principles for constructing mathematical models of traffic flows for shipping canals, rivers, and straits. Flow density is determined based on statistical observations. Flow density is considered as the end result of the impact of technical and management measures during the flow formation process. Visual representation of traffic flows allows not only to understand the current state of traffic but also to explore optimization opportunities, which, in turn, will affect not only the efficiency of individual vessels but also the state of the transport system as a whole, thereby indirectly contributing to local and global economic security. The study places particular emphasis on the development of a comprehensive assessment of traffic flows based on the obtained information on flow components in specific zones. The results of the study demonstrate the need to develop and analyze mathematical models of traffic flows in isolated waters, create the necessary databases, create standardized forms for recording individual components used in mathematical modeling, formalize processing processes and improve the quality of the source data, and ensure their timely archiving with preliminary deletion of data irrelevant to the modeling process. The study identifies areas for considering dispersed and integral flow indicators when assessing the current state of maritime transport infrastructure facilities. The proposed approaches to traffic flow modeling provide a basis for determining the need for modernization of maritime transport infrastructure facilities and assessing the impact of reconstruction measures on traffic flow dynamics.

KEEWORDS: mathematical model, water transport traffic flow, traffic flow speed, marine transport infrastructure facility, modernization, water transport traffic flow management

Strategies for Enhancing the Competitiveness and Attractiveness of Georgia's Black Sea Ports

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ABSTRACT

The author selected the Georgian Black Sea transport network as the study system for imports beyond the region's waters via Georgian ports, using container shipments and their subsequent transportation by road, rail, and air.

KEEWORDS: container shipments, road and rail transport, Georgian ports, Black Sea transport network.

აბსტრაქტი

ავტორმა შეარჩია საქართველოს შავი ზღვისპირეთის სატრანსპორტო ქსელი, როგორც შესწავლილი სისტემა, ქართული პორტების გავლით რეგიონის აკვატორი-ის საზღვარებს მიღმა იმპორტისათვის, საკონტეინერო გადაზიდვების მეშვეობით და მათი შემდგომი ტრანსპორტირებით საავტომობილო, სარკინიგზო და საავიაციო ტრანსპორტის გამოყენებით.

საკვანძო სიტყვები: საკონტეინერო გადაზიდვები, საავტომობილო დ სარკინიგზო ტრანსპორტი, ქართული პორტები, შავი ზღვისპირეთის სატრანსპორტო ქსელი.

შესავალი

ჩვენი ძირითადი სატრანსპორტო სიმძლავრეები კონცენტრირებულია როგორც აღმოსავლეთ და ცენტრალურ, ისე დასავლეთსა და სამხრეთ რაიონებში. ანუ საქართველოს მთელ ტერიტორიას გასდევს თანამედროვე საგზაო და საავიაციო, და შედარებით მოძველებული სარკინიგზო სატრანსპორტო გზები.

საქართველოს შავი ზღვისპირეთის პორტები უკავშირდებიან ქვეყნის ცენტრალურ და აღმოსავლეთ რაიონებს, ამიერკავკასიის რეგიონის სხვა ქვეყნებს და კასპიის ზღვის გავლით – აზიის ქვეყნებს, სარკინიგზო და საავტომობილო ტრანსპორტის ყველაზე უფრო განშტოებული ქსელით. იმავე რაიონებშია განლაგებული ძირითადი აეროპორტებიც.

დისკუსია

განვიხილოთ საქართველოს სატრანსპორტო ქსელი და ლოგისტიკური კავშირები, რომელიც წარმოვადგინეთ სურთში 1.

სურათი 1. საქართველოს სატრანსპორტო სისტემა და ლოჯისტიკური კავშირების რუკა

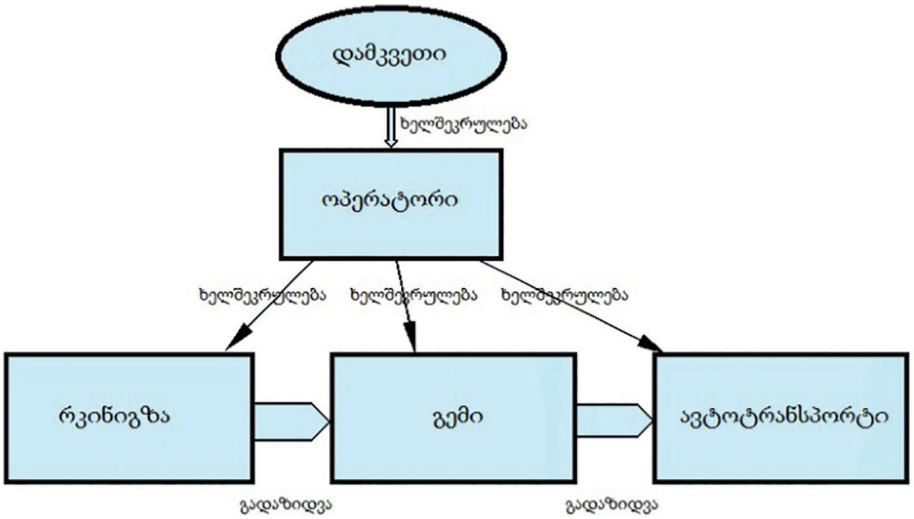
ყველა ნავსადგური და სარკინიგზო სასაზღვრო გადასასვლელი უკავშირდება ერთმანეთს სარკინიგზო და საავტომობილო მაგისტრალების მეშვეობით და აქვთ წვდომა საჰაერო მაგისტრალებთან. კავშირი ხორციელდება როგორც ერთმანეთთან, ქვეყნის შიგნით, ასევე მსოფლიოს ყველა მიმართულებით.

კონტეინერების ნაწილი, რომელიც გადაიზიდება ავტოტრანსპორტის მეშვეობით, რჩება საქართველოს ტერიტორიაზე. საქართველოში კონტეინერების ტრანსპორტირება სარკინიგზო ტრანსპორტის მეშვეობით არ მიიჩნევა, როგორც ნაკლებად შესაძლებელი, მაგრამ ობიექტური მიზეების გამო უკანასკნელი სამი წლის მანძილზე სარკინიგზო საკონტეინერო გადაზიდვებმა საგრძნობლად იკლო.

უფრო დაწვრილებით განვიხილოთ საქართველოს შავი ზღვისპირეთის სატრანსპორტო ქსელის ყველა შემადგენელი ელემენტი, რომელიც მონაწილეობს კონტეინერების იმპორტსა და შემდგომ ტრანსპორტირებაში.

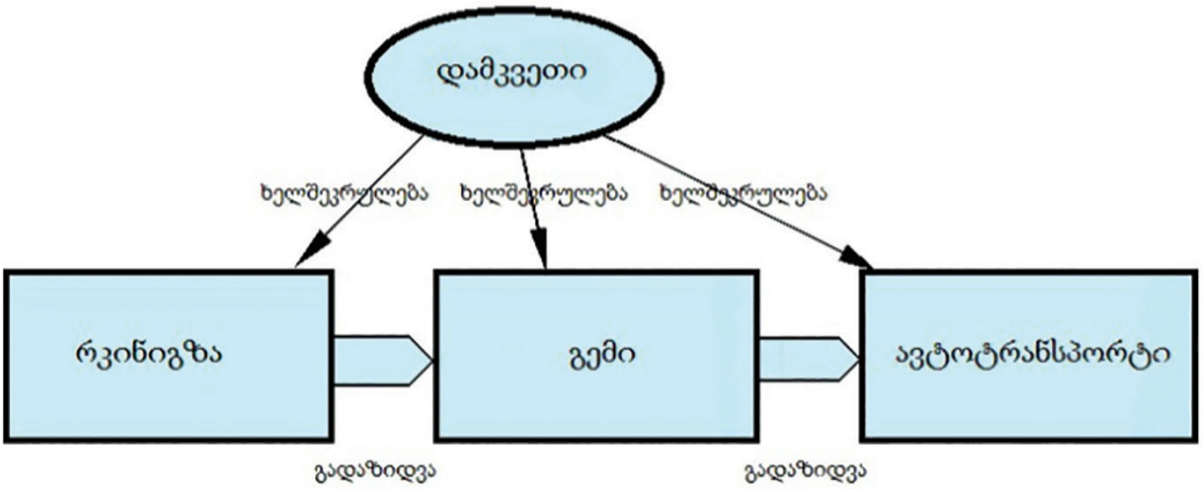
სატვირთო გადამზიდი ტრანსპორტის ტიპებისა და მიწოდების ტექნიკური და ორგანიზაციული ასპექტების გათვალისწინებით, სატვირთო გადაზიდვები შეიძლება დაჯგუფდეს შემდეგ სახეებად:

- **უნიმოდალური.** ასეთი გადაზიდვების შემთხვევაში გამოყენებულია ერთი სახეობის (მაგალითად, სარკინიგზო; ანდა საჰაერო) სატრასპორტო საშუალება და გზა გამგზავნი პუნქტიდან საბოლოო მიღების პუნქტამდე არის ერთიანი და უწყვეტი, ანუ არ სრულდება არც ერთი დამატებითი შუალედური ოპერაცია. სხვა სიტყვებით რომ ვთქვათ, არსებობს ერთიანი ლოგისტიკური ჯაჭვი;
- **მულტიმოდალური.** ასეთი გადაზიდვების შემთხვევაში გამოყენებულია რამდენიმე სახეობის სხვადასხვა სატრანსპორტო საშუალება და ლოგისტიკური ჯაჭვი საწყისსა და საბოლოო პუნქტებს შორის წყვეტილია. ანუ სრულდება ბევრი დამატებითი შუალედური ოპერაცია. ცხადია, გადაზიდვების ასეთი ტიპი გულისხმობს ოპერატორის არსებობას, რომელიც აკვირდება ტვირთის მოძრაობას „კარიდან კარამდე“ და ახდენს მისი გადაადგილების მონიტორინგს ოპერატორი სრულ პასუხისმგებლობას ატარებს ტვირთის შეუფერხებელ გადაზიდვაზე. იმ შემთხვევაში, როცა ოპერატორს არ გააჩნია გადაზიდვისათვის საჭირო სახეობის შესაბამისი სატრანსპორტო საშუალება, იგი აფორმებს სუბარენდის ხელშეკრულებას სხვა გადამზიდველთან (დიაგრამა 1).



დიაგრამა 1. მულტიმოდალური გადაზიდვების სქემა

- **ინტერმოდალური.** ეს არის სატრანსპორტო გადაზიდვების ისეთი სქემა, რომლის დროს დამკვეთი დებს ხელშეკრულებას სხვადასხვა გადამზიდავ კომპანიასთან. ამ შემთხვევაში ფორმდება იმდენი ხელშეკრულება, რამდენ გადამზიდველსაც ქირაობს დამკვეთი და თითოეული გადამზიდველი საკუთარ მონაკვეთზე ატარებს ტვირთის გადაზიდვის პასუხისმგებლობას. სხვა სიტყვებით რომ ვთქვათ, „კარიდან კარამდე" ტვირთვის გადატანაზე თვით დამკვეთია პასუხისმგებელი, რადგანაც ტვირთის გადაზიდვის პირობები და უსაფრთხოება დამოკიდებულია იმ ხელშეკრულებებზე, რომელსაც იგი გააფორმებს გადამზიდველებთან (დიაგრამა 2);
- **სეგმენტური.** გადაზიდვების ამ ტიპის დროს გადამზიდველი პასუხისმგებელია ტვირთის უსაფრთხო მოძრაობაზე მხოლოდ იმ სეგმენტში, რომელზეც დამკვეთთან გააფორმა ხელშეკრულება. გადაზიდვის ეს ტიპი რთულია, ვინაიდან ამ შემთხვევაში ტვირთის გადაზიდვა სრულდება ერთი გადასაზიდი საშუალებით (მაგალითად, ცისტერნით, კონტეინერით, სხვა), მაგრამ გამოყენებულია სხადასხვა სატრანსპორტო საშუალება (მაგალითად, ავტომობილი, თვითმფრინავი, გემი, სხვა).



დიაგრამა 2. ინტერმოდალური გადაზიდვების სქემა

- **კომბინირებული.** გადაზიდვის ეს ტიპი არის მულტიმოდალური და ინტერმოდალური ტიპის ნიშნების მატარებელი. თავისებურება, რომელიც განასხვავებს მას გადაზიდვის სხვა ტიპებისგან არის შემდეგი: კომბიმირებული გადაზიდვის შემთხვევაში გზის მხოლოდ საბოლოო მონაკვეთზე სრულდება ტვირთის გადატანა საავტომობილო ტრანსპორტით. ყველა დანარჩენ მონაკვეთზე გადაზიდვები სრულდება სხვა ტიპის სატრანსპორტო საშუალებებით.
- **პორტები.** 2019 წლის პირველ ნახევარის შედეგების მიხედვით, საქართველოს შავი ზღვისპირეთის კონტინენტური პორტების და სტივიდორული კომპანიების მეშვეობით გადამუშავდა 219 293 TFE რაოდენობის ტვირთები.

ცხრილი 1. 2018-2019 წლების პირველი ნახევარში ქართულ პორტებში სტივიდორული კომპანიების მიერ კონტეინერების მეშვეობით გადაზიდული ტვირთების ბრუნვის მოცულობა, TFE (დატვირთული)

	ექსპორტი			იმპორტი			ტრანზიტი			კაბოტაჟი		
სტივიდორები	2019	2018	2019 / 2018, %	2019	2018	2019 / 2018, %	2019	2018	2019 / 2018, %	2019	2018	2019 / 2018, %
გიანთი – ლოჯისტიკს	1826	1255	45,5	13587	9330	45,6	0	0		19415	15936	21,8
LOGIXMENT	3515	0		1392	0		0	0		5147	5239	-1,8
EXPRESS EXPEDITION Ltd	31987	20194	58,4	52389	39748	31,8	50225	47990	4,7	0	0	
Batumi Rail Group	8994	1173	666,8	12487	2279	447,9	0	0		7843	8744	-10,3
INTERTEK CALEB BRETT – GEORGIA	184	269	-31,6	281	281	0,0	1600	1253	27,7	0	0	
Foregrove Ltd (UK)	1146	1219	-6,0	3447	2803	23,0	0	0		0	0	
BFI Ltd – Blacksea Ferry & Investment	852	832	2,4	1354	1611	-16,0	0	0		1622	0	
სულ	48504	24942	94,5	84937	56052	51,5	51825	49243	5,2	34027	29919	13,7

გადაზიდვების მატებამ შეადგინა 36,9% 2018 წლის ანალოგიურ პერიოდთან შედარებით (63 556 TFE), მათ შორის შემდეგი მიმართულებების ჩათვლით:

- ექსპორტის ზრდაში – 94.5% (23 257 TFE);
- იმპორტის ზრდაში – 51.5% (29,833 TFE);
- კაბოტაჟში ზრდამ შეადგინა – 13,7% (7,887 TFE);
- ტრანზიტში ზრდამ შეადგინა – 5.2% (2,579 TFE).

ქართულ პორტებში კონტეინერების დამუშავების შესახებ დეტალური შეჯამებული ინფორმაცია (სტივდორების მიხედვით) მოცემულია ცხრილში 1.

ცხრილი 2. 2019 წლის პირველ ნახევრში ქართული პორტების ტერმინალებში სტივიდორული კომპანიების მიერ TFE (დატვირთული) საკონეინერო ტვირთების გადამუშავება

ს ტ ი ვ ი დ ო რ ე ბ ი	2019 წლის I ნახევარი	წილი (%)
გიანთი – ლოჯისტიკს	34828	15,9
LOGIXMENT	10054	4,6
EXPRESS EXPEDITION Ltd	134601	61,4
Batumi Rail Group	29324	13,4
INTERTEK CALEB BRETT – GEORGIA	2065	0,9
Foregrove Ltd (UK)	4593	2,1
BFI Ltd – Blacksea Ferry & Investment	3828	1,7
სულ	219293	100,0

რეგიონში საკონტეინერო გადაზიდვების ნაკადის ზრდის ფონზე, ყველაზე მაღალი ზრდის ტემპები აჩვენა BCK, აქ მოცულობის ზრდამ 2019 წლის პირველ ნახევარში შეადგინა 140.4% (17 128 TFE). საერთაშორისო სტანდარტის შესაბამისი კონტეინერების გადაზიდვის ბაზარზე ტრადიციულად ლიდერად რჩება ბათუმის პორტი. 2019 წლის პირველი ნახევრის შედეგების მიხედვით, საკონტეინერო გადაზიდვებში მისი წილი საქართველოს შავი ზღვისპირეთის ტერმინალების მთლიან ბრუნვაში შეადგენს 61.4% (134 601 TFE).

მეორე ქართული პორტის – ფოთის ტერმინალის მეშვეობით საკონტეინერო გადაზიდვების ჯამური მოცულობა შეადგენს საქართველოს შავი ზღვისპირეთის პორტების საერთო საკონტეინერო ტვირთბრუნვის მოცულობის დაახლოებით 10%-ს. საქართველოს ყველა პორტს აქვს მნიშვნელოვანი პერსპექტივა საკონტეინერო გადაზიდვების მატებაში. ამგვარად, 2025 წლისთვის, ფოთის პორტს შეეძლება 150-200 ათასი TFE დამუშავება.

საზღვაო საკონტეინერო გადაზიდვების ხაზები. როგორც დავინახეთ, საქართველოში საკონტეინერო გადაზიდვები ყველაზე გავრცელებულ მიმართულებას წარმოადგენს. კონტეინერები საკმაოდ ინტენსიურად მოძრაობს ქართულ სატრანსპორტო კორიდორში და გადაადგილდება ყველა სახეობის ტრანსპორტის გამოყენებით. ეს ნიშნავს, რომ თუ ავაგებთ სისტემის ფუნქციონირების მოდელს, შეიძლება გამოვიყენოთ შემთხვევითი სიდიდეების გადანაწილების სტოქასტური კანონები (კერძოდ მაგალითად, გემების მოძრაობასთან მიმართებაში).

ცხრილი 3. საქართველოს სასაზღვრო გადასასვლელების კლასიფიკაცია სატრანსპორტო საშუალებების სახეობების მიხედვით

საზღვაო პორტები, აეროპორტები, რკ/გ სადგურები, სახმელეთო გადასასვლელები	**საბაჟო გამშვები პუნქტი**
საზღვაო ტრანსპორტზე	„ფოთისა და ყულევის პორტები“ „ფოთისა და ყულევის პორტები და ფოთის თავისუფალი ინდუსტრიული ზონა“
„ბათუმის პორტი“	„ბათუმის პორტი“
საჰაერო ტრანსპორტზე	
„თბილისის აეროპორტი“	„თბილისის აეროპორტი და თბილისის ტექნოლოგიური პარკის თავისუფალი ინდუსტრიული ზონა“
„ქუთაისისა და სენაკის აეროპორტები“	ქუთაისისა და სენაკის აეროპორტები და ქუთაისის თავისუფალი ინდუსტრიული და ქუთაისიჰუალინგის თავისუფალი ინდუსტრიული ზონები“
„ბათუმის პორტი“	„ბათუმის პორტი“
სარკინიგზო ტრანსპორტზე	
„გარდაბანი“	„გარდაბანი“
„სადახლო რკინიგზა“	„სადახლო რკინიგზა“
საავტომობილო ტრანსპორტზე	
„წითელი ხიდი“	„წითელი ხიდი“
„გუგუთი“	„გუგუთი“
„სადახლო“	„სადახლო-საავტომობილო“
„ლაგოდეხი“	„ლაგოდეხი“
„ვალე“	„ვალე“
„ნინოწმინდა“	„ნინოწმინდა“
„ყაზბეგი“	„ყაზბეგი“
„სარფი“	„სარფი“
„მტკვარი“	„მტკვარი“
„ახკერპი“	„ახკერპი“

სასაზღვრო გადასასვლელები. საქართველოში არსებობს რამდენიმე სასაზღვრო გადასასვლელი, რომლებიც ექსპედიტორების ინფორმაციით, მონაწილეობენ კონტეინერების ტრანსპორტირებაში. სისტემაში ჩართული სასაზღვრო გადასასვლელების ტრანსპორტის სახეობის მიხედვით დალაგებული კლასიფიკაცია არის თავმოყრილი ცხრილში 3.

აეროპორტი. საქართველოს შავი ზღვისპირეთიში მდებარეობს სამი აეროპორტი, რომელთაგან ყველაზე დიდია ქუთაისის „კოპიტნარი“. ეს აეროპორტი შეყვანილია სისტემაში ისევე, როგორც დანარჩენები, კერძოდ: თბილისის, ამბროლაურის, მესტიის, ფოთის და ბათუმის.

სისტემის აღწერა. შესასწავლი სისტემა მოიცავს 2 დიდ (ბათუმი, ფოთი) და ერთ მცირე (ყულევი) საზღვაო ნავსადგურს, 2 სარკინიგზო სასაზღვრო გადასასვლელს (გარდაბანი და სადახლო რკინიგზა), 10 საავტომობილო სასაზღვრო გადასასვლელს (წითელი ხიდი, გუგუთი, სადახლო, ლაგოდეხი, ვალე, ნინოწმინდა, ყაზბეგი, სარფი, მტკვარი, ახკერპი), 2 დიდ აეროპორტს (თბილისის, ქუთაისის და სენაკის) და თავად საქართველოს შავი ზღვისპირეთის ტერიტორიას.

საზღვაო პორტების მეშვეობით კონტეინერების იმპორტირებისთვის, ნაკადურად შემოვლენ კონტეინერებით დატვირთული გემები. გამავალი ნაკადების სახით გვექნება სატრანსპორტო საშუალებები (მანქანები, მატარებლები, თვითმფრინავები), ისინი დატვირთული იქნება კონტეინერებით, რომლებიც დატოვებენ სასაზღვრო გადასასვლელს, აეროპორტს, ან გაემგზავრებიან საავტომობილო მაგისტრალის გასწვრივ ევროპისკენ, ან კონტეინერებით დატვირთული ავტოსატრანსპორტო საშუალებები, რომლებიც ტოვებენ პორტს და დარჩებიან რეგიონის ტერიტორიაზე (ანუ საქართველოს ტერიტორიაზე).

სისტემის დასაწყისს წარმოადგენს – გემის შესვლა ქართულ პორტში. სისტემის დასასრულია – კონტეინერის მეშვეობით სატრანსპორტო საშუალების გამოსვლა საქართველოს ტერიტორიის გარეთ (ან, საქართველოდან იმპორტის შემთხვევაში – წარმოადგენს კონტეინერით დატვირთული საბუქსირო სატრანსპორტო საშუალების გამოსვლას ნავსადგურის ტერიტორიის გარეთ).

დასკვნა

ამდენად, სისტემის ფუნქციონირების ეფექტურობა უნდა დავახასიათოთ შემდეგი ნიშნებით:

- სისტემაში კონტეინერის ყოფნის დროის მიხედვით,
- სისტემაში კონტეინერის დამუშავების ღირებულების მიხედვით,
- სისტემაში კონტეინერის დამუშავების საიმედოობით (დაწუნებული კონტეინერების რაოდენობა).

ყველა ეს მაჩვენებელი დამოკიდებულია ქსელში ტვირთის გადაზიდვის სქემაზე. სადისერტაციო ნაშრომის ამ თავში ჩატარებული კვლევის მიზანია საქართველოს შავი ზღვისპირეთში განლაგებული სატრანსპორტო სისტემის ადეკვატური მოდელის შექმნა, რომ მოვახდინოთ მისი ფუნქციონირების ეფექტურობის შემდგომი ანალიზი და მისი ეფექტურობის გაზრდის ალტერნატიული ვარიანტების შემუშავება.

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Approaches to Maritime Network Resilience: A State-of-the-Art Review and Future Research Directions

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ABSTRACT

Purpose – Maritime networks play a critical role in global trade but are increasingly exposed to disruptions such as accidents, congestion, labour disputes, cyber-attacks, political instability, extreme weather, natural disasters, and technological failures. These disruptions can affect the network structure, connectivity and trigger cascading effects across global supply chains. The problem is not only determining whether the maritime network is resilient, but also understanding its resilience under various conditions, including when it performs well and when it fails, and identifying methods that can reliably assess its resilience. Existing studies have employed various metrics, models, and analytical approaches, which have yielded different conclusions and results that are difficult to compare. Therefore, this paper provides a comprehensive and state-of-the-art methodological review of maritime network resilience (MNR) studies to identify the strengths, limitations, and suitability of existing approaches, while guiding the development of more robust and consistent methodologies for future research.

Design/methodology/approach – Fifty studies on MNR published from 2002 to 2026 were reviewed. Studies were grouped into four categories based on their methodologies: conceptual studies, scenario-based simulation, mathematical optimisation, and other approaches. This review systematically identifies, classifies, and critically evaluates these approaches in terms of their applicability, strengths, limitations, and suitability for assessing MNR.

Findings – MNR refers to the ability of a maritime transport network to withstand disruptions, maintain operational functionality, and recover efficiently after disturbances. In general, MNR depends on both structural properties such as connectivity, redundancy, and centrality and dynamic behaviours such as traffic flows, rerouting capacity, and recovery speed. Existing MNR research primarily focuses on understanding how maritime transport systems respond to disruptions and has addressed several key resilience problems, in-

cluding vulnerability identification, critical port and route dependency analysis, disruption impact assessment, recovery optimisation, and adaptive routing strategies. Findings from previous studies indicate that no single methodological approach is sufficient to fully capture the complexity of MNR. The study categorises methodologies used in MNR research into four as conceptual studies, scenario-based simulations, optimisation and modelling, and other approaches like empirical and data-driven methods. Conceptual studies clarify resilience concepts, system boundaries, and theoretical drivers of cascading failure; however, they often lack empirical validation and quantitative assessment capabilities. Scenario-based studies are effective in evaluating network vulnerability and identifying critical nodes and links through disruption simulations but often do not offer optimal intervention strategies. Optimisation and modelling approaches offer prescriptive, decision-oriented solutions for enhancing resilience, including network configuration, recovery strategies, and investment planning. Studies using this approach are often based on simplifying assumptions and subject to data limitations. Empirical and data-driven approaches ground resilience analysis in observed data and improve validation but are often case-specific and rarely deliver direct prescriptive guidance. By examining the strengths and limitations of each approach, the resilience methodologies must combine descriptive diagnosis, predictive power, and prescriptive decision support. The findings of the review highlight a need for integrated, multi-methodological frameworks that not only build on the strengths of existing approaches but also extend them to better capture the complexity and dynamics of maritime transportation networks.

Research limitations – While the review provides a comprehensive synthesis, variations in data sources, modelling assumptions, and regional focus across studies may affect the generalisability of findings. Furthermore, since this paper evaluates methodological approaches rather than testing real-world interventions, future empirical validation and mixed-method studies are needed to determine which approaches are most effective for improving maritime network resilience in practice.

Originality – This paper provides a critical synthesis of methodological approaches in MNR research that has not been done in previous reviews. The study offers a systematic view of MNR research methodologies and how it can be extended and applied to an increasingly complex environment.

KEEWORDS: Complex network analysis; Maritime networks; Shipping networks; Port networks; Resilience

INTRODUCTION

Maritime trade has expanded significantly over the years with the growth of the global economy, becoming a cornerstone of international trade. Today, more than 90% of trade by volume is carried by sea (Huang et al, 2022), making maritime transport the most economical and environmental efficient mode to transport bulk and containerized cargo. Ac-

cording to United Nations Conference on Trade and Development (UNCTAD) Review of Maritime Transport (2025), the global volume of maritime trade has reached 12 billion tons by 2024, which highlights the persistent demand for more connected and resilient maritime networks. This expansion has been further supported by globalization, which has strengthened the interconnectivity within the maritime network, while technological advancements like digitalization, and automations have improved its productivity and transparency.

Despite these advancements, maritime networks face several challenges that can severely affect their stability and connectivity. Natural disasters (Verschuur et al., 2020), geopolitics (Noorali et al., 2022), severe weather conditions (Garcia-Alonso et al., 2020), labour strikes (Gong & Liu, 2020), and terrorist attacks (Zelenkov et al., 2022) can disrupt maritime networks. On the other hand, maritime networks are also vulnerable to events such as maritime accidents, wars and pandemics that could severely disrupt its operations and the supply chains (Bergantino et al., 2024; Shen et al., 2024). In addition, certain maritime routes serve as critical chokepoints, making them particularly vulnerable to political conflicts, terrorism or piracy and other security threats (Bruyelle et al., 2018). Given the highly interconnected nature of maritime transport systems, disruptions in one part of the network can trigger cascading effects across global supply chains. Ensuring the resilience of maritime networks is therefore essential not only for maintaining trade flows but also for supporting international cooperation and economic stability. However, the MNR concept remains fragmented across the literature. Existing studies adopt diverse definitions and prioritize various dimensions of resilience, such as robustness, recovery, and adaptability (Qi & Mei, 2024).

The challenge in MNR research is not only determining whether a maritime network is resilient or not, but also understanding how resilient the network is, under what conditions it can maintain functionality or fail, and which methods can reliably assess resilience. Due to the high complexity of the maritime networks, resilience cannot be understood as a single, static trait. Instead, resilience encompasses several dimensions like resisting disruptions, preserving network connectivity, adapting to changing conditions, restoring operational performance, and minimise cascading effects. Yet studies assess these dimensions using different metrics, assumptions, datasets, and analytical methods. Some research concentrates on structural robustness and connectivity, whereas other studies prioritise recovery speed, operational flexibility, or economic consequences. This conceptual inconsistency has led to a wide range of methodological approaches, each addressing particular aspects of resilience while often neglecting others. Consequently, existing methods offer only partial insights, limiting their ability to fully capture the complexity of real-world disruptions in maritime networks.

To address this issue, this paper critically reviews the main approaches that have been utilised to analyse the resilience of maritime networks in the literature. In particular, most of the existing literature has concentrated on analysing network disruptions with special attention to port failures (Chen et al., 2017; Folkman et al., 2021; Grant et al., 2024) and topological characteristics of the network (Cheung et al., 2020; C.-L. Liu et al., 2018; Xu et al., 2020). The primary aim of this paper is to identify key research gaps and to justify the need

for more integrated and advanced methodological approaches to assess MNR. Various approaches, including conceptual studies, scenario-based studies, mathematical modelling and other approaches, are reviewed to evaluate their applicability and limitations.

The remainder of the paper structured as follows. The section 2 introduces the key concepts and definitions related to MNR. Section 3 reviews the main methodological approaches used to assess MNR, highlighting their strengths and limitations. Finally, section 4 concludes the paper by summarising the key findings and outlining future research directions.

MARITIME NETWORK RESILIENCE

Maritime networks can be understood as interconnected systems composed of nodes, representing ports, and links, representing shipping routes. Research on networks has expanded across fields such as social, communication, and biological systems to explore system connectivity, interactions, and vulnerability. Within this context, resilience is generally defined as the ability of a system to adapt to and recover from disruptions (Shen et al., 2024; Wan et al., 2018). Extending this concept, network resilience emphasises the collective capacity of interconnected components to maintain functionality in the face of disturbances.

Maritime networks, consisting of seaports (nodes) and shipping routes (links), vessels and supporting infrastructure, form a complex socio-technical systems that that underpins global trade and economic development. However, their complexity also makes them highly vulnerable to a wide range of disruptions (Verschuur et al., 2020; Noorali et al., 2022; Garcia-Alonso et al., 2020; Gong & Liu, 2020; Zelenkov et al., 2022). Those disruptions can propagate across the network, creating cascading effects across trade systems, economies, and environmental processes, highlighting the importance of strengthening MNR. MNR refers to the ability of interconnected ports and shipping routes to withstand disruptions and recover while maintaining cargo flows. Mou et al. (2020) defined MNR as “the ability of the system to withstand damage and remain operational after disturbances, representing the invulnerability of the network and its ability to recover from harm”.

Despite its importance, research on MNR remains relatively limited and often fragmented. Some of the existing studies largely focus on how individual ports adapt to disruptions, balancing economic, environmental, and social demands (Chen et al., 2017; Folkman et al., 2021; Grant et al., 2024). Others concentrate on the structural and topological characteristics of maritime networks, such as centrality, connectivity, and clustering (Cheung et al., 2020; C.-L. Liu et al., 2018; Xu et al., 2020). Although these approaches improve understanding of network organisation and efficiency, they do not adequately address how maritime networks respond, recover, and adapt to disruptions at a system-wide level. Consequently, there is a lack of comprehensive analytical frameworks integrating resilience with maritime network analysis.

This has created a critical knowledge gap in understanding how shocks have ripple effects across the global network and how MNR can be modelled and measured. Due to the growing frequency of global disruptions like climate changes, pandemics, and geopolitical issues, it is critical to focus on network-level resilience. For example, the recent events such as the COVID-19 pandemic and the Suez Canal blockage in 2021 have exposed the vulnerabilities of maritime networks and highlighted the cause of widespread cascading effects across the entire maritime supply chain when a few nodes or links were disrupted. These incidents reveal that vulnerabilities extend beyond individual ports to include inter-port connectivity, dependency structures, and recovery mechanisms within the broader maritime network.

To address these gaps, there is a growing need for integrative approaches that explicitly incorporate resilience thinking into maritime network analysis. Future research should move beyond static and port-centric perspectives toward dynamic, network-level frameworks that capture disruption propagation, interdependencies, and recovery processes across the entire system. This includes developing quantitative metrics and modelling techniques to assess robustness, adaptability, and recovery performance under different shock scenarios. In addition, combining network science with real-time data, simulation models, and interdisciplinary insights can provide a more holistic understanding of MNR. Such advancements would support more informed decision-making, enabling stakeholders to design resilient maritime networks capable of sustaining global trade in the face of increasing uncertainties and complex disruptions.

APPROACHES TO MARITIME NETWORK RESILIENCE

Understanding MNR requires more than isolated analytical approaches; it demands a layered examination of how resilience is conceptualised, tested, operationalised, and validated across the literature. Existing MNR studies differ substantially in their theoretical assumptions, analytical objectives, methodological structures, and interpretation of resilience itself. As a result, the literature has evolved in a fragmented manner, with different approaches emphasising particular dimensions of resilience such as robustness, vulnerability, recovery, adaptability, or optimisation, while often overlooking the interdependencies between them. This methodological diversity has generated valuable insights into specific aspects of maritime resilience, yet it has also produced inconsistent findings and limited comparability across studies.

To critically evaluate these differences, this study categorises the existing MNR literature into four major methodological groups: conceptual studies, scenario-based simulations, optimisation and modelling approaches, and other approaches like empirical and data-driven methods. Each category is examined in terms of its analytical capabilities, practical applicability, and methodological limitations. Through this review, the study identifies how each approach contributes to understanding MNR, where important analytical gaps remain, and why greater methodological integration is necessary for developing more comprehensive and operational resilience assessment frameworks.

Conceptual studies

The conceptual studies provide a critical foundation for understanding MNR before empirical or quantitative analysis is undertaken. They help define key concepts such as network failure, recovery, and adaptation within maritime contexts, and guide the selection of appropriate analytical methods and metrics. These studies focus on clarifying resilience concepts (Berle et al., 2011; Laun et al., 2022), identifying key system properties relevant to resilience (Tai & Yang, 2016), developing conceptual modelling approaches (Vanlaer et al., 2022), and proposing theoretical frameworks that explain system behaviour under stress (Kim et al., 2021). In the maritime domain, conceptual research is largely theory-driven, aiming to explain how networks anticipate, absorb, respond to, and recover from disruptions . However, these studies are often qualitative and rely on limited empirical validation, constraining their ability to quantitatively assess resilience outcomes.

A range of conceptual frameworks has been developed to operationalise resilience across different maritime system boundaries. Verschuur et al. (2022) proposed a risk-based framework that highlights ports as critical nodes linking maritime transport with inland logistics and global supply chains, thereby amplifying cascading disruption effects. Similarly, a framework was introduced to assess economic risks associated with hurricane-induced port disruptions in the United States, focusing on losses from closures, reduced capacity, and supply chain interruptions. developed a port vulnerability assessment framework that standardises the evaluation of exposure, sensitivity, and adaptive capacity, enabling consistent assessments across regions.

Several studies adopted a broader system-level perspective (Omer et al., 2012; Mansouri et al., 2009). Omer et al. (2012) proposed a networked infrastructure resiliency framework incorporating three key metrics: tonnage resilience (volume of goods transported during and after disruptions), time resilience (speed of recovery), and cost resilience (financial recovery capability). This approach marked an important step toward linking resilience with measurable performance indicators. Mansouri et al. (2009) contributed a risk management–based decision framework that emphasises identifying risks, evaluating consequences, and supporting policy decisions under uncertainty. Their work highlights the importance of governance and institutional factors, categorising disruption causes into human, natural, organisational, and technological factors.

Chen et al. (2025) proposed a multi-method framework combining qualitative assessment, quantitative indicators, and scenario analysis to evaluate maritime supply chain resilience. The study identified key resilience pathways, including structural redundancy, operational flexibility, stakeholder collaboration, and adaptive decision-making, illustrating the multidimensional nature of resilience.

Overall, conceptual studies establish the theoretical foundation of MNR by identifying vulnerabilities, explaining network behaviour under stress, and outlining response and recovery mechanisms. They also provide the basis for subsequent empirical analysis, simulation modelling, and network-based approaches, enabling more comprehensive and operational assessments of MNR. Despite these advances, conceptual studies remain constrained by their largely qualitative orientation and limited empirical validation. While they

successfully identify key system properties and theoretical mechanisms, they often fall short in explaining how resilience can be measured consistently or improved in practice. This has resulted in a degree of conceptual fragmentation, where competing definitions and frameworks coexist without convergence, ultimately limiting their direct applicability for decision-making. Table 1 summarises the literature that has employed a conceptual study approach to analyse the MNR.

Table 1 – Summary of literature employed a conceptual study approach to analyse the MNR

Author(s)	Research Objective	Research Design/ Approach	Key Findings
Berle et al. (2011)	Develop a formal vulnerability assessment framework	Conceptual framework based on literature review, adaptation of Formal Safety Assessment steps, stakeholder interviews, and an illustrative liquefied natural gas case.	Stakeholders prioritise minor disruptions over rare major events. Lean supply chains increase vulnerability, while traditional risk methods are insufficient for unforeseen disruptions. The proposed Formal Vulnerability Assessment provides a structured and transparent framework for systematic risk evaluation and cost–benefit decision-making.
Laun et al. (2022)	Develop a conceptual data model	Literature review of architecture frameworks, methodology development identifying key data elements, and validation using a real-world case study	Existing frameworks are lack of learning components. Resilience is time-dependent across pre, during and post disruption stages. Data transformation is essential for quantitative assessment, and the built model improves traceability and supports learning from system performance.
Tai & Yang (2016)	Develop a policy-making framework to enhance the economic resilience	Analytic Hierarchy Process with expert interviews, survey of industry stakeholders, and multi-criteria decision analysis of resilience strategies	Shipping policy adjustment is the most critical resilience strategy, followed by incentives and operational changes. Port resilience depends on adapting to changing regional shipping dynamics.
Vanlaer et al. (2022)	Develop a framework to understand organisational resilience capabilities of ports	Qualitative conceptual study based on Duchek's resilience model, supported by participant observation, semi-structured interviews at the Port of Antwerp, and literature synthesis.	Port resilience operates through anticipation, coping, and adaptation stages and it depends on knowledge, resources, and social capital. Resilience is a dynamic capability that evolves over time. Port authorities act as ecosystem coordinators.

Kim et al. (2021)	Develop and validate a framework to measure port resilience	Conceptual framework based on resilience triangle theory, literature review, survey of 199 port stakeholders, and statistical validation using exploratory and confirmatory factor analysis.	Port resilience consists of absorptive, adaptive, and restorative capabilities. Ports should strengthen restoration planning and crisis response capabilities.
Verschuur et al. (2022)	Develop a systemic risk framework for port-connected networks and identify resilience strategies	Multi-scale hierarchical network representation of ports across local, regional, and global layers, supported by review of systems-of-systems models, input–output analysis, and complexity science approaches.	Systemic risks can generate indirect losses larger than direct damages to port assets. Resilience depends on rerouting and spare capacity but is constrained by system rigidity and technical constraints. Coordinated multi-level governance involving port authorities, national governments, and private firms is required to improve resilience.
Omer et al. (2012)	Develop a quantitative Networked Infrastructure Resiliency Assessment (NIRA) framework	Application of NIRA framework which includes three stages such as boundary definition, resiliency assessment process, and resiliency scheme identification.	Demonstrates that disruptions significantly reduce network performance while rerouting and diversification improve resilience. Collaboration and resource allocation are critical for recovery. The developed framework enables quantitative and repeatable evaluation of resilience strategies.
Mansouri et al. (2009)	Develop a Risk Management-based Decision Analysis (RMDA) framework for maritime transportation system	Propose an RMDA framework consists of three major phases including assessing risks, devising resilience strategies, and valuing investment strategies.	Vulnerability reduction strategies are more cost-effective than recovery-only approaches. Contingency planning is essential due to inevitable disruptions while resilience investments provide long-term economic benefits.
Chen et al. (2025)	Examine how maritime supply chain enterprises use resources to build resilience and identify synergistic pathways to high resilience under increasing disruption risks	Empirical multi-method framework built combining structural equation modelling, necessary condition analysis, and fuzzy set qualitative comparative analysis using survey data from 151 maritime firms in China.	Maritime supply chain resilience is driven by multiple interacting factors such as early warning capability, agility, collaboration, digitalization and carbon reduction rather than single variables where digitisation act as a key enabling factor.

SCENARIO-BASED SIMULATION

Scenario-based simulation has become a prominent approach for analysing MNR by explicitly modelling how networks behave under disruptions. This approach typically represents networks as graphs, where ports are nodes and shipping routes are links, and simulates disruptions through the removal or modification of these elements. By observing changes in network performance, researchers can assess robustness, vulnerability, and recovery dynamics in a controlled and reproducible manner. Within complex network analysis, this provides a systematic way to evaluate how maritime systems respond to shocks.

Most studies within this literature focus on disruption-based simulations, where nodes or links are removed to represent failures (Yang & Liu, 2022; Hu et al., 2026; Z. Li et al., 2024). These disruptions are generally categorised into random failures, representing unforeseen events such as natural disasters, and targeted attacks, which simulate disruptions to strategically important ports and routes. In maritime contexts, node-based disruptions are more common, with ports treated as primary elements of failure (Yang & Liu, 2022). Typically, one port is removed at a time along with all its associated connections, simulating a sudden halt in operations. Sequential removal of ports allows researchers to observe cumulative impacts on network performance.

Targeted node-removal strategies often rely on centrality measures to identify critical ports. Hu et al. (2026) assessed MNR using multiple disruption and recovery scenarios based on degree, betweenness, strength, and random attacks. Ports were ranked by importance and removed sequentially, with network performance evaluated after each step. The study also incorporated recovery processes by restoring nodes according to their original importance, enabling analysis of both disruption and recovery dynamics. Similarly, Z. Li et al. (2024) examined the impact of COVID-19 on the global container shipping network using betweenness and degree centrality-based attacks. Their findings showed that betweenness-based attacks were more destructive, as they target ports acting as key intermediaries in global shipping flows.

Other studies reinforce the vulnerability of maritime networks to targeted disruptions (Peng et al., 2018; Wang et al., 2016). demonstrated that while networks can withstand random failures such as typhoons or earthquakes, they are highly sensitive to deliberate attacks. Peng et al. (2018) compared container, oil tanker, and bulk cargo networks using random and targeted strategies based on degree, betweenness, and flux centrality. Their results indicated that container shipping networks are particularly fragile, fragmenting quickly when key nodes are removed.

This vulnerability is largely explained by the scale-free structure of maritime networks, where a small number of highly connected hubs dominate the system (Holme et al., 2002; Viljoen & Joubert, 2016). Targeted removal of these hubs leads to rapid breakdown of connectivity and efficiency. In contrast, random failures tend to affect fewer influential nodes, resulting in a more gradual performance decline. Bai et al. (2023) confirmed this pattern, showing that removing a few high-centrality ports causes significantly greater disruption

than random failures, highlighting the need for protecting critical nodes and enhancing redundancy.

Although node-based disruptions dominate the literature, some studies examine link-based failures. Viljoen and Joubert (2016) analysed vulnerability using targeted link removals based on link betweenness, which identifies routes that lie on many shortest paths. More recent approaches incorporate link salience, derived from network skeleton concepts (Shekhtman et al., 2014), to identify links that are consistently important across routing structures (Grady et al., 2012). Comparing different link-based disruption strategies, such as link betweenness and link salience, provides a more comprehensive understanding of network vulnerability beyond port-level analysis.

Beyond disruption-focused approaches, some studies explore resilience through network enhancement strategies (Xu et al., 2023; Poo et al., 2024). Instead of removing elements, these approaches add nodes or links to improve robustness. Xu et al. (2023) combined node-removal analysis with motif-based link addition, creating new connections between indirectly linked ports. These targeted additions significantly improved network robustness compared to random link additions and offer practical insights for strengthening connectivity, particularly for developing regions and Small Island Developing States. Similarly, Poo et al. (2024) examined the impact of introducing Arctic shipping routes by adding new links to the global container network. This increased overall connectivity, altered port centrality, and enhanced resilience by providing alternative routes without disrupting the existing network.

Overall, scenario-based simulations provide a powerful framework for identifying critical nodes and links, understanding disruption dynamics, and evaluating strategies for improving resilience. They demonstrate that MNR depends not only on the importance of individual ports or routes but also on the overall connectivity and redundancy of the network. By combining disruption and enhancement scenarios, these approaches offer valuable insights for both risk assessment and proactive resilience planning in maritime systems. However, scenario-based simulations are not without limitations. Although they provide valuable insights into network vulnerability and structural resilience, they offer limited guidance on how to design or implement effective resilience strategies in practice. Table 2 summarises the literature that has employed a scenario-based simulation approach to analyse the MNR.

Table 2 – Summary of literatures employed a scenario-based simulation approach to analyse the MNR

Author(s)	Research Objective	Research Design / Approach	Key Findings
Yang & Liu (2022)	Analyse how port failures affect the connectivity and efficiency of the Maritime Silk Road shipping network and identify dominant and vulnerable ports	Complex network analysis using resilience indicators, node-removal simulations, k-means clustering, and correlation analysis on a network of 179 ports.	The network is structurally vulnerable to port failures and especially dominant ports such as Singapore and Port Klang. Vulnerable ports depend heavily on core hubs. Node degree strongly affects resilience, whereas sailing distance has limited influence on resilience.
Hu et al. (2026)	Develop a resilience optimisation framework for the Maritime Silk Road shipping network	Complex network modelling using AIS ship call data, disruption and recovery simulations, iterative route optimisation, and resilience assessment	Strength centrality-based recovery is the most effective recovery strategy. Long-distance cross-regional links significantly improve resilience. Key strategic hub ports were identified as critical strategic gateways for reinforcement. Random disruptions are harder to mitigate under limited economic constraints.
Z. Li et al. (2024)	Assess the impact of COVID-19 on the global container shipping network and evaluate changes in network vulnerability and hub port status	Data-driven complex network analysis using AIS data, weighted network modelling, and intentional attack simulations based on degree and betweenness centrality.	Network structure remained robust despite reduced freight flows. Mega ports and long-distance links were most vulnerable. Attacks on high betweenness centrality ports caused the greatest disruption to network integrity.
Peng et al. (2018)	Evaluate the robustness of global cargo shipping networks	Complex network analysis using AIS data, subnetwork modelling for container, oil tanker, and bulk carrier networks, and attack simulations based on degree, betweenness, flux, and random failures	Bulk carrier networks are the most robust, while container shipping networks are the most vulnerable. Betweenness-based attacks cause the greatest disruption. Maritime networks are generally resistant to random failures due to dense connectivity and functional redundancy.
Wang et al. (2016)	Develop a quantitative approach to analyse network temporal robustness in the global container shipping network	Complex network analysis comparing 2004 and 2014 shipping networks using robustness metrics and simulations of random failures and intentional attacks.	The global container shipping network became more vulnerable over time, particularly to intentional attacks. Targeted disruptions caused earlier network failure despite network growth. Dual-core hub structures which is nearby pivotal ports can act as backup mechanisms if one port fails, provide backup resilience mechanisms.

Holme et al. (2002)	Analyse attack vulnerability and robustness of different complex network structures under selective disruptions	Numerical analysis of real-world and model-based networks using degree – and betweenness-based attack strategies with recalculated and initial removal methods.	Recalculated attack strategies based on the current network state are more destructive than static approaches. Betweenness-based attacks cause the greatest disruption. Higher clustering increases vulnerability to targeted attacks on vertices. Random network structures are comparatively more robust.
Viljoen & Joubert (2016)	Evaluate the vulnerability of the global container shipping network to targeted link disruptions	Complex network analysis using Lloyd's List Intelligence data, directed weighted network modelling, and iterative targeted link-removal simulations based on link betweenness and link salience strategies.	The network remains highly connected despite major link removals, but flexibility declines significantly under targeted disruptions. Betweenness-based removals reduce rerouting flexibility, while salience-based removals weaken the network skeleton and consolidation opportunities.
Bai et al. (2023)	Develop a framework to assess static and dynamic resilience of the global liner shipping network under disruptions	Data-driven complex network analysis using AIS data, overlapping community detection, node-attack simulations, and congestion propagation modelling.	The network is resilient to random failures but highly vulnerable to targeted attacks on hub ports. Traffic flow intensifies disruption impacts. Failures at key hubs and canals cause widespread congestion and major efficiency losses. Resilience planning should prioritise critical hubs and maritime chokepoints
Shekhtman et al. (2014)	Examine how network skeleton extraction methods perform under network perturbations and disruptions	Comparative network analysis using salience skeleton and disparity backbone methods under node removal, link removal, and link rewiring scenarios across transportation, biological, and random networks.	Skeleton structures remain globally robust under perturbations, but exact link topology is highly sensitive. Salience skeletons maintain connectivity through replacement paths, whereas disparity backbones are more fragile. Real-world networks are more robust than random networks under stress
Grady et al. (2012)	Develop a parameter-independent method to identify essential structural components in complex networks using link salience	Network analysis using shortest-path trees, effective proximity measures, empirical testing across multiple real-world networks, and epidemic spreading simulations.	Link salience produces a natural bimodal classification of important and non-important links. High-salience skeletons capture core network structure. Salience predicts spreading pathways better than traditional centrality measures and provides a distinct measure of network importance.

Xu et al. (2023)	Improve structural robustness of the global liner shipping network by identifying critical ports and developing link-adding strategies	Motif-based complex network analysis using Space-P modelling, rich-club and four-node motif detection, motif centrality development, and simulation of targeted attack and link-adding strategies.	The network shows a strong rich-club structure among major hubs. Motif centrality better identifies critical ports than traditional measures. Low-degree motif-based link addition significantly improves robustness and provides stronger benefits for vulnerable countries and small island developing states.
Poo et al. (2024)	Assess the impact of Arctic shipping routes on the connectivity and resilience of the global container shipping network	Data-driven network analysis using global shipping movement data, development of Latitudinal Centrality Index, and scenario simulations of Arctic route adoption.	Arctic shipping routes can improve overall connectivity and resilience under full integration scenarios. Incremental adoption has limited impact, while full commercialization significantly increases network density but faces operational barriers such as seasonality and reliability constraints.

OPTIMISATION AND MODELLING

To address gaps in the above methods, optimisation and modelling approaches have emerged as a more decision-oriented extension of conceptual and scenario-based studies. Other methods are often descriptive and limited in providing actionable strategies for improving MNR. Conceptual frameworks typically outline principles of network robustness, redundancy, and flexibility, while scenario-based approaches analyse the consequences of disruptions, such as port closures or route interruptions. However, neither approach explicitly identifies optimal strategies for improving performance or minimising losses. To address these gaps, optimisation and modelling approaches have emerged as a more decision-oriented methodology. By framing MNR as a quantitative problem, these approaches aim to optimise network structure, routing strategies, and recovery actions to improve operational performance under both expected and unexpected disruptions.

Despite their analytical power, many optimisation-based studies adopt simplified assumptions regarding operational behaviour, economic feasibility, and adaptive responses, which can limit their applicability in practice (Cheung et al., 2020; Hu et al., 2026; Fischer et al., 2016; Parvaresh et al., 2014). For example, some models assume fixed shipping schedules, ignore variable port handling times, or do not account for the dynamic behaviour of shipping companies and ports. Consequently, the effectiveness of these approaches depends critically on how well the models' assumptions, constraints, and objective functions reflect the actual complexity of maritime networks, including the interdependencies between ports, shipping lines, hinterland transportation, and supporting infrastructure.

At the network level, optimisation has been widely applied to improve resilience through structural enhancements. Hu et al. (2026) modelled maritime networks as directed weighted graphs and formulated resilience as an optimisation problem focused on minimising performance loss or maximising overall resilience. Their approach emphasised link addition to increase redundancy and alternative routing options, while incorporating

economic constraints such as investment budgets. Similarly, Cheung et al. (2020) used a max-min integer programming model to identify “missing links” that would most effectively improve network connectivity. By maximising the minimum relative improvement across all nodes, their model ensures balanced network enhancement rather than concentrating benefits on a few ports, highlighting key strategic connections in Asian shipping networks.

Optimization has also been applied to strategic network configuration. Parvaresh et al. (2014) developed a bi-objective, bi-level model for hub location selection that minimizes transportation costs under both normal and worst-case disruption scenarios, capturing the trade-off between efficiency and resilience. proposed a mixed-integer linear programming model to optimize freight flows in the Mediterranean, balancing operational efficiency with capacity utilization. Their model maximizes system performance by increasing flow efficiency while minimizing unused capacity, demonstrating how resource allocation decisions influence network robustness.

At the operational level, optimisation models focus on fleet deployment, scheduling, and disruption management. Fischer et al. (2016) introduced a model for roll-on roll-off shipping that integrates robustness strategies, such as buffer times and scheduling incentives, with recovery mechanisms like speed adjustments and rolling horizon re-planning. The objective is to minimise total operational cost while maintaining service reliability. This highlights the importance of combining proactive planning with adaptive responses to disruptions.

To better address uncertainty, stochastic and multi-stage optimisation models incorporate probabilistic disruptions and adaptive decision-making. Goldbeck et al. (2020) proposed a multi-stage stochastic framework that jointly optimises pre-disruption investments and post-disruption recovery actions. Zhen et al. (2022) developed a two-stage stochastic nonlinear model for port resilience within a green port context, integrating infrastructure and operational decisions under power-related disruptions. Huang et al. (2022) extended container shipping models by accounting for both complete hub failures and partial disruptions due to congestion, incorporating backup hub selection and congestion costs to enhance robustness.

Recovery-oriented optimisation is another critical area, focusing on restoring network functionality after disruptions. Kjeldsen (2012) developed a model for simultaneous rescheduling of vessels and cargo to minimize recovery costs. Brouer et al. (2013) addressed the vessel schedule recovery problem using mixed-integer programming, balancing fuel consumption, delays, and service levels, and demonstrating significant cost savings compared to standard practices. Qi (2014) further improved recovery modelling by incorporating flexible vessel routing, speed adjustments, and container re-routing, while Dui et al. (2021) focused on minimising residual resilience loss by evaluating post-disruption recovery capacity.

Beyond maritime routes and fleets, optimisation has also been applied to port and hinterland systems. Chen et al. (2017) developed an integer programming model to assess resilience in port-hinterland transport networks, highlighting the role of road transport as a flexible alternative during disruptions. Asadabadi and Miller-Hooks (2020) introduced a

stochastic, bi-level game-theoretic model that captures "co-opetition" among ports, where they simultaneously compete and cooperate through shared resilience investments. This reflects the strategic complexity of global maritime systems.

Optimisation and modelling approaches typically employ mathematical and computational techniques to identify resilience-enhancing interventions. For instance, network models often represent ports as nodes and shipping routes as links in directed or weighted graphs, allowing for quantitative analysis of network performance. Optimisation can then be used to determine the best allocation of resources, investment in infrastructure, or adjustment of operational strategies. These interventions may include route additions, capacity reallocations, hub selection, fleet deployment strategies, or scheduling adjustments. Importantly, the choice of optimisation technique, whether deterministic, stochastic, or heuristic, directly influences the model's ability to capture real-world complexities, including uncertain disruptions, operational delays, and economic constraints.

Overall, optimisation and modelling approaches provide a rigorous, quantitative framework for enhancing MNR. By integrating strategic planning, stochastic uncertainty, recovery-oriented mechanisms, and operational constraints, these models move beyond descriptive analysis to offer actionable guidance for network design, fleet deployment, investment prioritisation, and operational decision-making. They allow researchers and practitioners to quantify trade-offs between cost, redundancy, and network performance, thereby supporting evidence-based policies and investment strategies to improve the resilience of maritime networks in the face of growing environmental, economic, and operational challenges. Consequently, their effectiveness depends heavily on how well model assumptions align with the dynamic and interconnected nature of real-world maritime systems. Table 3 summarises the literature that has employed an optimisation and modelling approach to analyse the MNR.

Table 3 – Summary of literature employed an optimisation and modelling approach to analyse the MNR

Author(s)	Research Objective	Research Design / Approach	Key Findings
Cheung et al. (2020);	Identify "missing links" in the global shipping network that can improve overall connectivity and robustness	Graph-theoretic modelling using eigenvector centrality and largest eigenvalue optimisation, max–min integer programming, and a greedy LINK algorithm applied to real-world container shipping data	The model effectively identifies high-impact missing links that improve network connectivity. Adding new links (especially between unconnected ports) significantly increases network performance. Asian ports dominate connectivity importance in the global system.

Fischer et al. (2016)	Develop robust roll-on roll-off fleet deployment and recovery strategies to minimise disruption impacts and improve operational resilience	Mixed-integer linear programming fleet deployment model, Rolling Horizon Heuristic for large-scale optimisation, and simulation–optimisation framework with stochastic disruptions and recovery actions.	Robust planning strategies reduce real disruption costs and delays despite slightly higher planned costs. Recovery actions and re-planning improve performance, but introduce trade-offs between operational stability and flexibility
Hu et al. (2026)	Develop a resilience optimisation framework for the Maritime Silk Road shipping network	Complex network modelling using AIS ship call data, disruption and recovery simulations, iterative route optimisation, and resilience assessment	Strength centrality-based recovery is the most effective recovery strategy. Long-distance cross-regional links significantly improve resilience. Key strategic hub ports were identified as critical strategic gateways for reinforcement. Random disruptions are harder to mitigate under limited economic constraints.
Parvaresh et al. (2014)	Minimise normal and worst-case transportation costs through optimal hub location planning under intentional disruption scenarios	Bi-level optimisation model using a leader–follower game framework, solved with meta-heuristic algorithms and tested on benchmark transport networks.	Resilient hub design can significantly reduce worst-case disruption costs with only small increases in normal costs. Trade-offs exist across different interdiction scenarios and requiring careful decision-making under uncertainty.
Goldbeck et al. (2020)	Develop a multi-stage stochastic model to jointly optimise pre-disruption investments and post-disruption recovery	Multi-stage stochastic programming model using scenario trees and network flow representation of supply chains, tested through a real-world case study.	Sharing and pooling repair resources significantly improves resilience, reduces recovery loss, and lowers costs. It also improves resource efficiency, though it may slightly increase losses under extreme worst-case disruptions.
Zhen et al. (2022)	Maximise port resilience under disruption scenarios within budget constraints	Two-stage stochastic optimisation model with mixed-integer nonlinear formulation, using scenario-based simulation and linearisation for solution.	Integrated investment and operational decisions significantly improve resilience. Coupled power–transport modelling is essential as failures cascade between systems. Infrastructure is more critical than vehicle quantity, and coordinated pre – and post-disruption strategies yield the best outcomes
Huang et al. (2022)	Improve container shipping reliability by optimising hub location, spoke allocation, and backup hub design under complete and partial hub failures	Nonlinear optimisation model solved using particle swarm optimisation, incorporating simulation of congestion and failure scenarios in a case study of Asia–Europe ports.	Backup hubs significantly improve network reliability. Congestion and rerouting costs strongly influence optimal design. Redundancy and regional cooperation enhance resilience under both complete and partial hub failures.

Kjeldsen (2012)	Develop a model for simultaneous rescheduling of ships and cargo after disruptions	Formulated as a multicommodity flow problem with side constraints on a time-space network. And developed a Large Neighborhood Search (LNS) heuristic with iteratively destroys and repairs procedure for scheduling and routing.	The heuristic efficiently solves all test instances and produces high-quality recovery plans. Extending the recovery time horizon is more effective than expanding available resources for reducing unserved cargo.
Brouer et al. (2013)	Develop a decision-support model for vessel recovery under disruptions	Time-space network mixed-integer programming model incorporating vessel speed changes, port call omissions, and route swaps and validated using real disruption cases.	The model efficiently generates near real-time recovery decisions with substantial cost savings. Optimized recovery strategies generated by model outperform manual decisions.
Dui et al. (2021)	Develop an optimal recovery sequencing method for failed ports and routes	Dynamic network optimisation model of a maritime transport system with residual resilience metric, using multiple importance measures.	Recovery sequencing strongly depends on system dynamics and traffic redistribution. Supply nodes and their links are highest priority for restoration. Combining multiple importance measures yields more reliable recovery decisions than single metrics.
Chen et al. (2017)	Define and quantitatively measure resilience of Port Hinterland Container Transportation Network from a shipper (user) perspective	Develop a two-stage integer programming model including port recovery decisions and shipper routing decisions. Conduct Monte Carlo simulation.	The Port of Gothenburg network demonstrated relatively high resilience levels. Road transport is the key recovery mode. Seaport is the main critical node and resilience depends on redundancy and recovery efficiency; road disruption sharply reduces performance.
Asadabadi and Miller-Hooks (2020)	Develop a multi-stakeholder investment framework for port resilience in a competitive maritime network	Multi-leader, common-follower game theoretic approach to model the interactions between ports and shippers.	Co-opetitive investment improves total demand served and port performance while external investments can benefit investor ports indirectly. Unrestricted investment yields higher resilience and lower costs than restricted strategies. Decentralized decisions may create multiple equilibria and unequal outcomes across ports.

OTHER APPROACHES

There are some other approaches used by researchers, such as empirical and data-driven methods, to analyse MNR. By leveraging observational data, historical disruption records, and stakeholder surveys, these studies offer evidence-based insights into

how maritime systems perform under actual conditions. For instance, Kaliszewski et al. (2020) used a survey targeting 120 senior managers and directors of global shipping lines to rank competitiveness factors, highlighting the critical role of service quality, labour harmony, and nautical accessibility from a global shipping perspective. Notteboom et al. (2021) utilised the COVID-19 barometer survey to compare the pandemic's temporal and spatial shocks against the 2008–2009 financial crisis. This comparative analysis provides essential evidence-based insights into system resilience during extreme events. However, such data-driven evaluations must be balanced against routine operational disruptions to ensure a comprehensive understanding of port behaviour. Despite their strengths, empirical approaches are often limited by data constraints, inconsistencies, and a focus on specific events or regions. Moreover, they tend to capture observed outcomes rather than underlying causal mechanisms, making it difficult to generalise findings across different contexts. As such, their greatest value lies in complementing conceptual, simulation, and optimisation approaches by validating assumptions and refining model parameters. Table 4 summarises the literature that has employed other approaches to analyse the MNR.

Table 4 – Summary of literatures employed other approaches to analyse the MNR

Author(s)	Research Objective	Research Design / Approach	Key Findings
Kaliszewski et al. (2020)	Examine shipping lines' perspectives on global container port competitiveness	Quantitative survey of 120 shipping executives via LinkedIn and the respondents rated 20 port factors (1–10 scale). Analysis used Friedman test and post-hoc LSD ranking.	Service quality and labour stability are the most important factors, followed by nautical accessibility and connectivity. Larger firms value all factors more strongly. Non-price factors dominate port choice decisions.
Notteboom et al. (2021)	Compare the impacts of the COVID-19 pandemic and the 2008–2009 financial crisis on maritime systems	Empirical comparative study across supply chains, carriers, terminals, and ports. Uses operational, financial, and survey data and compares COVID-19 with 2008–09 crisis using quantitative indicators.	COVID-19 was a simultaneous external shock with faster recovery than 2008–09. Carriers showed higher resilience via capacity management (alliances, blank sailings). Vessel calls fell but cargo volumes were resilient due to larger ships. Past crisis performance does not predict COVID-19 impact.

CONCLUSION

This review of existing approaches to MNR reveals that the literature has advanced methodologically but remains conceptually and analytically fragmented. Conceptual studies, scenario-based simulations, optimisation models, and other analytical approaches differ not only in their techniques but, more fundamentally, in how they frame the problem of resilience itself. Rather than offering competing perspectives, these approaches can be

understood as addressing different layers of the resilience problems in complex maritime networks, from abstractoion and diagnosis to intervention and validation. However, their lack of integration has limited the development of a coherent and operational framework capable of capturing the full complexity of maritime networks.

Conceptual studies primarily focus on defining resilience, identifying core dimensions such as robustness, redundancy, adaptability, and recovery, and clarifying system boundaries within which resilience is assessed. They are particularly effective in capturing the socio-technical nature of maritime systems, where infrastructure, governance structures, institutional coordination, and stakeholder interactions are deeply intertwined. Yet, their analytical strength is also their primary limitation. The predominance of qualitative reasoning and the absence of standardised metrics result in conceptual ambiguity and limited comparability across studies. As a consequence, while these frameworks are indispensable for framing the problem, they provide insufficient guidance for measuring resilience or evaluating intervention strategies in real-world settings.

Scenario-based approaches advance the literature by operationalising resilience through quantitative analysis of network behaviour under disruption. Their application of complex network theory enables systematic identification of critical nodes and links, offering clear insights into structural vulnerabilities and failure dynamics. In particular, the distinction between random and targeted disruptions has significantly improved understanding of the inherent fragility of hub-dependent maritime networks. However, these approaches remain largely diagnostic. By focusing on simulated disruptions, often based on stylised assumptions such as complete node removal, they risk oversimplifying the partial, dynamic, and adaptive nature of real-world disruptions. More critically, they do not adequately address the question of how resilience should be enhanced, as they lack the capacity to incorporate economic trade-offs, behavioural responses, and operational constraints into their analysis.

Optimisation and modelling approaches attempt to fill this gap by reframing resilience as a decision-making problem. These methods provide a more prescriptive perspective, enabling the identification of optimal strategies for network design, resource allocation, and recovery planning under various constraints and uncertainties. Their ability to integrate multiple objectives such as cost efficiency, service reliability, and recovery performance, makes them particularly valuable for policy and operational applications. Nonetheless, their practical relevance is often undermined by simplifying assumptions regarding system dynamics, data availability, and stakeholder behaviour. Many models fail to capture the adaptive and strategic interactions that characterise global maritime systems, thereby limiting their applicability in highly uncertain and rapidly evolving environments.

Other approaches, including empirical and data-driven methods, provide an important counterbalance to theory-driven and model-based analyses by grounding MNR research in observed system behaviour. By leveraging observational datasets, historical disruption records, and stakeholder surveys, these approaches generate evidence-based insights into how maritime networks perform under real-world conditions. However, the analytical scope of empirical approaches remains inherently constrained. Their strong reliance on

data availability often results in fragmented or region-specific analyses, limiting the generalisability of findings across different maritime contexts.

Taken together, the central limitation across all approaches is not methodological inadequacy per se, but the absence of integration. Each approach captures a partial dimension of resilience conceptual clarity, structural vulnerability, decision optimisation, or empirical validation yet none fully addresses the interdependencies, dynamic feedback, and multi-scalar nature of maritime networks. This fragmentation ultimately restricts the field's ability to move from theoretical understanding to actionable resilience planning. Therefore, advancing MNR research requires a shift from isolated methodological applications toward cohesive, multi-layered frameworks that systematically combine these perspectives.

Future research should prioritise the development of integrated frameworks that bridge conceptual, analytical, and empirical approaches to provide a more holistic understanding of MNR. In particular, there is a need to move beyond static and topological representations of networks toward dynamic models that capture disruption propagation, recovery processes, and the behaviour of stakeholders. Methodologically, combining scenario-based simulations with optimisation techniques and data-driven validation can enable both robust diagnosis and actionable decision-making. Finally, emerging challenges such as climate change, geopolitical instability, and digital transformation require resilience frameworks that explicitly account for deep uncertainty, multi-hazard interactions, and long-term system adaptation. Addressing these directions will be critical for developing resilient maritime networks capable of sustaining global trade under increasingly complex and uncertain conditions.

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B2B Place Marketing and Strategic Positioning in Sustainable Supply Chains: A Conceptual Analysis Focusing on the Iyidere Logistics Port

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ABSTRACT

Today, as the global trade axis is being reshaped along the East-West route, the Black Sea has begun to emerge as a crucial node (the Middle Corridor) within international trade routes. The security and stability of the Black Sea have gained significance concerning the regional countries and their integration with other nations. Beyond being a transit route, the Middle Corridor stands out as a sustainable transportation alternative against global crises.

Ports are transforming beyond being purely physical infrastructures into service brands and B2B marketing ecosystems that must be marketed globally. Therefore, for ports to achieve international competitive advantage, it is considered necessary to integrate their location with a comprehensive place marketing strategy of the region.

The aim of this study is to present a conceptual analysis of the İyidere Logistics Port from a place marketing perspective and to discuss the envisioned sustainable transportation system. In the study, an evaluation is conducted based on existing infrastructure data, reports, and academic literature.

The İyidere Logistics Port, currently under construction in İyidere, Rize, is regarded as one of the significant logistical and geostrategic initiatives that will enhance Turkey's influence in the region. Supported by robust hinterland connectivity, particularly the Ovit Tunnel, the İyidere Logistics Port will offer a seamless supply chain linking the Black Sea basin to the Caucasus, the Middle East, and Western Asia via Eastern and Southeastern Anatolia.

The planned infrastructural capacity and location of the İyidere Logistics Port are addressed as a 'Unique Selling Proposition' (USP) that provides strategic positioning in the international logistics market. Its infrastructural capacity and location will enable high-ton-

nage vessels to transport cargo, thereby achieving economies of scale and reducing unit transportation costs. Furthermore, the İyidere Logistics Port is also considered to present a strong brand promise that fulfills the expectations of a sustainable green supply chain.

Due to the port's location, it is anticipated that the one-month transit time in the import shipments of powerful regional actors like Iran will be reduced to approximately 15 days. This indicates substantial time and cost savings within global B2B networks. Additionally, the interaction with the Anaklia project in Georgia is evaluated in the context of 'regional clustering,' which increases the overall attractive force and sustainability of the Black Sea basin in global trade, rather than as a zero-sum competition. In conclusion, it is believed that the İyidere Logistics Port can act as a driving force in regional development and emerge as a strong, sustainable brand in the logistics sector.

KEEWORDS: Sustainable Logistics, B2B Place Marketing, İyidere Logistics Port, Middle Corridor, Port Marketing.

STPA-Based Safety Analysis in Pilot Transfer Operations

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ABSTRACT

Pilot transfer operations represent one of the highest-risk procedures in maritime transport, involving the physical transfer of a marine pilot between a pilot boat and a vessel under varying and often adverse environmental conditions. Despite the existence of international regulatory frameworks such as SOLAS Chapter V Regulation 23, IMO Resolution A.1045(27), and ISO 799-1:2019, accidents during pilot boarding and disembarking continue to occur, indicating systematic gaps in current safety management approaches. Traditional risk analysis methods applied to this operation—including statistical techniques, Fuzzy AHP, Fault Tree Analysis, FMEA, HAZOP, and HFACS address accidents within a linear cause–effect framework and are limited in their capacity to capture the complexity of sociotechnical interactions and systemic control loop deficiencies. This study applies System-Theoretic Process Analysis (STPA) to develop a proactive safety analysis of pilot transfer operations. The analysis proceeds through four structured phases: definition of system-level losses and hazards; modelling of the hierarchical control structure encompassing port authority, vessel bridge, pilot boat, and operational control levels; systematic identification of Unsafe Control Actions (UCAs) across all controller–control action pairs using the four standard STPA guide words; and elaboration of causal scenarios linking process model flaws, communication failures, and environmental disturbances to the identified UCAs. Environmental parameters including wind force, sea state, visibility, and vessel freeboard height are incorporated as scenario-based variables, enabling the model to reflect the dynamic and context-sensitive nature of the operation. Preliminary findings derived from the literature review, regulatory synthesis, and initial STPA modelling reveal critical vulnerabilities in feedback channels between the pilot boat crew and the vessel bridge, particularly under adverse weather conditions and at high-freeboard vessels, as well as a recurrent gap in the literature regarding the systemic treatment of pilot transfer risk. The preliminary UCA taxonomy and causal scenario set provide a structured, evidence-based foundation for the subsequent quantitative phase of the ongoing research and for the development of targeted safety barriers in port and maritime environments.

KEEWORDS: Pilot transfer operations; STPA, unsafe control actions; maritime safety; hierarchical control structure

1. INTRODUCTION

Maritime Pilot transfer operations are among the most hazardous activities in maritime transport. The process of embarking and disembarking a marine pilot using a pilot ladder, a combination arrangement, a trap door, or mechanical hoisting equipment occurs in an exposed and dynamic environment where human performance is subject to a wide range of physical, organizational, and environmental stressors (Aydin et al., 2022). Pilotage requires the pilot to board a vessel frequently under adverse weather conditions and, in narrow waters with minimal margin for error, to integrate rapidly with a bridge team with whom they are unfamiliar (Öztürk et al., 2024). Studies consistently report that human error is the primary contributing factor in approximately 80 to 90 percent of all maritime accidents (Chauvin, 2011), underscoring the need for safety analysis techniques capable of capturing both the human and systemic dimensions of risk in this operation.

Existing risk analyses of maritime pilot transfer operations in the literature have been shaped around statistical methods, fuzzy logic–based approaches, and cognitive modeling techniques. Uğurlu et al. (2017) examined the relationship between operational variables and accident occurrence using chi-square analysis; Luo and Shin (2019) and Doğru and Bucak (2025) applied Fuzzy Analytic Hierarchy Process (AHP) to calculate risk weights; Tunçel et al. (2021) employed Fuzzy Fault Tree Analysis to estimate accident probabilities; and Aydın et al. (2022) used a Success Likelihood Index Method integrated with HFACS-PV to examine cognitive error mechanisms. Although these studies yield valuable insights, traditional techniques such as FMEA, HAZOP, and HFACS predominantly address accidents within a linear cause effect framework and are limited in their capacity to capture the complexity of sociotechnical systems, human–machine interactions, and systemic control loop deficiencies (Bruno and Lützhöft, 2009) None of the reviewed studies has addressed system-level control deficiencies in pilot transfer operations within a unified analytical framework based on systems theory.

System-Theoretic Process Analysis (STPA), developed by Leveson (2011), offers a proactive alternative by reframing safety analysis around the concept of control: accidents are understood not as chains of failure events, but as the result of inadequate control actions within a hierarchical sociotechnical control structure. STPA has been successfully applied across domains including aviation, nuclear power, automotive systems, and healthcare; its application to maritime pilot transfer operations, however, remains limited. The present paper reports the preliminary findings of an ongoing master's thesis study that addresses this gap by conducting an STPA analysis of pilot transfer operations, producing a catalogue of Unsafe Control Actions (UCAs) and causal scenarios that can directly inform safety barrier design and port safety management systems. The quantitative extension of the analysis will be developed in a subsequent journal article.

2. METHODOLOGY

2.1 Research Design

The study adopts a qualitative systems-theoretic research design grounded in STPA methodology. The unit of analysis is the pilot transfer operation as a sociotechnical system, encompassing all human controllers, automated systems, physical processes, and environmental factors involved in the embarkation and disembarkation of marine pilots. Data sources include international regulatory standards (SOLAS Chapter V Regulation 23, IMO Resolution A.1045(27), ISO 799-1:2019), IMPA safety guidelines, port authority operational procedures, and documented accident and incident reports from maritime investigation bodies including the Marine Accident Investigation Branch (MAIB) and the National Transportation Safety Board (NTSB).

2.2 Phase 1: System Definition – Losses and Hazards

In the first phase, system-level losses were defined as the unacceptable outcomes that the safety analysis seeks to prevent. Primary losses identified include fatal or serious injury to the pilot, pilot boat crew, or vessel crew (L1); damage to the vessel, pilot boat, or port infrastructure (L2); and environmental damage resulting from a maritime incident during transfer (L3). System hazards were then derived as system states or conditions that could lead to these losses under specific environmental conditions. Key hazards identified include pilot contact with the vessel hull or water surface during transfer (H1); pilot ladder or hoisting equipment failure under load (H2); loss of control of the pilot boat in proximity to the vessel (H3); and failure of communication between the pilot boat and vessel bridge during the approach and transfer phases (H4).

The overall system losses, corresponding hazards, and safety constraints were then organized to establish traceability between the defined system goals and potential accident mechanisms. Tables 1 through 3 summarize the identified losses (Lx), hazards (Hx), and safety constraints (SCx) that form the foundation of the subsequent controlstructure and UCA analysis.

Table 1. SystemLevel Losses

Code	Loss Description	Affected Element	Explanation
L1	Fatal or serious injury to pilot, pilot boat crew, or vessel crew	Human	Physical fall, impact, or entrapment during transfer
L2	Damage to vessel, pilot boat, or port structure	Equipment / Infrastructure	Collision, contact, or failure of transfer equipment
L3	Environmental pollution due to fuel or oil release	Environment	Collision-induced leakage or spill during transfer
L4	Disruption of port operations and economic loss	Organizational	Transfer accident-causing delay, diversion, or downtime

Table 2. System Hazards

Code	Hazard Description	Related Loss (Lx)	Explanation
H1	Pilot contacts the vessel hull or the water surface during transfer.	L1	Balance loss, wave impact, or ladder instability causing fall or collision.
H2	Failure of pilot ladder, combination arrangement, or hoisting gear under load.	L1, L2	Structural weakness, improper rigging, or inadequate maintenance leads to equipment breakage.
H3	Loss of control of the pilot boat during approach or positioning alongside the vessel.	L1, L2, L3	Caused by heavy sea state, wind gusts, or steering/propulsion malfunction.
H4	Communication failure between the vessel's bridge team and the pilot boat crew during approach and transfer.	L1, L2	Misinterpretation, delays, or missing confirmations create mismatched timing and conflicts.
H5	Continuation of transfer operations under adverse environmental conditions exceeding safety thresholds.	L1, L2, L3,L4	Operation proceeds despite high wind, waves, or poor visibility, violating go/nogo limits.

Table 3. System Safety Constraints

Code	Safety Constraint Description	Linked Hazard (Hx)	Control Level
SC1	Pilot transfer shall only take place within defined meteorological and sea-state limits.	H1, H3, H5	Harbor Master/ Regulatory Level
SC2	Pilot ladder and combination arrangements must comply with ISO 799-1 and be verified prior to operation.	H2	Vessel / Deck Crew
SC3	Vessel speed during pilot-boat approach shall not exceed 6 knots.	H3	Vessel Bridge
SC4	A three-way verbal confirmation (bridge–pilot–boat) must precede the transfer initiation.	H4	Bridge & Pilot
SC5	During pilot climb, vessel propulsion and rudder actions must remain fixed and stable.	H1, H3	Vessel Bridge

2.3 Phase 2: Hierarchical Control Structure Modeling

Building upon the losses, hazards, and safety constraints defined in the previous phase (Tables 1–3), a hierarchical control structure was developed to represent all controllers involved in the pilot transfer operation and the control actions and feedback channels between them. The control structure encompasses four levels: (1) regulatory and port authority level, including flag state administration, port state control, and harbour master; (2) vessel bridge level, including the master, officer of the watch, and lookout; (3) pilot boat level, including the pilot boat master and deck crew; and (4) operational level, comprising the pilot and the physical transfer equipment. Control actions flowing downward in the hierarchy include speed and heading commands, approach authorization, equipment deployment orders, and go/no-go decisions. Feedback channels flowing upward include position reports, weather observations, equipment status reports, and verbal confirmations.

2.4 Phase 3: Unsafe Control Action (UCA) Identification

For each controller and control action pair identified in the control structure, UCAs were systematically analyzed using the four standard STPA guide words: (1) control action not provided when required; (2) control action provided causes hazard; (3) control action provided with wrong timing (too early, too late, or out of sequence); and (4) control action stopped too soon or applied too long. This analysis was applied to all major control actions in the pilot transfer operation, including vessel speed reduction commands, pilot boat approach authorization, pilot ladder deployment and securing, hoisting equipment operation, and go/no-go transfer decisions. Environmental variables including wind force, sea state, visibility, and vessel freeboard were incorporated as contextual parameters that modify the hazard potential of each UCA, yielding scenario-specific UCA classifications. The application of the four standard STPA guide words to the control actions identified in the hierarchical model resulted in a structured setof Unsafe Control Actions (UCAs). A representative subset of these UCAs is shown in Table 5, together with the associated hazards defined in Phase 1.

2.5 Phase 4: Causal Scenario Analysis

For each identified UCA, causal scenarios were elaborated to explain how the UCA could arise within the control structure. Causal factors were categorized as follows: inadequate process models held by the controller (incorrect, incomplete, or outdated mental models of system state); failures in feedback channels (delayed, missing, or misleading feedback to the controller); inadequate control algorithms (flawed procedures, decision rules, or training); and external disturbances acting on the controlled

process. A standardized causal scenario documentation template was developed to ensure consistency and reproducibility, with each scenario recorded in terms of the triggering condition, the affected controller, the resulting UCA, and the associated system hazard.

3. PRELIMINARY FINDINGS

This section presents the preliminary findings obtained from the literature review, regulatory analysis, and initial STPA modeling conducted in the first stage of the ongoing thesis research. These findings establish the analytical foundation on which the subsequent phases of the study will be developed and demonstrate the operational relevance of the proposed framework.

3.1 Literature Gap and Methodological Positioning

The systematic review of the literature on pilot transfer safety analysis revealed that prior studies have predominantly relied on three methodological families: statistical techniques, fuzzy logic–based approaches, and cognitive modeling techniques. While each contributes partial insight, all share a common limitation: they conceptualize accidents as linear chains of failure events rather than as emergent outcomes of control structure deficiencies. No prior study in the reviewed literature has modeled pilot transfer operations as a hierarchical control problem using systems-theoretic analysis. Table 4 summarizes the comparative positioning of the present study with respect to the main prior works.

Table 4. Comparative positioning of prior studies on pilot transfer safety.

Study	Method	Focus	Systemic View
Uğurlu et al. (2017)	Chi-square analysis	Operational variables vs. accidents	No
Luo and Shin (2019)	Fuzzy AHP	Risk weighting	No
Aydın et al. (2022)	SLIM + HFACS-PV	Cognitive error mechanisms	Partial
Tunçel et al. (2023)	Fuzzy Fault Tree Analysis	Accident probability	No
Doğru and Bucak (2025)	Fuzzy AHP	Risk factor prioritization	No
Present Study	STPA	Hierarchical control structure	Yes

3.2 Regulatory Framework Synthesis

The regulatory analysis identified three primary normative sources governing pilot transfer operations: SOLAS Chapter V Regulation 23, which establishes the technical requirements for pilot transfer arrangements; IMO Resolution A.1045(27), which defines the recommendations for pilot transfer arrangements including ladder specifications and combination arrangements; and ISO 799-1:2019, which specifies the design, manufacturing, and testing requirements for pilot ladders. The cross-referencing of these regulatory sources with documented incident reports from MAIB and NTSB revealed that a significant proportion of serious pilot transfer incidents involve arrangements that were formally compliant with these standards at the time of the accident. This observation reinforces the hypothesis that regulatory compliance at the equipment level is insufficient on its own, and that systemic control-level analysis is required to address latent accident pathways.

3.3 Preliminary Control Structure and Identified Vulnerabilities

The initial modeling of the hierarchical control structure of pilot transfer operations produced a four-level representation with mapped control actions and feedback channels between each level. The preliminary analysis of this structure revealed several recurring vulnerabilities in the information flow. First, the feedback channel between the pilot boat deck crew and the vessel bridge is frequently limited to VHF voice communication, without a formal status feedback mechanism for equipment readiness and crew position (Bruno & Lützhöft, 2009). Second, the feedback loop from the pilot to both the vessel and boat teams is largely severed during the ladder climbing phase, during which the pilot is in the most physically exposed state. Third, the feedback from environmental conditions to the go/no-go decision is often mediated through subjective assessment rather than through structured decision thresholds linked to measurable parameters such as wind force, significant wave height, visibility, and vessel freeboard. These vulnerabilities form candidate input points for the UCA identification phase.

3.4 Preliminary UCA Catalogue

The preliminary catalogue indicates that UCAs distribute across all four standard STPA categories and involve all four controller levels, confirming that the hazard space of pilot transfer operations is genuinely systemic rather than concentrated at a single point of failure. The most frequently recurring UCA categories in the preliminary set are 'provided causes hazard' and 'wrong timing,' both of which are strongly modulated by environmental conditions.

Table 5. Representative subset of the preliminary UCA catalogue.

Controller	Control Action	UCA Category	Example UCA	Linked Hazard
Vessel Bridge	Speed reduction command	Not provided	Excessive speed during pilot boat approach	H2, H3
Pilot Boat Master	Approach authorization	Wrong timing	Approach initiated before ladder ready	H1, H3
Vessel Crew	Pilot ladder deployment	Provided causes hazard	Ladder secured below required height	H1, H2
Harbor Master	Go/No-Go authorization	Provided causes hazard	Transfer approved above weather limits	H1, H3, H4, H5
Pilot	Ladder climb initiation	Wrong timing	Climb started while boat unstable	H1

3.5 Preliminary Causal Factor Patterns

Preliminary causal scenario analysis of the identified UCAs revealed three recurring patterns. The first pattern involves inadequate process models, where the vessel bridge team holds an outdated mental model of pilot boat position or of ladder readiness status, leading to premature or mistimed control actions. The second pattern involves feedback channel failures, particularly the absence of structured environmental threshold communication between the harbor master and operational levels, which contributes to go/no-go decisions being made on subjective rather than objective grounds. The third pattern involves inadequate control algorithms, where procedural gaps in the coordination between vessel and pilot boat crews during the approach phase create windows during which no controller holds unambiguous authority. These preliminary causal patterns will be elaborated and validated in subsequent phases of the study through expert consultation and accident report cross-referencing.

CONCLUSION

This study has presented the preliminary findings of an STPA-based safety analysis of pilot transfer operations, addressing a recognized gap in the proactive, systems-theoretic assessment of risk in this safety-critical maritime activity. By modeling the hierarchical control structure of the pilot transfer system and systematically identifying Unsafe Control Actions and their causal scenarios. This analysis reveals systemic vulnerabilities that are not captured by traditional linear hazard analysis methods. In particular, the preliminary findings highlight critical weaknesses in feedback channels between the pilot boat deck

and the vessel bridge, in the process models held by controllers regarding environmental conditions and equipment status during the transfer phase, and in the absence of structured decision thresholds for go/no-go authorization.

The scenario-based incorporation of environmental variables wind force, sea state, visibility, and vessel freeboard enable the analysis to reflect the context-sensitive nature of risk in pilot transfer operations, producing a differentiated picture of safety-critical conditions rather than a single static risk assessment. The standardized documentation format developed for the control structure diagrams, UCA catalogue, and causal scenario tables supports reproducibility and provides a practical template for application in other port environments and high-risk maritime operations.

The principal limitation of the present stage of the study is the qualitative nature of the STPA output, which does not directly yield quantitative risk estimates. Future work within the broader thesis project will extend this analysis through the integration of quantitative human reliability analysis techniques to enable probabilistic risk quantification, and through the application of the framework to empirical incident data for validation. The STPA control structure and preliminary UCA catalogue developed in this study provide a strong foundation for such extensions and offer immediate practical value for safety barrier design and risk mitigation planning within port and maritime safety management systems.

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Temporal Changes and Operational Risk Factors in Maritime Container Loss Events

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ABSTRACT

Container shipping, the lifeblood of global trade, has become a fundamental pillar of the world economy, supporting more than 80% of it, and has seen a massive 1500% increase in capacity over the last fifty years. However, this industrial growth has also introduced new safety risks, including pushing ship design limits, increasing operational complexity, and diversifying environmental exposures. One of the most concrete and devastating consequences of these risks for the marine ecosystem is "container loss at sea," which jeopardizes navigational safety and creates sources of permanent pollution on the seabed and surface that can last for decades. This study aims to analyze the temporal variations of container loss events at sea and the underlying operational risk factors from a longitudinal perspective with academic rigor. The research's methodological framework is based on statistical tools that are widely used and highly reliable in the maritime safety literature. In the analysis of time series data, the nonparametric Mann-Kendall test statistic, which does not assume normality and is robust to outliers, was used. The significance levels obtained using this method, supported by the non-parametric Sen's slope estimator, quantitatively reveal the magnitude and direction of the observed annual changes. This integrated methodological approach provides scientific evidence that container losses are not merely a series of isolated accidents but exhibit statistically significant trends directly related to global trade dynamics and evolving ship technologies. The study finds that container loss incidents have exhibited a characteristic change, particularly over the last ten years, in parallel with the increase in ship sizes. While traditional risk factors such as severe weather conditions and storm exposure remain critically important, the most dramatic increase has been concentrated in structural risks arising from the proliferation of Ultra Large Container Ships (ULCS). The increase in ship sizes and record-high deck stacking heights has made modern ships more vulnerable to dynamic natural phenomena such as "parametric resonance" and "synchronous rolling," which can disrupt ship stability within seconds. In addition to these technical risks, this study thoroughly examines the decisive impact of operational weaknesses, such as misdeclaration of cargo, material fatigue of lashing equipment, and deck fires, on the total volume of losses. Aimed at filling existing gaps in the literature, this research not only provides a retrospective

overview of past data but also offers strategic insights for international maritime policies. In particular, in light of the mandatory reporting regimes implemented by the IMO (International Maritime Organization) at the beginning of 2026 and the current revisions to SOLAS (International Convention for the Safety of Life at Sea) standards, it identifies areas where current inspection and enforcement mechanisms lag behind technological advancements. The analyses strongly emphasize that static risk assessment methods are no longer sufficient; instead, AI-powered dynamic decision support systems that integrate meteorological data, ship hydrodynamics, and cargo characteristics in real time should be standardized on ships. In conclusion, this study argues that a correct understanding of the evolving nature of operational risk factors is vital for establishing a sustainable safety culture in maritime transport. The research results offer a comprehensive, data-driven roadmap for ship operators, classification societies, insurance companies, and international regulatory authorities. Minimizing container losses is crucial not only for preventing billions of dollars in economic losses but also for protecting the global marine environment and maintaining the reliability of maritime transport in line with the "Blue Economy" goals.

KEEWORDS: Mann-Kendall trend analysis, maritime container loss, operational risk factors, Sen's slope estimator

INTRODUCTION

Container shipping, the most vital component of global trade, currently carries approximately 80% of commercial goods transported by sea (Cosar & Demir 2017). Although the industry's massive 1500% increase in capacity since 1968 has improved economic efficiency, it has also introduced new risk factors for generation by placing serious pressure on ship design and operational limits (Kaup et al., 2022). World Shipping Council (WSC) data show that an average of 1,566 containers were lost at sea annually between 2008 and 2022, but this figure exceeded the 3,000 threshold during periods of catastrophic events (Molina-Padrón et al., 2024). Container losses not only result in direct financial losses but also threaten ecosystem security due to the collision risks posed by containers drifting on the sea surface and the widespread pollution caused by the hazardous substances they contain (Wan et al., 2022).

In the legal framework for the prevention of container losses, the SOLAS Convention, the CSS Code, and the Verified Gross Mass (VGM) rules, which came into force in 2016, are the primary tools aimed at minimizing stability problems arising from incorrect weight declarations (Aras & Chen 2019). However, until recently, the absence of a mandatory reporting mechanism for these losses was considered a significant governance gap that restricted transparency in the sector. To address this deficiency, the International Maritime Organization (IMO) has ushered in a new era of data-driven safety management by approving rule changes mandating the reporting of all container losses as of January 1, 2026 (Molina-Padrón et al., 2024).

In the literature, the causes of these losses are attributed to a combination of cargo management elements, such as improper containerization, incorrect weight declaration,

and inadequate lashing equipment, and environmental factors, such as parametric rolling (France et al., 2003; Levadou & Palazzi, 2003; Carmel, 2006). Particularly, human-induced errors in loading operations have been identified as the decisive factor in 55% of cases (Erdem et al., 2023). While most existing studies focus on historical data, this study aims to address gaps in the literature by presenting a predictive model that incorporates geopolitical and environmental factors using a 15-year longitudinal dataset.

2. LITERATURE REVIEW

Losses in maritime container transport are addressed in the literature as a complex risk area where environmental dynamics, operational flaws, and regulatory gaps intersect. Studies reveal that the massive growth in the physical dimensions of container ships has strained existing stability criteria and lashing systems (Kaup et al., 2022). In particular, the increase in ship capacities has expanded the windage area by raising stack heights, thereby making the rolling motions exhibited by ships in dynamic sea conditions more critical.

One of the most prominent risk factors in the literature is "parametric rolling." Spyrou-Sioula et al. (2022) state that large container ships, especially those sailing in head seas, are exposed to sudden and severe rolling motions due to the synchronization between wave frequency and the ship's natural roll period. This situation is the primary trigger for containers falling overboard, placing stress on lashing equipment well beyond its design limits (Gaidai et al., 2025). Furthermore, excessive whipping effects and high stress accumulation on the ship's hull in stormy weather conditions threaten structural integrity and accelerate cargo losses.

On the operational dimension, the most discussed topic is procedural errors before and during loading. Öztürk (2024), in an analysis using Fuzzy Bayesian Networks, identified that the primary causes of containers falling overboard are incorrect weight declarations and imbalances in the stowage plan. Despite the Verified Gross Mass (VGM) regulation under SOLAS, discrepancies between paper data and actual weights continue to lead to incorrect ship stability calculations (Kaup et al., 2022). Research on the human factor confirms that a significant portion of accidents stems from inadequate training, fatigue, or flawed decision-making processes under commercial pressures (Yi et al., 2025).

The environmental impacts of losses constitute another focal point of the literature. Plastic pellets and chemical substances inside lost containers cause long-term pollution in marine ecosystems (Jo, 2020). Technical difficulties in the detection and recovery operations of containers carrying dangerous goods (IMDG), in particular, negatively affect both navigational safety and marine tourism (Behforouzi, 2019). At this point, Molina-Padrón et al. (2024) draw attention to the necessity of a global surveillance system for the real-time tracking of lost containers and emphasize the role that existing technological infrastructure (IoT, satellite tracking, etc.) can play in mitigating the impact of these losses (Oberjatzas et al., 2024).

When the literature on container losses is examined, it is observed that studies are generally limited to static models based on historical events. However, today, sudden route alterations due to geopolitical crises, along with the complex environmental risks these new routes pose, necessitate more dynamic and integrated approaches. By using a dataset cov-

ering a wide period and advanced statistical methods, this research fills this gap in the literature and presents a strategic predictive model for the future.

3. METHODOLOGY

3.1 Research Design and General Approach

This longitudinal, observational, quantitative study examines maritime container loss events documented globally between 1997 and 2022. Its primary objective is to statistically determine monotonic trends in container losses over time and systematically identify the operational risk factors driving these trends. The research questions are structured around: (i) whether the annual frequency and severity of events exhibit a significant upward trend, (ii) how this trend differs at the levels of event category and causal factors, and (iii) how the identified trends can be associated with current regulatory and operational frameworks.

The study has adopted official maritime accident investigation reports as the primary source. These reports provide causal hierarchies based on comprehensive field investigations and technical analyses, significantly reducing reporting bias and observer errors commonly observed in other secondary data sources (Kaup et al., 2022). In the analysis, the nonparametric Mann-Kendall (MK) trend test and Sen's slope estimator, which do not require parametric assumptions and yield robust results in small to medium-sized samples, were used.

3.2 Data Sources and Sample Selection

3.2.1 Database Structure

The dataset forming the basis of the analysis comprises 100 container loss events compiled from the reports of 9 recognized national and international maritime accident investigation authorities (DMAIB – Danish Maritime Accident Investigation Board, ATSB – Australian Transport Safety Bureau, NTSB – US National Transportation Safety Board, MAIB – Marine Accident Investigation Branch, JTSB – Japan Transport Safety Board, TSB – Transportation Safety Board of Canada, EMSA – European Maritime Safety Agency, Sri Lanka NMIB, and DGS – Directorate General of Shipping India) for the period 1997–2022. The dataset includes only investigations conducted by authorized investigative authorities and is limited to fully completed, publicly available reports. In this way, the risk of inconsistent characterization standards leading to measurement error has been minimized. EMSA's European Marine Casualty Information Platform (EMCIP) and the World Shipping Council's (WSC) annual Container Losses at Sea Report records were used as auxiliary reference sources for cross-validation purposes.

3.2.2 Inclusion and Exclusion Criteria

The following inclusion criteria were applied while establishing the sample: (i) direct involvement of a commercial container ship, (ii) resulting in the permanent loss of at least one intermodal ISO container at sea, and (iii) the presence of reasonable evidence that

the event was non-criminal. Conversely, events where the TEU count could not be reliably determined due to the inability to document lost containers, incidents occurring in inland waterways, and events without an official investigation authority report were excluded from the scope. This methodological preference ensures terminological consistency and enhances the dataset's measurement reliability.

3.2.3 Variable Coding

Each event record has been structured around three primary variable groups to ensure the depth of the analysis. The first group, process variables, includes the year of the event, the category it falls into among four main categories (Category 1: Parametric Resonance & Severe Weather; Category 2: Lashing & Equipment Failures; Category 3: Structural Damage, Fire & Sinking; Category 4: Stability, VGM & Operational Errors), and the reported amount of loss in terms of TEU. Causal factors in the second group were coded under eight primary headings based on findings in official investigation reports: severe wind, high wave height, parametric resonance, lashing equipment failures, stability/GM errors, container stowage defects, lack of situational awareness, insufficient crew training and familiarity, maintenance failures, and failures in structural damage detection. The third group, event severity variables, consists of derived metrics such as total annual TEU loss and average TEU loss per event. To maintain data objectivity, the coding process of causal factors was conducted by two independent coders. The disagreement rate between the coders was 7.4%, and Cohen's kappa coefficient ($\kappa = 0.81$) indicates a high level of statistical reliability and compliance with criterion validity standards. All emerging discrepancies were resolved through expert evaluation until full consensus was achieved in the dataset.

3.3 Event Categorization Framework

Event categories were derived inductively from official investigation results and designed in alignment with existing literature (Kaup et al., 2022; Spyrou-Sioula et al., 2022). Each event was assigned to one of four categories based on its primary causal mechanism (Table 1).

Table 1. Container loss event categories: definitions and example cases.

Code	Category	Definition and Primary Causal Mechanism
I	Parametric resonance and severe weather conditions	Container losses arising from parametric rolling, synchronous rolling, or dynamic loads caused by extreme weather. The primary trigger is the resonance interaction between the wave frequency and the ship's natural roll period.
II	Lashing equipment failure	Events where broken, inadequately deployed, or non-compliant lashing equipment meeting certification requirements constitute the direct failure mode. Chronic neglect of maintenance is a decisive factor in recurring cases.
III	Structural damage, fire, and sinking	Large-scale cargo losses resulting from loss of structural integrity, uncontrollable fire, or sinking. Violations of dangerous goods declarations have been identified as a frequently accompanying risk factor in this category.

IV	Stability errors and VGM non-compliance	Events where ship stability is compromised due to incorrect or intentionally falsified container weight declarations. Cases where GM calculation errors lead to unexpected ship motions are included in this category.

During the categorization process, only one primary category was assigned to each event; this approach ensured both discrete-coding reliability and intercategorical independence in the time-series analysis. In events where multiple causal mechanisms were intertwined, the primary causal chain determined by the official investigation authority was taken as the basis.

3.4 Statistical Analysis Methods

3.4.1 Mann-Kendall Trend Test

The Mann-Kendall (MK) trend test was selected as the primary statistical tool for time series analysis. This choice is based on three methodological justifications: (i) Parametric tests do not yield reliable results, considering that annual event count data is unlikely to meet the assumption of normal distribution; (ii) The MK test exhibits strong robustness against time series that include sudden jumps caused by external factors (e.g., geopolitical events, climate variability); (iii) Its widespread application in event loss studies enhances inter-methodological comparability (Hussain & Mahmud, 2019; Wang et al., 2020; Zhou et al., 2023).

The MK test statistic S is calculated through a monotonic comparison of observation pairs; subsequently, the obtained value is converted into the standard Z statistic (Equation 1):

$$S = \Sigma \Sigma \operatorname{sgn}(xj - xk),\ j > k \quad (1)$$

The significance threshold was set at $\alpha = 0.05$, and the Hamed-Rao variance correction, which is robust against autocorrelation, was applied (Hamed and Rao, 1998). This correction is critical for eliminating serial dependence frequently encountered in maritime accident datasets. All calculations were performed using the XLSTAT add-in for Excel.

3.4.2 Sen's Slope Estimator

Sen's slope estimator (β) was used to quantitatively express the observed trend. This estimator, which is significantly less affected by outliers compared to parametric regression, is calculated using (Equation 2) (Gocić & Trajković, 2012):

$$\beta = \operatorname{median}[(xj - xk) / (j - k)],\ j > k \quad (2)$$

The estimator provides a more robust measure of central tendency by limiting the impact of episodic catastrophic events in the dataset—specifically outlier years resulting in losses of several thousand TEU that could exert excessive pressure on the overall slope—on the estimated trend.

3.5 Qualitative Validation and Contextual Analysis

Statistical findings were supported by a mixed quantitative-qualitative approach. The examination of official investigation reports through detailed event analysis provides explanatory mechanisms for the identified trends and reveals contextual factors that numerical analysis alone might overlook. The causal interpretation framework for quantitative trends in parametric resonance, lashing equipment adequacy, and structural integrity is established through official examinations conducted by the relevant investigative authorities. The primary causal chains consistently presented in these reports play a decisive role in understanding the mechanisms supporting the statistical trend.

This qualitative layer is critical to evaluating whether events with high statistical significance are incidental or reflect structural dynamics, such as vessel size growth, route changes, and regulatory gaps.

3.6 Methodological Limitations

The study's findings should be addressed transparently, taking into account the existing methodological limitations. Firstly, the research may be subject to "selection bias" arising from the systematic exclusion of events that do not meet official investigation criteria, which may lead to the omission of unrecorded cases, particularly in regions where accident investigation capacity is limited. Secondly, the causal coding process is susceptible to measurement errors arising from terminological diversity and differing characterization frameworks among national authorities. Finally, although the 15-year observation window provides sufficient depth for a longitudinal analysis, it should be noted that structural improvements affecting data quality, such as the proliferation of satellite tracking technologies and reforms to IMO reporting standards, were not uniformly distributed throughout the period.

Despite these limitations, the systematic approach and statistical tools used ensure the study's internal validity and its contribution to the literature. The methodological workflow and analysis steps followed within the scope of the research are summarized collectively in Figure 1.

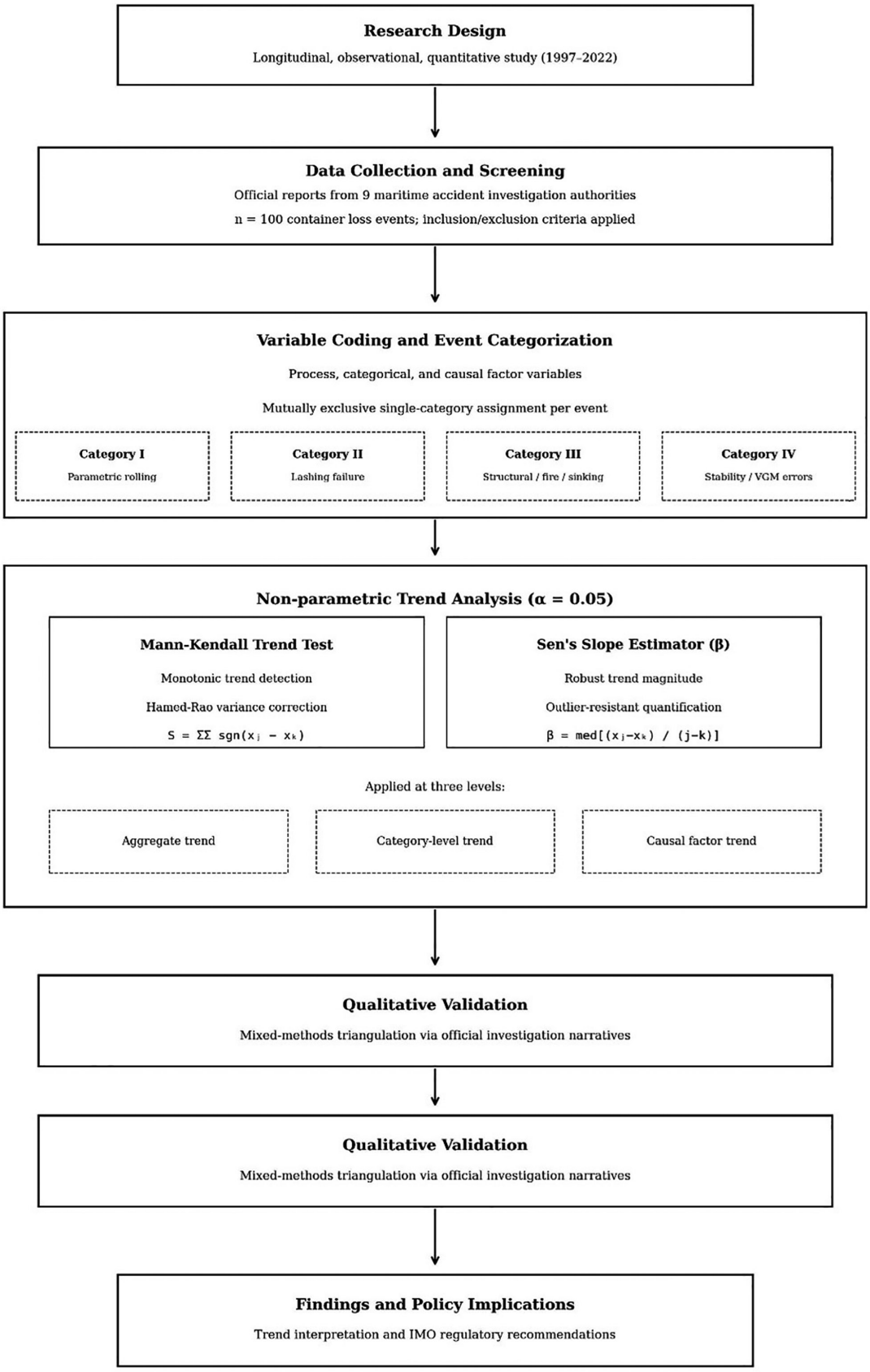

Figure 1. Methodological workflow of the study

4. FINDINGS

This section presents the findings of the non-parametric Mann-Kendall (MK) trend test and Sen's slope estimator applied to 100 container loss events recorded between 1997 and 2022. The dataset spans 15 calendar years and includes investigations conducted by 9 recognized maritime accident investigation authorities. Analyses were performed at three levels of detail: (i) total annual series, (ii) time series based on event category, and (iii) causal factor time series. Statistical significance was evaluated at the traditional $\alpha = 0.05$ threshold.

4.1 Total Trend Analysis

The MK test applied to the annual event frequency series revealed a statistically significant positive trend ($S = +214$, $\tau = +0.356$, $Z = +2.394$, $p = 0.017$). Sen's slope estimator indicates that the number of recorded container loss events increased at a rate of approximately 0.21 events per year throughout the period of investigation. This finding aligns with the expansion of the global container fleet and the entry into service of ultra-large container ships with nominal capacities exceeding 20.000 TEU in significant numbers starting around 2013. Conversely, neither the total annual TEU loss ($\tau = +0.281$, $p = 0.064$) nor the average TEU loss per event ($\tau = +0.221$, $p = 0.145$) reached the significance threshold.

This result points to a critical divergence: while event frequency is increasing, the severity per event measured in TEU does not exhibit a monotonic upward trend. The high interannual variance in total TEU loss stems from the excessive pressure on the slope exerted by individual catastrophic events, resulting in loss of structural integrity or capsizing, which negatively affects the statistical power of the trend test.

4.2 Trend Analysis at Category Level

The disaggregation of the annual number of events by causal category reveals that the overall trend is not evenly distributed across event types. Table 2 summarizes the MK test statistics and Sen's slope estimates for all series.

Table 2. Mann-Kendall test statistics and Sen's slope estimates for total, category-level, and causal factor time series (1997–2022).

Series	S	Kendall τ	Z	p-value	Sen's Slope	Trend
Annual event frequency	+214	+0.356	+2.394	0.017*	+0.21/year	↑ Increasing
Total annual TEU loss	+168	+0.281	+1.854	0.064	+18.3/year	— None
Avg. TEU loss per event	+130	+0.221	+1.458	0.145	+3.1/year	— None
Category I: Parametric resonance and severe weather	+284	+0.431	+3.064	0.002**	+0.09/year	↑↑ Strong Increase
Category II: Lashing equipment failure	−94	−0.142	−1.016	0.310	−0.04/year	— None
Category III: Structural damage / fire / sinking	+227	+0.344	+2.435	0.015*	+0.05/year	↑ Increasing
Category IV: Stability / VGM errors	−18	−0.028	−0.196	0.845	0.00/year	— None
Cause: Severe wind	+253	+0.383	+2.605	0.009**	+0.11/year	↑↑ Strong Increase
Cause: High wave height	+253	+0.383	+2.605	0.009**	+0.11/year	↑↑ Strong Increase
Cause: Lack of situation-al awareness	+214	+0.324	+2.295	0.022*	+0.05/year	↑ Increasing
Cause: Lack of training / familiarity	+201	+0.304	+2.154	0.031*	+0.05/year	↑ Increasing
Cause: Stability / GM errors	+190	+0.289	+2.032	0.042*	+0.05/year	↑ Increasing
Cause: Container stow-age errors	+180	+0.273	+1.837	0.066	+0.10/year	— None

Series	S	Kendall τ	Z	p-value	Sen's Slope	Trend
Cause: Maintenance failure	−18	−0.028	−0.170	0.865	0.00/year	— None
Cause: Failure in structural damage detection	+172	+0.261	+1.915	0.056	0.00/year	— None

4.2.1 Category I: Parametric Resonance and Severe Weather Conditions

Category I—comprising container losses resulting from dynamic loads caused by parametric resonance, synchronous rolling, and extreme weather conditions—exhibits the strongest and statistically most reliable positive trend in the dataset ($S = +284, \tau = +0.431, p = 0.002$). Corresponding investigation reports consistently identified storm-force winds, extreme sea states, and shallow-water wave amplification as the primary proximate causes. Even in cases where prevailing sea conditions were not unusual by historical standards, parametric resonance was identified as a probable causal mechanism, indicating that vessel-specific dynamic characteristics—particularly the flared bow forms and increased deck load centers of ultra-large container ships—play a decisive role. This finding supports the structural relationship between vessel size and susceptibility to parametric resonance.

4.2.2 Category II: Lashing Equipment Failure

Category II events, involving broken or inadequately deployed lashing equipment, show a statistically non-significant negative value of $\tau = -0.142$ ($p = 0.310$), with a Sen's slope of − 0.04 events/year. Although the trend did not meet the significance threshold, this downward orientation in lashing-related losses is consistent with the gradual tightening of the IMO CSS Code (2014) and mandatory lashing equipment certification requirements. Nevertheless, investigation reports have documented lashing element thicknesses falling significantly below nominal specifications due to chronic maintenance neglect. These findings reveal residual systemic gaps in lashing maintenance regimes despite regulatory progress. Recurring cases demonstrate that the mere existence of rules does not guarantee compliance; the effectiveness of inspections remains a decisive factor.

4.3.2 Human and Organizational Factors

Lack of situational awareness ($\tau = +0.324$, $p = 0.022$) and inadequate training/familiarization ($\tau = +0.304$, $p = 0.031$) both exhibit significant positive trends, with a Sen's slope of +0.05 occurrences per year. These findings are particularly noteworthy considering the general expansion of training requirements under the STCW Manila Amendments (2010). The operational complexity of ultra-large container ships—characterized by stowage capacities exceeding 20,000 TEU and the requirement for real-time dynamic stability monitoring—appears to be outpacing the pace at which crew competencies are updated. This discrepancy is resulting in a widening gap in human factors risk.

4.3.3 Technical and Maintenance Factors

In contrast to the aforementioned factors, maintenance failure does not exhibit a statistically significant trend ($\tau = -0.028$, $p = 0.865$); while the failure to detect structural damage also falls short of the significance threshold ($\tau = +0.261$, $p = 0.056$). The absence of a maintenance trend may be interpreted as evidence that Port State Control (PSC) inspections, ISM Code audits, and classification society survey regimes maintain a generally stable baseline in technical condition oversight. The stability/GM error factor ($\tau = +0.289$, $p = 0.042$) marginally exceeds the significance threshold. This trend is driven by incidents in which incorrect or intentionally falsified container weight declarations contribute to unexpected vessel motion. This finding underscores that declaration non-compliance remains a persistent risk element, even following the implementation of VGM (Verified Gross Mass) reforms.

5. DISCUSSION

This section systematically compares the findings obtained from the analysis of 100 container loss incidents (1997–2022) using the Mann-Kendall trend test and Sen's slope estimator with current literature. The analysis is structured around the hypothesis of increased incident frequency and ship size, heterogeneous risk profiles by category, explanatory mechanisms for meteorological and human factor trends, and the study's original contributions to the literature.

The significant positive trend in annual incident frequency ($\tau = +0.356$, $p = 0.017$; incidents/year) temporally overlaps with the expansion of the global container fleet, particularly the emergence of Ultra-Large Container Vessels (ULCVs) exceeding 20,000 TEU since 2013. The fact that 58% of the cumulative TEU loss data falls in the post-2013 period strengthens this correlation. While Yi et al. (2025) demonstrated that larger ships experience incidents less frequently but face much more severe consequences in terms of average TEU loss, the failure of total annual TEU loss ($\tau = +0.281$, $p = 0.064$) and average TEU loss per incident ($\tau = +0.221$, $p = 0.145$) to reach significance in the current study confirms this "frequency-severity decoupling." This suggests that the rising incident count is associated with a wide spectrum of vessel sizes rather than a uniform escalation in severity; rare catastrophic cases, such as loss of structural integrity or capsizing, limit statistical power by suppressing the cumulative curve. Findings by Yu et al. (2023) regarding the disproportionate dynamic loads carried by ULCVs under equivalent sea conditions explain the fundamental physical mechanism behind the concentration of incidents observed after 2013.

Category-level analyses reveal a highly heterogeneous risk profile. Category I (Parametric Resonance and Severe Weather), which exhibits the strongest positive trend ($\tau = +0.431$, $p = 0.002$), is theoretically supported by the susceptibility of ULCVs to parametric rolling in head seas, as highlighted by Spyrou-Sioula et al. (2022) and Gaidai et al. (2025). Conversely, the lack of a significant trend in Category II (Lashing Equipment Failure; $\tau = -0.142$, $p = 0.310$) points to the countervailing effect of the IMO CSS Code and mandato-

ry certification regimes. Öztürk (2024) complements this stagnant picture by identifying locking equipment as a moderate root cause with an impact rate of 6.1%. Category III, encompassing structural damage, fire, and sinking, exhibits a significant upward trend (τ= +0.344, p = 0.015). Krmek et al. (2022) indicate that this trend is further fueled by regulatory gaps in SOLAS detection requirements for on-deck containers and increased fire frequency on vessels exceeding 100.000 GT. While the stable course of Category IV (Stability Errors; τ= – 0.028, p = 0.845) reflects the positive impact of the Verified Gross Mass (VGM) reform, the marginally significant rise in the stability/GM error causal factor (τ= +0.289, p = 0.042) creates a paradox: while institutional compliance increases, the actual quality of weight declarations remains contentious.

Regarding causal factors, severe winds and high wave heights exhibit the steepest rising gradient (τ = +0.383, p = 0.009), indicating an increasing impact of meteorological exposure. While Yi et al. (2025) attribute 57.14% of incidents to weather conditions, Dong et al. (2024) predict that climate change will increase extreme weather events on main trade routes. These data demonstrate that the current trend is a precursor to future climate-induced risk escalation. Simultaneously, the rise in lack of situational awareness (τ= +0.324, p = 0.022) and inadequate training (τ= +0.304, p = 0.031) indicates that, despite the STCW Manila Amendments, crew competencies lag behind the operational complexity of ULCVs. Öztürk (2024) noted that human factor nodes form complex probabilistic dependencies with stability and lashing variables; the longitudinal data of this study prove that these dependencies have evolved into a risk axis that strengthens over time. In contrast, the stagnant trend in maintenance failures (τ = – 0.028, p = 0.865) confirms that inspection regimes establish a protective baseline for technical standards.

The original value of this study is embodied in three dimensions. First, unlike the static or short-term cross-sectional analyses by Öztürk (2024) and Yi et al. (2025), this study measures the "evolutionary velocity" of risks over a 26-year longitudinal period. Second, it deepens existing knowledge about larger vessels, leading to greater losses by decoupling frequency and severity trends. Finally, by conducting independent trend tests for all risk categories, it clearly distinguishes between the stable profiles of Categories II and IV and the structurally rising profiles of Categories I and III. This differentiation provides a data-driven roadmap for resource allocation and strategic intervention priorities in maritime safety management.

6. CONCLUSION

This study has revealed the quarter-century transformation in the industry's risk profile from a longitudinal perspective, applying the Mann-Kendall trend test and the Theil-Sen estimator to 100 container loss incidents spanning 1997–2022. The findings prove that global container shipping is in a critical transition phase, not only in terms of operational scale but also regarding risk dynamics. The analysis highlights five fundamental conclusions: First, a statistically significant and continuous increase in the annual frequency of incidents was

observed ($\tau = +0.356$, $p = 0.017$). This rise exhibits a temporal parallel with the acceleration of fleet capacity growth, particularly since the introduction of Ultra-Large Container Vessels (ULCVs) in 2013. Second, it was observed that this increase is not distributed homogeneously across incident types. While parametric rolling and severe weather conditions (Category I), alongside structural damage and fire incidents (Category III), show a distinct upward trend, the stagnation in lashing equipment failures and stability errors confirms the protective impact of regulatory regimes (ISM and CSS Code) on technical standards. Third, the causal factor analysis indicates that meteorological variables constitute the steepest rising gradient. This suggests that current trends are not merely a reflection of past risk accumulation but also serve as leading indicators for future risk escalations driven by climate change.

Fourth, despite STCW reforms, the rise in situational awareness gaps and training inadequacies points to a growing "human factor gap" between the operational complexity of ULCVs and crew competencies. Finally, despite the increase in incident frequency, the fact that the TEU-based severity trend did not reach the significance threshold documents a unique frequency-severity decoupling, in which isolated, staggering massive losses suppress the statistical signal.

The results of this study offer tangible policy recommendations in light of the IMO mandatory reporting regime that entered into force on January 1, 2026. It is essential to integrate parametric rolling risks into ULCV design standards and SOLAS stability criteria as dynamic parameters. Furthermore, to mitigate the risk of deck fires—a core component of the Category III trend—the detection and response gaps in the current SOLAS framework must be urgently addressed.

Among the methodological limitations of the research are risks of selection bias stemming from regions with low investigative capacity and measurement errors arising from terminological differences. Additionally, it should not be overlooked that recent improvements in reporting standards may partially account for the concentration observed post-2013. Future research is encouraged to focus on the impact of geopolitical route changes, such as the Red Sea crisis, on meteorological exposure and to integrate probabilistic risk models with the longitudinal data from this study. Ultimately, this work emphasizes the necessity of a dynamic, data-driven governance model that accounts for evolving risk factors, rather than static approaches, to ensure the sustainability of safety in container shipping.

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Improving the Interaction between Seaports and Rail Transport

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ABSTRACT

This article analyzes the relationship between seaports and rail transport and their influence on port performance. Rail transport plays a key role in freight movement in Georgia. Despite the effects of the pandemic crisis both in Georgia and worldwide, the volume of rail freight moving in and out of ports continues to grow steadily. According to the Georgian Seaport Infrastructure Development Strategy until 2030, this trend is expected to persist. The analysis indicates that seaport performance will largely depend on the efficient operation of rail transport and on its coordination with other transportation modes. The increase in freight traffic to Batumi and Poti ports caused a decline in 2021, mainly affecting containerized cargo. Possible reasons for this include: shipowners refusing to ship cargo by sea; imbalance in rolling stock; limited railway capacity; inadequate port infrastructure for handling increased cargo volumes; and poor coordination between ports and rail transport. Notably, attention should be given to the lack of clear, well-coordinated interaction between seaport and rail transport, which results in downtime for ships and rail cars, longer cargo handling times, and ultimately delays in delivering goods to recipients. The article emphasizes the importance of improving control and coordination between the port and the port railway station. It also includes a diagram illustrating information exchange within the port. It proposes an integrated information exchange system to address these issues and improve the efficiency of both seaports and rail transport.

KEEWORDS: Seaport, rail cars, rail transport, wagon handling at ports, interaction between the port and the railway station.

INTRODUCTION

Rail transport plays a key role in domestic freight transportation in Georgia, significantly affecting seaport operations. Clear and coordinated interaction between related modes of transport at a seaport is essential to its operational efficiency. [1] provides a detailed analysis of the interaction between the seaport and rail transport and proposes a structure for managing rail transport processing at the seaport, clearly linking them to management functions and periods based on their importance in developing management decisions. Key tasks require scientific and methodological support for their solution, while preceding and related tasks are addressed by management personnel based on their practical experience and strict adherence to instructions. To improve the efficiency of interaction between related modes of transport at seaports, it is primarily necessary to improve the methodology for operational planning of rail transport processing at the port.

DISCUSSION

1. Operational planning of vehicle handling at the port

This type of planning is based on the port's annual cargo handling plan (with quarterly and monthly breakdowns), developed and compiled from the existing cargo base, concluded contracts and agreements, and forecasts. The main goal of operational planning and management is to coordinate the activities of transport process participants, efficiently allocate and utilize port resources to achieve maximum productivity and cost-effectiveness in loading and unloading operations, and implement shift-, daily-, monthly-, quarterly-, and annual-port plans. The port's main dispatch service plans, organizes, and manages various modes of transport. The following regulatory documents are used in operational planning: the Port Code of Practice, the Transport Charter of Georgian Railways, and the Rules for the Carriage of Freight by Various Modes of Communication. In addition, the Nodal Agreement between the port and the railway station, process diagrams and maps, the annual specialization of handling complexes or berths, vessel-handling standards, standards for optimal concentration of mechanized lines, and existing contracts and agreements with port clients are used [2, 3].

The port's operational schedule is compiled and updated daily by the port's main dispatch service to expand operational planning, determine port capacity, prioritize and sequence vessel handling, calculate the required number of labor and machinery, and optimally organize port operations. Furthermore, the functions of this port service include drafting a shift-daily plan for the port, organizing, managing, and monitoring its implementation during the operational day. The shift-daily plan for the port is the main guiding document directing the port's production work during the planned 24-hour period. The operational day is divided into shifts in accordance with the established (announced) port operating mode. The shift-daily plan for the port is approved by the daily dispatch meeting, with the port's General Director. The daily dispatch meeting is attended by the port's

deputy general directors, chief engineer, chief port dispatcher, chief technologist, directors of stevedoring and freight forwarding companies, and heads of enterprises, directorates, services, and departments involved in vehicle handling and port operations. Once approved, the port's daily shift plan becomes a mandatory document for all port operations. This plan is communicated to those responsible within two hours of its approval.

Stevedoring companies, enterprises, directorates, and departments are required to promptly submit requests, summaries, plans, and other necessary documents and information to the port's main dispatch service. These documents are used for operational planning, accounting, and monitoring of the daily shift plan and vehicle handling.

Railway car handling is carried out under a contract for the delivery and removal of cars between the railway station and the port. The port's main dispatch service plans, coordinates, monitors, and records the handling of rail transport in accordance with the cargo arrival plan at the port, based on the approved cargo flow distribution. In addition, the specified port service is required to communicate the following information to stevedoring companies: the availability of railcars at the station and on the railway, estimated times for railcar delivery and removal, the time and location of shunting operations, and scheduled railcar loading and unloading assignments for the current day.

Developing a plan for distributing railcars for handling is one of the tasks of operational port planning. The purpose of this task is to distribute loaded railcars arriving at the railway station and those located on the approaches to it among the port handling complexes, and to determine the need for empty rolling stock for removing cargo from the port. The solution to this task is based on the following: the distribution plan for vessels among the port handling complexes, the assigned berth specialization, the availability of railcars at the port railway station or on the approaches to it, vessel loading plans, the availability of cargo in warehouses, and the port's production capacity. Unfortunately, at present, this problem lacks both theoretical development and a satisfactory description of practical procedures that would allow it to be solved.

A potential solution was developed at a working group meeting, including representatives from the port's dispatching office and the port railway station. As a rule, the decision is based on the experience of operational management personnel [2, 4].

2. Existing information exchange system at the port

For clear and coordinated interaction between the railway station and the port, mutual information on the arrival dates of ships and trains, as well as current information on cargo, technical, and commercial operations involving vehicles, is required.

Information on trains, ships, and cargo is transmitted by both the port and the railway station in accordance with the vehicle arrival schedule, which is finalized during daily shift planning at a working group meeting.

Preliminary information on the passage of cargo trains for the port is transmitted by the Far Eastern Railway's information center in real time (the port dispatcher's automated

workstation (AWS) program is a self-updating, dynamic network-level program that accurately reflects the current technological situation at a specific control facility at any given time; these facilities may include the railway network, a specific control area, a railway station, a port, or a berth).

The purpose of the port dispatcher's automated workstation program is to automatically process, archive, and store various data related to the loading, unloading, and movement of all transiting cargo. The primary purpose of this program is to create a comprehensive model of train and container cargo arrivals, analyze cargo delivery timelines, and provide information on request at any time.

The existing system for automating information exchange between participants in the transportation process is shown in Figure 1.

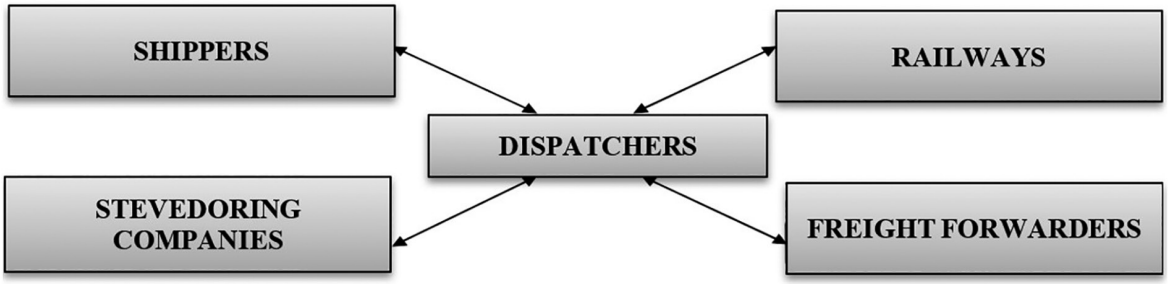

Fig. 1. Information exchange system in the port

3. IMPROVING THE PORT INFORMATION EXCHANGE SYSTEM

To improve the planning and organization of vehicle handling at the port, as well as the coordinated interaction between the port and rail transport, it is proposed to develop and implement a transport hub information system to ensure effective communication among all participants in the cargo delivery logistics chain.

Such an information system should be implemented in accordance with the principles of an integrated logistics operator across various modes of transport, enabling the efficient organization of the delivery of various cargoes while taking into account the interests of port customers and various carriers. The goal of its creation is to improve the efficiency of the transport hub, ensure coordinated interaction between all participants in the transport process, including rail transport, increase the volume of transhipment of various types of cargo, and improve the speed of transhipment and delivery.

Furthermore, the use of the transport hub information system will improve the efficiency of various vehicles, port-handling equipment and mechanisms, and infrastructure. It will also reduce the cost of loading and unloading operations. Clear coordination of management processes for the interaction of all links in integrated supply chains will enable the achievement of established goals and, overall, improve the efficiency of transport hub management. This type of coordination is possible through the full utilization of the transport hub's information system, which integrates automated

control systems for various modes of transport and participants in freight transportation.

An integrated information exchange system is necessary to address the challenges presented in [1]. Addressing these challenges, which focus on coordinating and developing the logistics infrastructure, will increase freight transport volumes and enhance the sustainability and stability of the supply chain as a whole, including all its links. It should be noted that one of the key functions of this information system is the development of a unified transport hub operation plan, taking into account the financial interests of various participants in the freight transportation process, as well as the study of freight flows and their attraction to the port.

A schematic of the integrated information exchange system is shown in Figure 2.

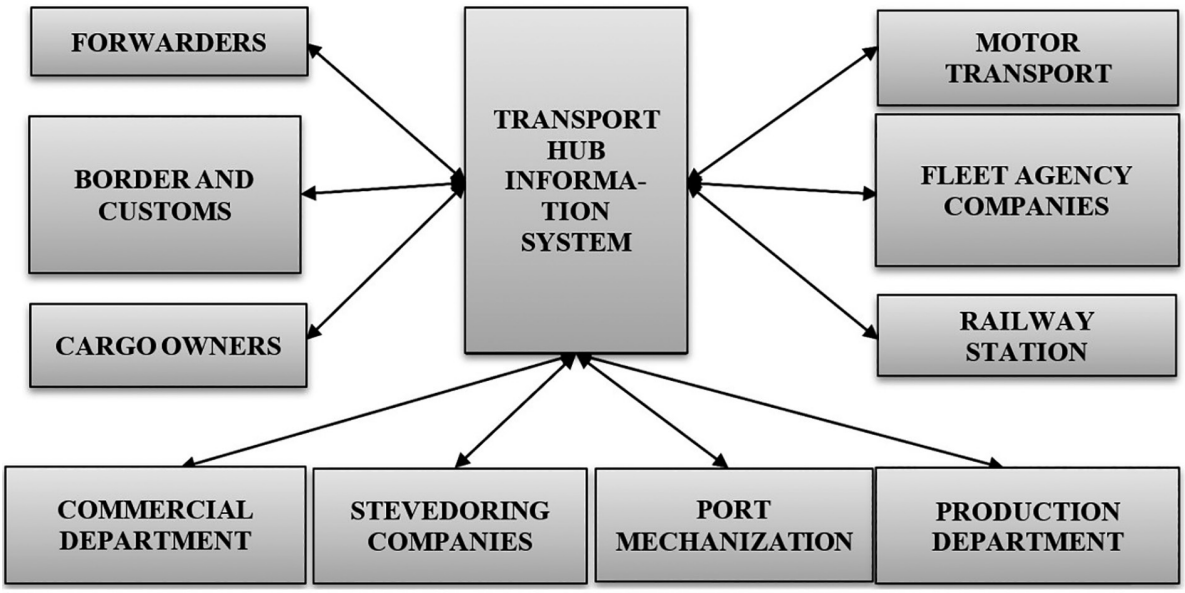

Fig. 2. Integrated information exchange system

The use of principles such as full and comprehensive information exchange among all participants in the logistics chain is a prerequisite for developing an automated "Transport Hub Information System" program.

The automated transport hub information system must enable prompt management decision-making by the dispatcher, monitor the implementation of planned cargo handling targets (in real time), and report any deviations to enable prompt adjustments. The current status of the transport hub in real time requires the system to include information such as the progress of handling operations at the port berths, the readiness of cargo consignments for loading onto ships, the expected dates and times of arrival of rail and sea transport at the port, the planned timing of cargo operations for arriving vehicles, etc. [5].

CONCLUSION

Using an information exchange system at the port will eliminate the need for marketing research on emerging cargo flows for up to 15 days, as it allows the use of resources that span from the planning stage to the moment of their formation. The development and use of this integrated information exchange system will solve the following problems:

- Accounting for all participants in transport and logistics activities at a specific transport hub;
- Accumulating a database of cargo flows passing through the transport hub, with the ability to update in real time;
- Accepting and dispatching various cargo documents scheduled for transshipment at the transport hub;
- Creating a rough daily plan for distributing fleet and railcars among port handling complexes and berths;
- Maintaining a digital log of reserve storage facilities (open and closed warehouse areas, berths of port handling complexes, and railway yards) reflecting potential capacity and readiness to receive cargo or vehicles; summarizing statistical information on vehicle handling times at the port and terminal occupancy.

The functionality of the automated information system as a whole will allow for the coordination of operations between the seaport and rail transport, reduce vehicle downtime at the port, improve the efficiency of both ports and rail transport, and reduce cargo delivery times.

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Risk Management in Global Energy Maritime Logistics under Geopolitical and Supply Chain Disruptions: A Review

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ABSTRACT

Increased geopolitical uncertainty – fuelled by trade wars, sanctions and regional tensions, and interruptions at strategic maritime chokepoints – has laid bare structural weaknesses in global maritime supply chains. These challenges require us to move from efficiency-focused frameworks to systems with resilience to external shocks. Amid these challenges, a transformational avenue of improving resilience in the maritime supply chain persists through the convergence of additive manufacturing (AM), blockchain, and big data analytics. This paper explores the synergistic effect of the integration of additive manufacturing, blockchain, and big data analytics for resilient maritime supply chains to tackle global geopolitical risk. The paper reviews peer-reviewed documents published during 2015–2025 in supply chain management, maritime logistics, and digital technologies. The results show that additive manufacturing can produce at a decentralised, on-demand, and nearby ports and shipping sites for key components, which limits the global supply chains and disrupts potential risks. Blockchain technology improves transparency, traceability, and trust for maritime parties by making secure, immutable transactions, particularly valuable under conditions of geopolitical instability. On the other hand, big data analytics processing large volumes of operational and environmental data ensures real-time visibility, anticipatory risk assessment, and decisions made according to big data. The research also points out major resilience capabilities facilitated by this integration, such as agility, adaptability, visibility, and rapid recovery. These technologies can work hand in hand in enabling digitally connected, decentralized, and intelligent maritime supply chains that are flexible enough to meet the challenges created by geopolitical disruption. However, some of the challenges, such as interoperability challenges, high implementation cost, regulatory limitations, cybersecurity threats, and the absence of standard frameworks, have inhibited the global adoption. Thus, our paper introduces a holistic model combining additive manufacturing, blockchain, and big data analytics, with three core aspects of resilience: robustness, flexibility, and responsiveness in maritime supply chains. The results offer port authorities and logistics officials practical guidance to design resilient and future-ready maritime systems in an increasingly uncertain global environment.

KEEWORDS: Marine Supply Chain Resilience, Additive Manufacturing, Blockchain, Big Data Analytics.

Geopolitical risk and maritime logistics disruptions: The case of the Strait of Hurmuz

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ABSTRACT

The Strait of Hormuz represents one of the most strategically sensitive maritime chokepoints within the global transport system. Due to its geographical characteristics and concentration of energy flows, any form of geopolitical instability in the area immediately generates repercussions for maritime transport operations, global supply chains, energy markets and broader economic stability. The objective of this paper is to analyse the relationship between geopolitical tensions in the Strait of Hormuz and their implications for maritime logistics and shipping activities. Special attention is placed on operational disruptions, navigational safety, insurance costs, rerouting options and the vulnerability of supply chains dependent on energy. This study is based on a qualitative analytical approach combining institutional reports, maritime security advisories, market analyses and recent academic contributions related to maritime transport disruptions and geopolitical risk. The paper analyses the 2026 escalation in the Persian Gulf as a contemporary example of how geopolitical tensions concentrated within narrow maritime corridors may rapidly affect global maritime operations. The findings indicate that the Strait of Hormuz should not be viewed solely as a regional geopolitical issue but rather as a multidimensional maritime logistics problem. Even in the absence of a complete physical blockade, the perception of insecurity significantly reduces traffic flows and alters commercial decision-making processes within the shipping industry. Increased war risk insurance premiums, navigational interference, rerouting decisions, congestion pressures, and uncertainty regarding freedom of navigation collectively contribute to reduced transport efficiency and increased logistics costs. The analysis additionally highlights that disruptions within the Strait of Hormuz generate non-linear consequences extending beyond the maritime sector itself, particularly through energy price transmission, industrial supply vulnerability, and inflationary pressure. Conclusions indicate that geopolitical risk has become an opera-

tional variable within modern maritime logistics systems. Therefore, shipping companies, ports, policymakers, and international institutions must integrate geopolitical analysis more systematically into strategic planning, risk management, and long-term resilience frameworks.

KEEWORDS: Strait of Hormuz, maritime logistics, geopolitical instability, maritime transport, supply chain resilience, shipping risk

INTRODUCTION

Maritime chokepoints have historically represented areas of increased strategic sensitivity due to the concentration of global trade flows within geographically constrained sea passages.1 In contemporary maritime transport systems, the vulnerability of such corridors has become even more pronounced because modern supply chains depend heavily on schedule reliability, uninterrupted cargo flows, and stable energy markets.2 Among existing global maritime chokepoints, the Strait of Hormuz occupies a particularly important position due to the exceptional concentration of crude oil, petroleum products, and liquefied natural gas (LNG) transported through the passage. The strategic relevance of the Strait of Hormuz extends significantly beyond its regional geographical context. The corridor represents a critical maritime connection between the Persian Gulf and the wider Indian Ocean trading system, enabling energy exports from several Gulf states toward Europe and Asia. Accordingly, geopolitical tensions within the area rapidly affect not only regional maritime operations, but also freight markets, energy pricing mechanisms, insurance systems, and broader macroeconomic stability.3 In recent years, periodic incidents involving ship seizures, missile attacks, military escalation, and threats of navigational restrictions have increased concerns regarding the resilience of maritime transport operations within the region. The escalation initiated at the start of 2025 in and around the Persian Gulf once again demonstrated that maritime disruptions concentrated within narrow corridors may produce consequences far beyond the immediate conflict zone. Even before any complete closure scenario was realized, shipping companies, insurers, and cargo interests reacted through route reassessment, transit postponements, increased insurance premiums and heightened operational precautions.4, 5 Such developments indicate that the perception of insecurity alone may significantly influence maritime transport performance.6 From the perspective of maritime logistics, the Strait of Hormuz should therefore not be analysed exclusively as a diplomatic or military issue. Instead, it represents a multidimensional logistics challenge involving navigational reliability, operational continuity, insurance exposure, bunker costs, cargo security, and supply chain resilience. This approach is particularly important as geopolitical instability increasingly influences operational shipping decisions in real time.7

Existing studies predominantly analyze the Strait of Hormuz from the aspect of energy security, international relations, and military strategy, while less attention has been de-

voted to the operational implications for maritime logistics systems, particularly regarding transport continuity, navigational reliability, and supply-chain resilience under conditions of geopolitical instability. In that context, this paper strives to contribute to the existing literature by positioning geopolitical risk as an operational variable within maritime transport systems rather than solely as an external political condition. The objective of this paper is to analyze how geopolitical instability in the Strait of Hormuz affects maritime logistics and global shipping operations. Special emphasis is placed on operational disruptions, maritime risk exposure, supply chain implications, and strategic mitigation responses. The paper additionally seeks to demonstrate that geopolitical risk has evolved into a direct operational variable within contemporary maritime transport systems. Methodologically, the study is based on qualitative document analysis using secondary data sources. The analysis combines institutional reports, maritime security advisories, market assessments, and academic literature related to maritime transport disruptions and geopolitical risk. This approach enables a broader understanding of the relationship between geopolitical instability and maritime logistics performance, particularly within strategically sensitive maritime corridors. Based on the research settings defined, three research questions were drawn:

- What types of geopolitical risks currently define navigation through the Strait of Hormuz?
- How do those risks translate into operational, economic, and supply-chain disruption?
- Which mitigation options are realistically available to shipowners, charterers, states, and international institutions?

The paper is structured as follows: after the introduction, the second section analyses the strategic importance of the Strait of Hormuz within global maritime trade. The third section discusses the principal geopolitical risks and recent developments in the region. The fourth section examines operational and economic impacts on maritime logistics systems, while the fifth section analyses risk mitigation measures and strategic responses. Finally, the conclusion summarizes the main findings and outlines broader implications for maritime transport resilience.

Strategic importance of the Strait of Hormuz

The strategic importance of the Strait of Hormuz primarily derives from its geographical position and concentration of global energy flows. The corridor connects the Persian Gulf with the Gulf of Oman and the Arabian Sea, thereby representing the principal maritime outlet for major Gulf exporters including Saudi Arabia, Qatar, Kuwait, Bahrain, the United Arab Emirates, Iran, Oman, and Iraq. Due to the narrowness of the passage and limited navigational flexibility, maritime traffic within the area remains highly exposed to geopolitical and security-related disturbances.6 From the standpoint of maritime logistics, the Strait of Hormuz represents a typical example of a highly concentrated maritime

chokepoint characterized by low short-term substitutability. The corridor accommodates substantial volumes of crude oil, LNG, refined petroleum products, and petrochemical cargoes transported toward Asian and European markets. Hence, even temporary disruptions generate disproportionate consequences for maritime transport operations and energy markets.1 Recent assessments published by international organizations and market institutions additionally confirm the exceptional concentration of maritime trade within the corridor. According to UNCTAD,3 approximately one quarter of global seaborne oil trade and a substantial share of LNG shipments (20%) depend on uninterrupted navigation through the Strait of Hormuz. Similar findings are presented by Ratner et al.,8 who emphasize that the corridor remains one of the world's most strategically sensitive energy chokepoints. Such dependency significantly increases systemic vulnerability, as disruptions within a geographically limited area rapidly affect multiple interconnected supply chains.9 An important characteristic of the Strait of Hormuz is the absence of fully adequate alternative transport routes. Although certain pipeline systems partially reduce dependency on maritime exports through the corridor, available bypass infrastructure remains insufficient to replace existing transport volumes.10 This is particularly evident in the LNG sector, where maritime transport remains practically irreplaceable in the short term. Consequently, maritime disruptions within the Strait of Hormuz cannot be fully mitigated through transport alternatives on land. The strategic importance of the corridor also extends beyond energy transport alone. Fertilizers, petrochemical products, and industrial raw materials additionally depend on stable maritime operations within the Persian Gulf region. Therefore, disruptions in the Strait of Hormuz influence not only shipping markets and energy pricing, but also agricultural production systems, industrial supply chains, and broader trade stability.9 In that context, the corridor should be understood as a critical node within the contemporary global logistics network. Regional dependency patterns additionally demonstrate the asymmetric exposure of global economies to potential disruptions. Asian economies remain particularly dependent on Gulf crude oil exports, while European economies are more significantly exposed through LNG imports, energy price transmission, and industrial supply vulnerability.11 Such differences indicate that geopolitical instability within the Strait of Hormuz generates both direct and indirect logistics consequences depending on the structure of regional trade and energy dependency. Another crucial element concerns the relationship between geographical concentration and commercial behaviour within the shipping industry. Maritime operators generally prefer predictable transit conditions characterized by stable insurance costs, reliable navigational systems, and reduced operational uncertainty. However, the concentration of traffic within a narrow corridor significantly amplifies the perception of vulnerability during geopolitical escalation. As a result, commercial reactions often emerge even before any formal restrictions or physical closures occur.12,13 From a broader maritime transport perspective, the Strait of Hormuz shows how geography itself may become a strategic variable within global logistics systems. The combination of narrow navigational space, high traffic concentration, and geopolitical tension transforms the corridor into an area where operational shipping decisions become directly linked with regional political developments.

Geopolitical risks and recent developments

Geopolitical risks within the Strait of Hormuz are multidimensional and continuously growing. While conventional discussions frequently focus on direct military confrontation, contemporary maritime disruptions increasingly involve hybrid forms of insecurity, including navigational interference, cyber-related disruption, sanctions uncertainty, and commercial pressure mechanisms. Such developments demonstrate that maritime risk in strategically sensitive regions extends beyond traditional kinetic threats.4,5,6 The 2026 escalation in the Persian Gulf highlighted the complexity of the contemporary maritime threat environment. According to operational advisories issued by ARC4 and the Joint Maritime Information Center (JMIC),5 the region experienced multiple incidents involving missiles, drones, attacks against maritime infrastructure, and interference with commercial vessel navigation systems. These developments significantly affected maritime operations not only within the Strait of Hormuz itself, but also across the wider Gulf region. One of the most important characteristics of the crisis was the rapid deterioration of navigational confidence. Even without the establishment of a complete physical blockade, commercial shipping activity decreased substantially due to concerns regarding vessel safety, insurance exposure, and operational uncertainty. This distinction between physical closure and commercial denial represents an important analytical aspect in terms of maritime logistics. In practice, maritime disruption does not necessarily require absolute navigational denial if shipping companies and insurers conclude that operational risks exceed acceptable commercial thresholds. Traffic reductions observed during the escalation period additionally illustrate the sensitivity of maritime transport systems to geopolitical perception. According to UNCTAD,3 daily vessel transits through the Strait of Hormuz declined dramatically during the peak of the crisis, from an average of 141 ships in February to lows of only 3 to 6 vessels per day in early March. Similar observations were reported by JMIC,5 which identified historically low levels of commercial vessel movement under elevated threat conditions. Such developments indicate that maritime transport systems may rapidly transition from normal operational conditions toward severe disruption even in the absence of formal closure measures. Another particularly important aspect of the crisis involved electronic navigational interference. Maritime advisories highlighted repeated GNSS disruption, AIS anomalies, and communication irregularities affecting commercial shipping operations. From an operational perspective, such interference significantly complicates navigational decision-making processes, particularly within geographically constrained waters characterized by dense vessel traffic. Therefore, vessel operators were forced to increase reliance on manual navigation procedures, radar verification, and enhanced bridge resource management.6 The crisis additionally revealed the vulnerability of maritime infrastructure beyond the transit corridor itself. Ports, offshore facilities, bunkering operations, and energy terminals across the Gulf region became increasingly exposed to security concerns and operational interruptions. This indicates that maritime chokepoint disruptions should not be analysed exclusively through transit passage itself, but rather through the broader logistics ecosystem supporting maritime trade

flows. Legal and political dimensions further complicated the operational environment. International legal discussions emphasized that the Strait of Hormuz constitutes an international strait where transit passage rights should remain protected under international law. However, competing political narratives regarding sovereignty, maritime security, and external intervention contributed to uncertainty regarding the practical implementation of navigational freedoms. Such ambiguity additionally increased operational risk perception within the commercial shipping sector.14 An additional challenge concerns the growing integration between geopolitical risk and commercial maritime decision-making. Shipping companies increasingly rely on real-time risk assessments involving insurance markets, naval advisories, intelligence reporting, and charter-party obligations. Based on the aforementioned, geopolitical instability directly affects voyage planning, port selection, transit timing, and contractual arrangements.15 The developments observed during the 2026 escalation, therefore, confirm that geopolitical risk within maritime chokepoints should be understood as a dynamic operational variable rather than a purely external political condition. In contemporary shipping systems, geopolitical instability increasingly influences commercial maritime activity in real time through both physical and psychological disruption mechanisms.

Impact on shipping and maritime logistics

The operational consequences of geopolitical instability in the Strait of Hormuz become visible almost immediately after threat escalation. Shipping companies operating within high-risk environments are required to reassess voyage planning, transit schedules, insurance exposure, and crew safety considerations within very short timeframes. As a result, geopolitical tension rapidly transforms into operational disruption affecting multiple segments of the maritime logistics chain. One of the first observable impacts concerns changes in vessel routing and transit behaviour. During periods of elevated insecurity, shipping companies may postpone departures, reduce transit frequency, wait offshore for updated security assessments or avoid specific operational zones altogether. Such decisions significantly reduce transport efficiency and increase uncertainty within maritime supply chains.1, 9 In addition, prolonged waiting times near anchorage areas and port approaches may contribute to congestion pressures and additional navigational complexity. Navigational interference represented a particularly important operational challenge during the escalation in 2026. Reports issued by JMIC5 identified widespread GNSS disruption and AIS irregularities affecting commercial vessel operations. In terms of maritime safety and logistics management, such developments increase operational workload on bridge teams and reduce navigational reliability within already constrained waters. Consequently, maritime operations become slower, more labor-intensive, and operationally less predictable. The vulnerability of maritime infrastructure additionally intensified logistics disruption. Security concerns affecting offshore terminals, bunkering facilities, and port operations significantly influenced the continuity of maritime services within the region.

This aspect is especially important because maritime transport systems depend not only on safe sea passage but also on the uninterrupted functioning of ports and associated logistical infrastructure. Disruption affecting even one segment of the logistics chain may generate broader cascading consequences throughout regional maritime operations. Economic impacts emerged simultaneously with operational disruption. War risk insurance premiums increased substantially during the escalation period, thereby significantly altering voyage economics within the region. According to Ratner et al.,8 war risk premiums rose multiple times above pre-crisis levels, while insurers introduced additional operational requirements and voyage declarations for vessels transiting the Gulf region. Thus, shipping companies faced considerably higher operational costs even before accounting for delays, rerouting decisions or additional fuel consumption.16 Freight market volatility additionally intensified logistics pressures. The reduction in maritime traffic through the Strait of Hormuz generated concerns regarding global crude oil availability and energy market stability (a loss of more than 20 million barrels per day of crude oil and refined products). Since bunker prices remain closely linked with global oil markets, increases in crude oil prices rapidly translate into higher maritime transport costs more broadly. Therefore, the consequences of regional geopolitical instability extended well beyond Gulf shipping operations themselves.3 An important characteristic of maritime logistics disruption is the non-linear nature of supply chain consequences. Short-term interruptions may often be absorbed through inventories, schedule flexibility, and temporary rerouting practices. However, prolonged disruption generates cumulative pressure on vessel rotations, cargo availability, terminal operations, and downstream production systems. Klimek et al.9 emphasize that extended disruption scenarios produce disproportionately larger economic and logistical consequences due to the interconnected nature of global supply chains. The implications are particularly significant for energy-dependent industrial sectors. Also, Sachdeva15 argues that a prolonged Hormuz crisis could expose deeper weaknesses in the petrodollar system by combining maritime insecurity, pressure for non-dollar settlement, and questions about the durability of the U.S. security umbrella over Gulf trade. LNG disruptions influence electricity generation systems and industrial production processes, while fertilizer supply interruptions affect agricultural markets and food production systems. Therefore, maritime chokepoint instability increasingly produces broader economic and social implications extending far beyond maritime transport itself.3 Goldman Sachs12 estimated that each 10% increase in oil prices could reduce global GDP by slightly more than 0.1% and raise global headline inflation by around 0.2 percentage points, with stronger effects in Europe and much of Asia. Another important dimension concerns uncertainty within commercial decision-making processes. In periods of geopolitical instability, shipowners, charterers, and cargo interests frequently face incomplete or rapidly changing operational information. Such uncertainty complicates contractual arrangements, increases market volatility, and reduces predictability within maritime logistics planning. Therefore, the perception of insecurity itself becomes an important operational factor. The 2026 escalation additionally demonstrated the growing integration between maritime logistics and macroeconomic stability. Increases in transport costs, energy prices, and insurance

premiums contribute directly to inflationary pressure and reduced industrial competitiveness. Thus, maritime disruptions concentrated within strategically sensitive chokepoints increasingly represent systemic economic risks rather than isolated shipping-sector problems. From a maritime logistics perspective, the Strait of Hormuz therefore represents an illustrative example of how geopolitical instability may affect the full operational cycle of maritime transport. The consequences extend from navigational safety and port operations to freight markets, energy pricing, and global supply chain resilience.

Risk mitigation and strategic responses

Mitigating geopolitical risk within the Strait of Hormuz requires a combination of operational, military, commercial, and strategic responses. However, the escalation in 2026 showed that no individual measure can eliminate the structural vulnerability associated with concentrated maritime chokepoints. As a result, contemporary maritime risk management increasingly focuses on resilience enhancement rather than absolute risk elimination.1, 7, 13 One of the most immediate responses to elevated insecurity involves naval protection and escort operations. Historical experiences from previous Gulf conflicts (Tanker war from the 1980s), indicate that coordinated naval presence may partially reduce exposure to maritime threats, particularly through surveillance activities, mine countermeasure operations, and convoy protection. Nevertheless, recent assessments suggest that escort systems alone are insufficient to restore normal commercial traffic volumes during periods of heightened geopolitical tension.10 An important limitation relates to the distinction between operational capability and available capacity. Although naval forces may secure the transit of selected vessels, restoring full-scale commercial maritime activity requires significantly broader stabilization of the operational environment. Maritime traffic concentration within the Strait of Hormuz additionally complicates escort coordination because even temporary delays may generate substantial congestion pressure and schedule disruption. Mine threats and navigational insecurity represent another important challenge. As emphasized in multiple operational and legal assessments, demining operations within active conflict environments remain slow, technically demanding, and operationally hazardous. Thus, even limited uncertainty regarding maritime mines or missile threats may discourage commercial operators from resuming normal transit activity. Infrastructure diversification represents a second important mitigation pathway. Existing bypass pipelines partially reduce dependency on maritime exports through the Strait of Hormuz, particularly for crude oil transportation. However, available infrastructure remains insufficient to replace the total volume of maritime trade flows normally transiting the corridor. Ruhe10 and Ratner et al.8 both note that Saudi Arabia’s East-West pipeline and the UAE’s Habshan–Fujairah pipeline can divert only part of the disrupted oil flows, while LNG remains much harder to reroute by land-based infrastructure. Alternative maritime routes may provide partial operational flexibility under certain circumstances. Diversion around the Cape of Good Hope, for example, enables continuity for selected cargo flows, but simultaneously

increases voyage duration, fuel consumption, and schedule uncertainty. Hence, rerouting practices generally represent emergency operational adjustments rather than economically sustainable long-term solutions.16,9 At the company level, resilience increasingly depends on the integration of geopolitical analysis into operational decision-making processes. Shipping companies, insurers, and charterers require continuous access to reliable intelligence regarding navigational conditions, maritime security developments, and regional operational risks. Real-time coordination between vessels, ports, insurers, and naval coordination centers, therefore, becomes an increasingly important component of maritime logistics management. Operational recommendations issued during the crisis additionally emphasized the importance of enhanced bridge procedures, secondary navigation verification, communication reporting, and increased situational awareness. Such measures demonstrate that maritime resilience depends not only on large-scale strategic decisions but also on detailed operational discipline at the vessel level.4, 5 Long-term strategic adaptation additionally requires broader structural adjustments within global logistics systems. Economies primarily import-oriented may reduce exposure through strategic reserves, supplier diversification, and investment in alternative energy systems. Ports and shipping companies may additionally improve resilience through enhanced business continuity planning, flexible logistics arrangements, and improved risk-sharing mechanisms. International institutions also play an important role in maintaining navigational stability and freedom of navigation. This crisis highlighted the importance of coordinated legal and political responses supporting international maritime law and secure commercial transit.14 Nevertheless, recent developments additionally indicate that existing international mechanisms frequently remain reactive rather than preventive in nature. From the perspective of maritime transport policy, one of the most important lessons concerns the necessity of integrating geopolitical analysis more systematically into shipping strategy and logistics planning. Maritime operators can no longer treat geopolitical instability as an isolated external condition unrelated to operational shipping performance. Instead, geopolitical risk increasingly influences fleet deployment, charter-party negotiations, insurance arrangements, port investment strategies, and supply chain organization. The Strait of Hormuz therefore, illustrates a broader transformation within contemporary maritime transport systems. In an era characterized by repeated disruptions affecting the Black Sea, Red Sea, and Persian Gulf regions, geopolitical instability has become an operational component of global maritime logistics rather than an exceptional external disturbance.

CONCLUSION

The Strait of Hormuz is highlighted as one of the most strategically sensitive maritime chokepoints within the contemporary global transport system. Its importance derives from the concentration of energy flows, geographical constraints, and limited short-term alternatives available for global maritime trade. The escalation from 2026 demonstrated that even without a complete physical blockade, geopolitical instability may significantly

disrupt maritime operations and generate broader economic repercussions. The analysis confirms that maritime disruption within the Strait of Hormuz should not be interpreted exclusively through traditional military or diplomatic perspectives, but rather from a multidimensional maritime logistics aspect, involving navigational reliability, insurance exposure, port vulnerability, freight market instability, and supply chain resilience. The observed reduction in vessel traffic, increased war risk premiums, and operational uncertainty demonstrate how rapidly geopolitical tension may transform into commercial and logistical disruption. An important finding of the paper concerns the distinction between physical closure and commercial denial. The perception of insecurity alone may significantly suppress maritime traffic flows if shipping companies, insurers, and cargo interests conclude that operational risks exceed commercially acceptable thresholds. Therefore, geopolitical instability increasingly affects maritime transport systems through both direct and indirect disruption mechanisms. The paper additionally shows that the consequences of maritime chokepoint disruption are strongly non-linear. While short-term interruptions may be partially absorbed through inventories and operational flexibility, prolonged instability generates downstream effects across vessel rotations, energy markets, industrial production systems, and broader supply chains. Such dynamics confirm the systemic importance of strategically sensitive maritime corridors within the contemporary global economy. One of the central implications of the paper lies in the contribution, which implies the treatment of geopolitical risk as a direct operational variable within shipping and logistics systems. Route planning, chartering decisions, insurance structures, fleet deployment, and terminal operations increasingly depend on real-time geopolitical assessments. This means that maritime risk management can no longer remain exclusively technical in orientation. The findings additionally indicate that mitigation measures remain inherently limited. Naval escorts, alternative routes, strategic reserves, and intelligence-sharing mechanisms may reduce vulnerability, but they cannot fully eliminate structural dependency on concentrated maritime corridors such as the Strait of Hormuz. Therefore, resilience enhancement rather than complete risk elimination should represent the principal strategic objective. Finally, the Strait of Hormuz represents an important contemporary example of the growing interdependence between geopolitics and maritime logistics. As long as global trade remains heavily dependent on narrow maritime chokepoints, the ability to anticipate, analyse, and manage geopolitical risk will remain one of the key determinants of maritime transport stability and supply chain resilience.

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Implementing Maritime Labour Convention 2006 in Cadet Education: A Seafarer Rights Awareness Model at STIP Jakarta

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ABSTRACT

Indonesia is one of the world's largest suppliers of seafarers, with hundreds of thousands of Indonesian officers and ratings serving on vessels globally. Despite this, persistent cases of contract violations, abandonment, wage disputes, and inadequate welfare protection indicate that many Indonesian seafarers lack sufficient knowledge of their rights under the Maritime Labour Convention (MLC) 2006—the so-called "fourth pillar" of the international regulatory regime alongside SOLAS, MARPOL, and STCW. This gap in legal literacy often begins during pre-employment education, where cadets may receive only cursory coverage of MLC provisions without practical guidance on how to interpret employment contracts, recognize rights violations, or access grievance mechanisms. This study addresses that gap by developing and evaluating a dedicated, context-specific educational model for integrating MLC 2006 into cadet training at Sekolah Tinggi Ilmu Pelayaran Jakarta (STIP Jakarta). The purpose is to equip cadets with the legal literacy and practical skills needed to protect their welfare and uphold their rights throughout their seafaring careers. A developmental research approach was adopted, consisting of three phases. Phase 1 involved a curriculum audit and focus groups with cadets, alumni, and instructors to identify specific knowledge deficiencies and real-world challenges faced by Indonesian seafarers. Phase 2 involved the design of a case-study-based learning module using authentic scenarios drawn from Indonesian manning agencies and documented MLC compliance cases. Phase 3 comprised a pilot implementation with 60 cadets, evaluated through pre- and post-intervention assessments measuring knowledge of MLC provisions, ability to interpret employment contracts, and understanding of grievance procedures. The results showed a substantial improvement across all measures, with post-test scores

increasing by an average of 52%. Cadets demonstrated enhanced capacity to identify red flags in contracts, articulate procedures for reporting violations, and understand the roles of flag states, port states, and seafarer welfare organizations. The main contribution is a practical, replicable educational model that transforms MLC 2006 from an abstract convention into actionable knowledge. By embedding legal literacy into cadet education, the research supports the long-term welfare of Indonesian seafarers and strengthens the industry's compliance with international labor standards.

KEEWORDS: MLC 2006; seafarer rights; cadet education; legal literacy; Indonesian seafarers.

Blockchain-based Solution for Maritime Crew Certification: Sustainability Enhancement for Maritime Sector

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ABSTRACT

The International Maritime Organization has expressed significant concern about the increasing number of fraudulent STCW certificates, which have been detected during Port State Control inspections and applications for certificate recognition. In this context, blockchain has emerged as a compelling solution to mitigate fraud in maritime crew certification. However, academic studies on digital crew certification remain limited, particularly in contextual and conceptual analyses, especially in a sustainable context. This study applies Design Science Research Method to analyze and design a new technological solution based on blockchain technology, which aims at preventing fraudulent crew certificates while supporting maritime sustainability. The research method begins with problem analysis, thereby identifying the objectives of the new technological solution. Additionally, the solution is illustrated with process involving relevant stakeholders such as Port State Control, crewing agencies, or Flag states before evaluating the potential contribution to maritime sustainability. The solution is expected to speed up certificate verification and save more time in comparison with the traditional paper-based process. With the combination of hybrid blockchain, Proof of Authority consensus mechanism, on-chain and off-chain data storage, the solution demonstrates the contribution to not only ESG framework but also SDGs in maritime sustainability.

KEEWORDS: blockchain; maritime crew certification; fraudulent certificates; sustainability; ESG; SDGs.

1. INTRODUCTION

The International Maritime Organization has expressed significant concern about the increasing number of fraudulent STCW certificates, as detected during Port State Control inspections and in applications for certificate recognition (IMO, 2019). Specifically, the number of fraudulent certificates reported to IMO increased considerably from 55 cases to more than 150 during 2017-2024 (IMO 2019, IMO 2023a, IMO 2025).

However, the practical size of this global problem is even much bigger. Get Quality, an EU-funded project, reports that approximately one in ten seafarers worldwide have experienced fraudulent certificates (Hellenic Shipping, 2020). Consequently, unqualified seafarers can be assigned to work on board, thereby adversely affecting ship safety and operational efficiency (Lušić et al., 2019).

Therefore, the Maritime Safety Committee emphasized the importance of detecting and reporting fraudulent certificates (IMO, 2024, Sections 16.6–16.9). The maritime industry is undergoing a transition to electronic certification for seafarers. Notably, since 1st January 2025, all newly issued or renewed STCW certificates of seafarers have been required to be provided in electronic format, in line with amendments adopted by the Maritime Safety Committee at its 107th session in 2023 (IMO, 2023b. MSC.1/Circ.1665).

In this context, blockchain has emerged as a compelling solution to mitigate fraud in maritime crew certification. Specifically, O'Dwyer (2022), Borwankar & Colmorn (2022), and MARINA (2024) initiated pivotal projects with a focus on detection of fraudulent seafarers' certificates, ensuring the transparency and strengthening the verifiability of digital certificates. However, the number of such projects remains limited relative to other areas of the maritime industry. In addition, there is a lack of clarity related to the security mechanism such as consensus algorithm, the type of blockchain integrated and the data storage models underlying in the system. Meanwhile, blockchain technology cannot guarantee the trust of the solution without appropriate security mechanisms (Teng, 2023). Furthermore, critical aspects such as energy consumption, scalability and transaction-processing speed are not demonstrated explicitly. Therefore, the selection of consensus mechanism, type of blockchain and data storage model should be considered as fundamental technological design to develop a blockchain-based solution ensuring both trustworthiness and sustainable development in maritime industry.

On the other hand, academic studies on digital crew certification remains limited with contextual and conceptual analysis. Specifically, Kivalov (2020) emphasized the importance of IT innovations in improving the transparency as well as addressing administrative and corruption challenges but mainly focus on Ukraine from legal perspective. Behforouzi et al. (2023) conducted a survey to assess the merits and drawbacks of such digitalization. They proposed a digital certification innovation to reduce reliance on paper and to develop a trustworthy verification system for seafarers, masters, shipping companies, and port state control. Conceptually, Mataac, Manuel, & Pazaver (2025) analyzed the components of effective e-certificates and emphasized the coexistence of paper and electronic certification owing to technical and legal challenges, including accessibility, convenience, time,

verification, security, and data privacy. However, these studies have limited emphasis on design and evaluation of a technological solution to digitalize maritime crew certification. In addition, digital power consumption and carbon emissions are potential environmental concerns (Sharma & Dash, 2022), especially in the context of sustainable development, which have not been considered thoroughly in prior studies.

Therefore, it is necessary to adopt an appropriate research method that integrates problem analysis, solution development, and evaluation within a sustainable context. This study applies Design Science Research Method to analyze and design a blockchain-based solution to prevent fraudulent crew certificates while supporting maritime sustainability. Additionally, the research questions are designed to (RQ1) develop a conceptual blockchain-based solution for maritime crew certification and (RQ2) analyze the potential contribution to sustainable maritime governance.

RQ1: How can blockchain technology be integrated to prevent fraudulent crew certificates in maritime sector?

RQ2: How can proposed blockchain solution support sustainable development in maritime industry?

The remainder of the paper is organized as follows. Section 2 presents a theoretical review with the concept of sustainable blockchain and maritime sustainability, Section 3 explains the research methodology, and Section 4 presents the conceptual framework of the Digital ESSG crew passport. Section 5 discusses how the Digital ESSG crew passport can align with SDGs and IMO's strategic plan. Finally, a conclusion with some implications and research agenda for the future is indicated in section.

2. THEORETICAL REVIEW

2.1. Blockchain technology

Blockchain is explained as a chain of consecutive blocks which record immutable data related to all up-to-date transactions of digital assets in chronological order (Swan, 2015; Tschorsch and Scheuermann, 2016; Fahim, Rahman, & Mahmood, 2023). As a distributed ledger, each block in the system links with previous block by the reference called hash value of block header (illustrated in the figure 1) (Zheng et al., 2018). In other words, by adding a new validated block with timestamp, hash value, and nonce; blockchain demonstrates a comprehensive transaction history (Nofer et al., 2017)

It is worth noting that the transaction or new block is formed only when all or the majority of network validators (nodes in a block) reach consensus before it is added to the blockchain-based ledger. (Nofer et al., 2017; Chen et al., 2018). If there is any modification in the transaction or block, the system will immediately detect and break the linkage between that block and all block following it. (Guo & Yu, 2022). This mechanism makes blockchain highly transparent, tamper-proof and trustworthy for recording and verifying transactions.

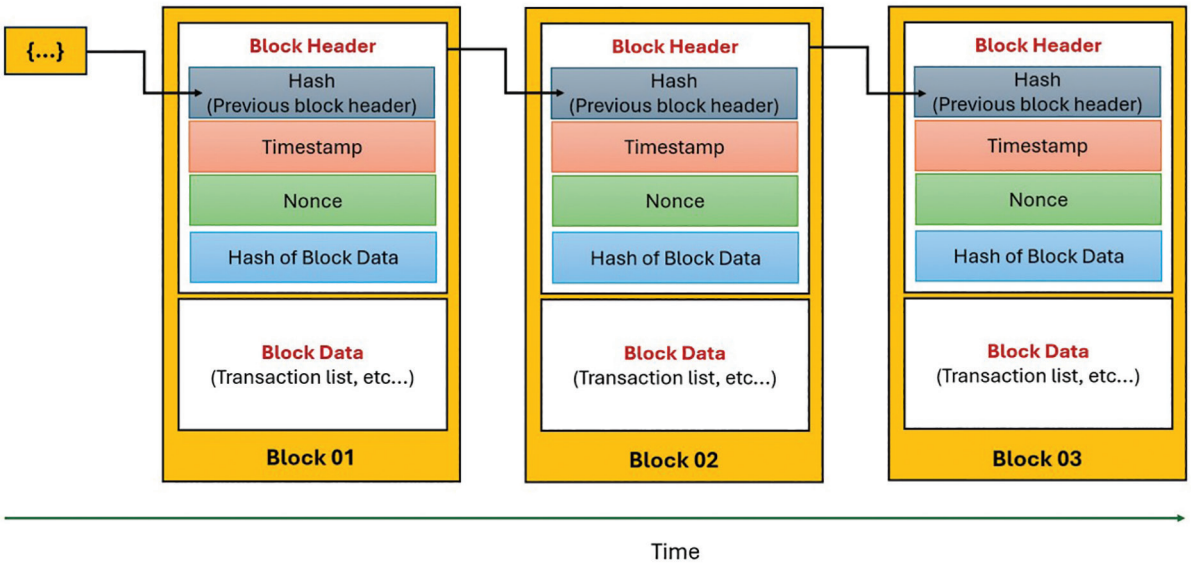

Figure 1: Blockchain structure
Note: Hash value: a fixed string of characters which is used as a digital fingerprint for block data. Nonce – Number used once: the number is used to generate valid hash for blockchain, ensuring that each block has a unique hash.

2.2. Sustainable blockchain – beyond the concept of green blockchains

Sustainable blockchain is a broader concept than focusing on the green factor by saving energy. From an environmental perspective, sustainable blockchain emphasizes the potential to reduce CO2 emissions by adopting energy-efficient consensus mechanisms (Rani, Sharma, & Gupta, 2024). For example, the calculated carbon footprint of office paper is approximately 4.64 g CO2 per A4 sheet with the ISO 14040/14044 standards (Dias & Arroja, 2012). Meanwhile, a certificate, which is issued by blockchain system with PoS – Proof of Stake consensus mechanism, consume about 6.29 Wh or 4.76 Wh, which is equivalent to 3.15g or 2.38g CO2 emissions respectively. These figures are only equivalent to one third or a half of energy consumption to traditional blockchain with PoW – Proof of Work consensus mechanism (Alzoubi & Mishra, 2023). In particular, PoA (Proof of Authority) is much more energy-efficient than PoS. Typically, VeChainThor, built on a PoA consensus mechanism, consumes approximately 0.216 Wh/transaction, equivalent to 0.108 g of CO2 per transaction (VeChain, 2023). This significant reduction in energy consumption and CO2 emissions demonstrates the potential of sustainable blockchain to achieve decarbonization targets and other sustainability goals in the maritime sector.

However, sustainable blockchain also includes governance, security and social factor. Specifically, sustainable blockchain must consider social impact as one of top priorities (Najjar et al., 2023). According to Rani, Sharma, & Gupta (2024), this sustainable technological solution must ensure the balanced distribution of benefits among all stakeholders, address security concerns (of paramount importance), and implement a robust governance mechanism to guarantee the system's trust and resilience.

2.3. elationship among blockchain, ESG and SDGs in maritime sustainability

In 1987, the World Commission on Environment at Development proposed a concept of sustainability as economic-development activities which meet the contemporary demand without negatively affecting the future generation (WCED 1987:39 as cited by Portney, 2015). Unlike environmental protection or the conservation of natural resources, sustainability adopts a more proactive and comprehensive approach, focusing on a balanced condition in which the Earth can support economic development without endangering the well-being of humans, animals, and plants in the long term (Portney, 2015). In terms of corporate, the economic component in “triple bottom line” has been replaced by governance in the ESG framework, which brings long-term value for the shareholders by utilizing opportunities and addressing risks associated with the company’s social and environmental effects (Robinson, 2012; Hedstrom, 2018).

In the maritime industry, sustainability not only refers to shipping efficiency and environmental protection but also the importance of comprehensive administration with international cooperation, and global standard compliance (IMO, 2013). However, traditional “triple bottom line” emphasizes the balance of economic, environmental and social pillars (Robinson, 2012), lacking the governance dimension for addressing challenges of maritime sustainability. Therefore, the ESG approach provides a stronger framework, in which the governance mechanism establishes a foundation for achieving environmental and social goals within the context of sustainable maritime development.

On the other hand, IMO, as a trusted facilitator for global maritime standards, aims to promote safety, security, efficiency, and sustainability in shipping through international cooperation. Specifically, IMO recognized that integration of new and advanced technologies would have a significant influence on shipping efficiency (Article 17, Resolution A.1110(30), IMO 2017). However, the adopted technology has been required to balance innovation benefits with security, environmental protection and impact on maritime human resources (Article 18, Resolution A.1110(30), IMO 2017).

Additionally, relationships among stakeholders in the maritime sector are complex, underscoring the importance of trust in managing documents from customs clearance to seafarer certificates, especially when this paperwork is prone to fraud or error (CNS, 2020). Therefore, blockchain technology has emerged as a compelling solution to enhance trust among stakeholders in maritime crew certification while balancing security concerns with environmental effects by selecting the appropriate security mechanism (as indicated in Section 2.2).

Blockchain technology also supports the reinforcement of three pillars of the ESG framework. Specifically, emerging sustainable blockchain with PoS or PoA consensus mechanism not only ensures transparency and security in data management but also reduces a large amount of energy consumption and CO2 emissions in comparison to traditional blockchain technology (Rani, Sharma, & Gupta, 2024); thereby significantly supporting environmental protection in the ESG framework. In terms of the social aspect, transparency and immutability of blockchain technology can stimulate stakeholders’ cooperation for sustainable

development by enhancing trust, accountability and trust from community and investors (Li et al., 2024; Wong et al., 2023; Cunha et al, 2025), and anti-corruption (França et al., 2020; Qian et al., 2023; Wong et al., 2022). Additionally, Khan et al. (2025) explain that blockchain can facilitate secure information sharing among supply chain stakeholders, thereby reinforcing the governance pillar.

On the other hand, the adoption of blockchain also represents an advanced approach to achieving SDGs by combining environmental responsibility with enhanced social value in the ESG framework (Singh & Kumar, 2024). The research from Cunha et al. (2025) indicates that ESG indicators have a considerable impact on several SDGs. In terms of environmental aspect, ESG indicators demonstrate the influence on SDG9, SDG12, SDG13, SDG14, while social and governance dimensions showcase the relevance for SDG2, SDG5, SDG8, SDG10, SDG11, SDG17. Another study by Delgado-Ceballos et al. (2023) indicated that sustainability efforts should be assessed more comprehensively through the integration of SDGs and the ESG model.

These above insights imply that sustainable blockchain improves not only operational and energy efficiency but also the ESG framework; therefore, establishing a foundation for achieving SDGs in maritime transportation system (as illustrated in Figure 2)

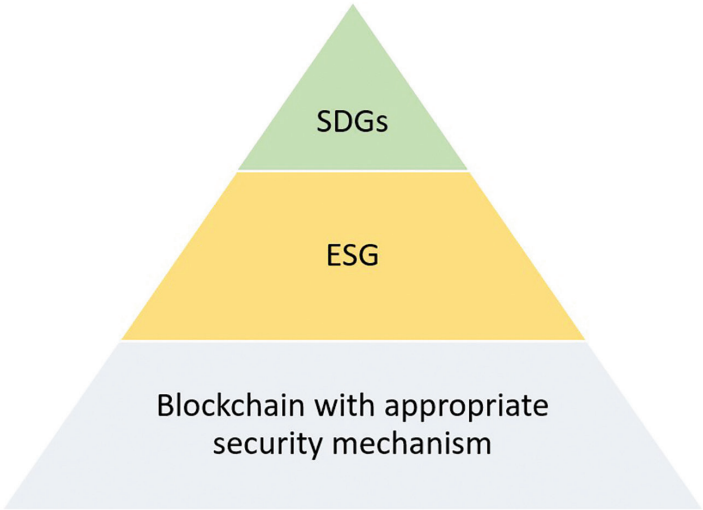

Figure 2: Relationship among blockchain, ESG and SDGs in maritime sustainability

3. RESEARCH METHODOLOGY

This paper employs Design Science Research Method to develop a conceptual framework and a technological solution for maritime crew certification management. According to Peffers et al. (2012), Design Science Research method focuses on developing a framework, simulation, prototype, or product to explain how technological innovation should work. This method contributes to extending the boundaries of existing knowledge (Hevner et al., 2004).

Design Science Research is also considered an effective method for addressing contemporary technological problems in business (Van Aken, 2005), particularly in recent studies on blockchain-based solutions designed to support sustainable development (França et al., 2020; Gong et al., 2024; Cerchione, 2024). In this study, Design Science Research is employed to develop a blockchain-based conceptual framework for maritime crew certification management and to evaluate the solution's potential contribution to maritime sustainability. Figure 3 demonstrates how Design Science Method is employed to develop a blockchain platform for maritime crew certification, reinforcing maritime sustainability, which is divided into six stages (as guided by França et al., 2020; Gong et al., 2024; Cerchione, 2024)

Stage 1: Analyzing problem. As indicated in Section 1, the research problem is the limited academic contributions and technological designs for blockchain adoption in maritime contexts, particularly in the context of marine sustainability.

Stage 2: Identifying objectives of a solution. This study aims to design a blockchain-based solution to prevent fraudulent crew certificates while supporting maritime sustainability. The research questions which align with research objectives are also pointed out in Section 1.

Stage 3: Designing and developing a new technological solution. Section 4.1 demonstrates the conceptual framework and architecture of blockchain-based solution for maritime crew certification management, including main components of the platform, relevant stakeholders and operation mechanism to ensure the accessibility, convenience, time, verification, security and data privacy of the solution.

Stage 4: Demonstration. The solution is illustrated through use cases in maritime crew certification with process illustration (Section 4.2)

Stage 5: Evaluation. Design Science Research Method requires the comparison with research objectives. Therefore, the study is conducted with qualitative analysis to evaluate the blockchain-based solution based on potential contributions to three pillars of ESG framework and SDGs in maritime sustainability (Section 5)

Stage 6: Communication. Finally, the research findings should be discussed with researchers and practitioners in maritime sector about the practical significance and effectiveness of the proposed blockchain platform.

4. CONCEPTUAL FRAMEWORK OF DIGITAL ESG CREW PASSPORT

4.1. Technological Design

From the above analysis, "Digital ESG crew passport" is proposed as a potential solution to manage STCW certificates of seafarers on a sustainable blockchain. This is a digital platform which store and verify all certificates transparently through blockchain integration while meeting ESG dimensions (environment, social and governance) with security enhancement.

The "Digital ESG crew passport" is designed using a typical combination of on-chain and off-chain mechanisms for data storage to ensure transparency, privacy, and extensibility (Xu et al., 2016). The Hash value of block data, used for certificate verification, is

stored on-chain, whereas digital certificates (including personal information) are stored off-chain in decentralized systems. This approach enables the effective storage of a large number of certificates, reducing the workload on the blockchain-based system and protecting data privacy.

Furthermore, the platform employs hybrid blockchain-based model, allowing organizations to control accessibility to the specific data broadcasted into the blockchain system and decide what data will be public (Vaigandla et al., 2023). Accordingly, this hybrid blockchain-based model preserves data confidentiality by not publicly sharing crew certificates (which are stored off-chain in decentralized systems).

Notably, this platform adopts PoA consensus mechanism, only allowing specific authorized nodes to validate the transaction (Fahim, Rahman, & Mahmood, 2023). In this system, a transaction is a certificate. Therefore, energy consumption is significantly reduced compared with traditional blockchain systems with PoW (Manolache, Manolache, & Tapus, 2022). On the other hand, PoA speeds up transaction-processing and complies with security protocols by requiring authorized nodes to solve a difficult puzzle as PoW (Wan et al., 2020), thereby ensuring the time requirement for e-certification while preventing cyberattacks on the platform. Figure 3 illustrates the information flow of managing seafarer certificates on sustainable blockchain-based platform, using PoA consensus mechanism.

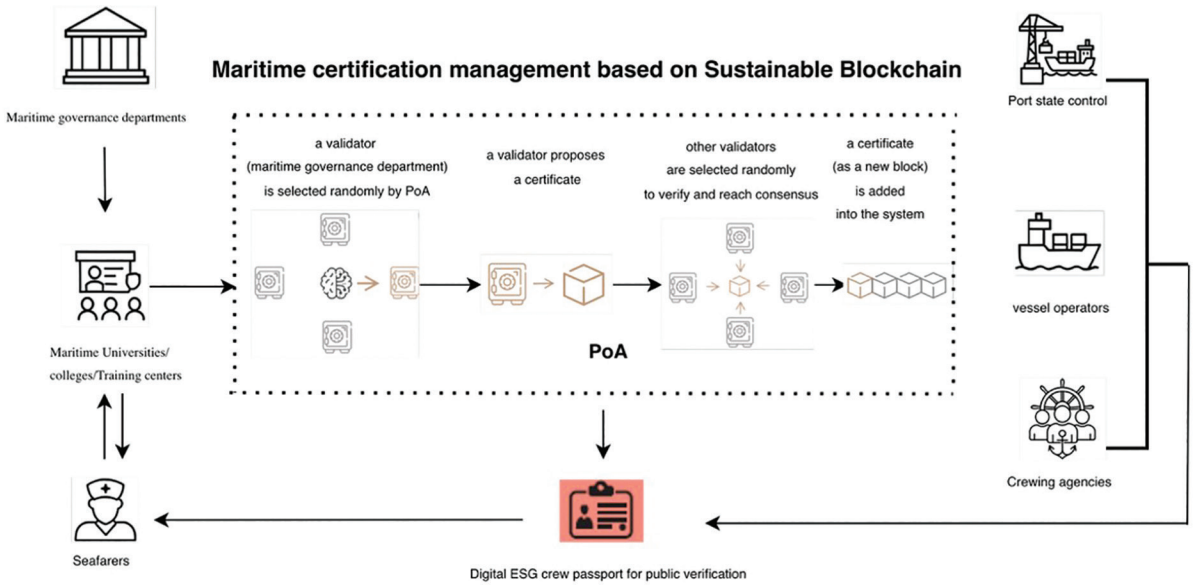

Figure 3: Maritime certification management based on sustainable blockchain

4.2. Process illustration

Issuing certificates: National maritime governance departments coordinate with maritime universities/colleges and training centers (MET institutions) to organize STCW-standard training courses and professional training. After completing the courses, seafarers take the exam organized by MET institutions. The results and related information on certificates will be uploaded to the "Digital ESG crew passport", allowing seafarers to check

and confirm (certificate details, competency/proficiency details, medical details). Only after seafarers confirm, the certificate is digitally signed (by National Maritime governance departments for CoC and by MET institutions for CoP) and then is uploaded on a blockchain-based platform (Figure 4). Notably, each digital document has a unique "fingerprint", which is generated by a "cryptographic hash function" (the commonly used algorithm is MD5). "Fingerprint" is used because it is a one-way process. It is impossible to copy or edit a digital document (certificate/ studying transcript) from a "fingerprint". Furthermore, the length of the "fingerprint" in the form of MD5 is short, which is suitable for saving space and processing time on the blockchain platform.

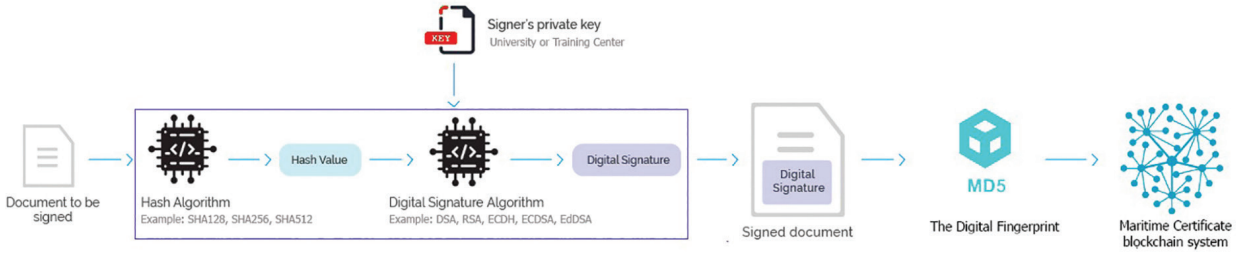

Figure 4: How certificate is digitally signed before being uploaded on blockchain

Generating block for each certificate: Maritime governance departments and MET institutions play a role as a validator proposing certificates. Other validators are selected randomly by PoA consensus mechanism to approve and verify certificates. After reaching consensus, certificate data will be stored on the platform as new block, ensuring transparency, persistency, and immutability.

Verifying certificates: Related stakeholders (Port State Control, vessel operators, crewing agencies, maritime universities/colleges/training centers, and seafarers can easily access, check and verify online certificates through “Digital ESG crew passport”. When verifying certificate, the platform will compare on-chain data (hash value) with corresponding certificate, which is stored off-chain. If they match, the certificate is verified as valid and unaltered, shortening the time required for verification in comparison to traditional paper-based process. Besides, owning to the sustainable blockchain in ESG framework, “Digital ESG crew passport” demonstrates safety and transparency for all stakeholders to verify the authenticity of certificate while reducing energy consumption, meeting governance and social requirements from maritime industry in the context of digitalization.

5. ALIGNMENTS OF DIGITAL ESG CREW PASSPORT WITH ESG AND SDGS

5.1. Alignments of Digital ESG crew passport with ESG

Beyond security enhancement, blockchain adoption in digital maritime crew certification contributes to the three pillars of the ESG framework. From environmental perspective, reduction in paper usage and sustainable blockchain adoption with appropriate security mechanism can reduce resource consumption and CO2 emissions.

In terms of "Social" pillar, "Digital ESG crew passport" demonstrates the transparency attribute of blockchain (Sun, Yan & Zhang, 2016) as well as accessibility, convenience, verification efficiency of e-certification (Mataac, Manuel, & Pazaver, 2025), which support seafarers in managing and sharing their credentials transparently while reducing fraudulent certificates. The transparency in maritime crew certification also support in preventing corruption, which is one of the causes for the existence of fraudulent crew certificates (Lušić et al., 2019). By ensuring transparency and data immutability, the security mechanism in this blockchain platform can encourage cooperation among Flag State, Port State control, MET institutions, and shipping organizations/crewing agencies, thereby contributing to preventing fraudulent certificates in the maritime industry.

On the other hand, this blockchain-based platform for e-certification can demonstrate capabilities of efficiency, data management and control (Mataac, Manuel, & Pazaver, 2025), while mitigating cyberattack, enhancing security, reducing administrative burden and making contribution to stronger institutions. Additionally, this solution aligns with international regulatory frameworks (IMO's FAL.5/Circ.39/Rev.23 of 2016; STCW 2017 – Resolution 5 in Attachment 3 to the Final Act of 2010 STCW Conference), thereby reinforcing "Governance" pillar in ESG framework.

5.2. Alignments of Digital ESG crew passport with SDGs

The platform "Digital ESG crew passport" not only reinforces three pillars in the "ESG" framework but also makes contributions to multiple SDGs. Specifically, Target 8.8 of the SGD8 emphasizes "Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment" (UN, n.d.-a). This blockchain-based solution aligns with SDG8 by reducing the prevalence of fraudulent certificates and ensuring fair crew recruitment for seafarers holding authentic certificates. (See Fig. 5)

Furthermore, this platform contributes to SDG9 by accelerating digital innovation in maritime certifications, in line with Target 9.1 "Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all"; and target 9.4 "By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities" (UN, n.d.-b).

Transition into electronic certificates on a blockchain platform also makes contributions to SDG12, especially target 12.5 "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse" by facilitating paperless certification and reducing waste of resources (UN, n.d.-c). Additionally, this solution aligns with SDG13 by supporting target 13.2 "Integrate climate change measures into national policies, strategies and planning" by reducing paper consumption and CO2 emissions from electronic certificates with energy-saving technologies (UN, n.d.-d).

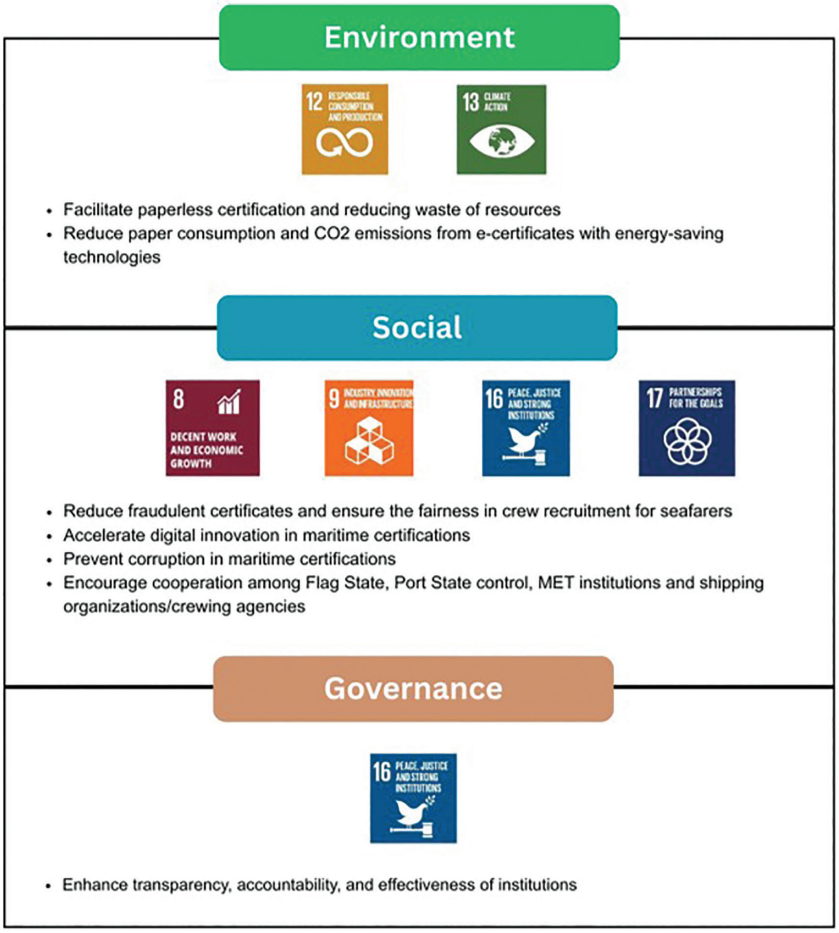

Figure 5: Potential contribution of Digital ESG Crew Passport to ESG and SDGs in maritime sustainability

Notably, the immutability of blockchain reinforces SDG16 by reducing corruption in maritime certifications (target 16.5, “Substantially reduce corruption and bribery in all their forms”) and enhancing the transparency, accountability, and effectiveness of institutions (target 16.6, “Develop effective, accountable and transparent institutions at all levels”).

Interoperability and interconnectedness of “Digital ESSG crew passport” also stimulate SDG17 by encouraging cooperation among Flag State, Port State control, MET institutions and shipping organizations/crewing agencies; making contributions to Target 17.16 “Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries” (UN, n.d.-f).

Considering IMO’s strategic plan for the period 2018-2023, “Digital ESSG crew passport” platform demonstrates the similarity in SDGs’ alignment. According to Christodoulou & Echebarria Fernández (2021), IMO makes contributions to SDG14 (concerning sustainable usage of seas, oceans and marine resources), SDG3 (through international regulatory framework for air pollutant reduction from shipping in the port as well as coastal areas),

SDG8 (supporting sustainable development of economy through international safety and security regulations), SDG7 (reducing greenhouse gas emission and promoting energy efficiency), SDG9 (innovation and infrastructure), SDG13 (urgent climate action), and SDG17 (global partnership) as a core priority to implement instruments of maritime governance effectively. It is evident that this blockchain-based solution not only aligns with SDG 8, SDG 9, SDG 13, and SDG 17, which IMO prioritizes, but also extend to SDG 12 and SDG 16 as an essential aspect of transparent governance, fraud prevention, and resource waste reduction, making contributions to sustainable strategic direction of IMO.

CONCLUSION

This study proposed the concept of "Digital ESG crew passport" to prevent fraudulent STCW certificate while evaluating the potential contribution of the solution to maritime sustainability. The first research question was addressed by integrating blockchain technology into the issuance and verification of STCW certificates on a decentralized platform that provides high transparency, strong data privacy, and low energy consumption. Besides, the research question 2 was answered by analyzing how this solution contributes maritime sustainability. The solution not only prevents fraudulent STCW certificates but also reinforces environmental, social, and governance dimensions in the ESG framework, which establishes the foundation to achieve multiple SDGs in the maritime industry.

A digital ESG framework is a feasible solution for maritime administrations and other relevant stakeholders to modernize the process of maritime crew certification. Digitalizing certificates on a decentralized and secure platform demonstrates the potential in eliminating the fraudulent STCW certificates and ensuring that only qualified seafarers are allowed to work on board. Therefore, maritime safety and operational performance can be improved. Furthermore, this solution enables relevant stakeholders such as Port State Control, crewing agencies or Flag states to speed up certificate verification, saving more time in comparison with traditional paper-based process.

Especially, the proposed blockchain-based platform is aligned with the requirement of IMO, in which all newly issued or renewed STCW certificates of seafarers have been required to be provided in electronic format since 1st January 2025 (IMO, 2023b). Furthermore, the solution probably reduces paper and energy consumption with the combination of hybrid blockchain-based model, PoA consensus mechanism, on-chain and off-chain data storage. The transparency and immutability of data also prevent corruption in maritime crew certification. Therefore, the study not only makes academic contribution but also demonstrates a practical significance in enhancing trust among stakeholders in maritime crew certification and improving maritime sustainability.

However, the research scope is conceptually limited. Therefore, future studies should focus on empirical test to evaluate the feasibility, efficiency and factors affecting the acceptance of the system to accelerate the blockchain technology in maritime crew certification, aiming at maritime sustainability. Additionally, digital STCW certificates need to be

recognized internationally. Therefore, it is necessary to ensure the compatibility among different national systems and compliance with regulatory framework. The solution can also be extended to the management of other types of documents in the maritime sector – such as vessel certificates – to enhance transparency and efficiency across the maritime supply chain.

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Object Detection in Marine Environment: Enhancing Indonesia Maritime Safety via Yolov8 Computer Vision and Kalman Filter

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ABSTRACT

Maritime safety is a crucial aspect of global maritime activities, given that the majority of international trade relies on maritime transport. It is estimated that 90% of global trade is transported by sea, underscoring its vital role in international trade. With more than 50,000 ships operating daily, the high volume of maritime traffic inherently increases the risk of incidents, including ship collisions, which can have serious consequences for assets, the environment, and personnel. This research explores the integration of advanced computer vision techniques, specifically YOLO26n for robust object detection, with Kalman filtering for optimized tracking, to address critical challenges in maritime traffic safety within Indonesia's diverse aquatic environments. This approach aims to leverage real-time object detection and multi-object tracking capabilities, which are crucial for enhancing surveillance, accident prevention, and overall operational efficiency in complex maritime scenarios. This model is ready for deployment with an excellent performance of mAP@0.5 = 0.944. Training proceeded smoothly without overfitting. The main recommendation is to use a confidence threshold of 0.58 and consider adding more data for the passenger_ship and container_ship classes to further improve recall.

KEEWORDS: Computer Vision; Obejct Detection; Safety; Yolo26n; Kalman Filter.

Predictive Analytics for SIRE Tanker Inspections Using Machine Learning: A Data-Driven Approach to Proactive Risk Management

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ABSTRACT

The global maritime industry, responsible for transporting approximately 90% of international trade, operates under increasingly stringent safety and environmental regulations to ensure sustainable operations. Within this context, the tanker segment faces particular scrutiny due to the potential environmental and economic consequences of operational failures. The Ship Inspection Report Programme (SIRE), established by the Oil Companies International Marine Forum (OCIMF), has emerged as the global industry standard for assessing tanker vessel quality and operational safety. Despite the wealth of data generated through these inspections, the current approach to inspection management remains largely reactive. Vessel operators typically receive detailed feedback only after an inspection is completed, which limits their ability to implement proactive measures that could prevent findings or reduce their severity. This research addresses this critical gap by developing a comprehensive machine learning-based approach to predict specific observations in SIRE tanker inspections, facilitating a transition toward proactive risk management and enhanced operational efficiency.

The research methodology follows the Cross-Industry Standard Process for Data Mining (CRISP-DM) framework, ensuring a structured progression from business understanding to model deployment. The study utilizes a comprehensive real-world dataset comprising over 2,500 individual inspection records from SIRE and CDI inspections conducted between 2009 and 2025, obtained from various tanker operating companies. A primary technical challenge addressed in this research is the severe class imbalance within the dataset, which includes over 2,000 unique observation types (remarks). To mitigate this imbalance, the Synthetic Minority Over-sampling Technique (SMOTE) was implemented to

generate synthetic examples of minority classes. This approach ensures that the model can effectively learn rare but critical technical findings, which are often overlooked by traditional algorithms that bias toward majority classes.

A Random Forest classification model was selected and trained using advanced feature engineering techniques. The model incorporates temporal features, vessel characteristics, and geographic variables to capture the multi-dimensional nature of maritime risks. Feature engineering included calculating vessel age as a critical indicator of maintenance requirements and applying logarithmic scaling to gross tonnage data to address skewed distributions. The model achieved significant predictive accuracy in Top-3 predictions, demonstrating that actual inspection findings consistently appear among the three most probable predictions generated by the model. Feature importance analysis revealed that vessel age is the most influential predictor, followed by the specific inspection company and vessel type.

To operationalize these findings, we developed SmartSIRE, an interactive web-based decision support system built using the Streamlit framework. SmartSIRE guides vessel operators through the data input process and presents the top three most likely inspection remarks along with confidence intervals. This research contributes to the maritime economics literature by providing the first comprehensive predictive analysis framework specifically designed for commercial inspection regimes, moving beyond the more commonly studied Port State Control (PSC) data. By enabling proactive risk management, this study supports the industry's broader goals of safety, sustainability, and digital transformation.

KEEWORDS: Maritime Safety, Tanker Inspections, SIRE, Machine Learning, Predictive Analytics

1. INTRODUCTION

The Oil Companies International Marine Forum (OCIMF) has introduced SIRE 2.0, a risk-based vessel inspection framework designed to enhance safety and environmental protection in tanker operations. This transition from the previous Vessel Inspection Questionnaire version 7 (VIQ7) reflects a strategic shift towards proactive risk management by digitalizing inspections through explosion-proof tablets and employing an algorithm-driven questionnaire tailored to vessel type, operational history, and onboard equipment. The questionnaire is organized into core, rotational, and campaign categories, with conditional questions addressing specific ship factors. A key advancement in SIRE 2.0 is the explicit integration of human factor considerations, which assess physical, psychological, and social influences on crew interactions via performance influencing factors (PIFs) such as task criticality recognition, procedural adherence, team dynamics, workload stressors, morale, ergonomics, and human-machine interfaces (Pavić et al. 2024). Inspectors evaluate crew groupings rather than individuals to better capture onboard safety culture.

This evolution underscores the need to move beyond traditional, largely reactive inspection regimes that provide feedback only after deficiencies arise, often resulting in

unforeseen maintenance costs and operational delays (Genis et al., 2026). SIRE 2.0's risk-based approach aims to anticipate and mitigate risks before they manifest, thereby supporting more effective and timely interventions. By integrating empirical vessel-specific predictors with balanced sampling methods and aligning with human factor-inclusive frameworks, predictive analytics can facilitate this proactive stance in tanker inspections (Chawla et al. 2002; Genis et al., 2026). Such analytics leverage key features, including vessel age, inspection company, vessel type, and operational context, to identify infrequent but commercially significant deficiencies that may impact chartering decisions or reputational standing.

Ultimately, SIRE 2.0's combination of digitalization, tailored risk assessment, and human factor integration advances the goal of proactive risk management in maritime safety. This approach not only enhances the detection and prevention of potential incidents but also promotes sustainable maritime transport by optimizing operational efficiency within a highly regulated sector (Genis et al., 2026).

1.1. Feature Importance and Critical Predictors

Feature importance analysis within predictive models for SIRE tanker inspections serves as a quantitative lens through which operational, technical, and human-factor determinants of inspection outcomes are ranked and interpreted. Applying the Random Forest algorithm to multi-year datasets spanning 2009–2025, variable importance analysis consistently elevates Vessel Age to the top position (Genis et al., 2026). Age is calculated from keel-laying or build date relative to inspection dates, reflecting empirical correlations between aging vessels and increased likelihood of deficiencies or gateway failures. This finding mirrors governmental Port State Control (PSC) models, where operating years similarly emerge as dominant predictors for detentions or high-deficiency events, accounting for up to 40% of such outcomes (Tsou 2025). The convergence across regulatory and commercial frameworks underscores that vessel aging effects are structurally embedded in maritime safety risk profiles regardless of context.

The second-ranked predictor in SIRE models is Inspection Company, indicating measurable organisational variability in inspection outcomes (Genis et al., 2026). Differences among inspecting bodies likely stem from divergent procedural emphases, interpretative thresholds, or focus on specific risk domains. While PSC analyses recognise analogous organisational influences, often subsumed under broader oversight factors such as flag state, SIRE's emphasis on inspection company identity reflects its commercial vetting orientation, where procedural subjectivity can determine the presence of gateway failures (Tsou 2025). This prominence highlights inspection company identity as a key organisational performance driver specific to commercial vetting processes.

Vessel Type occupies third place in importance rankings for SIRE tanker inspections (Genis et al., 2026). Tanker subcategories differ in structural design, cargo handling systems, and operational hazards, each presenting unique inspection focal points. PSC re-

search corroborates this pattern by associating certain ship types with higher rates of deficiencies related to stability or safety equipment maintenance (Tsou 2025). Integrating vessel type distinctions into modelling captures design-driven differential risk exposure, guiding targeted compliance preparatory measures and tailored inspection focus areas.

Additional predictors contribute substantively despite lower rankings. Gross tonnage, preprocessed via logarithmic scaling to correct distribution skewness, functions as a proxy for structural capacity and operational scale (Genis et al., 2026). Without transformation, gross tonnage variance could distort nearest neighbour calculations during Synthetic Minority Over-sampling Technique (SMOTE) application by improperly weighting magnitude differences (Chawla et al. 2002). Flag state affiliation provides insight into the regulatory environment traversed by each vessel; differences at this level affect inspection probabilities and deficiency profiles in PSC settings (Tsou 2025). Classification society membership similarly encapsulates technical-standard compliance histories relevant to both statutory and commercial oversight regimes (Pavić et al. 2024).

In datasets exhibiting severe imbalance, as with SIRE's thousands of remark categories or PSC's small detention proportion, balancing via SMOTE enhances the reliability of feature importance outputs (Chawla et al. 2002; Genis et al., 2026). Unbalanced models tend to bias importance toward predictors tied predominantly to majority-class outcomes, obscuring variables linked to high-impact rare events. SMOTE's interpolation process operates by selecting nearest neighbours for a minority-class instance, computing attribute-wise differences, applying a random gap factor between and, and adding the adjusted difference back into the original instance. This populates feature space regions proximate to existing minority samples with plausible synthetic cases; decision trees trained on these enriched distributions exhibit improved recall for minority targets while avoiding excessive complexity growth characteristic of replication oversampling at high rates (Chawla et al. 2002).

Comparative evidence from PSC detention models reinforces the translational value of balancing strategies. Adjusting prediction targets, for example, modelling " 5 deficiencies" instead of binary detention status, and then applying oversampling produced improved sensitivity for high-risk vessels without sacrificing specificity (Tsou 2025). Retraining on reduced feature sets after importance scoring preserved predictive accuracy while lowering computational demands. These results align conceptually with SIRE workflows: once vessel age, inspection company identity, and vessel type are confirmed as high-weight predictors through balanced data training, subsequent model iterations can focus on these variables to streamline processing and enhance interpretability.

Beyond technical and organisational variables, incorporating human-factor elements under SIRE 2.0, such as task criticality recognition, procedural accessibility, team dynamics, stress management, workplace ergonomics, human–machine interface clarity, and opportunities for skill reinforcement, extends the predictive scope (Pavić et al. 2024). While Random Forest models primarily quantify measurable attributes like age or tonnage using structured datasets (Genis et al., 2026), balanced sampling ensures that qualitative contributions from human factors are not overshadowed by dominant technical predictors when linked statistically to rare but consequential remark categories.

Interpreting these ranked features within a commercial vetting context connects them to operational intervention points. High vessel age rankings signal maintenance prioritisation needs; inspection company prominence suggests targeted engagement strategies with vetting bodies whose procedural interpretations might increase adverse finding probabilities; vessel type significance implies tailored compliance checks aligned with subtype-specific vulnerabilities. Secondary predictors like gross tonnage, flag state, and classification society contextualise these interventions within regulatory environments and fleet composition constraints. The link between these variables and gateway failure scenarios, whereby negative remarks prevent chartering approval, reinforces their practical relevance beyond statistical ordering (Genis et al., 2026).

In both PSC and SIRE contexts, these critical predictors serve as actionable indicators embedded within sustainable transport strategies. Early detection through balanced machine learning enables preventative measures that lower environmental hazard exposure and preserve operational continuity before defects escalate into detentions or contractual barriers (Genis et al., 2026; Tsou 2025). The convergence of technical condition parameters (age, tonnage), organisational identifiers (inspection company, classification society), structural descriptors (vessel type), regulatory affiliations (flag state), and human-factor assessments forms a composite predictive architecture capable of supporting proactive maritime safety management grounded in empirical evidence across diverse inspection regimes.

Through balanced sampling integration and robust Random Forest ranking mechanisms, feature importance analysis in maritime safety predictive systems delivers empirically grounded hierarchies of influence. These hierarchies guide proactive measures consistent with sustainable transport objectives by anticipating inspection outcomes over reactive corrections post-finding, whether through preventing detentions under PSC regimes or avoiding commercially damaging gateway failures within SIRE 2.0 vetting processes (Genis et al., 2026; Tsou 2025).

2. RESEARCH METHODOLOGY AND DATA FOUNDATIONS

The empirical dataset comprised over 2,500 inspection records from SIRE and CDI tanker inspections spanning 2009 to 2025 (Genis et al., 2026). To address class imbalance inherent in rare but critical inspection outcomes, including those related to human factors, Synthetic Minority Over-sampling Technique (SMOTE) was applied exclusively to training subsets within a 5-fold cross-validation framework. This approach ensured adequate representation of minority classes without contaminating validation data (Chawla et al. 2002; Genis et al., 2026). Feature preprocessing included logarithmic scaling of gross tonnage to mitigate skewness during synthetic sample generation.

Random Forest classifiers were trained and evaluated using Top-3 prediction accuracy, reflecting operational priorities where multiple plausible inspection findings inform pre-inspection risk mitigation. This metric captures the presence of actual outcomes with-

in the three highest-ranked predictions, supporting more comprehensive and actionable vetting decisions (Genis et al., 2026). Feature importance analyses consistently identified vessel age, inspection company identity, and vessel type as primary predictors, with reduced-feature retraining confirming that focusing on these variables maintained predictive performance while reducing computational complexity. Together, these implementation choices yielded a robust predictive model tailored to the commercial vetting context of SIRE inspections.

3. OBTAINED RESULTS AND DISCUSSION

Following the methodology outlined in Section 2 the experimental results offer quantitative insights into model performance across tanker inspection scenarios. Key elements include Table 1 summarizing dataset characteristics, Table 2 presenting classification metrics, and Figure 1 depicting feature importance from the Random Forest model.

3.1. Dataset Overview

Table 1 details the empirical dataset comprising over 2500 SIRE and CDI inspection records from 2009 to 2025, encompassing over 2,000 unique remark categories. Variables include vessel age, gross tonnage (log-scaled), vessel type, inspection company, flag state, classification society, and inspection dates, providing diverse yet manageable input dimensions for multi-class classification.

Table 1: Dataset Composition for SIRE/CDI Inspection Records (2009–2025) (Genis et al., 2026)

Variable	Type	Count / Range
Total records	–	Over 2,500
Remark categories	–	2,000 unique types
Vessel age	Numeric	0–48 years
Gross tonnage (scaled)	Numeric	log adjusted from to GT
Vessel type	Categorical	7 tanker subcategories
Inspection company	Categorical	12 identified bodies
Flag state	Categorical	38 states
Classification society	Categorical	14 societies
Temporal span	–	Jan 2009–Dec 2025

3.2. Model Performance

Table 2 reports aggregated metrics from 5-fold cross-validation with SMOTE applied on training folds to address class imbalance (Chawla et al. 2002). The model achieves a Top-3 accuracy of 87,6%, with micro-averaged precision, recall, and F1 scores above 80%, demonstrating robust predictive capability across diverse remark categories.

Table 2: Random Forest Classifier Performance on Balanced Dataset (Genis et al., 2026; Tsou 2025)

Metric	Value (%)	Notes
Top-3 Accuracy	87,6	Actual remark in top predictions across folds
Precision (micro)	80.4	Aggregated over all remark categories
Recall (micro)	83.0	Enhanced by minority balancing via SMOTE
F1 Score (micro)	81.7	Harmonic mean indicating balanced trade-off
Average tree depth	–	14 levels; controlled to avoid overfitting
Computational time per fold	–	45 s on reference hardware

3.3. Feature Importance Analysis

Figure 1 shows impurity-based importance scores from the Random Forest model. Vessel age (18.3%) and inspection company (14.7%) emerge as the most influential predictors, followed by vessel type and gross tonnage. These results align with maritime safety literature emphasizing structural ageing and organisational variability as key risk factors (Genis et al., 2026; Tsou 2025).

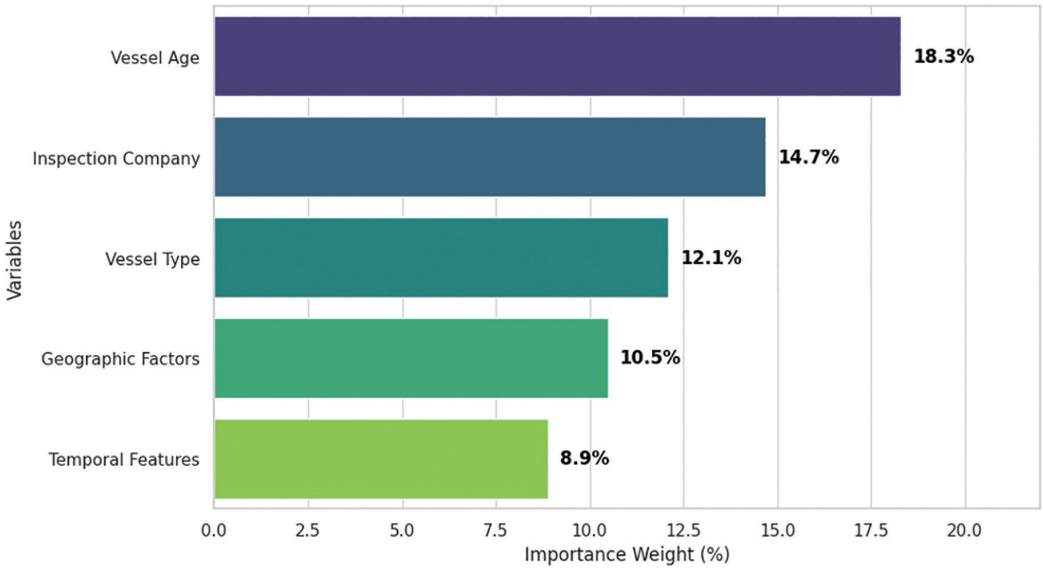

Figure 1: Feature Importance Ranking for SIRE Inspection Remarks

3.4. Interpretation and Implications

The prominence of vessel age reflects its role as a proxy for accumulated wear and system degradation, consistently correlating with a broader distribution of adverse remark categories and gateway failures affecting chartering eligibility (Genis et al., 2026). Similarly, inspection company importance captures procedural heterogeneity among vetting bodies, influencing inspection outcomes beyond technical vessel condition (Pavić et al. 2024). This organisational factor enables tailored pre-inspection strategies based on historical company-specific remark patterns.

The combined effect of these predictors suggests that older vessels subject to inspections by stringent companies face elevated risk exposure. SMOTE balancing ensures these scenarios are well represented during training, enhancing model sensitivity to such compounded risk profiles (Chawla et al. 2002).

1. Operationally, these findings support targeted interventions:
2. Implement vessel-age thresholds to trigger intensified maintenance and crew readiness protocols.
3. Customize preparation checklists according to inspection company profiles to address likely remark domains.
4. Allocate resources strategically for high-risk vessel-inspector combinations, focusing on both technical and procedural readiness.

Utilize reduced-feature models emphasizing these predictors for efficient, accurate forecasting integrated into fleet management.

By grounding feature importance in empirical data, this analysis informs proactive risk mitigation aligned with SIRE 2.0 objectives, bridging predictive analytics and operational safety management (Genis et al., 2026).

4. CONCLUSION

Advancements in predictive analytics within the SmartSIRE framework enable precise identification of key risk factors, notably vessel age and inspection company identity, which influence inspection outcomes. By leveraging balanced machine learning techniques such as SMOTE and Random Forest classifiers, SmartSIRE improves detection of rare but critical inspection remarks, facilitating targeted and data-driven interventions that enhance inspection efficacy and operational decision-making.

The integration of SmartSIRE's predictive insights into tanker inspection processes supports proactive risk management aligned with specific vessel subtypes. This approach empowers stakeholders to prioritize maintenance and optimize engagement with vetting bodies, thereby reducing the likelihood of inspection failures and associated commercial disruptions. Importantly, these actionable insights contribute to environmental sustainability by enabling early identification and mitigation of high-risk vessels, minimizing potential ecological hazards linked to tanker operations.

Embedding SmartSIRE within the SIRE 2.0 framework advances the maritime industry toward a more resilient and environmentally responsible operational model. This data-driven strategy enhances safety and compliance while promoting sustainable maritime practices through informed, timely interventions that address both operational and environmental challenges.

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International Review of Emerging Technologies in Container Ports and Terminals: A Study of Asia-Pacific Region

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ABSTRACT

Purpose – This study constructs a consolidated dataset linking port specifications, port performance data, and emerging technology adoption for a common sample of Asia-Pacific container ports. No such dataset currently exists in the academic or industry literature. The study addresses the gap by extracting and coding technology adoption and impact claims from port and terminal secondary sources, enabling direct analysis of relationships between technology adoption and port performance across operational, environmental, financial, social, and supply chain dimensions.

Design/Methodology/Approach – The study applies a three-step method. First, a sample of 97 terminals across 71 ports in 11 Asia-Pacific countries was selected using inclusion and exclusion criteria applied to the Society for Maritime Data Group (SMDG) terminal database, the United Nations Conference on Trade and Development (UNCTAD) throughput data, and the World Bank Liner Connectivity Index. Second, AI-assisted Systematic Data Analysis (SDA) used NotebookLM to extract and deductively code port specifications, port performance claims, and technology adoption claims from 385 port websites and 136 annual reports. Third, AI-assisted Enhanced Thematic Analysis (ETA) applied NotebookLM to support inductive pattern-finding across 156 coded technology adoption claims at a scale that manual analysis alone would not permit. Analytical rigour is established through the Lincoln and Guba (1985) trustworthiness framework, addressing credibility, transferability, confirmability, and dependability.

Findings – Four themes are identified. Automation adoption is concentrated at high-throughput, long-quay terminals, while smaller facilities adopt only gate-level systems. Digital adoption follows a two-tier pattern: mega-ports deploy AI, blockchain, and digital twins, while smaller terminals are still implementing baseline terminal operating systems and e-booking platforms. Green technology adoption is geographically clustered:

shore-side power dominates at Chinese ports, alternative fuels at Japanese ports, and yard electrification across Southeast Asia. Multi-category technology adoption – across automation, digital, and green simultaneously – is associated with larger declared port capacity and throughput.

Research Limitations – The study relies on self-reported secondary data from commercially oriented port and terminal sources, which may overstate adoption maturity or attribute impacts without causal evidence. The dataset represents a cross-sectional snapshot from February to April 2026 and does not capture longitudinal adoption trajectories.

Implications – The consolidated dataset provides a foundation for the survey instrument and econometric analysis in subsequent research phases. The methodological template demonstrates a replicable approach for applying AI-assisted tools to large volumes of heterogeneous secondary data in compliance with established qualitative trustworthiness criteria.

Originality – This study produces the first consolidated dataset linking port specifications, performance data, and emerging technology adoption across a common sample of Asia-Pacific container ports. It also demonstrates a validated, replicable AI-assisted methodology for secondary data analysis at regional scale.

KEEWORDS: container ports and terminals, emerging technologies, port automation, digitalisation, green technology, AI-assisted inference, Asia-Pacific, technology adoption

1. INTRODUCTION

Container ports are adopting emerging technologies to perform faster, more reliably, and more sustainably (Notteboom et al., 2025). Automation technologies, such as automated guided vehicles, increase throughput per unit of labour. Digital technologies, such as terminal operating systems, enable real-time optimisation of complex terminal workflows. Green technologies, such as shore-side power, address regulatory compliance and energy cost reduction (Iris & Lam, 2019).

Emerging technology adoption in container ports is not linked to a consolidated dataset of port specifications, port performance data, and technology adoption for a common sample of ports. The absence of such a dataset means that the technologies ports have adopted cannot be systematically related to the performance outcomes they report (Wang et al., 2023; Neugebauer et al., 2024). Studies in this field largely examine the drivers, barriers, and perceived benefits of technology adoption rather than measuring actual impacts (Forsberg et al., 2016; Roibás-Rozas et al., 2023; Villabruna et al., 2024). Each port is also unique in its operational context, ownership structure, geographic setting, and cargo profile, meaning comparable performance and technology data is rarely available across facilities (Baafi, 2024; Liu et al., 2024).

This study addresses the gap as follows. A sample of Asia-Pacific container ports is

selected. Port specifications, port performance claims, and technology adoption claims are extracted from their documentary sources. The extracted data are coded against an emerging technology taxonomy and an emerging technology impact framework, both developed for this study. The result is a consolidated dataset that enables researchers to ask direct questions about the relationship between technology adoption and port performance across operational, environmental, financial, social, and supply chain dimensions.

This study uses secondary data, namely port and terminal websites and port annual reports, to construct the dataset. These sources are published directly by the ports and terminals themselves and constitute the most systematic publicly available secondary data on technology adoption and operational performance. They are large in volume, spanning hundreds of ports and terminals across the region, and heterogeneous in structure, varying widely in depth, format, and commercial framing across operators and countries. News articles, produced by third parties, are excluded from this study.

Manual extraction across such a large and heterogeneous source base is impractical; this study employs AI-assisted methods due to their ability to analyse such material reliably and at scale. Ahmad et al. (2026) applied AI-assisted thematic analysis to over 5,000 publicly available social media posts and found the approach could surface credible signals from large volumes of unstructured public data. Lee et al. (2024) demonstrated ChatGPT applied to a publicly available podcast transcript, finding the model identified themes comparable to a human analyst, though with variation across repeated prompts. Williams (2024) argued that AI can reliably support preliminary analysis of secondary textual material when grounded in explicit analytical frameworks and subject to human validation.

1.1 Study design

The study design is illustrated in Figure 1, which has three parts – available information, analytical steps and validation standard. (1) Available information has (i) secondary data of port and terminal websites as well as the port annual reports (ii) and has two grounding documents developed in this study from the literature review. The first is the emerging technology taxonomy (Annex 1), which classifies the technologies relevant to this study into categories and sub-categories. The second is the emerging technology impact framework (Annex 2), which maps technology categories to the processes they impact, the outcomes they produce, and the terminal locations where they operate. Both were developed from the secondary data literature reviewed for this study and both grounding documents are reproduced in full in the annexes.

(2) Analytical steps have, a sample selection of container ports and terminals followed by two AI two AI-assisted analytical steps namely, Systematic Data Analysis (SDA) and Enhanced Thematic Analysis (ETA). The SDA uses NotebookLM to extract port specifications, port performance claims, and technology adoption claims from the available information using grounding documents of taxonomy and impact framework loaded alongside result-

ing in deductive coding along with extraction. The ETA uses NotebookLM to support inductive pattern-finding across the coded entries in the dataset. Both steps are described in full in 2.0 review section.

(3) Validation standard addresses questions of reliability and replicability of using AI-assisted tools for qualitative research. To do this, this study is designed to comply with the trustworthiness framework of Lincoln and Guba (1985), which defines four criteria for evaluating the rigour of qualitative research: credibility, transferability, confirmability, and dependability. Each criterion is mapped to a design decision in this study.

(i) Credibility concerns with the study findings being accurately represented by the selected sources, i.e. it concerns with AI-assisted tools are capable and reliable as any standard tool available to the scientific community. To comply with, NotebookLM was selected because its source-grounding architecture constrains model outputs to the content of user-supplied documents rather than drawing on pre-trained knowledge (Google, 2023). This ensures that extraction and coding outputs can only report what is present in the loaded sources. (ii) Transferability concerns with whether the method is documented in enough detail for others to replicate it. This paper and its annexes constitute the full replication record: the taxonomy, the impact framework, and all prompts with their version history are reproduced in full. (iii) Confirmability concerns with whether the findings are shaped by the data rather than by fictional data. (iv) Dependability with whether the process is consistent and auditable. How both were ensured in practice is reported in the validation sub-sections of Sections 2.2.1

Therefore, to achieve trustworthiness, credibility allows for the selection of the correct tool, transferability allows for the recording of the correct process and confirmability and dependability allow for conducting the correct process.

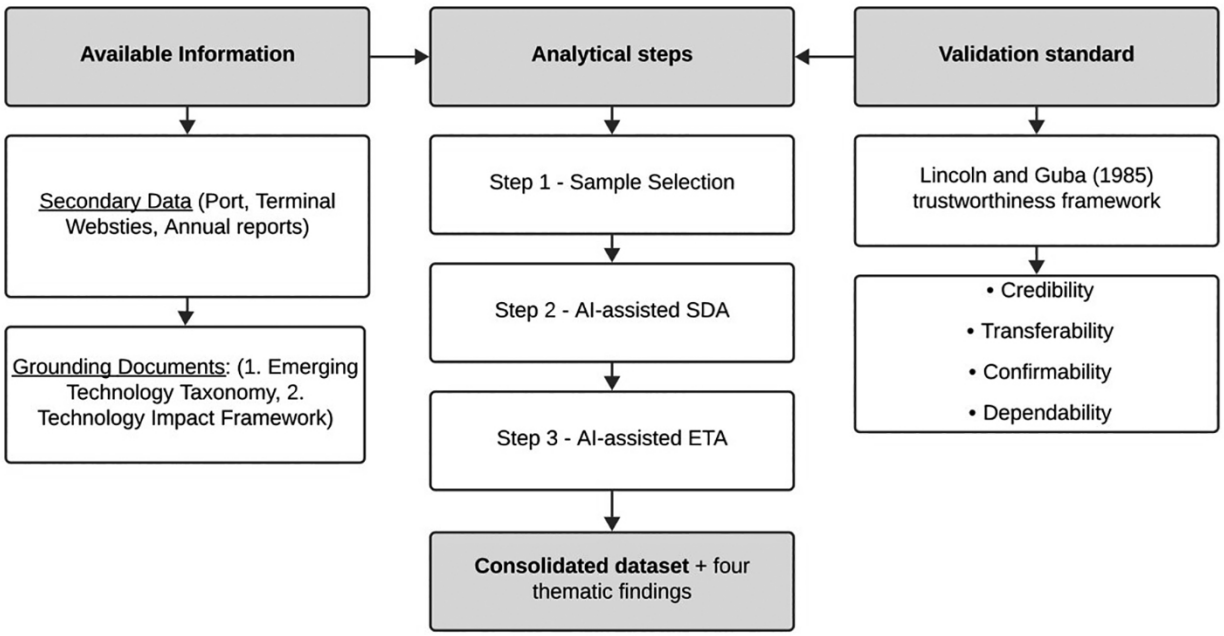

Figure 1. Study design

This study addresses two research questions: first, what emerging technologies have been adopted in Asia-Pacific container ports; and second, what are the potential benefits of those technology adoptions as reported in port and terminal sources. The geographic scope is the Asia-Pacific region. This region was selected because it represents the highest concentration of global container throughput and provides a manageable boundary for a study of this scale. The temporal scope is cross-sectional, covering the state of technology adoption as documented in port sources available between February and April 2026. The study therefore represents a snapshot of the current technology landscape rather than a longitudinal tracking of adoption over time.

2. REVIEW METHODS

This review applies a three-step method. Step 1 is sample selection, which identifies the ports, terminals, and documentary sources that form the study corpus. Step 2 is AI-assisted Systematic Data Analysis (SDA), in which NotebookLM is used to extract and deductively code port specifications, port performance claims, and technology adoption claims from the source documents in a single operation. Step 3 is AI-assisted Enhanced Thematic Analysis (ETA), in which NotebookLM is used to support inductive pattern-finding across the coded dataset at a scale that manual analysis alone would not permit. The three-step process is illustrated in Figure 2.

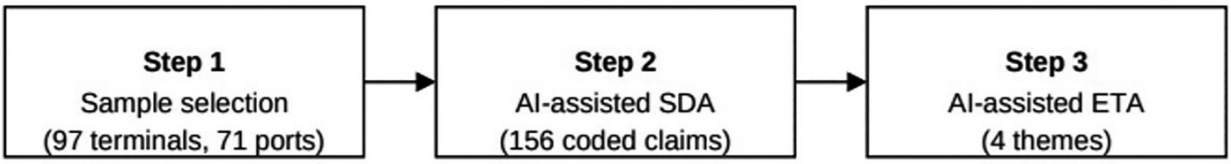

Figure 2. Three-step review method

2.1 Step 1 – Sample selection

The starting point for sample selection is the Sea-going Marine Data Group (SMDG) terminal database (SMDG, 2026), which lists 1,255 container terminals across 729 ports in 162 countries worldwide. This full global list is too large for a study of this scale. A sequential set of filters was applied to narrow it to a manageable and coherent sample. The filters and their outcomes are described below and illustrated in Figure 3.

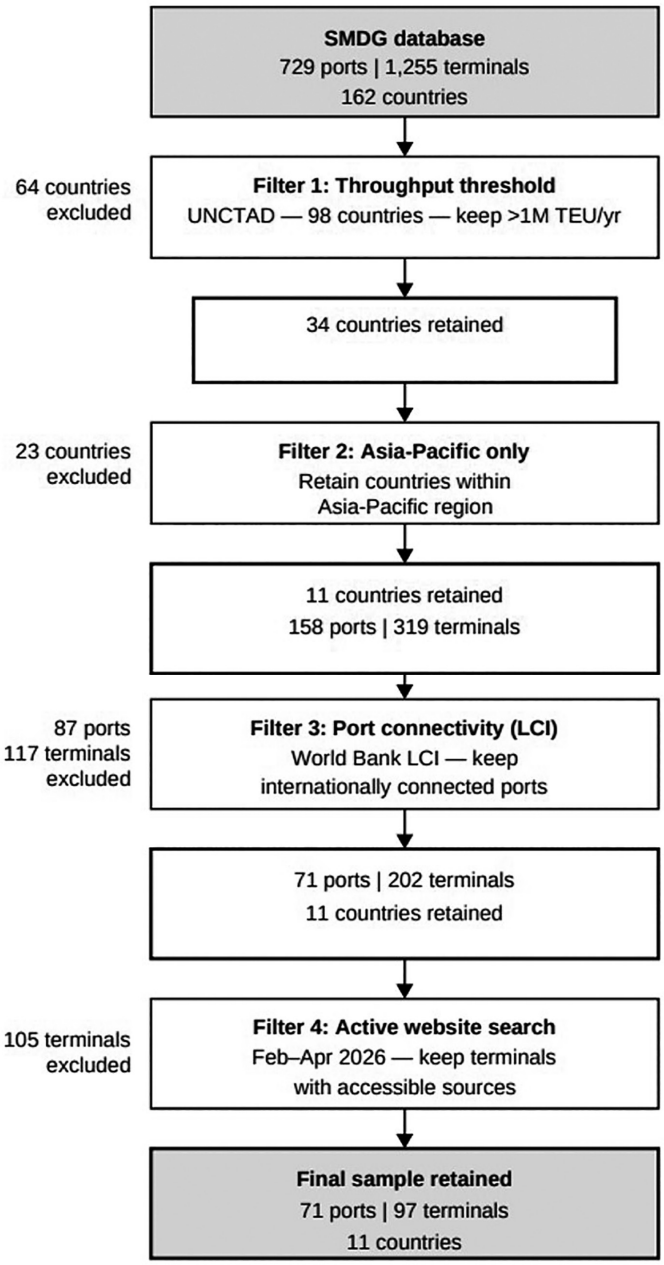

Figure 3. Sample selection

The first filter addressed geographic scope. This study focuses on the Asia-Pacific region, which represents a high concentration of global container throughput and provides a relevant and bounded regional context. To identify which countries, fall within this scope, annual container throughput data was collected from the UNCTAD (2025) dataset. This dataset is available at the country level across 98 countries. Countries with annual throughput below one million TEU were excluded, as ports in those countries are unlikely to have achieved the scale of operations that would justify investment in emerging technologies. This excluded 64 countries and retained 34 countries. Of these, those within the Asia-Pacific region were identified, producing a final list of 11 countries. Applying the SMDG database to these 11 countries yielded 158 ports and 319 terminals.

The second filter addressed port connectivity. Not all ports in the 11 countries are internationally connected; some serve only domestic routes and are therefore outside the scope of this study. The Liner Connectivity Index (LCI), sourced from the World Bank (2025) dataset, was used to identify internationally connected ports. Ports with no LCI entry were excluded, as the absence of a value indicates that the port does not meet the threshold of at least 24 international vessel calls per year. This filter excluded 87 ports and 117 terminals, retaining 71 ports and 202 terminals.

The third filter addressed source availability. The SDA step requires each port and terminal to have an accessible website or annual report. An active search was conducted for each of the 202 terminals between February and April 2026. Terminals for which no accessible website or annual report could be located were excluded. This excluded 105 terminals, retaining 97 terminals across 71 ports in 11 countries.

For the 97 retained terminals, 385 websites and 136 port annual reports were identified as available sources. Japan contributed the largest source base, with 108 websites and 53 annual reports. China followed with 61 websites and 28 annual reports. Australia contributed 45 websites and 8 annual reports. The remaining countries contributed between 6 and 27 websites and between 3 and 9 annual reports each. This source sample forms the documentary corpus for the SDA step.

2.2 Step 2 – AI-assisted Systematic Data Analysis (SDA)

Port and terminal websites and annual reports are commercially oriented documents. Every port and terminal uses these sources to market its capabilities and achievements. Despite variation in structure, depth, and formatting across sources, three types of data were found to be consistently available: port specifications, port performance claims, and technology adoption & impact claims. Port specifications describe the physical and operational attributes of each facility. Port performance claims describe the outputs and metrics the port reports against. Technology adoption claims describe the technologies the port or terminal states it has deployed, along with the benefits attributed to those deployments.

For each country in the sample, a dedicated NotebookLM notebook was established. Port website URLs and annual reports were loaded as sources. The emerging technology taxonomy (Annex 1) and the emerging technology impact framework (Annex 2) were also loaded as grounding documents. Three structured prompts were then run per notebook: one to extract port specifications, one to extract port performance claims, and one to extract technology adoption claims. Because the taxonomy and impact framework were loaded as grounding documents, extraction and deductive coding occurred in a single operation. Each prompt was structured to return not just what technology a port reported, but also how that technology was classified against the taxonomy categories and what impact was attributed to it against the impact framework dimensions. The prompts are reproduced in full in Annex 3. The full SDA process is illustrated in Figure 4.

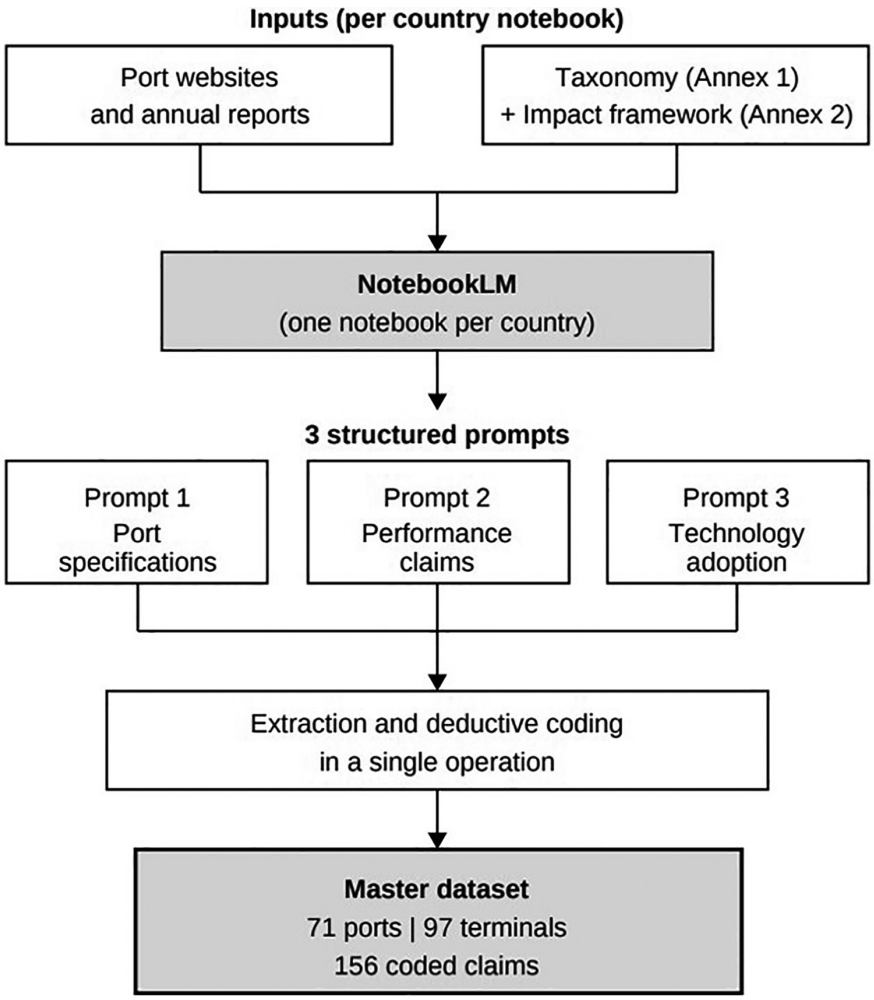

Figure 4. AI-assisted SDA process

The SDA process yielded a master dataset comprising 71 ports, 97 terminals, and 156 technology adoption claims, each coded against the taxonomy and impact framework. The full dataset is available on request.

2.2.1 Validation

As mentioned in the 1.1 study design, the validation standard follows the Lincoln and Guba (1985) trustworthiness framework. This framework has four parts, the first two (i) credibility and (ii) transferability are concerned with tool selection and process recording. The latter two (iii) confirmability and (iv) dependability are concerned with process compliance. In this section, the latter two are described of the trustworthiness framework.

For (iii) confirmability, every prompt submitted to NotebookLM was designed to return an output accompanied by evidence quote drawn directly from the source material. Upon receiving each output table, the cited source passages were opened and evaluated to confirm that the extraction was genuine and that the quoted material accurately supported the reported finding. This verification process identified a recurring error pattern: NotebookLM tended to report an impact as technology-driven when the source material men-

tioned the impact in proximity to a technology, even where no causal link was stated. This error was addressed through iterative prompt modification. After the third iteration of the prompt, this pattern of misattribution ceased to appear in the outputs. Hence confirming that the output of the AI-assisted tool, NotebookLM was reliable.

For (iv) dependability, all prompts are stored in full in Annex 3, together with a description of the purpose of each prompt and a record of the iterative changes made across successive versions. This prompt audit trail documents how the extraction process was refined over time, including the modifications introduced to address the misattribution error described above. Therefore, the four parts of the Lincon and Guba (1985) trustworthiness framework are complied with in this study hence making the use of AI-assisted tool NotebookLM in qualitative analysis reliable.

2.3 Step 3 – AI-assisted Enhanced Thematic Analysis (ETA)

The SDA dataset, 156 technology adoption claims, each coded against the taxonomy and impact framework, forms the input to this step. ETA uses NotebookLM to support inductive pattern-finding across the four dimensions recorded for each entry: technology adoption (category and name), attributed impact (impacted process and specific impact), port specifications (quay length, crane equipment, and yard configuration), and port performance (annual capacity and throughput where available). NotebookLM was used to surface groupings and clusters across these dimensions simultaneously, enabling the analysis to work across all 156 entries at a consistency and scale that manual review alone would not permit. The clusters identified by NotebookLM were then examined, questioned, and refined by the researchers. Where clusters were not coherent or were not supported by the underlying entry data, they were collapsed or redefined. This human-led questioning and verification of the AI-generated groupings is what distinguishes the enhanced thematic analysis from a purely automated process. Four themes were identified through this process and are reported in 3.0 results section.

3. RESULTS

The ETA produced four themes from the 156 coded technology adoption claims across 97 terminals in 11 Asia-Pacific countries. Each theme reflects a pattern identified across the four analytical dimensions: technology adoption, attributed impact, port specifications, and port performance. The themes are presented below with supporting evidence drawn directly from the dataset.

Finding 1: Automation adoption is concentrated at high-throughput, long-quay terminals.

Automation technology adoption is not evenly distributed across the sample. It is concentrated at terminals with long quays, high crane counts, and high annual throughput.

The fully automated Yangshan Phase IV terminal in Shanghai operates a 2,770m quay with throughput exceeding 10 million TEU annually and describes itself as the largest automated terminal in the world. Qingdao New Qianwan Container Terminal operates a 2,088m quay with 85 electric AGVs and throughput of 11.7 million TEU. Mawan Smart Port in Shenzhen operates autonomous vehicles across a 3,440m quay facility at a port reporting 15.9 million TEU. Hong Kong International Terminals deploys remote-control RTGCs across a 2,987m quay with throughput of 6.6 million TEU. In Australia, VICT Melbourne operates a fully automated quay and yard across 800m of berth, and Patrick Terminals Brisbane deploys AGVs across 660–929m of quay. By contrast, the smaller terminals in the dataset, such as Kanazawa (60,962 TEU), Samalaju Industrial Port (13,889 TEU), and Sapangar Bay (307,083 TEU), adopt limited or no automation. Gate automation (autogates, OCR systems) appears at smaller terminals, but crane and vehicle automation is concentrated at facilities with long quays and multi-million TEU throughput. The dataset therefore shows that automation adoption is associated with large-scale terminal infrastructure, and that the attributed impacts, throughput capacity at the quay and throughput efficiency at the yard, are consistent with the physical scale of the facilities adopting these technologies.

Table 1. Automation adoption and terminal scale – selected entries

Port / Terminal	Country	Automation Technology	Quay Length	Annual TEU
Yangshan Phase IV	China	Equipment (automated cranes)	2,770m	10.15M (2025)
Qingdao QQCTN	China	Electric AGVs	2,088m	11.7M (2024)
Mawan Smart Port	China	Autonomous vehicles	3,440m	15.9M
Hong Kong HIT	China	Remote control RTGCs	2,987m	6.6M (2025)
VICT Melbourne	Australia	Unmanned operations / AGVs	800m	1M+ (target)
Busan New Port BCT	South Korea	Remote control cranes	1,150–1,200m	24.4M (port-wide)
Kanazawa Gokuden ICT	Japan	Gantry crane (non-automated)	Not stated	60,962

Finding 2: Digital adoption is tiered – advanced digital technologies at mega-ports, baseline systems at smaller terminals.

Digital adoption appears across the full-size range of the sample, from small Japanese ports to Singapore, but the type of digital technology differs substantially by port scale. The largest ports in the dataset have progressed beyond baseline digital infrastructure to advanced applications. Singapore Port of Singapore (41.12 million TEU) deploys a Just-in-Time Planning Platform, a Maritime Digital Twin, and Generative AI for document processing. Shanghai SIPG (55 million TEU) deploys blockchain. Yantian (16.1 million TEU) deploys blockchain. Qingdao QQCTN (11.7 million TEU, 34.2 million TEU port-wide) deploys AI. Busan

(24.4 million TEU) deploys a blockchain Chain Portal and AI for risk assessment. Ningbo Zhoushan (43.2 million TEU) deploys AI for intelligent tallying.

Smaller and mid-size ports in the dataset are still adopting the baseline layer of digital infrastructure. Terminal Operating Systems (Navis N4 at Tanjung Pelepas, Navis SPARCS at Manila South Harbor, Navis and computerised systems at multiple Thai ports, real-time management software at Cat Lai Vietnam) represent the primary digital investment for ports in the sub-one million TEU range. E-booking and paperless customs platforms appear across Thailand, the Philippines, Vietnam, and Japan at terminals with no declared throughput or with throughput well below one million TEU. The dataset therefore shows a two-tier digital adoption pattern: mega-ports deploying AI, blockchain, digital twins, and generative AI; smaller terminals still implementing TOS and e-booking as their primary digital step.

Table 2. Digital adoption by tier – selected entries

Port / Terminal	Country	Digital Technology	Annual TEU
Port of Singapore	Singapore	JIT Platform, Digital Twin, Generative AI	41.12M
SIPG (Group-wide)	China	Blockchain	55M
Yantian	China	Blockchain	16.1M
Qingdao QQCTN	China	Artificial Intelligence	11.7M
Busan (All terminals)	South Korea	Blockchain, AI	24.4M
Tanjung Pelepas	Malaysia	TOS (Navis N4)	Not stated
Cat Lai Terminal	Vietnam	Real-time management software	248,000
Ranong Port	Thailand	TOS (computer systems)	Not stated

Finding 3: Green technology type is geographically clustered – shore-side power in China, electrification in Southeast Asia, alternative fuels in Japan.

Green technology adoption is the most common category in the dataset, with 40 entries across all 11 countries. All 40 entries attribute their impact to emissions control. However, the type of green technology adopted varies sharply by geography. Shore-Side Power (SSP), which allows vessels to connect to onshore electricity while at berth rather than running ship engines, appears exclusively at Chinese ports and one South Korean port. Six of the seven SSP entries are at Chinese facilities: Yantian (16.1 million TEU), Shekou (5.6 million TEU), Ningbo Zhoushan (43.2 million TEU), Quanzhou (13.6 million TEU), Tianjin Pacific International, and Jiangyin Sunan. Alternative fuels appear primarily in Japan (six entries across Hanshin, Kobe, Yokohama, Ishikari) and China (Yangshan, DaChan Bay, Ningbo Zhoushan). Electrification of yard equipment, including electric and hybrid RTGs, eRTGs, and electric yard tractors, is the dominant green pathway in Southeast Asia, appearing in Malaysia, Vietnam, the Philippines, South Korea, and Thailand, as well as in Australia and New Zealand. Renewable energy installations (solar) appear in Thailand (Bangkok,

Chiang Saen), South Korea (Busan PNIT), China (Ningbo Meishan, Tianjin, Qinzhou), and Australia (Hutchison Sydney). The dataset therefore shows that while all green adopters in the sample claim the same impact (emissions control), the specific technology pathway is geographically clustered rather than uniformly distributed across the region.

Table 3. Green technology type by country – entry counts

Country	Shore-Side Power	Electrification	Alternative Fuels	Renewable Energy	Total
China	6	1	3	3	13
Japan	0	0	6	1	7
South Korea	1	4	2	1	8
Australia	0	1	0	1	2
Malaysia	0	2	0	0	2
Thailand	0	1	0	2	3
Vietnam	0	1	0	0	1
Philippines	0	2	0	0	2
New Zealand	0	1	1	0	2

Finding 4: Multi-category adoption is associated with larger port scale – smaller ports adopt from a single category.

Across the 71 ports in the dataset, 39 ports adopt technology from only one category. Of these single-category adopters, the majority adopt green technology only, reflecting the broad distribution of green adoption regardless of port size. Ports adopting from only the digital category tend to be smaller terminals implementing baseline systems (e-booking, TOS). Ports adopting from only the automation category are few and tend to be terminals at which a single specific upgrade is documented.

By contrast, the ports that adopt across two or three categories tend to be larger facilities. Mawan Smart Port in Shenzhen adopts automation (autonomous vehicles), digital (5G networks, IoT), and green (electrification, alternative fuels), reporting port-wide throughput of 15.9 million TEU. Qingdao QQCTN adopts automation (AGVs, unmanned gate), digital (AI), and has associated green adoption at the port level. Busan New Port adopts automation (remote control cranes), digital (blockchain, AI), and green (alternative fuels, renewables, SSP). Brisbane Port reports adoption across all three categories. The dataset therefore shows that broader multi-category technology adoption appears alongside larger declared port capacity and throughput, while smaller terminals in the sample tend to report adoption in a single category, most commonly green electrification, which requires less capital integration than automation or advanced digital systems.

4. DISCUSSION

Technology adoption across Asia-Pacific container ports varies primarily by two factors: port size and geography. Port size determines the type of automation adopted: larger terminals with long quays and high throughput invest in crane and vehicle automation, while smaller terminals are limited to gate automation as a lower-capital entry point. Geography determines the type of green technology adopted: Chinese ports cluster around shore-side power, Japanese ports around alternative fuels, and Southeast Asian ports around yard electrification, each reflecting locally available infrastructure and prevailing operational conditions. Digital technology is the exception to both patterns: it appears across ports of all sizes and in all countries, as every port in the sample is pursuing some form of digital enhancement, whether at the baseline level of TOS and e-booking or at the advanced level of AI, blockchain, and digital twins. These two drivers, size and geography, together explain the variation in adoption observed across the dataset and provide the basis for the survey instrument to be developed in the next phase of this research.

5. SUMMARY

This study constructs a consolidated dataset linking port specifications, port performance data, and emerging technology adoption for a common sample of Asia-Pacific container ports. No such dataset currently exists in the academic or industry literature. To construct the dataset, the study applied AI-assisted Systematic Data Analysis (SDA). NotebookLM extracted and deductively coded data from 385 port websites and 136 annual reports across 97 terminals in 11 countries. This produced 156 coded technology adoption claims, validated against the Lincoln and Guba (1985) trustworthiness framework. The dataset was then analysed using AI-assisted Enhanced Thematic Analysis (ETA), which produced four themes relating technology adoption to port size, geography, and category. The study makes two contributions: the dataset itself, available on request; and a replicable methodological template for using AI assistance to analyse large volumes of heterogeneous text-based secondary data at scale, in compliance with established trustworthiness criteria.

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ANNEX 1: EMERGING TECHNOLOGY TAXONOMY

The following taxonomy defines the emerging technology categories and specific technologies used to classify technology adoption in this study. This taxonomy was developed in the literature review chapter of this thesis and applied as a grounding document in the NotebookLM notebooks used for data extraction (see Annex 3 for prompts).

Emerging Technology Category	Emerging Technology Name	Emerging Technology Description	Reference List
Automation	Equipment	A key trend involving automated quay cranes (AQCs), stacking cranes (ASCs), and handling units for increased efficiency and safety.	(Lee et al. 2025; Wang et al. 2023)
	Vehicles	Deployment of Automated Guided Vehicles (AGVs) and truck platooning for horizontal transport and optimizing internal movements.	(Benkert 2023; Yu et al. 2022)
	Miscellaneous	Includes gate automation, and unmanned operations to reduce operational uncertainties.	(Clemente et al. 2023; Zhou et al. 2022)
Digital	Artificial Intelligence	Encompasses Machine Learning (ML) and Deep Learning for predictive analytics, energy optimization, maintenance, and real-time decision-making.	(Elsisi et al. 2025; Li et al. 2023)
	Internet of Things	Uses sensors for real-time monitoring of operational processes, asset location, and environmental conditions.	(Clemente et al. 2023; Elsisi et al. 2025)
	Big Data Analytics	The process of analysing large volumes of data to enable data-driven decision-making and continuous operational optimization.	(Clemente et al. 2023; Neugebauer et al. 2024)
	Digital Twins	High-fidelity digital representations of port systems used for real-time monitoring, predictive optimization, and simulation.	(Notteboom et al. 2025; Wang & Li 2023)
	Cloud Computing	Provides scalable infrastructure for managing and processing data from interconnected digital systems.	(Filom et al. 2022; Sadiq et al. 2021)
	Blockchain	Technology for enhancing transparency, efficiency, and security in maritime supply chains and port operations.	(Ferreira et al. 2024; Li et al. 2023)
	5G Networks	High-bandwidth, low-latency mobile communication networks required for advanced IoT and real-time automation systems.	(Neugebauer et al. 2024; Wang et al. 2024)
	Miscellaneous	Includes Computer Vision (CV), Vision-Based Monitoring (VBM), LiDAR, e-booking systems, and Drones.	(Benkert 2023; Zeng et al. 2021)
Green	Electrification	The shift to electrically powered port equipment, ships, and ferries to reduce greenhouse gas (GHG) emissions.	(Iris & Lam 2019; Wang & Li 2023)

	Shore-Side Power (SSP)	Also known as Cold Ironing, allows vessels to connect to the port's electricity grid to curb on-ship emissions while at berth.	(Elsisi et al. 2025; Sadiq et al. 2021)
	Renewable Energy	Integration of marine renewable energy (MRE) sources (wind, solar, wave, etc.) for sustainable, energy-self-sufficient ports.	(Dragovic et al. 2024; Iris & Lam 2019)
	Microgrids	Systems for efficient energy management, enabling the integration of diverse energy sources and optimizing demand and supply.	(Sadiq et al. 2021; Zhou et al. 2022)
	Alternative Fuels	Adoption of fuels like Liquefied Natural Gas (LNG) for decarbonization strategies.	(Iris & Lam 2019; Wang et al. 2023)
	Energy Storage Systems	Systems such as batteries and flywheels to manage energy fluctuations and provide power during peak periods.	(Iris & Lam 2019; Wang et al. 2023)
Other	Advanced Storage Systems	Systems like Automated Storage and Retrieval Systems (AS/RS) and Boxbay High Bay Store Systems (HBS) to enhance container density and handling.	(Zhou et al. 2022)

ANNEX 2: TECHNOLOGY IMPACT FRAMEWORK

The following framework defines the processes, specific impacts, outcome categories, and terminal locations used to classify technology impacts in this study. This framework was developed as part of the emerging technology impact framework chapter of this thesis and applied as a grounding document in the NotebookLM notebooks used for data extraction (see Annex 3 for prompts).

Table A2.1: Processes impacted by emerging technologies and their outcome categories.

Processes Impacted	Outcome Category
Port throughput	Operations
Internal throughput	Operations
Emissions control	Environment
Surveillance – security, safety – monitoring, risk assessment	Social
Emergency response – security, safety	Social
Data processing – collection, analysing, reporting (internal & external)	Supply Chain, Financial
Operations sequencing – planning, deploying, execution	Operations

Table A2.2: Specific impacts

Specific Impact
Increase productivity
Increase efficiency
Increases capacity

Table A2.3: Outcome categories

Outcome Categories
Operational
Environmental
Supply chain
Social benefits
Financial
Other benefits

Table A2.4: Impact locations within the port

Impact Locations
Yard
Quay
Gate
Overall
Waterway
Other

ANNEX 3: NOTEBOOKLM PROMPTS FOR DATA EXTRACTION

The prompts in this annex were applied in NotebookLM to extract port specification, port performance, and port technology adoption data from the country notebooks. The prompts are numbered to reflect their sequence of development. The technology taxonomy (Annex 1) and the technology impact framework (Annex 2) were uploaded as source documents to each notebook before the extraction prompts were run. Iterative refinement from Prompt 1 through Prompt 3 addressed validation errors identified through the confirmability and dependability checks described in section 4.2.

A3.1 Overview

The prompts in this annex were used in NotebookLM to extract three forms of data from the port website and annual report sources loaded for each country notebook. The extraction process went through iterative refinement to address four types of error identified during validation: inaccuracy of extraction, inaccuracy of interpretation, conflation of current adoption with planned future adoption, and mis association of an impact with a technology when the source material did not establish a causal link. The prompts are numbered to reflect the sequence of development and the three data extraction domains.

A3.2 Prompt 1: Technology adoption and impact extraction – initial iteration (Australia and New Zealand)

Purpose: To extract automation technology adoption evidence and impacts from the first country notebooks, establishing the initial extraction approach.

Extract Automation emerging technology adoption and Automation emerging technology impacts: make table to answer which automation technology is adopted in each port – one row for each automation technology for each port – column for source quotation that evidences the adoption of automation technology – column for the specific impact of the automation technology as mentioned in the source – column for the source quotation mentioning the specific impact of the automation technology in the port – column to classify the stated impact as positive (beneficial impact) or negative (detrimental impact).

Validation and clarification prompts applied during this iteration: Technology adoption evidence was challenged where descriptions were insufficiently specific to confirm autonomous rather than remote-operated equipment. Impact evidence was challenged where the stated impact could not be directly attributed to the named technology. These challenges are documented in the reflexive journal as part of the dependability audit trail.

A3.3 Prompt 2: Technology adoption and impact extraction – second iteration (Malaysia and Singapore)

Purpose: To standardise the extraction approach based on outputs from the first iteration, incorporating the taxonomy and impact framework as grounding documents and expanding to all three technology categories.

Make a table for automation technology adoption in container ports: each row is for a port terminal; columns are needed for: Port, Terminal, Emerging technology category (use the taxonomy for determining), Emerging Technology Name (use the taxonomy for determining), Source Quotation: Adoption Evidence (provide quotation from source that proves that the above specific technology has been adopted – check that it is directly linked and not evidencing plans or designs for future adoption), Impacted process (use the technology impact framework for determining), Specific impact (use the technology impact framework for determining), Impact location in port (use the technology impact framework for determining), Source Quotation: Impact Evidence (provide quotation from source that proves the above impact of technology adoption – check that it is directly linked and not evidencing impact of something else).

A3.4 Prompt 3: Technology adoption and impact extraction – third iteration (all countries, all technology categories)

Purpose: Final standardised prompt applied to all country notebooks, covering automation, digital, green, and other technologies after refinement of the adoption vs. plan distinction and the technology-impact causal link requirement. Translation instruction added for non-English source material.

Make a table for automation, green, digital and other technology adoption in container ports: each row is for a container terminal (ignore non-container terminals such as bulk and others); columns are needed for: Port, Terminal, Emerging technology category (use the taxonomy for determining), Emerging Technology Name (use the taxonomy for determining), Source Quotation: Adoption Evidence (provide quotation from source that proves that the above specific technology has been adopted – check that it is directly linked and not evidencing plans or designs for future adoption), Impacted process (use the technology impact framework for determining), Specific impact (use the technology impact framework for determining), Impact location in port (use the technology impact framework for determining), Source Quotation: Impact Evidence (provide quotation from source that proves the above impact of technology adoption – check that it is directly linked and not evidencing impact of something else). Translate evidence quotes into English.

A3.5 Prompt 4: Port specifications extraction

Purpose: To extract standardised port and terminal physical specification data for the sample.

Make a table with port specifications: rows for each container terminal (ignore other types of terminals such as bulk, ro-ro, etc.); columns for: port, terminal, quay specification (length), quay cranes (type, quantity), yard specification (size, layout), yard cranes (type, quantity), internal vehicles such as straddle carrier etc. (type, quantity), gate (specifications, type), rail yard (specification, quantity), other port specifications.

A3.6 Prompt 5: Port performance extraction

Purpose: To extract standardised port performance data for the sample.

Make a table for the port performance of each port and terminal: only consider container ports and container terminals (ignore all other types of terminals such as bulk, ro-ro); rows for each port; columns for: port, terminal, annual throughput capacity in TEU, last reported annual throughput in TEU, last reported number of port calls.

Information Systems for Logistics Management

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ABSTRACT

Effective management of the movement of physical goods is largely based on the ability to quickly and easily identify what an object is. Thus, the ability to identify and track physical objects, as well as to record their movements, becomes a crucial factor in the success of a logistics information system.

KEEWORDS: logistics, information system.

Logistics information systems were developed to eliminate errors in operations taking place both within and outside the warehouse. The use of various applications in the processes of production, storage and dispatch of goods improves the efficiency of the supply chain.

These logistics management programmes facilitate the development of digital warehousing, i.e. facilities where tasks such as stock control and order fulfilment are carried out by software, thereby avoiding delays and errors in these operations.

Logistics information systems (LIS) are digital applications implemented to facilitate decision-making and the management of operations such as procurement, storage, order fulfilment, as well as the dispatch and transport of goods.

These logistics programmes ensure a continuous flow of information between companies involved in the development, production, storage and marketing of a product or service, linking all organisations and maintaining product traceability.

Depending on which warehouse tasks are being automated, different types of logistics information systems may be used. For example, a Transportation Management System (TMS) plans and organises delivery routes, whilst an Enterprise Resource Planning (ERP) system synchronises processes and data between the company's departments – including the logistics department.

However, a Warehouse Management System (WMS) is the information system that acts as the facility's brain. In other words, it controls everything that happens inside the building, from

the receipt of goods to the dispatch of orders to end customers. Deploying a digital solution such as a WMS minimises the risk of errors caused by manual management. This software helps operators with tasks such as restocking, order picking and planning goods dispatch.

Similarly, in automated warehouses, WMS software coordinates the operation of automated equipment as well as operators' tasks. These digital programmes not only significantly increase goods throughput but also enhance safety at the facility.

Benefits of implementing logistics information systems.

Logistics information systems offer a host of benefits, namely:

- process automation: logistics management software eliminates the need for manual data entry. It also automates the generation of the necessary documentation for logistics operations, minimising the risk of errors in processes such as stock control and order fulfilment.
- automated information flows: logistics software extracts information from operations to coordinate warehouse processes and the various levels of the supply chain with one another. State-of-the-art programmes analyse logistics activities to provide real-time information on a facility's throughput capacity.
- Improved logistics planning: Information systems enable products to be tracked throughout the supply chain and data to be collected, providing logistics managers with all the information required for logistics planning.

Ultimately, logistics software improves the efficiency of warehouse operations by synchronising the facility with other levels of the supply chain, such as the building housing the production lines or the distribution centre.

In terms of specialisation, logistics information systems can be divided into horizontal software, which comprises several modules with solutions for different departments within an organisation, and vertical software, which specialises in specific functions for a single division of the company.

The category of horizontal software includes, for example, most ERP systems. These programmes offer basic functions for all types of business units, i.e. document management, sales and invoicing, as well as basic inventory management.

Vertical information systems, on the other hand, are designed to provide solutions for specific requirements. In the case of logistics, these may include advanced inventory management functions, demand planning, transport route strategies and the coordination of automated equipment.

Among the vertical applications that can be implemented in logistics, the best known is warehouse management system (WMS) software, a digital solution that manages the flow of goods and operations. This tool also synchronises the tasks of operators and automated equipment, creating a productive, safe and error-free working environment.

In the field of international logistics, the use of a warehouse management system (WMS) can be very useful for improving and optimising the following operations:

- Real-time stock monitoring and visibility. WMS controls logistics operations and provides full real-time visibility of the status and location of stock throughout the supply chain.

In the field of international logistics, the use of a warehouse management system (WMS) can be extremely beneficial for improving and optimizing the following operations:

- real-time stock monitoring and visibility. A WMS oversees logistics operations and provides full, real-time visibility of stock status and location throughout the supply chain;
- international stock tracking. Warehouse management software is capable of managing stock across different geographical locations, thereby coordinating the planning and supply of goods. This is done based on demand in each market to avoid stock shortages (or surpluses);
- optimization of routes and modes of transport. Some WMS systems have advanced features for optimizing delivery routes and selecting appropriate modes of transport. The technology helps companies selling their products in other countries to reduce delivery costs, minimize transit times and improve customer satisfaction;
- collaboration and communication with logistics partners. Warehouse management software facilitates communication between international logistics partners. Companies exchange relevant information and data, which optimizes operations and prevents errors and delays in information exchange;
- metrics to improve decision-making. Digitalization enables the tracking of logistics metrics, the assessment of operational efficiency, and data-driven decision-making to continuously improve international logistics processes.

In short, warehouse management software improves product visibility and effectively coordinates various supply chain operations. Digitalization also facilitates inventory management, the creation of customs documents, and collaboration with logistics partners in different countries. Warehouse management software is capable of managing stock across different geographical locations, thereby coordinating the planning and delivery of goods. This is done based on demand in each market to avoid stock shortages (or surpluses).

In addition to WMS, other digital applications operate at one or more levels of the supply chain and can be coordinated with one another. Here are the most common ones:

- transportation management system: logistics information software designed to optimize the planning of order distribution routes in order to improve delivery efficiency and eliminate the risk of errors;
- production management system: a digital solution deployed in warehouses and production centers to organize, control and monitor production processes on production lines;
- distributed order management software: a logistics information system specializing in order fulfillment. The software coordinates operations from the moment a customer places an order until its fulfillment.

Although these information systems are widely used in businesses, the complexity of supply chain operations is driving many forward-thinking logistics software developers to add new features to adapt to the sector's changing needs.

The growth of e-commerce and omnichannel retailing has increased the complexity of logistics operations. E-commerce logistics has brought customer satisfaction to the

fore, establishing norms such as free returns and same-day delivery. To ensure maximum efficiency, more and more companies are choosing to replace manual management – or management using low-complexity software such as Excel – with advanced management systems capable of automating all warehouse operations.

CONCLUSION

Logistics information systems can be configured to operate in various scenarios, and they often support warehouse and transport management, optimizing processes and tracking the location and movement of stock.Logistics information systems are also valuable for managing costly operations such as reverse logistics. Companies most often use IT systems that support reverse logistics process management, driven by the need to sell new products and prevent the accumulation of unwanted stock in order to maintain their market position.

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A Multi-Layer Approach to Event Prediction Using Semantic Network Models

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ABSTRACT

This paper introduces a multi-layer semantic network model designed to analyze causal relationships between events and generate forecasts across interconnected stages. The model is structured into three hierarchical levels – initial triggering events, intermediate processes, and final outcomes – connected by probabilistic transitions derived from both historical data and expert judgment. This framework enables the representation of complex event chains, supports recursive subnetworks, and allows for the integration of heterogeneous data sources, including geophysical observations, statistical records, and qualitative expert assessments. The proposed approach is applicable to forecasting natural disasters such as earthquakes, floods, and landslides, as well as to analyzing political and economic developments. Key findings indicate that combining multiple complementary models, limiting the number of stages to two or three, and incorporating expert knowledge in data-sparse environments significantly enhances predictive reliability. The model's modular structure also facilitates the integration of machine learning techniques for adaptive forecasting. Practical validation confirms its utility in real-world decision-support systems.

KEEWORDS: multi-stage forecasting, semantic networks, probabilistic modeling, expert evaluation, hybrid prediction systems

INTRODUCTION

Multi-stage forecasting models represent a structured approach in which predictions are developed progressively across several levels. Each level may rely on different datasets, analytical tools, or modeling techniques, and the final outcome emerges from their sequential integration.

Natural hazards such as earthquakes, floods, and landslides are typically the result of multiple interconnected factors, including geological, climatic, and hydrological conditions. In many cases, one event triggers another, forming a chain of consequences. By constructing individual models for each stage and linking them together, it becomes possible to represent and predict these complex processes more effectively.

Such systems can be visualized as semantic networks, where nodes correspond to specific events or models, and connections represent transition probabilities between them. These probabilities are derived either from historical observations or expert assessments when data is limited.

An important feature of this approach is that each node can itself represent a subnetwork, which enhances the flexibility and precision of the overall model. As noted in [6], such hierarchical structures enable the decomposition of complex predictive tasks into manageable components while preserving interdependencies between events.

The framework allows the integration of multiple data sources, including:

- meteorological and geophysical data,
- statistical records,
- expert knowledge.

The combination of these diverse inputs improves the reliability and depth of forecasting.

LITERATURE REVIEW

In recent years, forecasting methodologies have undergone substantial transformation, driven by the integration of hybrid models and advanced computational techniques. Traditional single-model approaches are increasingly being replaced by multi-component systems that combine different algorithms and data sources to improve prediction accuracy.

A significant direction in this field is the development of hybrid intelligent models. For example, the integration of genetic algorithms, particle swarm optimization, and neural networks has demonstrated strong performance in seismic risk assessment, particularly in identifying vulnerable regions and improving prediction reliability [1]. Such approaches highlight the advantages of combining optimization techniques with machine learning models.

Another important trend is the use of multi-factor and multi-source data within unified predictive frameworks. Studies show that integrating geophysical, geological, and environ-

mental data using artificial intelligence methods significantly enhances forecasting performance [2]. These approaches allow models to capture complex relationships between variables that cannot be identified using isolated datasets.

Deep learning has also become a key component in modern forecasting systems. Hybrid architectures, such as those combining convolutional neural networks (CNN) and gated recurrent units (GRU), are particularly effective in modeling both spatial and temporal dependencies in data. These models have been successfully applied to earthquake prediction and have shown improved accuracy compared to traditional methods [3].

In addition to data-driven techniques, the integration of expert knowledge remains a critical aspect of forecasting. In cases where statistical data is incomplete or uncertain, expert assessments can provide valuable supplementary information. Hybrid frameworks that combine statistical analysis, expert judgment, and artificial intelligence are especially useful in emergency response planning and risk management.

The integration of expert knowledge is particularly valuable when statistical data are scarce or uncertain. Hybrid frameworks that combine expert judgment with data-driven models have shown effectiveness in risk assessment and emergency response [4]. Recent studies further emphasize the role of expert competence in multi-factor forecasting systems [7], the use of expert evaluations in probabilistic risk modeling [8], and the development of hybrid prediction methods that synergistically combine expert input with computational models [9].

Moreover, multifactor approaches to forecasting emphasize the importance of considering multiple influencing variables simultaneously. These methods focus on identifying key precursors of events and incorporating them into predictive models, thereby improving their explanatory and predictive capabilities [5].

Overall, the literature reflects a clear shift toward hybrid, multi-source, and adaptive forecasting systems. These approaches not only enhance predictive accuracy but also provide more flexible tools for analyzing complex and interconnected processes.

Structure of the Three-Stage Semantic Network Model

The increasing complexity of global processes requires models capable of capturing interdependencies between events. The proposed multi-stage semantic network addresses this need by organizing events into interconnected layers.

The model consists of three main levels:

- **Stage 1 (M):** initial triggering events (e.g., earthquakes, elections)
- **Stage 2 (K):** intermediate processes that result from initial events
- **Stage 3 (N):** final outcomes or consequences

The corresponding semantic network for three-step forecasting models is shown in Fig. 1.

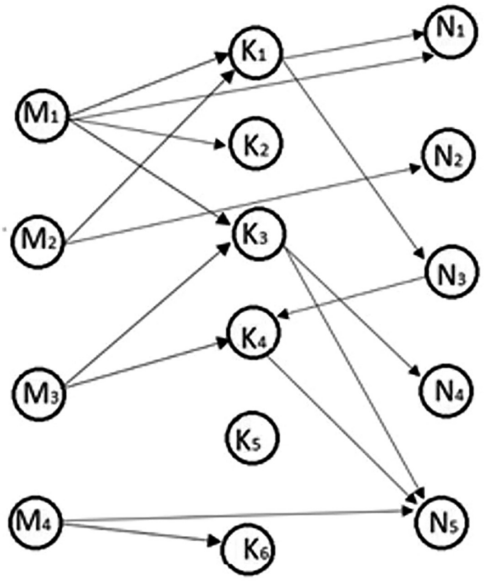

Fig. 1. A network corresponding to a three-step forecasting model

Connections between these stages are quantified using probabilities derived from data analysis or expert input.

For example, an earthquake may lead to a tsunami, which then results in coastal damage. At the same time, the initial event may also directly cause the final outcome without intermediate steps.

In the scheme presented in Figure 1, we write down the percentages of all the peaks, which are calculated over several years of observations in one specific place, for example, Tbilisi, the Vera River Gorge, etc. We will obtain the following semantic network (see Figure 2):

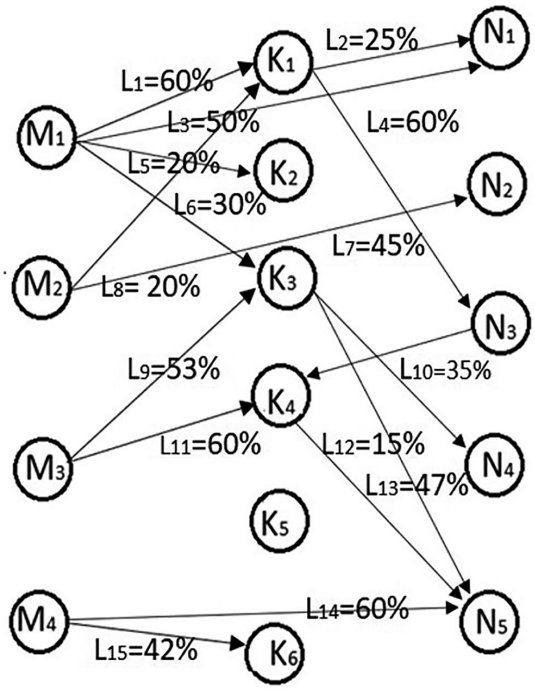

Fig. 2. Semantic network corresponding to three-step forecasting models

In this semantic network, one event can be connected to another from both sides, which means that a third-step event can cause both another and its own step event. In the figure: N2 →K5, N3→K4, N5→K5 connections.

Two types of network structures can be distinguished:

- **Deterministic networks,** where probabilities are fixed,
- **Probabilistic networks**, which incorporate uncertainty and variability.

Moreover, a final-stage event can serve as the starting point for another network, forming a multi-layered predictive system capable of modeling highly complex processes.

APPLICATION EXAMPLES

A. Natural Disasters

The model is particularly useful in situations where the full sequence of events is not completely known. For example, a flood may lead to a landslide, which ultimately results in a disaster. Even if intermediate stages are unclear, the model allows for estimating direct and indirect relationships between events.

B. Political and Economic Analysis

Beyond environmental applications, the model can be used to analyze socio-political and economic processes. For instance, elections may trigger political changes that influence economic stability or national security. This framework enables the evaluation of different development scenarios and their likelihood.

C. Integrated Forecasting Workflow

A comprehensive forecasting system may include several stages:

1. Long-term risk assessment based on historical and environmental data
2. Short-term forecasting using recent observations
3. Real-time monitoring through sensors and remote data
4. Evaluation of economic and social impacts

KEY FINDINGS

The study leads to several important conclusions:

- Relying on a single model is insufficient for accurate forecasting
- Integrating multiple data sources significantly improves prediction quality
- Identifying precursor events enhances forecasting capability
- Combining models produces more reliable results than using them independently
- A limited number of well-selected models (2–3) is optimal in terms of efficiency
- Expert knowledge is essential when empirical data is incomplete
- Decision-support systems play a crucial role in applying model outputs
- Practical validation confirms the applicability of the approach in real-world scenarios

CONCLUSION

The proposed multi-stage semantic network model provides a robust framework for analyzing and predicting cause-and-effect relationships between events. Its flexibility allows it to be applied across various domains, including natural disaster management and socio-economic analysis.

Future work may focus on:

- automating data collection processes,
- integrating machine learning techniques for adaptive forecasting.

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A Combined Salt Spray and Cyclic Loading Test Protocol for Characterizing Weld Zone Corrosion in AH36 Steel

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ABSTRACT

Welded joints are critical structural elements in marine engineering, yet they represent the most vulnerable locations for corrosion-mechanical degradation. The welding process introduces microstructural alterations, residual stresses, and geometric discontinuities that significantly affect corrosion behaviour. Among the distinct zones of a welded joint—base metal (BM), weld metal (WM), and heat-affected zone (HAZ)—the HAZ is particularly susceptible due to its heterogeneous microstructure and the presence of peak residual stresses. Traditional residual life assessment methods for marine structures rely on averaged corrosion rates that do not account for local heterogeneity across weld zones. This simplification leads to systematic errors: the HAZ service life is overestimated while the risk of premature failure is underestimated. The advancement of predictive maintenance strategies and digital technologies for sustainable maritime transport has created an urgent need for spatially differentiated, high-fidelity input data that can capture zone-specific corrosion kinetics.

Current accelerated corrosion testing standards, such as ASTM B117 and ISO 9227, provide well-established protocols for salt spray testing under purely environmental conditions. Similarly, mechanical testing standards address fatigue and tensile properties in isolation. However, real marine service conditions involve the synergistic effect of corrosive environment and cyclic mechanical loading—a combination that is not captured by separate tests. Moreover, no standardised protocol exists for simultaneously subjecting welded specimens to accelerated corrosion and cyclic loading while maintaining the ability to distinguish corrosion behaviour across BM, WM, and HAZ. This gap limits the calibration of probabilistic corrosion models and the development of reliability-based maintenance strategies for marine transport systems.

This paper presents a comprehensive experimental framework for investigating corrosion heterogeneity in welded joints of AH36 shipbuilding steel under combined environmental and cyclic loading. AH36 steel is selected due to its widespread use in shipbuilding

and the availability of field exposure data for validation. The proposed protocol integrates accelerated salt spray testing in accordance with ASTM B117 with simultaneous cyclic tensile loading. Flat dog-bone specimens are machined from a welded plate transverse to the welding direction so that the gauge section (50 × 15 × 5 mm) contains BM, WM, and two symmetric HAZ regions, enabling direct comparison under identical conditions. Environmental parameters include 5% NaCl solution at 35 ± 2°C with fog collection rate of 1.0–2.0 mL/80 cm^2/h. Cyclic tensile loading is applied with maximum stress of 117 MPa (0.3 σ_0.2), stress ratio R = 0.1, and frequency f = 0.1 Hz, representing typical wave-induced cyclic stresses in ship structures while remaining below yield strength to avoid plastic deformation. Total test duration is 500 hours with sampling at 0, 100, 200, 300, 400, and 500 hours. Three replicates per time point (total 18 specimens) provide statistical robustness.

Post-test characterisation includes gravimetric analysis (ASTM G1) for mass loss measurement with ±0.1 mg accuracy, optical microscopy for zone identification and morphological assessment, and 3D profilometry for quantitative pitting characterisation including pit depth, pit density, and surface roughness parameters. Statistical analysis using ANOVA will test for significant differences between zones, while regression analysis will model time-dependent corrosion kinetics.

Pre-test design validation is supported by finite element analysis (FEA) confirming uniform stress distribution across all weld zones with variation ≤ 2%, and statistical power analysis demonstrating that n = 3 replicates per time point is sufficient to detect the expected 50% difference between HAZ and BM corrosion rates with 80% power at 95% confidence. Validation against field exposure data from the Adriatic Sea (Vukelic et al., 2022) will establish confidence in accelerated test outcomes through comparison of zone ranking, morphology, and corrosion kinetics.

Expected outcomes include zone-specific corrosion rates with HAZ exhibiting 50–60% higher rates than BM, quantitative coefficients for probabilistic models (k_HAZ/BM ≈ 1.5–1.6), detailed pitting morphology characterisation, and time-dependent kinetic parameters. These outputs will enable calibration of probabilistic degradation models, provide essential input for reliability-based maintenance strategies, support sustainable maritime transport operations through improved asset management, and contribute to the development of enhanced testing protocols for marine structures. This methodological framework addresses a critical data gap and advances predictive maintenance capabilities for sustainable transport systems and maritime logistics.

KEYWORDS: welded joint, heat-affected zone, AH36 steel, salt spray test, cyclic loading, test protocol, maritime transport, reliability-based maintenance.

1. INTRODUCTION

Welded joints are the most vulnerable locations for corrosion-mechanical degradation in marine structures due to microstructural alterations and residual stresses. Among the distinct zones—base metal (BM), weld metal (WM), and heat-affected zone (HAZ)—the HAZ is particularly susceptible. Traditional residual life assessment relies on averaged corrosion rates, neglecting local heterogeneity, which leads to overestimation of HAZ life and underestimation of failure risk. The advancement of predictive maintenance strategies and digital technologies for sustainable maritime transport has created an urgent need for spatially differentiated input data.

Current accelerated corrosion testing standards (ASTM B117, ISO 9227) do not incorporate mechanical loading, and no standardised protocol exists for combined salt spray and cyclic loading of welded specimens with zone-specific analysis. Field studies on AH36 steel confirm accelerated degradation in HAZ, but probabilistic corrosion models lack controlled laboratory data for calibration.

This paper presents a concise experimental design to quantify corrosion kinetics in BM, WM, and HAZ under combined salt spray and cyclic loading, supported by pre-test analyses.

2. MATERIALS AND METHODS

2.1 Material and Specimen Design

Material: AH36 shipbuilding steel (σ_0.2 ≥ 355 MPa). A welded plate is fabricated using GMAW (AWS ER70S-6), butt joint, 10 mm thickness, no post-weld heat treatment.

Specimen geometry: Flat dog-bone specimens machined transverse to the welding direction. Gauge section (50 × 15 × 5 mm) contains BM, WM, and two symmetric HAZ. Non-test areas masked. Surface finish target: Ra ≤ 0.8 μm.

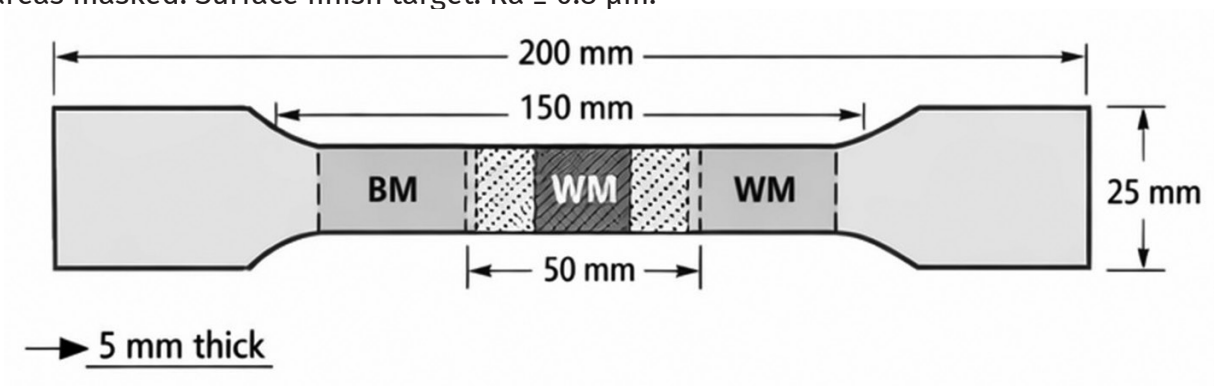

Figure 1: Geometry of the flat dogbone specimen with dimensions (in mm)

2.1.1 Specimen Extraction Scheme

Specimens are extracted transverse to the welding direction so that the gauge section spans perpendicularly across the weld. This ensures all three zones—BM, WM, and HAZ—are present within the central region.

2.2 Combined Test Setup

The setup integrates a salt spray chamber (ASTM B117) with an electromechanical loading frame.

Environmental parameters: 5% NaCl, 35 ± 2°C, pH 6.5–7.2, fog collection rate 1.0–2.0 mL/80 cm²/h.

Cyclic loading: σ_max = 117 MPa (0.3 σ_0.2), R = 0.1, f = 0.1 Hz (sinusoidal).

Duration: 500 hours with sampling at 0, 100, 200, 300, 400, 500 hours. Three replicates per time point (total 18 specimens).

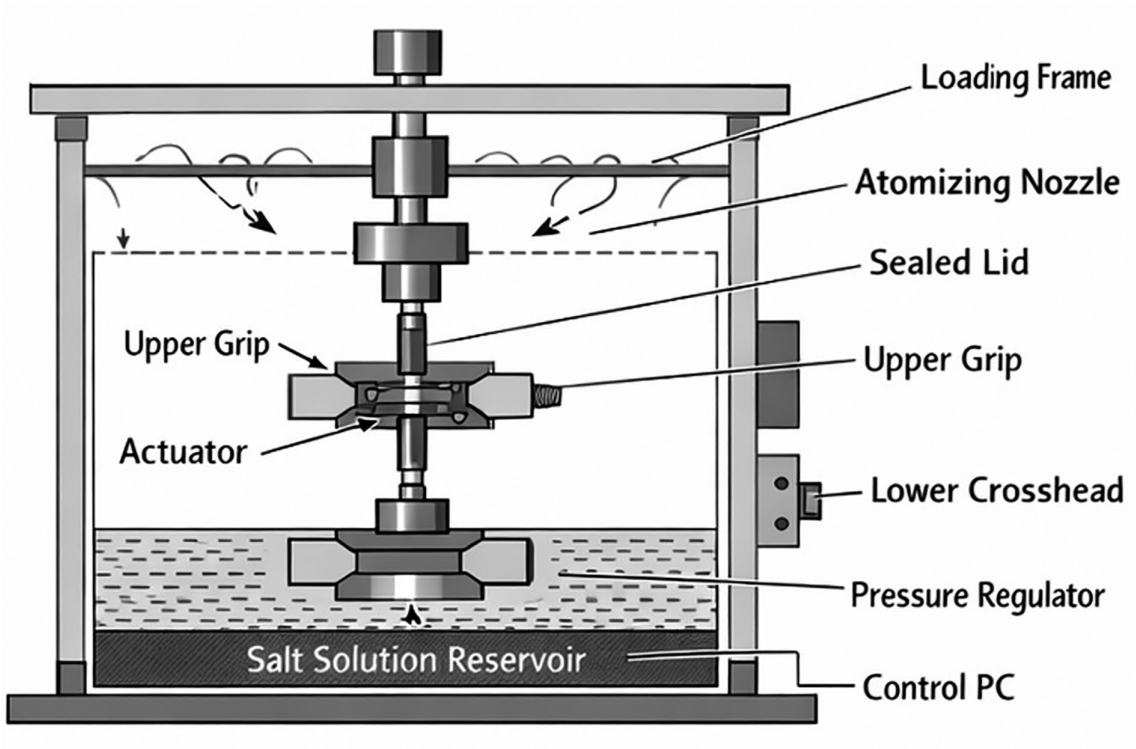

Figure 3. Schematic diagram of the combined salt spray and cyclic loading test setup

2.3. Characterisation Methods

Gravimetric analysis (ASTM G1): Mass loss (±0.1 mg), corrosion rate (mm/year).
Optical microscopy: Zone identification, corrosion morphology.
3D profilometry: Pit depth, pit density, surface roughness per zone.
Statistical analysis: ANOVA for zone differences; regression for kinetics.

3. PRE-TEST DESIGN RATIONALE

3.1 Finite Element Analysis

3D linear elastic FEA (Abaqus/ANSYS) verified uniform stress distribution across BM, WM, and HAZ. Load: 117 MPa.

Results: Stress variation across gauge section ≤ 2%; difference between zones ≤ 1%; maximum Von Mises stress < 150 MPa (well below yield). Specimen design acceptable.

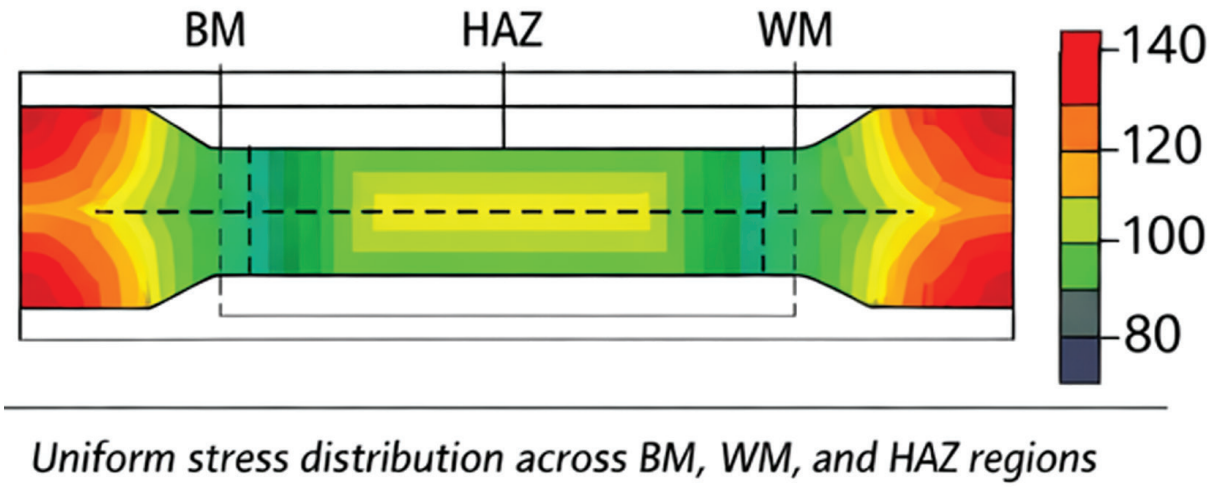

Figure 4. Finite element analysis results: Von Mises stress distribution in the gauge section

3.2 Statistical Power Analysis

Based on literature [2, 8]: BM 0.14 mm/year, HAZ 0.21 mm/year (50% higher), CV = 15%. Two-sample t-test ($\alpha = 0.05$, power = 0.80) yields $n \approx 2.8$.

Conclusion: n = 3 replicates per time point sufficient to detect expected 50% difference between HAZ and BM.

4. VALIDATION STRATEGY

Validation uses field exposure data from Vukelic et al. [8] (AH36 steel, Adriatic Sea).

Acceptance criteria:

Zone ranking: HAZ > WM > BM (consistent with field)

Morphology: BM – uniform; HAZ – localised pitting

Relative ratio: |R_HAZ/BM_accelerated − R_HAZ/BM_field| ≤ 0.20

Internal consistency: CV ≤ 20%, mass loss-profilometry correlation $R^2 \geq 0.85$, power-law exponent n = 0.3–0.7.

Limitations: constant temperature, continuous salt spray, uniaxial loading. Expected acceleration factor: 20–50.

5. EXPECTED OUTCOMES AND APPLICATIONS

5.1 Expected Results, Table 1

Zone	Expected Corrosion Rate (mm/year)	Relative to BM
BM	0.12 – 0.16	1.00
WM	0.15 – 0.20	1.20 – 1.40
HAZ	0.18 – 0.24	1.50 – 1.60

Pitting morphology: BM – uniform with shallow pits; HAZ – deep localised pitting (150–250 μm after 500 h); WM – mixed.

Kinetics: Power law $d(t) = k \cdot t^n$ with n = 0.4–0.6 (BM), 0.5–0.7 (WM), 0.6–0.8 (HAZ).

5.2. Applications

Probabilistic model calibration: Zone-specific coefficients (k_HAZ/BM, k_WM/BM) replace averaged rates [3, 4].

Reliability-based maintenance: Risk-based inspection planning focusing on HAZ.

Sustainable maritime transport: Improved asset management and extended service life.

Standards development: Foundation for combined testing protocols.

6. CONCLUSION

This paper presents a concise experimental framework for investigating corrosion heterogeneity in welded AH36 steel joints under combined salt spray and cyclic loading. The protocol specifies specimen geometry, environmental and mechanical parameters, sampling schedule, and characterisation methods.

Pre-test analyses (FEA, power analysis) confirm design validity. A validation strategy using field data establishes confidence in accelerated test outcomes. Expected zone-specific corrosion rates (HAZ 50–60% higher than BM) will enable calibration of probabilistic models, support reliability-based maintenance, and contribute to sustainable maritime transport operations.

Next steps: Experimental execution, data collection, validation, and dissemination.

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Forensic Evaluation of Systemic Failures in the Beirut Port Ammonium Nitrate Explosion under Maritime Risk Management Perspective

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ABSTRACT

The catastrophic detonation of 2,750 tons of ammonium nitrate at the Port of Beirut on August 4, 2020, represents one of the most significant industrial disasters in modern maritime history. This article utilizes Fault Tree Analysis (FTA) framework in evaluating the systemic failures across four primary domains: management, human, environmental, and facility-cargo factors. Quantitative analysis reveals a top event probability of 2.01x10-03, driven by secondary factors such as improper storage, neglected warnings, and inadequate regulatory oversight. The study highlights how the close proximity of hazardous cargo to dense urban populations exacerbated casualties and property damage. Findings underscore the urgent necessity for stringent international compliance with the International Maritime Dangerous Goods (IMDG) Code and the development of proactive resilience strategies. This report serves as a critical evaluative tool for port authorities to enhance safety protocols and mitigate the risks associated with the long-term storage of volatile chemical precursors.

KEEWORDS: Ammonium nitrate, Fault Tree Analysis, maritime risk, Beirut explosion, port safety.

Biodiesel Competency Framework for Engine Cadets to Support Indonesia's National

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ABSTRACT

As an archipelagic nation with a rapidly growing domestic shipping sector, Indonesia has committed to reducing its dependence on fossil fuels by mandating the use of biodiesel blends—currently B30 (30% biodiesel) and transitioning toward B40. These mandates are integral to Indonesia's national energy mix and its Nationally Determined Contributions under the Paris Agreement. However, palm oil-based biodiesel presents unique operational challenges, including increased risk of microbial growth, filter clogging, cold-flow issues even in tropical climates, and potential impacts on engine durability. Despite these complexities, maritime education curricula in Indonesia rarely provide systematic training on the handling, storage, and maintenance of biodiesel fuels, leaving engineering cadets ill-prepared to manage the fuels they will encounter on domestic vessels. This study addresses that gap by developing and piloting a competency-based training module on B30/B40 biodiesel specifically for engine cadets at Sekolah Tinggi Ilmu Pelayaran Jakarta (STIP Jakarta). The purpose is to equip cadets with the technical knowledge and practical skills required to safely operate and maintain engines using biodiesel blends, thereby reducing the risk of operational failures and supporting the national energy transition. A developmental research approach was used, comprising three phases: a needs analysis involving surveys and focus groups with engine instructors, manning agencies, and shipping companies operating in Indonesian waters; the design of a short-course module that integrates classroom instruction, laboratory analysis of biodiesel samples, and case-based scenarios; and a pilot implementation with 40 cadets, evaluated through pre – and post-tests, practical troubleshooting assessments, and structured feedback. The needs analysis revealed that most instructors had limited practical experience with biodiesel, and that no standardized training materials existed. The pilot results showed a 45% improvement in

knowledge scores, with cadets demonstrating competence in identifying fuel degradation signs, selecting appropriate filtration, and troubleshooting common biodiesel-related engine issues. The principal contribution of this study is a structured competency framework and a replicable training module tailored to the Indonesian context. By integrating biodiesel-specific content into the engineering curriculum, the research addresses an urgent industry need and strengthens the alignment between maritime education and national energy policy.

KEEWORDS: Biodiesel; B30/B40; engine cadets; competency framework; Indonesian domestic shipping.

Application of HAZOP Methodology for Risk Assessment in Chemical Tanker Tank Washing Operation

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ABSTRACT

Chemical tanker vessels are vital to global maritime trade, safely transporting hazardous and sensitive liquid cargoes. Among shipboard activities, tank washing is one of the most environmentally sensitive and operationally complex processes, requiring strict adherence to international regulations. This operation is essential to remove residues, prevent cross-contamination, and prepare for subsequent loads. However, the process generates significant volumes of wash water containing chemical residues, governed strictly by MARPOL 73/78 Annex II. The inherent complexity of washing machines, stripping systems, and slop tanks creates various opportunities for process deviations that may lead to environmental pollution, safety hazards, or regulatory non-compliance.

This study employs the Hazard and Operability (HAZOP) methodology to systematically identify and evaluate potential hazards within the tank washing system of a chemical tanker. By applying standardized guide words (e.g., NO, MORE, LESS) to process parameters such as flow, pressure, and temperature, the study identifies latent risks not always apparent in routine checks. The analysis was conducted across four operational nodes: prewash, main washing/recirculation, slop tank transfer/stripping, and shore discharge.

A total of thirty-four deviations were identified: nine classified as HIGH risk, eighteen as MEDIUM, and seven as LOW. The highest-risk scenarios involved slop tank overflows and inadequate prewash procedures for MARPOL Annex II Category X cargoes, both of which pose severe environmental threats. Human factors, specifically procedural non-compliance and communication failures, were prominent contributing causes. Furthermore, the study explores how digital monitoring technologies—such as automated flow meters and integrated alarms—can mitigate these risks. The findings demonstrate that a proactive, HAZOP-informed approach provides critical hazard visibility, offering a practical pathway toward more sustainable and compliant chemical tanker operations.

KEEWORDS: HAZOP, Tank Washing Operations, Chemical Tanker, MARPOL Annex II, Marine Environmental Protection, Risk Assessment.

1. INTRODUCTION

1.1. Background and Operational Risks

Chemical tanker vessels are the backbone of global maritime trade, tasked with the safe transportation of hazardous and sensitive liquid cargoes. These operations are governed by strict international regulations, primarily MARPOL 73/78 Annex II, which sets the standards for the control of pollution by noxious liquid substances in bulk. Among shipboard activities, tank washing is identified as one of the most environmentally sensitive and operationally complex processes, essential for removing cargo residues, preventing cross-contamination, and ensuring vessel readiness for subsequent loads. However, the inherent complexity of washing machines, stripping systems, and slop tanks—combined with factors such as flammable, toxic chemical residues, enclosed space entry, and fluctuations in pressure or temperature—renders these operations high-risk. Incidents involving leakages, fires, explosions, or exposure can lead to severe consequences for personnel safety, vessel integrity, and the marine environment (Ay et al., 2022; Güler et al., 2024; Fuentes-Bargues et al., 2017).

Consequently, implementing systematic and proactive risk analysis methods in tank cleaning processes has become critical for both compliance with international regulations and the effectiveness of safety management systems (De J. Penelas & Pires, 2021; Lee & Chang, 2014; Fuentes-Bargues et al., 2017). Hazard and Operability (HAZOP) analysis is one of the most widely used methods in the process industry for identifying hazards and operability problems. It is a structured process hazard analysis methodology applicable throughout the entire lifecycle of a system, from design to decommissioning (Mocellin et al., 2022; Marhavilas et al., 2020; De J. Penelas & Pires, 2021; Fuentes-Bargues et al., 2017). By utilizing guide words and process parameters, HAZOP systematically examines deviations from the design intent to reveal potential causes, consequences, and existing layers of protection (Mocellin et al., 2022; De J. Penelas & Pires, 2021; 2022; Fuentes-Bargues et al., 2017). In literature, HAZOP has been successfully applied to refineries, crude oil production units, storage terminals, volatile organic compounds (VOC) recovery systems, and inert gas systems, contributing to risk reduction through numerous additional recommendations (Jung et al., 2025; Marhavilas et al., 2020; De J. Penelas & Pires, 2021; 2023; Lee & Chang, 2014; Fuentes-Bargues et al., 2017).

Despite its proven success in other sectors, detailed HAZOP-based risk assessments specifically for tank cleaning operations on chemical tankers remain limited in the maritime field. Existing studies focus more on subsystems such as loading/unloading, VOC control, or inert gas systems (Ay et al., 2022; Güler et al., 2024; Durukan et al., 2024; Lee & Chang, 2014). This study aims to apply the HAZOP methodology directly to chemical tanker tank cleaning processes to identify deviations based on equipment and operational steps, determine critical hazards, and develop operational/technical improvement recommendations. By doing so, the research seeks to fill the gap in current literature and contribute to the systematic reduction of fire, explosion, leakage, and environmental pollution risks in chemical tanker operations.

1.2. Environmental Rationale and Impact

Tank washing operations on chemical tankers represent a significant source of potential marine pollution due to the discharge of wash water containing residues of hazardous and noxious liquid substances. Even when conducted in accordance with international regulations such as MARPOL Annex II, these discharges may still pose environmental risks depending on the nature, concentration, and persistence of the substances involved.

One of the primary environmental concerns is the toxicity of residual chemicals present in tank washings. Many chemical cargoes transported in bulk exhibit acute or chronic toxic effects on marine organisms. When discharged into the sea, these substances can affect phytoplankton, zooplankton, fish, and benthic organisms, potentially disrupting the marine food chain. Substances classified under Category X are considered to present a severe hazard to either marine resources or human health, justifying the strict requirement for mandatory prewash and shore discharge.

Another critical factor is bioaccumulation; whereby certain chemical compounds accumulate within the tissues of marine organisms over time. Persistent substances, especially those categorized as “persistent floaters,” may not readily degrade in the marine environment and can remain in surface waters or sediments for extended periods. This leads to long-term ecological consequences, including reduced biodiversity and contamination of higher trophic levels, ultimately impacting human consumers through the seafood chain.

The physical behaviour of discharged substances also plays a key role in determining environmental impact. Depending on their density and solubility, chemicals may float, dissolve, or sink. Floating substances can spread over large surface areas, forming thin films that reduce oxygen transfer between air and water. Heavier substances may settle on the seabed, affecting benthic habitats and organisms. Soluble substances, on the other hand, may disperse more widely but still exert toxic effects at lower concentrations.

In addition, cumulative discharges from multiple vessels operating in busy shipping routes or designated areas may lead to localized pollution hotspots. Although individual discharges may comply with regulatory limits, their combined effect can exceed the assimilative capacity of the marine environment, particularly in semi-enclosed seas or ecologically sensitive regions.

From a regulatory perspective, MARPOL Annex II establishes strict discharge criteria to mitigate these impacts, including limitations based on distance from land, water depth, and operational conditions. However, the effectiveness of these measures largely depends on proper implementation and compliance onboard. Deviations identified through HAZOP analysis—such as improper prewash procedures or uncontrolled discharge—can significantly increase environmental risk.

To further reduce environmental impact, the adoption of advanced treatment technologies and monitoring systems is recommended. These include improved stripping efficiency, real-time monitoring of discharge parameters, and the use of environmentally friendly cleaning agents. Additionally, increasing awareness and training among

crew members regarding the environmental consequences of tank washing operations is essential.

In conclusion, while regulatory frameworks provide a structured approach to controlling pollution from tank washing operations, the inherent risks associated with chemical residues require continuous attention. A combination of strict procedural compliance, technological innovation, and environmental awareness is necessary to minimize the ecological footprint of chemical tanker operations.

2. HAZOP METHODOLOGY

The Hazard and Operability (HAZOP) study is a structured, team-based technique used to identify potential hazards and operability problems. Originally developed for the chemical industry, its effectiveness in revealing hidden risks within complex maritime systems is well-documented (Crawley and Tyler, 2015).

The methodology involves examining a process by applying a series of standardized guide words (e.g., NO, MORE, LESS) to specific design parameters (e.g., flow, pressure, temperature) (Aydin, 2023). In this study, the tank washing process was divided into four operational nodes.

Node 1: The cargo tank prewash node.

Chemicals carried by chemical tankers are divided into four categories X, Y, Z and OS (IMO 2022). For MARPOL Annex II Category X substances, the regulations clearly prohibit. Discharge into the sea is prohibited. This includes ports, harbors, anchorages, and coastal waters. The ship cannot discharge any residues or tank washings containing Category X cargo directly overboard. On the other hand if the cargo is Category Y and high-viscosity or solidifying, then: Mandatory prewash must be carried out at the port of unloading. In this case Category Y cargoes are treated similarly to Category X under specific conditions and same regulations shall be complied for Category Y cargoes. Also if the cargo is listed under specific regulations in IBC Chapter 16.2.7, cargo shall be considered as Persistant floater category as per Marpol Annex II regulations which area is shown as highlighted in orange-red in Figure 1. Before any tank washing operations or discharge procedures are carried out, the tank shall be emptied at the port of unloading to the maximum extent according to the ships' procedures and arrangements manual (P&A Manual). A tank from which a category X substance has been unloaded must be prewashed before the ship leaves the port and the resulting wash water and residues must be discharged to a reception facility. The same rules apply when a tank has contained Y substances that are highly viscous, solidifying or persistent floaters (Larsson, K., Carlson, U., & Stålnacke, E. 2024).

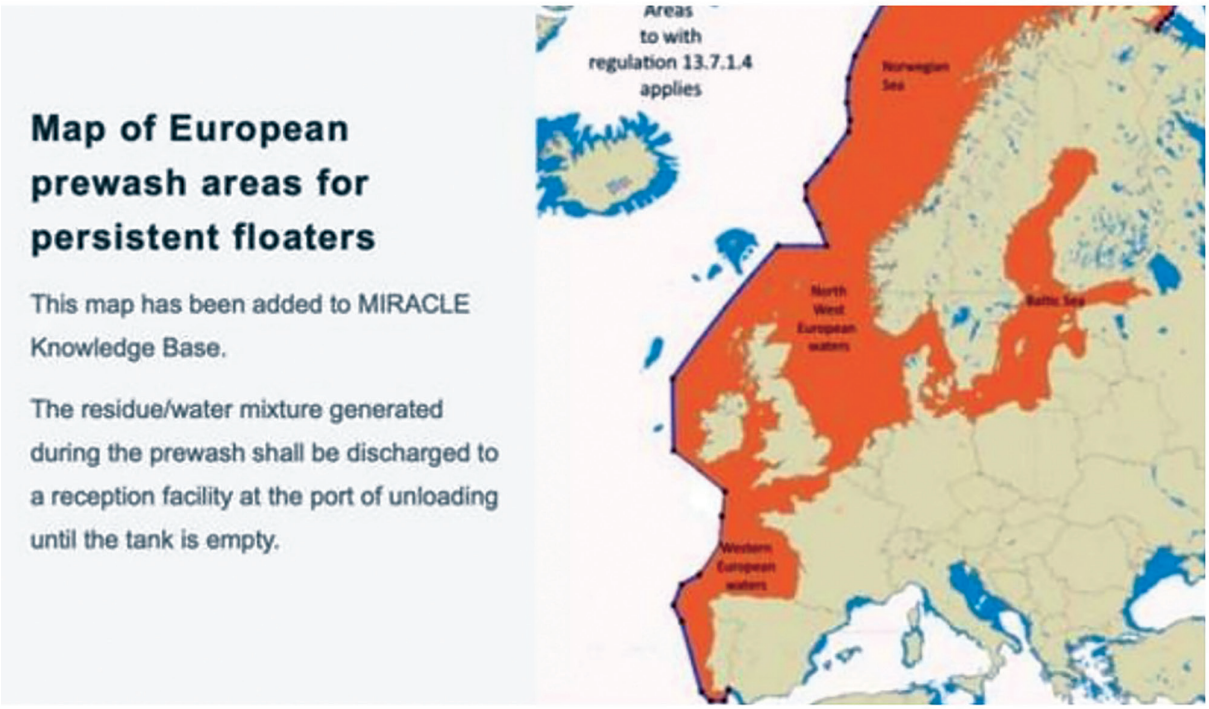

Figure 1. Map of European prewash areas for persistent floaters

Node 2: The main washing and recirculation with detergents node.

MARPOL Annex I regulates oil pollution from ships, including strict rules for discharging oily water overboard. However, MARPOL Annex II regulates for the tank washings can be disposed into sea under several conditions as below:

Annex II Category X Cargoes: Mandatory prewash in port. All residues and washings must go to shore reception facilities. Tanks must be stripped first.

Annex II Category Y Cargoes: Ship must be proceeding en route, Distance shall be greater than 12 nautical miles from nearest land, Water depth shall be equal or greater than 25 meters, Discharge below the waterline through underwater outlet and the discharging area should be outside of the regulation's designated areas. Which are Lat: Southern of 60o South (Around Antartica).

After the initial residues are removed, the main washing stage is carried out using either hot water, cold water, or specialized cleaning chemicals. The choice of washing method depends on the chemical properties of the cargo residue, including solubility, viscosity, and reactivity.

In some cases, detergents or specialized tank cleaning chemicals are used to dissolve stubborn residues that cannot be removed by water alone.

Node 3: The slop tank transfer and stripping node.

The slop tank transfer and stripping node represents a critical stage in the tank washing process, involving the transfer of contaminated wash water from cargo tanks to the slop tank, followed by the stripping of residual liquids from cargo lines and tank bot-

toms. This operation ensures that remaining cargo residues are effectively removed and managed in accordance with environmental regulations, particularly MARPOL Annex II.

Due to the involvement of multiple interconnected systems—including stripping pumps, transfer lines, valves, and level gauging systems—this node presents a high potential for operational deviations. Improper execution may lead to serious consequences such as marine pollution, cargo contamination, and non-compliance with regulatory requirements.

Within the HAZOP framework, this node was analyzed by applying standard guide words (e.g., no, more, less, high) to key process parameters including flow, level, and pressure.

One of the most critical deviations identified is more level, which occurs when the slop tank level exceeds its safe operational capacity. This may result from failure of the level gauging system, continuous transfer without adequate monitoring, or incorrect valve alignment. The consequences of this deviation are severe, including overflow of contaminated wash water into the marine environment, leading to significant pollution and violation of MARPOL Annex II regulations. Existing safeguards include high-level alarms, automatic pump shutdown systems, and independent level measurement devices.

Another significant deviation is no flow in the stripping line, typically caused by pump failure, pipeline blockage, or incorrect valve positioning. This results in incomplete removal of cargo residues, increasing the risk of cross-contamination during subsequent cargo operations. Preventive measures include regular maintenance of stripping systems, line flushing procedures, and pre-operation verification checks.

The deviation less flow may arise due to partial blockages, reduced pump efficiency, or leakage within the transfer system. This condition leads to inefficient stripping and prolonged operation time, which may increase crew exposure to hazardous vapors. Safeguards include flow monitoring instruments and routine inspection of pipelines and pumps.

In addition, high pressure conditions may occur due to downstream valve closure or blockage in discharge lines. This can lead to equipment damage, pipeline rupture, and potential safety hazards for crew members. Pressure relief valves, alarm systems, and strict valve operation procedures serve as primary safeguards.

Overall, the HAZOP analysis indicates that the slop tank transfer and stripping node is one of the most critical phases of tank washing operations, requiring both reliable technical safeguards and strict adherence to operational procedures. Human factors, particularly improper valve handling and insufficient monitoring, play a significant role in the occurrence of deviations within this node.

Node 4: The shore discharge node.

The shore discharge node constitutes the final stage of the tank washing process, involving the transfer of collected tank washings and residues from the vessel's slop tanks to designated shore reception facilities. This operation is critical for ensuring full

compliance with MARPOL Annex II requirements, particularly for Category X and certain Category Y cargoes, where discharge into the marine environment is strictly prohibited. The process requires precise coordination between ship and shore personnel, as well as the proper functioning of transfer systems, valves, pipelines, and pressure control mechanisms.

Due to the ship–shore interface, this node is particularly vulnerable to operational and communication-related deviations. within the HAZOP framework, guide words such as no, more, less, reverse, and high were systematically applied to key parameters including flow, pressure, and direction.

One of the most critical deviations identified is reverse flow, which occurs when back-pressure from the shore facility causes discharged liquid to flow back into the vessel. this may result from non-return valve failure, improper line isolation, or pressure imbalance between ship and shore systems. the consequences include contamination of onboard systems, potential mixing of incompatible substances, and increased safety risks for crew members. safeguards include the installation of non-return valves, implementation of double-block-and-bleed arrangements, and verification of pressure conditions prior to transfer operations.

Another important deviation is more flow, typically caused by excessive pumping rates or incorrect valve configurations. this can lead to overloading of shore reception facilities, increased stress on transfer hoses, and a heightened risk of leakage or spillage. control measures include regulated pumping procedures, continuous communication with shore personnel, and the use of flow control valves.

The deviation no flow may occur due to closed valves, line blockages, or malfunctioning shore reception systems. this condition results in operational delays and prolonged onboard storage of hazardous residues, increasing both safety and environmental risks. preventive actions include pre-transfer system checks, verification of line readiness, and established contingency procedures.

Overall, the HAZOP analysis demonstrates that the shore discharge node is highly dependent on effective coordination, procedural compliance, and reliable system design. Human factors—particularly communication failures and inadequate procedural adherence—significantly contribute to the likelihood of deviations. Therefore, strict operational discipline, supported by technical safeguards and real-time monitoring systems, is essential to ensure safe and compliant discharge operations.

3. RESULT AND DISCUSSION

3.1. HAZOP Worksheet and Critical Findings

The analysis identified a total of 34 deviations across the four nodes. The findings are categorized by their risk level using a matrix that combines likelihood and severity scores.

Table 1. Detailed HAZOP Worksheet Extract

Node	Parameter	Deviation	Cause	Consequence	Safeguards
1. Prewash	Flow	NO FLOW	Valve misalignment or pump failure.	Incomplete removal of Category X residues; MARPOL violation.	Pressure alarms; crew checklist verification.
2. Main Wash	Temp.	MORE TEMP	Heat exchanger malfunction.	Degradation of tank coating; release of toxic vapors.	Temp. sensors with high-temp shutoff.
3. Slop Transfer	Level	HIGH LEVEL	Failure of gauging system; incorrect valve routing.	HIGH RISK: Slop tank overflow; severe marine pollution.	High-level alarms with automatic pump shutoff.
4. Shore Discharge	Flow	REVERSE FLOW	Back-pressure from shore; non-return valve failure.	Contamination of ship systems; uncontrolled residue release.	Double-block-and-bleed valves; pressure checks.

Node 1 – Prewash Operation: Deviation NO FLOW (guide word: NO applied to flow parameter) was identified when the tank washing machine supply line is blocked or the pump fails. Cause: valve misalignment or pump mechanical failure. Consequence: incomplete removal of Category X cargo residues, potential MARPOL Annex II violation and marine pollution. Safeguard: pressure alarms on the washing line, regular pump maintenance schedule, and crew checklist verification before commencing prewash.

Node 2 – Main Washing and Recirculation: Deviation MORE TEMPERATURE (guide word: MORE applied to temperature parameter) was identified when washing water temperature exceeds the recommended range. Cause: heat exchanger malfunction or incorrect steam supply setting. Consequence: degradation of tank coating, potential release of VOCs, and risk of crew exposure to toxic vapors. Safeguard: temperature sensors with high-temperature shutoff, personal protective equipment (PPE) requirements, and ventilation system activation protocols.

Node 3 – Slop Tank Transfer and Stripping: Deviation HIGH LEVEL (guide word: MORE applied to level parameter) was identified when the slop tank level exceeds its capacity. Cause: failure of level gauging system or incorrect valve routing during transfer. Conse-

quence: overflow of contaminated wash water to sea, severe marine pollution, and MARPOL violation with potential port state control detention. Safeguard: high-level alarms with automatic pump shutoff, independent level gauging backup, and dedicated officer oversight during transfer operations. For every chemical cargo listed in the IBC Code, the table shows:

Node 4 – Shore Discharge: Deviation REVERSE FLOW (guide word: REVERSE applied to flow parameter) was identified when a back-pressure event from the shore reception facility causes wash water to flow back into the vessel. Cause: inadequate isolation of the ship-shore connection or failure of the non-return valve. Consequence: potential contamination of ship systems and uncontrolled release of chemical residues. Safeguard: double-block-and-bleed valve arrangement at manifold, pre-connection pressure checks, and dedicated shore connection procedure.

For MARPOL Annex II Category X substances, the rules are simple. Discharge into the sea is prohibited. This includes ports, harbors, anchorages, and coastal waters. The HAZOP analysis was also cross-referenced with applicable regulatory requirements, including MARPOL 73/78 Annex II, the IBC Code, and the ISM Code, to assess whether existing onboard safeguards provide sufficient protection against identified deviations. It was found that while regulatory requirements mandate prewash procedures for Category X cargoes and discharge restrictions for Category Y cargoes, the specific technical safeguards required to prevent deviations – such as automated alarm systems and remote monitoring capabilities – are often left to the discretion of individual operators. This regulatory gap represents a systemic vulnerability that warrants further attention from flag state administrations and classification societies.

3.2. Risk Profile and the Human Element

Of the 34 deviations, 9 were classified as HIGH risk, 18 as MEDIUM, and 7 as LOW. The high-risk scenarios are predominantly associated with slop tank overflows and inadequate prewash of MARPOL Annex II Category X cargoes, which prohibit any discharge into the sea.

A significant finding of this study is the impact of the human element. A large proportion of deviations were linked to procedural non-compliance and communication failures between deck officers and engine room personnel. This aligns with literature suggesting that comprehension and workload of procedural information are critical to maritime safety.

3.3. Mitigation and Recommended Actions

To address the identified risks, the study recommends a structured prioritization of actions:

a. **Immediate (within 24h):** Review of valve alignment procedures and communication protocols during high-risk nodes.

b. **Short-term (one voyage):** Implementation of targeted training programs and drill scenarios based on the HAZOP results.

c. **Long-term:** Adoption of digital monitoring technologies, such as automated flow meters and remote level gauging systems, to reduce human error and provide a digital audit trail for inspections.

CONCLUSION

This study applied the HAZOP methodology to systematically analyze the risks associated with tank washing operations on chemical tanker vessels, with particular focus on their implications for marine environmental protection. By defining four operational nodes and applying HAZOP guide words to each relevant process parameter, the analysis identified 34 distinct deviations, of which 9 were classified as HIGH risk due to their potential to cause significant marine pollution or regulatory non-compliance.

The findings highlight that the most critical risks are concentrated in the prewash and slop tank transfer nodes, and that human error is a significant contributing factor in the majority of identified deviation scenarios. These results underscore the need for improved procedural controls, enhanced crew training, and the adoption of digital monitoring technologies to reduce the likelihood of process deviations during tank washing operations.

The study also identified a regulatory gap regarding the technical safeguards required to prevent HAZOP-identified deviations and recommends that flag state administrations and classification societies consider incorporating HAZOP-based risk assessment into the periodic survey requirements for chemical tankers. The integration of HAZOP results into shipboard Safety Management Systems represents a practical and effective pathway toward more proactive environmental risk governance in the chemical tanker sector.

Future research should aim to validate the HAZOP findings through quantitative risk assessment (QRA) techniques, such as fault tree analysis (FTA) and event tree analysis (ETA), to assign numerical probability values to the identified deviations and further refine risk prioritization. Additionally, comparative HAZOP studies across different vessel types and cargo categories would provide a broader evidence base for industry-wide safety improvements.

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The Effects of Climate Change on Human Physiology

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ABSTRACT

The maritime environment is widely recognized as one of the most physically and psychologically demanding occupational settings. Unlike land-based professions, seafarers are required to operate in confined spaces under continuous motion, vibration, and irregular working schedules for prolonged periods. These unique working conditions expose individuals to multiple environmental stressors that significantly affect human physiological systems. This study aims to examine the effects of life at sea on human physiology by analyzing the interaction between environmental factors and biological adaptation mechanisms One of the most critical physiological challenges in maritime life is the disruption of the circadian rhythm. The shipping industry predominantly operates on a shift-based watchkeeping system, commonly structured as 4-hours-on and 8-hours-off rotations. Such irregular and fragmented sleep patterns interfere with the natural regulation of melatonin secretion, leading to circadian desynchronization. As a result, seafarers frequently experience chronic sleep deprivation, reduced cognitive performance, decreased alertness, and an increased risk of human error. Over time, these disruptions may contribute to serious health conditions, including cardiovascular diseases, metabolic disorders, and gastrointestinal problems. Additionally, limited exposure to natural sunlight, particularly for personnel working in enclosed areas such as engine rooms, may result in vitamin D deficiency and weakened immune system function.

Another important aspect of physiological impact is related to the vestibular system, which is responsible for maintaining balance and spatial orientation. Continuous ship motion creates a sensory conflict between the vestibular and visual systems, often leading to motion sickness, also known as kinetosis. Although the human body demonstrates the ability to adapt to such conditions through neuroplasticity, this adaptation process is not without consequences. In some cases, seafarers may experience Mal de Debarquement Syndrome after returning to land, where the sensation of motion persists despite the absence of actual movement.

Furthermore, the musculoskeletal system is significantly affected by the dynamic conditions onboard ships. Even during periods of rest, individuals must constantly perform micro – adjustments to maintain balance on a moving surface. This continuous physical demand leads to increased muscle fatigue, spinal loading, and a higher prevalence of chronic musculoskeletal disorders, particularly in the lower back and joints. Environmental factors such as constant engine vibration and high noise levels also contribute to long-term health issues, including sensorineural hearing loss and elevated In conclusion, although the human body exhibits remarkable adaptability to maritime conditions, prolonged exposure to such an environment poses substantial health risks. This study highlights the importance of addressing the physiological challenges faced by seafarers and emphasizes the need for improved working conditions. Recommendations include the implementation of optimized shift schedules, ergonomic ship design, and the use of circadian-friendly lighting systems. Prioritizing the well-being of seafarers is essential not only for occupational health but also for ensuring safety and efficiency in maritime operations.

KEEWORDS: Maritime Physiology, Circadian Rhythm Disruption, Seafarer Health, Vestibular System, Occupational Stress.

INTRODUCTION

Maritime occupations are widely recognized as one of the most demanding work environments due to their unique combination of physical, environmental, and psychological stressors. Seafarers operate under conditions that significantly differ from land-based professions, including prolonged isolation, confined living spaces, irregular working hours, continuous exposure to ship motion, and limited access to natural environmental cues such as sunlight.1

The relevance of this research lies in the increasing awareness of occupational health risks in maritime industries. Fatigue-related accidents, reduced cognitive performance, and chronic health conditions among seafarers have raised serious concerns regarding both safety and operational efficiency. Understanding how maritime conditions influence human physiological systems is essential for developing preventive strategies and improving working conditions.

This study focuses on three major physiological domains affected by maritime life: circadian rhythm regulation, vestibular system adaptation, and musculoskeletal responses. Additionally, environmental stressors such as noise, vibration, and limited sunlight exposure are examined in relation to long-term health outcomes.

RESEARCH METHODOLOGY

This study was conducted as a narrative literature review. Scientific publications were collected from PubMed, Scopus, and Web of Science databases using keywords such as maritime physiology, seafarer health, circadian rhythm disruption, and motion sickness.

Only peer-reviewed articles published in English and directly related to physiological or occupational health effects in seafarers were included. Approximately 40 studies 3 were screened, and 15 key sources were selected based on relevance and scientific contribution.

Obtained Results and Discussion

Circadian Rhythm Disruption

One of the most significant physiological challenges in maritime life is circadian rhythm disruption. The commonly used watchkeeping system leads to fragmented sleep and misalignment with the natural light-dark cycle. This disruption negatively affects melatonin secretion and sleep quality, resulting in chronic fatigue and decreased alertness.

Sleep deprivation impairs cognitive performance, reaction time, and decision-making ability, significantly increasing the risk of human error in maritime operations. Long-term circadian disruption is associated with cardiovascular diseases, metabolic disorders, and gastrointestinal dysfunction. Additionally, limited sunlight exposure may lead to vitamin D deficiency, which negatively impacts immune function and bone health.

Vestibular System and Motion Sickness

The vestibular system is essential for maintaining balance and spatial orientation. Continuous ship motion creates a mismatch between visual and vestibular inputs, resulting in motion sickness.Although the human body adapts through neuroplasticity, individual differences influence the adaptation process. In some cases, individuals develop Mal de Debarquement Syndrome (MdDS), characterized by persistent sensations of motion even after returning to land.

Musculoskeletal System Adaptation

Seafarers are constantly required to maintain balance on unstable surfaces, resulting in continuous activation of postural muscles. This leads to increased muscle fatigue, spinal loading, and a higher prevalence of musculoskeletal disorders. Whole-body vibration further exacerbates these conditions, contributing to chronic lower back pain and reduced functional capacity.

Environmental Stressors: Noise and Vibration

Maritime environments are characterized by high levels of noise and vibration. Prolonged exposure to noise can lead to sensorineural hearing loss and increased stress hormone levels. Noise and vibration are also associated with sleep disturbances and cardiovascular strain, amplifying the negative effects of circadian disruption.

Integrated Physiological Response

The combination of environmental and occupational stressors activates the hypothalamic-pituitary-adrenal (HPA) axis, leading to elevated cortisol levels. Chronic stress negatively affects immune function, metabolic regulation, and cardiovascular health. Therefore, maritime physiology should be evaluated using a holistic approach that integrates both physical and psychological factors.

CONCLUSION

Maritime life presents a complex and demanding environment that significantly impacts human physiology. Although the body demonstrates adaptive capacity, prolonged exposure to maritime conditions leads to substantial health risks. Key findings include: circadian rhythm disruption leading to sleep and metabolic disorders, vestibular challenges causing motion sickness, increased musculoskeletal load resulting in chronic pain, and environmental stressors contributing to hearing loss. Recommendations include the implementation of circadian-friendly shift systems, improvement of ergonomic ship design, and regular health monitoring programs.

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Prospects for Realizing the Transit Potential of the Eurasian Economic Union in the System of International Transport Corridors

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ABSTRACT

The article explores the strategic geographic position of the Eurasian Economic Union at the intersection of major trade routes, which gives it significant transit potential within the global transport network. It highlights that the transit potential of the Eurasian Economic Union is currently underutilized due to the region's transport and logistics infrastructure's weak competitiveness and the lack of a comprehensive, unified transport system. The author argues that underutilizing this transit potential denies member countries an additional source of government revenue, thereby impeding their economic growth.

KEEWORDS: transit potential of the Eurasian Economic Union, transport corridor, logistics infrastructure.

INTRODUCTION

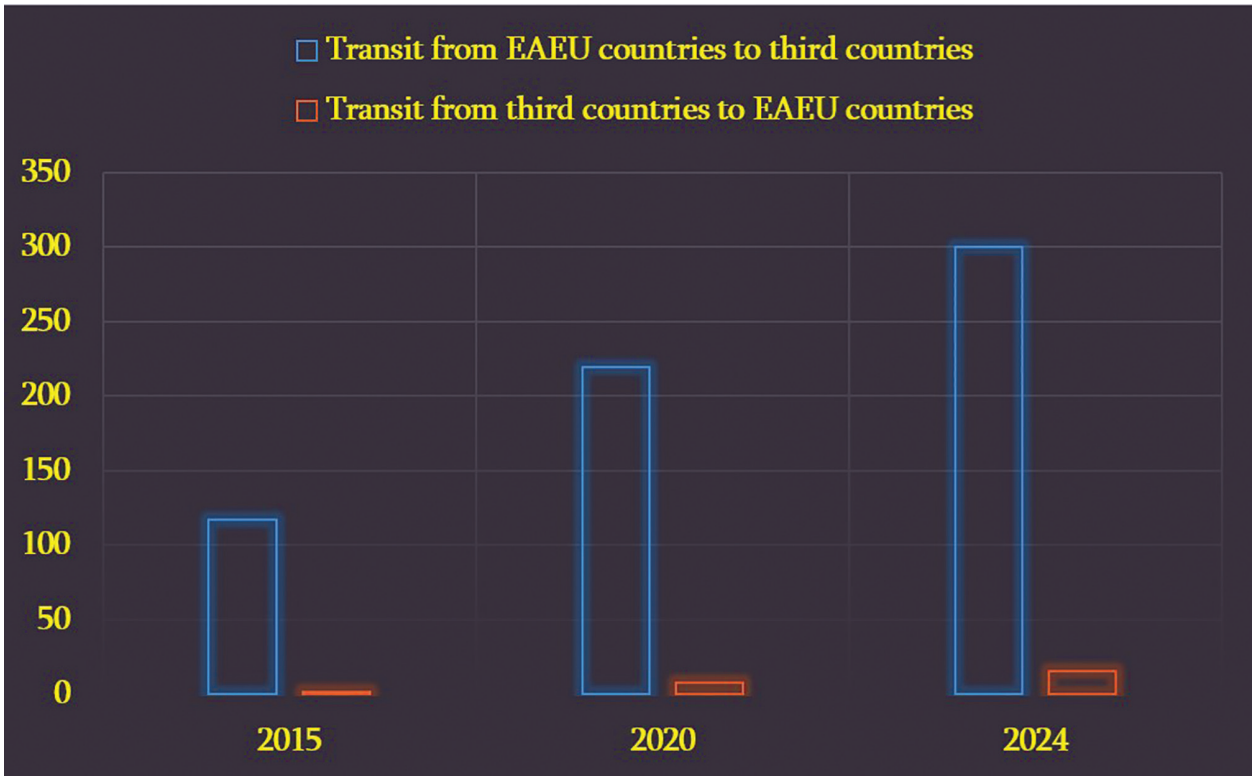
Creating a modern transit system through the development of the EAEU ITC can help deepen transportation and logistics cooperation within the EAEU as part of Eurasian economic integration, ultimately boosting competitiveness. Building a comprehensive EAEU transit infrastructure can promote growth in internal connections, leading to increased bilateral trade, higher investment inflows, and the development of large cross-border projects. Effective transit communication can also support the economic unity of EAEU member states and strengthen relationships between their producers, encouraging coop-

eration within new transport value chains based on multimodality and integrated services. According to OECD calculations, a 10% boost in transport productivity results in a 0.8% rise in GDP.

DISCUSSION

The structure of EAEU transit communications is primarily driven by transit traffic from EAEU countries to third nations through the EAEU (internal transit). In contrast, transit from third countries to third countries via the EAEU accounts for only 3.5% of the total transit volume. Due to duty-free transportation within the single customs territory, transit from one endpoint to another has become the main source of budget revenue for transit countries. Overall, the integration processes of the EAEU have helped boost end-to-end transit, which increased fourfold in volume from 2015 to 2015, with a forecast reaching up to 16 million tons by 2025 (Figure 1).

Diagram 1. Structure of transit shipments in the territories of the EAEU countries, million tons.



Source: National Transport Agencies of EAEU Countries: URL: http://www.armstat.am, http://www.belstat.gov.by, http://www.stat.gov.kz, http://www.stat.kg, http://www.gks.ru

Today, less than 1% of the total volume of international cargo transported between the East and the West passes through the territory of the EAEU. In contrast, in 1982, the USSR accounted for 20% of the same figure. According to UNCTAD, in 2024, regional trade reached

800 billion dollars, and by 2027, it is projected to grow to 1.2 trillion dollars, equivalent to 240 million tons of cargo. Of this, 170 million tons (about $ 800 billion) will stem from the EU's trade with China. Up to 90% of trade between Asia-Pacific countries and the EU moves via the Southern Sea Route through the Suez Canal. The annual volume of containerized sea freight from the EU to China is 4.5 million TEU, while in the opposite direction it is 11.2 million TEU, with an average transit time of 35-40 days. In the future, the Suez Canal may struggle to handle the growing cargo volume, freeing up capacity for the EAEU. Land transportation costs within the EAEU are roughly twice those of sea transportation, but the main advantage of land transit is its speed, which is two to three times that of sea routes. Therefore, land transit within the EAEU remains economically viable mainly for goods where speed is essential, such as high-value items or perishable foods. Consequently, the primary goal of transport and logistics cooperation with the EAEU in transit should be to develop effective tools to reroute maritime cargo flows from China to the EAEU's land territory, and to establish alternative, competitive routes for Eurasian freight movement.

The developing transport corridor system of the EAEU consists of two Eurasian corridors – the "East-West" and "North-South," which are connected, respectively, to Pan-European corridors No. 2 and No. 9. The East-West corridor begins in the ports of Nakhodka and Vladivostok, follows the Trans-Siberian railway route to Moscow, and then joins Pan-European corridor No. 2 via Minsk and Warsaw to reach Berlin. The North-South corridor starts in Helsinki and then coincides with Pan-European corridor No. 9—through the ports of St. Petersburg and the Leningrad region to Astrakhan, then through Iran to the port of Bandar Abbas, heading toward the Persian Gulf and India. The East-West corridor of Eurasia focuses on transporting cargo not only from China but also from Japan, South Korea, Indonesia, Malaysia, and Singapore to the European Union. Russia and Kazakhstan have expressed strong interest in developing this corridor, vying for transit cargo—they are both partners and competitors. The transit potential of the EAEU in this direction exceeds 1 million TEU, with the annual value of container transit alone surpassing $2 billion. Currently, experts from the International Discussion Club of Experts estimate it is loaded at only 30-35%. It appears that full-capacity loading could increase competition between the Russian and Kazakh segments for transit cargo, but in the long run, having both options will likely encourage policies to equalize tariffs for land transit across the EAEU, as rail transit has traditionally received budget subsidies. The core of the Russian segment of the East-West corridor remains the Trans-Siberian Railway, which has served as the primary land bridge between Europe and Asia since the 19th century. Transportation via the Trans-Siberian allows for the crossing of 8,000 kilometers and shortens routes from Europe to Asia, saving 10-20 days in transit time. In 2024, the volume of container traffic on this railway reached 700,000 TEU, exceeding transit from third countries and highlighting the advantages of domestic transit. To modernize this transport route, Russia allocated 562 billion rubles (around 6 billion USD) from the National Welfare Fund, the JSC Russian Railways budget, and other state funds.

The multimodal status of the North-South Corridor of Eurasia should be strengthened by establishing ferry services with a maritime transportation component. Plans

include transforming the ports of Olya and Aktau into primary maritime hubs along the corridor. However, the limited infrastructure development at both ports and their focus on processing a narrow range of cargoes hinder the creation of a competitive transport and logistics value chain in this region. Olia Port's current infrastructure can handle 1.7 million tons of dry cargo annually, accounting for less than 5% of the total shipping volume in the Caspian Sea. In 2024, cargo throughput at Olia was approximately 300 thousand tons. The port of Aktau primarily exports oil and oil products to Europe via Baku. A major obstacle to executing Kazakhstan's program is redirecting some export flows to the European Union, which requires either routing through Russian territory or using tankers through Azerbaijan and Turkey, due to Kazakhstan's underdeveloped tanker fleet. Aktau's shallow waters (10 m depth) limit its ability to accommodate larger tankers; it can handle tankers with a deadweight of 3-5 thousand tons, while a 13-thousand-ton tanker is considered optimal for this route. By 2015, Kazakhstan's tanker fleet consisted of 20 vessels, which were insufficient to transport 3.5 million tons of oil. By 2028, plans aim to increase tanker capacity to 22 million tons, aligned with projected throughput. Additionally, the multimodal trans-Caspian transit route China-Kazakhstan-Azerbaijan, operated by the container ship Nomad Express, exemplifies this; containers are transported by rail from China to Aktau before being ferryed across the Caspian Sea to Kishli near Baku. The average transit time is 5 days, and given the potential of this route, it could generate substantial transit revenue of 300 thousand TEU for Kazakhstan. Effective organization of transit along the developing North-South sections would enable EAEU countries to serve as connecting links in strategically significant yet still partly open Iranian and Indian corridors. Due to similar infrastructural limitations in multimodality, Russia and Kazakhstan are more partners than competitors in the North-South corridor. A key aspect in expanding and deepening transport and logistics cooperation within the EAEU—through the creation of modern value chains—is the Russian socio-economic project Trans-Eurasian Belt Razvitie (TEPR). This project envisions establishing an advanced development zone along the Trans-Siberian Railway and the Baikal-Amur Mainline, centered on a comprehensive infrastructure system that integrates transport, telecommunications, and energy into a unified whole, aligned with a common development goal. The primary objective is to significantly increase transit freight traffic along the Trans-Siberian Railway, leading to a broad socio-economic transformation from dependence on resource extraction to diversified industrial management, with rail transport playing a leading role. This approach aligns with the main aim of Eurasian economic integration: fostering cooperation in non-resource sectors within the EAEU economy. TEPR is more than just a transport corridor; it acts as a structured force for reindustrialization by leveraging advanced technologies and creating industrial clusters within the EAEU and along its eastern and southern transport routes. The initiative to introduce infrastructure integration into the EAEU economy will promote comprehensive growth in socio-economic indicators across member countries, further incentivizing deeper integration.

CONCLUSION

Therefore, the TEPR development vector, integrated into the system of developing transport corridors in Eurasia, can prioritize the growth of regional infrastructure within the EAEU over national projects. At the same time, efficient organization of internal and cross-border transit within the EAEU, through the East-West and North-South international transport corridors, aims to promote the economic unity of the member countries.

Effective transport and logistics cooperation for Georgia, both regionally and transcontinentally within the EAEU, can serve as a foundation for deepening and expanding Eurasian economic integration by developing multimodal transport and improving the quality of transport and logistics services. The transcontinental routes of the EU-EAEU-APR based on the East-West ITC and the EU-EAEU-Iran-India based on the North-South ITC will generally help increase the EAEU's foreign economic and foreign policy influence, which the rapid globalization of the economy will support, optimize the timely delivery of goods, and decrease transport and logistics costs as a proportion of the final price.

Georgia faces a difficult choice in this regard.

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Maritime Logistics, Climate Change and Housing Markets in Cities

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ABSTRACT

This study examines the multifaceted relationship between climate change, maritime logistics, and housing markets in coastal cities. While the existing literature largely focuses on the impacts of climate change on port infrastructure or the consequences of climate risks on real estate markets separately, the interactions between these areas are addressed to a limited extent. To fill this gap, the study is designed as an integrative literature review and conceptual research; it aims to bring together these three literature areas within a single analytical framework. The study examines the impacts of climate-related risks such as sea level rise, coastal flooding, and extreme weather events on port infrastructure and maritime logistics; and evaluates the consequences of these impacts on logistics costs, trade flows, and port competitiveness. In addition, drawing on the literature on housing markets, the effects of climate risks on housing prices, real estate values, and spatial price differentiation are analyzed.

The findings show that the effects of climate change on housing markets occur not only directly but also indirectly through a transmission mechanism via maritime logistics and port systems. This process is particularly decisive in determining housing demand, prices, and spatial inequalities in coastal cities. Furthermore, the higher impact of climate risks on low – and middle-income groups can lead to a deepening of social inequalities in housing markets.

The study proposes a new analytical framework by integrating different literature areas and offers policy and planning implications for coastal cities. In this respect, it both contributes to the academic literature and provides a basis for future empirical research.

KEEWORDS: Maritime Logistics, Climate Change, Housing Markets, Cities.

INTRODUCTION

Global climate change is having profound and multifaceted impacts on economic and urban systems, particularly in coastal regions. Processes such as rising sea levels, coastal erosion, storm surges, and increased extreme weather events pose serious risks to port infrastructure and maritime logistics. The fact that ports are critical infrastructures hosting approximately 80% of global trade shows that these risks directly affect not only logistics systems but also the economic and spatial development dynamics of coastal cities (Asariotis et al., 2024; Semrau, 2025; Koç & Çelik, 2022).

Coastal cities have historically been shaped around port activities; trade, employment, and urban growth have largely depended on maritime activities (Sümer, 2021). In this context, the climate risks faced by ports are not only an infrastructural problem but also a process with critical consequences for the urban economy, spatial structure, and housing markets. Global studies reveal that climate change places port cities among the most vulnerable regions, both physically and economically (Hanson et al., 2011; Hallegatte et al., 2011).

The effects of climate change on maritime logistics result in consequences such as changes in trade routes, increased logistics costs, and the reshaping of port competitiveness (Çavdar, 2025). This transformation directly affects the structure of economic activities in port cities, leading to significant changes in housing demand and urban development dynamics. Studies focusing particularly on port-city interaction emphasize that logistics activities are one of the fundamental elements reshaping urban space (Hesse & McDonough, 2018; Nikolovski & Wiig, 2026).

On the other hand, the literature on the effects of climate change on housing markets is also rapidly developing. Rising sea levels and increasing climate risks are having significant impacts on housing prices, mortgage markets, and real estate values in coastal areas (Keys & Mulder, 2020; Clayton et al., 2021). The pricing of climate risk by financial systems can lead to spatial value differentiation and suppress housing values, particularly in high-risk areas. This is more pronounced in port cities, as they are located at the intersection of both economic concentration and climate risk. Furthermore, climate change has significant social consequences. The increased vulnerability of low – and middle-income groups to climate risks can lead to a deepening of inequalities in housing markets (Federal Reserve Bank of San Francisco, 2019). This demonstrates that the relationship between climate change and urban inequalities is becoming even more critical in the context of port cities. However, a review of the existing literature reveals that studies largely focus either on maritime logistics and port infrastructure or on housing markets and climate risk. Studies that comprehensively address the interactions between port activities, climate change, and urban housing markets are quite limited (Yorulmaz & Baykan, 2023).

The main objective of this study is to analyze how climate change affects housing markets in coastal cities through maritime logistics. The study aims to fill a significant gap in the literature by examining the multifaceted relationship between port activities, climate risks, and urban housing markets within a conceptual and empirical framework.

In this context, the research questions of the study have been determined as follows:

- How do climate change-related risks affect maritime logistics and port activities?
- How do transformations in maritime logistics affect the economic structure and housing markets of coastal cities?
- How do climate change adaptation policies and infrastructure investments shape the future of housing markets?

LITERATURE

The relationship between climate change, maritime logistics, and urban systems has become an increasingly important subject of research in recent years. This literature generally revolves around three main axes: (i) climate impacts on ports and maritime logistics, (ii) port-city relations and urban transformation, and (iii) climate change and housing markets.

Firstly, studies conducted in the context of ports and maritime logistics focus on the physical and operational impacts of climate change on these infrastructures. Rising sea levels, coastal floods, and extreme weather events directly threaten the functioning of port infrastructure (Asariotis et al., 2024). It is stated that these risks have significant impacts on port operations, logistics costs, and trade flows (Semrau, 2025). In addition, the vulnerability of ports to climate change and the inadequacy of adaptation policies to these risks constitute a significant area of discussion in the literature (Karditsa et al., 2025). In this context, engineering solutions such as floating ports, port repositioning, and coastal protection infrastructures stand out (Kurt, 2024).

Secondly, studies addressing the port-city relationship emphasize the role of maritime logistics in shaping urban space. Ports are not only trade infrastructures but also fundamental elements determining the economic and spatial organization of cities (Hesse & McDonough, 2018). Recently, the "logistics-oriented urbanization" approach has revealed that port activities reshape the urban structure and transform urban development through hinterland relations (Nikolovski & Wiig, 2026). Furthermore, it is emphasized that port cities need to be restructured within the framework of sustainability, green economy, and circular economy (Jonas et al., 2017; Van den Berghe et al., 2024; Ribeiro, 2017).

Thirdly, the literature examining the relationship between climate change and housing markets focuses particularly on the impact of climate risks on real estate values. Empirical studies have shown that risks such as rising sea levels reduce housing prices in coastal areas and affect mortgage markets (Keys & Mulder, 2020). Furthermore, the pricing of climate risk by market actors leads to spatial differentiation in real estate values (Clayton et al., 2021). This situation leads to changes in investment behavior, especially in high-risk areas.

However, the social impacts of climate change also hold a significant place in the literature. It is emphasized that low and middle-income groups are more vulnerable to climate risks, and this increases inequalities in housing markets (Federal Reserve Bank of San Francisco, 2019). In this context, climate change is considered not only an environmental problem but also a social and economic one.

Finally, studies examining the relationship between logistics, trade, and climate change in the literature reveal that the global trade system is being restructured in the face of climate change (Çavdar, 2025). Changes in maritime transport directly affect the economic competitiveness of port cities, and this is reflected in urban development dynamics. Overall, while the existing literature makes significant contributions, studies that comprehensively address the interactions between maritime logistics, climate change, and housing markets are limited. This study aims to fill this gap by integrating these three areas.

METHODOLOGY

This study is designed as an integrative literature review and conceptual study examining the interactions between climate change, maritime logistics, and housing markets. In this respect, the study offers a significant theoretical foundation by combining three fundamental areas, which are addressed fragmentarily in the existing literature, into a single analytical framework. It also develops a practical perspective by aiming to generate policy and planning implications for coastal cities. Furthermore, the study presents several opportunities for future research.

Firstly, empirically testing the conceptual model proposed in this study constitutes an important area of research. Future studies could quantitatively examine the climate change-maritime logistics-housing market relationship using panel data, spatial econometric models, or causality analyses. Datasets specifically created for port cities are important for testing the model's validity in different geographical contexts.

Secondly, studies that analyze the spatial dimension of the port-city interaction in greater depth could make significant contributions to the literature. Using geographic information systems (GIS) and spatial data analysis techniques, the distribution of climate risks within cities and the differing effects of these risks on housing prices can be examined. Such studies will help to more clearly reveal spatial value losses, especially in risky areas.

Thirdly, there is a need to increase micro-level studies evaluating the effects of climate change adaptation policies on housing markets. The effects of port infrastructure investments, coastal protection projects, and urban planning strategies on housing demand and prices can be examined through case studies or comparative country studies. In this context, the study emphasizes the importance of policy and planning approaches to be developed for coastal cities and provides a framework for empirical research in this area.

Fourthly, the social dimension needs to be addressed more. In particular, the vulnerability of low – and middle-income groups to climate risks, how inequalities are deepening in housing markets, and the effects of this process on social justice should be a significant focus of future research. In this context, studies examining the effects of climate change on housing accessibility can fill an important gap in the literature.

Finally, the long-term impacts of the transformation in maritime logistics on global trade structures and urbanization processes should be addressed more comprehensively.

In particular, the effects of green port practices, digitalization, and sustainable logistics solutions on urban economies and housing markets can be examined through interdisciplinary approaches. Overall, this study opens a new line of research in the literature by providing a theoretical framework; it also creates a guiding foundation for future empirical studies by generating policy and planning implications for coastal cities.

CONCLUSION AND POLICY RECOMMENDATIONS

This study comprehensively examines the multifaceted relationship between climate change, maritime logistics, and urban housing markets. Designed as both an integrative literature review and a conceptual paper, it establishes an analytical bridge between these three areas, which are often studied separately in the literature. The findings demonstrate that climate change is not merely an environmental problem; it also creates far-reaching economic and spatial impacts through logistics systems, the urban economy, and housing markets.

The most significant finding of the study is that the effects of climate change on housing markets occur not directly, but largely indirectly through a transmission mechanism via maritime logistics and port systems. The vulnerability of port infrastructure to climate risks, increased logistics costs, shifts in trade flows, and transformations in port competitiveness are reshaping the economic structure of port cities; this transformation is decisive in determining housing demand, prices, and spatial value distribution.

Furthermore, the study reveals that the impacts of climate risks on housing markets have not only economic but also social consequences. The fact that low – and middle-income groups are particularly vulnerable to climate change can lead to a deepening of inequalities in housing markets. This situation demonstrates that the relationship between climate change and social justice has become even more critical in the context of coastal cities.

However, the study offers important implications for rethinking the port-city relationship. The transformation in maritime logistics is reshaping the economic structure and spatial organization of cities; in this process, housing markets are becoming one of the areas where climate risks are most concretely felt. Therefore, sustainability and resilience policies in port cities need to be addressed not only through an infrastructure-focused approach but also through a holistic approach encompassing urban development and housing policies.

POLICY IMPLICATIONS

The findings of this study offer important implications for policymakers and urban planners, particularly for coastal cities.

First, enhancing the resilience of port infrastructure to climate change should be a critical priority. Infrastructure investments that provide protection against rising sea levels

and extreme weather events (such as coastal protection systems, floating ports, and port relocation) are essential not only for the sustainability of logistics systems but also for the stability of the urban economy and housing markets.

Second, climate risk integration should be ensured in urban planning processes. Land use, housing development, and infrastructure planning, especially in high-risk coastal areas, should be redesigned taking long-term climate projections into account. In this context, the effective use of risk mapping and spatial planning tools is of great importance.

Third, social policies aimed at reducing inequalities in housing markets need to be developed. Affordable housing policies, insurance mechanisms, and financial support tools should be implemented to protect low – and middle-income groups most affected by climate risks.

Fourth, policies that strengthen port-city integration and promote sustainable logistics systems should be developed. Green port practices, low-carbon transportation systems, and digitalization processes will both enhance environmental sustainability and create positive impacts on the urban economy.

Finally, multi-stakeholder governance mechanisms need to be strengthened in the fight against climate change. Integrated policy approaches should be developed by ensuring coordination between central governments, local governments, port authorities, and the private sector.

In general, this study generates policy and planning implications for coastal cities and offers a new research perspective on understanding the interactions between climate change, maritime logistics, and housing markets. In this respect, the study contributes to the academic literature and presents a strategic framework for implementation.

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Maritime Value Chain towards Environmental Standards for Sustainable Growth from Malaysia Experience

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ABSTRACT

The global maritime industry, facilitating over 80% of international trade by volume, stands at a transformative juncture where economic expansion must be decoupled from environmental degradation. This research examines the maritime value chain as a comprehensive sequence spanning resource extraction, vessel construction, multimodal transport, port operations, and decommissioning through the lens of emerging environmental standards and sustainable growth. The central to this transition is the rigorous regulatory framework established by the International Maritime Organization (IMO), specifically the 2025 Net-Zero Framework and the 2023 Greenhouse Gas Strategy, which introduce mandatory emissions limits and carbon-pricing mechanisms with the aims of Net-Zero carbon by 2050. The analysis explores the integration of Standards and Environmental, Social, and Governance (ESG) criteria as strategic imperatives that enhance transparency, attract green finance, and optimize operational efficiency. The key technological enablers, including alternative fuels such as ammonia and methanol, wind-assisted propulsion, and digital innovations such as Artificial Intelligence and Digital Twins, are evaluated for their potential to drive the sector toward Industry 5.0. Furthermore, the research underscores the critical role of maritime education, stakeholder collaboration, and regional initiatives in Southeast Asia in fostering a resilient, circular blue economy. By aligning regulatory compliance with market-driven incentives, the maritime value chain can achieve long-term viability while safeguarding marine ecosystems for future generations.

KEEWORDS: Maritime Value Chain, Decarbonization, Sustainable Growth, ESG Integration, IMO Net-Zero Framework.

Integrating IMO's GHG Strategy into Engine Curriculum: A Green Simulation Module at STIP Jakarta

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ABSTRACT

Artificial intelligence (AI) is gradually making its way into daily work onboard ships, gradually replacing manual paperwork and printed reference materials. In the engine room, and more specifically within the Engine Control Room (ECR), AI already plays an active role by organizing equipment monitoring data, producing technical repair reports in accordance with International Association of Classification Societies (IACS) standards, and developing Standard Operating Procedures (SOPs) for complex tasks such as high-voltage switchboard servicing or automation system troubleshooting.

The advantages of AI aboard vessels are becoming increasingly evident across engine room. For ship mechanics, AI serves as a powerful maintenance and diagnostic tool. It can analyze vibration patterns, temperature trends, and pressure readings from machinery such as main engines, auxiliary engines, purifiers, and compressors, identifying anomalies before they develop into critical failures. When a defect is detected, AI can instantly compare the data with the equipment's technical manual, suggest probable root causes, and outline a step-by-step repair procedure. It also assists in planning Planned Maintenance System (PMS) schedules, creating work orders, and generating repair reports.

For ship electro-technical officers and electricians, AI proves particularly valuable when dealing with complex electrical and automated systems. Troubleshooting switchboards, frequency converters, programmable logic controllers (PLCs), and integrated automation systems (IAS) can be labor-intensive and dangerous without proper guidance. AI can assist by interpreting alarm logs and fault codes, creating electrical diagrams, and recommending safe shutdown procedures in compliance with onboard permit-to-work systems. When working with high-voltage equipment, where errors carry serious safety

consequences, AI can perform real-time risk assessments and step-by-step switching sequences in real time.

For both maritime occupations, AI is also becoming a practical tool for interpreting complex IMO regulations such as STCW, SOLAS, and MARPOL. Marine engineers and electrotechnical personnel have long struggled to understand the complex legal language of these conventions, and AI can provide clear, equipment-specific regulatory guidance almost instantly when given a well-formulated query.

Maritime English lessons play a foundational role in helping marine engineering students effectively use AI tools, since the quality of interaction with AI depends almost entirely on language proficiency. AI produces accurate results only when given precise, well-structured queries. Maritime English lessons that focus on technical writing and sentence clarity directly train students to formulate effective queries. For example, requesting a repair procedure for a specific piece of equipment rather than asking a vague question.

AI-generated reports, SOPs, and regulatory summaries are produced in technical English. Strong reading comprehension skills allow engineers to critically evaluate, verify, and apply AI responses rather than accepting them blindly.

A solid command of maritime and engineering terminology enables students to communicate with AI using the correct terms, such as "oil sludge removing procedure" instead of "separator cleaning", resulting in far more relevant and useful responses. Maritime English lessons focused on formal writing prepare students to review, edit, and assume responsibility for AI-generated reports and SOPs, ensuring they meet IACS, Flag State, and company standards before submission.

Language learning encourages students to question, paraphrase, and double-check information. These are the essential skills when working with AI, which can occasionally produce inaccurate or outdated technical content. In short, English proficiency is the interface between the maritime engineer and AI. Without it, even the most advanced AI tool becomes difficult to use effectively and safely.

KEEWORDS: AI soft skills, marine engineers, Maritime English proficiency, effective queries.

THE MAIN BODY

The modern maritime industry is changing a lot because of new technology. This is having a huge effect on the work of crews. The digitalisation of ship operations, the automation of monitoring systems and the rapid introduction of AI tools are fundamentally changing the nature of everyday work on board. For example, paper logs are being replaced by intelligent maintenance management systems and printed manuals are being replaced by real-time diagnostic algorithms. In the engine room and engine control centre (ECR), AI is already doing jobs that only an experienced engineer could do ten years ago. These include analysing how equipment is working, spotting problems

early on, writing reports that meet IMO standards and creating accepted ways of doing complicated jobs.

In this context, the role of a ship's mechanic and electromechanic is undergoing a fundamental reassessment. While the traditional model of maritime education primarily trained technicians capable of servicing and repairing specific equipment, then modern conditions necessitate a new type of specialist. This is a competent user of intelligent systems, capable of effectively interacting with AI tools, critically evaluating their results and taking responsibility for the technical decisions made on their basis. This transformation significantly expands the range of competencies required for safe and effective work on board.

At the same time, practice shows that the effectiveness of AI on board a ship is determined not only by technical equipment but also by the language skills of specialists. Since interaction with the vast majority of modern AI systems is conducted in English, the quality of the query formulated directly determines the relevance and accuracy of the response received. A marine engineer unable to clearly formulate technical request or critically read an AI-generated report is actually deprived of the opportunity to fully utilize the potential of these tools. This places fundamentally new demands on Maritime English in the training of marine engineers, making it an essential tool for developing the technological literacy of future maritime specialists.

For marine mechanics or electromechanics, the most important thing to use AI for is the continuous monitoring of engine room equipment. Unlike traditional watchkeeping, AI systems analyze data from vibration, temperature, and pressure sensors on the main engine, auxiliary machinery, separators, and compressors in real time, detecting deviations from the norm long before they develop into a critical failure. This enables a transition from reactive repairs to preventative maintenance, significantly reducing the risk of unplanned downtime at sea. If a malfunction is detected, the AI instantly compares recorded data with the equipment's technical documentation, identifies the most likely root causes of the failure, and generates step-by-step troubleshooting instructions.

AI plays an equally important role in managing planned maintenance (PMS) systems. By analyzing operating hours and the current state of systems, it automatically optimizes maintenance schedules, creates work orders, and monitors their implementation, reducing the administrative burden on watch engineers. Finally, AI tools can automatically generate technical reports and defect information in formats compliant with flag state requirements and IACS standards, reducing the risk of formal errors during port state control inspections.

The success of AI in helping ship mechanics and electromechanics depends on how well the specialist speaks English. In this context, Maritime English acts as a bridge. It is through language that the engineer gives AI a task, gets a result and is responsible for using it. Even if an AI system is technically perfect, it can't make up for a query that is unclear, uses the wrong terms, or is structured poorly. The result of this is that the response from the AI system will also be unclear, irrelevant, or even dangerous.

The first aspect is the accuracy of the wording of queries. Technical writing, which is taught in the Maritime English course, certainly requires cadets to be clear and unambig-

uous about a specific topic, language, and way of thinking. To ensure this, it is essential to include the name of the problem, its nature, the context of the situation, and the format of the report. For example, the query Provide a step-by-step procedure for replacing the fuel injection valve on MAN B&W 6S50MC-C engine while docked in port will generate a qualitatively different answer than the vague How to fix fuel injector? Technical writing exercises, where cadets learn to describe a malfunction, compile a defect report, or formulate a request for a spare part, provide direct preparation for effective interaction with AI.

Equally important is reading comprehension. AI can generate text that sounds technical but is not accurate. It may also contain outdated data or procedures that don't fit the specifics of a particular vessel. A mechanic with developed reading comprehension is able to identify the following inconsistencies. He will recognize a sequence of actions unusual for the equipment, notice a reference to a cancelled standard, or identify a recommendation that contradicts the company's internal safety management system (SMS). Maritime English courses, which include work with authentic technical texts, such as technical manuals, IMO circulars, and accident reports, help cadets to read more critically.

Critical thinking, cultivated through language tasks as paraphrasing, comparing sources, searching for contradictions in the text, is a fundamental skill for working safely with AI. The habit of checking, doubting, and comparing information with other sources is a specialist's conscious attitude toward a technological tool. This is also an important factor for safety.

Integrating AI-oriented tasks into the Maritime English course does not require a radical revision of the program. It is enough to rethink the format of traditional exercises, giving them a practical technological dimension. An effective format is a four-step training cycle: formulating a query, receiving an answer, verification, and editing a report. In the 1st stage, cadets are given a technical situation and have to write a query to the AI in English. The instructor analyzes the group’s queries, paying attention to the accuracy of terminology, sentence structure, and completeness of context. In the 2nd stage, the cadets work with the received AI response. They identify technical terms, determine the structure of the text and check the compliance of the recommended procedure with the existing technical manual. The verification stage involves comparing AI-generated content with authentic sources, such as IMO circulars, IACS standards or equipment manufacturer documentation to verify it is true and up-to-date. In the 4th stage cadets adapt the received material to the format of an official technical report or SOP, adhering to corporate and regulatory design standards.

An additional technic can be a comparative analysis of queries. Cadets are asked to formulate two types of queries – a vague one and a precise one, and then analyze the differences in the responses received. This approach demonstrates the direct connection between linguistic accuracy and the quality of the technical result, motivating cadets to think about how they use words and grammar in their own speech. This underscores the importance of Maritime English as a valuable asset for professionals in the contemporary maritime sector.

CONCLUSION

The integration of AI into the engine room marks a shift from manual, reactive maintenance to data-driven, proactive operations. While AI has enormous potential for monitoring equipment, improving diagnostic accuracy, and ensuring regulatory compliance, its effectiveness relies entirely on human interaction.

Ultimately, knowledge of maritime English is no longer just a communication requirement, but a critical technical skill. Accurate terminology and clear syntax are essential for formulating effective queries, while good reading comprehension and critical thinking enable engineers to verify that AI results meet safety standards. To ensure safety and efficiency at sea, modern maritime education must consider language proficiency as a fundamental tool that allows engineers to manage AI technologies rather than blindly rely on them.

Maritime English courses should move beyond basic communication and incorporate AI-oriented tasks. Training process must emphasize reading comprehension and critical thinking. Engineers should be trained to cross-reference AI suggestions with authentic manufacturer manuals and IMO circulars to identify contradictions or outdated data. Cadets must prioritize mastering standardized technical terms to ensure the highest quality of AI interaction and operational safety. Digital literacy, based on English language proficiency, will become a key element of the STCW framework, so the ability to safely use digital tools requires further study and integration into the training process.

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Dual Award Master's programme in Transport Technologies: Case of University of Plymouth and Kherson State Maritime Academy

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ABSTRACT

The paper investigates a new dual award graduate (Master's) programme developed together by University of Plymouth, the UK and Kherson State Maritime Academy, Ukraine. The study reveals specific features of the dual award programme implementation through LMS Moodle and distance learning using the e-learning technique, which facilitates the transfer and acquisition of knowledge via the Internet and modern digital technologies. The article analyzes the key features of the technique proposed which include the flexibility in developing the learning process, that is relevant for the up-to-date Ukrainian education system under conditions of war; accessibility of the learning process (convenient time, place, etc.); skills practice and training using online simulators. The main principles of quality e-learning are defined, which include the quality of learning materials, multiplicity of formats, gamification, accessibility, personalisation, effectiveness and socialisation.

KEEWORDS: Moodle, dual award, maritime professionals, e-learning.

INTRODUCTION

In 2022, Ukraine was exposed to a full-scale aggression by russia, which affected all life spheres in the country, especially the education system. Kherson State Maritime Academy (KSMA) is located in the south of Ukraine, in the city of Kherson, which was occupied in the first days of invasion. All educational institutions were shut down, and the academic build-

ings of KSMA were occupied. The Academy's staff faced the issue of saving the institution and continuing its function. KSMA was relocated to the Ukraine-controlled territory, to the city of Odesa.

Since summer 2022, the University of Plymouth (UK) has become an active partner of the Academy. Due to the University's support, a project that received a grant from the Cormack Consultancy Group had been prepared. The project implies a dual award programme under the field of study "Ship Power Plants Operation" at the second (master's) level of higher education, KSMA (Ukraine) and the University of Plymouth (UK), 2023-2024 ay. The main challenge in implementing the programme constituted creation of a study programme that would meet the educational requirements of both countries, and its legal implementation [1].

Distance learning, as a synthetic form of learning, has become the main way of studying. This form allows the use of a wide range of electronic tools that contribute to the creation of a "syncretic" model of teaching educational components: starting with the presentation of learning material, formation of the individual work, and a "dialogue cooperation" between a teacher and a student. However, distance learning allows all participants in the learning process not to relate to a specific place and time. Today, this way of studying is very essential both towards scientific substantiation, and participants in the learning process. In Ukraine, the relevance of this form of education is emphasised by the war, as the learning process safety comes to the fore.

Distance learning sets the same goals as the offline form of education, but it differs completely in its fundamental principle, i.e., the use of virtual space for interaction between a teacher and students. It is important to note that this way of learning does not imply completely individual study, but constant contact with a teacher to fully understand the material. A teacher and students communicate on Zoom, various chats, and LMS Moodle.

In this research we present double-degree graduate (Master's) program in Transport Technologies developed together by University of Plymouth, the UK and Kherson State Mari-time Academy, Ukraine. We describe its e-learning process and assessment, share our experiences that could be of interest to the international community.

E-LEARNING

Both higher education institutions have chosen e-learning as the main teaching method. This learning system allows students to complete tasks individually from any convenient and safe place, while using various innovative methods, technologies and programmes. Such learning has gained popularity in recent years, especially during the COVID-19 outbreak.

The European Commission defines e-learning as an opportunity to utilize the latest technologies, in particular the Internet and multimedia, to improve the learning system, as well as the ability to provide global access to a variety of educational web resources. UNESCO experts share the same opinion.

Thus, implementation of the dual award programme enables us to use a variety of electronic resources and material, PCs and mobile devices, to include diverse web resources, libraries, YouTube, Telegram channels and other possible resources in our work. In addition, both work teams can quickly and efficiently transfer information to each other, contact each other to solve any problems and issues, and also very effectively convey relevant information to students. In fact, this procedure makes it possible to combine theory, practice, procedures and techniques into a single synergistic system.

In practical terms, e-learning is the creation of unified, procedural, educational and technical complexes to ensure an integral learning process.

Thus, KSMA has created a page on LMS Moodle for the dual award programme, which contains all learning material of both KSMA and the University of Plymouth [2], enabling students to quickly and efficiently obtain the necessary information on each educational component, as well as complete information on the learning process organization (see Fig. 1).

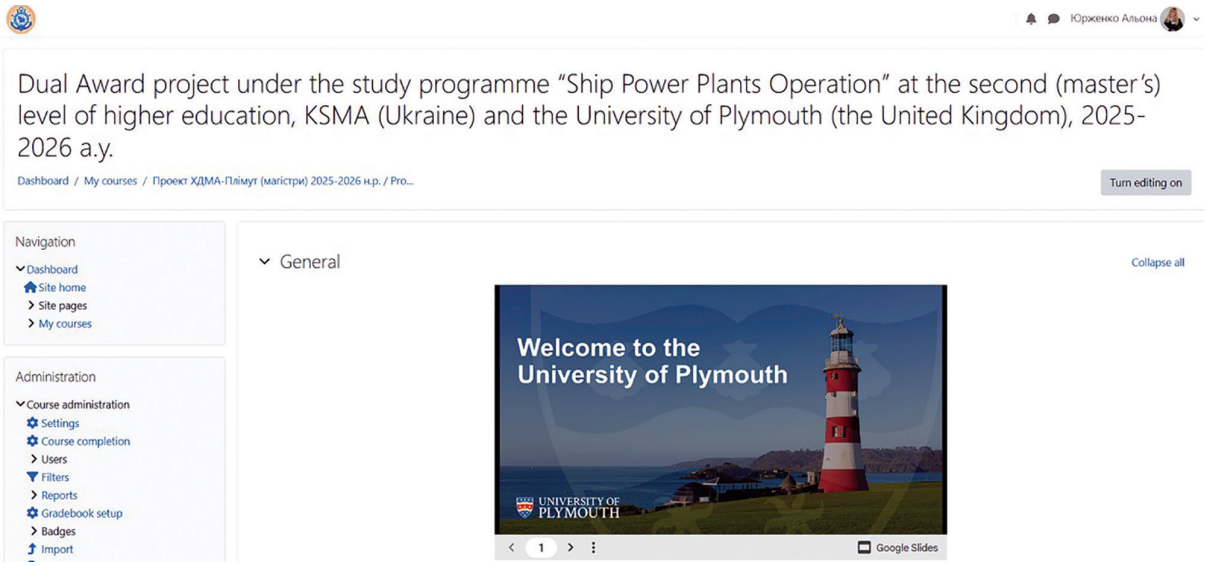

Fig. 1. LMS Moodle course for Dual Award Project

Lectures, recommendations for individual work, practical tasks and instructional guidelines are created for each educational component. Tests, a reference book, a system of current and final assessments are added (see Fig.2).

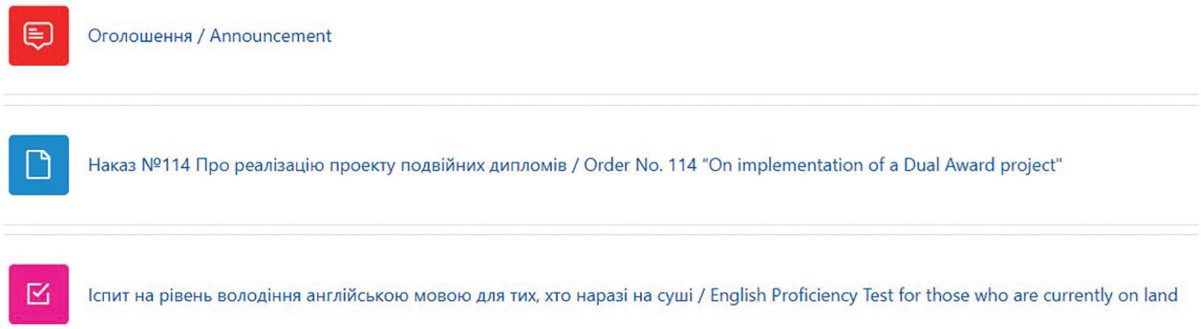

Fig. 2. Part of online course on LMS Moodle with Forum, File and Assignment

A student can model processes and objects of interest, create a system of contextual clues and links, and perform the necessary calculations in each educational component. For example, a necessary video from a YouTube channel or video lecture [3].

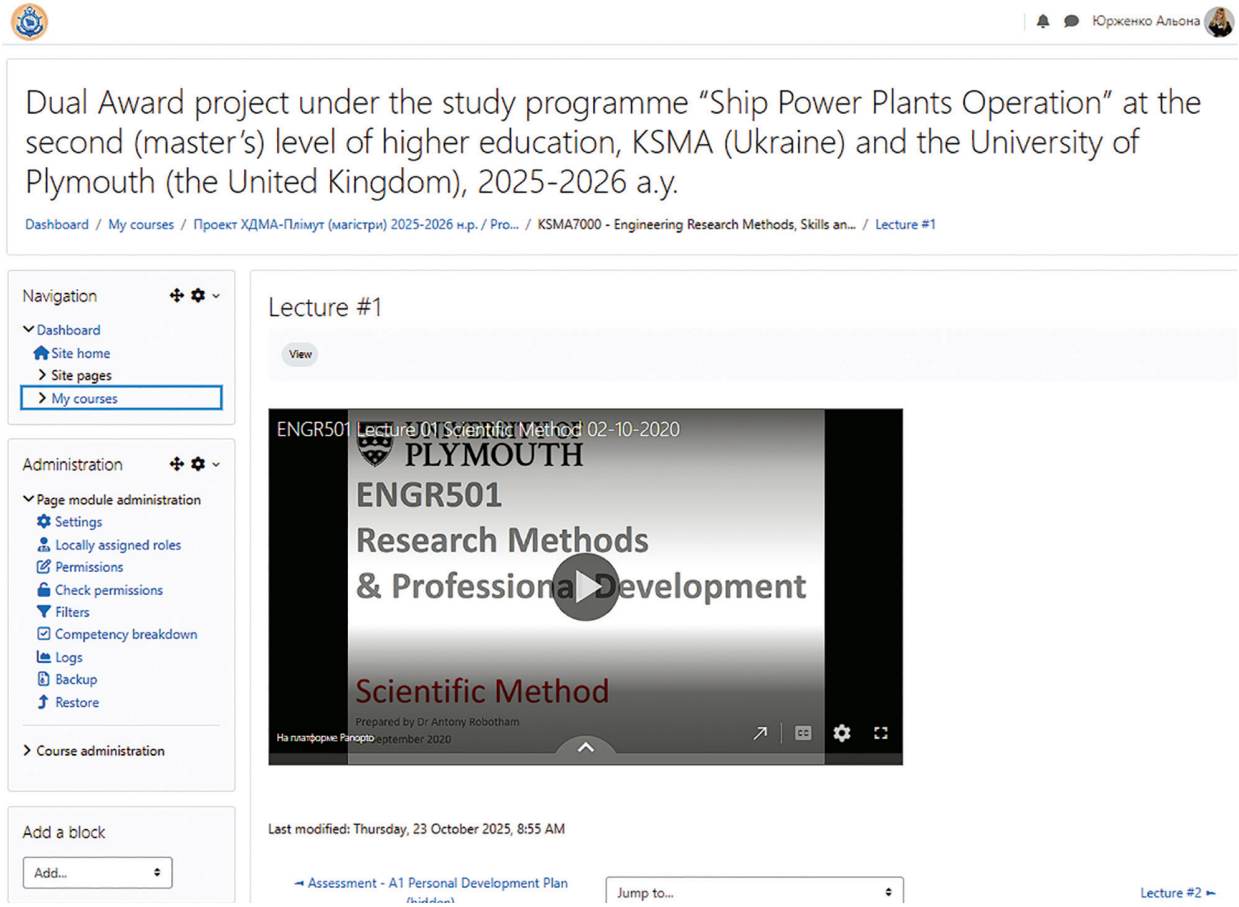

Fig. 3. Video Lecture of a teacher of University of Plymouth

Development of an e-learning methodology requires a clear statement of goals and objectives of learning process. While implementing the study programme, it is necessary

to enhance the measurability of the outcomes to be obtained, as well as to develop systems of performance indicators and the quality of the technology used, as these issues require special attention and in-depth analysis [4].

E-learning organizing requires the creation of a distance learning system that includes tools and capabilities necessary for arranging, controlling the learning process and analyzing results. The main e-learning tools for the implementation of the dual award programme include e-learning courses with video lectures, automatic testing systems, forums and chats, online seminars, wikis, links to external resources, files (a system supports any format such as an audio, video, gif., pdf., doc.). Participants of the workflow use different types of e-courses in terms of their complexity, from elementary to complex ones, where the interactive component dominates, allowing students to interact with the material. Simple courses are a sequence of slides with navigation tools and minimal interactive pieces. These courses are effective for simple training topics that do not require detailed explanation, and for informing students [5].

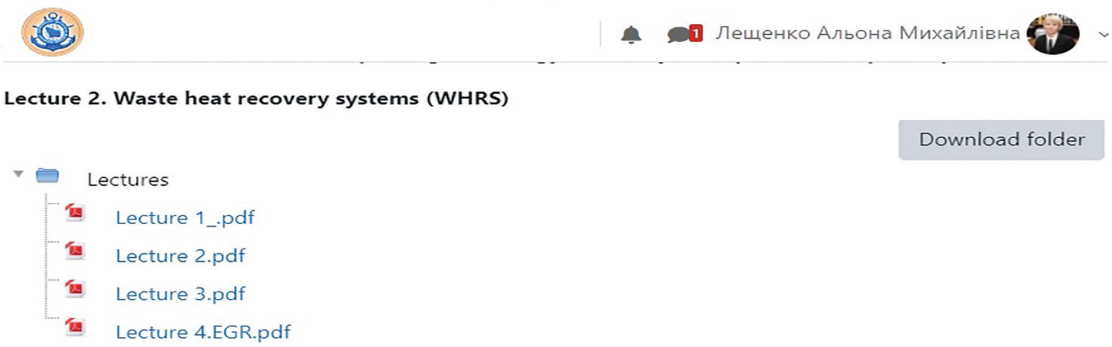

Fig. 3. Fig. 4. Simple course construction – list of lecture materials.

The second type includes interactive courses, which are more like an animated film, where animation and special graphics are needed to visual illustration. Such courses can be accessed via mobile phone.

The most complex courses are games and simulators. These courses are applied to train practical skills in order to avoid numerous mistakes. Such courses are very effective as they not only transfer information but also build experience. Corse structure is built in the form of a game. There is a map at the beginning of the course where students can see names and number of modules, course rules [6, 7].

Course also includes missions and tasks to be completed, leaderboards, digital badges and other gamification elements. Course also has its own plot (e.g. cadet of ship engineering department wants to get a promotion and students need to complete the missions after which they receive badges: Engine Cadet, Fourth Engineer, Third Engineer, Second Engineer, Chief Engineer). The badges are represented as digital images of marine epaulets

An automatic testing system is an equally important tool in e-learning. The use of testing technologies helps to ensure a high level of learning, its consistency, and detection of losses [8]. In addition, this type of testing improves the learning process due to organisational, diagnostic, controlling and motivational functions of test tasks (see Fig. 5).

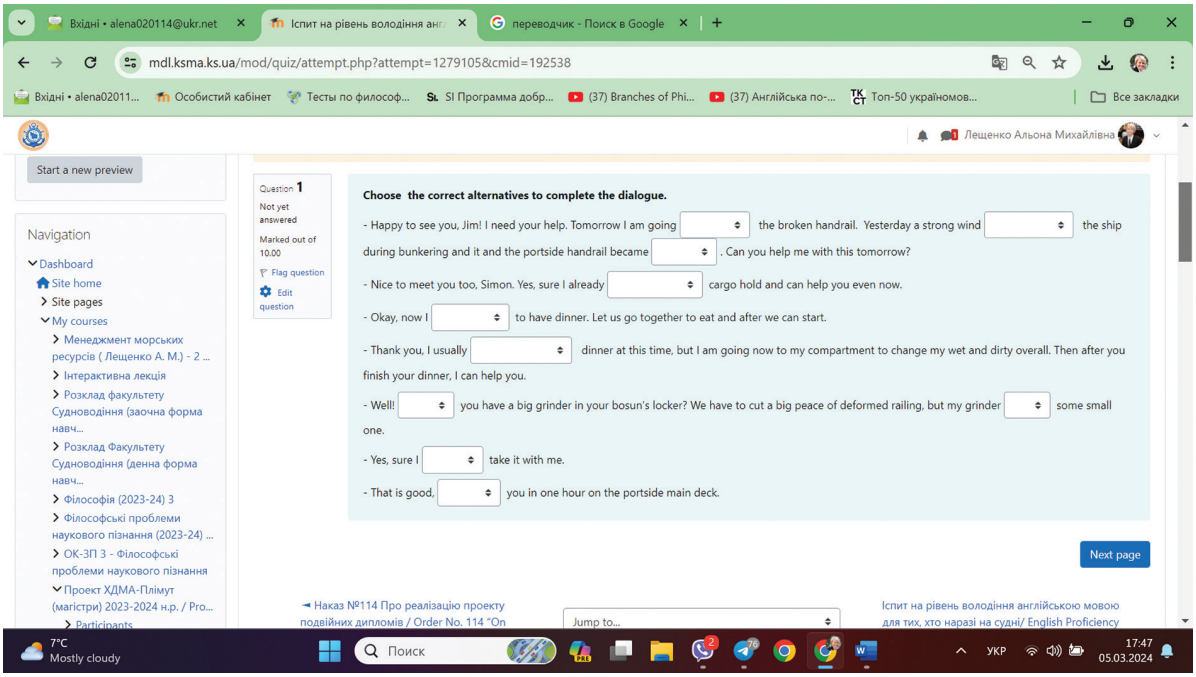

Fig. 5. Example of LMS MOODLE testing question.

Chats and forums are designed for communication between students and a teacher. Participation in a forum involves an educator or teachers who ask questions and check answers. A forum is important for developing critical thinking, while a chat develops the skill of synchronous communication. It is worth noting that a forum is a more flexible tool, as each participant can post an answer at a convenient time (within the given deadlines), while when using the chat, everyone must be online at the same time, which reduces the flexibility of this tool, but does not negate its role and importance in the learning process [9, 10].

One of the most relevant and integral tools in e-learning is a webinar or online seminar, i.e., a video or audio conference. Conducting such a class involves a teacher and students, as well as a presentation, videos, audio recordings are used, and students can ask or answer questions. A webinar or a seminar can be recorded and added to the platform, which is very useful both for repetition and for those students who could not join the lesson [11, 12].

In general, the use of e-learning justifies the tasks assigned, and has a number of advantages, such as convenient time and place for studying, solid knowledge acquisition, constant contact with a teacher, individual study schedule, time saving, etc.

CONCLUSION

Thus, it should be emphasised that the dual award programme is based on such guidelines as the quality of learning material, polyformatting, gamification, accessibility, personalisation, and effectiveness. This, in turn, contributes to the development of students' ability to self-organisation, self – and time management, which is very essential for a

modern maritime professional. The use of e-learning enables students to build their own course of individual study, facilitates forming self-education skills, which are important for a modern professional who will have to shape and work under conditions of LLP, as an engineering develops globally and intensively. In order to update knowledge and be able to work in this industry, students will need to constantly educate and improve themselves, attend trainings, webinars, etc.

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Acknowledgments. Dual degree program between Kherson State Maritime Academy and University of Plymouth was funded by Cormack Consultancy Group.

AI Literacy as an Emerging Non-Technical Competency in Maritime Officer Training: Implications for STCW and IMO Model Courses

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ABSTRACT

The maritime industry is undergoing a profound transformation driven by the rapid integration of artificial intelligence (AI) technologies into navigation, vessel management, cargo operations, and fleet administration. Autonomous decision-support systems, AI-assisted route optimisation, predictive maintenance algorithms, and intelligent cargo management platforms are increasingly embedded in operational shipboard environments. This technological shift demands not only technical proficiency but a qualitatively new category of competency – AI literacy – understood as the cognitive and professional capacity to critically evaluate, interact with, and exercise authority over AI-driven systems. Non-technical skills (NTS) – encompassing situational awareness, decision-making, communication, teamwork, and leadership – have been established as critical determinants of maritime safety within the frameworks of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers and the associated IMO Model Courses. However, the current regulatory architecture, rooted in the Manila Amendments of 2010, was designed prior to the widespread deployment of AI technologies in maritime operations. As AI systems increasingly function as decision-making partners aboard vessels, the boundaries of human-machine interaction, authority allocation, and cognitive task distribution raise fundamental questions regarding the adequacy of existing competency frameworks for contemporary professional training. This paper argues that AI literacy constitutes an emerging dimension of non-technical competency that has not yet been systematically integrated into STCW standards or IMO Model Course curricula. In the present context, AI literacy encompasses: the capacity to critically assess AI-generated navigational or operational recommendations; understanding of the limitations, biases, and potential failure modes of AI systems; ability to maintain situational awareness in hy-

brid human-AI operational environments; and informed decision-making authority when AI outputs conflict with professional human judgement. The study employs a theoretical-analytical methodology, drawing on competency-based education frameworks, analysis of current STCW Convention provisions and Manila Amendments, review of relevant IMO HTW Sub-Committee documents pertaining to the integration of new and emerging technologies, and scholarly literature on human factors in AI-assisted work environments. The paper further examines how Safety-II paradigms and High Reliability Organisation principles relate to the challenge of maintaining effective human oversight in increasingly automated maritime operations. The analysis identifies a significant regulatory gap: while the IMO has initiated discussions on Maritime Autonomous Surface Ships and digitalisation under its regulatory scoping exercises, the specific competency implications for serving seafarers – particularly with respect to AI interaction capacity as a component of NTS – remain underarticulated in binding international instruments. The paper proposes a conceptual framework for integrating AI literacy as a structured competency dimension within maritime officer training programmes, offering recommendations for curriculum developers, training institutions, and policy bodies engaged in the forthcoming revision of STCW standards. The practical significance of this research lies in its contribution to the ongoing IMO HTW process and to national maritime education institutions seeking to align their programmes with the emerging demands of a digitally transformed maritime labour market. For Ukrainian maritime education, currently undergoing significant modernisation in the context of European integration, this framework offers a timely and directly applicable reference point.

KEEWORDS: AI literacy; non-technical skills; maritime education; STCW; IMO Model Courses; human-machine interaction; Safety-II

INTRODUCTION

The accelerating integration of artificial intelligence into maritime operations has fundamentally altered the technological landscape within which seafarers exercise their professional judgement. Across the spectrum of shipboard activities – from navigational route optimisation and collision avoidance systems to predictive maintenance platforms and automated cargo management – AI-driven decision-support tools are becoming embedded in the operational fabric of modern vessels. This trajectory is not incidental but structural: the International Maritime Organization (IMO) has formally acknowledged the transformative potential of emerging technologies through its regulatory scoping exercise on Maritime Autonomous Surface Ships (MASS), the outcomes of which were consolidated in MSC.1/Circ.1638 (IMO 2021a), and through the ongoing development of a non-mandatory MASS Code, the adoption of which is targeted for MSC 111 in May 2026 (IMO 2025a).

Yet the professional education and certification framework governing seafarers – principally the International Convention on Standards of Training, Certification and Watch-

keeping for Seafarers (STCW), as amended by the Manila Amendments of 2010 – has not been substantially revised to reflect the competency implications of operating in AI-assisted environments. The comprehensive review of the STCW Convention and Code currently being conducted by the IMO Sub-Committee on Human Element, Training and Watchkeeping (HTW), which completed phase 1 in February 2025 and is now in phase 2, has identified more than four hundred gaps in the existing framework, including issues related to emerging technologies on ships (IMO 2025b). This regulatory lag constitutes a meaningful professional safety risk: as AI systems become operational partners aboard vessels, the absence of formalised competency standards for human-AI interaction undermines the very purpose for which the STCW framework was established.

This paper argues that resolving the regulatory gap requires the formal conceptualisation and curricular integration of AI literacy as an emerging category of non-technical skills (NTS) in maritime officer training. The aim of the paper is threefold: first, to map the existing NTS framework in maritime professional education as established under STCW and IMO Model Courses; second, to analyse the specific competency challenges arising from the deployment of AI systems in maritime operations; and third, to propose a conceptual framework, structured along four principal axes, for integrating AI literacy into the training and certification of maritime officers. The study adopts a theoretical-analytical methodology, drawing on competency-based education theory, human factors research, and international maritime regulatory documents. The contribution is both conceptual – by articulating AI literacy as a structured competency dimension – and practical, by offering recommendations that may inform the forthcoming revisions of STCW and the human element provisions of the MASS Code.

MAIN BODY

Non-Technical Skills in Maritime Education: The Established Framework

The centrality of non-technical skills to maritime safety has been formally recognised since the incorporation of leadership, teamwork, and resource management competencies into the STCW Convention through the Manila Amendments of 2010. These amendments introduced mandatory requirements for training in leadership and managerial skills at the operational and management levels of seafaring, codified inter alia in STCW Regulation II/1 and the associated sections of the STCW Code (IMO 2010). The IMO subsequently developed Model Course 1.39 (Leadership and Teamwork) to provide structured pedagogical guidance for the delivery of NTS training at the operational level (IMO 2014).

The conceptual underpinning of NTS in the maritime context draws substantially from aviation crew resource management and broader human factors research. Flin, OConnor, and Crichton (2008) define non-technical skills as the cognitive, social, and personal resource skills that complement technical skills and contribute to safe and efficient task performance. In the maritime domain, NTS frameworks typically encompass situational awareness, decision-making under uncertainty, communication, team coordination, and

leadership – competencies whose importance has been consistently underscored by incident investigation reports citing human error as a primary causal factor (EMSA 2023).

Situational awareness, as theorised by Endsley (1995), involves three hierarchical levels: the perception of environmental elements within a volume of time and space, the comprehension of their significance in relation to operational goals, and the projection of their future states. This construct has become foundational in maritime safety education, as breakdowns in situational awareness are amongst the most frequently cited contributory factors in navigational accidents (Lützhöft and Dekker 2002). The STCW frameworks emphasis on maintaining an effective navigational watch may be understood, in competency terms, as an institutionalised requirement for sustained situational awareness.

Parallel to situational awareness, the management of organisational and systemic risk has been theorised through Reasons (1997) model of organisational accidents, which identifies latent conditions within sociotechnical systems as the precursors of catastrophic failure. This perspective has informed both maritime safety management systems under the ISM Code and the broader Safety-I paradigm, which locates safety in the prevention and mitigation of failures. Hollnagel, Wears, and Braithwaite (2015) subsequently articulated the complementary Safety-II perspective, which directs attention to the conditions enabling adaptive, successful performance under variable operational realities – a perspective with particular relevance to the cognitive demands of AI-assisted environments.

Artificial Intelligence and the Automation Paradox in Maritime Operations

The deployment of AI in maritime operations spans a broad spectrum of autonomy and functional scope. Parasuraman, Sheridan, and Wickens (2000) propose a model for types and levels of human interaction with automation, extending the earlier ten-level taxonomy of Sheridan and Verplank (1978) by mapping the application of automation across four broad classes of functions: information acquisition, information analysis, decision and action selection, and action implementation. Within each of these classes, automation may be applied along a continuum from fully manual operation to fully autonomous execution. Contemporary AI-assisted maritime systems typically occupy intermediate positions within this taxonomy: they process environmental data, generate recommendations, and in some configurations execute limited operational decisions, whilst retaining the human operator as the locus of ultimate authority.

The IMOs classification of MASS into four degrees of autonomy – from ships with automated processes and decision support, through remotely controlled ships, to fully autonomous ships – provides the regulatory framework within which the human-machine relationship in navigation is being reconceptualised (IMO 2021a). Critically, the intermediate degrees of autonomy, which will characterise the operational reality of most vessels in the near-to-medium term, create a category of cognitive challenge that existing NTS frameworks do not adequately address.

This challenge has been characterised in the human factors literature as the automation paradox. As Parasuraman and Riley (1997) demonstrate in their seminal analysis of human use, misuse, disuse, and abuse of automation, increasingly automated and reliable systems generate predictable behavioural consequences: operators become less actively engaged in continuous monitoring, less proficient at the manual execution of automated tasks, and less able to recognise system failures or anomalies when they occur. In the maritime context, this dynamic manifests as overreliance on electronic chart display and information systems, automatic identification systems, and integrated bridge systems – a tendency documented in accident investigation findings and simulator-based studies. The grounding of the Royal Majesty, analysed by Lützhöft and Dekker (2002), exemplifies the phenomenon: an unnoticed loss of GPS reception caused the navigation system to revert silently to dead reckoning mode, and the bridge teams progressively eroded engagement with the system meant that the visible indication of this mode change went unobserved for approximately thirty-four hours, contributing directly to the grounding.

The integration of AI introduces qualitatively new dimensions to this challenge. Unlike rule-based automation, machine learning systems generate outputs through processes that are not transparently interpretable by non-specialist users – the so-called black box problem. A maritime officer confronted with an AI-generated route recommendation or collision avoidance suggestion requires not merely the technical competency to operate the interface, but the epistemological capacity to critically evaluate the recommendations basis, its limitations, and its applicability to the specific operational context. This capacity does not arise spontaneously from technical training; it must be explicitly cultivated through purposefully designed educational interventions.

AI Literacy as Non-Technical Competency: A Four-Axis Conceptual Framework

The concept of AI literacy has been theorised in educational and human factors research as a multidimensional competency encompassing the knowledge, skills, and dispositions required to critically understand, evaluate, and interact with AI systems. Long and Magerko (2020) identify a set of seventeen competency dimensions of AI literacy, organised around themes including the recognition of AI, an understanding of what AI can and cannot do, the workings of machine learning, the human role in AI, the social implications of AI, and the critical evaluation of AI outputs. Whilst their framework was developed in a general educational context, its core dimensions are directly translatable to the professional maritime environment.

For maritime officers, AI literacy as a non-technical competency may be conceptualised along four principal axes that operationalise these dimensions within the specific cognitive and regulatory context of seafaring.

Critical evaluation of AI outputs. The first axis concerns the capacity to assess navigational or operational recommendations generated by AI systems, including an understand-

ing of the conditions under which such systems may perform unreliably – degraded sensor data quality, edge-case scenarios, adverse weather conditions, or situations outside the systems training distribution. This dimension corresponds to Endsleys (1995) second and third levels of situational awareness: the comprehension and projection of system-generated information within a broader operational picture. A maritime officer trained in this axis does not treat AI output as authoritative input but as one element within a larger sensemaking process that integrates the officers direct environmental perception, professional experience, and contextual judgement.

Understanding of AI system limitations. The second axis encompasses knowledge of the fundamental constraints of machine learning systems, including their susceptibility to systematic bias in training data, their inability to extrapolate reliably beyond trained parameters, and their opacity regarding the reasoning underlying their outputs. This dimension supports the informed exercise of human override authority and guards against the misplaced attribution of infallibility to AI recommendations – a particularly important safeguard given the documented tendency of operators to develop inappropriate trust in automated systems even when those systems demonstrate measurable unreliability.

Human-AI task allocation and authority maintenance. The third axis comprises the metacognitive capacity to determine when AI system outputs should be deferred to and when human professional judgement must override automated recommendations. Parasuraman and Riley (1997) distinguish between appropriate use, misuse (overreliance), and disuse (underutilisation) of automation; AI literacy in this dimension involves the practical wisdom to navigate these distinctions in dynamic operational environments where the stakes of misallocation may be severe. This is not merely a technical skill but a structured form of professional judgement that requires sustained reflective practice and deliberate pedagogical development.

Psychological safety and crew dynamics in AI-assisted environments. The fourth axis addresses the capacity to maintain effective team communication and shared situational awareness when crew members may hold differing levels of trust in, or familiarity with, AI system outputs. Weick and Sutcliffe (2007) emphasise the role of collective mindfulness and structured scepticism in preventing catastrophic failure in High Reliability Organisations; these dispositions require specific cultivation in AI-integrated bridge teams, where social dynamics around technology acceptance may undermine the conditions for safe collaborative performance. The capacity to voice doubts about AI recommendations, to question automated outputs without fear of social sanction, and to coordinate collective sensemaking in the presence of system uncertainty are competencies that traditional NTS frameworks address only obliquely.

Taken together, this four-axis framework aligns with the Safety-II paradigm articulated by Hollnagel, Wears, and Braithwaite (2015), which shifts focus from the prevention of failure to the understanding and cultivation of the conditions that enable safe, adaptive performance under variable conditions. In AI-assisted maritime operations, Safety-II thinking demands that training institutions develop curricula addressing not only procedural compliance with AI system interfaces, but the professional resilience and critical judgement required to maintain safe performance when AI systems behave unexpectedly.

The Regulatory Gap and the Window of Opportunity

The Manila Amendments of 2010, whilst representing a significant advancement in the formalisation of NTS in maritime training, were developed without anticipation of the operational role that AI systems would come to play aboard vessels. The relevant STCW competency tables – particularly those governing navigational watch management, collision avoidance, and cargo operations – specify performance standards in terms of human-to-instrument interaction that do not encompass the critical evaluation of AI-generated recommendations as a distinct competency category (IMO 2010). Similarly, the IMO Guidelines on Maritime Cyber Risk Management, most recently issued as MSC-FAL.1/Circ.3/Rev.3 in April 2025, address the protection of computer-based shipboard systems against cyber threats but do not establish competency requirements for the cognitive interaction between seafarers and AI-driven decision-support tools (IMO 2025c).

This regulatory situation is not, however, static. The IMO HTW Sub-Committee, which oversees the development of human element, training, and watchkeeping standards, completed phase 1 of the comprehensive review of the STCW Convention and Code in February 2025, identifying gaps across twenty-two specific areas, including emerging technologies on ships, mental health, and gender sensitisation (IMO 2025b). Phase 2, focused on the development of concrete amendments, is currently underway, with the comprehensive review expected to be completed by approximately 2029. Concurrently, the IMO Maritime Safety Committee, at its 110th session in June 2025, advanced the draft non-mandatory MASS Code, finalising eighteen of its twenty-six chapters; Chapter 15, addressing the human element, remains under further review, with the adoption of the non-mandatory Code targeted for MSC 111 in May 2026 (IMO 2025a). The mandatory MASS Code is envisaged to enter into force on 1 January 2032.

This convergence of regulatory processes – the comprehensive review of STCW and the development of the MASS Code – constitutes a window of opportunity, narrow but substantive, for the formal integration of AI literacy into binding international competency frameworks. The present paper contributes to this process by proposing that AI literacy be incorporated as an explicit competency dimension within NTS requirements at both the operational and management levels.

Concretely, three curricular developments are proposed.

First, the introduction of a dedicated AI literacy module within IMO Model Course 1.39 (Leadership and Teamwork), addressing the four competency axes outlined above. This module should be delivered through scenario-based simulation, enabling trainees to practise the critical evaluation of AI-generated navigational recommendations under controlled conditions that replicate the cognitive pressures of real operational environments.

Second, the revision of STCW competency standards for officers of the navigational

watch (Regulation II/1) to include explicit performance indicators for the management of AI-assisted navigational systems, distinguishing between routine interface competency and the higher-order competency of critical AI output evaluation. The phase 2 work of the HTW Sub-Committee provides the appropriate institutional vehicle for the elaboration of these performance indicators.

Third, the integration of AI literacy provisions into Chapter 15 of the MASS Code, which addresses the human element. As MASS operations will involve precisely the intermediate degrees of autonomy in which AI literacy becomes most consequential, the MASS Code represents the natural locus for the codification of these competencies. The fact that Chapter 15 remains under review at the time of writing creates an immediate practical opening for the substantive proposals advanced here.

CONCLUSION

The integration of artificial intelligence into maritime operations represents a qualitative shift in the nature of seafarer professional practice. The cognitive demands placed upon maritime officers by AI-assisted operational environments – demands for critical evaluation, epistemological scepticism, and informed authority maintenance over automated systems – constitute a category of non-technical competency that has not yet been formally recognised within the STCW Convention or IMO Model Course frameworks.

This paper has argued that AI literacy, conceptualised along four axes – critical evaluation of AI outputs, understanding of system limitations, human-AI authority allocation, and psychological safety and crew dynamics in AI-assisted environments – constitutes a substantively important addition to the NTS competency framework governing maritime officer training. The regulatory implications are significant: as AI systems become more pervasive across vessel types and operational contexts, the absence of formalised AI literacy requirements in international training and certification standards represents a meaningful safety risk, compounded by the automation paradox documented extensively in human factors research.

The current moment is particularly favourable for the integration of AI literacy into binding international frameworks. The phase 2 of the comprehensive STCW review and the imminent adoption of the non-mandatory MASS Code at MSC 111, with Chapter 15 on the human element still under active development, together provide the institutional forums in which the proposals advanced here may find concrete expression. For maritime education institutions, the conceptual framework articulated in this paper may inform curriculum development ahead of formal regulatory change. The scenario-based, simulation-supported pedagogical approach recommended here is consistent with established best practice in NTS training and is practically realisable within the existing infrastructure of accredited maritime training providers.

For Ukrainian maritime education, currently undergoing substantial modernisation in the context of European integration and post-war institutional renewal, the proactive in-

tegration of AI literacy frameworks into both initial training and continuous professional development pathways represents both a timely academic contribution and a strategic institutional response to evolving labour market demands. In this sense, the incorporation of AI literacy into maritime professional education need not await regulatory mandate: it may be pursued as a proactive institutional response to the evolving demands of a digitally transformed maritime labour market.

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Challenges Eco Port and Green Shipping : Overview of Current and Future Action

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ABSTRACT

In an era where environmental sustainability is paramount, the shipping industry is undergoing a transformative shift towards eco-friendly practices. Eco ports and green shipping represent a vital response to the growing concerns surrounding climate change, air pollution, and the depletion of marine resources. These initiatives aim to minimize the ecological footprint of maritime operations while promoting economic growth and social responsibility.

Eco ports are designated marine terminals that prioritize environmental protection and sustainability in their operational frameworks. They implement a range of practices designed to reduce emissions, conserve energy, and protect local ecosystems. By adopting innovative technologies and sustainable management practices, eco ports strive to create a balance between port activities and environmental conservation, thereby enhancing the overall quality of life for communities surrounding these facilities.

Green shipping, on the other hand, encompasses the broader spectrum of eco-friendly practices adopted by the shipping industry as a whole. This includes the use of cleaner fuels, energy-efficient vessels, and the integration of renewable energy sources into shipping operations. The goal of green shipping is to mitigate the industry's impact on the environment while fulfilling the global demand for maritime transport services.

The convergence of eco ports and green shipping is essential in addressing the pressing environmental challenges faced by the maritime sector. As international regulations tighten and public awareness rises, the need for sustainable shipping practices becomes increasingly critical. This article will explore the current challenges in implementing eco ports, the barriers to green shipping, and the actions required to shape a sustainable maritime future. By examining regulatory, technological, and financial hurdles, as well as potential solutions, we can better understand the path forward for eco ports and green shipping in the years to come.

When it comes to linking Indonesia, the biggest archipelagic state in the world, sea transportation is very necessary in order to accomplish the goals of facilitating logistical distribution and economic development. Based on the information provided by KP 432 Year 2017 JO KP 217 Year 2022, Indonesia is equipped with a total of 1322 Location Plan for the new ports, in addition to 534 non-commercial ports, 102 commercial ports, and 63 public terminals.

As a consequence of marine transportation, the International Energy Agency estimates that 646 million metric tons of carbon dioxide (MTCO2) were released into the atmosphere in the year 2020. This is about 2% of the total carbon emissions that occurred worldwide. In the year 2022, the number of vessels registered in Indonesia is as follows: 44.178 cargo vessels, 4.796 fishing boats, and 49.221 passenger vessels. Therefore, in order to reduce carbon emissions, Indonesia needs to create a sustainable marine transportation infrastructure by means of eco ports and green shipping.

The Indonesian government is tasked with addressing a number of concerns, some of which include the enhancement of maintenance and monitoring systems, as well as the development of the skills and competencies of sustainable human resources. Green shipping has extra obstacles, including the need to strike a balance between the need for operational efficiency and the requirement for environmental sustainability, as well as the need for crew training and competence. The descriptive qualitative methodologies were used in the literature review that was conducted for this research. Furthermore, it is believed that this study will be finished by doing further research.

KEEWORDS: Eco ports, green shipping, emission, sustainability.

INTRODUCTION

The As the largest archipelagic state in the world which is comprised more than 17.000 islands, sea transportation plays an essential role to connect Indonesia into one whole country to support the distribution of logistics and economic growth into the outer, isolated, and under developed areas of Indonesia. However, according to International Energy Agency (IEA) sea transportation contributed to 646 Million Metric Ton Carbon (MTCO2) Emission in 2020 or around 2% of Global Carbon Emission. Therefore, Indonesia should implement sustainable sea transportation ecosystem to reduce the carbon emission through Eco Port and Green Shipping.

The challenges in developing eco-ports and green shipping include the need to reduce the environmental impact of maritime transport, such as pollution and CO2 emissions, and to comply with environmental standards. There is a growing recognition that shipping is not as environmentally friendly as previously thought, with concerns about greenhouse gas emissions and health-damaging pollutants emitted by ships [2]. The current and planned regulatory regime for improving the industry's environmental footprint is outlined, highlighting the need for greater market regulation and technological innovation.

Ports have a pivotal role to play in supporting the shipping industry's efforts to reduce its environmental impact, but they need to go beyond their traditional operational milieu. Efforts to achieve sustainability in ports have focused on sustainable ports, eco-ports, and green ports, but there is a need for integration and a maritime supply chain perspective to effectively achieve sustainability. The construction of green ports is considered a fundamental way to address the problems caused by climate change and promote sustainable development in the port industry.

Eco Port

According to KP 432 Year 2017 JO KP 217 Year 2022 about the Blueprint of Indonesia National Ports (Rencana Induk Pelabuhan Nasional), Indonesia has 636 Existing Ports (consist of 534 non-commercial ports and 102 commercial ports), 63 Public Terminals, and 1322 Location Plan for the new ports. Considering the enormous number of Ports in Indonesia, the implementation of Eco Port would give a significant impact in reduction of carbon emission.

Definition, General Concept, and Four Pillars of Eco Port

Eco Port, as an environmental management initiative, has garnered substantial attention in recent years. This prominence reflects the growing global awareness of the pressing need to address the intricate and multifaceted environmental challenges intrinsic to port operations. This approach represents a sophisticated and comprehensive framework characterized by a meticulous delineation of prioritized criteria meticulously designed for the precise evaluation of port authorities' environmental performance. These criteria provide a meticulously structured and methodical approach that empowers ports to harmonize their operational activities with the exacting standards and best practices stipulated on the international stage, thereby contributing meaningfully to the overarching global endeavour of advancing sustainability in maritime transportation (Puig et al., 2022).

Ecological Port (Eco Port) is a Port within the scope of sustainable development (sustainable development port), which is not only considering environmental aspects, but also economical aspects. The general concept of Eco Port is to establish a port that is environmentally friendly through the Implementation of: (a) Environmental management program in Environmental Financial Activities, Technical and Operational Aspects, Institutional and Personal Aspects, and Rule of Law as well as Legal Provision; (b) Standard Measurement (Goal) in certain indicators such as the reduction of environmental impacts at Ports, improvement of cleanliness, comfort, health, and safety, improvement of institutional capacity in environmental aspects, and improvement of stakeholder participation in environmental management.

Moreover, the implementation of Eco Port should fulfil four pillars that consist of:

1. Fulfilment of all regulatory requirements in the environmental field (compliance).

The environmental aspect is in the form of environmental sustainability. Sustainable transportation is expected to be able to integrate intra and intermodal, connectivity between transportation infrastructure, shipping industry, human resources, integration between stakeholders, so that sea transportation can be multidimensional and not egotistical through Industry 4.0 based technological innovation. The presence of an environmental policy (95.7%) is the indication with the highest implementation, followed by the inventory of environmental legislation (96.7%). Air quality continues to be the most important environmental concern, followed by noise and energy use. Waste is the environmental issue that is most closely watched. Ports are becoming more environmentally conscious and conscious of the effects of climate change.

In recent years, people's awareness of the protection of the environment has increased. The sustainability of port operations is growing in importance since, although ports boost employment and economic growth in port communities, they can negatively affect the environment. The selection and adoption of sustainable practices by the port authority are heavily influenced by factors unique to the port, including its financial resources, competition areas, regulations, and environmental priorities. These factors can vary greatly between ports and between regions.

International maritime organizations' political discourse gave rise to the concept of "green ports," with the main focus being on elucidating the economic benefits and implications of implementing environmental policies and developing green guidelines and codes of conduct for port authorities. Consequently, in order to attain a high degree of environmental competitiveness, all stakeholders in seaports, including port authorships, policy makers, port users, and local communities, must make significant resource investments.

A model of the quantities of carbon dioxide (CO2), NOx, and PM2.5 released at sea and at ports in Norwegian seas was built and utilized by Simonsen et al. They discovered that around 14.6% of these pollutants are deposited in ports, particularly in Bergen, Oslo, and Stavanger. These results attest to the notable variations in cruise ships' environmental performance. These results might be used to create maritime regulations that compel cruise lines to use greener technology and reconsider their operational procedures.

2. Implementation environmental management system.

An environmental management system can be effectively implemented by following a series of steps. First, an initial environmental review should be conducted to identify cause and effect, understand legislative and regulatory issues, and develop a policy and objectives. Next, an environmental management program should be designed and implemented, focusing on prioritizing actions and resources, increasing efficiency, and minimizing costs. Regular audits and reviews should be conducted to evaluate environmental performance and ensure continuous improvement. Additionally, public participation should be encouraged to involve local communities and legal entities in the development and implementation of environmental programs. By implementing an environmental management system, organizations can achieve benefits such as compliance with environmental

legislation, care for clients, resource and energy savings, and improved image. Overall, effective implementation of an environmental management system requires careful planning, monitoring, and engagement with stakeholders.

3. Implementation of green initiative.

Green initiatives such as energy management, water saving, using of environmentally friendly technology, habitat protection and biodiversity are some example that can be implemented at the area of the Port.

4. Stakeholder's involvement to support fulfilment regulation in the environmental sector and implementation green initiatives ports.

The key stakeholders involved in the implementation of green initiatives in ports include port authorities, shippers, carriers, terminals, and port users. These stakeholders play a crucial role in driving sustainable growth and environmental protection in port operations. Additionally, the Green Marine (GM) program encourages Canadian ports to integrate sustainability into their operations, indicating the involvement of port authorities and other stakeholders in implementing green initiatives. The Johor Port Association (JPA) in Malaysia has also launched a Green Port Policy, highlighting the involvement of port authorities in promoting environmentally friendly port development and operation. Furthermore, the implementation of the Green Port concept at selected ports in Turkey, Europe, and the US involves various stakeholders, such as port authorities, shipping companies, and personnel, who adhere to strict waste management and environmental policies.

Technical Guidelines of Eco Port

The Technical Guidelines for Eco Port contain guidelines for the Implementation of Environmentally Friendly Port Management, which includes 10 clusters below:

1. Eco port Cultural and Institutional Development

Developing eco ports with a focus on cultural and institutional development requires several best practices. Firstly, it is important to acknowledge and incorporate societal and environmental considerations in port development. Secondly, sustainable development policies and practices should be adopted, considering the specific environmental aspects such as air pollution, water quality, waste disposal, and land/resource use. Thirdly, public-private partnerships and policies negotiated with all stakeholders can foster port sustainability. Additionally, an ecosystem-based port design approach can be implemented, which involves understanding the system, designing alternatives, modelling and evaluating them, and finalizing the design. Furthermore, effective planning and development of logistics centres, development of information technology, and regulatory and administrative measures are crucial for successful eco ports. By following these best practices, eco ports can be developed with a focus on cultural and institutional development.

2. Air Quality Management

The aegis of air quality, historically a salient preoccupation within the realm of ports, remains an enduringly critical criterion underpinning the Eco Port evaluation framework. The maritime industry's pivotal role in the propagation of greenhouse gas emissions underscores, in no uncertain terms, the profound importance of instituting a comprehensive regimen of measures aimed at robustly curtailing air pollution (Wan et al., 2018). Port authorities find themselves increasingly tasked with the profound obligation of assimilating sustainable practices across the manifold spectrum of their operational domains. This includes, but is not confined to, the critical imperative of significantly reducing emissions stemming from vessel operations, the meticulous handling of cargo, and ancillary activities that pervade the port's operational tapestry.

3. Quality and Consumption Water Management

The Eco Port framework cogently underscores the intrinsic and indissoluble nexus between ports and water quality. The preservation of optimal water quality stands as an ontological imperative in sustaining aquatic habitats and fostering ecological equilibrium (Lam and Li, 2019). Within the Eco Port paradigm, water management and pollution abatement constitute cardinal pillars of environmental stewardship. This connotes a profound and non-negotiable responsibility incumbent upon port authorities to safeguard the immaculate quality of adjacent water bodies. In this regard, stringent adherence to environmental norms assumes paramount significance (Puig et al., 2022).

4. Ship and Port Waste Management

The seventh criterion embedded within the Eco Port framework is concerned with ship-generated waste, a pivotal facet given its potential ramifications on port environments. Ship-generated waste encompasses the refuse and by products originating from vessels upon their arrival at port facilities. This criterion is emblematic of the substantial role that ports play in mitigating ship-source pollution, a composite issue involving the inadvertent discharge of deleterious biological entities, including plants, animals, or microorganisms, into port waters. Beyond ecological repercussions, ship-source pollution poses discernible hazards for people's health, the stability of marine/ocean ecosystems, and the integrity of economic assets (Jeevan et al., 2022). Effective and conscientious management of ship-generated waste is indispensable, aligning seamlessly with the overarching ethos of Eco Port, which endeavours to foster sustainable port administration.

Holding the eighth position in the prioritized hierarchy, port waste management emerges as a conspicuous concern within the Eco Port paradigm. Ports, serving as crucial nodal points in the global logistics chain, inherently entail the generation of pollutants. These encompass emissions stemming from exhaust gases as well as the disposal of diverse waste materials arising from port-associated activities (Chang and Wang, 2012). The term "port waste" in this context pertains to the waste streams generated concomitant with port operations. The discernible ascent of port waste's standing, progressing from the tenth position to the eighth in the year 2022, accentuates the burgeoning emphasis on fostering

judicious and efficacious waste management practices within the precincts of ports. This escalation in priority is emblematic of the growing cognizance among port authorities regarding the multifaceted environmental repercussions and the concomitant need to align assiduously with the sustainability imperatives espoused by Eco Port.

Port development, encapsulating the intricate nexus between economic, societal, and environmental paradigms intrinsic to port ecosystems (Salsas et al., 2022), assumes the ninth slot among Eco Port's defining criteria. Ports epitomize dynamic and transformative entities, serving as pivotal nodes within the global trade matrix. Port development, in this context, subsumes construction and expansion initiatives undertaken within the port environs. Such developmental undertakings are invariably necessitated by the burgeoning cargo volumes coursing through these ports. However, the flip side of port development often entails unintended ecological consequences, such as habitat degradation and ecological disruption (Darbra et al., 2004). The repercussions can extend to encompass particulate emissions, wildlife disturbances, noise pollution, and even light pollution. The recurrent imperative for enhancing or enlarging port infrastructure underscores the perennial significance of this criterion, compelling port authorities to champion strategies underpinned by sustainable development principles that uphold ecological preservation and societal well-being.

5. Energy and Climate Change Management

Energy efficiency, the fulcrum of Eco Port's environmental calculus, stands as an indispensable facet of port operations. This precept resonates with the broader industry acknowledgment of the imperious necessity to curtail energy consumption and, correspondingly, ameliorate the spectre of greenhouse gas emissions (Di Vaio et al., 2018). Elevating energy efficiency across the multifarious realms of port operations promises not only to mitigate emissions but also to foment substantial advancements in environmental stewardship. The strategic optimization of energy utilization within ship operations, port equipment functionality, and industrial processes is integral to the attainment of these overarching objectives.

Positioned at the vanguard of Eco Port's evaluative criteria, climate change mitigation stands as a paramount concern of this environmental management framework. The ever-intensifying impact of climate change on global sustainability underscores, in unequivocal terms, the compelling need for ports to proactively curtail their carbon footprint (Konstantinos et al., 2022). The potential of maritime transport to exacerbate the inexorable progression of climate change underscores the inescapable imperative that port authorities must reduce emissions emanating from their multifaceted activities. The labyrinthine facets of this endeavour demand a meticulous dissection of variables encompassing local environmental conditions, the intricacies of transport systems, the labyrinthine web of policies, and the adaptive measures necessary to mitigate carbon emissions within the purview of port operations efficaciously (UNCTAD, 2009).

6. Hazardous and toxic Materials (B3) Contaminated Land Management

Effective management of contaminated land involves considering multiple factors such as human health risks, ecological risks, economic costs, technical feasibility of re-

medial actions, and societal value placed on clean-up and re-use of contaminated lands. Decision-making in this context is complex and requires standardized approaches and decision support tools to ensure reproducibility and transparency. Land-use planning plays a crucial role in managing contaminated land, and it is important to have access to advice and assistance from environmental health practitioners. Remediation techniques are also essential in addressing contaminated land, with a focus on techniques that can effectively clean up and convert contaminated sites for other uses. Additionally, sustainability considerations have gained importance in contaminated land management, including the environmental, social, and economic consequences of risk-management activities. Overall, effective management of contaminated land requires a multidisciplinary approach, involving various disciplines such as environmental health, toxicology, ecology, land use planning, economics, and risk communication.

7. Dredging, Reclamation, Development Management

The tenth and culminating criterion residing within the Eco Port matrix pertains to the sphere of dredging operations, an arena of profound pertinence to numerous ports. Dredging activities underwater are indispensable for sustaining navigational channels and facilitating the seamless conduct of port operations. Nonetheless, these operations are not without their environmental repercussions, most notably acoustic disturbances that can significantly perturb local wildlife and the delicate marine ecosystems and habitats (Sugrue and Adriaens, 2022). The multifaceted nature of dredging encompasses variables ranging from underwater depth and tidal flow to currents, velocity, and wave dynamics. These facets conspire to yield diverse and often adverse consequences, encompassing the depletion of fishing resources, the re-suspension of pollutants, and alterations to local hydrological conditions. Hence, the meticulous and assiduous conduct of dredging operations emerges as an inescapable imperative, mandating the application of stringent control mechanisms to ameliorate their environmental footprints and to preserve the fragile ecological equilibrium characterizing the surrounding environs.

In summation, these ten Eco Port criteria amplify the comprehensive and multifaceted nature of its environmental management framework. They spotlight the manifold challenges confronting port authorities in their relentless pursuit of sustainability and conscientious environmental stewardship. These criteria signify a clarion call for strategic foresight, responsible practices, and innovative solutions within the intricate and variegated operational landscape of ports.

8. Traffic and Noise Management

Within the Eco Port paradigm, the issue of noise pollution assumes an elevated stature. Noise pollution, a multi-dimensional concern encompassing environmental and underwater acoustical dynamics, is significantly accentuated by cargo handling activities that hold a pivotal place within port operations (Lam and Notteboom, 2014). The imperative to reduce noise pollution resonates beyond the immediate benefits to port personnel, reverberating profoundly in its salutary impact on the well-being of local communities and the

preservation of local wildlife populations. This underscores the ineluctable need for port authorities to innovate and implement cutting-edge noise reduction strategies as a central tenet of their operational ethos.

9. Relationship with Local Communities Management

Successful relationships with local communities are influenced by several key factors. These factors include environmental preservation, community well-being, self-esteem, and organizational effectiveness. Additionally, building and strengthening social networks within communities can contribute to successful relationships. Understanding and forming productive partnerships with communities is crucial for the effectiveness and sustainability of projects aimed at achieving global environmental benefits. Familiarity among individuals and groups, as well as functional interdependence and consensus, are important for integration and successful relationships within the local community. Finally, managing size and diversity, addressing coalition conflict, and recognizing life cycles are behaviours that differentiate strong community health partnerships from weak ones.

10. Native Habitat, Valuable Sites and Green Open Space Management

To best protect and manage native habitat, valuable sites, and green open space, it is important to consider the benefits provided by these areas and address the challenges they face. Protected areas play a crucial role in producing wild food, supporting biodiversity, regulating climate, and providing cultural services. Additionally, the management of these areas can contribute to rural development, climate change mitigation and adaptation, and private sector participation in conserving biodiversity and ecosystem services. It is also necessary to recognize the changing nature of conservation and the importance of human-dominated ecosystems in sustaining animal and plant populations. Understanding the habitat requirements of threatened species and implementing strategies to manage suitable habitat in extirpated patches is vital for metapopulation persistence. Finally, it is essential to maintain protected natural areas as a means to sustain species, key habitats, and ecological processes.

Function and Responsibility of Related Parties of Related Parties in Port

To implement Environmentally Friendly Port Management, related parties in Port such as Harbour Master, Port Authorities, and Port Operator should perform their functions and responsibilities:

Harbour Master. The function and responsibilities consist of: (a) To perform supervision and law enforcement in the protection of the maritime environment in port, (b) To perform coordination with the Environmental Supervisory Officer and/or Regional Environmental Supervisory Officer.

Port Authority. The function and responsibilities consist of: (a) To approve the agreement and doing cooperate the construction and provision of waste storage and manage-

ment facilities at ports provided by the Business Entity, (b) To conduct construction of shelter facilities and waste management if not doing by Business Entity and report periodically to Minister of the Environment every 3 (three) months about Scale Waste, Number of delivery waste certificates that have been issued with their code, and serial numbers, (c) To report implementation of environmentally port to the Director General of Sea Transportation with a copy to Director Sea Port, Director Shipping and Maritime, and Director Marine and Coastal Guard, according to the format in the attachment of this Technical Guide every June and December every year, (d) To ensure the suitability of the location of the shelter facilities and waste management to build in accordance with the Port Master Plan.

Port Operator. The function and responsibilities consist of : (a) To perform construction shelter facilities and waste management, (b) To fill out and sign the waste certificate, (c) To report receipt of waste to the port operator before issuing a certificate of delivery of waste, (d) To give certificate of delivery waste to the owner and/or operator of the ship who has submitted the waste, (e) To report to Minister of Environment every 3 (three) months regarding scale waste and number of delivery waste certificate that have been issued with their code and serial numbers.

Implementation of Eco Port in Foreign Countries and in Indonesia

Eco Port has been implemented in various countries. The implementation of Eco Port in Port of Long Beach California is considered as the best practice of Eco Port in which it successfully reduced the diesel dependency by 75%. The other success story of Eco Port also could be found in Sydney Port that implement the concept of equilibrium between resource consumption and environmental quality. Meanwhile, Shanghai Green Port also manage to establish integrated port amidst agricultural area.

On the other hand, Eco Port in Indonesia has been applied in Teluk Lamong Terminal, East Java in which it reduces the carbon emission without using fossil energy and replace it with electric power and gas engine power plant. Energy saving is also performed by using solar cell system, Light Emitting Diode (LED), and Gas Exhaust for AC System. Teluk Lamong Port also has Management Trash, Incinerator, and Oily Water Separator. In addition, Teluk Lamong is also the first semi-automatic port in Indonesia thus its operational is much more safety.

Green Shipping

Green shipping practices in the maritime industry include strategies such as speed reduction, fuel switching, and the use of alternative fuels to decrease harmful emissions and increase environmental sustainability. Factors that motivate shipping firms to adopt green shipping practices (GSP) include industrial norms, customer demand for environmental friendliness, and the desire to create a positive image. Adopting GSP can improve

the environmental and productivity performance of shipping firms. Public concerns about environmental issues caused by shipping activities, such as air pollution and resource depletion, have been growing rapidly. The shipping sector, which facilitates global trade, generates environmental pollution, including CO2 emissions and oil spills. Understanding why green management practices (GMPs) should be adopted in the shipping industry is important for various reasons.

According to the data from ministry of transportation, the number of Indonesia registered vessels in 2022 consist of 4.796 Passenger vessels, 49.221 fishing vessels, and 44.178 cargo vessels. Therefore, considering the number of vessels in Indonesia, green shipping should be conducted to reduce carbon emission.

IMO Recommendation to Reduce Carbon Emission

According to the IMO, three ways that could be performed to reduce carbon emission consist of:

Energy Efficiency Design Index (EEDI). EEDI stands for Energy Efficiency Design Index, which is an index that measures the energy efficiency of a ship based on its fuel consumption per unit of tonnage and distance travelled. EEDI is set by the International Maritime Organization (IMO) as part of its efforts to reduce greenhouse gas emissions from ships. IMO's EEDI targets 30%, 40%, and 50% from the improvement of baseline EEDI efficiency in 2025, 2030, and 2035 respectively.

Energy Efficiency Operational and Ship Energy Efficiency Management Plant. Mandatory requirement for all ships 400 gross tonnage (GT) and above engaged in international voyages. Structured approach to improving energy efficiency and SEEMP through Voyage planning and optimization, Weather routing, Speed optimization, Hull and propeller maintenance, Engine management, and Waste heat recovery.

Market-based Measurement That Considers Carbon Markets Operational Measures. It is a cost-effective, flexible, and innovative approach that can create incentives for shipping companies to invest in new technologies and practices that reduce emissions For example, Maersk Line, the world's largest container shipping company, has committed to reducing its CO2 emissions per container-moved by 40% by 2030, compared to 2019 levels.

International Cooperation on Shipping Coordination

Glo Fouling Partnership. This IMO-initiated activity, in collaboration with the Global Environment Facility (GEF) and the United Nations Development Program (UNDP), aims to minimise the transfer of aquatic species through biofouling, or to minimise the development of aquatic organism assemblages on the underside of hulls and ship

On Shore Power Supply. An electrical system to connect a ship at berth with the onshore power grid to enable the ship to continue to receive electricity to power cooling,

heating, lighting and other equipment and to shut down the ship's auxiliary engines while the ship is loading and unloading at the harbour.

Mitigation Action Steps Implemented

There are some mitigation steps that has been conducted based two categories:

Energy Efficiency. There are some actions that can be taken for energy efficiency such as : (a) Ship modernization and ship recycle. A structured analysis of the most pivotal innovations in green shipping technologies are Hull Optimization, ship coatings, air lubrication technologies. The focal point here has been the optimization of hull designs to ameliorate hydrodynamic efficiency and attenuate resistance. Computational Fluid Dynamics (CFD) has emerged as the vanguard tool in this endeavor (Chang et al., 2023). Progress in ship coatings, particularly the development of bio-coatings impervious to deleterious organisms and corrosion, is a linchpin of energy efficiency enhancement (Ravenna et al., 2022; Hakim et al., 2023). Air lubrication systems, by minimizing the interaction between the vessel's hull and water, exhibit promise in reducing resistance (Tadros et al., 2022e). ; (b) Implementation Ship Energy Efficiency Management Plan (SEEMP). The Ship Energy Efficiency Management Plan (SEEMP), introduced in 2013 by the IMO and further improved in 2023, is a systematic, useful instrument for assisting ship owners in managing their environmental performance and enhancing operational efficiency. The SEEMP is divided into three sections e.g Ship management plan to improve energy efficiency, Ship fuel oil consumption data collection plan, Ship operational carbon intensity plan. All ships over 400 GT must have Part I of the SEEMP on board at all times. All ships above 5,000 GT must have a certified Part II as part of the Data Collection System. All ships subject to the Carbon Intensity Indicator (CII), including cargo, Ro-Pax, and cruise passenger ships exceeding 5,000 GT, must have a validated Part III. In order to maximize the performance of the ship, the SEEMP mandates that owners and operators take into account and put innovative technology and methods into operation. Examples of operational efficiency and carbon intensity improvements include: Optimization of speed, climate planning, Monitoring and upkeep of hulls, installing heat recovery equipment. ; (c) Implementation Certification of Anti Fouling System. The use of harmful organotin compounds in anti-fouling paints used on ships will be prohibited by the international convention on the control of harmful anti-fouling systems on ships, which was adopted on October 5, 2001. The convention will also establish a mechanism to stop the potential use of other harmful substances in anti-fouling systems in the future. The Convention becomes effective on September 17, 2008.

According to the provisions of the Convention, Parties are required to forbid and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as on ships that are not authorized to fly their flag but are under their control and on all ships that enter a Party's port, shipyard, or offshore terminal

Utilisation of Renewable Energy. Implementation Onshore Power Supply (OPS), Electrification loading unloading port facilities, Utilization of Solar Panel system (Street Light-

ing) in Ports, Utilization of Biofuel for ships using FAME (Fatty Acid Methyl Ester), and Aid to Navigation renewable energy power.

Challenges

The barriers to the development of eco-ports include power requirement, investment cost, and electricity cost. Additionally, environmental quality is a crucial factor in green port development, with a focus on carbon dioxide emissions. Furthermore, organizational barriers and technological barriers also hinder the transformation of traditional industrial zones into eco-industrial parks. The underutilization of eco-innovations, despite their potential competitive gains and environmental benefits, is another barrier to their diffusion in the economy. Policymakers need to address these barriers by improving regulations, procedures, and support resources for industrial zones, raising awareness about the sustainable value of industrial zones, and establishing long-term partnerships with NGOs.

Eco Port Challenges

The challenges of eco-ports include improving environmental performance, reducing emissions, and addressing concerns of stakeholders. Port operators need to consider environmental concerns of stakeholders, such as shippers, and make plans for intermodal network design that take into account port competition and route choice behaviours of shippers. Voluntary initiatives by port authorities can promote environmental upgrading, but implementation complexity and issue visibility are key facilitators. Bulk materials handling in ports presents difficulties related to energy efficiency, dust emissions, noise, and handling of hazardous materials. Ports are required to invest in environmental facilities and comply with regulations addressing air-polluting gases from ships. While there is not yet a clear business case associating environmental performance with direct port competitiveness, enhancing environmental performance is important for addressing current needs and supporting the development of ports as major players in ocean borne trade.

Optimization of Maintenance and Monitoring System. The optimization of maintenance and monitoring systems for eco-friendly technology infrastructure, especially in the areas of water treatment and renewable energy systems, is crucial. This will help ensure that these systems operate optimally and effectively reduce environmental impacts.

The Development of skills and competencies of Sustainable human Resources. (through a comprehensive HR strategy includes the development of skills and competencies related to sustainable practices, such as training staff in the use of environmentally friendly technologies, environmental impact monitoring, and other efforts that support sustainable port management (Eco Port)

Green Shipping Challenges

The challenges in green shipping include the need to decarbonize the industry in order to meet the goals of the Paris Agreement. Shipping activities have a significant environmental footprint, including air pollution and resource depletion. Public concerns about these environmental issues have been growing rapidly with the globalization of business activities. However, there is a positive association between greening and firm performance in shipping operations, indicating that shipping firms have the capability to improve their environmental and financial performance To address these challenges, a solid regulatory framework is needed to regulate shipping practices and promote environmentally friendly operations. Additionally, shipping firms should pay more attention to the environmental and financial ramifications of their business routines, such as company policy and procedure, shipping documentation, shipping materials, and shipping design for compliance.

Operational Efficiency vs Environmental Sustainability. Balancing the need for operational efficiency with environmental sustainability can be challenging. Some green technologies, while reducing emissions, may impact the speed and efficiency of vessels, potentially affecting schedules and profitability.

Crew Training and Expertise. The adoption of green technologies often requires crew members to be trained in new equipment and practices. Ensuring that maritime professionals have the necessary skills and knowledge can be a logistical challenge.

CONCLUSION

As the global shipping sector struggles with environmental sustainability, Eco Ports and green shipping face both challenges and opportunities. To prevent climate change and maintain our seas and coastal ecosystems, sustainable behaviours are essential.To overcome this article's problems, stakeholders must emphasize multifaceted approaches. Investing in green technology comes first. An ecologically friendly shipping sector will depend on creative solutions including alternative fuels, energy-efficient boats, and better waste management systems. These technologies may be adopted faster and made available to all ports via public-private research and development.

Furthermore, collaboration is essential. Collaboration between shipping firms, port authorities, local governments, and environmental groups may improve information exchange and resource pooling. Shipping companies may improve best practices and systemic change by forming partnerships that play to their strengths. International collaboration is particularly important because common standards and harmonized legislation may level the playing field and enable a coordinated environmental response.

Eco Ports and green shipping depend on policy creation and campaigning. Governments must create clear, ambitious, but feasible regulatory frameworks that encourage sustainable behaviours and support implementation. This involves offering grants and subsidies to reduce financial limitations that impede advancement. Innovation and sus-

tainability may be fostered by advocating for improved national and international environmental legislation.

The path to Eco Ports and green shipping is complicated and involves collaboration from all parties. The maritime sector can create a sustainable future by investing in technology, collaborating, and promoting strong legislation. As we look forward, all stakeholders must stay committed to converting the shipping industry into an environmental stewardship model to keep our seas vibrant and our ports thriving.

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Human Factors and Their Impact on Maritime Safety and Operational Efficiency

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აბსტრაქტი

საზღვაო ინდუსტრია წარმოადგენს გლობალური ეკონომიკური სისტემის ერთ-ერთ ფუნდამენტურ სექტორს, რომელიც უზრუნველყოფს საერთაშორისო ვაჭრობის დაახლოებით ოთხმოცდაათი პროცენტის ტრანსპორტირებას და მნიშვნელოვან გავლენას ახდენს მსოფლიო ეკონომიკურ სტაბილურობასა და საერთაშორისო ლოგისტიკურ პროცესებზე. მიუხედავად ნავიგაციის სისტემების, გემების ავტომატიზაციისა და საერთაშორისო მარეგულირებელი ჩარჩოების მნიშვნელოვანი ტექნოლოგიური განვითარების, საზღვაო ინციდენტები და ოპერაციული არაეფექტიანობა კვლავ მნიშვნელოვან გამოწვევად რჩება. თანამედროვე კვლევები მიუთითებს, რომ მსგავსი შემთხვევების მნიშვნელოვანი ნაწილი უფრო მეტად ადამიანურ ფაქტორებთან არის დაკავშირებული, ვიდრე მხოლოდ ტექნიკურ გაუმართაობასთან. შესაბამისად, ადამიანური ფაქტორების კვლევა თანამედროვე საზღვაო მეცნიერებაში განსაკუთრებულ მნიშვნელობას იძენს, განსაკუთრებით უსაფრთხოების გაუმჯობესებისა და ოპერაციული ეფექტიანობის ზრდის მიმართულებით.

ადამიანური ფაქტორები მოიცავს ინდივიდებს, ტექნოლოგიურ სისტემებს, ორგანიზაციულ სტრუქტურებსა და ოპერაციულ გარემოს შორის არსებულ ურთიერთქმედებას, რომლის ფარგლებშიც საზღვაო პერსონალი ასრულებს პროფესიულ საქმიანობას. საზღვაო კონტექსტში აღნიშნული ფაქტორები მოიცავს პროფესიულ კომპეტენციას, სიტუაციურ ცნობიერებას, კომუნიკაციის ეფექტიანობას, გადაწყვეტილების მიღების პროცესებს, დაღლილობის მართვას, ლიდერულ უნარებსა და გუნდურ თანამშრომლობას. ეს ელემენტები განსაზღვრავს მეზღვაურთა შესაძლებლობას, უსაფრთხოდ და ეფექტიანად იმოქმედონ რთულ და ხშირად არაპროგნოზირებად გარემოში. მათი ეფექტიანი მართვა მნიშვნელოვნად უწყობს ხელს ავარიების პრევენციას, ოპერაციული რისკების შემცირებასა და გემის საქმიანობის ოპტიმიზაციას.

ნაშრომი განიხილავს ადამიანური ფაქტორების გავლენას საზღვაო უსაფრთხოებასა და ოპერაციულ ეფექტიანობაზე. განსაკუთრებული ყურადღება ეთმობა კომუ-

ნიკაციის როლსა და იმ ადამიანურ დეტერმინანტებს, რომლებიც გავლენას ახდენენ გემზე მიმდინარე ოპერაციებსა და ნავიგაციურ გადაწყვეტილებებზე. საზღვაო საქმიანობა მოითხოვს მუდმივ მონიტორინგს, ინფორმაციის სწრაფ ანალიზსა და ეკიპაჟის წევრებს შორის კოორდინირებულ თანამშრომლობას. ასეთ პირობებში ეფექტიანი კომუნიკაცია და ურთიერთგაგება კრიტიკულად მნიშვნელოვანია ოპერაციული პროცესების უსაფრთხოდ და დროულად განხორციელებისთვის. კომუნიკაციურმა ხარვეზებმა, გაუგებრობებმა ან არასაკმარისმა კოორდინაციამ შესაძლოა სერიოზული შეცდომები გამოიწვიოს და საფრთხე შეუქმნას ნავიგაციურ უსაფრთხოებასა და ოპერაციულ სტაბილურობას.

კვლევაში ასევე ყურადღება გამახვილებულიასაზღვაო პერსონალზ ის დაღლილობისა და სამუშაო დატვირთვის გავლენაზე. მეზღვაურები ხშირად საქმიანობენ ხანგრძლივი სამუშაო საათების, არარეგულარული გრაფიკისა და შეზღუდული დასვენების პირობებში, რაც ნეგატიურად აისახება კოგნიტურ ფუნქციებზე, მათ შორის ყურადღებასა და გადაწყვეტილების მიღების უნარზე. შესაბამისად, დაღლილობა აღიარებულია ადამიანური შეცდომების ერთ-ერთ მნიშვნელოვან გამომწვევ ფაქტორად საზღვაო ოპერაციებში. აღნიშნული პრობლემის მართვა საჭიროებს არა მხოლოდ რეგულაციების დაცვას, არამედ ისეთი ორგანიზაციული პოლიტიკის დანერგვას, რომელიც უზრუნველყოფს პერსონალის ფიზიკურ და ფსიქოლოგიურ კეთილდღეობას.

გარდა ამისა, ნაშრომი ხაზს უსვამს უსაფრთხოების კულტურის მნიშვნელობას საზღვაო ორგანიზაციებში. ძლიერი უსაფრთხოების კულტურა ხელს უწყობს უსაფრთხოების ნორმების დაცვას, კომუნიკაციის გამჭვირვალობასა და პროაქტიული რისკ-მენეჯმენტის განვითარებას. ორგანიზაციები, რომლებიც განსაკუთრებულ ყურადღებას უთმობენ პროფესიულ განვითარებასა და „თითქმის ინციდენტების" („near-miss") შემთხვევების ანგარიშგებას, უფრო ეფექტიანად ამცირებენ ოპერაციულ რისკებს.

დასკვნის სახით შეიძლება აღინიშნოს, რომ ადამიანური ფაქტორების სიღრმისეული გააზრება და სისტემური მართვა მნიშვნელოვან გავლენას ახდენს როგორც საზღვაო უსაფრთხოების, ისე ოპერაციული ეფექტიანობის გაუმჯობესებაზე. მიუხედავად ტექნოლოგიური პროგრესისა, ადამიანური ფაქტორი კვლავ რჩება საზღვაო ოპერაციების უსაფრთხოებისა და ეფექტიანობის განმსაზღვრელ ძირითად ელემენტად. შესაბამისად, ადამიანური ფაქტორების ეფექტიანი ინტეგრაცია უსაფრთხოების მართვის სისტემებში აუცილებელი წინაპირობაა მდგრადი და უსაფრთხო საზღვაო ოპერაციების უზრუნველსაყოფად.

საკვანძო სიტყვები: ადამიანური ფაქტორები; საზღვაო უსაფრთხოება; ოპერაციული ეფექტიანობა; კომუნიკაციის ეფექტიანობა; ადამიანური შეცდომა.

ABSTRACT

The maritime industry represents one of the most critical components of the global economic system, ensuring the transportation of approximately ninety percent of international trade. Despite remarkable technological progress in navigation systems, vessel automation, and regulatory frameworks, maritime accidents and operational inefficiencies continue to occur. Numerous studies indicate that a considerable proportion of such incidents are closely associated with human factors rather than purely technical failures. Consequently, the examination of human factors has become an increasingly significant area of research in maritime studies, particularly in relation to improving safety standards and enhancing operational performance.

Human factors encompass the interaction between individuals, technological systems, organizational structures, and the operational environment in which maritime personnel perform their duties. Within the maritime context, these factors involve elements such as professional competence, situational awareness, communication effectiveness, decision-making processes, fatigue management, leadership practices, and teamwork. These elements collectively influence the ability of seafarers to perform tasks efficiently and safely under demanding and often unpredictable conditions. When these human-centered aspects are effectively managed, they contribute significantly to the prevention of accidents, the reduction of operational risks, and the optimization of vessel performance.

This study examines the role of human factors in shaping both maritime safety outcomes and operational efficiency. Particular emphasis is placed on identifying the key human-related determinants that influence shipboard operations and navigational decision-making. Maritime operations require continuous monitoring, rapid information processing, and coordinated teamwork among crew members. In such an environment, effective communication and mutual understanding are essential for ensuring that operational procedures are executed accurately and without delay. Communication breakdowns, misunderstandings, or insufficient coordination among crew members may result in critical errors that compromise navigational safety and operational stability.

Another important dimension of this research concerns the impact of fatigue and workload on maritime personnel. Seafarers frequently operate within complex working environments characterized by long duty periods, irregular watch schedules, and limited opportunities for rest and recovery. These conditions can negatively influence cognitive functioning, including attention, perception, and decision-making capabilities. As a result, fatigue has been widely recognized as a significant contributor to human error in maritime operations. Addressing this issue requires not only regulatory compliance but also the implementation of practical fatigue management strategies and organizational policies that support the physical and psychological well-being of maritime professionals.

Furthermore, the study highlights the critical role of organizational safety culture in influencing human behavior and operational performance within maritime organizations. A strong and well-established safety culture encourages adherence to established safety procedures, promotes transparency in communication, and supports proactive

risk management practices. Organizations that actively foster such a culture tend to emphasize continuous professional development, encourage the reporting of near-miss incidents, and adopt preventive approaches aimed at minimizing operational hazards. In this regard, safety culture functions as a fundamental mechanism through which human factors can be effectively integrated into the broader safety management framework of the maritime sector.

The analysis suggests that a comprehensive understanding and systematic management of human factors can significantly contribute to improving both maritime safety and operational efficiency. Investments in advanced training programs, improved leadership practices, effective communication protocols, and supportive working conditions can substantially reduce the probability of human-related incidents while enhancing overall operational reliability.

In conclusion, although technological innovation continues to transform maritime transportation, the human element remains a decisive factor in determining the safety and effectiveness of maritime operations. Therefore, strengthening the integration of human factors into maritime safety management systems represents an essential step toward achieving sustainable, resilient, and efficient maritime operations in an increasingly complex global shipping environment.

KEEWORDS: Human factors; maritime safety; operational efficiency; communication effectiveness; human error.

INTRODUCTION

The contemporary maritime industry occupies a central position within the global economic system, facilitating approximately 80–90 percent of international trade by volume and serving as the backbone of global supply chains (UNCTAD 2023). As globalization continues to intensify economic interdependence among nations, maritime transportation has become increasingly complex, technologically advanced, and operationally demanding. Despite substantial progress in vessel design, navigation technologies, and regulatory frameworks, maritime accidents and operational inefficiencies persist, often with significant economic, environmental, and human consequences.

A growing body of research suggests that the majority of maritime incidents cannot be attributed solely to technical malfunctions or environmental conditions but are, instead, closely linked to human-related factors (Hollnagel 2014; Hetherington, Flin, and Mearns 2006). Human factors—encompassing cognitive, behavioral, organizational, and environmental dimensions—play a decisive role in shaping operational outcomes within maritime contexts. These factors include, but are not limited to, communication effectiveness, decision-making processes, situational awareness, fatigue, leadership, and teamwork. Their interaction within complex socio-technical systems significantly influences both safety performance and operational efficiency.

The relevance of examining human factors in maritime operations has increased considerably in recent decades, particularly in light of high-profile maritime accidents such as the Costa Concordia disaster and the Exxon Valdez oil spill, which highlighted the critical role of human error and organizational shortcomings in accident causation. These incidents demonstrated that even in technologically sophisticated environments, human decision-making failures, miscommunication, and inadequate safety cultures can lead to catastrophic outcomes. Consequently, there has been a paradigm shift in maritime safety research toward a more holistic understanding of human-centered risk factors and their systemic implications.

In modern maritime operations, communication represents one of the most critical components of safe and efficient performance. Ships operate as complex, high-risk environments where crew members must coordinate tasks, interpret information, and respond to rapidly changing conditions. Ineffective communication—whether due to language barriers, cultural differences, or organizational hierarchies—can lead to misunderstandings, delayed responses, and operational errors (IMO 2017). In multinational crews, where English is commonly used as a lingua franca, variations in language proficiency and communication styles further complicate interaction, increasing the likelihood of misinterpretation and reduced situational awareness.

Moreover, fatigue and workload have emerged as significant contributors to human error in maritime settings. Seafarers frequently work under demanding conditions characterized by long shifts, irregular sleep patterns, and high levels of responsibility. Empirical studies have shown that fatigue negatively affects cognitive performance, impairing attention, reaction time, and decision-making abilities (Oldenburg, Jensen, and Wegner 2013). As a result, fatigue-related errors remain a persistent challenge in ensuring maritime safety and operational reliability.

Another critical dimension of human factors relates to organizational safety culture. A strong safety culture promotes adherence to procedures, encourages open communication, and supports proactive risk management practices. Conversely, weak safety cultures—characterized by poor leadership, lack of accountability, and inadequate training—can exacerbate human errors and increase vulnerability to accidents (Reason 2000). In this regard, safety culture serves as a fundamental framework through which human factors can be systematically managed and integrated into organizational practices.

The primary aim of this study is to examine the impact of human factors on maritime safety and operational efficiency, with particular emphasis on communication, fatigue, and organizational culture as key determinants of performance. The study seeks to analyze how these factors interact within maritime systems, identify their implications for safety outcomes, and propose evidence-based recommendations for improving operational practices.

The significance of this research lies in its contribution to the ongoing discourse on maritime safety management. By adopting a human-centered perspective, the study highlights the necessity of moving beyond purely technical solutions and addressing the underlying behavioral and organizational factors that shape maritime operations. In doing

so, it provides valuable insights for policymakers, maritime organizations, and training institutions seeking to enhance safety standards and operational effectiveness in an increasingly complex global shipping environment.

THEORETICAL FRAMEWORK: HUMAN FACTORS AND MARITIME COMMUNICATION

Building upon the introductory discussion, it is essential to further conceptualize human factors within the framework of maritime operations as a complex interaction between individuals, technologies, and organizational systems. Contemporary maritime research increasingly adopts a socio-technical systems perspective, recognizing that safety and efficiency are shaped not only by technological reliability but also by human interaction and communication processes (Hollnagel 2014).

Within this framework, communication emerges as a central component of operational performance. Maritime environments are inherently dynamic and high-risk, requiring continuous information exchange among crew members, shore-based personnel, and external stakeholders. Effective communication ensures that navigational decisions are based on accurate and timely information, thereby reducing uncertainty and enhancing situational awareness. Conversely, communication failures can disrupt coordination, delay responses, and ultimately compromise safety outcomes (Barnett, Gatfield, and Pekcan 2006).

In particular, the role of communication in bridge operations and engine room coordination has been widely emphasized in maritime safety literature. Bridge Resource Management (BRM), for example, highlights communication as a key competency necessary for effective teamwork and decision-making. Clear, concise, and standardized communication protocols are essential for minimizing ambiguity and ensuring that instructions are properly understood and executed.

INTERCULTURAL COMMUNICATION AND MULTINATIONAL CREWS

A defining characteristic of the modern maritime workforce is its multicultural composition. Ships are frequently staffed by crew members from diverse linguistic, cultural, and educational backgrounds. While such diversity offers valuable perspectives and skills, it also introduces significant challenges in terms of communication and mutual understanding.

Intercultural communication refers to the process of exchanging information across cultural boundaries, where differences in language, norms, values, and communication styles can influence interpretation and interaction. In maritime contexts, these differences may manifest in various ways, including indirect communication styles, hierarchical attitudes, and varying perceptions of authority and responsibility (Pike et al. 2013).

For instance, crew members from high-context cultures may rely more on implicit communication and contextual cues, whereas those from low-context cultures tend to favor di-

rect and explicit communication. Such differences can lead to misunderstandings, particularly in high-pressure situations where clarity and speed are essential. Additionally, cultural norms related to hierarchy may discourage junior crew members from questioning decisions made by senior officers, even when potential risks are identified. This lack of assertiveness can significantly increase the likelihood of human error and operational incidents.

Empirical studies have demonstrated that cultural misunderstandings have been contributing factors in several maritime accidents, underscoring the importance of intercultural competence as a key component of maritime training (Hetherington, Flin, and Mearns 2006). Therefore, developing intercultural awareness and communication skills is essential for enhancing teamwork and ensuring safe operations in multinational crews.

LANGUAGE BARRIERS AND THE ROLE OF MARITIME ENGLISH

Closely related to intercultural communication is the issue of language proficiency. English has been widely adopted as the standard working language in international maritime operations, as codified in the International Maritime Organization's Standard Marine Communication Phrases (SMCP) (IMO 2017). However, variations in English language proficiency among crew members remain a significant challenge.

Language barriers can lead to misinterpretation of instructions, incomplete information transfer, and reduced situational awareness. In critical situations, even minor misunderstandings can have severe consequences. For example, ambiguous phrasing, incorrect terminology, or mispronunciation may result in delayed or inappropriate responses, thereby increasing operational risk.

Furthermore, non-native speakers may experience difficulties in expressing complex ideas or understanding technical instructions, particularly under stress. This limitation can hinder effective decision-making and coordination. Studies have shown that inadequate language skills are frequently associated with communication breakdowns in maritime incidents (Trenkner 2010).

To address these challenges, maritime training programs increasingly emphasize the importance of Maritime English as a specialized form of communication. This includes not only vocabulary and grammar but also standardized phraseology, pronunciation, and communication strategies tailored to maritime contexts. The use of standardized communication protocols, such as SMCP, aims to reduce ambiguity and ensure clarity, particularly in safety-critical situations.

COMMUNICATION FAILURES AND THEIR CONSEQUENCES

The consequences of ineffective communication in maritime operations can be severe and far-reaching. Communication breakdowns may result in navigational errors, collisions, groundings, and delays in emergency response. In many cases, such failures are not the re-

sult of a single error but rather a chain of miscommunications that accumulate over time.

One of the most critical risks associated with poor communication is the loss of situational awareness. When information is not accurately shared or properly understood, crew members may develop incomplete or incorrect mental models of the operational environment. This can lead to inappropriate decisions and actions, particularly in complex or rapidly evolving situations (Endsley 1995).

Additionally, communication failures can undermine teamwork and trust among crew members. Effective teamwork relies on open communication, mutual respect, and shared understanding. When communication is unclear or inconsistent, it can create confusion, reduce confidence, and hinder collaboration.

Another important aspect is the role of communication in emergency situations. During emergencies, such as collisions or equipment failures, clear and immediate communication is essential for coordinating response efforts and minimizing damage. Any delay or misunderstanding in communication can exacerbate the situation and increase the severity of the outcome.

INTEGRATION WITH HUMAN FACTORS AND OPERATIONAL EFFICIENCY

Communication, intercultural competence, and language proficiency are integral components of the broader human factors framework. Their influence extends beyond safety to encompass overall operational efficiency. Efficient communication facilitates coordination, reduces delays, and enhances decision-making processes, thereby improving productivity and performance.

Moreover, the integration of effective communication practices into organizational systems contributes to the development of a strong safety culture. Organizations that prioritize communication training, encourage open dialogue, and implement standardized procedures are better equipped to manage risks and prevent accidents (Reason 2000).

From an operational perspective, investing in communication training and human factors management can yield significant benefits, including reduced accident rates, improved efficiency, and enhanced organizational reputation. As maritime operations continue to evolve in response to technological advancements and globalization, the importance of human-centered approaches to communication will only increase.

This study adopts a qualitative research design, supported by elements of secondary quantitative data analysis, in order to examine the impact of human factors on maritime safety and operational efficiency. The research is based on a comprehensive review and synthesis of academic literature, international maritime reports, and empirical studies published between 2000 and 2024. The use of secondary data sources enables the identification of consistent patterns, trends, and relationships between human factors and safety outcomes in maritime operations.

The methodological framework is grounded in a descriptive and analytical approach. First, relevant scholarly articles and institutional reports were systematically reviewed to

identify key themes related to human factors, including communication effectiveness, intercultural interaction, fatigue, and organizational safety culture. Second, a comparative analysis was conducted to evaluate how these factors influence maritime incidents across different operational contexts.

In addition, the study incorporates statistical data from international organizations such as the International Maritime Organization (IMO), the European Maritime Safety Agency (EMSA), and the United Nations Conference on Trade and Development (UNCTAD). These data sources provide empirical evidence regarding the prevalence of human error in maritime accidents and the role of communication-related failures in operational disruptions.

Particular attention is given to case-based evidence and incident reports, which offer valuable insights into the practical implications of communication breakdowns, language barriers, and cultural misunderstandings. By integrating theoretical perspectives with empirical findings, the study aims to provide a comprehensive and well-founded analysis of the role of human factors in maritime safety.

RESULTS AND ANALYSIS

The Prevalence of Human Error in Maritime Incidents

The analysis of existing literature and statistical data confirms that human factors remain a dominant cause of maritime accidents. According to reports by the European Maritime Safety Agency, approximately 75–96% of maritime accidents involve some form of human error, either as a primary cause or as a contributing factor (EMSA 2022). These findings are consistent with earlier studies, which emphasize that technological advancements alone are insufficient to eliminate risks in maritime operations.

Human error manifests in various forms, including poor decision-making, lack of situational awareness, miscommunication, and procedural violations. Among these, communication-related failures represent one of the most critical and recurrent issues.

Communication Failures as a Critical Risk Factor

The findings of this study highlight that ineffective communication is a significant contributor to operational failures and safety incidents. Research indicates that over 50% of maritime incidents involve communication breakdowns at some stage of the operational process (IMO 2017).

Communication failures may occur due to:

- unclear or ambiguous instructions,
- misinterpretation of messages,
- lack of standardized terminology,
- insufficient feedback or confirmation,
- hierarchical barriers preventing open dialogue.

In high-risk environments such as navigation and maneuvering operations, even minor communication errors can escalate into serious incidents. For example, incorrect interpretation of navigational commands or delayed information exchange can lead to collisions, groundings, or equipment damage.

Furthermore, the absence of effective communication protocols reduces the ability of crew members to maintain shared situational awareness, which is essential for coordinated decision-making.

Impact of Intercultural Differences on Communication

The results also demonstrate that intercultural differences significantly influence communication effectiveness in maritime settings. Multinational crews often face challenges related to differing communication styles, cultural norms, and attitudes toward authority.

Studies show that cultural factors contribute to approximately 30% of communication-related misunderstandings in maritime operations (Pike et al. 2013). These misunderstandings may arise from:

- indirect vs. direct communication styles,
- varying interpretations of instructions,
- reluctance to question authority,
- differences in non-verbal communication.

For instance, in hierarchical cultures, junior crew members may hesitate to report errors or challenge decisions made by senior officers. This lack of assertiveness can prevent the timely identification of risks and increase the likelihood of accidents.

The analysis indicates that intercultural competence is essential for mitigating these risks. Training programs that focus on cultural awareness, communication strategies, and teamwork can significantly improve interaction and reduce misunderstandings.

Language Barriers and Operational Risks

Language proficiency represents another critical factor affecting communication. Although Maritime English is widely used as the standard communication language, variations in proficiency levels among crew members create significant challenges

Empirical evidence suggests that language-related issues contribute to a substantial proportion of communication failures, particularly in emergency situations (Trenkner 2010). Common problems include:

- misunderstanding technical terminology,
- incorrect pronunciation or accent-related confusion,
- limited vocabulary for expressing complex ideas,
- difficulty in understanding rapid or unclear speech.

These challenges are further intensified under stress, fatigue, or time pressure. In such conditions, the likelihood of miscommunication increases, potentially leading to delayed or incorrect decisions.

The implementation of standardized communication systems, such as the IMO's Standard Marine Communication Phrases (SMCP), has been shown to reduce ambiguity and improve clarity. However, the effectiveness of these systems depends on proper training and consistent application.

Fatigue, Workload, and Cognitive Performance

The analysis confirms that fatigue is a major contributing factor to human error in maritime operations. According to recent studies, fatigue is involved in up to 25% of maritime incidents, particularly those related to navigation and watchkeeping (Oldenburg, Jensen, and Wegner 2013).

Fatigue negatively affects:

- attention and concentration,
- reaction time,
- decision-making ability,
- communication effectiveness.

When crew members are fatigued, their ability to process information and communicate clearly is significantly impaired. This increases the risk of misunderstandings and reduces overall operational efficiency.

Moreover, heavy workloads and irregular schedules further exacerbate these effects, creating a cumulative risk that can compromise both safety and performance.

Organizational Safety Culture and Communication

Another key finding is the strong relationship between organizational safety culture and communication practices. Organizations with well-developed safety cultures tend to promote open communication, encourage reporting of errors, and support collaborative decision-making.

Research indicates that organizations with strong safety cultures experience significantly lower accident rates and improved operational performance (Reason 2000). In such environments:

- communication is transparent and structured,
- crew members feel confident to express concerns,
- feedback mechanisms are actively used,
- continuous training is prioritized.

Conversely, weak safety cultures often lead to communication breakdowns, lack of accountability, and increased risk of human error.

Overall, the results of this study demonstrate that communication-related human factors play a central role in shaping both maritime safety and operational efficiency. The interaction between communication, cultural diversity, language proficiency, fatigue, and organizational context creates a complex risk environment that requires systematic management. The findings clearly indicate that improving communication practices—through

training, standardization, and cultural awareness—can significantly reduce the likelihood of accidents and enhance overall performance.

The present study has demonstrated that human factors constitute a fundamental determinant of both maritime safety and operational efficiency. While technological advancements have significantly improved navigation systems, automation, and regulatory compliance, they have not eliminated the risks associated with human performance. On the contrary, the findings confirm that the human element remains central to the functioning of maritime operations, particularly in complex, high-risk, and multicultural environments.

One of the most significant findings of this research is the dominant role of communication in shaping safety outcomes. Effective communication has been identified as a critical mechanism for ensuring coordination, maintaining situational awareness, and supporting accurate decision-making. Conversely, communication failures—arising from ambiguity, misinterpretation, or insufficient feedback—represent a major source of operational risk. The study highlights that such failures often occur not in isolation but as part of a chain of errors, ultimately leading to serious maritime incidents.

Furthermore, the analysis emphasizes the growing importance of intercultural communication in the context of multinational crews. Cultural diversity, while beneficial in many respects, introduces complexities that may hinder mutual understanding and collaboration. Differences in communication styles, attitudes toward hierarchy, and behavioral norms can contribute to misunderstandings and reduce the effectiveness of teamwork. The findings suggest that intercultural competence is no longer an optional skill but an essential requirement for safe and efficient maritime operations.

Another key finding relates to the impact of language barriers on communication effectiveness. Despite the widespread adoption of Maritime English as a standard working language, variations in language proficiency continue to pose significant challenges. Misinterpretation of instructions, limited vocabulary, and difficulties in understanding technical terminology can lead to critical errors, particularly under conditions of stress and time pressure. This underscores the necessity of continuous language training and the consistent application of standardized communication protocols.

In addition, the study confirms the significant influence of fatigue and workload on human performance. Prolonged working hours, irregular schedules, and insufficient rest negatively affect cognitive functions, including attention, perception, and decision-making. Fatigue not only increases the likelihood of human error but also reduces communication effectiveness, thereby amplifying operational risks.

The role of organizational safety culture has also been identified as a crucial factor in shaping human behavior and communication practices. Organizations that promote open communication, encourage reporting of errors, and invest in training and professional development are better positioned to manage risks and prevent accidents. A strong safety culture fosters trust, accountability, and proactive risk management, all of which contribute to improved operational performance.

RECOMMENDATIONS

Based on these findings, several important recommendations can be proposed.

First, maritime education and training institutions should place greater emphasis on communication skills, including Maritime English, intercultural communication, and teamwork. Training programs should move beyond theoretical knowledge and incorporate practical simulations that reflect real-life operational scenarios.

Second, shipping companies and maritime organizations should invest in continuous professional development programs aimed at enhancing human factors competencies. This includes not only technical training but also soft skills such as leadership, communication, and decision-making.

Third, the implementation and enforcement of standardized communication protocols, such as the IMO's Standard Marine Communication Phrases (SMCP), should be strengthened. Ensuring consistent use of these protocols can significantly reduce ambiguity and improve clarity in critical situations.

Fourth, effective fatigue management strategies must be prioritized. Organizations should adopt policies that ensure adequate rest periods, monitor workload distribution, and promote the well-being of maritime personnel.

Finally, fostering a strong organizational safety culture should remain a strategic priority. This involves encouraging open communication, supporting error reporting systems, and promoting a non-punitive approach to safety management.

Future Perspectives

Looking ahead, the importance of human factors in maritime operations is expected to increase further as the industry continues to evolve. The growing complexity of global shipping, combined with rapid technological advancements, will require even greater attention to the interaction between humans and systems.

Future research may focus on several key areas. One important direction is the impact of digital communication technologies and automation on human performance and decision-making. As vessels become more technologically advanced, understanding how humans interact with automated systems will be essential.

Another promising area of research involves the role of artificial intelligence in supporting communication and reducing human error. AI-based systems may offer new opportunities for improving situational awareness, decision support, and risk management.

Additionally, further studies are needed to explore innovative training methods, including simulation-based learning and virtual reality, which can enhance communication skills and intercultural competence in maritime education.

In conclusion, this study reaffirms that the human element remains the cornerstone of maritime safety and operational efficiency. Effective communication, intercultural understanding, language proficiency, fatigue management, and organizational culture collectively shape the performance of maritime operations. Strengthening the integration of

these human factors into safety management systems is essential for achieving sustainable, resilient, and efficient maritime transport in an increasingly interconnected global environment.

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Integrating AI Soft Skills into Maritime Engineering Education

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ABSTRACT

Artificial intelligence (AI) is gradually making its way into daily work onboard ships, gradually replacing manual paperwork and printed reference materials. In the engine room, and more specifically within the Engine Control Room (ECR), AI already plays an active role by organizing equipment monitoring data, producing technical repair reports in accordance with International Association of Classification Societies (IACS) standards, and developing Standard Operating Procedures (SOPs) for complex tasks such as high-voltage switchboard servicing or automation system troubleshooting.

The advantages of AI aboard vessels are becoming increasingly evident across engine room. For ship mechanics, AI serves as a powerful maintenance and diagnostic tool. It can analyze vibration patterns, temperature trends, and pressure readings from machinery such as main engines, auxiliary engines, purifiers, and compressors, identifying anomalies before they develop into critical failures. When a defect is detected, AI can instantly compare the data with the equipment's technical manual, suggest probable root causes, and outline a step-by-step repair procedure. It also assists in planning Planned Maintenance System (PMS) schedules, creating work orders, and generating repair reports that meet Flag State and Classification society requirements, significantly reducing the administrative burden on watchkeeping engineers.

For ship electro-technical officers and electricians, AI proves particularly valuable when dealing with complex electrical and automated systems. Troubleshooting switchboards, frequency converters, programmable logic controllers (PLCs), and integrated automation systems (IAS) can be labor-intensive and dangerous without proper guidance. AI can assist by interpreting alarm logs and fault codes, creating electrical diagrams, and recommending safe shutdown procedures in compliance with onboard permit-to-work systems. When working with high-voltage equipment, where errors carry serious safety consequences, AI can perform real-time risk assessments and step-by-step switching sequences in real time.

For both maritime occupations, AI is also becoming a practical tool for interpreting

complex IMO regulations such as STCW, SOLAS, and MARPOL. Marine engineers and electrotechnical personnel have long struggled to understand the complex legal language of these conventions, and AI can provide clear, equipment-specific regulatory guidance almost instantly when given a well-formulated query.

Maritime English lessons play a foundational role in helping marine engineering students effectively use AI tools, since the quality of interaction with AI depends almost entirely on language proficiency. AI produces accurate results only when given precise, well-structured queries. Maritime English lessons that focus on technical writing and sentence clarity directly train students to formulate effective queries. For example, requesting a repair procedure for a specific piece of equipment rather than asking a vague question.

AI-generated reports, SOPs, and regulatory summaries are produced in technical English. Strong reading comprehension skills allow engineers to critically evaluate, verify, and apply AI responses rather than accepting them blindly.

A solid command of maritime and engineering terminology enables students to communicate with AI using the correct terms, such as "oil sludge removing procedure" instead of "separator cleaning", resulting in far more relevant and useful responses.

Maritime English lessons focused on formal writing prepare students to review, edit, and assume responsibility for AI-generated reports and SOPs, ensuring they meet IACS, Flag State, and company standards before submission.

Language learning encourages students to question, paraphrase, and double-check information. These are the essential skills when working with AI, which can occasionally produce inaccurate or outdated technical content.

In short, English proficiency is the interface between the maritime engineer and AI. Without it, even the most advanced AI tool becomes difficult to use effectively and safely.

KEEWORDS: AI soft skills, marine engineers, Maritime English proficiency, effective queries.

THE MAIN BODY

The modern maritime industry is changing a lot because of new technology. This is having a huge effect on the work of crews. The digitalisation of ship operations, the automation of monitoring systems and the rapid introduction of AI tools are fundamentally changing the nature of everyday work on board. For example, paper logs are being replaced by intelligent maintenance management systems and printed manuals are being replaced by real-time diagnostic algorithms. In the engine room and engine control centre (ECR), AI is already doing jobs that only an experienced engineer could do ten years ago. These include analysing how equipment is working, spotting problems early on, writing reports that meet IMO standards and creating accepted ways of doing complicated jobs.

In this context, the role of a ship's mechanic and electromechanic is undergoing a fundamental reassessment. While the traditional model of maritime education primarily trained

technicians capable of servicing and repairing specific equipment, then modern conditions necessitate a new type of specialist. This is a competent user of intelligent systems, capable of effectively interacting with AI tools, critically evaluating their results and taking responsibility for the technical decisions made on their basis. This transformation significantly expands the range of competencies required for safe and effective work on board.

At the same time, practice shows that the effectiveness of AI on board a ship is determined not only by technical equipment but also by the language skills of specialists. Since interaction with the vast majority of modern AI systems is conducted in English, the quality of the query formulated directly determines the relevance and accuracy of the response received. A marine engineer unable to clearly formulate technical request or critically read an AI-generated report is actually deprived of the opportunity to fully utilize the potential of these tools. This places fundamentally new demands on Maritime English in the training of marine engineers, making it an essential tool for developing the technological literacy of future maritime specialists.

For marine mechanics or electromechanics, the most important thing to use AI for is the continuous monitoring of engine room equipment. Unlike traditional watchkeeping, AI systems analyze data from vibration, temperature, and pressure sensors on the main engine, auxiliary machinery, separators, and compressors in real time, detecting deviations from the norm long before they develop into a critical failure. This enables a transition from reactive repairs to preventative maintenance, significantly reducing the risk of unplanned downtime at sea. If a malfunction is detected, the AI instantly compares recorded data with the equipment's technical documentation, identifies the most likely root causes of the failure, and generates step-by-step troubleshooting instructions.

AI plays an equally important role in managing planned maintenance (PMS) systems. By analyzing operating hours and the current state of systems, it automatically optimizes maintenance schedules, creates work orders, and monitors their implementation, reducing the administrative burden on watch engineers. Finally, AI tools can automatically generate technical reports and defect information in formats compliant with flag state requirements and IACS standards, reducing the risk of formal errors during port state control inspections.

The success of AI in helping ship mechanics and electromechanics depends on how well the specialist speaks English. In this context, Maritime English acts as a bridge. It is through language that the engineer gives AI a task, gets a result and is responsible for using it. Even if an AI system is technically perfect, it can't make up for a query that is unclear, uses the wrong terms, or is structured poorly. The result of this is that the response from the AI system will also be unclear, irrelevant, or even dangerous.

The first aspect is the accuracy of the wording of queries. Technical writing, which is taught in the Maritime English course, certainly requires cadets to be clear and unambiguous about a specific topic, language, and way of thinking. To ensure this, it is essential to include the name of the problem, its nature, the context of the situation, and the format of the report. For example, the query Provide a step-by-step procedure for replacing the fuel injection valve on MAN B&W 6S50MC-C engine while docked in port will generate a qualita-

tively different answer than the vague How to fix fuel injector? Technical writing exercises, where cadets learn to describe a malfunction, compile a defect report, or formulate a request for a spare part, provide direct preparation for effective interaction with AI.

Equally important is reading comprehension. AI can generate text that sounds technical but is not accurate. It may also contain outdated data or procedures that don't fit the specifics of a particular vessel. A mechanic with developed reading comprehension is able to identify the following inconsistencies. He will recognize a sequence of actions unusual for the equipment, notice a reference to a cancelled standard, or identify a recommendation that contradicts the company's internal safety management system (SMS). Maritime English courses, which include work with authentic technical texts, such as technical manuals, IMO circulars, and accident reports, help cadets to read more critically.

Critical thinking, cultivated through language tasks as paraphrasing, comparing sources, searching for contradictions in the text, is a fundamental skill for working safely with AI. The habit of checking, doubting, and comparing information with other sources is a specialist's conscious attitude toward a technological tool. This is also an important factor for safety.

Integrating AI-oriented tasks into the Maritime English course does not require a radical revision of the program. It is enough to rethink the format of traditional exercises, giving them a practical technological dimension. An effective format is a four-step training cycle: formulating a query, receiving an answer, verification, and editing a report. In the 1st stage, cadets are given a technical situation and have to write a query to the AI in English. The instructor analyzes the group's queries, paying attention to the accuracy of terminology, sentence structure, and completeness of context. In the 2nd stage, the cadets work with the received AI response. They identify technical terms, determine the structure of the text and check the compliance of the recommended procedure with the existing technical manual. The verification stage involves comparing AI-generated content with authentic sources, such as IMO circulars, IACS standards or equipment manufacturer documentation to verify it is true and up-to-date. In the 4th stage cadets adapt the received material to the format of an official technical report or SOP, adhering to corporate and regulatory design standards.

An additional technic can be a comparative analysis of queries. Cadets are asked to formulate two types of queries – a vague one and a precise one, and then analyze the differences in the responses received. This approach demonstrates the direct connection between linguistic accuracy and the quality of the technical result, motivating cadets to think about how they use words and grammar in their own speech. This underscores the importance of Maritime English as a valuable asset for professionals in the contemporary maritime sector.

Conclusion

The integration of AI into the engine room marks a shift from manual, reactive maintenance to data-driven, proactive operations. While AI has enormous potential for monitoring equipment, improving diagnostic accuracy, and ensuring regulatory compliance, its effectiveness relies entirely on human interaction.

Ultimately, knowledge of maritime English is no longer just a communication requirement, but a critical technical skill. Accurate terminology and clear syntax are essential for formulating effective queries, while good reading comprehension and critical thinking enable engineers to verify that AI results meet safety standards. To ensure safety and efficiency at sea, modern maritime education must consider language proficiency as a fundamental tool that allows engineers to manage AI technologies rather than blindly rely on them.

Maritime English courses should move beyond basic communication and incorporate AI-oriented tasks. Training process must emphasize reading comprehension and critical thinking. Engineers should be trained to cross-reference AI suggestions with authentic manufacturer manuals and IMO circulars to identify contradictions or outdated data. Cadets must prioritize mastering standardized technical terms to ensure the highest quality of AI interaction and operational safety. Digital literacy, based on English language proficiency, will become a key element of the STCW framework, so the ability to safely use digital tools requires further study and integration into the training process.

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Logistics as a Scientific Tool for Managing Flow Processes

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ABSTRACT

This article examines the development of scientific approaches and practical methods in logistics that coincided with Georgia's transition to a market economy. The authors note that certain difficulties arose in developing logistics concepts, primarily due to the difficult economic situation and social tensions across all social strata. The article describes logistics ideas that are fundamentally new to most Georgian entrepreneurs and have not found support in domestic businesses. Stagflation, high levels of monopoly power in key industries, a financial crisis, a rapid decline in production volumes and living standards, ongoing negative economic restructuring, and a decline in investment—this is far from a complete description of the socioeconomic situation in Georgia, which negatively impacts logistics development.

KEEWORDS: Flow processes, flow process management, Georgian logistics market size, flow development potential.

INTRODUCTION

As the Georgian economy develops, production processes designed to meet diverse market needs are becoming increasingly important. Logistics methodologies that optimize the entire supply chain—from logistics to product distribution and after-sales support—can ensure the efficient implementation of these processes.

DISCUSSION

The development of scientific approaches and practical methods in logistics coincided with Georgia's transition to a market economy. The development of logistics concepts has encountered certain difficulties, primarily due to the challenging economic situation and social tensions across all sectors of society. For most Georgian entrepreneurs, logistics ideas are fundamentally new and have not found support in domestic businesses. Stagflation, a high level of monopoly in key sectors, a financial crisis and non-payments, a rapid decline in production volumes and living standards, ongoing negative economic restructuring, and a decline in investment—this is far from a complete description of the socio-economic situation in Georgia, which negatively impacts the development of logistics [1].

The European Commission ranks Georgia 99th out of 150 countries in its logistics development ranking. Both international and Georgian experts agree that logistics in Georgia is a relatively underdeveloped, yet exceptionally promising, segment of the market economy.

Speaking at the International Transport and Logistics Exhibition in Paris in the spring of 2023, the Prime Minister of Georgia estimated the size of the Georgian transport and logistics services market at $8.5 billion and forecast that this figure could increase by almost 2.5 times, and even three times, by 2030.

Such growth should primarily come from the development of transport and logistics infrastructure, improved quality of logistics services, and improved supply chain management [5].

For a long time, the role of the distribution sector was underestimated in Georgia, even though in the West, supply and distribution occupy a fundamental position in logistics. Initially, service culture in Georgia lagged behind that of the manufacturing sector. Service was characterized by slow movement of goods from producers to consumers, high levels of unmet demand, low reliability, and insufficient customer service. Service was always financed on a residual basis; senior management developed a persistent psychological stereotype of underestimating the role of service in the economy.

Table 1. Development of logistics services in Georgian enterprises (according to questionnaire surveys, % of responses received)

Logistics services	2020	2023	2025
Implemented and developing	40	54	68
Implemented but not developing	44	58	75
Not implemented	16	–	–

The modern environment in which businesses operate is characterized by instability, inconsistency, and unpredictability, which, to a certain extent, devalues long-term forecasts. The low network readiness of Georgian enterprises makes it difficult to respond to

changes in real time. Therefore, the problem of managing logistics services in the face of global competition and the development of information technology in business is objectively moving into the realm of experimental, scientific, and practical work.

Over the past few years, most companies have begun devoting significantly more attention to logistics than before. This is not surprising, as business profits depend on stable supplies and optimal routes. CFOs are increasingly responsible for logistics—they possess the skills that help businesses gain a competitive advantage in this area. At the same time, planning becomes more transparent, allowing the company to remain profitable through accelerated product turnover, reduced customs costs, and prompt responses to customer requests.

Considering that the main goal of a company's logistics department is to ensure a competitive position in the market, one can speak to the need for logistics departments and the broader development of logistics. Competition in all leading industries is reaching global proportions today, and therefore, organizational management is striving to transform simple logistics supply chains from mere service tools into strategic business assets. This functional component of a company positively impacts the bottom line, including its capitalization. It has not yet become generally accepted that the flexibility and responsiveness of a logistics service are key factors in today's success. However, a small number of companies, having optimized their logistics service, realized that a strategic asset (a competitive advantage in the market) was practically under their noses [3] [7] [11].

Logistics, like mathematics, physics, and the strength of materials, is establishing itself as a universal scientific tool for the rational (optimal) management of any flow processes in a sufficiently developed and productive market economy. Domestic and foreign scientists have accumulated significant experience in developing solutions to economic problems grounded in the theoretical and methodological foundations of logistics. Currently, leading companies have integrated traditional logistics functional areas (transportation, inventory management, purchasing and order management, warehousing, cargo handling, and packaging) on a common information technology platform, creating a strategic innovation system.

Implementing logistics management methods in business practices enables companies to significantly reduce all types of product inventory across production, supply, and distribution, accelerate working capital turnover, reduce production and distribution costs, and ensure the highest possible customer satisfaction with the quality of goods and services.

Table 2 shows how Michael R. Linders estimated the share of logistics costs in product value.

Table 2. Share of logistics costs in various economic sectors

Industry	**Industry Share of logistics costs from turnover, %**
Food industry	Over 30
Metal production and metalworking	26-27

Chemical industry	20-25
Paper industry	16-17
Woodworking	16-17
Agricultural products	16-17
Electronic and electrical products	16
Textile industry	15
Re-export of machinery	Over 40

As in many other developing sectors, Georgian logistics is oriented toward Western standards. Companies operating in the transportation and logistics market can be divided into several segments based on the quantity and quality of services provided, the degree of integration with the client's business, and market access. With a 1PL (First Party Logistics) system, a company handles all necessary logistics (raw material procurement, finished product distribution) itself, using internal resources. 2PL (Second-Party Logistics) involves providing traditional transportation services or simple warehousing. [8]

Today, the most widespread and responsive level of integrated logistics services worldwide is 3PL (Third Party Logistics).

3PL providers are logistics operators that manage a full range of services, including transportation, shipping, intermediate and final warehousing, inventory management, document flow, etc. Furthermore, 3PL companies, using information technology, provide management and control over the service delivery process at every stage.

3PL companies, with their own or leased vehicles and warehouse facilities, assume responsibility and risk for moving goods throughout the entire supply chain. They outsource this process, relieving the client of the need to work on this area and acting as an intermediary between the manufacturer and the consumer. 4PL companies are primarily consulting firms that may not even own the logistics infrastructure or transport, but instead focus on integrating all links in the supply chain. Using an information base, the 4PL provider plans, monitors, and manages all operations, acting as a single service provider [9].

But even this level is far from the limit. There's already talk of the next stage of development – fifth-party logistics (5PL), which leverages internet technologies to solve logistics problems.

“Logistics connects people, markets, continents” – this motto from one of the World Logistics Congresses clearly defines the importance of logistics in the modern world. And Georgia's future depends, in no small part, on how quickly and successfully it integrates into the global logistics space, while ensuring the sustainability and security of its supply chains [11].

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The Impact of Mobile OTG Resources on English Communicative Competence Onboard

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ABSTRACT

This article investigates the impact of mobile on-the-go learning resources on the development of English communicative competence among seafarers working in a multilingual environment onboard ship. Effective communication at sea is a critical safety factor, particularly in the context of standardized procedures such as the International Maritime Organization's communication framework and the use of standard maritime communication phrases. However, traditional training systems, often delivered through structured platforms such as the Ocean Learning Platform developed by Ocean Technologies Group, can be limited by accessibility, time constraints, and challenges in engaging learners onboard.

In response, mobile on-the-go learning resources, including smartphone apps, offline learning modules, and microlearning tools, have emerged as flexible alternatives that enable continuous language learning outside of formal classroom settings. The aim of this study is to evaluate whether such resources effectively improve communicative competence, particularly in speaking, listening, and situational interaction, which are essential for safe and effective shipboard operations.

The study utilized a mixed-methods approach, combining quantitative data from a survey of seafarers in the deck and engine rooms with qualitative interviews and onboard observations. Participants were divided into two groups: those who primarily used structured training systems (LMS-based training) and those who supplemented or replaced formal training with mobile tools for on-the-go work. Key performance indicators included comprehension of operational instructions, accuracy of verbal reporting, confidence in communicating in English during training, and adherence to standardized phraseology.

The results show that mobile resources for on-the-go work significantly improve language retention and spontaneous communication skills due to their accessibility, fre-

quency of use, and contextual relevance. Seafarers reported increased confidence in informal and semi-formal communication situations, particularly during routine operations and intercultural interactions. However, the study also shows that such tools often do not meet maritime standards and do not provide systematic assessment or certification of competence.

In contrast, structured systems, such as those offered by Ocean Technologies Group, demonstrate superior results in terms of standardized knowledge acquisition, regulatory compliance, and measurable competency development. Notably, tools like Marlins assessments provide validated English proficiency benchmarks, which are not typically offered by mobile apps. However, these systems may be perceived as less engaging or less adaptable to individual learning.

The article concludes that the most effective approach to improving English communicative competence onboard is a blended model that combines the strengths of both structured training systems and mobile resources for on-the-go use. While formal platforms ensure compliance and structured development, mobile tools facilitate continuous practice and application of knowledge in real time, bridging the gap between theoretical knowledge and practical communication. Recommendations are offered for shipping companies and training providers to incorporate mobile learning strategies into existing competency assessment systems, thereby optimizing both learning outcomes and operational safety.

KEEWORDS: Maritime English, communicative competence, on-the-go training, seafarers, onboard communication

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Virtual Reality for Contextual Maritime English Training: A Model for Situational Awareness at STIP Jakarta

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ABSTRACT

The maritime industry is undergoing a profound digital transformation, and the International Maritime Organization (IMO), through its Human Element, Training and Watchkeeping (HTW) processes, has called for the integration of advanced technologies into maritime education and training. Virtual Reality (VR) offers immersive, risk-free environments where cadets can develop language and situational awareness skills in contextually rich scenarios. However, Indonesian maritime institutes have been slow to adopt such technologies, relying predominantly on traditional classroom methods that often fail to convey the spatial, temporal, and communicative complexities of real port and shipboard operations. This study addresses that gap by designing, implementing, and evaluating a VR-based Maritime English training module specifically tailored to the operational context of Tanjung Priok Port—Indonesia's busiest seaport—and the vessel types commonly encountered by STIP Jakarta cadets. The purpose of the research is to determine whether immersive VR scenarios can enhance situational awareness, technical vocabulary acquisition, and communicative confidence in Maritime English compared to conventional instruction. A quasi-experimental design was employed with two groups of nautical cadets (n=60). The control group received traditional classroom-based Maritime English instruction, while the treatment group participated in VR scenarios replicating pilotage, bunkering operations, mooring, and emergency communication, all developed using 360° video and interactive decision-points modeled on actual port environments. Pre – and post-intervention assessments measured vocabulary retention through standardized tests, response time in simulated communication tasks using the IMO Standard Marine Communication Phrases, and self-reported situational awareness using a validated survey instrument. The results demonstrated that the VR group achieved significantly higher scores in vocabulary re-

tention ($p < 0.01$), exhibited faster and more accurate communication responses during simulated tasks, and reported markedly higher levels of engagement and confidence. Qualitative feedback indicated that VR learners developed a stronger mental model of the operational environment, enabling them to anticipate communication needs more effectively. The main contribution of this study is a replicable VR-based pedagogical model that bridges the gap between decontextualized language instruction and the practical communication demands of maritime operations. By providing a scalable, context-rich training solution, this research supports the digital transformation of maritime education in Indonesia and offers a pathway for other institutions seeking to align with IMO's competency-based training frameworks.

KEEWORDS: Virtual reality; Maritime English; situational awareness; digital transformation; STIP Jakarta

The Impact of Logistics on Business Performance

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ABSTRACT

This article explores the vital role that logistics plays in today's business environment. It discusses how logistics has become an essential part of a company's success and why it is a critical element in gaining a competitive advantage. In the global economy, logistics is crucial for companies to expand their markets and international operations. Efficient logistics allows for the quick and reliable delivery of goods worldwide. The authors emphasize that logistics encompasses a wide range of operations, from inventory management to route optimization. They examine the impact of logistics on delivery times, customer service levels, and storage costs. The authors also explore how modern technologies and logistics innovations enhance processes and increase efficiency. These advancements enable companies to significantly improve operational efficiency, strengthen competitiveness, and deliver higher levels of customer service. The article highlights the importance of logistics management for companies in the global market and how logistics supports global business integration. The authors cite successful companies that have achieved their goals through optimizing logistics processes. In conclusion, the article emphasizes that logistics is an integral part of modern business, and companies seeking efficiency and competitiveness must focus on this key factor.

KEEWORDS: Logistics as a factor of efficiency, supply management, inventory management, automation, and product delivery.

INTRODUCTION

In today's marketplace, competition is becoming increasingly fierce, requiring companies to adopt new and effective approaches to survive and thrive. Logistics, as a key factor, plays a vital role in achieving outstanding business results. This article examines the role

and importance of logistics in today's business world and explores how it can become a defining element for achieving competitive advantage. In the context of accelerated technological change and dynamic shifts in consumer preferences, logistics has a significant impact on company success. From supply chain and inventory management to efficient and rapid product delivery to customers, every stage of the supply chain is crucial.

In this article, we will examine in detail how modern companies use logistics to improve their efficiency and competitiveness. We will discuss innovations in logistics, such as automation, artificial intelligence, and digital platforms, their impact on business processes, and how to implement them. Logistics covers a wide range of operations, from supply chain and inventory management to efficient customer product delivery. Modern technologies and innovations have made logistics more complex and dynamic, offering companies numerous new opportunities to optimize processes and reduce costs. Automation of logistics operations allows companies to reduce manual labor, reduce the likelihood of errors, and speed up task execution. Examples include automated order management, warehouse robots for handling goods, and autonomous delivery vehicles. Artificial intelligence enables the analysis of large volumes of data to forecast demand, optimize routes, and manage inventory. Companies are also looking toward sustainable logistics solutions, such as electric and hybrid vehicles, route optimization to reduce CO2 emissions, and environmentally friendly packaging. Innovations in these areas improve efficiency, reduce costs, and enhance customer service. They can also help companies adapt to rapidly changing market conditions and customer demands. Implementing these innovations requires not only investment in technology but also changes in a company's culture and processes. However, they can be key to achieving competitive advantage and successfully surviving in the modern business environment. Overall, the role of logistics in modern business cannot be underestimated. It has become an integral part of successful enterprises and, more importantly, its influence continues to grow. Today, understanding, optimizing, and innovating logistics processes have become strategic priorities for companies seeking to remain competitive and efficient in today's dynamic economic environment. By analyzing the role of logistics and applying innovative approaches to its improvement, we aim to demonstrate how it can become a key source of significant competitive advantage for organizations.

RESULTS AND DISCUSSION

The literature review confirms that logistics has become an integral part of corporate success. It plays a critical role in achieving competitive advantage and enables companies to compete effectively in the global marketplace.

Logistics solutions enable companies to:

1. Reduce costs. Logistics can help companies reduce the costs of transportation, storage, production, and other processes.
2. Improve customer service. Effective logistics enables companies to deliver a higher

level of service to customers, for example, by ensuring fast delivery and efficient order processing.

3. Increase profits. Logistics can contribute to a company's profit growth by reducing costs and improving customer service.

In an environment of globalization and increasing competition, logistics is becoming increasingly important for companies. In today's environment, companies must be able to quickly and efficiently move goods and information around the world to remain competitive. The literature review confirms this trend. Specific examples of how logistics helps companies achieve success can be found across various industries. In the automotive industry, logistics plays a vital role in ensuring the smooth production and delivery of vehicles to consumers. Logistics solutions enable companies to deliver parts and components worldwide quickly and efficiently. This allows companies to reduce production times and lower costs. For example, Toyota uses logistics solutions to ensure smooth vehicle production at its global factories. The company uses a just-in-time system, enabling it to receive parts and components exactly when needed. This helps the company reduce production times and lower costs.

In retail, logistics plays a vital role in ensuring the timely delivery of products to stores. Logistics solutions enable companies to reduce delivery times and improve customer service. For example, Amazon uses logistics solutions to ensure fast delivery of products to customers. The company uses a global network of warehouses and distribution centers, enabling it to deliver products to customers quickly and affordably.

In e-commerce, logistics plays a vital role in ensuring fast and affordable delivery of products to customers. Logistics solutions enable companies to reduce delivery times and improve customer satisfaction. For example, AliExpress uses logistics solutions to ensure fast delivery of goods to customers worldwide. The company partners with various logistics companies to offer customers a variety of delivery options.

These examples demonstrate that logistics plays a vital role in the success of companies across various industries. Logistics solutions enable companies to reduce costs, improve customer service, and increase profits.

Here are a few more examples of how logistics helps companies succeed:

UPS uses logistics solutions to ensure same-day package delivery in major US cities. This has allowed the company to increase its market share. Walmart uses logistics solutions to ensure two-day delivery of goods to stores. This has allowed the company to reduce storage costs and improve customer service. The Coca-Cola Company uses logistics solutions to ensure the smooth delivery of beverages to consumers. Coca-Cola uses logistics to deliver beverages from its factories to stores around the world. This allows the company to be present in markets across multiple countries. Nike uses logistics to ship goods from China to Nike stores around the world. This allows the company to offer its products to consumers in multiple countries. Apple uses logistics to deliver its products to China. This allows the company to enter one of the largest markets in the world.

These examples demonstrate that logistics can be a powerful tool for company success and is an important factor in the globalization of business. Logistics is of global importance to companies (Table 1).

Table 1. Benefits of logistics for companies

Benefits of Logistics for Companies	Examples
Expanding Markets	A company can enter new markets by offering goods and services to consumers in other countries.
Carrying Out International Operations	A company can collaborate with partners in other countries, using logistics to deliver goods and services between these partners.
Reducing Costs	Efficient logistics can help a company reduce costs for transportation, storage, and other logistics processes.
Improving Customer Service	Efficient logistics can help a company improve customer service by enabling faster, more reliable delivery of goods.
Facilitating Global Business Integration	Efficient logistics facilitates global business integration, enabling companies from different countries to collaborate.

The data in Table 1 demonstrate that effective logistics enables companies to expand their markets, conduct international operations, reduce costs, improve customer service, and facilitate global business integration.

The diversity of logistics operations highlights their multifaceted nature and complexity. This aspect is important, as logistics encompasses numerous stages and processes, beginning with inventory management, which includes not only inventory storage but also planning, forecasting, and order management. Furthermore, logistics also addresses the selection of optimal transport routes, which involves solving complex problems of cargo distribution and routing.

The multifaceted nature and complexity of logistics operations highlight that effective logistics management requires a comprehensive, integrated approach. Companies striving for success must pay attention to every stage of the supply chain and continuously improve their processes to ensure reliable product delivery and customer satisfaction (Table 2).

Table 2. Stages of the logistics chain to ensure a reliable supply of goods and meet customer needs

Supply Chain Stage	Goal	Key Success Factors
Planning	Identify customer needs and develop a logistics plan that meets them.	Accurate understanding of customer needs, effective inventory management, selection of appropriate suppliers, and transport companies.
Purchasing	Purchase goods or services in accordance with the logistics plan.	Effective procurement management, identification of reliable suppliers, and conclusion of favorable contracts.
Storage	Store goods in a safe and convenient location.	Optimization of warehouse operations, ensuring product safety, and compliance with safety requirements.

Transportation	Transfer goods from the supplier to the customer.	Selecting the optimal route, ensuring product safety, and meeting delivery deadlines.
Distribution	Deliver goods to customers according to their needs.	Effective delivery management, ensuring customer satisfaction, and providing information on delivery status.
Returns processing	Customer returns.	Effective returns management, ensuring customer satisfaction, and minimizing return costs.

These stages of the supply chain are interconnected and must be coordinated to ensure reliable product delivery and customer satisfaction.

Logistics impacts delivery times, customer service levels, and storage costs. This demonstrates that effective logistics can significantly impact a company's business processes and financial results. Let's examine these aspects in more detail:

1. Delivery times: Prompt and accurate product delivery is essential for satisfying customer needs and maintaining their loyalty. Effective logistics can reduce delivery times, which is especially important in today's fast-paced business environment.
2. Customer service levels: Logistics directly impacts customer service levels. Fast and accurate delivery, along with proper inventory management, ensures customers receive the products they need on time, helping to meet their needs and strengthen long-term relationships.
3. Storage costs: Optimizing logistics processes can reduce storage costs. This includes reducing the need for warehouse space and optimizing inventory. Research into these aspects shows that logistics is not simply an operational activity but also a strategic element that contributes to creating competitive advantage and improving financial performance. Company leaders must pay attention to this aspect and invest in its optimization.

Modern technologies and innovations in logistics significantly improve the efficiency of logistics processes. These technologies and innovations enable companies to:

1. Optimize logistics operations. For example, the use of artificial intelligence (AI) and machine learning (ML) can help companies optimize delivery routes, forecast demand, and manage inventory. AI and ML can be used to analyze.
2. Large volumes of data to determine the most efficient delivery routes. They can also be used to analyze sales data, market trends, and other factors to predict future demand for goods or services. Furthermore, AI and ML can be used to analyze sales data, expiration dates, and other factors to determine optimal inventory levels. This can help companies avoid over – or under-stocking. Amazon uses artificial intelligence and machine learning technologies to optimize delivery routes. This allows the company to reduce fuel costs and improve delivery times. As a result, Amazon can offer its customers faster and more reliable delivery, which is one of its key competitive advantages.
3. Automate logistics processes. For example, robots and drones can help companies automate warehouse operations and product delivery. Robots can be used to perform

repetitive tasks in warehouses, such as order picking, palletizing, and transporting goods. This can help companies increase productivity and reduce costs. Drones, in turn, can be used for short-distance deliveries, such as food or package delivery. This can help companies reduce delivery times and improve customer service. Walmart uses robots to automate warehouse operations. This allows the company to process more orders and deliver goods to customers faster. As a result, Walmart can reduce storage costs and improve the efficiency of logistics operations.

4. Improve product traceability. For example, the use of RFID and GPS technologies allows companies to track the location of goods in real time. RFID technology allows companies to track the location of goods in warehouses and during delivery. This can help companies provide customers with delivery status information. GPS technology allows companies to track the location of vehicles transporting goods. This can help companies manage inventory and prevent loss. DHL uses RFID technology to track goods' locations in real time. This allows the company to provide customers with delivery status information. As a result, DHL can improve customer service and increase customer satisfaction.

Benchmarking the logistics practices of different companies reveals best practices that can be adapted to improve efficiency (Table 3). These practices include the use of artificial intelligence and machine learning technologies, automation of logistics operations, and real-time product tracking. Implementing these improvements can help companies reduce costs, improve customer service, and increase competitiveness.

Table 3. Comparative analysis of logistics practices of different companies

Company	Logistics practice	Comments	Possible improvements
Amazon	Using artificial intelligence and machine learning technologies to optimize delivery routes	An effective way to reduce fuel costs and improve delivery times	Using AI and machine learning technologies to optimize other logistics processes, such as demand forecasting and inventory management
Walmart	Using robots to automate warehouse operations	An effective way to increase productivity and reduce costs	Expanding the use of robots to automate other logistics operations, such as transportation and cargo handling
DHL	Using RFID technology to track the location of goods in real time	An effective way to improve customer service and reduce losses	Using RFID technologies to track other logistics metrics, such as vehicle location and inventory status

Based on an analysis of logistics practices at various companies, the following improvements can be implemented based on logistics best practices:

1. Expanding the use of AI and machine learning technologies to optimize other logistics processes, such as demand forecasting and inventory management. This can help companies reduce costs and improve customer service.

2. Expanding the use of robots to automate other logistics operations, such as transportation and cargo handling. This can help companies improve productivity and reduce costs.
3. Using RFID technologies to track other logistics metrics, such as vehicle location and inventory status. This can help companies improve customer service and reduce waste.

The above demonstrates that logistics plays a vital role in modern business and that innovative approaches to improving logistics can significantly increase organizations' competitiveness. Here are several ways logistics can become a key source of competitive advantage:

1. Improving operational efficiency. The use of new technologies, such as warehouse management systems (WMS), transportation management systems (TMS), artificial intelligence, and machine learning, optimizes route planning, inventory management, and order processing, reducing costs and delivery times. Innovative solutions, including blockchain and the Internet of Things (IoT), improve transparency in logistics operations. This helps manage risks, improve cargo tracking accuracy, and ensure secure deliveries. The use of sustainable logistics practices and technologies reduces the negative environmental impact, which can be a significant competitive advantage in light of growing consumer environmental awareness.
2. Inventory optimization, improved customer service. Using analytics and big data to forecast demand and optimize inventory levels reduces storage costs and minimizes losses from excess inventory. Innovations in logistics can help improve customer service by providing more accurate delivery times, order status tracking, and more flexible delivery options.
3. Global market expansion and competitive conditions. Innovations in logistics can help organizations expand globally by ensuring efficient delivery of goods across countries and regions. Optimized logistics processes can reduce shipping costs and offer more competitive rates, attracting new customers and increasing loyalty among existing ones.

Thus, logistics, enhanced by innovation, can be a key factor in achieving significant competitive advantage for organizations, enabling more efficient operations, improved customer service, and reduced costs. The use of modern technologies such as artificial intelligence (AI) and machine learning (ML) enables the automation of many logistics operations. This includes delivery routing, inventory management, demand forecasting, and route optimization, reducing the time and resources spent on these tasks. Collecting and analyzing data on logistics operations allows organizations to make more informed decisions. Analytics enables inventory optimization, improved demand forecasting, and the identification of potential bottlenecks in the process. Electric and autonomous vehicles, as well as drones and delivery robots, reduce costs and improve delivery accuracy and speed. The transition to more environmentally friendly technologies and transportation methods helps reduce environmental impacts and meet the needs of eco-conscious customers. Using specialized software solutions and algorithms to find optimal routes saves fuel, reduc-

es time, and reduces emissions. Smart devices and sensors can provide real-time status information on cargo and equipment, improving logistics management.

Overall, innovations in logistics enable organizations to create a more flexible, adaptive system, enabling them to serve customers more effectively, reduce costs, and achieve a competitive advantage in the marketplace. Investing in logistics innovation is becoming a strategically important step for organizations in modern business.

CONCLUSION

Based on the analysis of the role of logistics as a key factor in business performance, the following conclusions can be drawn:

1. The study confirms that logistics is a key element of a company's success. Effective management of logistics processes enables businesses to achieve high efficiency and meet customer needs. Logistics plays a critical role in achieving competitive advantages and enabling companies to compete effectively in the global market. One key finding is the link between logistics quality and customer satisfaction. Businesses should actively work to optimize delivery and service to build long-term customer relationships.
2. It has been proven that effective logistics reduces costs and optimizes resource utilization, which contributes to increased profits and competitiveness. The study also emphasizes the importance of incorporating logistics into strategic business planning. It should be viewed as a strategic tool for achieving company goals. Businesses must be prepared to adapt their logistics systems in response to changing market conditions and customer demands. Flexibility in logistics is becoming a key competitive advantage. Supply chains play a vital role in logistics, and their effective management helps optimize procurement and distribution processes.
3. Technology is proven to be transforming logistics. Modern technologies and management systems have become catalysts for changing logistics operations, increasing their efficiency and reducing costs. These changes, along with the benefits of implementing modern technologies in logistics, have a profound impact on various aspects of business and society. Thanks to modern technologies, companies can provide a higher level of service, which contributes to customer satisfaction and the formation of long-term relationships. Technologies help reduce delivery times, which is especially important amid growing interest in online shopping and expectations for fast delivery. Modern management and monitoring systems provide greater access to global markets, enabling companies to expand their operations beyond national borders. Technology can help reduce resource consumption, such as fuel and materials, which is important for both businesses and the environment. Technology enables more effective security monitoring and risk management in logistics operations, particularly for the transportation of valuable and hazardous goods. The integration of technology into logistics supports companies' overall digital

transformation, enabling them to remain competitive in today's digital economy.

4. Thus, modern technologies are truly transforming logistics and have a profound impact on business, society, and the economy as a whole. Companies that actively implement and use these technologies can expect significant competitive advantages and contribute to more efficient, sustainable logistics and overall business development.
5. It has been proven that logistics management not only helps optimize internal processes but also contributes to increased profitability, customer satisfaction, and overall company competitiveness. Firstly, companies that can deliver goods or services quickly and reliably typically have an advantage over competitors. This can lead to increased market share and a stronger market position. Customers increasingly value service quality, including delivery speed and order fulfillment accuracy. Secondly, improving logistics processes helps increase customer satisfaction, which in turn fosters loyalty and repeat purchases. Optimizing logistics can reduce a company's costs for storage, transportation, and inventory management. This increases profitability and competitiveness. Well-established logistics processes help build long-term customer relationships. Thirdly, in the context of the global economy and global trade, logistics enables companies to compete effectively in the global market. Effective logistics facilitates the export and import of goods, expanding the company's geographic reach.
6. The study emphasizes the need to invest in modern technologies and management systems to improve logistics operations and increase efficiency. Modern technologies and management systems have become integral to logistics operations. They not only improve the efficiency and reliability of processes but also provide companies with valuable information for more informed decision-making. Investments in modern logistics technologies can make a company more competitive in the market. The ability to deliver quickly, accurately, and reliably can provide a significant advantage over competitors. Management and monitoring systems enable closer customer interaction, providing them with information on order status and product tracking. This contributes to increased customer satisfaction. Optimizing logistics processes with technology can save companies money by reducing warehousing, transportation, and inventory management costs. Modern systems provide rich analytical information that can be used to optimize logistics strategies, forecast demand, and develop more effective business plans.

Overall, the study confirms that investing in modern technologies and management systems for logistics operations is not only justified but also a strategic necessity for companies striving for success and growth in the modern business environment. These investments increase efficiency, competitiveness, and customer satisfaction, ultimately supporting sustainable development and high performance. Logistics is a key factor in business success and should be treated as a strategic asset that requires attention and investment. Its role in modern business cannot be underestimated, and optimization of logistics processes can lead to significant improvements in a company's results.

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Optimizing EEOI Training for Deck and Engine Officers: A Collaborative Model for CII Compliance at STIP Jakarta

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ABSTRACT

The introduction of the Carbon Intensity Indicator (CII) and the enhanced role of the Energy Efficiency Operational Indicator (EEOI) under IMO's regulatory framework have fundamentally changed how ship performance is evaluated. Effective CII compliance depends not only on technical measures but also on real-time collaboration between deck and engine officers, who must coordinate navigational decisions with propulsion management to optimize fuel efficiency. Traditional maritime education, however, often trains nautical and engineering cadets in isolation, perpetuating a siloed approach that does not reflect the integrated reality of modern ship operations. This study addresses that disconnect by developing and testing a collaborative training model at Sekolah Tinggi Ilmu Pelayaran Jakarta (STIP Jakarta) that brings together deck and engine cadets in full-mission simulator exercises specifically focused on EEOI data collection, analysis, and operational decision-making. The purpose is to assess whether integrated cross-departmental simulation training can improve cadets' understanding of CII implications, enhance their ability to implement coordinated efficiency measures, and foster a shared mental model of ship energy management. A pre-test/post-test design was employed with a cohort of 48 cadets (24 nautical, 24 engineering) who participated in a structured simulation program. The program consisted of baseline scenarios where cadets operated separately, followed by integrated scenarios requiring joint decisions on weather routing, engine load optimization, trim, and speed. Performance was measured using quantitative metrics (fuel consumption, EEOI values, CII rating outcomes) and qualitative assessments of communication, collaboration, and decision-making processes. Results showed that after the integrated training, the combined teams achieved an average 12% reduction in fuel consumption per voyage compared to baseline, with improved CII

ratings. Communication frequency and quality also increased significantly, with cadets demonstrating greater awareness of how navigational choices impact engine performance. The principal contribution is a replicable cross-departmental simulation-based training module that prepares cadets for the collaborative realities of green shipping operations. By embedding EEOI and CII training into a collaborative simulation environment, the research offers a practical model for maritime institutions seeking to produce graduates capable of leading energy efficiency initiatives onboard.

KEEWORDS: EEOI; CII; deck and engine collaboration; simulation-based training; decarbonization.

Problems of Relations with the Eurasian Economic Union

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ABSTRACT

The article examines the further expansion and deepening of transport and logistics cooperation within the EAEU, which faces several obstacles. These obstacles are categorized into two groups: infrastructural and institutional. According to the author, the current state of transport and logistics infrastructure hampers cooperation with the EAEU because it cannot fully address the EAEU's internal integration issues and cannot compete effectively in the globalized economy.

KEEWORDS: Eurasian Economic Union, infrastructure challenges, institutional challenges, logistical cooperation.

აბსტრაქტი

სტატიაში განხილულია EAEU-ში სატრანსპორტო და ლოგისტიკური თანამშრომლობის შემდგომი გაფართოება და გაღრმავება, რომელსაც აფერხებს მთელი რიგი პრობლემები. ხელის შემშლელი პრობლემები დაყოფილია ორ ჯგუფად: ინფრასტრუქტურული და ინსტიტუციური. ავტორის აზრით, სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურა მისი ამჟამინდელი ფორმით აფერხებს სატრანსპორტო და ლოგისტიკური თანამშრომლობის განვითარებას EAEU-სთან, რადგანაც სრულად EAEU ინტეგრაციის შიდა პრობლემების გადაჭრასაც ვერ ახერხებს და სრულიად უძლურია, გაუმკლავდეს კონკურენციას ეკონომიკის გლობალიზებულ ბაზარზე.

საკვანძო სიტყვები: ევრაზიული ეკონომიკური კავშირი, ინფრასტრუქტურული გამოწვევები, ინსტიტუციური გამოწვევები, ლოგისტიკური თანამშრომლობა.

შესავალი

როგორც ცნობილია, ინფრასტრუქტურული პრობლემები მოიცავს:

i. EAEU-ს სატრანსპორტო და ლოგისტიკური ბაზრის განვითარების დაბალ დონეს;

ii. EAEU-ს არსებული სატრანსპორტო, სასაწყობო, საბაჟო და მართვის ინფრასტრუქტურის არაეფექტიანობას;

iii. EAEU-ს სატრანსპორტო და ლოგისტიკური კომპლექსის კონკურენტუნარიანობის მუდმივ გლობალურ ნაკლებობას.

ძირითადი ინსტიტუციური პრობლემები ემყარება EAEU-ს კოორდინირებული (ჰარმონიზებული) სატრანსპორტო პოლიტიკის ფრაგმენტულ ხასიათს და კონტექსტში EAEU-ს ქვეყნების სარკინიგზო და საავტომობილო გადამზიდავების კონკურენტუნარიანობის შენარჩუნების ეფექტური მექანიზმის არქონას.

დისკუსია

EAEU-ს სატრანსპორტო და ლოგისტიკის ბაზარზე 1 და 2 PL პროვაიდერების არსებობის მაღალი წილი, ყველა სხვა თანაბარი პირობის შემთხვევაში, მიუთითებს მის განუვითარებლობაზე შექმნილი დამატებითი ღირებულებისა და ხარისხობრივი ჩართულობის თვალსაზრისით, რაც ზოგადად უარყოფით გავლენას ახდენს EAEU-ს ეკონომიკაზე. ამრიგად, EAEU-ში ტრანსპორტისა და ლოგისტიკის მთლიანი მოცულობის დაახლოებით 68% ახორციელებს საწარმოების სატრანსპორტო და ლოგისტიკური განყოფილებები, ხოლო სატრანსპორტო და ლოგისტიკური ხარჯების წილი EAEU მომხმარებლის საქონლის საბოლოო ღირებულებაში არის 20-25% (ზოგჯერ აღწევს 30%-ს), ხოლო მსოფლიოში საშუალო მაჩვენებელი 11%-ია, ევროკავშირში 11%, აშშ-ში 10%, ჩინეთში 14%.

კიდევ ერთი მაჩვენებელი, რომელიც მიუთითებს EAEU-ს სატრანსპორტო და ლოგისტიკური ბაზრის განუვითარებლობაზე, არის სატრანსპორტო და ლოგისტიკური ოპერაციების კონტეინერიზაციის დაბალი დონე. საქონლის კონტეინერებში ტრანსპორტირება იძლევა დატვირთვა-გადმოტვირთვის ოპერაციებზე დროის დაზოგვის საშუალებას, რაც საბოლოო ჯამში იწვევს პროდუქტის ფასის შემცირებას საბოლოო მომხმარებლისთვის.

დღეს მშრალი, მათ შორის სამომხმარებლო, საქონლისა და ავტომობილების, გლობალური ტრანსპორტირების კონტეინერიზაციის დონე საშუალოდ 50-60%-ს შეადგენს, ხოლო EAEU-ში ძლივს აღწევს 5%-ს, მათ შორის დაახლოებით 3%-ს საერთაშორისო ტრაფიკში. 1000 ადამიანზე, EAEU-ში ტრანსპორტის კონტეინერიზაციის დონე არის 37 კონტეინერი 127 ერთეულის წინააღმდეგ.

მისი ამჟამინდელი ფორმით, სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურა ადეკვატურად ვერ უჭერს მხარს ინტეგრაციის მიმდინარე ტემპს. EAEU-ს სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის ქვეშ ვგულისხმობთ სატრანსპორტო ინფრასტრუქტურის მთლიანობას; ანუ ტექნიკურ და მობილურ აღჭურვილობას,

ასევე სტაციონარულ კომპონენტებს – ლიანდაგის ობიექტებს, სასაწყობო ინფრასტრუქტურას, ანუ სასაწყობო სისტემებს, საბაჟო ინფრასტრუქტურას, საბაჟო ფორმალობების სწრაფად შესრულების პირობებსა და მართვის ინფრასტრუქტურას; გარდა ამისა, სატრანსპორტო და ლოგისტიკური ცენტრების ქსელებს (TLC) EAEU-ს გარე საზღვარზე და EAEU-ს ჰაბ ცენტრებში. ევრაზიული ინტეგრაციის ინფრასტრუქტურული კომპონენტის მ.შ. ტრანსპორტის, საწყობის, საბაჟოს, მენეჯმენტის, ტელეკომუნიკაციების და ა. შ. სისუსტემ, გრძელვადიან პერსპექტივაში შეიძლება ითამაშოს ევრაზიული ინტეგრაციის გამხლეჩის როლი ისევე, როგორც არასატარიფო ბარიერების შენარჩუნებამ ორმხრივ ვაჭრობაში.

EAEU-ს სატრანსპორტო ინფრასტრუქტურა ხასიათდება მატერიალურ-ტექნიკური ბაზის ცვეთის მაღალი ხარისხით. სატრანსპორტო ინფრასტრუქტურის 70%-ზე მეტი მორალურად თუ ტექნიკურად მოძველებულია, რაც მისი მოდერნიზაციის საკითხს EAEU-ს მაკროინტეგრაციის პრიორიტეტების სიის სათავეში აყენებს. წამყვან ქვეყნებს (რუსეთი, ბელარუსი, ყაზახეთი) შორის არსებული ინფრასტრუქტურის მოდერნიზების საკითხი განსაკუთრებით მწვავედ დგას ყაზახეთში, რომელსაც 2030 წლისთვის 50 მილიარდი დოლარი დასჭირდება მის განახლებისთვის. ინფრასტრუქტურის ძირითადი ელემენტების მნიშვნელოვანი ცვეთა დაფიქსირდა ყაზახეთის სარკინიგზო ტრანსპორტში – 70%, მათ შორის: მობილური მანქანები – 71%, მისასვლელი გზები – 85%, სატრანსპორტო საშუალებები – 64%, ელექტრომომარაგების მოწყობილობები – 62%, ავტომატიკა და საკომუნიკაციო მოწყობილობები – 80%139. ბელორუსის საავტომობილო ტრანსპორტში, პირიქით, მიმდინარეობს ქვეყნის სატვირთო პარკის სწრაფი განახლების პროცესი. დღეს სატვირთო მანქანების 50%-ზე მეტი შეესაბამება ევრო-4 და ევრო-5 გარემოსდაცვით სტანდარტებს, რაც საუკეთესო მაჩვენებელია EAEU-ში და მანქანების დაახლოებით 37% ექსპლუატაციაშია სამ წელზე ნაკლები ხნის განმავლობაში.

ამჟამინდელი სახით, რეგიონის სასაწყობო ინფრასტრუქტურა ასევე აფერხებს EAEU-ს ეკონომიკის ეფექტურ ფუნქციონირებას. EAEU-ს საწყობები ძირითადად ორიენტირებულია საქონლის გადამუშავებაზე, რომელიც არ საჭიროებს შენახვის სპეციალურ პირობებს, როგორიცაა მინერალური პროდუქტები, სამრეწველო ნახევარფაბრიკატები და სასოფლო-სამეურნეო ნედლეული და განლაგებულია EAEU ქვეყნების დიდ ინდუსტრიულ ცენტრებსა და დედაქალაქებში. ამ მხრივ, სასაწყობო ძირითადი ფუნქცია ხდება განაწილების ფუნქცია, ე.ი. სასაქონლო ნაკადების განაწილება ცენტრიდან რეგიონებში, ქმნის დამატებული ღირებულების უმნიშვნელო რაოდენობას, ხოლო კონსოლიდაციური ფუნქცია, ე.ი. ტვირთთან მუშაობის ყოვლისმომცველი სერვისი საწყობში ტვირთის მიღებიდან მის დანიშნულებამდე გაგზავნამდე, მათ შორის დამუშავება, კონსოლიდაცია, შეფუთვა, ეტიკეტირება და ა.შ. წარმოდგენილია უმნიშვნელოდ.

ჩვენი შეფასებით, უმაღლესი ინფრასტრუქტურის A კლასის საწყობების წილი EAEU-ს ტერიტორიაზე არის საწყობების მთლიანი რაოდენობის არაუმეტეს 30%-ისა.

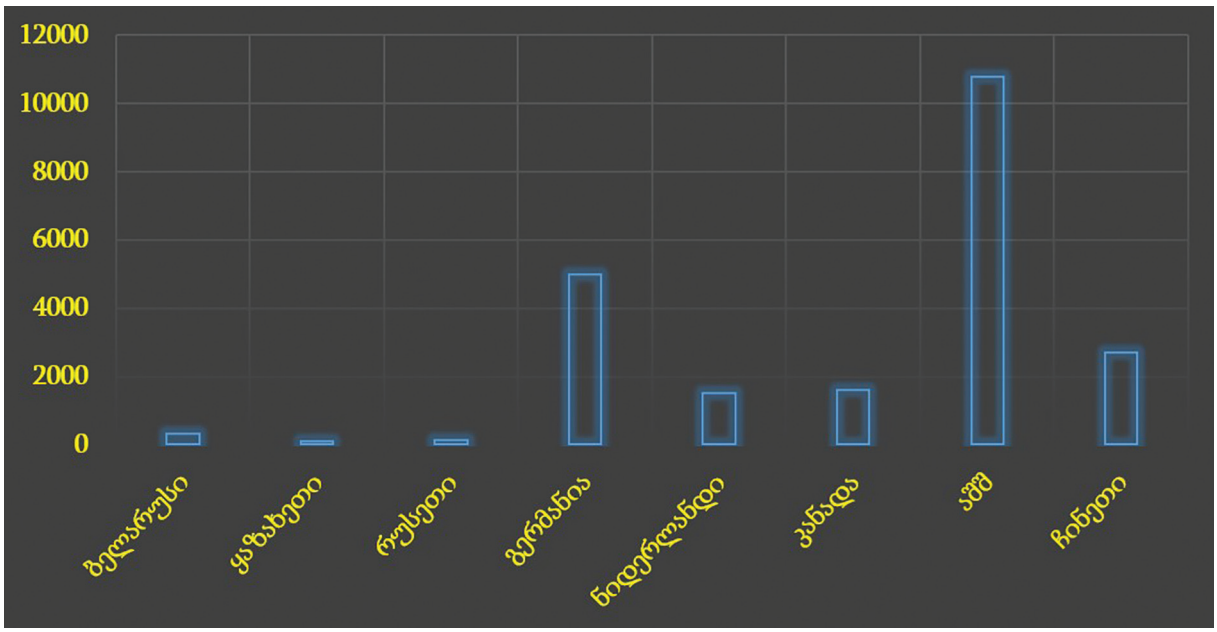
EAEU-ს საბაჟო ინფრასტრუქტურა მთლიანობაში უზრუნველყოფს ერთიანი საბაჟო ტერიტორიის ფუნქციონირებას, მაგრამ ხასიათდება საბაჟო წარმომადგენლობისა და უფლებამოსილი ეკონომიკური ოპერატორების ინსტიტუტის განვითარების

დაბალი დონით, რომელიც შექმნილია საგარეო ვაჭრობის მონაწილეებსა და საბაჟო ორგანოებს შორის ურთიერთქმედების ეფექტიანობის უზრუნველსაყოფად. პრაქტიკა ხელს უწყობს საბაჟო პროცედურების გამარტივებას და დაჩქარებას როგორც ექსპორტ-იმპორტის, ასევე ტრანზიტის დროს, რაც იწვევს საქონლის საბოლოო ღირებულებაში სატრანსპორტო და ლოგისტიკური ხარჯების წილის შემცირებას.

EAEU-ს ქვეყნებს შორის რეგისტრირებული AEO-ების რაოდენობით ლიდერია ბელორუსი. ამ მაჩვენებლის მიხედვით, EAEU ქვეყნები მნიშვნელოვნად ჩამორჩებიან ევროკავშირის ქვეყნებს, NAFTA-ს და ჩინეთს (დიაგრამა 1).

ამავდროულად, EAEU-ს საბაჟო ინფრასტრუქტურის განვითარებას აფერხებს EAEU-ს ერთიანი საბაჟო კოდექსის არარსებობა, რომლის მიღებას ხელს უშლის ხელშემკვრელი მხარეების მუდმივი უთანხმოება ორგანიზაციული და პრაქტიკული ადაპტაციის შესახებ. მაგალითად, ყაზახეთის WTO-ში გაწევრიანებისას აღებული ვალდებულებების მიხედვით, ყაზახი იმპორტიორების მიერ WTO-ს ფარგლებში CTT-მდე მიღებულმა შეღავათიანმა პირობებმა შეიძლება გამოიწვიოს საქონლის დაუბრკოლებელი რეექსპორტი ყაზახეთის ტერიტორიიდან მისი პარტნიორების ბაზრებზე EAEU-ში, რაც ეწინააღმდეგება ერთიანი საბაჟო ტერიტორიის პრინციპებს.

დიაგრამა 1. დარეგისტრირებული AEO რაოდენობა EAEU ევროკავშირის და NAFTA-ს ქვეყნებში და ჩინეთში



წყარო: ხაპიღინი ს. „ევრაზიული ეკონომიკური ინტეგრაციის განვითარება საბაჟო რეგულირების მექანიზმის მოდერნიზაციის საფუძველზე" ეკონომიკურ მეცნიერებათა დოქტორის ხარისხის მოსაპოვებლად წარმოდგენილი დისერტაცია

ამდენად, ამ გაერთიანების შიგნთ არსებული ხელშეკრულებები შესაბამისობაშია მოსაყვანი გარე პირობებთან და ხელშეკრულებებთან. აქედან გამომდინარე, სხვა პირობების დამაკმაყოფილებლობის შემთხვევაშიც კი, ეს კონკრეტული პირობა საკმაოდ ართულებს EAEU-ს ქვეყნებთან ურთიერთობას.

EAEU-ს სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის განვითარების დაბალი დონის კიდევ ერთი მტკიცებულება არის თანამედროვე სატრანსპორტო და ლოგისტიკური ცენტრების (TLC) ნაკლებობა, როგორც გარე საზღვრებზე, ასევე EAEU-ს ფარგლებში არსებულ ჰაბ ცენტრებში. მოქმედი TLC-ების რაოდენობის მიხედვით, EAEU შესამჩნევად ჩამორჩება ევროკავშირს. ჩვენი შეფასებით, ამჟამად დაახლოებით 30 საერთაშორისო და რეგიონული TLC მუშაობს EAEU-ში, ხოლო ევროკავშირში 100-ზე მეტი. ქვეყნის თვალსაზრისით, არის ერთი TLC, რომელიც მდებარეობს ერევანში, სომხეთში, ხუთი TLC – ბელორუსიაში – ბრესტში, გომელში და მინსკის რეგიონში, ყაზახეთში არის შვიდი TLC – ასტანაში (ყველაზე დიდი ცენტრალურ აზიაში), შიმკენტში, აქტაუ, აქტობე, ქ. დოსტიკი და ხორგოსის სასაზღვრო გადასასვლელი, ყირგიზეთში არის ორი TLC – ბიშკეკში და სოფ. სოკულუკში, რუსეთში არის დაახლოებით თექვსმეტი TLC – მოსკოვში და მოსკოვის რეგიონში, სანკტ-პეტერბურგში და ლენინგრადის რეგიონში, ნოვოსიბირსკში, უფაში, ყაზანში, ჩელიაბინსკში, ვლადივოსტოკში, პსკოვში და სხვა.

ინფრასტრუქტურის მშენებლობის დაფინანსების ამჟამინდელი მოცულობა EAEU-ში საშუალოდ შეადგენს მშპ-ს 2-2,5%-ს, ხოლო ეკონომიკის გამართული ფუნქციონირების უზრუნველსაყოფად ფინანსური ინექციების რაოდენობა არ უნდა იყოს 4,5%-ზე ნაკლები.

ამრიგად, სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურა შეზღუდულად ფუნქციონირებს, ახასიათებს მნიშვნელოვანი ცვეთა, სისტემა მოქმედებს არასაკმარისი დაფინანსებით, რასაც, ყველა დანარჩენის პირობების გათანაბრების შემთხვევაში, ნაკლებად შეუძლია გაფართოებისა და ინტეგრაციის გაღრმავების მოცემული ტემპის შენარჩუნება.

ინტეგრაციის მთავარი ინსტიტუციური დაბრკოლება არის EAEU-ს კოორდინირებული სატრანსპორტო პოლიტიკის ფრაგმენტული ბუნება, რომელიც არ გამოირჩევა გადაწყვეტილებების სისტემურობით, თუნდაც სარკინიგზო და საგზაო ტრანსპორტის რეჟიმებში. EAEU-ს სატრანსპორტო და ლოგისტიკური ბაზრისთვის ყოვლისმომცველი ერთიანი წესებისა და რეგულაციების არარსებობა ხელს უშლის მიწოდების პროცესის ლიბერალიზაციას, მისი ხარისხის გაუმჯობესებას, ადეკვატურ ფასების ფორმირებას და, შესაბამისად, ევრაზიული ინტეგრაციის ეკონომიკური კომპონენტის საერთო ეფექტიანობის გაზრდას.

სარკინიგზო ტრანსპორტის რეჟიმში ინტეგრაციის ძირითადი ინსტიტუციური პრობლემებია EAEU ქვეყნების კოორდინირებული მიდგომების არარსებობა, ყველაზე ხელსაყრელი ორგანიზაციული და ეკონომიკური პირობების შექმნასა და ტერიტორიის მასშტაბით ტრანზიტის განხორციელებაში.

ტრანზიტული ტრანსპორტისთვის EAEU-ს ერთიანი სარკინიგზო ტარიფის გამოყენების შემდგომი ინსტიტუციონალიზაციის უპირველესი სირთულე არის ის, რომ მესამე ქვეყნიდან მესამე ქვეყანაში EAEU-ს ტერიტორიის გავლით ტრანზიტული ტრანსპორტირება ჯერ კიდევ რეგულირდება დსთ-ს სატარიფო პოლიტიკის ფარგლებში. ამავდროულად, EAEU-ს არსებული სატრანსპორტო პოლიტიკა არ შეიცავს დებულებებს CIM/SMGS სარკინიგზო ზედნადების გამოყენების სტიმულირების შესახებ EAEU-ს ტერიტორიაზე ტრანზიტის დროს, რაც ზოგადად ანელებს პროცესს.

ავტორის შეფასებით, CIM/SMGS ზედნადების გამოყენების პოტენციალი, რომელიც საშუალებას იძლევა შემცირდეს სარკინიგზო ვაგონების რაოდენობა ტრანზიტის საზღვარზე სამი დღიდან 1,5 საათამდე, ამჟამად გამოიყენება EAEU-ში 30%-ზე ნაკლებით.

EAEU-ს სატრანზიტო პოტენციალის განხორციელებას ასევე აფერხებს EAEU-ს ერთიანი ტექნიკური რეგლამენტებისა და სტანდარტების არარსებობა სარკინიგზო ტრანსპორტის უსაფრთხოების სფეროში, მათი გარემოსდაცვითი კეთილგანწყობა, სატრანსპორტო საშუალებების სავალდებულო სერტიფიცირების პროცედურები, აგრეთვე ერთიანი მოთხოვნები. სარკინიგზო ინფრასტრუქტურა.

საგზაო ტრანსპორტში ინტეგრაციის მთავარი ინსტიტუციური დაბრკოლებებია: (i) ტრანსსასაზღვრო საგზაო ტრანსპორტის ელექტრონულ რეგისტრაციაზე გადასვლის მუდმივი სირთულეები; (ii) EAEU საგზაო ტრანსპორტის ბაზრის რუსული სეგმენტის დომინირება; (iii) რუსული კომპანიების დომინირება და მათ საპირისპიროდ სომხური, ბელორუსული, ყაზახური და ყირგიზული ომპანიიებისათვის საგზაო გადამზიდავების კონკურენტუნარიანობის უზრუნველყოფის ეფექტური მექანიზმის არარსებობა.

EAEU-ს გარე საზღვარზე საავტომობილო გამშვები პუნქტების ეფექტური ფუნქციონირება შესაძლებელია მხოლოდ იმ შემთხვევაში, თუ მათი სატრანსპორტო, ლოგისტიკური და საბაჟო ინფრასტრუქტურა მკაფიოდ არის დაკავშირებული, მაგრამ ამის მექანიზმი ჯერ კიდევ არ არის ბოლომდე გასაგები. დადგინდა, მაგალითად, რომ საქონლის ტრანსსასაზღვრო გადაადგილების მთლიანად ელექტრონულ განბაჟებაზე გადატანა შეამცირებს საბაჟო პროცედურების დროს 30-35%-ით, რაც საბოლოოდ გამოიწვევს მიწოდების დროის შემცირებას და ოპტიმიზაციას. სატრანსპორტო და ლოგისტიკური დარგის ერთიანი მარეგულირებელი სტანდარტების ნაკლებობამ და EAEU ქვეყნების ურთიერთ ვაჭრობაში არასატარიფო შეზღუდვების მუდმივმა არსებობამ ასევე განაპირობა საბაჟო კონტროლის მოკლევადიანი აღდგენა რუსეთის სასაზღვრო პუნქტებზე ბელორუსისა და ყაზახეთთან, რაც ეწინააღმდეგება „ოთხი თავისუფლების" პრინციპს.

კოორდინირებული (შეთანხმებული) სატრანსპორტო პოლიტიკის მარეგულირებელი სავალდებულო მექანიზმების ნაკლებობამ საშუალება მისცა რუსეთს, ცალმხრივად, ამ გადაწყვეტილების პარტნიორებთან კოორდინაციის გარეშე, შეეჩერებინა TIR Carnets150-ის გამოყენება მის ტერიტორიაზე, რამაც გამოიწვია „დომინოს ეფექტი" EAEU ქვეყნებში და არ მიაღწია კრიზისამდელ დონეს.

როგორც ჩანს, რუსეთის ხელისუფლების ეს ნაბიჯი იყო საკუთარი ეროვნული სატრანზიტო სტანდარტების შექმნის მცდელობა, კერძოდ, ფულადი დეპოზიტების სისტემა და ფინანსური გარანტიები, რომლებიც წარმოდგენილი იყო რუსეთის საბაჟო საზღვრის თითოეულ გადაკვეთაზე, რაც საბოლოოდ გამოიწვევს ეროვნული ბიუჯეტში შემოსავლების ზრდას. წესების ამ ცვლილებამ გამოიწვია მიწოდების დროის ზრდა საშუალოდ 30-40%-ით და რუსეთმა დაკარგა საერთაშორისო საგზაო ტრანსპორტის წლიური მოცულობის 15%-მდე (დაახლოებით 70 მილიარდი რუბლი; 720 მლნ აშშ დოლარი). რუსული მხარის ამგვარმა ნაბიჯმა მნიშვნელოვნად დაარტყა ყაზახეთის საგზაო ტრანსპორტის ინდუსტრიას, რომელიც უზრუნველყოფს ევროკავშირი-

დან რუსეთის ტერიტორიის გავლით ყაზახეთში მთელი იმპორტირებული საავტომობილო ტრანსპორტის 75%-ს. ამრიგად, მიწოდების საშუალო ღირებულება გაიზარდა 500 ათასი აშშ დოლარით, რაც ყაზახეთის სამანქანო ტრანსპორტს არაკონკურენტუნარიანს ხდის რკინიგზასთან შედარებით, ეს ყაზახეთისთვის შეადგენს 100 მილიონ დოლარს.

დასკვნა

ამრიგად, სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურა მისი ამჟამინდელი ფორმით აფერხებს სატრანსპორტო და ლოგისტიკური თანამშრომლობის განვითარებას EAEU-სთან, რადგანაც სრულად EAEU ინტეგრაციის შიდა პრობლემების გადაჭრასაც ვერ ახერხებს და სრულიად უძლურია, გაუმკლავდეს კონკურენციას ეკონომიკის გლობალიზებულ ბაზარზე.

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Enhancing ISM Code Compliance Through Simulation-Based Safety Culture Training for Cadets at STIP Jakarta

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ABSTRACT

The International Safety Management (ISM) Code represents a cornerstone of maritime safety, mandating that shipping companies establish safety management systems that follow a Plan-Do-Check-Act (PDCA) cycle. However, in many Indonesian shipping contexts, ISM implementation has been reduced to a bureaucratic exercise—focused on documentation rather than the development of a proactive safety culture. This disconnect often begins at the education stage, where cadets are taught the ISM Code as a set of rules to be memorized rather than a behavioral framework to be internalized. The purpose of this study is to investigate whether simulation-based training can significantly improve cadets' behavioral compliance with the ISM Code, transforming their understanding from theoretical knowledge to practical safety leadership. Conducted at Sekolah Tinggi Ilmu Pelayaran Jakarta (STIP Jakarta), the research employed a quasi-experimental design involving 80 deck and engine cadets. The treatment group participated in a series of structured full-mission simulator scenarios specifically designed to elicit safety management behaviors: reporting non-conformities, conducting risk assessments before critical operations, closing out corrective actions, and demonstrating effective safety leadership during emergencies. The control group received conventional classroom instruction on the ISM Code covering the same content but without simulation application. Performance was evaluated using validated observation checklists during simulator exercises, supplemented by debriefing sessions and self-assessment surveys. The findings revealed that the simulation group exhibited significantly higher adherence to ISM principles across all PDCA elements. Notably, cadets in the simulation group were more likely to proactively identify hazards, initiate reporting procedures without prompting, and demonstrate clear safety leadership during unplanned events. In contrast, the control group showed good recall of ISM terminology

but struggled to apply the principles in dynamic situations. The principal contribution of this study is a validated simulation-based pedagogical model that shifts ISM education from theoretical compliance to behavioral safety competence. By embedding the ISM Code into realistic operational scenarios, the research provides a replicable approach for maritime institutes to strengthen safety culture and align cadet training with the human element priorities emphasized by IMO.

KEEWORDS: ISM Code; safety culture; simulation-based training; behavioral compliance; STIP Jakarta

Evaluating STCW-Based Maritime English Instruction on Deck and Engine Cadets' Operational Readiness at STIP Jakarta

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ABSTRACT

The International Maritime Organization (IMO) has long emphasized the human element as a critical factor in maritime safety, with effective communication being a cornerstone of safe ship operations. Miscommunication between deck and engine officers consistently ranks among the top contributing factors to maritime incidents, yet maritime education institutions frequently treat Maritime English as a general linguistic competency rather than a discipline-specific operational tool. This disconnect is particularly pronounced in the Indonesian context, where cadets often enter with heterogeneous English backgrounds and where classroom instruction may not fully replicate the high-stakes communication demands of an integrated bridge and engine room environment. This study addresses the gap between theoretical Maritime English instruction and practical communication performance among cadets at Sekolah Tinggi Ilmu Pelayaran Jakarta (STIP Jakarta), one of Indonesia's leading maritime institutes. The primary purpose is to develop and validate a diagnostic framework for STCW-based English instruction that can identify specific communication deficiencies and inform targeted pedagogical interventions. A mixed-methods design was employed, involving 80 cadets (40 nautical, 40 engineering) who underwent standardized pre – and post-proficiency assessments aligned with STCW Table A-II/1 and A-III/1 language requirements. Additionally, full-mission simulator sessions were observed to capture authentic communication exchanges between bridge and engine room teams during scenarios such as maneuvering, emergency drills, and machinery failures. Structured interviews with experienced instructors were conducted to explore perceived barriers to effective communication training. The findings revealed a significant discrepancy between cadets' performance on written English examinations and their ability to execute real-time operational communication, particularly in the use of IMO Standard Marine Com-

munication Phrases (SMCP) during unplanned events. Departmental silos were also identified as a major obstacle, as nautical and engineering cadets rarely train together in communication-rich environments. The study's principal contribution is a validated diagnostic framework that maps communication gaps to specific STCW competencies, along with a set of contextualized, cross-departmental communication modules tailored to the Indonesian maritime education context. These outputs provide a replicable model for integrating communication training into simulator-based exercises, thereby enhancing cadet operational readiness and aligning classroom practice with IMO's human element priorities. The research underscores the need for maritime academies to move beyond discrete language courses and embrace integrated, simulation-driven communication training that reflects the collaborative reality of modern ship operations.

KEEWORDS: Maritime English; STCW; communication competence; deck and engine cadets; simulation-based training.

საქართველოს სავაჭრო ნაკადების განმსაზღვრელები 3+3 ფორმატის ქვეყნებთან: ეკონომიკური, კულტურული და ლოგისტიკური ფაქტორების ანალიზი პანელური გრავიტაციის მოდელის გამოყენებით

Determinants of Georgia's Trade Flows with the 3+3 Format Countries: An Analysis of Economic, Cultural, and Logistics Factors Using a Panel Gravity Model

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აბსტრაქტი

წინამდებარე კვლევა 2020 წლის შემდეგ სამხრეთ კავკასიაში წინაპლანზე წამოწეული „3+3“ ინიციატივის ეკონომიკურ, კულტურულ და ლოგისტიკურ განზომილებებს იკვლევს საქართველოს საგარეო სავაჭრო ურთიერთობების კონტექსტში. როგორც რეგიონული თანამშრომლობისა და ინტეგრაციის გაღრმავების მცდელობის ნაწილი ასევე აღნიშნული ფორმატი მნიშვნელოვანი პოტენციალის მატარებელია საქართველოს სავაჭრო ურთიერთობების და რეგიონული კავშირების ხელახალი ფორმირებისთვის. აღნიშნულ კონტექსტში, კვლევის მიზანია საქართველოს საგარეო სავაჭრო ნაკადების განმსაზღვრელი ძირითადი ფაქტორების ანალიზი პანელური გრავიტაციის ეკონომეტრული მოდელის გამოყენებით.

ემპირიული შედეგები ცხადყოფს, რომ საქართველოს საგარეო ვაჭრობის ძირითადი განმსაზღვრელი, ქვეყნის ეკონომიკური ზომა და გეოგრაფიული სიახლოვის ერთად სავაჭრო პარტნიორებთან საერთო სახმელეთო საზღვარია. აგრეთვე, კვლევის შედეგების მიხედვით, ექსპორტის განყოფილებაში მანძილის ცვლადი უარყოფითი და სტატისტიკურად მნიშვნელოვანი აღმოჩნდა, რაც ვაჭრობაზე გეოგ-

რაფიული დაშორებით გამოწვეული ხარჯების ზრდის უარყოფით ეფექტს ცალსახად ადასტურებს. იმპორტის განყოფილებაში კი მანძილის ცვლადი და პარტნიორი ქვეყნის ეკონომიკური ზომა სტატისტიკურად მნიშვნელოვანი არ აღმოჩნდა. ეს კი მიუთითებს, რომ იმპორტი უფრო მეტად საქართველოს შიდა მოთხოვნის დინამიკით ფორმირდება. საერთო რელიგიის ცვლადი ბევრ მოდელში უარყოფითი და სტატისტიკურად მნიშვნელოვანი აღმოჩნდა, რაც ცხადყოფს, რომ ქვეყნებს შორის რელიგიური და კულტურული სიახლოვე სავაჭრო ურთიერთობებზე მოსალოდნელ პოზიტიურ ეფექტს ვერ ახდენს. კვლევის შედეგების მიხედვით თავისუფალი ვაჭრობის შეთანხმებებს კი შეზღუდული ან უმნიშვნელო ეფექტი აქვს.

საერთო ჯამში, საქართველოს საგარეო ვაჭრობაში მეზობელი ქვეყნების ეკონომიკური ზომა და ქვეყნებს შორის საერთო სახმელეთო საზღვარი ერთ-ერთ ძირითად განმსაზღვრელ ფაქტორად იკვეთება. კვლევა ასევე მიუთითებს, რომ საქართველოს რეგიონულ სავაჭრო სტრატეგიებში განსაკუთრებული მნიშვნელობა უნდა მიენიჭოს მეზობელ ქვეყნებთან ეკონომიკური თანამშრომლობის გაღრმავებასა და რეგიონული ლოგისტიკური ინფრასტრუქტურის შემდგომ განვითარებას. მიღებული შედეგები აჩვენებს, რომ ქვეყნის საგარეო სავაჭრო პოლიტიკის ეფექტიანობის ზრდა მნიშვნელოვნად არის დაკავშირებული ინფრასტრუქტურულ ინვესტიციებთან, საზღვრის გადაკვეთის პროცედურების გამარტივებასთან და არსებული სავაჭრო შეთანხმებების პრაქტიკული ეფექტიანობის გაძლიერებასთან.

საკვანძო სიტყვები: საქართველო, „3+3“ ფორმატის ქვეყნები, საგარეო ვაჭრობა, რეგიონული ლოგისტიკური ინფრასტრუქტურა, პანელური გრავიტაციის მოდელი

ABSTRACT

This study examines the economic, cultural, and logistical dimensions of the "3+3" initiative, which has gained prominence in the South Caucasus since 2020, within the context of Georgia's foreign trade relations. As part of broader efforts to deepen regional cooperation and integration, this format holds significant potential for reshaping Georgia's trade relations and regional connectivity. In this context, the study aims to identify and analyze the key determinants of Georgia's external trade flows using a panel gravity econometric model.

The empirical results indicate that the main determinants of Georgia's foreign trade are the economic size of partner countries and the existence of shared land borders, which reflect geographic proximity. In the export model, the distance variable is negative and statistically significant, confirming the adverse impact of increased costs associated with geographic distance on trade flows. In contrast, in the import model, both distance and partner country size are not statistically significant, suggesting that imports are primarily driven by domestic demand dynamics. The common religion variable is found to be negative and statistically significant across several model specifications, indicating that religious and cultural proximity does not exert the expected positive effect on trade relations. Furthermore, free trade agreements appear to have limited or negligible effects.

Overall, the economic size of neighboring countries and the presence of shared land borders emerge as key determinants of Georgia's foreign trade. The findings also suggest that greater emphasis should be placed on strengthening economic cooperation with neighboring countries and further developing regional logistical infrastructure within Georgia's trade strategy. The results indicate that improving the effectiveness of Georgia's external trade policy is closely linked to infrastructure investment, the simplification of border-crossing procedures, and the enhanced practical implementation of existing trade agreements.

KEEWORDS: Georgia, 3+3 Format Countries, Foreign Trade, Regional Logistics Infrastructure, Panel Shooting Model

შესავალი

როგორც ცნობილია სამხრეთ კავკასია წარმოადგენს სტრატეგიულად მნიშვნელოვან რეგიონს, სადაც იკვეთება როგორც ენერგეტიკული ტრანსპორტირების ასევე სავაჭრო გზებისა და სხვა გეოპოლიტიკური ინტერესების მნიშვნელოვანი ხაზები. რეგიონში არსებული პოლიტიკური დაძაბულობები და უსაფრთხოების გამოწვევები ზრდის ქვეყნებს შორის თანამშრომლობის მექანიზმების მნიშვნელობას, როგორც პოლიტიკური სტაბილურობის, ისე ეკონომიკური განვითარებისათვის. სწორედ ამ კონტექსტში, 2020 წლის შემდგომ პერიოდში აქტუალობა შეიძინა „3+3“ ფორმატმა, რომელიც მიზნად ისახავს რეგიონული დიალოგისა და თანამშრომლობის გაძლიერებას.

აღნიშნული ფორმატი მოიცავს სამ დიდი სახელმწიფოს (რუსეთი, თურქეთი, ირანი) და სამხრეთ კავკასიის პატარა ქვეყნებს (საქართველო, აზერბაიჯანი, სომხეთი) და თეორიულად ითვალისწინებს თანამშრომლობის საკმაოდ ფართო სპექტრს, უსაფრთხოებიდან ვაჭრობამდე. თუმცა, რიგი პოლიტიკური ფაქტორები, განსაკუთრებით საქართველოსა და რუსეთის შორის არსებული ურთიერთობები, აფერხებს ფორმატის სრულფასოვან ჩამოყალიბებას და შემდგომ ფუნქციონირებას. მიუხედავად ამისა აღსანიშნავია ის ფაქტიც რომ ბოლო წლებში ეკონომიკური თანამშრომლობის პოტენციალი, განსაკუთრებით კი ტრანსპორტისა და ენერგეტიკის სფეროში, მნიშვნელოვნად იზრდება.

საქართველოს გეოპოლიტიკური მდებარეობა ქვეყანას აქცევს მნიშვნელოვან სატრანზიტო და ლოგისტიკურ ჰაბად, რაც ზრდის მის როლს როგორც რეგიონულ ასევე გლობალურ ვაჭრობაში. შესაბამისად, საქართველოს სავაჭრო ურთიერთობების ანალიზი „3+3“ ფორმატის ქვეყნებთან მნიშვნელოვანია როგორც ეკონომიკური, ისე სტრატეგიული თვალსაზრისით. ამრიგად, აღნიშნული კვლევა მიზნად ისახავს „3+3“ ფორმატის ფარგლებში საქართველოსა და პარტნიორ ქვეყნებს შორის სავაჭრო ურთიერთობების განმსაზღვრელი ძირითადი ფაქტორების იდენტიფიცირებასა და მათ კომპლექსურ ანალიზს ეკონომეტრიული მოდელის გამოყენებით. კვლევა განსაკუთრებულ ყურადღებას ამახვილებს ისეთი ცვლადების გავლენაზე, როგორიცაა ქვეყნების ეკონომიკური მასშტაბი, ქვეყნებს შორის გეოგრაფიული მანძილი, სა-

ვალუტო კურსის დინამიკა და ინსტიტუციური გარემო. ამასთანავე, ნაშრომი მიზნად ისახავს არსებული სამეცნიერო ლიტერატურაში არსებული დანაკლისის შევსებას და ემპირიულ საფუძველზე საქართველოს სავაჭრო პოლიტიკისა და რეგიონული ეკონომიკური ინტეგრაციის პროცესების უკეთ გააზრებას.

„3+3" ფორმატი

მდგრადი მშვიდობისა და თანამშრომლობის უზრუნველყოფის მიზნით ინიციირებული 3+3 ფორმატი (სამხრეთ კავკასიის 3+3 პლატფორმა) რეალურად ახალი ინიციატივა არ არის. თურქეთის რესპუბლიკის პრეზიდენტი რეჯეფ თაიფ ერდოღანი და რუსეთის ფედერაციის პრეზიდენტი ვლადიმირ პუტინი მასზე ჯერ კიდევ 2015 წლიდან საუბრობდნენ. თუმცა ფორმატმა რეალური აქტუალობა 2020 წლის ყარაბაღის ომის შემდეგ შეიძინა, როდესაც აზერბაიჯანის პრეზიდენტმა ილჰამ ალიევმა და თურქეთის პრეზიდენტმა რეჯეფ თაიფ ერდოღანმა იგი საერთაშორისო დღის წესრიგის წინა პლანზე წამოწიეს. აღნიშნული ფორმატის ძირიტადი მიზანია დიალოგისა და თანამშრომლობის ჩამოყალიბება სამ სამხრეთ კავკასიურ ქვეყანას (აზერბაიჯანი, სომხეთი, საქართველო) და სამ რეგიონულ ძალას (თურქეთი, რუსეთი, ირანი) შორის. აღნიშნული ფორმატის პირველი შეხვედრა გაიმართა 2021 წლის დეკემბერში მოსკოვში, თუმცა შეხვედრაში საქართველომ მონაწილეობა არ მიიღო. მთავარი მიზეზად კი დასახელდა ის, რომ საქართველოს ტერიტორიაზე კვლავ რჩებოდა რუსული ჯარები და რუსეთს აქვს ოკუპირებული საქართველოს ორი რეგიონი (აფხაზეთი და სამხრეთ ოსეთი), რის გამოც საქართველომ თავი შეიკავა აღნიშნულ შეხვადრაზე დასწრებასა და ალიანსში შემდგომ გაწევრიანებაზე (Daily Sabah, 2021; Topchubasashov Center, 2025).

ფორმატის მეორე შეხვედრა 2022 წელს გაიმართა ირანის დედაქალაქ თეირანში, ხოლო მესამე შეხვედრა 2024 წელს სტამბოლში (MFA, 2024). როგორც ზემოთ აღინიშნა, ბოლო წლებში პლატფორმის ყველაზე აქტიური მხარდამჭერები არიან თურქეთი და აზერბაიჯანი. ასევე აქტიურ მხარდაჭერას გამოხატავენ რუსეთი და ირანი. თუმცა საქართველო ფორმატის შექმნის დღიდან არც ერთ შეხვედრაში არ მონაწილეობს და ოფიციალურად თბილისმა არაერთხელ აღნიშნა, რომ „აღნიშნულ ფორმატში მონაწილეობა დღის წესრიგში არ დგას". მიუხედავად იმისა, რომ ფორმატის ორგანიზატორები რეგულარულად იწვევენ საქართველოს ყველა შეკრებაზე და აღნიშნავენ, რომ ქვეყნისთვის კარი ღიაა, საქართველო აცხადებს, რომ „წინაპირობების (განსაკუთრებით ტერიტორიების ოკუპაციის საკითხის) გადაჭრის გარეშე აღნიშნულ ფორმატში ქვეყნის მონაწილეობა შეუძლებელია" (Topchubashov Center, 2025).

როგორც დასაწყისში აღინიშნა, 3+3 ფორმატის იდეა რეალურად უფრო ადრინდელ პერიოდს უკავშირდება. ალიანსის შექმნის საჭიროების საკითხი პირველად თურქეთმა და რუსეთმა დააყენეს დღის წესრიგში, ხოლო ორი ქვეყნის ლიდერები აქტიურად მონაწილეობდნენ ინიციატივის პოპულარიზაციაში. აქვე მნიშვნელოვანია აღინიშნოს, რომ ირანი, სანქციების პირობებში, რეგიონული თანამშრომლობის გაძლიერებისა და ენერგეტიკისა და სტაბილურობის სფეროში საკუთარი როლის ზრდის მოტივაციით, ფორმატის ჩამოყალიბებაში მნიშვნელოვან აქტიურობას იჩე-

ნდა. ფორმატის საწყისი ეტაპი დაიწყო ქვეყნებს შორის თანამშრომლობის ძირითადი მიმართულებების განსაზღვრით. 2015-2017 წლებში ჩამოყალიბდა პოლიტიკური და დიპლომატიური დიალოგის მექანიზმები, ხოლო შემდგომ პერიოდში ერთობლივი შეხვედრებისა და ლიდერთა სამიტების მეშვეობით გამოიკვეთა ფორმატის განვითარების ძირითადი მიმართულებები. 2018-2020 წლებში ფორმატის პოლიტიკური და ეკონომიკური განზომილებები უკვე კონკრეტული პროექტებით გამყარდა. პოლიტიკურ სფეროში განვითარდა რეგიონული უსაფრთხოების მექანიზმები და ჩამოყალიბდა ენერგეტიკული უსაფრთხოების მიმართულებით თანამშრომლობის საერთო ხედვა. აგრეთვე ეკონომიკურ სფეროშიც გადაიდგა კონკრეტული ნაბიჯები სავაჭრო ბრუნვის გაზრდის მიმართულებით; დღის წესრიგში დადგა საბაჟო პროცედურების ჰარმონიზაცია და ერთობლივი საინვესტიციო შესაძლებლობების შექმნა. სავაჭრო განზომილება მოიცავდა ექსპორტისა და იმპორტის არხების დივერსიფიკაციას, ლოგისტიკური ინფრასტრუქტურის გაძლიერებასა და სავაჭრო შეთანხმებების პრაქტიკულ ამოქმედებას. ანუ მიუხედავად იმისა, რომ ინიციატივა თავდაპირველად ჩამოყალიბდა როგორც პოლიტიკური დიალოგის პლატფორმა, დროთა განმავლობაში იგი გარდაიქმნა მრავალგანზომილებიან რეგიონული თანამშრომლობის მექანიზმად, რომელმაც მოიცვა ეკონომიკური, სავაჭრო და უსაფრთხოების სფეროები (Belkania, 2021).

მრავალი რეგიონული და გლობალური ფაქტორის გათვალისწინებით, დღესდღეობით 3+3 ფორმატი შეიძლება შეფასდეს როგორც რეგიონული თანამშრომლობის პოტენციალის მქონე, თუმცა პრაქტიკაში შეზღუდული პროგრესით გამორჩეული ინიციატივა. განსაკუთრებით ბოლო პერიოდში ირანში განვითარებული საომარი მოქმედებები, აგრეთვე საქართველოს ტერიტორიების რუსეთის მხრიდან ოკუპაციის საკითხი, ასუსტებს პლატფორმის ჩამოყალიბების პერსპექტივებს. მიუხედავად იმისა, რომ სომხეთსა და აზერბაიჯანს შორის 2025 წლის აგვისტოში გაფორმებული სამშვიდობო დეკლარაცია და ახალი სატრანზიტო კორიდორებთან დაკავშირებული შეთანხმებები მიუთითებს, რომ რეგიონული კავშირები ხელახლა ფორმირდება, ეკონომიკური და სავაჭრო განზომილებები ჯერ კიდევ სრულად არ არის ინსტიტუციონალიზებული. მიუხედავად იმისა, რომ შეხვედრები და მოლაპარაკებები გრძელდება, ვაჭრობის მოცულობა, საინვესტიციო პროექტები და ინფრასტრუქტურული თანამშრომლობა კვლავ ვერ აღწევს მოსალოდნელ დონეს. შესაბამისად, რეგიონში პოლიტიკური და ეკონომიკური სტაბილურობის მიღწევა, ქვეყნებს შორის ნდობის განმტკიცება, ინფრასტრუქტურული პროექტების დაჩქარება და უფრო ინკლუზიური სტრუქტურის ჩამოყალიბება ფორმატის განვითარების მთავარი განმსაზღვრელი ფაქტორები იქნება.

კვლევის მეთოდოლოგია და მიღებული შედეგები

აღნიშნული კვლევის ჩასატარებლად პირველ რიგში სტატისტიკური მონაცემები შეგროვდა სანდო საერთაშორისო და ეროვნული წყაროებიდან, როგორიცაა UN Comtrade, World Bank და საქართველოს სტატისტიკის ეროვნული სამსახური. შემდგომ სტატისტიკური მონაცემები დამუშავდა და მომზადდა ანალიზისთვის

Excel-ის ფაილში, რის შემდეგაც ეკონომეტრიული ანალიზი შესრულდა EViews პროგრამაში. კვლევის მეთოდოლოგიად კი შერჩეულ იქნა პანელური გრავიტაციის ეკონომეტრული მოდელი, რომელიც ფართოდ გამოიყენება საგარეო ვაჭრობის კვლევებში. აღნიშნულ ეკონომეტრიულ ანალიზში დამოკიდებულ ცვლადად გამოყენებულ იქნა მთლიანი საგარეო ვაჭრობის მოცულობა (FTV). განმარტებითცვლადებად კი, გამოყენებულ იქნა საქართველოს მთლიანი შიდა პროდუქტი (GDPGEO), პარტნიორი ქვეყნების მთლიანი შიდა პროდუქტი (GDPPARTNER), ქვეყნებს შორის ფიზიკური მანძილი (DISTANCE), სახმელეთო სახვრის არსებობა – მეზობლობა (BORDER), საერთო რელიგიური კუთვნილება (RELIGION) და თავისუფალი ვაჭრობის შეთანხმება (FTA).

ჩატარებული ეკონომეტრიული ანალიზის შედეგები ცალსახად აჩვენებს, რომ საქართველოს 3+3 ქვეყნებისთან საგარეო ვაჭრობაში მთავარი განმსაზღვრელები ეკონომიკური მასშტაბები და ქვეყნებთან სახმელეთო საზღვრის არსებობაა. საქართველოსა და პარტნიორი ქვეყნების მშპ-ის ზრდასთან ერთად, სავაჭრო მოცულობა მნიშვნელოვნად იზრდება. ქვეყნებთან სახმელეთო საზღვრის არსებობა (მეზობლობა) კი ინარცუნებს ვაჭრობის გამარტივების თვალსაზრისით პოზიტიურ ეფექტს. მანძილის ცვლადის უარყოფითი ნიშნის მიუხედავად, სტატისტიკურად მნიშვნელოვანი არ აღმოჩნდა, რაც მიუთითებს, რომ რეგიონული ლოგისტიკური ინფრასტრუქტურა და პოლიტიკური ფაქტორები ფარავს ქვეყნებს შორის არსებული მანძილის გავლენას ვაჭრობაზე. ამასთანავე, საერთო რელიგიის ცვლადი ფიქსირებული ეფექტების მოდელში უარყოფითი და ეკონომეტრულად მნიშვნელობის მატარებელი აღმოჩნდა. ეს შედეგი მიუთითებს, რომ კულტურული და რელიგიური სიახლოვე ქვეყნებს შორის ვაჭრობაზე მოსალოდნელ პოზიტიურ გავლენას ვერ ახდენს. თავისუფალი ვაჭრობის შეთანხმების ცვლადი კი აღმოჩნდა არამნიშვნელოვანი, რაც შეიძლება მიუთითებდეს, რომ ამ შეთანხმებების ეფექტი დამოკიდებულია პერიოდზე ან მათი პრაქტიკული განხორციელების ინტენსივობაზე და შესაბამისად მოდელში სრულად არ აისახა.

ეკონომეტრული შედეგების ზოგადი შეფასების საფუძველზე შესაძლებელია ითქვას რომ, საქართველოს საგარეო ვაჭრობაში ქვეყნების ეკონომიკური ზომა და სახმელეთო საზღვრის არსებობა (მეზობლობა) ყველაზე ძლიერ განმსაზღვრელებად რჩება. ქვეყნებს შორის ფიზიკური მანძილი, რელიგიური და კულტურული ფაქტორები, ასევე თავისუფალი ვაჭრობის შეთანხმებების გავლენა კი შედარებით შეზღუდულია.

დასკვნა და რეკომენდაციები

აღნიშნულ კვლევაში შესწავლილ იქნა საქართველოს საგარეო სავაჭრო ურთიერთობები 3+3 ფორმატის ქვეყნებთან პანელური გრავიტაციის ეკონომეტრული მოდელის გამოყენებით. 2000-2024 წლების სტატისტიკურ მონაცემებზე დაყრდნობით ჩატარებული ეკონომეტრული ანალიზი აჩვენებს, რომ სავაჭრო ნაკადების ფორმირებაში ყველაზე მნიშვნელოვანი როლი ეკუთვნის ქვეყნის ეკონომიკურ ზომას და სავაჭრო პარტნიორებთან გეოგრაფიულ სიახლოვეს. საქართველოს ეროვნული

ეკონომიკის ზრდა მნიშვნელოვნად ზრდის როგორც ქვეყნის ექსპორტის, ასევე იმპორტის მაჩვენებლებს. ამასთანავე აღსანიშნავია, რომ სავაჭრო პარტნიორი ქვეყნების ეკონომიკური მასშტაბები ანალოგიურ პოზიტიურ ურთიერთკავშირშია ქვეყნების ექსპორტსა და მთლიან სავაჭრო სალდოსთან.

ანალიზის საფუძველზე მიღებული შედეგები აგრეთვე ცხადყოფს, რომ ქვეყნებს შორის სახმელეთო საზღვრის არსებობა სავაჭრო ურთიერთობებზე მეტად პოზიტიურ გავლენას ახდენს და ეს შედეგი ცალსახად უსმევს ხაზს ქვეყნისთვის რეგიონული ინტეგრაციისა და ლოგისტიკური ინფრასტრუქტურის მნიშვნელობას. ამის საპირისპიროდ, მანძილის ცვლადის ეკონომეტრულად არამნიშვნელოვანი შედეგი მიუთითებს, რომ საქართველოს სატრანსპორტო კორიდორებისა და ტრანზიტული უპირატესობების წყალობით დისტანციის ხარჯობრივი ეფექტი დაბალანსებულია. ასევე კულტურული სიახლოვის განმსაზღვრელი ცვლადის (საერთო რელიგია, მსგავსი კულტურა და ტრადიციები) ნეგატიური გავლენა ვაჭრობაზე ცალსახაა. რაც ნიშნავს, რომ კულტურული სიახლოვე ყოველთვის არ ამარტივებს ქვეყნებს შორის ვაჭრობას. ხოლო ქვეყნებს შორის მიღწეული თავისუფალი სავაჭრო შეთანხმებები ვაჭრობაზე პოზიტიური ეფექტი მიუთითებს, რომ ქვეყნებს შორის სავაჭო ინტეგრაცია პრიორიტულად მნიშვნელოვანია. ამის კარგი მაგალითი თურქეთ-საქართველოს მზარდი სავაჭრო ბალანსია.

მიღებული შედეგების საფუძველზე საქართველოს საგარეო სავაჭრო პოლიტიკაში სამი პრიორიტეტი გამოიკვეთა: (I) მეზობელ ქვეყნებთან ვაჭრობის გაღრმავების მიზნით ლოგისტიკურ და სატრანსპორტო არხების მოდერნიზაცია და დარგში ინვესტიციების გაზრდა, (II) თავისუფალი სავაჭრო შეთანხმებების ეფექტიანობის გაზრდა ტექნიკური და ბიუროკრატიული ბარიერების შემცირებით, (II) პოლიტიკური და ინსტიტუციური დიალოგის არხების გაძლიერება ვაჭრობის მდგრადობის უზრუნველსაყოფად. გარდა ამისა, საქართველოს 3+3 ფორმატში არმონაწილეობის პოზიციისა და რუსეთის მიერ ოკუპაციის (აფხაზეთი, სამხრეთ ოსეთი) საკითხის გათვალისწინებით, ქვეყნისთვის კრიტიკულია საგარეო სავაჭრო სტრატეგიების შემუშავებისას პოლიტიკური სენსიტიურობის დაბალანსება. შესაბამისად, საქართველოს უნდა ჰქონდეს მრავალმხრივი და დაბალანსებული პრაგმატული ეროვნული პოლიტიკა, რომელიც ერთდროულად აძლიერებს პოლიტიკურ და ეკონომიკურ თანამშრომლობას 3+3 ფორმატის ქვეყნებთან, ხოლო ეროვნული უსაფრთხოებისა და ტერიტორიული მთლიანობის საკითხებში კომპრომისს ნაკლებად უშვებს.

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პირდაპირი უცხოური ინვესტიციების გავლენა ზღვის ტრასპორტისა და ლოჯისტიკის განვითარებაზე საქართველოში

The Impact of Foreign Direct Investment on the Development of Maritime Transport and Logistics in Georgia

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აბსტრაქტი

საქართველოში საზღვაო ტრანსპორტისა და ლოჯისტიკის სექტორის განვითარებაში პირდაპირი უცხოური ინვესტიციები (FDI) მნიშვნელოვან როლს ასრულებს. განსაკუთრებით უცხოური ინვესტიციები ხელს უწყობს უწყობს ინფრასტრუქტურის მოდერნიზაციას, ახალი ტექნოლოგიების დანერგვას, ოპერაციების ეფექტიანობის ზრდას და ქვეყნის სატრანზიტო პოტენციალის რეალიზებას.

ფოთისა და ბათუმის პორტების კონკურენტუნარიანობის განვითარებაში გადამწყვეტი წვლილი შეაქვთ უცხოურ ინვესტიციებს.

ფოთის საზღვაო ნავსადგური – 2011 წლიდან ფოთის პორტს მართავს „APM Terminals“, რომელიც დანიური „A.P. Moller-Maersk Group“ს ეკუთვნის. კომპანია მუდმივად ახორციელებს ინვესტიციებს პორტის გაფართოებასა და მოდერნიზაციაში. უახლოეს პერიოდში დაგეგმილია 200 მილიონ აშშ დოლარზე მეტი მოცულობის ინვესტიცია ახალი ნავმისადგომის, ტალღმჭერი მოლის მშენებლობასა და თანამედროვე ამწეების დამონტაჟებაში. ეს პროექტები მიზნად ისახავს პორტის გამტარუნარიანობის მნიშვნელოვან ზრდას და უფრო დიდი ზომის გემების მიღების შესაძლებლობის შექმნას. განხორციელებული ინვესტიციების შედეგად, 2023 წელს დასრულდა ტალღმჭერი მოლის რეაბილიტაცია, რომლის ღირებულება 25 მილიონი აშშ დოლარი იყო. კომპანიის მიერ დანერგილი ახალი ტექნოლოგიები, როგორიცაა

თანამედროვე ბუნკერები, ზრდის ნაყარი ტვირთების დამუშავების ეფექტიანობას და ამცირებს გარემოზე ზემოქმედებას.

ბათუმის საზღვაო ნავსადგური – ბათუმის პორტი, რომელსაც "ყაზმუნაიგაზის" შვილობილი კომპანია მართავს, ასევე აქტიურად იზიდავს ინვესტიციებს. პორტში გაზრდილია ტვირთბრუნვა, განსაკუთრებით ნავთობპროდუქტების, მშრალი ტვირთებისა და საკონტეინერო გადაზიდვების მიმართულებით. 2025 წლის პირველ კვარტალში, წინა წლის ანალოგიურ პერიოდთან შედარებით, ტვირთბრუნვა 22%-ით გაიზარდა. 2024 წელს კი პორტის ტვირთბრუნვამ 3,6 მილიონი ტონა შეადგინა, რაც წინა წელთან შედარებით 9%-იანი ზრდაა.

ანაკლიის ღრმაწყლოვანი პორტი – ანაკლიის პორტის პროექტი საქართველოსთვის სტრატეგიული მნიშვნელობისაა, რადგან მას შეუძლია ქვეყნის სატრანზიტო როლის მნიშვნელოვნად გაძლიერება და "შუა დერეფნის" კონკურენტუნარიანობის ამაღლება. პროექტის თავდაპირველი განხორციელება, რომელიც "ანაკლიის განვითარების კონსორციუმის" მიერ იგეგმებოდა, ფინანსური ვალდებულებების შეუსრულებლობის გამო შეჩერდა. ამჟამად, მთავრობა პროექტის განხორციელებას ჩინურ-სინგაპურულ კონსორციუმთან ერთად გეგმავს. 2025-2028 წლებში ანაკლიის პორტის მშენებლობისთვის ჯამურად 562 მილიონ ლარზე მეტის დახარჯვა იგეგმება.

ლოჯისტიკური ცენტრების განვითარება – საზღვაო ინფრასტრუქტურის პარალელურად, უცხოური კაპიტალის მონაწილეობით ვითარდება ლოჯისტიკური ცენტრებიც.

თბილისის მშრალი პორტი

2025 წლის ივნისში ოფიციალურად გაიხსნა "თბილისის მშრალი პორტი", რომელიც წარმოადგენს მულტიმოდალურ ლოჯისტიკურ ჰაბს. პროექტი არაბთა გაერთიანებული საამიროების "Abu Dhabi Ports Group"-ის, ნორვეგიული "Wilhelmsen Port Services"-ისა და ადგილობრივი კომპანიის თანამშრომლობით ხორციელდება. პროექტის პირველ ფაზაში უკვე 21 მილიონი აშშ დოლარის ინვესტიცია განხორციელდა. ეს ცენტრი ხელს შეუწყობს ტვირთების ეფექტიან მართვას და საქართველოს ინტეგრაციას საერთაშორისო მიწოდების ჯაჭვებში.

პირდაპირი უცხოური ინვესტიციები (FDI) საქართველოს საზღვაო ტრანსპორტისა და ლოჯისტიკის სექტორისთვის არა მხოლოდ ფინანსური რესურსების, არამედ ტექნოლოგიური პროგრესის, მმართველობითი კომპეტენციებისა და სტრატეგიული განვითარების მძლავრი კატალიზატორია. მათი გავლენა კომპლექსურია და სცდება უშუალოდ ინფრასტრუქტურის მშენებლობას, ხოლო სამომავლო პერსპექტივები პირდაპირ კავშირშია ქვეყნის გეოპოლიტიკურ როლთან და გლობალურ სავაჭრო დერეფნებში ინტეგრაციასთან.

პირდაპირი უცხოური ინვესტიციები ხელს უწყობს არა მხოლოდინფრასტრუქტურის ფიზიკურ განახლებას, არამედ მენეჯერული გამოცდილებისა და თანამედროვე ნოუ-ჰაუს დანერგვას. ეს კი, თავის მხრივ, ზრდის სექტორის პროდუქტიულობას და აძლიერებს ქვეყნის პოზიციებს გლობალურ ლოჯისტიკურ რუკაზე. საქართველოს მთავრობის მიერ დამტკიცებული "ტრანსპორტისა და ლოჯისტიკის ეროვნული სტრატე-

გია 2023-2030" მიზნად ისახავს ქვეყნის ლოჯისტიკური ეფექტიანობის გაუმჯობესებას, რაც კიდევ უფრო შეუწყობს ხელს უცხოური ინვესტიციების მოზიდვას ამ სფეროში.

მსოფლიო ბანკის ლოგისტიკის ეფექტიანობის ინდექსის (LPI) 2023 წლის მონაცემებით, საქართველო ჩამორჩება ევროპისა და ცენტრალური აზიის საშუალო მაჩვენებელს, რაც დამატებითი ინვესტიციებისა და რეფორმების საჭიროებაზე მიუთითებს.

საკვანძო სიტყვები: პირდაპირი უცხოური ინვესტიციები (FDI); საზღვაო ტრანსპორტი; ლოჯისტიკა; ინფრასტრუქტურის განვითარება;

ABSTRACT

Foreign Direct Investment (FDI) plays a significant role in the development of the maritime transport and logistics sector in Georgia. Specifically, foreign investments contribute to the modernization of infrastructure, the introduction of new technologies, an increase in operational efficiency, and the realization of the country's transit potential.

Foreign investments make a decisive contribution to the development of the competitiveness of the Poti and Batumi ports.

Poti Sea Port – Since 2011, the Poti Sea Port has been managed by "APM Terminals," which is owned by the Danish "A.P. Moller-Maersk Group." The company continuously makes investments in the port's expansion and modernization. An investment of over 200 million USD is planned for the near future for the construction of a new deep-water berth, a breakwater, and the installation of modern cranes. These projects aim to significantly increase the port's throughput capacity and create the ability to receive larger vessels. As a result of the investments made, the rehabilitation of the breakwater was completed in 2023 at a cost of 25 million USD. New technologies introduced by the company, such as modern bunkers, increase the efficiency of bulk cargo handling and reduce the environmental impact.

Batumi Sea Port – The Batumi Sea Port, managed by a subsidiary of "KazMunayGas," also actively attracts investments. Cargo turnover at the port has increased, especially in the areas of oil products, dry cargo, and container shipments. In the first quarter of 2025, compared to the same period of the previous year, cargo turnover increased by 22%. In 2024, the port's cargo turnover amounted to 3.6 million tons, which is a 9% increase compared to the previous year.

Anaklia Deep Sea Port – The Anaklia Deep Sea Port project is of strategic importance for Georgia, as it can significantly strengthen the country's transit role and enhance the competitiveness of the "Middle Corridor." The initial implementation of the project, planned by the "Anaklia Development Consortium," was halted due to the failure to fulfill financial obligations. Currently, the government plans to implement the project together with a Chinese-Singaporean consortium. In 2025, the government spent 150 million GEL on the construction of the Anaklia port, and the construction of the access road to the port is planned to begin in 2026.

Development of Logistics Centers

In parallel with maritime infrastructure, logistics centers are also being developed with the participation of foreign capital.

Tbilisi Dry Port

In June 2025, the "Tbilisi Dry Port" was officially opened, which is a multimodal logistics hub. The project is being implemented through a collaboration between "Abu Dhabi Ports Group" of the United Arab Emirates, the Norwegian "Wilhelmsen Port Services," and a local company. An investment of 21 million USD has already been made in the first phase of the project. This center will facilitate the efficient management of cargo and Georgia's integration into international supply chains.

Foreign Direct Investment (FDI) is a powerful catalyst for the Georgian maritime transport and logistics sector, not only in terms of financial resources but also for technological progress, managerial competencies, and strategic development. Its impact is complex and extends beyond the direct construction of infrastructure, while future prospects are directly linked to the country's geopolitical role and its integration into global trade corridors.

Foreign direct investment promotes not only the physical renewal of infrastructure but also the introduction of managerial experience and modern know-how. This, in turn, increases the sector's productivity and strengthens the country's position on the global logistics map. The "National Transport and Logistics Strategy 2023–2030," approved by the Government of Georgia, aims to improve the country's logistics efficiency, which will further encourage the attraction of foreign investment in this field.

According to the World Bank's 2023 Logistics Performance Index (LPI) data, Georgia lags behind the average for Europe and Central Asia, which indicates the need for additional investments and reforms.

KEEWORDS: Foreign Direct Investment (FDI); Maritime Transport; Logistics; Infrastructure Development

შესავალი

პირდაპირი უცხოური ინვესტიციები (FDI) წარმოადგენს უმნიშვნელოვანეს მამოძრავებელ ძალას, რომელიც საქართველოს აძლევს შესაძლებლობას, თავისი გეოგრაფიული უპირატესობა სტრატეგიულ აქტივად აქციოს და საზღვაო ტრანსპორტისა და ლოჯისტიკის სფეროში რეგიონული მნიშვნელობის ცენტრად ჩამოყალიბდეს.

უცხოური კაპიტალდაბანდების გავლენა სექტორზე მრავალმხრივია და რამდენიმე ძირითადი ასპექტით გამოიხატება:

სოციალურ-ეკონომიკური გავლენა: FDI არის ეკონომიკური წინსვლის ერთ-ერთი მთავარი იმპულსი. საპორტო და ლოჯისტიკურ ინფრასტრუქტურაში განხორციელებული პროექტები სამუშაო ადგილების გენერირების მძლავრი წყაროა, როგორც

მშენებლობის, ისე შემდგომი ექსპლუატაციის ფაზაში. ეს პირდაპირ უწყობს ხელს დასაქმების დონის ზრდას, უმუშევრობის შემცირებას და მოსახლეობის შემოსავლების ზრდას. ამის ნათელი მაგალითია ანაკლიის პორტისა და მასთან ინტეგრირებული სპეციალური ეკონომიკური ზონის პროექტი, რომელიც ათასობით ადამიანის დასაქმების პოტენციალს შეიცავს. ამასთან, სექტორში კაპიტალის შემოდინება ზრდის მთლიან პროდუქტიულობას ეკონომიკაში.

ტექნოლოგიურ-ოპერაციული გავლენა: საერთაშორისო ინვესტორების, მაგალითად, ფოთში მოქმედი „APM Terminals“-ის შემოსვლა უზრუნველყოფს სექტორის მოდერნიზებას უახლესი ტექნოლოგიების, მართვის თანამედროვე მეთოდებისა და საერთაშორისო სტანდარტების დანერგვის გზით. ეს გულისხმობს ოპერაციების ავტომატიზაციას, ტვირთების მართვისა და მონიტორინგის ციფრული სისტემების ინტეგრაციას, ასევე ეკოლოგიური და უსაფრთხოების ნორმების მაღალი დონის დაცვას. ყოველივე ამის შედეგად, იზრდება საპორტო მომსახურების ეფექტიანობა, მცირდება როგორც გემების მომსახურების დრო, ისე დაკავშირებული დანახარჯები. ევროკავშირთან ასოცირების შეთანხმების ფარგლებში მიმდინარე რეფორმები დამატებით ასტიმულირებს საქართველოს საზღვაო სექტორის ჰარმონიზაციას ევროპულ სტანდარტებთან.

სტრატეგიულ-გეოპოლიტიკური გავლენა: სატრანსპორტო სექტორში განხორციელებული ინვესტიციები აძლიერებს საქართველოს, როგორც ევროპისა და აზიის დამაკავშირებელი „შუა დერეფნის“ ერთ-ერთი მთავარი აქტორის, პოზიციებს. უკრაინაში მიმდინარე კონფლიქტის გამო რუსეთის ტერიტორიაზე გამავალი ჩრდილოეთის დერეფნის მნიშვნელობის შემცირებამ მკვეთრად გაზარდა „შუა დერეფნის“ მიმართ ინტერესი. ამ ფონზე, ანაკლიის ღრმაწყლოვანი პორტის პროექტი იძენს განსაკუთრებულ სტრატეგიულ დატვირთვას. მისი რეალიზება ქვეყანას საშუალებას მისცემს, მოემსახუროს „პანამაქსისა“ და „პოსტ-პანამაქსის“ კლასის გემებს, რაც მნიშვნელოვნად გაზრდის სატრანზიტო პოტენციალს და შეამცირებს დამოკიდებულებას რეგიონის სხვა პორტებზე. ანაკლიის პორტი მიიჩნევა „შუა დერეფნის“ კრიტიკულად მნიშვნელოვან რგოლად, რომელსაც ევრაზიის კონტინენტზე მიწოდების ჯაჭვების მდგრადობის ამაღლება შეუძლია.

ინვესტიციების როლი საქართველოს საზღვაო ტრანსპორტისა და ლოჯისტიკის სექტორის მოდერნიზაციაში

საქართველოს საზღვაო-სატრანსპორტო და ლოჯისტიკური სექტორის ტრანსფორმაციაში პირდაპირი უცხოური ინვესტიციები (FDI) საკვანძო ფუნქციას ასრულებს. საერთაშორისო კაპიტალი წარმოადგენს კატალიზატორს ისეთი კრიტიკული მიმართულებების განვითარებისთვის, როგორიცაა ინფრასტრუქტურული განახლება, თანამედროვე ტექნოლოგიების დანერგვა, ოპერაციული ეფექტიანობის ამაღლება და ქვეყნის სატრანზიტო პოტენციალის სრული რეალიზება. უცხოური ინვესტიციების წვლილი განსაკუთრებით თვალსაჩინოა ფოთისა და ბათუმის პორტების კონკურენტუნარიანობის ამაღლების პროცესში.

ფოთის საზღვაო ნავსადგური

ფოთის საზღვაო ნავსადგურის მართვას 2011 წლიდან ახორციელებს „APM Terminals", დანიური გიგანტის „A.P. Moller-Maersk Group"-ის შვილობილი კომპანია. ოპერატორი უწყვეტ რეჟიმში ახორციელებს კაპიტალდაბანდებებს პორტის მოდერნიზაციისა და გაფართოების მიზნით. უახლოეს მომავალში დაგეგმილია 200 მილიონ აშშ დოლარზე მეტი მოცულობის ინვესტირება ახალი ნავმისადგომის, ტალღმჭერი მოლის მშენებლობასა და თანამედროვე ამწე ტექნიკის შეძენაში. აღნიშნული პროექტების მიზანია პორტის გამტარუნარიანობის გაზრდა და მასშტაბური გემების მიღების ტექნიკური შესაძლებლობის შექმნა. უკვე განხორციელებული პროექტებიდან აღსანიშნავია 25 მილიონი აშშ დოლარის ღირებულების ტალღმჭერი მოლის რეაბილიტაცია, რომელიც 2023 წელს დასრულდა. ამასთან, კომპანიის მიერ დანერგილი ინოვაციური ტექნოლოგიები, მაგალითად, თანამედროვე ბუნკერული სისტემები, მნიშვნელოვნად ზრდის ნაყარი ტვირთების დამუშავების ეფექტიანობას და ამცირებს ეკოლოგიურ ზემოქმედებას.

ბათუმის საზღვაო ნავსადგურიბათუმის პორტი, რომელიც „ყაზმუნაიგაზის" შვილობილი სტრუქტურის მართვაშია, ასევე ინვესტიციების მოზიდვის აქტიურ ფაზაშია. პორტში ფიქსირდება ტვირთბრუნვის ზრდა, განსაკუთრებით ნავთობპროდუქტების, მშრალი ტვირთებისა და საკონტეინერო გადაზიდვების კუთხით. 2025 წლის პირველი კვარტლის მონაცემებით, ტვირთბრუნვა 22%-ით გაიზარდა წინა წლის ანალოგიურ პერიოდთან შედარებით. 2024 წელს პორტის ჯამურმა ტვირთბრუნვამ 3,6 მილიონი ტონა შეადგინა, რაც 9%-ით მეტია წინა წლის მაჩვენებელზე.

ანაკლიის ღრმაწყლოვანი პორტიანაკლიის ღრმაწყლოვანი პორტის პროექტი ქვეყნისთვის უდიდესი სტრატეგიული მნიშვნელობის მატარებელია, რომელსაც შეუძლია რადიკალურად გააძლიეროს საქართველოს სატრანზიტო როლი და გაზარდოს „შუა დერეფნის" კონკურენტუნარიანობა. პროექტის თავდაპირველი მცდელობა, რომელსაც „ანაკლიის განვითარების კონსორციუმი" ხელმძღვანელობდა, ფინანსური ვალდებულებების შეუსრულებლობის გამო შეჩერდა. ამჟამად პროექტის განხორციელება იგეგმება ჩინურ-სინგაპურულ კონსორციუმთან პარტნიორობით. 2025-2028 წლების განმავლობაში, პორტის მშენებლობისთვის სახელმწიფო ბიუჯეტიდან 562 მილიონ ლარზე მეტი დაიხარჯება.

ლოჯისტიკური ცენტრების განვითარება

საზღვაო ინფრასტრუქტურის განვითარების პარალელურად, უცხოური კაპიტალის მონაწილეობით აქტიურად ვითარდება ლოჯისტიკური ცენტრები.

თბილისის მშრალი პორტი: 2025 წლის ივნისში ოფიციალურად გახსნილი ეს მულტიმოდალური ლოჯისტიკური ჰაბი წარმოადგენს არაბთა გაერთიანებული საამიროების „Abu Dhabi Ports Group"-ის, ნორვეგიული „Wilhelmsen Port Services"-ისა და ადგილობრივი პარტნიორის თანამშრომლობის შედეგს. პროექტის პირველ ეტაპზე უკვე 21 მილიონი აშშ დოლარის ინვესტიცია განხორციელდა. ცენტრი მიზნად ისახავს ტვირთების ნაკადების ოპტიმიზაციას და საქართველოს ინტეგრაციას გლობალურ ლოჯისტიკურ ქსელებში.

პირდაპირი უცხოური ინვესტიციები საქართველოს საზღვაო-ლოჯისტიკურ სექტორში არ არის მხოლოდ ფინანსური ნაკადი; ის წარმოადგენს ტექნოლოგიური განახლების, მართვის კულტურის დახვეწისა და სტრატეგიული განვითარების მამოძრავებელ ძალას. მისი გავლენა კომპლექსურია და მოიცავს როგორც ფიზიკური ინფრასტრუქტურის შექმნას, ისე მენეჯერული კომპეტენციებისა და თანამედროვე ნოუ-ჰაუს იმპორტს, რაც ზრდის სექტორის საერთო პროდუქტიულობას. ეს პროცესი სრულ თანხვედრაშია საქართველოს მთავრობის მიერ დამტკიცებულ „ტრანსპორტისა და ლოჯისტიკის ეროვნულ სტრატეგიასთან (2023-2030)“, რომელიც ქვეყნის ლოჯისტიკური ეფექტიანობის გაუმჯობესებას ისახავს მიზნად.

თუმცა, მსოფლიო ბანკის 2023 წლის ლოგისტიკის ეფექტიანობის ინდექსი (LPI), რომლის მიხედვითაც საქართველო ევროპისა და ცენტრალური აზიის საშუალო მაჩვენებელს ჩამორჩება, ხაზს უსვამს დამატებითი ინვესტიციებისა და სისტემური რეფორმების გაგრძელების აუცილებლობას, რათა ქვეყანამ სრულად გამოიყენოს თავისი გეოპოლიტიკური პოტენციალი გლობალურ სავაჭრო დერეფნებში.

დასკვნა

სექტორის მომავალი განვითარება პირდაპირაა დამოკიდებული როგორც დაგეგმილი პროექტების წარმატებულ განხორციელებაზე, ისე არსებული გამოწვევების ეფექტიან მართვაზე.

სამომავლო პერსპექტივები:

- **ინფრასტრუქტურის სრული მოდერნიზაცია:** ანაკლიის პორტის მშენებლობის დასრულება საქართველოს რეგიონულ ჰაბად გადაქცევის შესაძლებლობას შექმნის, რომელიც კავკასიის, ცენტრალური აზიისა და ჩრდილოეთ ირანის ბაზრებს მოემსახურება. პროექტის წარმატება ხელს შეუწყობს საერთაშორისო ვაჭრობის სტიმულირებას და ეკონომიკური ზრდის მდგრადობას.
- **„შუა დერეფნის“ პოტენციალის სრული ათვისება:** ინფრასტრუქტურულ განვითარებასთან ერთად, კრიტიკულად მნიშვნელოვანია მონაწილე ქვეყნებს შორის სატარიფო პოლიტიკის კოორდინაცია და საბაჟო პროცედურების ოპტიმიზაცია, რაც დერეფნის კონკურენტუნარიანობას გაზრდის. მიუხედავად იმისა, რომ ტვირთბრუნვა 2021-2023 წლებში 1.48 მილიონიდან 2.7 მილიონ ტონამდე გაიზარდა, დერეფნის რეალური პოტენციალი გაცილებით მაღალია.
- **ციფრული და ენერგეტიკული ჰაბის ფუნქციის განვითარება:** ანაკლიის პროექტი ითვალისწინებს რეგიონული ციფრული ჰაბის ფორმირებას, რაც ევროპა-აზიის დამაკავშირებელი ოპტიკურ-ბოჭკოვანი მაგისტრალის მშენებლობას გულისხმობს. ამასთან, პორტს შეუძლია კასპიის ზღვის ენერგორესურსების ევროპის მიმართულებით ტრანსპორტირების საკვანძო პუნქტის როლი შეასრულოს.

გამოწვევები:

- **რეგიონული არასტაბილურობა:** რეგიონში არსებული გეოპოლიტიკური ვითარება რჩება მთავარ რისკ-ფაქტორად, რომელმაც შესაძლოა უარყოფითად იმოქმედოს როგორც საინვესტიციო გარემოზე, ისე სატრანზიტო დერეფნის სტაბილურობაზე.
- **კონკურენცია და ეფექტიანობის საკითხები:** „შუა დერეფანი" ამჟამად ჩამორჩება ალტერნატიულ მარშრუტებს როგორც გადაზიდვის დროის, ისე ღირებულების თვალსაზრისით.
- **შიდა ინფრასტრუქტურის სინქრონიზაცია:** საპორტო ინფრასტრუქტურის გამტარუნარიანობის ზრდა მოითხოვს საავტომობილო და სარკინიგზო ქსელების ადეკვატურ განვითარებას, რათა თავიდან იქნას აცილებული ტვირთნაკადების შეფერხება ქვეყნის შიგნით.

საბოლოო ჯამში, პირდაპირი უცხოური ინვესტიციები საქართველოს საზღვაო ტრანსპორტისა და ლოჯისტიკის სექტორისთვის ტრანსფორმაციული მნიშვნელობის მატარებელია. ამ რესურსის სტრატეგიული და ეფექტიანი მართვა, „შუა დერეფნის" შესაძლებლობების მაქსიმალურ ათვისებასთან ერთად, ქვეყანას უნიკალურ შესაძლებლობას აძლევს, დაიმკვიდროს თავი, როგორც რეგიონული მასშტაბის ეკონომიკურმა და ლოჯისტიკურმა ცენტრმა.

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სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის ფორმირება და განვითარება საქართველოში

Formation and Development of Transport and Logistics Infrastructure in Georgia

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აბსტრაქტი

ტრანს-სასაზღვრო სასაქონლო ნაკადების რეგიონული ლოგისტიკური ქსელის ფორმირების ეფექტიანობა დიდწილად არის დამოკიდებული რეგიონის ეკონომიკური პოტენციალის ამჟამინდელ მდგომარეობაზე, ექსპორტზე ორიენტირებულ საწარმოებსა და მათი ეკონომიკის სექტორის ზრდის პირობებზე.

საკვანძო სიტყვები: ლოგისტიკური ინფრასტრუქტურა, საბაჟო ტერიტორია, ეკონომიკური პოტენციალი, ექსპორტი და იმპორტი.

ABSTRACT

The effectiveness of forming a regional logistics network for cross-border commodity flows largely depends on the region's current economic potential and its export orientation: industries and their great economic threat.

KEEWORDS: Logistics infrastructure, customs territory, economic potential, export and import.

შესავალი

საქართველოს საწარმოო და ინფრასტრუქტურული პოტენციალის მდგომარეობის შეფასების მნიშვნელობა, უპირველეს ყოვლისა, განისაზღვრება მისი განსაკუთრებული გეოსტრატეგიული პოზიციით, ანუ ევროპისა და აზიის სატრანზიტო ვაჭრობის ნაკადებში არსებული მთავარი როლით, დინამიურად განვითარებად მსოფლიო ბიზნეს ცენტრებს – ევროპასა და აზიას შორის. საქონლის ტრანზიტი საქართველოს საბაჟო ტერიტორიის გავლით ყოველთვის მოთხოვნადი იყო და მისი მნიშვნელობა უაღრესად გაიზარდა მე-20 საუკუნის მეორე ნახევარში. ყოფილი კავშირის საბაჟო ტერიტორიის გავლით, მხოლოდ ირანის მიმართულებით სხვადასხვა სახის ტრანსპორტით განხორციელებული ტრანზიტი ყოველწლიურად 5 მილიონ ტონამდე ტვირთს შეადგენდა. (WTO, 2024).

დისკუსია

ამჟამად საქართველოს ეკონომიკა წარმოადგენს ჩამოყალიბებულ ბუნებრივ-ეკონომიკურ კომპლექსს, რომელიც კარგად არის ინტეგრირებული ეროვნულ ეკონომიკაში. მას გააჩნია დიდი მინერალური რესურსები და საკმაოდ განვითარებული, თუმცა არაერთგვაროვანი სატრანსპორტო ინფრასტრუქტურა. ქვეყნის რამდენიმე რეგიონს აქვს ნაყოფიერი მიწები (კახეთი, შიდა ქართლი, ქვემო ქართლი, სამეგრელო, აჭარა, რაჭა და სხვა რეგიონები), აგრეთვე უდიდესი რეკრეაციული და ბალნეოლოგიური რესურსები (მინერალური წყლები, მინერალური და თერმული ტალახები, მაგნიტური ქვიშები, შავი ზღვის სანაპირო და სხვა). („მწვანე ალტერნატივა", 2013)

საქართველოს ეკონომიკურ პროფილს განსაზღვრავს აგროინდუსტრიული და ენერგეტიკული კომპლექსები, ქიმიური და მეტალურგიული მრეწველობა, აგრეთვე მექანიკური ინჟინერია. ქვეყანას გააჩნია მრავალფეროვანი სატრანსპორტო ინფრასტრუქტურა, რომელიც ქვეყნის სატრანსპორტო ეკონომიკის განუყოფელი ნაწილია და უზრუნველყოფს პირდაპირი საზღვაო და სახმელეთო ვაჭრობის ნაკადებს საქართველოსა და კავკასიის რეგიონს, ახლო აღმოსავლეთის და სამხრეთ-დასავლეთ აზიისა, ამერიკისა და ევროპის ქვეყნებს შორის. (საქართველოს მთავრობა, 2022)

საქართველოს საბაჟო ტერიტორიის ეკონომიკური პოტენციალის მდგომარეობა განისაზღვრება არა მხოლოდ მასზე განთავსებული ეკონომიკური რესურსების მთლიანობით, არამედ წლის განმავლობაში წარმოებული საქონლის მოცულობით, სტრუქტურით, ხარისხით და ტექნიკური დონით, რომელიც გაიყიდა ორივე, – შიდა და საგარეო ბაზრებზე.

საბაჟო ტერიტორიის ეკონომიკური აქტივობის საერთო დონე გამოიხატება მთლიანი შიდა პროდუქტის (მშპ) დინამიკაში და განისაზღვრება ეკონომიკის ძირითადი სექტორების ექსპორტის გაფართოების და იმპორტის შემცვლელი ზრდის ისეთი ფაქტორების არსებობით, როგორებიცაა:

- ინვესტიციების, ფინანსური და ეკონომიკური რისკების შემცირება და კოოპერატიული კავშირების საიმედოობის გაზრდა;

- ფინანსურ, სადაზღვევო და საინვესტიციო ბაზრებზე კაპიტალის კონცენტრაციის პროცესების წახალისება;
- რეგიონში ჰოლისტიკური და დაბალანსებული საინვესტიციო პოლიტიკის განხორციელება;
- საფონდო და სადაზღვევო ბაზრების განვითარება.

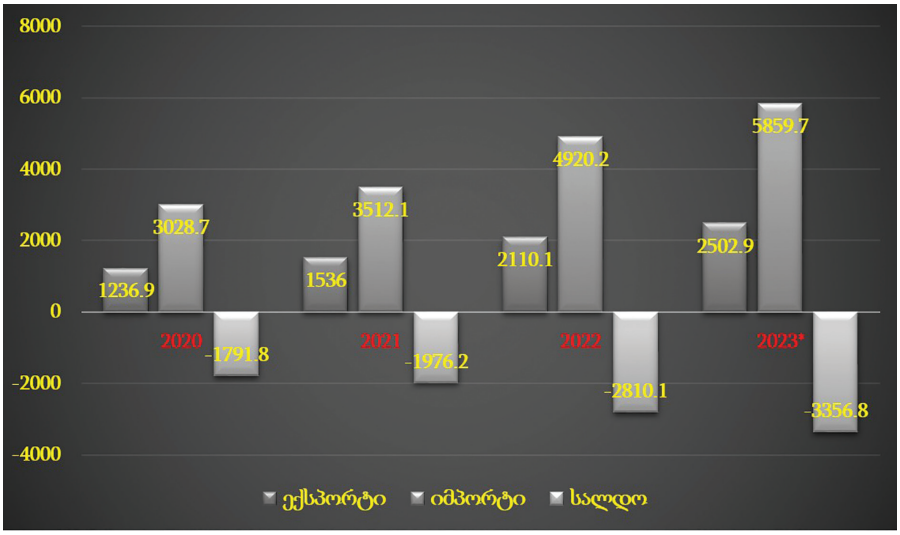
საბაჟო სტატისტიკის მასალების შესწავლა აჩვენებს, რომ საქართველოს ექსპორტის მოცულობა 2023 წელს (6 თვის მაჩვენებელი) შეფასებულია 2502,9 მილიარდ დოლარად. წინა წელთან შედარებით (2110,1 მლრდ დოლარი) ხარჯების მოცულობა გაიზარდა 18,6%-ით, ფიზიკურად 41%-ით.

ექსპორტის შემოსავლის ძირითადი მოცულობა უზრუნველყოფილია კახეთის (26%), ქვემი ქართლის (30%) და იმერეთის (26%) რეგიონების მიერ. საექსპორტო სასაქონლო ნაკადები ძირითადად ორიენტირებულია დსთ-ს არაწევრ ქვეყნებზეა, რომელთა წილი აღემატება 85%-ს.

საქართველოს იმპორტის სასაქონლო სტრუქტურას ჯერ კიდევ გააჩნია საწვავისა და ნედლეულის მიმართულება.

მინერალური საწვავის წილი მიმდინარე წელს შეადგენს 40%-ს, რაც 3 პროცენტული პუნქტით აღემატება გასული წლის ამავე მონაცემს. ამ ინდუსტრიის აბსოლუტური მოცულობა 1,66 მილიარდი დოლარია და 14,3 მილიონი ტონა. ძირითადი იმპორტიორები არიან არაბეთის საემიროები (GALF), რუსეთი (LUKOIL) და აზერბაიჯანი (SOCAR). (ავდალიანი, 2019).

დიაგრამა 1. საგარეო ვაჭრობის ზოგადი მაჩვენებლები 2020-2023 წწ (შედგენილია ავტორების მიერ საქსტატის მონაცემების საფუძველზე)



ექსპორტის ყველაზე დიდი წილი მოდის ავტომობილების რეექსპორტზე, იგი გაზრდილია 300 %-ზე მეტით, მინერალურ და სხვა სახეობის წყლებზე ექსპორტის წილი 96%-ით არის გაზრდილი, ხოლო სპირტიანი სასმელებისა კი 76%-ით.

რეგიონში საკმარისად არის განვითარებული მილსადენის ტრანსპორტი (გაზის, ნავთობის, წყლის მილსადენები). ტრანსპორტის საზღვაო და მილსადენი გზები

უფრო მეტად ორიენტირებულია საერთო ეროვნულ საჭიროებებზე. (საქართველოს რეგიონული განვითარების პროგრამა, 2018)

ტვირთბრუნვის სტრუქტურაში ყველაზე დიდი წილი სარკინიგზო ტრანსპორტს უკავია. მეორე ადგილზე საგზაო ტრანსპორტია. მესამეზე – საჰაერო ტრანსპორტი. სატვირთო და სამგზავრო მიმოსვლაში მდინარის ტრანსპორტის წილი ზოგადად უმნიშვნელოა. ქვეყნის ტერიტორიაზე წყლის გზებია შავი ზღვის აუზის საზღვაო პორტების, აგრეთვე სანაოსნო მდინარეების (მტკვარი და რიონი) მისადგომები. (გითოლენდია ბ., 2016).

დიაგრამა 2. უმსხვილესი სასაქონლო ჯგუფები საქართველოს ექსპორტში, 2023 წლის ნახევარი წლის წინასწარი მონაცემები (შედგენილია ავტორის მიერ საქსტატის მონაცემების მიხედვით)

	2022* წლის იანვარი - მაისი		2023* წლის იანვარი - მაისი		ცვლილება (%)
	ათასი აშშ დოლარი	პროცენტული წილი	ათასი აშშ დოლარი	პროცენტული წილი	
ექსპორტი სულ	2 110 138,2	100,0	2 502 872,4	100,0	18,6
მათ შორის:					
მსუბუქი ავტომობილები	191 001,1	9,1	795 023,4	31,8	316,2
სპილენძის მადნები და კონცენტრატები	465 867,8	22,1	315 515,1	12,6	-32,2
ყურძნის ნატურალური ღვინოები	79 827,4	3,8	103 515,1	4,1	29,7
ფეროშენადნობები	285 721,2	13,5	86 489,4	3,5	-69,7
აზოტოვანი სასუქები	152 729,6	7,2	85 555,0	3,4	-44,0
სპირტიანი სასმელები	40 079,9	1,9	68 520,9	2,7	71,0
მიწერალური და მტკნარი წყლები	41 125,3	1,9	52 156,5	2,1	26,8
წყლები, მიწერალურისა და დაგაზიანებულის ჩათვლით, შაქრის დანამატების შემცველობით	23 430,1	1,1	45 978,4	1,8	96,2
სამკურნალო საშუალებები დაფასოებული	43 227,1	2,0	41 481,4	1,7	-4,0
ოქრო	35 108,3	1,7	38 242,4	1,5	8,9
დანარჩენი საქონელი - სულ	752 020,2	35,6	870 214,7	34,8	15,7

ქვეყნის სატრანსპორტო კომპლექსის პერსპექტივები დიდწილად არის დაკავშირებული საზღვაო ნავსადგურების და ტერმინალების მშენებლობასა და გაფართოებასთან შავი ზღვისპირეთში. საზღვაო სავაჭრო პორტ ფოთში ახლა დაიწყო, ხოლო ახალ პორტში – ანაკლია, – იგეგმება ნავმისადგომის მეორე ეტაპის – საბორნე კომპლექსის მშენებლობა დიდი დატვირთვის მქონე გემების, როლკერების დასამუშავებლად. ახალი საზღვაო პორტის, მშენებლობამ ასევე შეიძლება მნიშვნელოვნად გააძლიეროს საქართველოს პოზიციები შავ ზღვაში. (ბლიაძე, ავტოტრანსპორტი და მისი მომავალი, 2018)

დასახული მიზნების განხორციელება და საქმის ფაქტობრივი მდგომარეობა საშუალებას გვაძლევს დავასკვნათ, რომ საქართველოს საბაჟო ტერიტორია მნიშვნელოვანი რგოლი გახდება საერთაშორისო სატრანზიტო ევრაზიული დერეფნის შექმნისას, რაც შექმნის საშუალებას, განხორციელდეს სატრანზიტო საქონლის გადაადგილება სპარსეთის ყურის რეგიონებიდან, ინდოეთიდან, პაკისტანიდან – აღმოსავლეთ და ცენტრალური ევროპისა და სკანდინავიის ქვეყნებში. არსებული პოზიტიური ტენდენციების შენარჩუნებისა და განვითარების მიზნით აუცილებელია

რეგიონების საწარმოო და ინფრასტრუქტურული პოტენციალის რესტრუქტურიზაცია.

ასეთი შესაძლებლობა მომავალ წლებში განისაზღვრება მთელი რიგი დადებითი ფაქტორების არსებობით ეროვნულ ეკონომიკაში, მათ შორის, იმ ფაქტორებისაც, რომლებიც წარმოების ხანგრძლივი შემცირების შედეგად წარმოიშვა. (ეკონომიკისა და მდგრადი განვითარების სამინისტრო, 2019)

პირველი ფაქტორი: „ბუნებრივი“ კაპიტალი, ე.ი. შენობები, კონსტრუქციები, ნაგებობები, დანადგარები, მექანიზმები, თერმული და ელექტრო კომუნიკაციები, რომლებიც ღრმა ეკონომიკური კრიზისის პირობებში სრულად არ გამოიყენება პროდუქციის წარმოებაში ან არ არის შეტანილი რეზერვში. სხვადასხვა მიზეზის გამო, ზოგიერთი მათგანის წარმოებაში ხელახლა გაშვება შეუძლებელია, მაგრამ მნიშვნელოვანი ნაწილი შენარჩუნებულია და ეფექტური მოთხოვნის დონის გაზრდის შემთხვევაში შესაძლებელია მათი მოქმედ კაპიტალში ჩართვა. ფუნქციონირებადი კაპიტალის მოცულობის გაზრდა ამ სიმძლავრეების ჩართვით არის პრაქტიკულად „თავისუფალი“ რესურსი ეკონომიკური ზრდისთვის, რადგან საწყის ეტაპზე ახალი სიმძლავრეების ექსპლუატაციისთვის მნიშვნელოვანი ინვესტიციები არ არის საჭირო.

მეორე ფაქტორი: „რბილი“ რესურსების შეზღუდვის არსებობა ქვეყნის ეკონომიკის განვითარებაში, რომელსაც ამჟამად არ აქვს მკაცრი შეზღუდვები ენერგეტიკის, ლითონის და სხვა ნედლეულის, ასევე სატრანსპორტო სისტემის სიმძლავრეზე. ერთადერთი სერიოზული შემზღუდველი ფაქტორი, განსაკუთრებით საწარმოო ინდუსტრიებში, შეიძლება გახდეს მრავალი საწარმოს მიერ ყველაზე კვალიფიცირებული მუშების, ინჟინრებისა და ტექნოლოგების, სფეროს სხვა სპეციალისტებისა და ექსპერტების დაკარგვა სტაგნაციის წლების განმავლობაში.

მესამე ფაქტორი: ლარის გაუფასურებასთან დაკავშირებულმა შიდა ხარჯების შედარებითმა კლებამ გამოიწვია იმპორტირებული პროდუქციის კონკურენტუნარიანობის შემცირება შიდა ბაზარზე, რამაც, თავის მხრივ, შესაძლებელი გახადა რეგიონში ფაქტიურად შეუცვლელი ინვესტიციების პირობებში გაშვებულიყო არა დატვირთული სამეწარმეო სიმძლავრეები.

მეოთხე ფაქტორი: ხარჯების შედარებითი შემცირება რეგიონის საწარმოო ინდუსტრიის ბევრ სექტორში სამრეწველო და ტექნიკურ პროდუქტებზე ფასების შედარებით ნელი ზრდის ფონზე. ამავდროულად, ტრადიციული ქართული საექსპორტო საქონლის კონიუნქტურის გაუმჯობესებამ მსოფლიო ბაზრებზე შესაძლებელი გახადა რეგიონული ეკონომიკის ექსპორტზე ორიენტირებული სექტორების ფინანსური მდგომარეობის მნიშვნელოვნად გაძლიერება. თავის მხრივ, ამან გამოიწვია ეკონომიკის სექტორებში მნიშვნელოვანი შემოსავლების ფორმირება, რაც შეიძლება გახდეს ეკონომიკური ზრდის ფინანსური საფუძველი.

მთლიანობაში, საქართველოს და მისი რეგიონების ეკონომიკას აქვს ყველა საჭირო და საკმარისი წინაპირობა ეკონომიკური აღმავლობის გასაგრძელებლად, კერძოდ: თავისუფალი საწარმოო სიმძლავრეები, მიმდინარე წარმოების რესურს-მოხმარების მოცულობის შესაბამისი ელასტიური მიწოდება და ეფექტიანობის ამაღლების გზების მაძიებელი ფინანსური რესურსები. (საავტომობილო გზების დეპარტამენტი, 2020)

ამავდროულად, რეგიონის საწარმოო და ინფრასტრუქტურული პოტენციალის რესტრუქტურიზაცია მიმდინარეობს არაერთი მნიშვნელოვანი შეზღუდვის ფონზე.

პირველი შეზღუდვა: შიდა მოთხოვნის არაეფექტური სტრუქტურა. ამჟამად საქართველოს ეკონომიკაში ჩამოყალიბებულია სიტუაცია, რომელიც ხასიათდება მის ერთერთ ნაწილში ისეთი შემოსავლის არსებობით, რომელიც არ შეიძლება ეფექტურად იქნას გამოყენებული და ამ თვალსაზრისით ზედმეტია, და ეკონომიკის სხვა ნაწილში არსებული წარმოების განვითარებისთვის საჭირო ფინანსური რესურსების მწვავე საჭიროებით.

პოტენციური დამატებითი მოთხოვნის ძირითადი ნაწილი ამჟამად წარმოიქმნება ეროვნული ეკონომიკის ექსპორტზე ორიენტირებული სექტორის შემოსავლით, რომელიც მიღებულია ლარის გაუფასურების და მსოფლიო ბაზრების კონიუნქტურის გაუმჯობესების შედეგად. რეალურად, საგარეო სავაჭრო კომპლექსი არც ხელფასების და არც ინვესტიციების გაზრდის კუთხით არ არის მზად შიდა ბაზარზე წარმოადგინოს მოთხოვნა, რომელიც შეესაბამება მისი შემოსავლის ზრდას. შედეგად, საქართველოს ეკონომიკის ექსპორტზე ორიენტირებული სექტორის დამატებითი შემოსავალი რეალურად წარმოადგენს პოტენციურად საექსპორტო კაპიტალს საზღვარგარეთ. (White House, 2024)

ამავდროულად, ეროვნული ეკონომიკის რეალური სექტორის საწარმოთა მნიშვნელოვანი ნაწილი ცუდად არის უზრუნველყოფილი საკუთარი საბრუნავი კაპიტალით. საბანკო სისტემას, რომელსაც აქვს ლიკვიდობის შედარებით დიდი მარაგი, არ შეუძლია განახორციელოს კაპიტალის სექტორთაშორისი გადაცემის ფუნქციები, რაც გამოიხატება საბანკო სესხების ხელმისაწვდომობაში და გრძელვადიანი სესხის აღების რეალური შესაძლებლობების არარსებობაში. ამ პირობებში ეკონომიკის რეალურ სექტორში საკუთარი სახსრების დეფიციტი იწვევს როგორც მოთხოვნის დაბალ დონეს, ასევე წარმოების ზრდის შეზღუდვას.

მეორე შეზღუდვა: ეკონომიკური რესურსების არასაკმარისი მობილურობა. გრძელვადიან პერსპექტივაში, არ ღირს ეკონომიკური ზრის რესურსული უზრუნველყოფის პრობლემების არასათანადოდ შეფასება. მაგალითად, ენერგორესურსებისა და სტრუქტურული მასალების „საბალანსო" სიჭარბე, რომელიც განვითარდა კრიზისის წლებში და გამოიხატება მათი ექსპორტის მნიშვნელოვან რაოდენობაში, არ არის მთლიანად მოძრავი და მხოლოდ შეზღუდული ხარისხით შეიძლება გადაერთოს შიდა ეკონომიკური ზრდის უზრუნველყოფაზე.

მესამე შეზღუდვა: ფასობრივი პროპორციები. ბოლო ორი წლის ეკონომიკური ზრდა დიდწილად განპირობებული იყო ფასების ხელსაყრელი პროპორციებით. პირველადი ნედლეულის (საექსპორტო) მრეწველობისთვის, ზრდისა და ფინანსური დანაზოგის მთავარი წყარო იყო ფასების ზრდა მსოფლიო ბაზრებზე, გაცვლით კურსსა და ლარის მსყიდველობითი უნარის პარიტეტს შორის მზარდი განსხვავების პირობებში, რაც განპირობებული იყო დევალვაციური ეფექტით. გადამამუშავებელი მრეწველობისათვის ყველაზე მნიშვნელოვანი ფაქტორი, რომელმაც წინასწარ განსაზღვრა პოზიტიური ეკონომიკური დინამიკა, იყო ტრანსპორტის ტარიფების, ასევე ელექტროენერგიასა და საწვავზე ფასების შედარებით ნელი ზრდა.

ცხრილი 1. პირდაპირი უცხოური ინვესტიციები რეგიონების მიხედვით 2018-2023 წლებში (შედგენილია ავტორების მიერ საქსტატის მონაცემების მიხედვით)

წელი / რეგიონი	2018	2019	2020	2021	2022	2023*
საქართველო	**1351529,7**	**1352181,7**	**589798,1**	**1241821,7**	**1999990,1**	**496649,8**
მ.შ.						
ქ. თბილისი	1072822,4	947519,5	340199,7	1043437,0	1713825,4	183172,2
აჭარა	85015,2	193271,3	78482,0	84938,2	116542,8	30494,6
კახეთი	-8237,7	2260,4	-4795,2	1145,4	-3324,2	-280,9
სამცხე-ჯავახეთი	45199,5	50735,9	25791,2	45540,0	18477,5	7975,8
ქვემო ქართლი	86279,8	48692,5	78709,2	21343,2	-8784,2	221363,3
სამეგრელო-ზემო სვანეთი	-8897,4	45862,7	31549,3	-4455,1	41202,9	23398,1
გურია	301,6	1649,4	68,9	900,4	1168,2	-133,5
იმერეთი	27011,0	45442,3	-2999,9	2415,8	68367,9	14915,3
რაჭა-ლეჩხუმი და ქვემო სვანეთი	2383,4	2345,4	2781,2	846,0	1342,8	156,3
შიდა ქართლი	15240,0	1243,0	18746,3	19639,3	37876,0	2385,4
მცხეთა-მთიანეთი	34411,7	13159,1	21265,5	26071,5	13294,9	13203,3

მეოთხე შეზღუდვა: ინფრასტრუქტურული (ბუნებრივი) მონოპოლიების კორპორაციული ინტერესები. საქართველოში, მისი პოლიტიკური არადმგრადობით, საიმედო ენერგომომარაგება და სატრანსპორტო კავშირები ყოველთვის იყო ეროვნული ეკონომიკის სტაბილურობის აუცილებელი ტექნოლოგიური პირობა. მრავალი თვალსაზრისით, სწორედ ამიტომ, ელექტროენერგიის, სითბოს და გაზმომარაგების სფეროები, ისევე როგორც სარკინიგზო ტრანსპორტი, იქცა მონოპოლიურ პოზიციაზე მყოფი მსხვილი კომპანიების აბსოლუტური დომინირების ინდუსტრიებად. ინფრასტრუქტურული მონოპოლისტების საქონელსა და მომსახურებაზე არსებული ფასების დონე კი იქცა ქვეყანაში ეკონომიკური დინამიკის განმსაზღვრელ ერთ-ერთ უმნიშვნელოვანეს ფაქტორად.

მეხუთე შეზღუდვა: საინვესტიციო კომპლექსის საწარმოო სიმძლავრე. მრავალწლიანი საინვესტიციო კრიზისის პირობებში, საინვესტიციო კომპლექსის სექტორების საწარმოები არა მხოლოდ მოკლებული აღმოჩნდნენ სრულფასოვან მოთხოვნას, არამედ დიდწილად დაკარგეს საკუთარი განვითარების სტრატეგიული სახელმძღვანელო პრინციპები. გადარჩენის რეჟიმში ფუნქციონირებამ გამოიწვია მათი წარმოების პოტენციალის დეგრადაცია, როგორც რაოდენობრივად, ისე ხარისხობრივად. ურთულეს მდგომარეობაში აღმოჩნდნენ როგორც ქვესექტორები, რომლებიც ქმნიან ინდუსტრიის ბირთვს, ისევე სექტორები, რომლებიც ორიენტირებულია კაპიტალის რეპროდუქციის უზრუნველყოფაზე მრეწველობასა და სოფლის მეურნეობაში.

ამჟამად საინვესტიციო აქტივობა საქართველოში ხასიათდება საწარმოებისა და ორგანიზაციების საკუთარი სახსრების როლის ზრდით, რომელთა ხარჯზეც ხდება ინვესტიციების უმეტესობის დაფინანსება, იმ დროს, როდესაც ადგილობრივი ბიუჯეტიდან სახსრების მიღება შემცირდა. საქართველოს ეკონომიკაში ფინანსურად სუსტი აგრარული სექტორის უპირატესობის გათვალისწინებით, მისი წილი ძირითად

კაპიტალში ინვესტიციების მთლიან ქართულ მოცულობაში არც ისე მნიშვნელოვანია – 2023 წელს მან შეადგინა დაახლოებით 12 პროცენტი.

მიუხედავად მნიშვნელოვანი რისკებისა, უცხოელ ინვესტორეს კვლავ იზიდავს ჩვენი ეკონომიკა. წინასწარი შეფასებით, 2023 წლის პირველ კვარტალში საქართველოში უცხოური ინვესტიციების საქართველოს ტერიტორიაზე განაწილდება ნაჩვენებია ცხრილში (2).

დაგროვილი გამოცდილება გვიჩვენებს, რომ კავკასიის თითქმის ყველა რეგიონისთვის საპორტფელო ინვესტიციებს, რიგი ობიექტური და სუბიექტური მიზეზების გამო, ჯერჯერობთ არ აქვთ შანსი უახლოეს მომავალში გადამწყვეტი გავლენა მოახდინონ კავკასიის რეგიონულ საინვესტიციო პროცესებზე. პოტენციური ინვესტორებისთვის ბევრად უფრო მიმზიდველ ფორმას წარმოადგენს პირდაპირი ინვესტიციები, რომლებიც საშუალებას იძლევა უშუალო გავლენა მოახდინოთ საწარმოს მენეჯმენტზე.

ჩვენი აზრით, საქართველოში ინვესტიციების რეგიონებში განაწილება შეიძლება კლასიფიცირდეს მინიმუმ სამი კრიტერიუმის: საინვესტიციო პირობების; საინვესტიციო რისკის; უცხოური ინვესტიციების მოზიდვის ალბათობის ხარისხის მიხედვით.

პირველი ნიშანი: საინვესტიციო პირობების მიხედვით. საინვესტიციო პოტენციალი, როგორც ქვეყნის ან რეგიონის საინვესტიციო მიმზიდველობის რაოდენობრივი მახასიათებელი, მოიცავს ძირითად სოციალურ-ეკონომიკურ მაჩვენებლებს (მოსახლეობა, შემოსავალი ერთ სულ მოსახლეზე, მთლიანი რეგიონული პროდუქტი და ა.შ.), აგრეთვე ტერიტორიის გაჯერებულობას წარმოების ფაქტორებით (ბუნებრივი რესურსები, შრომა, ძირითადი საშუალებები, ინფრასტრუქტურა და ა.შ.).

ცხრილი 2. სამხრეთ სუბიექტების რეიტინგი საინვესტიციო რისკის მიხედვით (შედგენილია ავტორების მიერ)

რისკის ინტეგრალური რეიტინგი	საქართველოს რეგიონები	საინვესტიციო რისკის ტიპები				
		ეკონომიკური	პოლიტიკური	სოციალური	ეკოლოგიური	კრიმინალური
3	თბილისი	10	42	12	29	6
9	აჭარის არ	78	25	25	12	2
17	ქვემო ქართლი	6	63	15	63	19
24	შიდა ქართლი	33	78	19	30	21
34	კახეთი	48.5	50	46.5	46	17

43	იმერეთი	58	41	75	37	9
45	სამეგრელო-ზემო სვანეთი	89	1	89	1	44
46	რაჭა-ლეჩხუმი და ქვედა სვანეთი	63	81	76	3	1
48	სამცხე-ჯავახეთი	70	73	27	20	38
56	გურია	62	87	9	16	69
70	მცხეთა-მთიულეთი	79	30	7	83	69

მეორე ნიშანი: საინვესტიციო რისკის მიხედვით. თეორიულად, საინვესტიციო რისკი, როგორც პოლიტიკური, სოციალური, ეკონომიკური, გარემოსდაცვითი და კრიმინალური მდგომარეობის განუყოფელი მაჩვენებელი, ასახავს ინვესტორის მიერ დაბანდებული კაპიტალის ან შეძენილი აქტივების მთლიანად ან ნაწილობრივ დაკარგვის ალბათობას.

მესამე ნიშანი: ალბათობის ხარისხის მიხედვით, რომელიც დიდწილად განისაზღვრება სოციალურ-ეკონომიკური, ფინანსური, სოციალურ-კულტურული, ორგანიზაციული, სამართლებრივი და გეოგრაფიული ფაქტორების კომბინაციით, რომლებიც თან ახლავს ამა თუ იმ რეგიონს და იზიდავს ან, შესაბამისად, ხელს კრავს ინვესტორებს.

რეგიონული საინვესტიციო კლიმატისა და იმიჯის შეფასება მუდმივად უნდა გაუმჯობესდეს როგორც მეთოდური, ასევე შინაარსობრივი თვალსაზრისით. რეგიონების საინვესტიციო კლიმატი, თანამედროვე საქართველოს პირობებში, უკიდურესად დინამიურია და მუდმივად იცვლება ამა თუ იმ მიმართულებით. ამ თვალსაზრისით ძალიან აქტუალურია საინვესტიციო კლიმატის მონიტორინგის პრობლემა.

ცხრილი 3. უცხოური ინვესტიციების მოზიდვის ალბათობის ხარისხობრივი შეფასება საქართველოს რეგიონებში (შედგენილია ავტორების მიერ)

ჯგუფი	რეგიონი	ალბათობა
A	თბილისი	მაღალი
A	აჭარის არ	მაღალი
A	ქვემო ქართლი	მაღალი
B	შიდა ქართლი	საშუალო
B	კახეთი	საშუალო
B	იმერეთი	საშუალო
B	სამეგრელო-ზემო სვანეთი	საშუალო
C	რაჭა-ლეჩხუმი და ქვედა სვანეთი	დაბალი

C	სამცხე-ჯავახეთი	დაბალი
D	გურია	უკიდურესად დაბალი
D	მცხეთა-მთიულეთი	უკიდურესად დაბალი

უფრო მეტიც, რეგიონულმა მონიტორინგმა არა მხოლოდ უნდა დააფიქსიროს მიმდინარე ცვლილებები, არამედ უნდა შეეცადოს დაამყაროს ღრმა მიზეზ-შედეგობრივი კავშირი რეგიონში მიმდინარე სოციალურ-ეკონომიკურ პროცესებს და იმას შორის, თუ რა გავლენას ახდენენ ისინი რეგიონის საინვესტიციო მიმზიდველობაზე და აგრეთვე მოახდინოს საინვესტიციო კლიმატის ყველაზე სუსტი ელემენტების პროფილაქტიკა. საქართველოს რეგიონების მთლიანი საინვესტიციო პოტენციალი დიდია, მაგრამ ჯერ კიდევ ბევრია გასაკეთებელი მის ეფექტურად გამოსაყენებლად.

დასკვნა

ზოგადად, საქართველოს ეკონომიკური პოტენციალის ამჟამინდელი მდგომარეობის შეფასება საშუალებას გვაძლევს, განვსაზღვროთ საქართველოს საგარეო სავაჭრო და ეკონომიკური ინტერესების განხორციელების ძირითადი მიმართულებები:

ეკონომიკური, სამეცნიერო და ტექნიკური პოტენციალის ეფექტური გამოყენება რეგიონის სახელმწიფოებთან ურთიერთსასარგებლო თანამშრომლობისთვის;

- მეზობელი სახელმწიფოებისთვის სამეცნიერო, ტექნიკური, სამრეწველო, სატრანსპორტო და სხვა მომსახურების გაწევის გააქტიურება ურთიერთსასარგებლო პირობებით;
- საქართველოს შავი ზღვისპირა სუბიექტებს შორის სავაჭრო-ეკონომიკური ურთიერთობების განვითარება სასაზღვრო (სანაპირო) ვაჭრობის პირობებით და შესაბამისი შეღავათებით;
- რეგიონის ინფრასტრუქტურისა და სატრანსპორტო სისტემის ჩამოყალიბება საქართველოს ტერიტორიაზე გამავალ საერთაშორისო სატრანზიტო დერეფნებში ჩართვით.

საქართველოს ტერიტორიაზე ტრანს-სასაზღვრო საქონლის ბაზრის შიდა (რეგიონული) ლოგისტიკური ქსელის ფორმირების ინტენსივობა დიდწილად დამოკიდებულია არსებული გზის წარმატებაზე.

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სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის როლი ტურისტული დანიშნულების ფორმირებაში: დუბაის განვითარების გამოცდილება

The Role of Transport and Logistics Infrastructure in Shaping Tourist Destinations: The Experience of Dubai's Development

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აბსტრაქტი

ტურიზმის განვითარება თანამედროვე ეკონომიკაში უაღრესად დამოკიდებულია სატრანსპორტო და ლოგისტიკურ ინფრასტრუქტურაზე. ქალაქი დუბაი წარმოადგენს უნიკალურ მაგალითს, სადაც სახელმწიფომ სტრატეგიულად გააერთიანა პორტები, ავიაკავშირები, გზები და ტურისტული ატრაქციონები, რათა პატარა სავაჭრო პორტი გლობალური ტურისტული დანიშნულების გამხდარიყო. 2000–იანი წლების დასაწყისში, ქალაქში ტურისტების რაოდენობა წელიწადში დაახლოებით 3 მილიონს შეადგენდა; დღეს ეს მაჩვენებელი აღემატება 18 მილიონს, რაც ნათლად წარმოაჩენს სატრანსპორტო ინფრასტრუქტურის ეფექტს ტურისტულ ნაკადებზე.

დუბაის განვითარების პროცესში აშენდა მაღალი კლასის სასტუმროები, კულტურული და გასართობი ცენტრები, აგრეთვე მსოფლიოს მასშტაბით წამყვანი სავაჭრო ცენტრებიც. განსაკუთრებული მნიშვნელობა აქვს ავიაკავშირების განვითარებას. საერთაშორისო აეროპორტების გაფართოება, თანამედროვე საჰაერო ლოგისტიკური სისტემების დანერგვა და მაღალი სერვისის სტანდარტები უზრუნველყოფს დუბაიში დღეში 1,200–ზე მეტი საერთაშორისო რეისის მიღებას.

პორტების ინფრასტრუქტურა დუბაიში ასევე მნიშვნელოვანი აღმოჩნდა. ზღვის პორტები არა მხოლოდ ვაჭრობის, არამედ ტურისტული გემების მიღების შესაძლებ-

ლობას უზრუნველყოფენ. სტატისტიკური მონაცემები ხაზს უსვამს სატრანსპორტო და ლოგისტიკური სისტემების გავლენას: 2024 წელს დუბაიმ მიიღო 18.72 მილიონი საერთაშორისო ვიზიტორი, რაც წმნიშვნელოვანი ზრდაა წინა წელთან შედარებით. დუბაის საერთაშორისო აეროპორტმა (DXB) იმუშავა 92.3 მილიონ მგზავრზე, ხოლო 2025 წელს ეს რიცხვი გაიზარდა 95.2 მილიონამდე, რაც აჩვენებს ქალაქის როლს როგორც გლობალური სატრანსპორტო ჰაბის. გარდა ამისა, 2023 წელს გაერთიანებულმა არაბულმა საემირატოებმა მიიღო დაახლოებით 3.2 მილიონი საკრუიზო ტურისტი, რაც აძლიერებს საზღვაო ლოგისტიკის როლს ტურიზმში.

ლოგისტიკური სისტემა უზრუნველყოფს მილიონობით ვიზიტორის გადაადგილებას ქალაქის სხვადასხვა პუნქტში. ეს მაგალითი ადასტურებს, რომ ტურიზმის წარმატება არ განისაზღვრება მხოლოდ სასტუმროებისა და რესტორნების არსებობით, არამედ მოითხოვს სრულად ინტეგრირებულ სატრანსპორტო და ლოგისტიკურ ინფრასტრუქტურას.

დუბაის განვითარების მოდელი ხაზს უსვამს მდგრადი განვითარების პრინციპების მნიშვნელობას. სწრაფი ეკონომიკური ზრდის პირობებში აუცილებელია მდგრადი სატრანსპორტო სისტემები, ენერგიის ეფექტიანი გამოყენება და ეკოლოგიურად პასუხისმგებლიანი ინფრასტრუქტურა. ამ კონტექსტში დუბაი აჩვენებს, რომ დაგეგმარება, რომელიც აერთიანებს ეკონომიკურ, გარემოსდაცვითა და სოციალურ ინტერესებს, უზრუნველყოფს ტურიზმის მდგრად და ხარისხიან განვითარებას.

ასევე მნიშვნელოვანია ტურისტული ატრაქციონების კონცეფცია, რომელიც მჭიდროდ უკავშირდება ლოგისტიკურ სისტემას. ორგანიზებული სატრანსპორტო ქსელები, კომფორტული გადაადგილების პირობები და დროული მომსახურება ზრდის ვიზიტორთა აქტიურობას, რაც პირდაპირ აისახება ადგილობრივ ეკონომიკურ მაჩვენებლებზე. დუბაის მაგალითი ნათლად ადასტურებს, რომ სწორი მენეჯმენტი სატრანსპორტო და ლოგისტიკურ სისტემებს შორის ქმნის დადებით ეკონომიკურ, სოციალურ და კულტურულ ეფექტებს.

კვლევა ეფუძნება დოკუმენტურ და შედარებით ანალიზს, რომელიც მოიცავს: ოფიციალურ სტატისტიკურ მონაცემებს (დუბაის ტურიზმისა და აეროპორტების მართვის ანგარიშები 2023–2025), საერთაშორისო კვლევებსა და ნაშრომებს ტურიზმის, ტრანსპორტისა და ლოგისტიკის სფეროში, დუბაის განვითარების მოდელის კომპლექსურ შესწავლას ეკონომიკური, სოციალური და კულტურული შედეგების გათვალისწინებით. გარდა ამისა, გამოყენებულია სტატისტიკური მოდელირება ვიზიტორთა რაოდენობისა და მოძრაობის ტენდენციების პროგნოზირებისთვის, საერთაშორისო გამოცდილების შედარებითი ანალიზი სხვა გლობალურ ტურისტულ ქალაქებთან, და რეკომენდაციების შემუშავება სხვადასხვა ტიპის ტრანსპორტის ინტეგრირებული მართვის პრაქტიკისთვის.

ნაშრომი ხაზს უსვამს, რომ თანამედროვე ტურისტული დანიშნულების წარმატება ვერ მიიღწევა იზოლირებული მიდგომებით. აუცილებელია ინტეგრირებული სტრატეგია, სადაც სატრანსპორტო ქსელები, პორტები, აეროპორტები, სასტუმროები, გასართობი ცენტრები და კულტურული ობიექტები ერთმანეთთან არის დაკავშირებული. დუბაი წარმოაჩენს მეთოდოლოგიას, რომლის საშუალებითაც ნებისმიერი ქალაქი შეიძლება მდგრადი ტურისტული ცენტრი გახდეს, თუ განხორციელდება

სტრატეგიული დაგეგმვა, ეფექტური ლოგისტიკა და ინოვაციური სატრანსპორტო გადაწყვეტილებები.

საკვანძო სიტყვები: ტურიზმის მენეჯმენტი, სატრანსპორტო ინფრასტრუქტურა, ლოგისტიკა, მდგრადი განვითარება, დუბაი, პორტები, ავიაკავშირები, ტურისტული დანიშნულება.

ABSTRACT

Tourism development in the modern economy is highly dependent on transport and logistics infrastructure. The city of Dubai represents a unique example where the state has strategically integrated ports, air connections, road networks, and tourist attractions in order to transform a small trading port into a global tourist destination. In the early 2000s, the number of tourists in the city amounted to approximately 3 million per year; today, this figure exceeds 18 million, clearly demonstrating the impact of transport infrastructure on tourist flows.

During the development process of Dubai, high-class hotels, cultural and entertainment centers, as well as world-leading shopping malls were constructed. Particular importance is attached to the development of air connectivity. The expansion of international airports, the implementation of modern air logistics systems, and high service standards enable Dubai to receive more than 1,200 international flights per day.

Port infrastructure in Dubai has also proven to be significant. Seaports provide not only trade opportunities but also the capacity to accommodate cruise ships. Statistical data underline the impact of transport and logistics systems: in 2024, Dubai received 18.72 million international visitors, representing a significant increase compared to the previous year. Dubai International Airport (DXB) handled 92.3 million passengers, while in 2025 this figure increased to 95.2 million, demonstrating the city's role as a global transport hub. In addition, in 2023 the United Arab Emirates hosted approximately 3.2 million cruise tourists, strengthening the role of maritime logistics in tourism.

The logistics system ensures the movement of millions of visitors across different parts of the city. This example confirms that tourism success is not determined solely by the presence of hotels and restaurants, but requires a fully integrated transport and logistics infrastructure.

Dubai's development model highlights the importance of sustainable development principles. Under conditions of rapid economic growth, sustainable transport systems, efficient energy use, and environmentally responsible infrastructure are essential. In this context, Dubai demonstrates that planning which integrates economic, environmental, and social interests ensures sustainable and high-quality tourism development.

The concept of tourist attractions is also important, as it is closely linked to the logistics system. Organized transport networks, comfortable mobility conditions, and timely services increase visitor activity, which directly affects local economic indicators. The

example of Dubai clearly demonstrates that proper management between transport and logistics systems creates positive economic, social, and cultural effects.

The research is based on documentary and comparative analysis, which includes: official statistical data (Dubai tourism and airport management reports for 2023–2025), international studies and academic works in the fields of tourism, transport, and logistics, and a comprehensive examination of Dubai's development model, taking into account economic, social, and cultural outcomes. In addition, statistical modeling has been used to forecast visitor numbers and mobility trends, along with a comparative analysis of international experience with other global tourist cities, and the development of recommendations for integrated management practices across different modes of transport.

The paper emphasizes that the success of a modern tourist destination cannot be achieved through isolated approaches. An integrated strategy is required, where transport networks, ports, airports, hotels, entertainment centers, and cultural sites are interconnected. Dubai presents a methodology through which any city can become a sustainable tourist center, provided that strategic planning, efficient logistics, and innovative transport solutions are implemented.

KEYWORDS: Tourism management, transport infrastructure, logistics, sustainable development, Dubai, ports, air connectivity, tourist destination.

შესავალი

აქტუალობა: მსოფლიო ტურიზმის ზრდის პირობებში ქალაქების კონკურენტუნარიანობა მნიშვნელოვანწილად განისაზღვრება ინტეგრირებული სატრანსპორტო და ლოგისტიკური სისტემების ეფექტიანობით. დუბაის მაგალითი ადასტურებს, რომ ტურიზმის წარმატებული განვითარება მოითხოვს არა მხოლოდ ტურისტულ ინფრასტრუქტურას, არამედ განვითარებულ ავიაკავშირებს, საზღვაო ლოგისტიკასა და საპორტო სისტემებს შორის კოორდინირებულ ფუნქციონირებას. აღნიშნული საკითხის კვლევა აქტუალურია, რადგან ტრანსპორტისა და ლოგისტიკის ეფექტიანი მართვა წარმოადგენს მდგრადი ტურიზმის განვითარების ერთ-ერთ ძირითად წინაპირობას.

კვლევის მიზანია დუბაის სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის როლის გაანალიზება ქალაქის გლობალურ ტურისტულ ცენტრად ტრანსფორმაციაში და მისი ეკონომიკური, სოციალური და კულტურული გავლენების კომპლექსური შეფასება.

ამოცანები: დუბაის აეროპორტებისა და პორტების განვითარების სტატისტიკური ანალიზი; სატრანსპორტო-ლოგისტიკური სისტემების გავლენის შეფასება ტურისტულ ნაკადებსა და ეკონომიკურ განვითარებაზე; საერთაშორისო გამოცდილების შედარებითი ანალიზი და საუკეთესო პრაქტიკის იდენტიფიკაცია; უსაფრთხოების ფაქტორის მნიშვნელობის შეფასება ტურისტულ ჰაბებში; რეკომენდაციების შემუშავება ინტეგრირებული სატრანსპორტო სისტემების დანერგვისთვის.

მეთოდოლოგია. კვლევა ემყარება დოკუმენტურ და შედარებით ანალიზს, ოფიციალურ სტატისტიკურ მონაცემებსა და საერთაშორისო აკადემიურ წყაროებს. დუბაის განვითარების მოდელის შეფასება განხორციელებულია კომპლექსური ანალიზის საფუძველზე, რომელიც მოიცავს განვითარების ძირითადი ტენდენციების, ინსტიტუციური მიდგომებისა და პოლიტიკის მექანიზმების შესწავლას. დამატებით, გამოყენებულია სხვადასხვა ქალაქებთან შედარებითი ანალიზი, რაც უზრუნველყოფს დუბაის მოდელის ეფექტიანობისა და მისი ადაპტირების შესაძლებლობების გამოვლენას

ძირითადი ტექსტი

ინოვაციურ სტრატეგიაზე დაფუძნებული დუბაის ეკონომიკური მოდელი ეფუძნება ინფრასტრუქტურის წინმსწრებ განვითარებას, რაც უზრუნველყოფს ბაზრის გაფართოებასა და ეკონომიკურ ზრდას. სატრანსპორტო და ლოგისტიკური სექტორი წარმოადგენს დუბაის კონკურენტუნარიანობისა და გლობალურ ეკონომიკურ სივრცეში ინტეგრაციის ერთ-ერთ ძირითად საფუძველს.

მისი საერთაშორისო აეროპორტი (DXB) გლობალურ საჰაერო სატრანსპორტო ქსელში წარმოადგენს ერთ-ერთ ყველაზე მნიშვნელოვან ჰაბს. 2025 წელს DXB-მ 95.2 მილიონი მგზავრი მიიღო. ლოგისტიკური ინოვაციების წყალობით (AI-ზე დაფუძნებული ნაკადების მართვა, Smart Gates), მგზავრთა 100% პასპორტის კონტროლს 15 წუთზე ნაკლებ დროში გადის. ეს ამცირებს „მოგზაურობის ბარიერებს" (Travel Friction) და ზრდის დუბაის, როგორც საბოლოო დანიშნულების ადგილის მიმზიდველობას. Emirates-ისა და FlyDubai-ს სტრატეგიული პარტნიორობა 280-ზე მეტ მიმართულებასთან უზრუნველყოფს ტურისტების მუდმივ შემოდინებას ისეთი მაღალმზარდი ბაზრებიდან, როგორებიცაა ინდოეთი, ჩინეთი და დასავლეთ ევროპა. 2025 წელს ინდოეთი იყო ერთ-ერთი წამყვანი ბაზარი, სადანაც იმოგზაურა დაახლოებით 11.9 მილიონმა მგზავრმა. მეორე და მესამე ადგილებზე მოდიოდა საუდის არაბეთი და გაერთიანებული სამეფო. ეს მონაცემები ხაზს უსვამს დუბაის მრავალფეროვან გეოგრაფიულ კავშირს და გლობალურ მნიშვნელობას ტურისტულ სექტორში.

დუბაის პორტები არა მხოლოდ ტვირთბრუნვის, არამედ მაღალბიუჯეტიანი ტურისტული ნაკადების გენერატორია, Mina Rashid მნიშვნელოვან როლს ასრულებს საკრუიზო ტურიზმში – 2025 წელს პორტმა 900,000-ზე მეტ ვიზიტორს უმასპინძლა. მისი თანამედროვე ინფრასტრუქტურა უზრუნველყოფს ერთდროულად რამდენიმე მეგა-ლაინერის მიღებას, რაც მნიშვნელოვნად ზრდის ტურისტების დანახარჯებს საცალო ვაჭრობასა და მომსახურების სექტორში.

Dubai Harbour – რეგიონის უდიდესი იახტ-კლუბი (1,100 მისადგომით) ხელს უწყობს "Luxury Tourism"-ის სეგმენტის განვითარებას. Jebel Ali Port-ის სიახლოვე Al Maktoum-ის აეროპორტთან ქმნის მსოფლიოში უნიკალურ „საზღვაო-საჰაერო" დერეფანს. ეს ამცირებს სასტუმროებისა და რესტორნების მომმარაგებელი ჯაჭვის ხარჯს, რაც პირდაპირ აისახება ტურისტული პროდუქტის კონკურენტუნარიანობაზე. 2025 წლის მონაცემებით, Port Rashid და Dubai Harbour ინარჩუნებენ დუბაის, როგორც საკრუიზო

ჰაბის, მზარდ როლს. წლის განმავლობაში პორტებმა უმასპინძლეს ასეულობით საკრუიზო გემს და რამდენიმე ასეულ ათას ტურისტს, რაც მიუთითებს სტაბილურ ზრდაზე წინა წელთან შედარებით.

თანამედროვე ინფრასტრუქტურა და ეფექტიანად ორგანიზებული ლოგისტიკური სისტემები უზრუნველყოფს მგზავრთა და ბარგის მომსახურების ოპერატიულობასა და ეფექტიანობას. რაც ზრდის ტურისტულ დანახარჯებსა და მომსახურების ხარისხს. მთლიანობაში, 2025 წელი ხასიათდებოდა საზღვაო ტურიზმის გაფართოებით და დუბაის პოზიციების გამყარებით საერთაშორისო საკრუიზო ბაზარზე. პორტების გაფართოება და მომსახურების სტანდარტების გაუმჯობესებამ ხელი შეუწყო სეზონურობის ეფექტის შემცირებასა და ახალ, უფრო მომგებიან ტურისტული სექტორების ჩამოყალიბებას.

ინვესტიციები ტრანსპორტსა და ლოგისტიკაში ქმნის ე.წ. „მულტიპლიკაციურ ეფექტს“ მთელ ეკონომიკაში: 2025 წელს არაბთა გაერთიანებული საამიროების ტურიზმისა და მასთან დაკავშირებული სატრანსპორტო სექტორი ქვეყნის ეკონომიკაში მნიშვნელოვან წილს შეადგენს. ოფიციალური მონაცემებით, ამ სექტორმა მშპ – ში 12% წილი შეიტანა და უზრუნველყო 570 000-ზე მეტი სამუშაო ადგილი. ტურიზმის ზრდის შედეგად ქვეყნის სასტუმრო ფონდი გაფართოვდა და 2025 წლის ბოლოს 154 000 ნომერს მიაღწია. საშუალო დატვირთვის კოეფიციენტი 80,7% იყო, რაც ქვეყანაში მუდმივ შემოსავალს ქმნის გადასახადების სახით. დუბაიში განხორციელდა 5 მილიარდი დოლარის ინვესტიცია მეტროს „ლურჯი ხაზი“ (Blue Line) პროექტში, რამაც უზრუნველყო ახალი ლოგისტიკური და ტურისტული ზონების სრული ინტეგრაცია. პროექტის შედეგად შემცირდა საცობები და გაიზარდა ქალაქის მიმზიდველობა, როგორც ჭკვიანი ტურისტული დანიშნულების ადგილი (Smart Destination). ეს მონაცემები ნათლად აჩვენებს, რომ ტურიზმი, სასტუმრო სექტორი და შიდა ტრანსპორტი ერთიანად ქმნიან ეკონომიკის მნიშვნელოვან საყრდენს, ზრდის დასაქმების მაჩვენებელს და უზრუნველყოფენ სტაბილურ შემოსავალს სახელმწიფო ბიუჯეტისთვის. 2025 წლის სტატისტიკა აჩვენებს, რომ ეფექტიანი ლოგისტიკა პირდაპირ კონვერტირდება ტურისტულ ნაკადებში, ახალ სამუშაო ადგილებსა და გლობალურ კონკურენტუნარიანობაში.

ტურიზმისა და ლოგისტიკის სფეროში დუბაის მოდელის ეფექტიანობის შესაფასებლად აუცილებელია მისი შედარება გლობალურ კონკურენტებთან, პირველ რიგში, სინგაპურთან, რომელიც ისტორიულად ანალოგიურ „ჰაბის სტრატეგიას“ ეყრდნობა. 2025 წლის მონაცემებით, დუბაიმ შეძლო არა მხოლოდ ამ სტანდარტების გაზიარება, არამედ საკუთარი, უნიკალური საუკეთესო პრაქტიკის ჩამოყალიბება. მიუხედავად იმისა, რომ სინგაპურის და ჩანგის აეროპორები წლების განმავლობაში ითვლებოდა მომსახურების ხარისხის ეტალონად, დუბაის მოდელმა 2025 წელს რამდენიმე პარამეტრით აჩვენა უპირატესობა: სინგაპური ფოკუსირებულია ტექნოლოგიურ ეფექტიანობაზე, თუმცა დუბაიმ აქცენტი გააკეთა ფიზიკურ მასშტაბზე. მაშინ, როცა სინგაპური 17 მილიონამდე ვიზიტორს მასპინძლობს, დუბაიმ 19.59 მილიონიანს უმასპინძლა, მისი სატრანსპორტო ინფრასტრუქტურა გაცილებით დიდ ტურისტულ ზეწოლას უძლებს. სინგაპური ეტაპობრივად აფართოებს არსებულ ჰაბებს, დუბაიმ კი რადიკალური ნაბიჯი გადადგა ათობით მილიარდიანი პროექტე-

ბით. ეს არის საუკეთესო პრაქტიკა – ინფრასტრუქტურის მშენებლობა არა არსებული მოთხოვნის დასაკმაყოფილებლად, არამედ მომავალი, კიდევ უფრო დიდი ნაკადების პროაქტიული გენერირებისთვის. დუბაის უნიკალურობა მდგომარეობს იმაში, რომ საზღვაო პორტი, თავისუფალი ეკონომიკური ზონა და საჰაერო ჰაბი ერთიან გეოგრაფიულ და ადმინისტრაციულ სივრცეშია მოქცეული. ეს სისტემა მინიმუმამდე ამცირებს ტურისტული ინდუსტრიისთვის საჭირო რესურსების იმპორტის დროსა და ხარჯს, რაც პირდაპირ აისახება სერვისების ხელმისაწვდომობაზე.

2026 წლის დასაწყისში ახლო აღმოსავლეთში გამწვავებულმა დაძაბულობამ უსაფრთხოების აღქმა მნიშვნელოვნად შეამცირა. რამაც გამოიწვია ვიზიტორთა ინტერესის კლება და ტურისტული მოთხოვნის შემცირება. საერთაშორისო ანალიტიკოსების შეფასებით, 2026 წელს სპარსეთის ყურის რეგიონში ვიზიტორთა რაოდენობა შესაძლოა 11%-დან 27%-მდე შემცირდეს, რაც მნიშვნელოვნად აისახება ტურისტული შემოსავლების რაოდენობაზე. ომიდან რამდენიმე კვირაში დუბაიში 80 000-ზე მეტი სასტუმრო ჯავშანი გაუქმდა, რადგან მოგზაურები თავიანთი ვიზიტების გადადებას ან გაუქმებას აუმჯობინებდნენ. ასეთმა გაუქმებებმა და ფრენების შეზღუდვამ პირდაპირ იმოქმედა სასტუმროების დატვირთვაზე, ტურისტულ მომსახურებასა და ღონისძიებების დაგეგმვაზე. უსაფრთხოების ზომების გაძლიერებით და ფრენების ეტაპობრივი აღდგენით, ქალაქმა შეძლო ნაწილობრივ ტურისტული აქტივობის შენარჩუნება. ვფიქრობთ რომ რეგიონული კონფლიქტი არ გამოიწვევს დუბაის ტურიზმის კრახს. შესაძლოა დროებით შეიქმნას ვიზიტორთა რაოდენობის შემცირება, განსაკუთრებით მეზობელი ქვეყნებიდან. მიუხედავად ამისა, დუბაის მყარ ბრენდს, ძლიერ საერთაშორისო კავშირს და მრავალფეროვან ტურისტულ პროდუქტებს შეუძლია ბაზრის სტაბილურობის შენარჩუნება. უსაფრთხოება მნიშვნელოვან გავლენას ახდენს ტურისტულ ჰაბებზე. მიუხედავად განვითარებული ინფრასტრუქტურისა, ქალაქის ან რეგიონული უსაფრთხოების მდგომარეობა პირდაპირ აისახება ვიზიტორთა რაოდენობაზე, ტურისტული ინტერესის დინამიკაზე და შემოსავლების შენარჩუნებაზე.

დუბაის გამოცდილება ნათლად აჩვენებს, რომ განვითარებული სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურა მნიშვნელოვან როლს თამაშობს ტურისტული დანიშნულების ადგილის შექმნაში. უსაფრთხოება, როგორც დამატებითი ფაქტორი, ამ ინფრასტრუქტურის ეფექტიანობასა და ტურისტული გამოცდილების ხარისხს კიდევ უფრო ამაღლებს.

დასკვნები და რეკომენდაციები

დუბაის ტრანსფორმაციის გამოცდილებაზე დაყრდნობით, ბათუმისთვის, როგორც საქართველოს მთავარი საზღვაო და ტურისტული ჰაბისთვის, მდგრადი განვითარების რეკომენდაციები ფოკუსირებული უნდა იყოს ინტეგრირებულ მობილობაზე, ციფრულ მენეჯმენტსა და სეზონურობის მართვაზე. 2025 წლის მონაცემებით, ბათუმის აეროპორტის მგზავრთა ნაკადი რეკორდულ 1.2 მილიონს აღწევს, რაც მოითხოვს ინფრასტრუქტურის ახალ საფეხურზე გადაყვანას.

დუბაის მსგავსად, ბათუმმა უნდა შექმნას ერთიანი სატრანსპორტო ხერხემალი, რომელიც დააკავშირებს საჰაერო, საზღვაო და სახმელეთო კვანძებს:

- **მულტიმოდალური ტერმინალები:** აეროპორტის, რკინიგზის სადგურისა და ავტოსადგურის ერთიანი ლოგისტიკური ჯაჭვით დაკავშირება (მაგ. სპეციალური ექსპრეს-ხაზები).
- **ჭკვიანი პარკირების პოლიტიკა:** ძველ ქალაქში პარკირების ახალი სისტემის დანერგვა და ქალაქის შესასვლელებთან Park-and-Ride (გააჩერე და იმგზავრე) ზონების მოწყობა ტურისტული ავტობუსებისა და კერძო მანქანებისთვის.
- **მდგრადი მობილობა:** ველო-ქსელის გაფართოება მინიმუმ 6 კმ-ით და დაბალი ემისიის მქონე ელექტრო-ავტობუსების წილის გაზრდა საზოგადოებრივ ტრანსპორტში.

მგზავრობის შემაფერხებელი ბარიერების (Travel Friction) შესამცირებლად საჭიროა ტექნოლოგიური ინტეგრაცია:

- **ერთიანი სატრანსპორტო ბარათი:** დუბაის „Nol Card“-ის ანალოგი, რომელიც იმუშავებს ავტობუსზე, საბაგიროზე, ველოსიპედის და სხვ. გაქირავებაზე.
- **მონაცემებზე დაფუძნებული გადაწყვეტილებები:** ტურისტული ნაკადების მართვისთვის რეალურ დროში მონიტორინგის სისტემის დანერგვა (Big Data), რაც ხელს შეუწყობს პიკურ საათებში საცობების თავიდან აცილებას.

ბათუმის პორტის პოტენციალი სრულად უნდა იქნას ათვისებული საკრუიზო მიმართულებით:

- **საკრუიზო ტერმინალის მოდერნიზაცია:** ნავმისადგომების გაფართოება დიდი ზომის ლაინერების მისაღებად და პორტიდან ქალაქის ცენტრამდე "მწვანე დერეფნების" მოწყობა.
- **წყლის ტაქსები:** სანაპირო ზოლის გასწვრივ (აეროპორტი – პორტი – ახალი ბულვარი) რეგულარული საზღვაო ტრანსპორტის გაშვება, რაც განტვირთავს სახმელეთო მაგისტრალებს.

სასტუმრო სექტორში უნდა გადაიზარდოს უფრო ფართო ეკო-სტანდარტების დანერგვა, როგორიცაა ენერგოეფექტურობა, წყლის რესურსების დაზოგვა და ნარჩენების მართვის თანამედროვე სისტემები. დუბაის მსგავსი ეკო-სერტიფიცირების პრაქტიკა, მიზანშეწონილია საქართველოში „მწვანე სერთიფიკატების“ სისტემის გაძლიერება. სეზონურობის შემცირების მიზნით აუცილებელია მრავალფეროვანი ტურისტული პროდუქტების განვითარება (ველნესი, კულტურული, საქმიანი ტურიზმი), რაც უზრუნველყოფს ვიზიტორთა ნაკადის უფრო თანაბარ გადანაწილებას წლის განმავლობაში.

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საზღვაო ტრანსპორტის რისკების კლასიფიკაცია

Classification of Maritime Transport Risks

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აბსტრაქტი

გემთმფლობელები თავიანთი საქმიანობის დროს სხვადასხვა სახის რისკებს აწყდებიან, რაც გავლენას ახდენს ენტროპიისა და რისკის დონეზე. ეს რისკები განსხვავდება გარე და შიდა ფაქტორების კომბინაციის, ასევე მათი ადგილმდებარეობისა და დროის მიხედვით. ამიტომ, ამ რისკების ანალიზი სხვადასხვა მეთოდს მოითხოვს. როგორც წესი, ყველა ტიპის რისკი ურთიერთდაკავშირებულია და გავლენას ახდენს გემთმფლობელის ოპერაციებზე. ეს ფაქტორები ართულებს რისკების მართვასთან დაკავშირებული გადაწყვეტილების მიღებას და მოითხოვს კონკრეტული რისკების დეტალურ ანალიზს, მათ შორის მათი გამომწვევი მიზეზებისა და ხელშემწყობი ფაქტორების ჩათვლით.

საკვანძო სიტყვები: საზღვაო სატრანსპორტო რისკები, რისკის ფაქტორები, რისკების კლასიფიკაცია.

ABSTRACT

Shipowners involved in their activities face a range of risks that affect the level of entropy and risk and differ in the combination of external and internal factors, as well as in the place and time of action. Accordingly, their analysis should be carried out using different methods. In general, all types of risks are interconnected and affect the shipowner's activities. These circumstances complicate decision-making on risk optimization and require an in-depth analysis of the composition of specific risks, as well as the causes and factors of their origin.

KEEWORDS: Maritime transport risks, risk factors, risk classification.

შესავალი

რისკების კლასიფიკაციის მიმართ მრავალი მიდგომა არსებობს, რომლებიც, როგორც წესი, განისაზღვრება კლასიფიკაციის მიზნებიდან და ამოცანებიდან გამომდინარე. საზღვაო ოპერაციებში რისკების კლასიფიკაციის ყველაზე მნიშვნელოვანი ელემენტებია: რისკის დადგომის დრო; კლების ძირითადი ფაქტორები; ბუღალტრული აღრიცხვის ბუნება; შედეგების ბუნება და ა.შ. განვიხილოთ ისინი დეტალურად.

დისკუსია

დადგომის მომენტის მიხედვით რისკები იყოფა რეტროსპექტულად, მიმდინარედ და სამომავალოდ. რეტროსპექტული რისკების ანალიზი, მათი ბუნება და შემცირების მეთოდები შესაძლებელს ხდის უფრო ზუსტად განვსაზღვროთ მიმდინარე და მომავალი რისკები.

წარმოშობის ფაქტორების მიხედვით რისკები იყოფა პოლიტიკურად და ეკონომიკურად (კომერციულად). პოლიტიკური რისკები გამოწვეულია პოლიტიკური სიტუაციის ცვლილებით, რომელიც გავლენას ახდენს საზღვაო ტრანსპორტზე (პორტების დახურვა, სხვა ქვეყნებში საქონლის ტრანსპორტირების აკრძალვა, ქვეყანაში სამხედრო ოპერაციები და ა.შ.). ეკონომიკური რისკები არის რისკები, რომლებიც გამოწვეულია კომპანიის ან ქვეყნის ეკონომიკაში მიმდინარე ან უკვე მომხდარი უარყოფითი ცვლილებებით.

ეკონომიკური რისკის ყველაზე გავრცელებული სახეობა, რომელშიც კონცენტრირებულია კერძო რისკები, არის სატვირთო ბაზრის ცვლილება, დაუბალანსებელი ლიკვიდურობა (გადახდის ვალდებულებების დროულად შესრულების შეუძლებლობა), მენეჯმენტის დონის ცვლილება და ა.შ. ამ ტიპის რისკები ურთიერთდაკავშირებულია და პრაქტიკაში ხშირად ძნელია მათი გამიჯნვა.

ბუღალტრული აღრიცხვის ხასიათის მიხედვით რისკები იყოფა გარე და შიდა სახეებად. გარე რისკები მოიცავს რისკებს, რომლებიც პირდაპირ არ არის დაკავშირებული კომპანიის საქმიანობასთან ან მის საკონტაქტო აუდიტორიასთან. გარე რისკების დონეზე გავლენას ახდენს ფაქტორების ძალიან დიდი რაოდენობა – პოლიტიკური, ეკონომიკური, დემოგრაფიული, სოციალური, გეოგრაფიული და ა. შ.

შიდა რისკები მოიცავს რისკებს, რომლებიც გამოწვეულია თავად კომპანიის საქმიანობით და მისი საკონტაქტო აუდიტორიით. მათ დონეზე გავლენას ახდენს კომპანიის მენეჯმენტის ბიზნეს-აქტივობა, ოპტიმალური მარკეტინგული სტრატეგიის არჩევანი, პოლიტიკა, ტაქტიკა და სხვა ფაქტორები, მაგალითად: წარმოების პოტენციალი, ტექნიკური აღჭურვილობა, სპეციალიზაციის დონე, შრომის პროდუქტიულობის დონე, უსაფრთხოების ზომები.

შედეგების ბუნების მიხედვით, რისკები იყოფა წმინდად და სპეკულაციურად.

წმინდა რისკები (უბრალო ან სტატიკური) ხასიათდება იმით, რომ ისინი თითქმის ყოველთვის აზარალებენ საზღვაო ტრანსპორტის სფეროში მიმდინარე საქმიანობას. წმინდა რისკები შეიძლება გამოწვეული იყოს ბუნებრივი კატასტროფებით, ომებით, უბედური შემთხვევებით, კრიმინალური ქმედებებით, მეკობრეობით, ორგანიზაციული წარუმატებლობით და სხვა.

სპეკულაციური რისკები (მათ ზოგჯერ დინამიურს ან კომერციულს უწოდებენ) ხასიათდება იმით, რომ მათ შეუძლიათ გემთმფლობელისთვის ზარალის და დამატებითი მოგების მოტანა მოსალოდნელ შედეგთან მიმართებაში. სპეკულაციური რისკების მიზეზები შეიძლება იყოს ბაზრის პირობების, გაცვლითი კურსის, საგადასახადო კანონმდებლობის ცვლილება და ა. შ.

ვინაიდან მენეჯერის მთავარი ამოცანაა რისკებისათვის თავის არიდება იმ ხაზების გადაკვეთის გარეშე, რომლის მიღმაც შესაძლებელია კომპანიის გაკოტრება, აუცილებელია გამოვყოთ მისაღები, კრიტიკული და კატასტროფული რისკები. მისაღები, ანუ ასატანი რისკი არის „მოგების სრული დაკარგვის საფრთხე კონკრეტული გეგმის განხორციელებიდან ან მთლიანად კომპანიის საწარმოო საქმიანობიდან. ასეთ შემთხვევაში შესაძლებელია ზარალი, მაგრამ მისი მოცულობა ნაკლებია წარმოების მოსალოდნელ მოგებაზე; ამრიგად, ამ ტიპის საწარმოო საქმიანობა ან კონკრეტული ტრანზაქცია, რისკის ალბათობის მიუხედავად, ინარჩუნებს თავის ეკონომიკურ მიზანშეწონილობას.

რისკის შემდეგი ხარისხი, უფრო საშიში, ვიდრე მისაღები, არის კრიტიკული რისკი, რომელიც დაკავშირებულია ზარალის რისკთან იმ ხარჯების ოდენობით, რომლებიც გაწეულია ამ ტიპის ბიზნეს-საქმიანობის ან ცალკეული ტრანზაქციის განხორციელებისთვის. ამავდროულად, პირველი ხარისხის კრიტიკული რისკი დაკავშირებულია მენეჯერის მიერ გაწეული მატერიალური ხარჯების კომპენსაციასა და ნულოვანი მოგების მიღების საფრთხესთან. მეორე ხარისხის კრიტიკული რისკი ასოცირდება ამ სამეწარმეო საქმიანობის განხორციელების შედეგად დანახარჯების სრული ოდენობით დაკარვის შესაძლებლობასთან, ანუ სავარაუდოა შემოსავლის დაკარგვა და მენეჯერი იძულებული გახდება, აანაზღაუროს დანაკარგი საკუთარი ხარჯებით.

კატასტროფულია რისკი, რომლის დროსაც ზარალის სიდიდე გემთმფლობელის მთლიანი ქონების ღირებულების ტოლია ან მეტი. კატასტროფული რისკი, როგორც წესი, იწვევს გემთმფლობელის კომპანიის გაკოტრებას, რადგან ამ შემთხვევაში მან შეიძლება გარკვეული ტიპის საქმიანობაში ან კონკრეტულ ტრანზაქციაში დაკარგოს არა მხოლოდ დაბანდებული თანხები, არამედ მთელი ქონება. ეს დამახასიათებელია იმ სიტუაციისთვის, როდესაც გადამზიდავმა კომპანიამ მიიღო საგარეო სესხები მოსალოდნელი მოგების გარანტიით; კატასტროფული რისკის შემთხვევაში გემთმფლობელმა სესხები პირადი სახსრებიდან უნდა დაფაროს.

დაზღვევის შესაძლებლობის შესაბამისად, საზღვაო ოპერაციების ყველა რისკი შეიძლება დაიყოს ორ დიდ ჯგუფად: დაზღვეული და დაუზღვეველი. გემთმფლობელს შეუძლია ნაწილობრივ გადასცეს რისკი სხვა ეკონომიკურ სუბიექტს, კერძოდ, გარკვეული ხარჯის გაღების საფასურად დაიცვას საკუთარი თავი სადაზღვევო პრემიით. ამდენად, ზოგიერთი სახის რისკი, როგორიცაა: გემის დაკარგვის რისკი, გემების დაზიანების რისკი, უბედური შემთხვევები და ა.შ., გემთმფლობელს შეუძლია დააზღვიოს.

სადაზღვევო რისკი არის სავარაუდო მოვლენა ან მოვლენათა ერთობლიობა, რომლის მიმართაც ხორციელდება დაზღვევა. საფრთხის წყაროდან გამომდინარე, სადაზღვევო რისკები იყოფა ორ ჯგუფად:

- რისკები, რომლებიც დაკავშირებულია ბუნების ძალების გამოვლინებასთან (ამინდის პირობები, ტაიფუნები და ა.შ.);
- რისკები, რომლებიც დაკავშირებულია პირის მიზანმიმართულ ქმედებებთან.

რისკები, რომლისგან დაზღვევაც ღირს, არის:

- სავარაუდო დანაკარგები ტაიფუნების და სხვა სტიქიური უბედურებების შედეგად;
- სავარაუდო დანაკარგები საზღვაო შეჯახების, ავარიების შედეგად;
- სავარაუდო დანაკარგები საზღვაო ტრანსპორტის მეშვეობით გადაზიდული საქონლის დაზიანების ან განადგურების შედეგად;
- სავარაუდო ზარალი მეზღვაურების, კომპანიის თანამშრომლების შეცდომების შედეგად;
- სავარაუდო ზარალი კომპანიის თანამშრომლების მიერ კონკურენტებისთვის კომერციული ინფორმაციის გადაცემის შედეგად;
- სავარაუდო ზარალი კომპანიის სამეწარმეო საქმიანობის შეჩერების შედეგად;
- სავარაუდო დანაკარგები კომპანიის ხელმძღვანელის ან წამყვანი თანამშრომლის შესაძლო გარდაცვალების ან ავადმყოფობის შედეგად;
- სავარაუდო ზარალი კომპანიის თანამშრომელთან შესაძლო ავადმყოფობის, სიკვდილის ან უბედური შემთხვევის შედეგად.

არის რისკების კიდევ ერთი ჯგუფი, რემელზედაც სადაზღვევო კომპანიები არ იღებენ ვალდებულებას, მაგრამ ამავე დროს სწორედ დაუზღვეველი რისკის დაშვება წარმოადგენს გემთმფლობელის მოგების პოტენციურ წყაროს. მაგრამ თუ სადაზღვევო რისკის შედეგად მიღებული ზარალი იფარება სადაზღვევო კომპანიისავის გადახდილი თანხებით, დაუზღვეველი რისკის შედეგად მიღებული ზარალის ანაზღაურება გადამზიდავი კომპანიის საკუთარი სახსრებიდან ხდება. რისკის დაფარვის ძირითადი შიდა წყაროებია: კომპანიის საკუთარი კაპიტალი, ასევე სპეციალურად შექმნილი სარეზერვო ფონდები.

შიდას გარდა, არსებობს სავარაუდო ზარალის დაფარვის გარე წყაროებიც, მაგალითად, ფილიალზე პასუხისმგებელია თავად კომპანია.

უნდა განვასხვავოთ რისკის კიდევ ორი დიდი ჯგუფი: სტატისტიკური (მარტივი) და დინამიური (სპეკულაციური). სტატისტიკური რისკების თავისებურება მდგომარეობს იმაში, რომ ისინი თითქმის ყოველთვის ზარალის მატარებლები არიან კომპანიის საწარმოო საქმიანობისთვის.

ზარალის გამომწვევი მიზეზების მიხედვით, სტატისტიკური რისკები შეიძლება დაიყოს შემდეგ ჯგუფებად:

- სავარაუდო ზარალი კომპანიის აქტივებზე სტიქიური უბედურებების (ტაიფუნები, უამინდობა, მიწისძვრები და ა.შ.) უარყოფითი გავლენის შედეგად;
- დანაშაულებრივი ქმედებების შედეგად სავარაუდო დანაკარგები;
- სავარაუდო ზარალი კომპანიისთვის არახელსაყრელი კანონმდებლობის მი-

ღებით (ზარალი დაკავშირებულია ქონების პირდაპირ ჩამორთმევასთან ან არასრულყოფილი კანონმდებლობის გამო დამნაშავისგან კომპენსაციის მიღების შეუძლებლობასთან);

- სავარაუდო ზარალი მესამე პირების საკუთრებისთვის არსებული საფრთხის შედეგად, რაც იწვევს მთავარი დამქირავებლის ან მიმწოდებლის საქმიანობის იძულებით შეწყვეტას;
- ზარალი კომპანიის ძირითადი თანამშრომლების ან გადამზიდავი კომპანიის მთავარი მფლობელის გარდაცვალების ან ქმედუუნარობის გამო (რაც დაკავშირებულია კვალიფიციური პერსონალით კომპანიის დაკომპლექტების სირთულესთან, საკუთრების გადაცემის პრობლემებთან და სხვა).

სტატისტიკური რისკისგან განსხვავებით, დინამიური რისკი გადამზიდავი კომპანიისთვის ზარალის ან მოგების მატარებელია და სწორედ ამიტომ შეიძლება ეწოდოს „სპეკულაციური“. გარდა ამისა, დინამიურმა რისკებმა, რომლებიც იწვევს ზარალს ცალკეული ფირმისთვის, შეიძლება ერთდროულად მოიტანოს სარგებელი მთლიანად საზოგადოებისთვის. ამიტომ დინამიური რისკების მართვა რთულია.

გარდა ამისა, შემდეგ პარაგრაფებში გავაანალიზეთ პოლიტიკური, წარმოებისა და ტექნიკური რისკების არსიც.

პოლიტიკური რისკი არის მთავრობის მიერ გატარებული პოლიტიკის შედეგად ზარალის ან შემცირებული მოგების მიღების შესაძლებლობა. ამრიგად, პოლიტიკური რისკი დაკავშირებულია ხელისუფლების კურსში შესაძლო ცვლილებებთან, კომპანიისთვის საქმიანობის პრიორიტეტულ სფეროებში. ამ ტიპის რისკის აღრიცხვა განსაკუთრებით მნიშვნელოვანია არასტაბილური კანონმდებლობის, ბიზნეს-კულტურისა და ტრადიციების ნაკლებობის მქონე ქვეყნებში. პოლიტიკური რისკის საფრთხე თითქმის თანდაყოლილია საზღვაო გადამზიდავი კომპანიის საქმიანობაში, მისი თავიდან აცილება შეუძლებელია. შესაძლოა მხოლოდ მისი სწორად შეფასება და გათვალისწინება.

ამერიკული კორპორაციების ლექსიკონში ტერმინი „პოლიტიკური რისკი“ გაჩნდა 1959 წელს, კუნძულ კუბაზე ხელისუფლებაში ფიდელ კასტროს მოსვლის შემდეგ. ერთერთი პირველი ნაშრომი ამ საკითხზე არის ფ. რუთის წიგნი „აშშ ბიზნესი საზღვარგარეთ და პოლიტიკური რისკი“, სადაც გაანალიზებულია ის პოლიტიკური რისკი, რომელიც ამერიკული კომპანიებს ემუქრება უცხო ქვეყნებში.

პოლიტიკური რისკები შეიძლება დაიყოს ოთხ ჯგუფად:

- ნაციონალიზაციისა და ექსპროპრიაციის რისკი ადეკვატური კომპენსაციის გარეშე;
- ადგილობრივი ვალუტის კონვერტაციისა და გადაცემის შესაძლო შეზღუდვასთან დაკავშირებული რისკი;
- ხელშეკრულების გაწყვეტის რისკი იმ ქვეყნის ხელისუფლების ქმედებების გამო, რომელშიც მდებარეობს კონტრაგენტი კომპანია;
- საომარი მოქმედებების და სამოქალაქო არეულობის რისკი.

ნაციონალიზაციის რისკი პრაქტიკაში გემთმფლობელების მიერ ძალიან ფართოდ არის განმარტებული. კომპანიის ქონების იძულებით შეძენამდე ექსპროპრიაცია ან უბრალოდ ინვესტორების აქტივების მართვაზე წვდომის შეზღუდვა. ნა-

ციონალიზაციის რისკის დადგენისას, სირთულე იმაში მდგომარეობს, რომ არცერთ ქვეყანაში ხელისუფლება არასოდეს აქვეყნებს რეკლამას ექსპროპრიაციის ან ნაციონალიზაციის შესაძლებლობის შესახებ. შედეგად, იურიდიულად არც ერთი დოკუმენტი ზუსტად არ განსაზღვრავს, თუ რით განსხვავდება, მაგალითად, ნაციონალიზაცია კონფისკაციისგან.

სატრანსფერო რისკი დაკავშირებულია ადგილობრივი ვალუტის უცხოურ ვალუტაში გადარიცხვებთან. ამის მაგალითია სიტუაცია, როდესაც კომპანია მუშაობს მომგებიანად, იღებს მოგებას ეროვნულ ვალუტაში, მაგრამ ვერ ახერხებს მის კონვერტაციას ინვესტორის ვალუტაში სესხის დაფარვის მიზნით. ამას მრავალი მიზეზი შეიძლება ქონდეს, მაგალითად, კონვერტაციისთვის სპეციალურად ორგანიზებული გრძელი რიგი.

ხელშეკრულების შეწყვეტის რისკი ითვალისწინებს სიტუაციებს, როდესაც ვერც ხელშეკრულებით გათვალისწინებული ჯარიმები და ვერც არბიტრაჟი ვერ ჭრის: ხელშეკრულება წყდება პარტნიორის კონტროლის აფეროს მიღმა წარმოქმნილი მიზეზების, მაგალითად, ეროვნული კანონმდებლობის ცვლილებების გამო.

პოლიტიკური რისკების ჯგუფიდან ბოლო არის სამხედრო მოქმედებისა და სამოქალაქო არეულობის რისკი, რის შედეგადაც გადამზიდავ კომპანიებს შეუძლიათ მძიმე ზარალი განიცადონ და გაკოტრდნენ კიდეც.

პოლიტიკური რისკი ასევე შეიძლება პირობითად დაიყოს სადაზღვევო, რეგიონულ და საერთაშორისო რისკებად. დაზღვეული პოლიტიკური რისკი უნდა გავიგოთ, როგორც ქვეყნის შიდა პოლიტიკური ვითარების არასტაბილურობა, რომელიც გავლენას ახდენს გადამზიდავი კომპანიების მუშაობაზე, ამასთან დაკავშირებით იზრდება კომპანიების ფინანსური მდგომარეობის გაუარესების რისკი და მათი გაკოტრების შესაძლებლობა. ეს განსაკუთრებით ეხება მცირე გადამზიდავ კომპანიებს, რადგან ქვეყანაში პოლიტიკური ვითარების დაძაბულობა იწვევს ეკონომიკური კავშირების მოშლას, რაც ყველაზე მეტად აისახება მცირე კომპანიების საქმიანობაზე, აყენებს მათ გაკოტრების პირას საწვავის, ტექნიკური მასალების, სათადარიგო ნაწილებისა და აღჭურვილობის ნაკლებობის გამო.

რეგიონული პოლიტიკური რისკის ქვეშ მოიაზრება კონკრეტულ რეგიონში პოლიტიკური სიტუაციის არასტაბილურობა, რაც გავლენას ახდენს კომპანიების მუშაობაზე; კერძოდ, ეს შეიძლება იყოს მოცემულ რეგიონში სამხედრო ოპერაციების შედეგად დანაკარგების მიღების ალბათობა, ასევე რეგიონული მთავრობების მხრიდან კომპანიების საქმიანობაში ჩარევა და სხვა.

საერთაშორისო პოლიტიკური რისკის აღრიცხვა მნიშვნელოვანია გადამზიდავი კომპანიების საქმიანობისთვის, რომლებიც დაკავებულნი არიან საერთაშორისო ტრანსპორტირებით.

ვინაიდან გემთმფლობელს არ შეუძლია პირდაპირ გავლენა მოახდინოს პოლიტიკურ რისკებზე, რადგან მათი წარმოშობა არ არის დამოკიდებული მისი საქმიანობის შედეგებზე, რისკის ეს სახეობა უნდა მივაკუთვნოთ გარე რისკების ჯგუფს.

ტექნიკური რისკი. გადამზიდავი კომპანიის ეფექტური საქმიანობა, როგორც წესი, დაკავშირებულია ახალი აღჭურვილობისა და ტექნოლოგიების განვითარებასთან, რეზერვების ძიებასთან და ტრანსპორტირების ინტენსივობის მატებასთან. თუმცა,

ახალი აღჭურვილობისა და ტექნოლოგიების დანერგვა იწვევს ადამიანის მიზეზით გამოწვეული ავარიებისა და კატასტროფების საშიშროებას.

ტექნიკური რისკი განისაზღვრება წარმოების ორგანიზების ხარისხით, პრევენციული ღონისძიებებით (აღჭურვილობის რეგულარული პროფილაქტიკური მოვლა, უსაფრთხოების ზომები), გადამზიდი კომპანიების მიერ აღჭურვილობის დამოუკიდებლად შეკეთების შესაძლებლობის გათვალისწინებით.

ტექნიკური რისკები მოიცავს:

- სამეცნიერო კვლევის უარყოფითი შედეგების გამო დანაკარგების ალბათობას;
- საპროექტო და ტექნოლოგიური განვითარების პროცესში დაგეგმილი ტექნიკური პარამეტრების მიუღწევლობის შედეგად დანაკარგების ალბათობას;
- წარმოების დაბალი ტექნოლოგიური შესაძლებლობების შედეგად დანაკარგების მიღების ალბათობას, რაც არ იძლევა ახალი განვითარების შედეგების დაუფლების საშუალებას;
- ახალი ტექნოლოგიებისა და პროდუქტების გამოყენებისას პრობლემების გვერდითი ან დაგვიანებული გამოვლინების წარმოქმნის შედეგად დანაკარგების ალბათობა;
- დანაკარგების ალბათობას ტექნიკის გაფუჭებისა და ავარიის შედეგად.

უნდა აღინიშნოს, რომ ტექნიკური რისკი განეკუთვნება შიდა რისკების ჯგუფს, ვინაიდან გემთმფლობელს შეუძლია უშუალოდ გავლენა მოახდინოს ამ რისკებზე და მათი წარმოშობა, როგორც წესი, დამოკიდებულია თავად გემთმფლობელის საქმიანობაზე.

წარმოების რისკი ასოცირდება სატრანსპორტო სერვისების წარმოებასთან, რომლის დროსაც გემთმფლობელები აწყდებიან ნედლეულის არაადეკვატური გამოყენების, ტრანსპორტირების ღირებულების მატებას, სამუშაო დროის დაკარგვის ზრდას. წარმოების რისკის ძირითადი მიზეზებია:

- გადაზიდული ტვირთის დაგეგმილი მოცულობის შემცირება შრომის პროდუქტიულობის შემცირების, გემების გაჩერების დროის ხანგრძლიობის გაზრდის გამო, რომლებიც დრეიფზეა გაჩერებული მგზავრობისა და მუშაობის გაუმართავი პირობების გამო;
- გადაზიდვის ტარიფების შემცირება სატრანსპორტო მომსახურების არასაკმარისი ხარისხის, საბაზრო პირობების არახელსაყრელი ცვლილებისა და მოთხოვნის შემცირების გამო;
- საწვავის, ტექნიკური მასალების, სათადარიგო ნაწილების, საპორტო გადასახადების და სხვა შემთხვევითი მატერიალური ხარჯების გადაჭარბების შედეგად მოხმარების ზრდა;
- სახელფასო ფონდის ზრდა სამიზნე რაოდენობის გადამეტების ან ცალკეული თანამშრომლებისთვის დაგეგმილზე მაღალი ხელფასის გადახდის გამო;
- გადასახადებისა და სხვა გამოქვითვების ზრდა, ძველი მოდელების აღჭურვილობისა და მექანიზმების ფიზიკური და მორალური გაუარესება.

დასკვნა

დასკვნის სახით, შეგვიძლია ვთქვათ, რომ საზღვაო სატრანსპორტო კომპლექსების (სსკ) სტრუქტურის, შემადგენლობისა და მუშაობის რეჟიმების ყველა ანალიზი აჩვენებს, რომ მათი ფუნქციონირების ხარისხის გაუმჯობესება და სრული ჯამური დანახარჯების ინდიკატორის შემცირების უზრუნველყოფა შესაძლებელია:

- საზღვაო სატრანსპორტო კომპლექსების (სსკ) სტრუქტურის წინასწარი დიზაინის ხარისხის, მოცულობის, გეომეტრიული და სივრცითი მახასიათებლების, ძირითადი ელემენტების განლაგების, სატრანსპორტო საშუალებების შემადგენლობისა და მახასიათებლების, საპორტო კომპლექსის (სკ) ძირითადი ტექნოლოგიური და დამხმარე აღჭურვილობის (ჩამოტვირთვა-გადმოტვირთვის ზონები, საცავი, სატრანსპორტო ზონები და მაგისტრალები, შესაკეთებელი სამუშაოების ზონები და ა.შ.) გაუმჯობესებით;
- კონტეინერთა სისტემების რაციონალური გამოყენება ტვირთის შენახვისა და ტრანსპორტირებისთვის;
- საზღვაო სატრანსპორტო კომპლექსების (სსკ) გაუმჯობესებული დაგეგმვა და მართვა.

საზღვაო სატრანსპორტო კომპლექსების (სსკ) (მათ შორის საპორტო კომპლექსის) სტრუქტურული და მოცულობითი მახასიათებლების ოპტიმიზაცია, ასევე კომპლექსების კონტროლისა და დაგეგმვის სისტემები უნდა განხორციელდეს კოორდინირებული გზით. ეს უზრუნველყოფს სხვადასხვა სატრანსპორტო ერთეულების ეფექტურობის ინდიკატორების სინქრონიზაციას.

ფუნქციური სექციები და ზონები, აღმასრულებელი მოდულები და აღჭურვილობა და, გარდა ამისა, ასევე მთლიანობაში საზღვაო სატრანსპორტო კომპლექსების (სსკ) ფუნქციონირების ეკონომიკური მახასიათებლები.

თუ სატრანსპორტო საშუალებების ან სპეციალიზებული პორტის აღჭურვილობის ეფექტურობის ზრდა განისაზღვრება ძირითადად სპეციალური ტექნოლოგიის დონით, მაშინ სტრუქტურული და მოცულობითი მახასიათებლების, აგრეთვე მართვისა და დაგეგმვის სისტემების გაუმჯობესებამ შეიძლება დიდი გავლენა მოახდინოს არსებულ ტექნოლოგიურ ბაზაზე, რაც განსაკუთრებით მნიშვნელოვანია არსებული საზღვაო სატრანსპორტო კომპლექსების (სსკ) მოდერნიზაციის პრობლემების გადაჭრისას.

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სახელმწიფო ინვესტიციების როლი პორტების ოპტიმიზაციასა და ეფექტიანობაში და გავლენა რეგიონულ ეკონომიკურ განვითარებაზე

The Role of Public Investment in Port Optimization and Efficiency and Its Impact on Regional Economic Development

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აბსტრაქტი

თანამედროვე გლობალური ეკონომიკის პირობებში სატრანსპორტო ინფრასტრუქტურა და განსაკუთრებით პორტები მნიშვნელოვან როლს ასრულებენ როგორც საერთაშორისო ვაჭრობის ხელშეწყობაში, ასევე ადგილობრივი, საპორტო მუნიციპალიტეტების, ეკონომიკური განვითარების სტიმულირებაში. პორტების ეფექტიანობა და ოპტიმიზაცია განსაზღვრავს ლოგისტიკური პროცესების ხარისხს, ტრანზიტული პოტენციალის რეალიზებას და ეკონომიკური აქტივობის ზრდას შესაბამის რეგიონებში. აღნიშნულ კონტექსტში განსაკუთრებული მნიშვნელობა ენიჭება სახელმწიფო ინვესტიციებს, როგორც პორტების ინფრასტრუქტურის განვითარებისა და ოპერაციული ეფექტიანობის გაუმჯობესების მთავარ ინსტრუმენტს. საჯარო ფინანსების მოცულობა სტრატეგიული ობიექტების ინვესტირებაში მნიშვნელოვანი და შესასწავლად საინტერესოა.

წინამდებარე კვლევის მიზანია სახელმწიფო ინვესტიციების როლის შეფასება პორტების ოპტიმიზაციასა და ეფექტიანობაში და მათი გავლენის განსაზღვრა რეგიონულ ეკონომიკურ განვითარებაზე. კვლევა ეყრდნობა ჰიპოთეზას, რომ პორტის ინფრასტრუქტურაში განხორციელებული საჯარო ინვესტიციები ხელს უწყობს ოპერაციული მაჩვენებლების გაუმჯობესებას, რაც თავის მხრივ დადებითად აისახება რეგიონული ეკონომიკური აქტივობის ზრდაზე.

კვლევის მეთოდოლოგიური ჩარჩო მოიცავს როგორც თვისობრივ, ასევე რაოდენობრივ ანალიზს. გამოყენებულია მეორადი სტატისტიკური მონაცემების დამუშავება, პორტების ოპერაციული მაჩვენებლების (ტვირთბრუნვა, მომსახურების სიჩქარე, ლოგისტიკური ეფექტიანობა) შედარებითი ანალიზი და მაგალითის მეთოდი. კვლევის ფარგლებში განსაკუთრებული ყურადღება ეთმობა საქართველოს საპორტო ინფრასტრუქტურას, როგორც ადგილობრივი რეგიონული ეკონომიკური განვითარების ერთ-ერთ საკვანძო ფაქტორს. ანალიზი ასევე მოიცავს სახელმწიფო საინვესტიციო პოლიტიკის შეფასებას და მის კავშირს პორტების ფუნქციონირების ეფექტიანობასთან.

კვლევის წინასწარი მიგნებები მიუთითებს, რომ სახელმწიფო ინვესტიციები მნიშვნელოვან გავლენას ახდენს პორტების ტექნოლოგიურ განახლებაზე, ინფრასტრუქტურულ შესაძლებლობებზე და ოპერაციულ ეფექტიანობაზე. აღნიშნული ცვლილებები ზრდის პორტების გამტარუნარიანობას, ამცირებს ლოგისტიკურ ხარჯებს და აუმჯობესებს მომსახურების ხარისხს. შედეგად, იზრდება რეგიონების მიმზიდველობა როგორც ადგილობრივი, ასევე უცხოური ინვესტიციებისთვის, რაც საბოლოოდ განაპირობებს ეკონომიკური აქტივობის ზრდას, დასაქმების გაფართოებას და ბიზნესგარემოს გაუმჯობესებას.

კვლევა ხაზს უსვამს სახელმწიფო ინვესტიციების სტრატეგიული დაგეგმვის მნიშვნელობას საპორტო ინფრასტრუქტურის განვითარების პროცესში და აჩვენებს, რომ ეფექტიანად განხორციელებული საინვესტიციო პოლიტიკა შეიძლება იქცეს რეგიონული ეკონომიკური განვითარების მნიშვნელოვან მამოძრავებელ ძალად. მიღებული შედეგები შეიძლება გამოყენებულ იქნეს როგორც პოლიტიკის შემმუშავებლებისთვის, ასევე ეკონომიკური დაგეგმვისა და ინფრასტრუქტურული განვითარების სფეროში ჩართული სხვა აქტორებისთვის.

საკვანძო სიტყვები: სახელმწიფო ინვესტიციები, პორტების ოპტიმიზაცია, რეგიონული ეკონომიკური განვითარება, სახელმწიფო საინვესტიციო პოლიტიკა, შედარებითი ანალიზი

ABSTRACT

In the context of the modern global economy, transport infrastructure—and ports in particular—plays a crucial role both in facilitating international trade and in stimulating the economic development of local port municipalities. The efficiency and optimization of ports determine the quality of logistics processes, the realization of transit potential, and the growth of economic activity in respective regions. In this context, public investment acquires particular importance as a primary instrument for the development of port infrastructure and the enhancement of operational efficiency. The scale of public financial resources allocated to strategic infrastructure investments is both significant and worthy of thorough examination.

The present study aims to assess the role of public investment in port optimization and efficiency, as well as to determine its impact on regional economic development. The research is based on the hypothesis that public investments in port infrastructure contribute to improvements in operational performance indicators, which in turn positively affect the growth of regional economic activity.

The methodological framework of the study combines both qualitative and quantitative approaches. It includes the analysis of secondary statistical data, comparative evaluation of port operational indicators (cargo throughput, service speed, and logistical efficiency), and a case study method. Particular attention is devoted to Georgia's port infrastructure as one of the key drivers of local and regional economic development. The analysis also encompasses an assessment of state investment policy and its relationship with the operational efficiency of ports.

Preliminary findings suggest that public investments have a significant impact on technological modernization, infrastructural capacity, and operational efficiency of ports. These improvements increase port throughput, reduce logistical costs, and enhance service quality. As a result, regional attractiveness for both domestic and foreign investment increases, ultimately leading to higher economic activity, expanded employment, and an improved business environment.

The study underscores the importance of strategic planning of public investments in the development of port infrastructure and demonstrates that effectively implemented investment policy can serve as a powerful driver of regional economic growth. The findings may be utilized by policymakers as well as by other stakeholders involved in economic planning and infrastructure development.

KEYWORDS: State Investments; Port Optimization; Regional Economic Development; State Investment Policy; Comparative Analysis.

საზღვაო ლოგისტიკა და ნავსადგურების მართვა

Maritime Logistics and Port Management

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აბსტრაქტი

საკონფერენციო თემის მიზანია განვიხილოთ საზღვაო ლოგისტიკა და ნავსადგურების მართვა. ნამუშევარში მიმოვიხილავთ: ჭკვიან პორტებს (Smart Ports), პორტების ოპტიმიზაციას და ეფექტიანობას, საზღვაო მიწოდების ჯაჭვის მართვას; ციფრულ ტრანსფორმაციას და ბლოკჩეინ ტექნოლოგიებს ლოგისტიკაში. ჩემი მსჯელობა დაფუძნებულია და ეყრდნობა სხვადასხვა კვლევებს და ნაშრომებს. წარმოდგენილი კვლევის მიზანია, შეგვექმნას წარმოდგენა თუ რა როლს თამაშობენ ზემოთ ჩამოთვლილი მექანიზმები საზღვაო და სანავსადგურო პროცესებში. ჩატარებული კვლევის პერიოდი მოიცავს 1991 წლიდან დღემდე პერიოდს. ეს პერიოდი გვაძლევს შედარების ყველაზე საუკეთესო საშუალებას, ბლოკჩეინ ტექნოლოგიების, როგორც 21-ე საუკუნის ყველაზე მასშტაბური ინოვაციის შესახებ.

მთავარი ამოცანაა, თანამედროვე საზღვაო ლოჯისტიკის მწვერვალზე ასვლა. თანამედროვე ტექნოლოგიების და მონაცემების საფუძველზე გადაწყვეტილებების საოპერაციო ეფექტურობის, უსაფრთხოებისა და ეკონომიკის მდგრადობის ოპტიმიზაცია. წარმოდგენილია ამ ცვლილებების გამომწვევი მიზეზებიც. ნაშრომი მოგიყვებათ იმ კომპანიებზე და ქვეყნებზე რომლებმაც ეს სისტემები დანერგეს. ასევე, გავლენაზე რომელსაც ზემოაღნიშნული ტექნოლოგიები ახდენენ ბიზნესზე. ვინაიდან ისინი ქმნიან საერთო ფონს ეკონომიკის წინსვლაში. თამამად შეიძლება ითქვას, რომ ტექნოლოგიებს უდიდესი ზეგავლენა აქვთ ბიზნესის განვითარებაში, სიჭკვიანესა და სასურველი შედეგის უმარტივესად მიღებაში.

ასევე, ამ სტატიის მიზანია დავინახოთ თუ როგორი მნიშვნელოვანია ეკონომიკისთვის ტექნოლოგიებს ავუწყოთ ფეხი, განსაკუთრებით კი განვითარებადი ქვეყნებისთვისთვის, სადაც სუსტია ეკონომიკური ძვრები.

თანამედროვე გლობალური ვაჭრობის პირობებში საზღვაო პორტები წარმოა-

დგენენ კრიტიკულ კვანძებს, სადაც კონცენტრირდება საერთაშორისო მიწოდების ჯაჭვების მნიშვნელოვანი ნაწილი. ტექნოლოგიური პროგრესის ფონზე აქტიურად ყალიბდება„ჭკვიანი პორტების“ კონცეფცია, რომელიც ეფუძნება ციფრული ტექნოლოგიების, ავტომატიზაციისა და მონაცემთა ანალიტიკის ინტერპრეტაციას პორტის ოპერაციებში. აღნიშნ ული კვლევა მიზნად ისახავს ჭკვიანი პორტების განვითარების გავლენის შეფასებას პორტების ოპტიმიზაციასა და ოპერაციულ ეფექტიანობაზე, ასევე საზღვაო მიწოდების ჯაჭვის მართვის გაუმჯობესებაზე.

ნაშრომში გაანალიზებულია პორტების ოპტიმიზაციის თანამედროვე მიდგომები, მათ შორის რეალურ დროში მონაცემთა მართვა, ხელოვნური ინტელექტის გამოყენება ტვირთნაკადების პროგნოზირებისთვის და რესურსების ეფექტიანი განაწილება. განსაკუთრებული ყურადღება ეთნმობა ციფრულ ტრანსფორმაციას, რომელიც გულისხმობს ტრადიციული ლოგისტიკური პროცესების სრულ ან ნაწილობრივ ავტომატიზაციას, რაც ამცირებს ხარჯებს, ზრდის გამჭვირვალობას და ამცირებს ოპერაციულ რისკებს.

კვლევის ერთ-ერთი ძირითადი მიმართულებაა ბლოკჩეინ ტექნოლოგიების გამოყენების ანალიზი ლოგისტიკაში. ბლოკჩეინი უზრუნველყოფს მონაცემთა უსაფრთხოებას, ტრანზაქციების გამჭვირვალობასა და ტრესაბელობას (Traceability), რაც განსაკუთრებით მნიშნელოვანია მრავალმხრივი მონაწილეების მქონე საზღვაო მიწოდების ჯაჭვში.

ნაშრომში განხილულია ბლოკჩეინ ტექნოლოგიების ინტეგრაციის შესაძლებლობები სატრანსპორტო დოკუმენტაციის, კონტრაქტების მართვასა და ტვირთის მონიტორინგში.

კვლევის შედეგები მიუთითებს, რომ ჭკვიანი პორტების დანერგვა და ციფრული ტექნოლოგიების ინტეგრაცია მნიშვნელოვნად აუმჯობესებს პორტების გამტარუნარიანობას, ამცირებს დროით დანაკარგებს და ზრდის ლოგისტიკური სისტემების საერთო ეფექტიანობას. ამასთან, ბლოკჩეინის გამოყენება ამცირებს კორუფციულ რისკებს და აძლიერებს ნდობას მიწოდების ჯაჭვის მონაწილეებს შორის.

დასკვნა

ნაშრომი ამტკიცებს, რომ ციფრული ტრანსფორმაცია და ინოვაციური ტექნოლოგიების ინტეგრაცია წარმოადგენს პორტების მდგრადი განვითარების, კონკურენტურანიანობის ზრდისა და გლობალურ ლოგისტიკურ ქსელებში ეფექტიანი ინტეგრაციის მთავარ წინაპირობას. აღნიშნული კვლევა შეიძლება გამოყენებულ იქნესროგორც თეორიული და პრაქტიკული საფუძველი პოლიტიკის შემმუშავებლებისა და ლოგისტიკის სფეროს პროფესიონალებისთვის.

საკვანძო სიტყვები: 1. ჭკვიანი პორტები; 2. ციფრული ტრანსფორმაცია; 3. საზღვაო მიწოდების ჯაჭვი; 4. ბლოკჩეინ ტექნოლოგიები.

ABSTRACT

The aim of the conference topic is to discuss maritime logistics and port management. The paper reviews smart ports, port optimization and efficiency, maritime supply chain management, as well as digital transformation and blockchain technologies in logistics. My discussion is based on and supported by various studies and academic works.

The purpose of the presented research is to provide an understanding of the role that the above-mentioned mechanisms play in maritime and port processes. The research period covers the timeframe from 1991 to the present day. This period offers the best opportunity for comparison, particularly in relation to blockchain technology as one of the most significant innovations of the 21st century.

The main objective is to reach the pinnacle of modern maritime logistics by optimizing operational efficiency, safety, and economic sustainability through the use of modern technologies and data-driven decision-making. The paper also presents the driving factors behind these changes. It discusses the companies and countries that have implemented these systems, as well as the impact these technologies have on business. These innovations contribute significantly to overall economic progress.

It can be confidently stated that technology has a major influence on business development, intelligence, and achieving desired results in the simplest and most efficient way.

Additionally, this article aims to highlight how important it is for economies to keep pace with technological advancements, especially in developing regions where economic progress remains limited.

In the context of modern global trade, maritime ports represent critical nodes where a significant portion of international supply chains is concentrated. Amid rapid technological advancement, the concept of "smart ports" is increasingly emerging, based on the integration of digital technologies, automation, and data analytics into port operations. This study aims to assess the impact of smart port development on port optimization and operational efficiency, as well as on the improvement of maritime supply chain management.

The paper analyzes contemporary approaches to port optimization, including real-time data management, the use of artificial intelligence for cargo flow forecasting, and the efficient allocation of resources. Particular attention is given to digital transformation, which involves the full or partial automation of traditional logistics processes, leading to reduced costs, enhanced transparency, and minimized operational risks.

One of the key focuses of the research is the analysis of blockchain technologies in logistics. Blockchain ensures data security, transaction transparency, and process traceability, which are especially important in maritime supply chains involving multiple stakeholders. The paper discusses the potential integration of blockchain in transport documentation, contract management, and cargo tracking systems.

The research findings indicate that the implementation of smart ports and the integration of digital technologies significantly improve port throughput, reduce time losses, and enhance the overall efficiency of logistics systems. Furthermore, the use of blockchain reduces corruption risks and strengthens trust among supply chain participants.

CONCLUSION

The study demonstrates that digital transformation and the integration of innovative technologies are essential prerequisites for sustainable port development, increased competitiveness, and effective integration into global logistics networks. The research can serve as both a theoretical and practical foundation for policymakers and logistics professionals.

KEEWORDS: 1. Smart Ports; 2. Digital Transformation; 3. Maritime Supply Chain; 4.Blockchain Technologies.

საზღვაო ინდუსტრიის უსაფრთხოების სტანდარტები და მათი რეგულირების მექანიზმები

Safety Standards in the Maritime Industry and Their Regulatory Mechanisms

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აბსტრაქტი

წარმოდგენილ ნაშრომში ნათქვამია, რომ საზღვაო ინდუსტრიის უსაფრთხოებისათვის ბრძოლა დღევანდელი საქართველოსა თუ მსოფლიოს აქტუალური პრობლემაა. თუ გვსურს რომ ვიცხოვროთ ჯანსაღ გარემოში, საერთაშორისო ვაჭრობის ძირითადი ნაწილი საჭიროებისამებრ განვახორციელოთ, საჭიროა, გლობალური ეკონომიკის ერთ-ერთ მნიშვნელოვან საყრდენს გავუფრთხილდეთ და დავიცვათ ყველა აუცილებელი ზომა იმისათვის, რომ საზღვაო ინდუსტრია იყოს მაქსიმალურად გამართული. ეს ყოველივე კი მიიღწევა საერთაშორისო სტანდარტებზე მორგებული კანონმდებლობის დანერგვით, სათანადო რეგულაციების შემუშავებითა და მუდმივი კონტროლით სახელმწიფო რგოლის მხრიდან.

საკვლევი საკითხი მოიცავს იმის დადგენას, რომ რამდენად უსაფრთხოა საზღვაო ინდუსტრია, ეს უმნიშვნელოვანესი სფერო რამდენადაა დაცული და, რაც ყველაზე მთავარია, მისი ახლანდელი მდგომარეობის შენარჩუნებისათვის კონკრეტულად რა სახის შეფასების სკალა, კრიტერიუმები გამოიყენება. თუკი აღნიშნავენ, რომ საზღვაო ინდუსტრია უსაფრთხოა, საინტერესოა, როგორი სტანდარტებია გათვალისწინებული ამ მიმართულებით და დაცვისა თუ რეგულირების რა სახის მექანიზმებია დღის წესრიგში.

კვლევის მეთოდია: საკანონმდებლო ბაზებზე გაცნობა და დასკვნის გამოტანა იმასთან დაკავშირებით, რას ამბობს საქართველოს კონსტიტუცია, საზღვაო სამართლის შესახებ კანონმდებლობა ლოკალური, მხოლოდ საქართველოს, მასშტაბით და ერთიანი იურიდიული მსჯელობის ჩამოყალიბება.

კვლევისა და საკონფერენციო ნაშრომის შექმნის მიზნებია: დადგენა იმისა თუ რამდენად უსაფრთხოა საზღვაო ინდუსტრია, ამ სფეროში რა სახის შეფასებები და რეგულაციები არსებობს, აგრეთვე თუ არსებობს საერთაშორისო კანონმდებლობა, რომელიც ადასტურებს საზღვაო ინდუსტრიის უსაფრთხოების ნორმების გამართულობას. საკონფერენციო ნამუშევრის უმთავრეს მიზანს წარმოადგენს საზოგადოების ცნობიერების ამაღლება და რაც შეიძლება მეტი ინფორმაციის მოძიება-გაზიარება საზღვაო ინდუსტრიასთან დაკავშირებით, რადგან ეს არის ქვეყნის განვითარებისათვის უმთავრესი„დარგი“.

ძირითადი მიგნებები მოიცავს იმას, რომ საზღვაო უსაფრთხოების სტანდარტები აერთიანებს ტექნიკურ და სამართლებრივ ასპექტებს, რომლებიც უზრუნველყოფს ადამიანის უფლებების, უმთავრესად კი, სიცოცხლის უფლების დაცვას და გარემოს უსაფრთხოებაზე ზრუნვის კულტურის ჩამოყალიბებას. ამ სფეროში მნიშვნელოვანია, რასაკვირველია, ადგილობრივი დონის კანონმდებლობა, თუმცა არანაკლებ საყურადღებოა, აგრეთვე, საერთაშორისო რეგულაციები, მექანიზმები, რომლებიც აკონტროლებს შემდეგ საკითხს: მაგალითად, რამდენად შეესაბამება გემების ტექნიკური გამართულობა დადგენილ სტანდარტებს. ასევე კონტროლდება ეკიპაჟის კვალიფიკაცია და საგანგებო სიტუაციებისათვის უცაბედი რეაქციის უნარის გამომუშავება, ანუ პროტოკოლის წესების დაუყოვნებლივ დაცვის გარანტიაცაა უზრუნველყოფილი. საბოლოო ჯამში კი შეიძლება ითქვას რომ, საზღვაო ინდუსტრიის უსაფრთხოება საზოგადოების ნორმალური ფუნქციონირების ქვაკუთხედია და აუცილებლად სათანადოდ გაკონტროლებულ უნდა იყოს.

საკვანძო სიტყვები: საზღვაო ინდუსტრია, საზღვაო ინდუსტრიის უსაფრთხოების სტანდარტები, სიცოცხლის უფლება, გარემოს უსაფრთხოებაზე ზრუნვა.

ABSTRACT

The presented paper states that ensuring safety in the maritime industry is a pressing issue both for modern Georgia and the world. If we wish to live in a healthy environment and carry out the majority of internation trade as needed, it is essential to take care of one of the key pillars of the global economy and implement all necessary measures to ensure that the maritime industry functions at the highest possible level. This can be achieved through the introduction of legislation aligned with international standards, the development of appropriate regulations, and continuous supervision by state authorities.

The research issue involves determining how safe the maritime industry is, to what extent this crucial sector is protected, and, most importantly, what types of assessment scales and criteria are used to maintain its current condition. If it is claimed that the maritime industry is safe, it is important to understand what standards are considered in this regard and what types of protection and regulatory mechanisms are in place.

The research method includes reviewing legislative frameworks and drawing conclu-

sions regarding what the Constitution of Georgia and maritime law legislation state at the local level, as well as forming a unified legal analysis.

The objectives of the research and conference paper are to determine how safe the maritime industry is, what types of assessments and regulations exist in this field, and whatever there is international legislation that confirms the proper functioning of maritime industry safety standards. The primary goal of the conference paper is to raise public awareness and to gather and disseminate as much information as possible about the maritime industry, as this is a key sector for national development.

The main findings indicate that maritime safety standards encompass both technical and legal aspects, ensuring the protection of human rights – primarily the right to life – and fostering a culture of environmental safety. In this field, local legislation is certainly important; however, international regulations and mechanisms monitor issues such as whether the technical condition of vessels complies with established standards. They also oversee crew qualifications and the ability to respond promptly compliance with protocol procedures. Ultimately, it can be concluded that maritime industry safety is a cornerstone of the normal functioning of society and must be properly regulated and controlled.

KEEWORDS: maritime industry, maritime industry safety standards, right to life, environmental protection.

Digital Twin ტექნოლოგია როგორც ტრანსპორტისა და ლოგისტიკის ოპტიმიზაციის ინოვაციური ინსტრუმენტი

Digital Twin Technology as an Innovative Tool for Transport and Logistics Optimization

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აბსტრაქტი

ციფრული ტრანსფორმაციის თანამედროვე ეტაპზე ტრანსპორტისა და ლოგისტიკის სექტორი მნიშვნელოვან ცვლილებებს განიცდის, რაც განპირობებულია ინოვაციური ტექნოლოგიების ინტეგრაციით და მონაცემებზე დაფუძნებული მართვის სისტემების განვითარებით. ერთ-ერთ ყველაზე პერსპექტიულ და სწრაფად განვითარებად ტექნოლოგიას წარმოადგენს Digital Twin კონცეფცია, რომელიც გულისხმობს ფიზიკური ობიექტების, პროცესებისა და ინფრასტრუქტურის ვირტუალური ასლების შექმნასა და მათ სინქრონიზაციას რეალურ მონაცემებთან. აღნიშნული ტექნოლოგია უზრუნველყოფს სისტემების ფუნქციონირების დეტალურ ანალიზს, პროგნოზირებას და ოპტიმიზაციას რეალურ დროში.

წარმოდგენილი კვლევის მიზანია Digital Twin ტექნოლოგიის გამოყენების შესაძლებლობების შესწავლა ტრანსპორტისა და ლოგისტიკის პროცესების ოპტიმიზაციის მიმართულებით. ნაშრომში გაანალიზებულია მისი როლი მიწოდების ჯაჭვის მართვაში, სატრანსპორტო ოპერაციების დაგეგმვაში, ტვირთების გადაადგილების მონიტორინგში და საწყობების ეფექტიან მართვაში. განსაკუთრებული ყურადღება ეთმობა რეალურ დროში მონაცემთა შეგროვებისა და დამუშავების მნიშვნელობას, რაც მიიღწევა IoT მოწყობილობების, სენსორების და ინტეგრირებული ციფრული პლატფორმების გამოყენებით. აღნიშნული მიდგომა საშუალებას იძლევა სისტემაში მიმდინარე პროცესები შეფასდეს არა მხოლოდ მიმდინარე მდგომარეობის მიხედ-

ვით, არამედ შესაძლებელი გახდეს სხვადასხვა სცენარის მოდელირება და ოპტიმალური გადაწყვეტილებების წინასწარ განსაზღვრა.

კვლევის ფარგლებში განხილულია Digital Twin ტექნოლოგიის გამოყენების პრაქტიკული მაგალითები, რომლებიც ცხადყოფს მის ეფექტიანობას ტრანსპორტისა და ლოგისტიკის სფეროში. მიღებული შედეგები მიუთითებს, რომ აღნიშნული ტექნოლოგიის დანერგვა ხელს უწყობს ოპერაციული ხარჯების შემცირებას, პროცესების გამჭვირვალობის ზრდას, მიწოდების დროის ოპტიმიზაციას და მომსახურების ხარისხის გაუმჯობესებას. ამასთან, Digital Twin უზრუნველყოფს რისკების ადრეულ იდენტიფიცირებას და კრიზისული სიტუაციების ეფექტიან მართვას.

მიუხედავად არსებული უპირატესობებისა, კვლევა ასევე გამოყოფს ტექნოლოგიის დანერგვასთან დაკავშირებულ გამოწვევებს, როგორიცაა მაღალი საწყისი ინვესტიციები, მონაცემთა უსაფრთხოების უზრუნველყოფის სირთულეები, სისტემების ინტეგრაციის ტექნიკური ბარიერები და შესაბამისი კვალიფიკაციის მქონე პერსონალის დეფიციტი. აღნიშნული ფაქტორები მნიშვნელოვან გავლენას ახდენს ტექნოლოგიის მასობრივ დანერგვაზე, განსაკუთრებით განვითარებად ბაზრებზე.

Digital Twin ტექნოლოგია წარმოადგენს ტრანსპორტისა და ლოგისტიკის ოპტიმიზაციის ერთ-ერთ ყველაზე ეფექტიან და ინოვაციურ ინსტრუმენტს, რომელიც ხელს უწყობს ბიზნეს პროცესების გაუმჯობესებას, გადაწყვეტილებების მიღების ხარისხის ზრდას და კონკურენტული უპირატესობის შექმნას გლობალურ ბაზარზე. მისი შემდგომი განვითარება და ფართომასშტაბიანი დანერგვა მნიშვნელოვნად განსაზღვრავს სექტორის მომავლის ფორმირებას.

საკვანძო სიტყვები: Digital Twin; ლოგისტიკა; მიწოდების ჯაჭვის ოპტიმიზაცია; IoT მოწყობილობები; ჭკვიანი სისტემები.

ABSTRACT

At the current stage of digital transformation, the transport and logistics sector is undergoing significant changes driven by the integration of innovative technologies and the development of data-driven management systems. One of the most promising and rapidly evolving technologies is the concept of the Digital Twin, which involves the creation of virtual replicas of physical objects, processes, and infrastructures, synchronized with real-time data. This technology enables detailed analysis, forecasting, and real-time optimization of system performance.

The aim of the present study is to explore the potential of Digital Twin technology in optimizing transport and logistics processes. The paper analyzes its role in supply chain management, transportation planning, cargo tracking, and efficient warehouse operations. Particular attention is paid to the importance of real-time data collection and processing, achieved through the use of IoT devices, sensors, and integrated digital platforms. This

approach allows for the evaluation of ongoing processes not only based on their current state but also through the modeling of various scenarios and the identification of optimal decision-making strategies in advance.

The study also examines practical examples of Digital Twin implementation, demonstrating its effectiveness in the transport and logistics sector. The findings indicate that the adoption of this technology contributes to reducing operational costs, increasing process transparency, optimizing delivery times, and improving service quality. Furthermore, Digital Twin technology facilitates early risk identification and the effective management of crisis situations.

Despite its advantages, the research highlights several challenges associated with the implementation of Digital Twin technology, including high initial investment costs, data security concerns, technical barriers to system integration, and a shortage of qualified personnel. These factors significantly influence the large-scale adoption of the technology, particularly in developing markets.

In conclusion, Digital Twin technology represents one of the most effective and innovative tools for optimizing transport and logistics processes. It enhances business performance, improves the quality of decision-making, and creates competitive advantages in the global market. Its further development and widespread adoption are expected to play a crucial role in shaping the future of the sector.

KEEWORDS: Digital Twin; Logistics; Supply Chain Optimization; IoT devices; Smart Systems

შესავალი

ინდუსტრია 4.0-ის ეპოქამ რევოლუციური ცვლილებები შეიტანა ტრადიციულ ლოგისტიკურ პროცესებში. ფიზიკური და ციფრული სამყაროების ინტეგრაცია აღარ არის მხოლოდ თეორიული კონცეფცია, იგი გახდა ბიზნესის გადარჩენისა და კონკურენტუნარიანობის შენარჩუნების მთავარი პირობა. ტრანსპორტისა და ლოგისტიკის სფერო ხასიათდება მაღალი დინამიურობით, სადაც ნებისმიერ შეფერხებას-იქნება ეს ამინდის პირობები, გეოპოლიტიკური კრიზისები თუ ტექნიკური გაუმართაობა-შეუძლია უდიდესი ზარალი გამოიწვიოს.

ამ კონტექსტში Digital Twin (ციფრული ტყუპი) ტექნოლოგია წარმოადგენს ერთ-ერთ ყველაზე აქტუალურ ინოვაციას. Digital Twin არის ფიზიკური ობიექტის, პროცესის ან სისტემის ვირტუალური ასლი, რომელიც მუდმივად ახლდება რეალურ დროში მიღებული მონაცემების საფუძველზე. თუ ადრე სიმულაციები გამოიყენებოდა მხოლოდ პროექტის დაგეგმვის საწყის ეტაპზე, დღეს Digital Twin საშუალებას გვაძლევს ვმართოთ სისტემის ქცევა მისი მთელი სასიცოცხლო ციკლის განმავლობაში.

კვლევის მიზანია: Digital Twin ტექნოლოგიის თეორიული საფუძვლებისა და პრაქტიკული პოტენციალის კომპლექსური შესწავლა ტრანსპორტისა და ლოგისტიკის სექტორის ოპტიმიზაციის კონტექსტში.

კვლევის მეთოდოლოგია: ნაშრომში გამოყენებულია თვისებრივი და რაოდენობრივი კვლევის მეთოდების კომბინაცია, კერძოდ: სისტემური და ლიტერატურული მიმოხილვა; შემთხვევის შესწავლის მეთოდი; მათემატიკური მოდელირება და ოპტიმიზაციის ანალიზი.

კონცეფცია: Digital Twin პირველად 2002 წელს მაიკლ გრივსის მიერ იქნა გაჟღერებული პროდუქტის საციცოცხლო ციკლის მენეჯმენტის (PLM) კონტექსტში, თუმცა მისი პრაქტიკული რეალიზება მხოლოდ ბოლო ათწლეულში გახდა შესაძლებელი ტექნოლოგიური პროგრესის წყალობით. ციფრული ტყუპების გამოყენება ლოგისტიკაში აქტიური სამეცნიერო დისკუსიის საგანია. საერთაშორისო საკონსულტაციო გიგანტების (Gartner, DHL) ანგარიშების მიხედვით, Digital Twin დასახელებულია მიწოდების ჯაჭვის ტრანსფორმაციის ერთ-ერთ მთავარ ტრენდად. ლიტერატურაში გამოყოფენ ციფრული ტყუპის სიმწიფის სამ დონეს:

Digital Model (ციფრული მოდელი): მონაცემთა გაცვლა ფიზიკურ და ვირტუალურ ობიექტებს შორის ხდება მექანიკურად, არარეალურ დროში.

Digital Shadow (ციფრული ჩრდილი): ფიზიკური ობიექტიდან მონაცემები ავტომატურად მიედინება ვირტუალურში, მაგრამ უკუკავშირი მექანიკურია.

Digital Twin (სრული ციფრული ტყუპი): მონაცემთა ორმხრივი, სრულიად ავტომატური და რეალურ დროში ცვლა. თუ ვირტუალურ მოდელში შეიცვლება პარამეტრი, ფიზიკური ობიექტიც შესაბამისად რეაგირებს და პირიქით.

ლოგისტიკაში Digital Twin არ არის უბრალოდ 3D მოდელი. ის არის ცოცხალი ეკოსისტემა, რომელიც შედგება სამი ძირითადი ნაწილისგან: ფიზიკური პროდუქტი/პროცესი: რეალური აქტივი (სატვირთო მანქანა, გემი, საწყობი, კონტეინერი); ვირტუალური პროდუქტი/პროცესი: ციფრული პლატფორმა, სადაც ხდება ფიზიკური ობიექტის სიმულირება; მონაცემთა კავშირი: ორმხრივი საინფორმაციო არხი, რომელიც აკავშირებს ფიზიკურს ვირტუალურთან.

ციფრული ტყუპის ფუნქციონირება ეყრდნობა რამდენიმე საყრდენ ტექნოლოგიას:

- ნივთების ინტერნეტი (IoT) და სენსორები: ფიზიკურ ობიექტებზე დამონტაჟებული სენსორები აგროვებენ მონაცემებს ტემპერატურის, მდებარეობის, სიჩქარის, ვიბრაციისა და სხვა პარამეტრების შესახებ.
- დიდი მონაცემები (Big Data) და ღრუბლოვანი გამოთვლები: სენსორებიდან მიღებული გიგანტური მოცულობის ინფორმაცია საჭიროებს მყისიერ დამუშავებას და შენახვას.
- ხელოვნური ინტელექტი (AI) და მანქანური სწავლება: AI ალგორითმები აანალიზებენ ისტორიულ და რეალურ დროში მიღებულ მონაცემებს, რათა აღმოაჩინონ კანონზომიერებები და მოახდინონ მომავალი მოვლენების პროგნოზირებადი მოდელირება.

Digital Twin-ის გამოყენება ტრანსპორტსა და ლოგისტიკაში ამარტივებს პროცესებს, მაგალითად სასაწყობო მეურნეობა ლოგისტიკის ერთ-ერთი ყველაზე შრომატევადი და ძვირადღირებული ნაწილია, საწყობის ციფრული ტყუპის შექმნით კომპანიებს შეუძლიათ სივრცის, ტექნიკისა და ადამიანური რესურსების ოპტიმიზაცია. სივრცის დინამიკური დაგეგმარება-სისტემა აანალიზებს შემოსული ტვირთების ნაკადს და ვირტუალურად ანაწილებს ადგილებს ისე, რომ მინიმუმა-

მდე დაიყვანოს დამტვირთველების გადაადგილების ტრაექტორია. უსაფრთხოების სიმულაცია-შესაძლებელია პერსონალისა და ავტომატიზებული მართვადი მანქანების (AGV) მოძრაობის სიმულირება, რათა თავიდან იქნას აცილებული შეჯახებები.

ფლოტის მართვა და პროგნოზირებადი ტექნიკური მომსახურება – სატრანსპორტო საშუალებების (სატვირთო მანქანები, მატარებლები, თვითმფრინავები) მუშაობის პროცესში, გაუთვალისწინებელი დაზიანება ნიშნავს ჯარიმებსა და ფინანსურ ზარალს. პროგნოზირებადი სერვისის პრინციპი – ნაცვლად იმისა, რომ დეტალი შეიცვალოს წინასწარ გაწერილი გრაფიკით (მაგ. ყოველ 10,000 კმ-ში) ან მისი დაზიანების შემდეგ, Digital Twin ძრავის სენსორების (ვიბრაცია, ტემპერატურა, ზეთის წნევა) მეშვეობით ზუსტად განსაზღვრავს თუ როდის დადგება კონკრეტული ნაწილის მწყობრიდან გამოსვლის რეალური საფრთხე.

მიწოდების ჯაჭვის გლობალური End-to-End ხილვადობა-გლობალური მიწოდების ჯაჭვის ციფრული ტყუპი აერთიანებს მონაცემებს მომწოდებლებისგან, პორტებიდან, საბაჟო ტერმინალებიდან და სატრანსპორტო ხაზებიდან. ეს იძლევა ე.წ. Control Tower (მართვის კოშკურის) ეფექტს, სადაც მენეჯერებს შეუძლიათ დაინახონ მთელი გლობალური სურათი.

Digital Twin-ის ფარგლებში ოპტიმიზაციის პროცესი ეყრდნობა მათემატიკურ მოდელირებასა და ოპერაციათა კვლევას. განვიხილოთ ძირითადი ეტაპები, რომლებსაც ციფრული ტყუპი გადის გადაწყვეტილების მისაღებად.

ცხრილი 1. Digital twin ძირითადი ეტაპები გადაწყვეტილების მისაღებად.

ეტაპი	პროცესის აღწერა	გამოყენებული ტექნოლოგია/ ალგორითმი
1. მონაცემთა შეგროვება	სენსორებიდან, GPS მოდულებიდან და ERP სისტემებიდან ინფორმაციის მყისიერი მიღება.	IoT, MQTT პროტოკოლი, Edge Computing
2. დიაგნოსტიკა	მიმდინარე მდგომარეობის შეფასება, გადახრების იდენტიფიცირება.	ნიმუშის ამოცნობა (Pattern Recognition)
3.პროგნოზირება	"რა მოხდება თუ..." (What-if) სცენარების გათამაშება და მომავლის მოდელირება.	მანქანური სწავლება, Random Forest, Neural Networks
4. ოპტიმიზაცია	საუკეთესო მოქმედების გეგმის შერჩევა (მაგ. ალტერნატიული მარშრუტი).	გენეტიკური ალგორითმები, ხაზოვანი დაპროგრამება

წყარო: ავტორისეული.

ბოლო პერიოდში მსოფლიოს მსხვილი სატრანსპორტო და ლოგისტიკური კომპანიები აქტიურად ნერგავენ Digital Twin ტექნოლოგიას, მაგალითად: როტერდამის პორტი, რომელიც ევროპაში უდიდესია, აქტიურად ნერგავს Digital Twin-ს. მათ შექმნეს პორტის სრული ციფრული ასლი, რომელიც აკონტროლებს გემების მოძრაობას, ინფრასტრუქტურის მდგომარეობას, ამინდს, ქარისა და წყლის დინების სიჩქარეს. შე-

დეგად, გემების ლოდინის დრო შემცირდა 20%-ით, რაც კომპანიებისთვის მილიონობით ევროს ეკონომიას ნიშნავს.

ლოგისტიკურმა გიგანტმა DHL-მა აზიის რამდენიმე მსხვილ ჰაბში დანერგა საწყობების ციფრული ტყუპები. რეალურ დროში მონაცემების მიდევნებით მათ შეძლეს შეფუთვისა და დახარისხების პროცესში დაშვებული შეცდომების 15%-ით შემცირება და საწყობის შიდა ლოგისტიკის ეფექტიანობის 25%-ით გაზრდა.

მიუხედავად უზარმაზარი უპირატესობებისა, Digital Twin-ის ტექნოლოგიის მასშტაბური დანერგვა დაკავშირებულია სერიოზულ გამოწვევებთან: მაღალი საწყისი კაპიტალდაბანდება: სენსორების, IoT ინფრასტრუქტურისა და მაღალკვალიფიციური კადრების დაქირავება დიდ ფინანსურ რესურსებს მოითხოვს; მონაცემთა სილოსები და თავსებადობა: ხშირად მიწოდების ჯაჭვის სხვადასხვა მონაწილეები (გადამზიდავი, საბაჟო, საწყობი) იყენებენ სხვადასხვა, შეუთავსებელ პროგრამულ უზრუნველყოფას. სრული ციფრული ტყუპის შესაქმნელად კი საჭიროა მონაცემთა ერთიანი სტანდარტიზაცია; კიბერუსაფრთხოება: ვინაიდან ფიზიკური და ციფრული სისტემები მჭიდროდ არის დაკავშირებული, ციფრულ პლატფორმაზე ჰაკერულმა თავდასხმამ შეიძლება გამოიწვიოს რეალური სატრანსპორტო საშუალებების პარალიზება ან ფიზიკური ზიანი.

Digital Twin ტექნოლოგია წარმოადგენს არა უბრალოდ ევოლუციურ ნაბიჯს, არამედ პარადიგმის შეცვლას ტრანსპორტსა და ლოგისტიკაში. იგი საშუალებას აძლევს ინდუსტრიას გადავიდეს წარსულზე ორიენტირებული რეაქტიული მოდელიდან მომავალზე ორიენტირებულ პროაქტიულ და პროგნოზირებად მართვაზე.

ნაშრომში განხილული არგუმენტები და პრაქტიკული ქეისები ადასტურებენ, რომ მიუხედავად მაღალი საწყისი ხარჯებისა და ტექნიკური გამოწვევებისა, ციფრული ტყუპების დანერგვის ეფექტი-გამოხატული საოპერაციო ხარჯების შემცირებაში, ფლოტის ეფექტურ მართვასა და მომხმარებლის კმაყოფილების ზრდაში-სრულად ამართლებს ინვესტიციას. გრძელვადიან პერსპექტივაში, ის კომპანიები, რომლებიც ვერ შეძლებენ ფიზიკური და ციფრული აქტივების ამგვარ ინტეგრაციას, დაკარგავენ კონკურენტუნარიანობას გლობალურ ბაზარზე.

დასკვნა და რეკომენდაციები

Digital Twin ტექნოლოგიის მომავალი მჭიდროდ არის დაკავშირებული 5G და 6G ქსელების განვითარებასთან, რაც უზრუნველყოფს მონაცემთა გადაცემას თითქმის ნულოვანი დაყოვნებით. Digital Twin ტექნოლოგიის წარმატებული ინტეგრაციისა და საოპერაციო ეფექტიანობის მაქსიმიზაციისთვის, სატრანსპორტო და ლოგისტიკურ კომპანიებს, ეძლევათ შემდეგი სტრატეგიული და პრაქტიკული რეკომენდაციები:

ეტაპობრივი დანერგვის სტრატეგია – კომპანიებმა თავი უნდა აარიდონ გლობალური მიწოდების ჯაჭვის მასშტაბური ციფრული ტყუპის ერთდროულად შექმნას. რეკომენდებულია პროცესის დაწყება ე.წ. „პილოტური პროექტებით" მაღალი რისკის მქონე ან კრიტიკულ უბნებზე. მაგალითად, თავდაპირველად შეიქმნას კონკრეტული საწყობის ან ფლოტის ვიწრო სეგმენტის ციფრული მოდელი, რომელიც ეტაპობრი-

ვად გადაიზრდება სრულფასოვან, ორმხრივ ციფრულ ტყუპში.

მონაცემთა სტანდარტიზაცია და ღია არქიტექტურა-ვინაიდან ციფრული ტყუპი ეფუძნება სხვადასხვა წყაროდან (ERP, WMS, GPS, IoT) მიღებული მონაცემების სინთეზს, აუცილებელია კომპანიამ დანერგოს მონაცემთა ერთიანი სტანდარტები.

კიბერუსაფრთხოების მრავალდონიანი ჩარჩოს შექმნა-ფიზიკური და ციფრული აქტივების ღრმა ინტეგრაცია ზრდის კიბერმოწყვლადობას. კომპანიებმა უნდა დანერგონ: End-to-End შიფრაცია

ადამიანური კაპიტალის განვითარება და ტრანსფორმაცია-ტექნოლოგია ვერ იქნება ეფექტიანი, თუ პერსონალს არ აქვს მისი მართვის კომპეტენცია. რეკომენდებულია ტრადიციული ლოგისტიკის მენეჯერების გადამზადება მონაცემთა ანალიტიკის მიმართულებით და კომპანიის შიგნით მულტიდისციპლინური გუნდების შექმნა, სადაც ოპერაციული მენეჯერები, IT სპეციალისტები და მონაცემთა ანალიტიკოსები ერთად იმუშავებენ ციფრული ტყუპის მიერ გენერირებული პროგნოზების ბიზნეს-გადაწყვეტილებებად ტრანსფორმაციისთვის.

ორიენტაცია „მწვანე ლოგისტიკასა“ და მდგრადობაზე-ციფრული ტყუპის ოპტიმიზაციის ალგორითმების გამართვისას, კრიტერიუმებში, დროისა და ფინანსური ხარჯების მინიმიზაციასთან ერთად, აუცილებლად უნდა ჩაიდოს ნახშირორჟანგის ემისიების შემცირების კომპონენტი.

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Digital Twin ტექნოლოგიის როლი თანამედროვე ლოგისტიკასა და საქართველოს სატრანზიტო პოტენციალის განვითარებაში

The Role of Digital Twin Technology in Modern Logistics and the Development of Georgia's Transit Potential

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აბსტრაქტი

წინამდებარე ნაშრომში განხილულია Digital Twin (ციფრული ტყუპი) ტექნოლოგიის ფუნდამენტური როლი მდგრადი სატრანსპორტო სისტემებისა და საზღვაო ლოგისტიკის მართვის სფეროებში, რომლებიც თანამედროვე გლობალური ვაჭრობის ხერხემალს წარმოადგენს. კვლევა აანალიზებს ამ ინოვაციური ინსტრუმენტის გავლენას საქართველოს სატრანზიტო პოტენციალის რეალიზებაზე, რაც განსაკუთრებით აქტუალურია გლობალური მიწოდების ჯაჭვების გადაწყობისა და „შუა დერეფნის" სტრატეგიული მნიშვნელობის ზრდის ფონზე. ნაშრომი მიმოიხილავს ტექნოლოგიის ოთხშრიან არქიტექტურას – ფიზიკურ, აღქმის (სენსორულ), კავშირისა და ვირტუალურ შრეებს – და გვიჩვენებს, თუ როგორ გარდაიქმნება ფიზიკური აქტივებიდან მიღებული ნედლი მონაცემები სტრატეგიულ ინფორმაციად პოლიტიკის შემქმნელთათვის, ინდუსტრიის წარმომადგენელთათვის და აკადემიური წრისთვის.

ნაშრომის ერთ-ერთი ცენტრალური საკითხია სწორედ მდგრადი სატრანსპორტო სისტემების განვითარება ციფრული ინოვაციის გზით. Digital Twin ტექნოლოგიის გამოყენებით შესაძლებელი ხდება საწვავის მნიშვნელოვანი ეკონომია და ნახშირბადის ემისიების გაზომვადი შემცირება მარშრუტების დინამიური ოპტიმიზაციის ხარჯზე – რაც პირდაპირ უწყობს ხელს მწვანე დერეფნის ინიციატივებსა და

საერთაშორისო კლიმატურ ვალდებულებებს. საზღვაო და სახმელეთო უსაფრთხოების სტანდარტების გაუმჯობესება მიიღწევა პრევენციული ანალიტიკის მეშვეობით, რომელიც ტექნიკურ ხარვეზებსა და პოტენციურ რისკებს წინასწარ განსაზღვრავს. რეალურ დროში გადაწყვეტილებების მიღება ხდება უფრო მოქნილი და ნაკლებად დამოკიდებული ადამიანურ შეცდომებზე – რაც კრიტიკულად მნიშვნელოვანია მაღალი ინტენსივობის მულტიმოდალური სატრანზიტო ჰაბებისთვის, როგორებიცაა ფოთისა და ბათუმის პორტები და მომავალი ანაკლიის ტერმინალი.

ნაშრომში გაანალიზებულია საქართველოს გამოწვევები და შესაძლებლობები „შუა დერეფნის" საკვანძო რგოლის სახით. ხაზგასმულია, რომ სატრანზიტო პოტენციალის სრულფასოვანი რეალიზება მოითხოვს არა მხოლოდ ფიზიკური ინფრასტრუქტურის განვითარებას, არამედ სანებართვო სისტემებისა და დოკუმენტაციის სრულ გაციფრულებას. ECMT-ის ციფრული სანებართვო სისტემის დანერგვის პრაქტიკული მაგალითი საქართველოში განხილულია როგორც განმეორებადი პირველი ნაბიჯი გლობალურად კონკურენტული ციფრული ლოგისტიკური ჰაბისკენ – გამოცდილება, რომელიც უშუალოდ პასუხობს კონფერენციის ინოვაციური პრაქტიკიდან პოლიტიკამდე გადასვლის ამოცანას.

კვლევის შედეგები ეფუძნება სატრანსპორტო მიმართულებების პრაქტიკული რეალიზაციის ანალიზს, რაც პირდაპირ პასუხობს სექტორის მონაწილეთა მოთხოვნებს და ითვალისწინებს არსებული ბარიერების ეტაპობრივ აღმოფხვრას.

დღის წესრიგში დგას უმნიშვნელოვანესი საკითხი – CMR კონვენციის 2008 წლის დამატებითი ოქმის იმპლემენტაცია, რომელიც ზედდებულის ელექტრონული ფორმით წარმოებას (e-CMR) ითვალისწინებს. მიუხედავად იმისა, რომ აღნიშნულ პროტოკოლს უკვე შეუერთდნენ რეგიონის ისეთი ქვეყნები, როგორიცაა აზერბაიჯანი და თურქეთი, საქართველოში პროცესი პანდემიის (COVID-19) გამო შეფერხდა. ამჟამად ქართული მხარის მიერ აქტიურად მიმდინარეობს პროცედურების ხელახალი აქტივაცია საერთაშორისო სტანდარტებთან ინტეგრაციის მიზნით.

საქართველოს კანონმდებლობა დოკუმენტაციის გაციფრულების კუთხით უკვე ფლობს გარკვეულ პოზიტიურ გამოცდილებას. კერძოდ, საქართველოს ადმინისტრაციულ სამართალდარღვევათა კოდექსის 119-ე მუხლის შესაბამისად, მართვის უფლებისა და სატრანსპორტო საშუალების სარეგისტრაციო დოკუმენტების დადასტურება შესაძლებელია ელექტრონული ფორმით (გარკვეული კრიტერიუმების დაკმაყოფილების შემთხვევაში).

მიგვაჩნია, რომ საქართველოს აღნიშნული გამოცდილება და e-CMR-ის სრულფასოვანი დანერგვა უნდა გავრცელდეს სატრანსპორტო დერეფნის სხვა მონაწილე ქვეყნებზეც. ეს უზრუნველყოფს:

- საზღვრის კვეთის პროცედურების ოპტიმიზაციას;
- საგზაო მონიტორინგისა და საბაჟო სერვისების ეფექტიანობის ზრდას;
- ერთიანი ციფრული ეკოსისტემის ჩამოყალიბებას, რაც უფრო კომფორტულს გახდის გადაადგილებას როგორც კერძო, ისე სახელმწიფო სტრუქტურებისთვის.

კვლევის ეკონომიკური ანალიზი ადასტურებს ტექნოლოგიის მნიშვნელოვან სარგებელს: ტვირთის გატარების დროის შემცირება 20–40%-ით, საოპერაციო ხარჯე-

ბის კლება 15–30%-ით, ინვენტარის სიჭარბის შემცირება 30–50%-ით და CO_2-ის ემისიების 10–25%-იანი შემცირება, რაც ქვეყანას „მწვანე დერეფნის" სტატუსს ანიჭებს. ნაშრომი ასევე იდენტიფიცირებს ტრანსფორმაციის სისტემურ ბარიერებს – ინფრასტრუქტურულ ფრაგმენტაციას და მონაცემთა გაზიარების ერთიანი სტანდარტების არარსებობას – და სახელმწიფო-კერძო პარტნიორობის „ციფრული ხერხემლის" შექმნას სთავაზობს როგორც ძირითად პოლიტიკურ პასუხს.

მიღებული შედეგები ადასტურებს, რომ ინტელექტუალური მართვის სისტემები წარმოადგენს გადამწყვეტ გზას საქართველოს, როგორც მაღალტექნოლოგიური და მდგრადი სატრანზიტო პლატფორმის, პოზიციონირებისთვის – გამოცდილება, რომელიც გამოსადეგია მთელი რეგიონისთვის.

საკვანძო სიტყვები: Digital Twin, მდგრადი სატრანსპორტო სისტემები, საზღვაო ლოგისტიკა, სატრანზიტო პოტენციალი, შუა დერეფანი, e-CMR, ხელოვნური ინტელექტი, სანებართვო სისტემების გაციფრულება.

ABSTRACT

This paper examines the fundamental role of Digital Twin technology in the management of sustainable transport systems and maritime logistics, which constitute the backbone of modern global trade. The study analyzes the impact of this innovative tool on the realization of Georgia's transit potential, particularly in the context of the reconfiguration of global supply chains and the increasing strategic importance of the Middle Corridor. The paper reviews the four-layer architecture of the technology—physical, perception (sensor), communication, and virtual layers—and demonstrates how raw data obtained from physical assets is transformed into strategic information for policymakers, industry stakeholders, and academia.

A central focus of the research is the development of sustainable transport systems through digital innovation. The application of Digital Twin technology enables significant fuel savings and measurable reductions in carbon emissions through dynamic route optimization, thereby directly supporting green corridor initiatives and international climate commitments. Improvements in maritime and land transport safety standards are achieved through predictive analytics, which identifies technical failures and potential risks in advance. Real-time decision-making becomes more flexible and less dependent on human error, which is critically important for high-intensity multimodal transit hubs such as the ports of Poti and Batumi, as well as the future Anaklia terminal.

The paper analyzes Georgia's challenges and opportunities as a key link in the Middle Corridor. It emphasizes that the full realization of transit potential requires not only the development of physical infrastructure but also the complete digitalization of permit systems and documentation. The implementation of the ECMT digital permit system in Georgia is discussed as a replicable first step toward establishing a globally competitive

digital logistics hub—an experience that directly aligns with the transition from innovative practice to policy-making.

The research findings are based on the analysis of practical implementations in transport operations, directly addressing the needs of sector stakeholders and considering the phased elimination of existing barriers. A critical issue on the agenda is the implementation of the 2008 Additional Protocol to the CMR Convention, which provides for the use of the electronic consignment note (e-CMR). Although this protocol has already been adopted by regional countries such as Azerbaijan and Türkiye, the process in Georgia was delayed due to the COVID-19 pandemic. Currently, the Georgian side is actively reactivating the procedures to ensure integration with international standards.

Georgia's legislation already demonstrates positive experience in the digitalization of documentation. In particular, according to Article 119 of the Code of Administrative Offenses of Georgia, driving licenses and vehicle registration documents may be verified in electronic form under certain conditions.

It is argued that Georgia's experience and the full implementation of e-CMR should be extended to other countries participating in the transport corridor. This would ensure:

- optimization of border-crossing procedures;
- increased efficiency of road monitoring and customs services;
- the establishment of a unified digital ecosystem, facilitating operations for both private and public sector entities.

The economic analysis confirms the significant benefits of the technology: reduction of cargo transit time by 20–40%, decrease in operational costs by 15–30%, reduction of excess inventory by 30–50%, and a 10–25% decrease in CO_2 emissions, contributing to the country's positioning as a "green corridor." The paper also identifies systemic barriers to transformation—namely infrastructure fragmentation and the lack of unified data-sharing standards—and proposes the creation of a public-private "digital backbone" as a key policy response.

The results confirm that intelligent management systems represent a decisive pathway for positioning Georgia as a high-tech and sustainable transit platform, with applicability across the wider region.

KEEWORDS: Digital Twin, sustainable transport systems, maritime logistics, transit potential, Middle Corridor, e-CMR, artificial intelligence, digitalization of permit systems.

შესავალი

თანამედროვე გლობალური ეკონომიკური ლანდშაფტი განიცდის მიწოდების ჯაჭვების ფუნდამენტურ ტრანსფორმაციას. „შუა დერეფნის" სტრატეგიული მნიშვნელობის ზრდასთან ერთად, საქართველოს, როგორც სატრანზიტო ჰაბის, როლი კიდევ უფრო აქტუალური ხდება. ხდება. TRACECA-ს 2023 წლის მონაცემებით, ამ კორიდორზე ტვირთბრუნვა 2020–2023 წლებში 40%-ით გაიზარდა, ხოლო პოტენციური ზრდა 2030 წლამდე 3-ჯერ გადამეტებას პროგნოზირებს [7]. თუმცა, ფიზიკური ინფრასტრუქტურის განვითარება უკვე აღარ არის საკმარისი კონკურენტუნარიანობის შესანარჩუნებლად.

საქართველო, როგორც „შუა დერეფნის" საკვანძო რგოლი, ამჟამად ფიზიკური ინფრასტრუქტურის მასშტაბური მოდერნიზაციის ფაზაში იმყოფება. ქვეყნის 2023–2030 წლების ტრანსპორტისა და ლოგისტიკის ეროვნული სტრატეგია ითვალისწინებს საპორტო ინფრასტრუქტურის განვითარებას (მათ შორის ანაკლიის ღრმაწყლოვანი პორტის პროექტი), სარკინიგზო მაგისტრალების მოდერნიზაციასა და ავტომაგისტრალების გაფართოებას[1]. თუმცა, აღნიშნული ფიზიკური პროგრესის პარალელურად, იკვეთება „ციფრული პარადოქსი": სატრანსპორტო საშუალებების გამტარუნარიანობა იზრდება, მაგრამ მონაცემთა ნაკადების მართვა კვლავინდებურად ფრაგმენტულია. ეს სიტუაცია პირდაპირ ამცირებს ქვეყნის კონკურენტუნარიანობას 2022 წელს განსაზღვრული "ლოგისტიკური ეფექტიანობის ინდექსის" LPI კონტექსტში[10].

დღეის მდგომარეობით, საქართველოში ლოგისტიკის გაციფრულების პროცესი მიმდინარეობს, თუმცა ის ძირითადად ფრაგმენტულ მოდელს ეფუძნება. სხვადასხვა უწყება (საბაჟო, რკინიგზა, საზღვაო) იყენებს დამოუკიდებელ IT სისტემებს. მიუხედავად იმისა, რომ მიმდინარეობს ნავსადგურის გაერთიანების სისტემის დანერგვა, რომელიც მნიშვნელოვანი ნაბიჯია.

კვლევის შედეგად გამოიკვეთა, რომ საქართველოს ლოგისტიკური ჯაჭვის ყველაზე სუსტი რგოლი არის არა ტექნიკური აღჭურვილობის ნაკლებობა, არამედ თანამშრომლობის დეფიციტი – კერძოდ, მონაცემთა გაცვლის ერთიან, საერთაშორისო სტანდარტებთან თავსებადი ციფრული არქიტექტურის არარსებობა, კერძოდ: მონაცემთა ფრაგმენტაცია, e-CMR-ის დანერგვის შეფერხება, ტექნოლოგიური დამოკიდებულება.

ინფორმაცია ტვირთის სტატუსის, დოკუმენტაციისა და ლოგისტიკური ოპერაციების შესახებ არ არის ინტეგრირებული ერთიან, რეალურ დროში მოქმედ პლატფორმაში. ეს იწვევს „მონაცემთა ბოთლის ყელს", სადაც ფიზიკური ტვირთი ელოდება ადმინისტრაციულ პროცედურებს მხოლოდ იმიტომ, რომ სისტემები ერთმანეთს ვერ „ესაუბრებიან".

მიუხედავად იმისა, რომ რეგიონის ქვეყნები (აზერბაიჯანი, თურქეთი) და ევროპული ბაზარი აქტიურად გადადიან e-CMR-ზე (რაც სავალდებულო ხდება 2026-2027 წლებისთვის), საქართველოში პროცესის ტემპი არ შეესაბამება გლობალური ლოგისტიკის მოთხოვნებს. ქაღალდის დოკუმენტბრუნვის შენარჩუნება პირდაპირ ზრდის ტრანზიტულ დროსა და ხარჯებს.

ცალკეული კომპანიებისა და უწყებების მიერ სხვადასხვა „დახურული“ პროგრამული უზრუნველყოფის შექმნა ქმნის ბარიერებს სამომავლო ინტეგრაციისთვის. სისტემები, რომლებიც არ ითვალისწინებენ „ღია არქიტექტურას“ ვერ გახდებიან ოპერაციული ეფექტიანობის ინსტრუმენტები, რადგან მათგან მონაცემების მიღება და დამუშავება რთული ან შეუძლებელია. თუ სისტემაში გვაქვს „წყვეტა“ (მაგალითად, საბაჟო მონაცემები არ გადაიცემა ავტომატურად პორტის მართვის სისტემაში), ციფრული ტყუპი კარგავს თავის მთავარ ფუნქციას – რეალურ დროში სიმულაციას და პროგნოზირებას. შედეგად, საქართველო რისკავს, დარჩეს „ფიზიკურ ჰაბად“, ნაცვლად იმისა, რომ ჩამოყალიბდეს ინტეგრირებულ ციფრულ ლოგისტიკურ პლატფორმად, რომელიც ოპტიმიზაციას გაუკეთებს მთლიან სატრანზიტო ჯაჭვს. აქედან გამომდინარე აუცილებელია მენეჯმენტის სისტემების ციფრული მოდერნიზაცია, სადაც Digital Twin (ციფრული ტყუპი) ტექნოლოგია გვევლინება როგორც ინოვაციური ინსტრუმენტი მდგრადი განვითარებისთვის, რომელიც ეფუძნება მონაცემთა უწყვეტობას[2].

Digital Twin წარმოადგენს ფიზიკური სისტემის სრულ ვირტუალურ ასლს, რომელიც რეალურ დროში იღებს და ამუშავებს მონაცემებს. ლოგისტიკურ სექტორში ეს ტექნოლოგია ოთხ ძირითად შრედ სტრუქტურირდება:

1. ფიზიკური შრე – სატრანსპორტო საშუალებები, ინფრასტრუქტურა, ტვირთი;
2. სენსორული შრე – IoT სენსორები, GPS-ტრეკერები, RFID;
3. კავშირის შრე – 5G, ბლოკჩეინი, API ინტეგრაცია;
4. ვირტუალური შრე – AI-ზე დაფუძნებული სიმულაცია, პროგნოზირება და ოპტიმიზაცია.

Digital Twin ტექნოლოგია ცვლის ლოგისტიკური მართვის პარადიგმას "რეაქტიულიდან" "პრედიქტურ" რეჟიმზე. ეს გადასვლა კრიტიკულია ოპერაციული ეფექტიანობისა და მდგრადი სატრანსპორტო სისტემების განვითარებისთვის, განსაკუთრებით მაღალი ინტენსივობის მულტიმოდალური ჰაბებისთვის, როგორებიცაა ფოთი, ბათუმი და დაგეგმილი ანაკლიის ტერმინალი.

ლოგისტიკურ სისტემაში არსებული ციფრული შეფერხებების დიაგნოსტიკისთვის, ნაშრომში გამოყენებულია ციფრული ლოგისტიკის SWOT-ანალიზი (ცხრილი 1), რაც საშუალებას გვაძლევს, სისტემურად შევაფასოთ საქართველოს სატრანზიტო პოტენციალი ციფრულ კონტექსტში.

ცხრილი 1. ციფრული ლოგისტიკის SWOT-ანალიზი

S – ძლიერი მხარეები	W – სუსტი მხარეები
გეოსტრატეგიული მდებარეობა „შუა დერეფანში“. ინფრასტრუქტურის განვითარების მაღალი ტემპი. პოლიტიკური ნება ციფრული რეფორმების მიმართ.	სისტემური ინტეროპერაბელურობის დეფიციტი. e-CMR-ის სრულფასოვანი იმპლემენტაციის შეფერხება. „ფრაგმენტული“ IT-ინფრასტრუქტურა და მონაცემთა იზოლაცია.

O – შესაძლებლობები	T – საფრთხეები
Digital Twin ტექნოლოგიით ოპერაციული ხარჯების შემცირება. საერთაშორისო სატრანზიტო სტანდარტებთან (EU) ინტეგრაცია. მონაცემთა გაცვლის ერთიანი ეკოსისტემის შექმნა.	კონკურენტუნარიანობის დაკარგვა ალტერნატიულ სატრანსპორტო დერეფნებთან. კიბერუსაფრთხოების რისკები მონაცემთა არასწორი მართვის გამო. სატრანზიტო დროის ზრდა და ტვირთნაკადების გადამისამართება.

კვლევის ფარგლებში განხილულია Digital Twin-ის გავლენა სამ ძირითად მიმართულებაზე:

- ოპერაციული ეფექტიანობა და მდგრადობა,
- რისკების მართვა და პრევენციული ანალიტიკა,
- ადმინისტრაციული ბარიერები და მათი დაძლევა.

ტრადიციული ლოგისტიკური სისტემებისგან განსხვავებით, Digital Twin აერთიანებს გარე ფაქტორების მონაცემებს – ამინდის პირობები, საზღვრის დატვირთულობა, გზების მდგომარეობა – და ავტომატურად შესთავაზებს ოპტიმალურ მარშრუტებს. 2018 წლის კვლევების მიხედვით, რომელიც 15 ევროპული ლოგისტიკური კომპანიის მონაცემებს ეფუძნება, ამ ტიპის ოპტიმიზაცია 12–18%-ით ამცირებს საწვავის მოხმარებას [5].

"შუა დერეფნის" შემთხვევაში, ცენტრალური გამოწვევა არის ინტერმოდალური გადაბმის წერტილები „ზღვა-რკინიგზა-ავტო". Notteboom et al. (2022) ადასტურებს, რომ ციფრული ტყუპი ამ კვანძების სინქრონიზაციით ბუნდოვნებისა და მოლოდინის დროს ამცირებს საშუალოდ 35%-ით, რაც შუა დერეფნის ტვირთბრუნვის კომერციულ მიმზიდველობაზე პირდაპირ მოქმედებს [6].

ლოგისტიკური სისტემების გლობალური გამოწვევების ფონზე, საქართველოს სატრანზიტო დერეფნის მდგრადობა დამოკიდებულია არა მხოლოდ ფიზიკურ გამტარუნარიანობაზე, არამედ რისკების მართვის პროაქტიულ მექანიზმებზე. Digital Twin ტექნოლოგია ცვლის ტრადიციულ „კრიზის მართვის" მიდგომას პრევენციულ, მონაცემებზე დაფუძნებულ სტრატეგიაზე, რაც უზრუნველყოფს მიწოდების ჯაჭვის „რეზილიენტურობას" [3].

Digital Twin-ის საშუალებით შესაძლებელია ვირტუალურ სივრცეში სხვადასხვა კრიტიკული სცენარის სიმულაცია: გეოპოლიტიკური ცვლილებები, ბუნებრივი კატასტროფები, სასაზღვრო-გამტარი პუნქტების პარალიზება ან ინფრასტრუქტურული ავარიები. მოდელი აანალიზებს თითოეული სცენარის ზეგავლენას მთლიან სატრანზიტო ჯაჭვზე, რაც გადაწყვეტილების მიმღებ პირებს აძლევს საშუალებას, წინასწარ შეიმუშაონ საგანგებო გეგმა და შეამცირონ რეაგირების დრო.

პრედიქტური ალგორითმები იდენტიფიცირებენ პოტენციურ „ბოთლის ყელებს" მანამ, სანამ ისინი რეალურ პრობლემად იქცევიან. მაგალითად, თუ მონაცემები აჩვენებს ტვირთნაკადის ზრდის ტენდენციას, რომელიც აჭარბებს პორტის ამჟამინდელ რესურსს, სისტემა ავტომატურად აფრთხილებს ოპერატორებს, რათა განხორციელდეს რესურსების გადანაწილება ან ტვირთის გადამისამართება.

ციფრული ტყუპი მონიტორინგს უწევს ინფრასტრუქტურულ კვანძებს (რკინიგზის ლიანდაგები, ამწეები, ტერმინალები). სენსორული მონაცემების საშუალებით ხდე-

ბა ცვეთისა და დაზიანების რისკების პროგნოზირება. პრევენციული ტექნიკური მომსახურება გამორიცხავს მოულოდნელ ტექნიკურ შეფერხებებს, რაც კრიტიკულად მნიშვნელოვანია უწყვეტი სატრანზიტო დერეფნის ფუნქციონირებისთვის.

საქართველოს, როგორც „შუა დერეფნის“ საკვანძო რგოლისათვის, რისკების მართვის ეს ინსტრუმენტი წარმოადგენს გეოპოლიტიკურ და ეკონომიკურ უპირატესობას. საერთაშორისო დამკვეთები (ლოგისტიკური გიგანტები) ირჩევენ იმ დერეფნებს, სადაც ტვირთის მიწოდების ალბათობა და რისკების მინიმიზაცია უფრო მაღალია[4].

Digital Twin-ით აღჭურვილი სისტემა გვთავაზობს „გარანტირებულ მიწოდების ჯაჭვს“, სადაც რისკები არა მხოლოდ მართულია, არამედ – გამოთვლადი. ეს ნდობის ფაქტორი არის ის, რაც ზრდის ქვეყნის სანდოობას საერთაშორისო ბაზარზე.

საქართველოს სატრანზიტო დერეფნის კონკურენტუნარიანობის ამაღლება მოითხოვს არა მხოლოდ ფიზიკური ინფრასტრუქტურის განვითარებას, არამედ „პროცედურული დაბრკოლებების“ მინიმიზაციას. ადმინისტრაციული ბარიერები, რომლებიც ძირითადად გამოიხატება პროცედურების გაჭიანურებასა და უწყებათაშორისი მონაცემთა გაცვლის სირთულეებში, წარმოადგენს ფარულ ეკონომიკურ დანახარჯს, რაც აფერხებს ტვირთბრუნვის სიჩქარეს.

ადმინისტრაციული ბარიერები და ციფრული გარდაქმნები

საქართველოს სატრანზიტო დერეფნის კონკურენტუნარიანობა მოითხოვს პროცედურული ბარიერების მინიმიზაციას. ადმინისტრაციული ფრაგმენტაცია – სხვადასხვა უწყების (საბაჟო, ფინანსთა სამინისტრო, საზღვაო ადმინისტრაცია, რკინიგზა) განსხვავებული ციფრული სტანდარტები – ქმნის მონაცემთა ბოთლის ყელს, სადაც ფიზიკური ტვირთი ელოდება ადმინისტრაციულ პროცედურებს.

საქართველოს გამოწვევები და შესაძლებლობები „შუა დერეფნის" მნიშვნელობის გასაზრდელად მოითხოვს არა მხოლოდ ფიზიკური ინფრასტრუქტურის განვითარებას, არამედ უპირველეს ყოვლისა სანებართვო სისტემებისა და დოკუმენტაციის სრულ გაციფრულებას. ECMT-ის ციფრული სანებართვო სისტემის დანერგვის პრაქტიკული მაგალითი საქართველოში უნდა განვიხილოთ როგორც განმეორებადი პირველი ნაბიჯი გლობალურად კონკურენტული ციფრული ლოგისტიკური ჰაბისკენ – გამოცდილება, რომელიც უშუალოდ პასუხობს კონფერენციის ინოვაციური პრაქტიკიდან პოლიტიკამდე გადასვლის ამოცანას.

ამასთნავე, დღის წესრიგში განსაკუთრებული სიმწვავით დგება CMR კონვენციის 2008 წლის დამატებითი ოქმის იმპლემენტაცია, რომელიც ელექტრონული ზედდებულის (e-CMR) გამოყენებას ითვალისწინებს. მიუხედავად იმისა, რომ ამ ოქმს შეუერთდნენ რეგიონის ისეთი ქვეყნები, როგორებიცაა აზერბაიჯანი და თურქეთი, საქართველოში პროცესი COVID-19-ის პანდემიის გამო შეფერხდა. ევროკავშირი e-CMR-ს 2026–2027 წლებისთვის სავალდებულოს გახდის, რაც საქართველოს პროცედურების ტემპის დაჩქარებისკენ უბიძგებს.

პოზიტიური სამართლებრივი პრეცედენტი უკვე არსებობს: საქართველოს ადმინისტრაციულ სამართალდარღვევათა კოდექსის 119-ე მუხლი მართვის უფლების და

სარეგისტრაციო დოკუმენტების ელექტრონული ვალიდაციის შესაძლებლობას იძლევა. ეს ადასტურებს, რომ საკანონმდებლო ბაზა გაციფრულებისთვის მომზადებულია.

Digital Twin ტექნოლოგია ადმინისტრაციული ბარიერების დაძლევის სამ ძირითად მექანიზმს სთავაზობს: 1. "ერთი ფანჯრის" ციფრული პრინციპი – უწყებათაშორისი მონაცემთა გაცვლის ერთიანი ჰაბი; 2. ავტომატიზებული შესაბამისობა – სისტემური ვალიდაცია კორუფციული რისკების გამოსარიცხად; 3. რეალურ დროში ციფრული აუდიტი – ანომალიებზე დაფუძნებული, და არა შემთხვევითი, შემოწმებები.

ადმინისტრაციული ბარიერების დაძლევა მოითხოვს „ციფრულ ტრანსფორმაციას სტრუქტურულ დონეზე". Digital Twin-ის დანერგვა არ არის მხოლოდ ტექნიკური ამოცანა; ეს არის მოწოდება სახელმწიფოს მიმართ, რომ მოახდინოს კანონმდებლობისა და პროცედურების ჰარმონიზაცია ციფრულ ეპოქასთან. საქართველომ უნდა გადაინაცვლოს „კონტროლის პოლიტიკიდან" – „მომსახურების პოლიტიკაზე", სადაც ციფრული სისტემა თავად არის ადმინისტრაციული ბარიერების აღმომფხვრელი მექანიზმი.

Digital Twin-ის დანერგვის მოსალოდნელი ეკონომიკური და ოპერაციული ეფექტი საქართველოს სატრანსპორტო სექტორისთვის ნაჩვენებია ცხრილში 2.

ცხრილი 2. მოსალოდნელი ეკონომიკური და ოპერაციული ეფექტი საქართველოს სატრანსპორტო სექტორისთვის

მაჩვენებელი	მოსალოდნელი ცვლილება
ტვირთის გატარების დრო	20 – 40%
ოპერაციული ხარჯი	15% – 30%
მარაგების სიჭარბე	30% – 50%
CO_2-ის ემისიები (მწვანე ლოგისტიკა)	10% – 25%

წარმოდგენილი ეკონომიკური ეფექტიანობის მაჩვენებლები ეფუძნება საერთაშორისო ლოგისტიკურ სექტორში Digital Twin ტექნოლოგიის დანერგვის წარმატებული პრაქტიკის ანალიზს და ბენჩმარკინგს. კერძოდ, მსგავსი სტრუქტურის მქონე მულტიმოდალური ჰაბების გამოცდილებაზე დაყრდნობით, როგორიცაა როტერდამის პორტი (ნიდერლანდები), სინგაპურის პორტი და ანტვერპენის პორტი (ბელგია).

ტექნოლოგიის სრულფასოვანი იმპლემენტაცია პროგნოზირებს ტვირთბრუნვის დროის 20–40%-იან შემცირებას და საოპერაციო ხარჯების ოპტიმიზაციას 15–30%-ის ფარგლებში.

Digital Twin ტექნოლოგია უზრუნველყოფს მარაგების მართვის პროცესის რეალურ დროში მონიტორინგს, რაც აძლევს კომპანიებს საშუალებას, გადავიდნენ 'Just-in-Time' (ზუსტად დროულად) მომარაგების მოდელზე. ეს 30 – 50% ამცირებს ზედმეტ მარაგებს, რადგან სისტემა წინასწარ პროგნოზირებს მოთხოვნას და გამორიცხავს საჭიროზე მეტი პროდუქციის საწყობში განთავსებას.

მნიშვნელოვანია ხაზი გავუსვათ, რომ ეს მაჩვენებლები წარმოადგენს პოტენციური ეფექტის შუალედს სხვადასხვა დანერგვის სიღრმის პირობებში. ქვედა ზღვარი: 20%, 15%, 30%, 10% შეესაბამება ნაწილობრივ ინტეგრაციას, ხოლო ზედა ზღვარი: 40%,

30%, 50%, 25% – სრულ სისტემურ ინტეგრაციას. საქართველოს კონტექსტში, ინფრასტრუქტურული ფრაგმენტაციის გათვალისწინებით, რეალური ეფექტი პირველ ეტაპზე ქვედა ზღვარს უახლოვდება.

თანამედროვე გლობალურ ლოგისტიკაში ტვირთბრუნვის სიჩქარესთან ერთად გადამწყვეტი მნიშვნელობა ენიჭება მდგრად განვითარებასა და გარემოსდაცვით პასუხისმგებლობას. „შუა დერეფნის“ მიმზიდველობა საერთაშორისო დამკვეთებისთვის პირდაპირპროპორციულია იმისა, თუ რამდენად „მწვანე“ და ეკოლოგიურად ეფექტიანია ის. Digital Twin ტექნოლოგია წარმოადგენს არა მხოლოდ ოპერაციულ, არამედ სტრატეგიულ ინსტრუმენტს ლოგისტიკური პროცესების დეკარბონიზაციისა და ESG სტანდარტების დასაკმაყოფილებლად. ციფრული ტყუპი მოდელირებას უკეთებს საუკეთესო მარშრუტებს, რაც მინიმუმამდე ამცირებს სატრანსპორტო საშუალებების „ნულოვან გარბენს“ და საცობებში დგომის დროს. შესაბამისად, ხდება საწვავის დაზოგვა და CO_2-ის ემისიების პირდაპირი შემცირება, რაც ევროპული სატვირთო ლოგისტიკის ემისიების დაახლოებით 30%-ს შეადგენს [5].

ESG სტანდარტები ითხოვს კომპანიებისგან გამჭვირვალობას. Digital Twin-ის საშუალებით შესაძლებელია ემისიების ზუსტი გაზომვა და დოკუმენტირება, რაც აუცილებელია საერთაშორისო გარემოსდაცვითი რეპორტინგისთვის. ეს მონაცემები ეხმარება საქართველოს ლოგისტიკურ ჰაბებს, იყვნენ თავსებადი საერთაშორისო „მწვანე სტანდარტებთან“.

პორტის ციფრული ტყუპი არეგულირებს ტერმინალში სატვირთო ავტომობილებისა და გემების მოძრაობას, რაც ამცირებს უმოქმედო რეჟიმში მომუშავე ძრავების რაოდენობას. ეს მიდგომა უშუალოდ უწყობს ხელს „ჭკვიანი პორტების“ (Smart Ports) კონცეფციის განხორციელებას[11].

ამრიგად, საქართველოს სატრანზიტო დერეფანი შეიძლება პოზიციონირდეს არა მხოლოდ როგორც გეოგრაფიულად უმოკლესი, არამედ როგორც „ეკოლოგიურად ყველაზე მდგრადი ალტერნატივა“, ხოლო Digital Twin არ არის მხოლოდ ეკონომიკური ეფექტიანობის ინსტრუმენტი, არამედ ის წარმოადგენს საქართველოს სატრანზიტო დერეფნის გარემოსდაცვითი მდგრადობის (ESG) მთავარ გარანტს, რაც ქვეყანას აძლევს უნიკალურ შესაძლებლობას, დაიკავოს ადგილი გლობალურ „მწვანე“ ლოგისტიკურ რუკაზე [7,8,9].

წარმოდგენილი კვლევის ანალიზი ცხადყოფს, რომ Digital Twin ტექნოლოგია წარმოადგენს არა მხოლოდ ტექნოლოგიურ მოდერნიზაციას, არამედ საქართველოს ლოგისტიკური სექტორის სტრატეგიული ტრანსფორმაციის აუცილებელ წინაპირობას.

Digital Twin-ის დანერგვა არის საქართველოს ლოგისტიკური პოტენციალის სრულფასოვანი რეალიზაციის გასაღები. ეს ტექნოლოგია არის ხიდი დღევანდელ ფრაგმენტულ ოპერაციებსა და მომავლის ჭკვიან, მდგრად და უაღრესად ეფექტიან სატრანსპორტო ქსელს შორის. შესაბამისად, აღნიშნული ტექნოლოგიის პრიორიტეტად განსაზღვრა სახელმწიფო სტრატეგიაში არის გეოპოლიტიკური და ეკონომიკური აუცილებლობა, რათა საქართველომ დაიკავოს თავისი კუთვნილი ადგილი გლობალურ ლოგისტიკურ რუკაზე.

ძირითადი დასკვნები:

წარმოდგენილი კვლევა ადასტურებს, რომ Digital Twin ტექნოლოგია წარმოადგენს საქართველოს ლოგისტიკური სექტორის სტრატეგიული ტრანსფორმაციის აუცილებელ წინაპირობას. ოთხი ძირითადი

დასკვნა

ეკონომიკური ეფექტიანობა: Digital Twin-ის პრაქტიკული დანერგვა, საერთაშორისო ბენჩმარკინგზე დაყრდნობით, იძლევა საოპერაციო ხარჯების 15–30%-ით ოპტიმიზაციისა და ტვირთბრუნვის დროის 20–40%-ით შემცირების რეალურ პოტენციალს. ეს ეფექტი, ნაწილობრივი ინტეგრაციის პირობებშიც, საქართველოს LPI ქულის გაუმჯობესებას უზრუნველყოფს.

მდგრადობა და ESG სტანდარტები: ციფრული ოპტიმიზაცია პირდაპირ უკავშირდება ლოგისტიკის დეკარბონიზაციას. ტექნოლოგია საქართველოს სატრანზიტო დერეფანს პოზიციონირებს როგორც „მწვანე დერეფანს", რაც გადამწყვეტი უპირატესობაა თანამედროვე, გარემოსდაცვითი პასუხისმგებლობის მქონე საერთაშორისო ბაზარზე.

რისკების მართვა: პრევენციული ანალიტიკა მიწოდების ჯაჭვის რეზილიენტურობის გაძლიერებას უზრუნველყოფს, რაც განსაკუთრებით მნიშვნელოვანია გეოპოლიტიკური არასტაბილურობის პირობებში.

ინსტიტუციური გარდაქმნა: e-CMR-ის სრული იმპლემენტაცია, ერთიანი ციფრული ჰაბის შექმნა და კონტროლის პოლიტიკიდან – მომსახურების პოლიტიკაზე გადასვლა წარმოადგენს სახელმწიფო პოლიტიკის პრიორიტეტებს.

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Analysis of Port Operational Performance Indicators under Market Conditions

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აბსტრაქტი

სტატიაში განხილულია თანამედროვე პორტი, რომლის მახასიათებლებს გადაზიდვის პროცესის განხორციელებაში ჩართულ კლიენტებთან კონტრაქტი და გაწეული სერვისების მრავალფეროვნება წარმოადგენს. ავტორები აღნიშნავენ, რომ მენეჯმენტის ეფექტიანობა უზრუნველყოფილია შერეული სატრანსპორტო სახეობების, ნავმისადგომებთან და ტვირთის ფრონტებზე არსებული ტვირთის და ტვირთის დამუშავების ტექნოლოგიისა და სასაწყობო პროცედურების გამოყენებით გადაზიდვის ობიექტების მართვის ორგანიზების ერთობლივი სერვისით. სატრანსპორტო კვანძის მთავარი მიზანია – ტექნოლოგიური პროცესის სისტემური განხორციელება, შერეული ტიპის ტრანსპორტისა და საქონლის მიწოდების შეფერხების დროის შემცირება, რაც თავის მხრივ უზრუნველყოფილია პორტში დატვირთვა-გადმოტვირთვის სამუშაო პროცესის ეფექტიანობის ზრდით.

საკვანძო სიტყვები: პორტების საქმიანობა, დამუშავების ტექნოლოგიები, სასაწყობო პროცედურები, პორტი როგორც სატრანსპორტო კვანძი.

ABSTRACT

The article discusses a modern port, characterized by contracts with clients involved in transportation and a variety of services offered. The authors note that effective management depends on providing integrated services, including managing transportation facilities with multiple modes, handling cargo at berths and cargo fronts, and implementing warehousing procedures. The main goal of the transport hub is to systematically execute the technological process, minimizing delays in the movement of mixed transport and the delivery of goods. This is achieved by improving the efficiency of port loading and unloading operations.

KEEWORDS: Port activities, processing technologies, warehousing procedures, port as a transport hub.

შესავალი

პორტის, როგორც სატრანსპორტო კვანძის ნაწილის მუშაობა, ხორციელდება მოძრაობის რეჟიმების კოორდინაციის მიზნით, გადატვირთვის კომპლექსების რგოლებს შორის კოორდინირებული ურთიერთქმედების უზრუნველსაყოფად, სამუშაოს მოცულობის რაციონალური განაწილებით ტვირთის დამუშავების პირდაპირი და სხვა ტექნოლოგიური ვარიანტებისთვის, დასაბუთებული რეზერვებითა და საწყობებში არსებული სატვირთო მარაგებით საწყობებისა და ნავმისადგომების ფრონტის რაციონალური გაფართოებით და გადაკეთებით.

დისკუსია

ცნობილი ფაქტია, რომ თუ ტვირთის დამუშავების სისტემა წარმოდგენილია როგორც სატრანსპორტო კავშირების თანმიმდევრობა, მაშინ პორტში დატვირთვა-გადმოტვირთვის სამუშაო პროცესის გაუმჯობესება მოიცავს ტვირთის მინიმალური სატრანზიტო დროის (შიდა ტრანსპორტირების) უზრუნველყოფას საწყისი წერტილიდან – საბოლოო წერტილამდე, დატვირთვა-გადმოტვირთვის სამუშაო პროცესის ყველა ოპერაციებისა და ელემენტებისთვის. პორტში ასეთ პუნქტებს წარმოადგენს წყლის სატრანსპორტო განყოფილება და სახმელეთო სატრანსპორტო განყოფილება. ეფექტი მიიღწევა პორტის სუბიექტების მიერ დატვირთვა-გადმოტვირთვის სამუშაო პროცესის სხვადასხვა ოპერაციებსა და ელემენტებში მოქმედების სინქრონიზაციის კონვეიერული გზით და „ვიწრო ადგილების“ ლიკვიდაციით. სისტემის სრული რიტმის იდეალურ რეჟიმად ითვლება ტვირთის სინფაზური გავლა. ეს რეჟიმი ხასიათდება პორტში სატრანსპორტო საშუალებების რიგის არარსებობით, ხოლო საწყობები მკაცრად იცავენ ტვირთის მინიმალური რაოდენობით შენახვის ვადებს, რაც მიუთითებს რკინიგზისა და საავტომობილო მაგისტრალების და პორტის ნავ-

მისადგომების გამტარუნარიანობაზე. ხელსაყრელ ამინდში, ტვირთის არსებობისას, ტექნოლოგიური გადაზიდვის ხაზების უპრობლემო ექსპლუატაციისა და პორტის სუბიექტების მიერ დატვირთვა-გადმოტვირთვის სამუშაო პროცესის ოპერაციებისა და ელემენტების დაწყებისა და დასრულების დროების დადგენილ მნიშვნელობებში შესრულების პირობებში, დაცული უნდა იყოს გემის დამუშავების ტექნოლოგიური გეგმა-გრაფიკის განხორციელების ორგანიზება და უზრუნველყოფილი უნდა იყოს ნავმისადგომების მაქსიმალური გამტარუნარიანობა.

არითმიის რეჟიმში პორტში მაქსიმალურია სატრანსპორტო რიგები და შეფერხებები, ასევე საწყობში არსებული ტვირთის მარაგები და სასაწყობე ადგილების საჭიროება. ამავდროულად, ტვირთის დამუშავების ინტენსივობა და ნავმისადგომების გამტარუნარიანობა იღებს მინიმალურ მნიშვნელობებს.

ტერმინალის მუშაობის მაჩვენებლებზე დატვირთვა-გადმოტვირთვის სამუშაო პროცესების რიტმში არსებული შეფერხებების ზემოქმედების აღმოსაფხვრელად, აუცილებელია ვაგონების გაცვლითი ფლოტის, სასაწყობე რეზერვებისა და სატვირთო ფრონტის ნავმისადგომების ქონა, ან სარეზერვო გუნდების შექმნა, რათა უზრუნველყოთ დატვირთვა-გადმოტვირთვის სამუშაოს ექსპლუატაციური და ტექნოლოგიური პროცესის უწყვეტობა დოკერების ცვლის შეცვლის დროს.

იმის გამო, რომ პორტის საწყობებში ტვირთი ინახება მიმღებთან გაგზავნის მოლოდინში, განვითარებული საწყობები უზრუნველყოფენ სხვადასხვა ტიპის ტრანსპორტის გადაადგილების რეჟიმების დამოუკიდებლობას, თამაშობენ ერთგვარი „დამპერატორების" როლს და არბილებენ დროში ცვლად ელემენტებს, რომლებიც ნავმისადგომის გამოსაყენებლად ქმნიან დატვირთვა-გადმოტვირთვის სამუშაო პროცესის ციკლურ ოპერაციებს (გემის ნავმისადგომზე დამაგრების დასრულებიდან მისი ნავმისადგომიდან ჩახსნის დაწყებას შორის არსებული დრო).

პორტის პროდუქციას წარმოადგენს ტვირთის გადატვირთვისა და დასაწყობების და სატრანსპორტო საშუალებების მომსახურება, რომელიც მიეწოდება პორტის სუბიექტებს (გემის სააგენტო და საექსპედიტორო კომპანიებს, რომლებიც წარმოდგენილია მათი მმართველებით – ტვირთის მფლობელებითა და გემის მფლობელებით).

პორტის მუშაობის ეფექტიანობა ფასდება მათემატიკური ან ვერბალური ფორმის კრიტერიუმებით, რომლებიც ახასიათებს მიმდინარე საექსპლუატაციო მაჩვენებლებსა და მათ ინტეგრალურ მნიშვნელობებს. ყველაზე მნიშვნელოვანი ოპერატიული და ეკონომიკური ინდიკატორები, რომელთა მიხედვითაც უნდა დაიგეგმოს და ორგანიზებული იყოს დატვირთვა-გადმოტვირთვის სამუშაო პროცესის განხორციელება, ასევე უნდა განხორციელდეს გემის დამუშავების ტექნოლოგიური გეგმა-გრაფიკის შესრულების შედეგების შეფასება, აღრიცხვა და კონტროლი, მოიცავს დატვირთვა-გადმოტვირთვის სამუშაო პროცესის შემდეგ ექპლუატაციურ და ტექნოლოგიურ მაჩვენებლებს:

- დატვირთვა-გადმოტვირთვის სამუშაო პროცესის ოპერაციების, ელემენტების შესრულების ეფექტიანობა (%), როგორც ნორმალიზებული მნიშვნელობების თანაფარდობა რეალურ ინდიკატორებთან;
- ტვირთის გადატვირთვის ინტენსივობა, როგორც ტვირთის მოცულობის (Q)

თანაფარდობა ტვირთის ოპერაციების დროსთან (t2.4) ტვირთის თითოეული სახეობისთვის;

- ნავმისადგომის (Kკომპლ.) გადატვირთვის კომპლექსის ეფექტიანობა (%), როგორც ტვირთის ოპერაციების ნორმალიზებული (სახელშეკრულებო) ინტენსივობის თანაფარდობა ფაქტობრივ ინტენსივობასთან;
- ნავმისადგომის (K2) გამოყენების ეფექტიანობა (%), როგორც გემის ნავმისადგომზე ყოფნის ნორმალიზებული (სახელშეკრულებო) დროის თანაფარდობა ფაქტობრივ დროსთან;
- ნავმისადგომის სასარგებლო გამოყენების კოეფიციენტი (η), როგორც ტვირთის გადატვირთვის ინტენსივობის თანაფარდობა ნორმის მიხედვით (Vნ) და ფაქტობრივად (Vფ) დატვირთვა-გადმოტვირთვის აღჭურვილობის მაქსიმალურ მწარმოებლურობასთან (Vmax);
- ნავმისადგომის ტექნოლოგიური შეფერხების დრო ნორმის მიხედვით და ფაქტობრივად თითოეული გემისთვის (Tiტექ.შეფ.), რომელიც ტოლია გემის დამაგრებისა (ti1) და ჩახსნის (ti3) დროის ჯამისა;
- ნავმისადგომის უმოქმედობის დრო რიგში მყოფ გემებს შორის (Tiნავ.უმოქმ.), როგორც სხვაობა შემდგომი გემის () ნავმისადგომის ოპერაციულ აკვატორიამდე პილოტირების დროის დასაწყისსა და წინა გემის () ნავმისადგომის ოპერაციული აკვატორიიდან – პილოტების შეხვედრის ან პარკინგის ადგილისკენ პილოტირების დასასრულს შორის, ნავმისადგომის მეტეოროლოგიური პირობების (tkმ) გამო შექმნილი შეფერხების გამოკლებით;
- კონკრეტული გემის მიერ დატვირთვა-გადმოტვირთვის სამუშაო პროცესის (Tiდგსპ.მ.დ.) დაწყების მოლოდინის დრო, როგორც სხვაობა ამ გემის ნავმისადგომის ოპერაციული აკვატორიისკენ პილოტირების დაწყების დროს (ti1.1დ) და ამ გემის ნავსადგურში ან პორტის აკვატორიაში შესვლის დროს (Tiშეს.) შორის;
- ნავმისადგომის გამტარუნარიანობა (Gნ), როგორც გადაზიდული ტვირთის რაოდენობა (Q) დატვირთვა-გადმოტვირთვის სამუშაო (Tდგსპ) პროცესის დროს კონკრეტული გემისთვის (i) და ტვირთის თითოეული სახეობისთვის;
- ჰიდრავლიკური კონსტრუქციების ოპერაციულ აკვატორიაში გემის სამაგრი ოპერაციების დროს არსებული გარემოსდაცვითი უსაფრთხოების უზრუნველყოფის და პორტში სატრანსპორტო გემების ბუქსირების უზრუნველყოფის ეფექტიანობის ინდიკატორები.

პორტის სუბიექტებს შორის ელექტრონული დოკუმენტბრუნვის შექმნა და განვითარება არის უკიდურესად ეფექტიანი გზა ნავმისადგომების ტექნოლოგიური შეფერხების დროის შესამცირებლად და ტრანსპორტის ტიპის შეცვლისას ტვირთის შიდა ტრანსპორტირების დროის შესამცირებლად – ეს არის ახალი სატრანსპორტო, გადამზიდი, სასაწყობე, საბაჟო ტექნოლოგიების დანერგვის გზა. ამ მიმართულების განვითარება პორტის სუბიექტებს შორის ურთიერთობის საკითხებში მნიშვნელოვნად განავითარებს საპორტო გადაზიდვასა და სატრანსპორტო ტექნოლოგიებს, რაც ააჩქარებს საქონლის მოძრაობას.

დატვირთვა-გადმოტვირთვის სამუშაო პროცესის უსაფრთხოების მაჩვენებლები იმსახურებენ ისეთივე ყურადღებას, როგორსაც ექსპლუატაციური და ტექნოლოგი-

ური მაჩვენებლები. პორტში გადაზიდული სახიფათო ტვირთის წილის მატებასთან ერთად, იზრდება რისკის წილი, რომელიც დაკავშირებულია საგანგებო სიტუაციების წარმოქმნასთან, როდესაც გემები რჩებიან ნავმისადგომებთან, მის საოპერაციო აკვატორიაში სატრანსპორტო გემების დამუშავებისა და მანევრირების ქვეშ. პორტში სატრანსპორტო გემების ეკოლოგიურ და ნაოსნობის უსაფრთხოებაზე გავლენას ახდენს ჰიდროლოგიური ვითარება და სინოპტიკური ფაქტორი, რომლებიც საგანგებო სიტუაციების აღმოფხვრის გზით ავარიის თავიდან აცილების თვალსაზრისით, დაბალანსებულია ადამიანური ფაქტორით, რაც გამოხატულია პორტის ბუქსირების პილოტების მიერ ალოგიკური გადაწყვეტილების მიღებაში და მათ კარგ საზღვაო პრაქტიკაში. ნავმისადგომების ოპერაციულ აკვატორიაში სატრანსპორტო გემებისთვის უსაფრთხო მანევრირების უზრუნველყოფისას აუცილებელია კარგი საზღვაო პრაქტიკის ქონა გადაუდებელ სიტუაციებში ბუქსირების მართვაში.

მაგალითად, ბათუმის პორტი განიცდის კონტინენტური და ზღვიური პოლარული და ტროპიკული ჰაერის მასების ძლიერ გადანაცვლებას, რასაც თან მოქავს ძლიერი ჩრდილო-აღმოსავლეთის ქარი და სამხრეთის შტორმები. ეს იწვევს ძლიერ ღელვას და მაღალ, 5 მ-მდე სიმაღლის ტალღებს პორტის შიდა აკვატორიაში. ქარიშხლიან ამინდში შეიძლება მოხდეს გემის ნავმისადგომის კედლებისგან მოწყვეტა, გემების, ჰიდრავლიკური ობიექტების და სხვა ტიპის დაზიანება. ნავმისადგომზე გემის მიმაგრების ოპერაციის უსაფრთხოების ალბათობის და რისკის სიდიდის დასადგენად, სატრანსპორტო გემების ნავმისადგომის ოპერაციულ აკვატორიაში მანევრირებისას, აუცილებელია პორტის ბუქსირების პილოტების ადამიანური ფაქტორისა და კარგი საზღვაო პრაქტიკის ფორმალიზება, მათი შესაბამისი კოეფიციენტების მიღების სახით.

ნაყარი და ნაფანტი სახის ტვირთების გადაზიდვა დაკავშირებულია ატმოსფეროში დიდი რაოდენობით მასალების მტვრის სახით გამოშვებასთან, რაც უარყოფითად მოქმედებს გარემოს მდგომარეობის მაჩვენებლებზე. ეს, უპირველეს ყოვლისა, ეხება ტერმინალებს, რომელთა მუშაობას, როგორც პრაქტიკა გვიჩვენებს, თან ახლავს ჰაერისა და წყლის გარემოს ყველაზე ფართომასშტაბური დაბინძურება. დაბინძურების სხვა წყაროებს წარმოადგენენ ნავთობპროდუქტები და სხვადასხვა კომპონენტები, რომლებიც წყალში ხვდებიან სხვადასხვა მიზეზების გამო, მათ შორის ნალექი წყლისა და სხვა დაბინძურების წყაროების არასანქცირებული ჩაშვების შედეგად. გარემოს ეკოლოგიური მდგომარეობის შესაფასებლად შემუშავებულია კრიტერიუმთა ნაკრები, განსაზღვრული საქართველოს მოქმედი კანონმდებლობით, რომელიც ადგენს ამა თუ იმ ნივთიერებების მაქსიმალურ დასაშვებ კონცენტრაციას. გარემოს ყველაზე გავრცელებული საშიში დამაბინძურებელი ნივთიერებებია: გოგირდის დიოქსიდი და მისი რეაქციების პროდუქტები (გოგირდის მჟავა, მძიმე ლითონების – ვერცხლისწყალი, ტყვია, კადმიუმი – სულფატები და სხვა); კანცეროგენული ნივთიერებები; ქლორორგანული პესტიციდები; ნახშირბადის მონოქსიდი და აზოტის ოქსიდები, ტრანსპორტის დაგროვებისა და საწვავის სხვა სახის ენერგიად გადამყვანების ადგილებში (შიდაწვის ძრავების მუშაობა, სტაციონარული საქვაბე სახლები პორტში და ა.შ.).

დასკვნა

გარემოს მდგომარეობის გასაკონტროლებლად, მაქსიმალური დასაშვები კონცენტრაციის გარდა, გამოყენებულ უნდა იქნას მაქსიმალური დასაშვები ემისიის, მაქსიმალური დასაშვები გადაყრის, მაქსიმალური დასაშვები ნარჩენების დაგროვების და ასევე მაქსიმალური დასაშვები ეკოლოგიური დატვირთვების ინდიკატორები. თითოეულ პორტში, გარემოსდაცვითი მდგომარეობის კონტროლს ახორციელებენ სპეციალური სამსახურები, რომლებიც ასრულებენ დამაბინძურებელი ნივთიერებების ლაბორატორიულ გაზომვებსა და გარემოს მონიტორინგს.

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საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის განვითარების პროგნოზირება საქართველოში

Forecasting the Development of the Digital Transformation of Maritime Logistics in Georgia

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აბსტრაქტი

სტატიის აქტუალობა განისაზღვრება იმით, რომ საზღვაო ლოგისტიკა საერთაშორისო ვაჭრობისა და ტრანსნაციონალური მიწოდების ჯაჭვების ფუნქციონირების ერთ-ერთი საკვანძო საფუძველია, ხოლო მისი შედეგიანობა მზარდად დამოკიდებულია ციფრული ტექნოლოგიების დანერგვაზე, მონაცემთა ინტელექტუალურ მართვასა და ოპერაციული პროცესების ავტომატიზაციაზე.

თანამედროვე გლობალური გარემო, რომელიც ხასიათდება პანდემიური კრიზისებით, გეოპოლიტიკური დაძაბულობით, სამხედრო ესკალაციით, ენერგეტიკული რყევებით, ინფლაციური ზეწოლით, საზღვაო მარშრუტების შეფერხებითა და სადაზღვევო ხარჯების ზრდით, სექტორის წინაშე აყენებს მოქნილი, მდგრადი და ანტიკრიზისული მართვის მოდელების შემუშავების აუცილებლობას.

კვლევის მთავარი მიზანია საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციისა და მეწარმეობრივი განვითარების ურთიერთკავშირის სისტემურ გააზრება. ამ მიზნით გაანალიზებულია ისეთი ტექნოლოგიური მიმართულებები, როგორებიცაა ხელოვნური ინტელექტი, დიდი მონაცემების ანალიტიკა, ჭკვიანი პორტები, ციფრული პლატფორმები, კიბერუსაფრთხოების მექანიზმები და ინტეგრირებული ლოგისტიკური მართვის სისტემები.

კვლევაში შემოთავაზებულია საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციისა და მეწარმეობრივი განვითარების შეფასების ინტეგრირებული ეკონომიკურ-მათემატიკური მოდელი, რომელიც ერთიან ანალიტიკურ სისტემაში აერთიანებს ციფრული მზაობის, ლოგისტიკური ეფექტიანობის, მეწარმეობრივი აქტივობის, მოწყვლადობისა და მდგრადობის ინდიკატორებს.

კვლევა მოიცავს წრფივი ტრანსპორტირების ამოცანის გამოყენებას, რომლის საფუძველზეც ფორმალიზებულია ტვირთ-ნაკადების ოპტიმალური გადანაწილების, საზღვაო მარშრუტების შერჩევისა და ლოგისტიკური დანახარჯების მინიმიზაციის პროცესი მოთხოვნის, მიწოდების, გამტარუნარიანობისა და რისკფაქტორების გათვალისწინებით.

კვლევის ლოგიკის წარმოსაჩენად გამოყენებულია სიმულაციური ანალოგია „კაპიტანი – აისბერგი", რომელიც ეკონომიკურ ჭრილში ტრანსფორმირდება სქემად „ეკონომისტი – გლობალური ეკონომიკური შოკი" და მკაფიოდ წარმოაჩენს პროგნოზირების, ადრეული სიგნალების გამოვლენისა და პრევენციული რეაგირების მნიშვნელობას. აგრეთვე, ეკონომიკურ-მათემატიკური, ოპტიმიზაციური და სიმულაციური მიდგომების ინტეგრირება ქმნის სექტორის მრავალფაქტორული შეფასებისა და პროგნოზირების მყარ თეორიულ-მეთოდოლოგიურ საფუძველს.

კვლევის შედეგებმა აჩვენა, რომ აღნიშნული ინსტრუმენტები მხოლოდ დანახარჯების შემცირებასა და სერვისის ოპერატიულობის გაუმჯობესებას კი – არ ემსახურებაიან, არამედ, ქმნიან გარემოს ინსტიტუციურ და ეკონომიკურ წინაპირობებს ახალი ბიზნესმოდელების, პლატფორმული ლოგისტიკისა და საზღვაო სექტორში ციფრული მეწარმეობის განვითარებისთვის.

საკვანძო სიტყვები: საზღვაო ლოგისტიკა, ციფრული ტრანსფორმაცია, ციფრული მეწარმეობა, გლობალური შოკები, მიწოდების ჯაჭვები.

ABSTRACT

The relevance of the article is determined by the fact that **maritime logistics** constitutes one of the key foundations of international trade and the functioning of transnational supply chains, while its performance is increasingly dependent on the adoption of digital technologies, intelligent data management, and the automation of operational processes. The contemporary global environment, characterized by pandemic crises, geopolitical tensions, military escalation, energy fluctuations, inflationary pressure, disruptions to maritime routes, and rising insurance costs, has created a pressing need for the development of flexible, resilient, and anti-crisis management models within the sector.

The main objective of the research is to provide a systematic understanding of the interrelationship between the digital transformation of maritime logistics and entrepreneurial development. For this purpose, the study analyzes such technological directions as artificial intelligence, big data analytics, smart ports, digital platforms, cybersecurity mechanisms and integrated logistics management systems.

The paper proposes an integrated economic-mathematical model for assessing the digital transformation of maritime logistics and entrepreneurial development, which combines indicators of digital readiness, logistics efficiency, entrepreneurial activity, vulner-

ability, and resilience within a unified analytical framework. The research toolkit also includes the application of the linear transportation problem, through which the process of optimal cargo flow allocation, maritime route selection, and logistics cost minimization is formalized, taking into account demand, supply, capacity, and risk factors.

To illustrate the logic of the research, a simulation analogy, **“Captain – Iceberg,”** is employed, which in economic terms is transformed into the scheme **“Economist – Global Economic Shock”** and clearly demonstrates the significance of forecasting, identifying early signals, and ensuring preventive response. Furthermore, the integration of economic-mathematical, optimization, and simulation approaches provides a solid theoretical and methodological basis for the multifactor assessment and forecasting of the sector.

The findings of the study demonstrate that these instruments serve not only to reduce costs and improve service efficiency, but also to create the institutional and economic preconditions for the development of new business models, platform logistics, and digital entrepreneurship in the maritime sector.

KEEWORDS: maritime logistics, digital transformation, digital entrepreneurship, global shocks, supply chains.

შესავალი

თანამედროვე გლობალური ეკონომიკური სისტემის პირობებში საზღვაო ლოგისტიკა საერთაშორისო ვაჭრობის, რეგიონული ეკონომიკური ინტეგრაციისა და ტრანსნაციონალური მიწოდების ჯაჭვების ფუნქციონირების ერთ-ერთ ფუნდამენტურ საფუძველად განიხილება. მსოფლიო სავაჭრო ბრუნვის მნიშვნელოვანი ნაწილი საზღვაო ტრანსპორტის მეშვეობით ხორციელდება, რაც აღნიშნულ სექტორს განსაკუთრებულ ეკონომიკურ, სტრატეგიულ და გეოპოლიტიკურ მნიშვნელობას ანიჭებს.

თუმცა, ციფრული ეკონომიკის ფორმირებისა და ტექნოლოგიური პროგრესის პირობებში ტრადიციული ლოგისტიკური სისტემები ეტაპობრივად ტრანსფორმირდება ინტელექტუალურ და ავტომატიზებულ მართვის მოდელებად, სადაც განსაკუთრებულ მნიშვნელობას იძენს ხელოვნური ინტელექტის, მონაცემთა ანალიტიკის, ციფრული პლატფორმების, ნივთების ინტერნეტისა და კიბერუსაფრთხოების ინტეგრირებული მექანიზმების გამოყენება.

ბოლო წლებში განვითარებულმა პანდემიურმა კრიზისებმა, გეოპოლიტიკურმა დაძაბულობამ, რეგიონულმა სამხედრო კონფლიქტებმა, ენერგეტიკულმა რყევებმა და გლობალური მიწოდების ჯაჭვების დისბალანსმა მნიშვნელოვნად გაზარდა საზღვაო ლოგისტიკის სექტორის მოწყვლადობა. აღნიშნულმა პროცესებმა განსაკუთრებულად წარმოაჩინა პროგნოზირების, ოპერატიული რეაგირების, რისკების პრევენციული მართვისა და ლოგისტიკური მარშრუტების ოპტიმიზაციის აუცილებლობა. ასეთ პირობებში ციფრული ტრანსფორმაცია განიხილება როგორც სექტორის მდგრადობის, კონკურენტუნარიანობისა და ანტიკრიზისული ადაპტაციის ერთ-ერთი მნიშვნელოვანი წინაპირობა.

საქართველოსთვის აღნიშნული საკითხი დამატებით აქტუალურია ქვეყნის გეოეკონომიკური მდებარეობისა და სატრანზიტო ფუნქციის გათვალისწინებით. შავი ზღვის რეგიონში მიმდინარე ეკონომიკური და პოლიტიკური ცვლილებები საქართველოს წინაშე აყენებს როგორც ახალ გამოწვევებს, ასევე შესაძლებლობებს საზღვაო ლოგისტიკის, სატრანზიტო ინფრასტრუქტურისა და ციფრული მეწარმეობის განვითარების მიმართულებით. შესაბამისად, იზრდება საჭიროება ისეთი ანალიტიკური და პროგნოზული მოდელების შემუშავებაზე, რომლებიც შესაძლებელს გახდის სექტორის ციფრული განვითარების ტენდენციების, რისკებისა და სტრატეგიული პერსპექტივების კომპლექსურ შეფასებას.

ნაშრომის მიზანია საქართველოში საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის განვითარების პროგნოზირების თეორიულ-მეთოდოლოგიური საფუძვლების გააზრება და შესაბამისი ეკონომიკურ-მათემატიკური ინსტრუმენტარიუმის ფორმირება.

კვლევის ფარგლებში გაანალიზებულია ციფრული ტექნოლოგიების გავლენა ლოგისტიკურ ეფექტიანობაზე, ოპერაციული პროცესების ოპტიმიზაციასა და მეწარმეობრივი გარემოს განვითარებაზე.

თეორიული საფუძველი

თანამედროვე სამეცნიერო ლიტერატურაში საზღვაო ლოგისტიკის ციფრული ტრანსფორმაცია განიხილება არა მხოლოდ ტექნოლოგიური განახლებისა და ოპერაციული პროცესების ავტომატიზაციის პროცესად, არამედ სექტორის ეკონომიკური მდგრადობის, კონკურენტუნარიანობისა და მეწარმეობრივი განვითარების ერთ-ერთ სტრატეგიულ განმსაზღვრელ ფაქტორად.

აღნიშნული მიდგომა, რომლის თანახმადაც ციფრული ტექნოლოგიების ინტეგრირება ლოგისტიკური სისტემების ეფექტიანობაზე, რესურსების განაწილების ოპტიმიზაციაზე, გადაწყვეტილების მიღების პროცესის სისწრაფესა და გლობალური ეკონომიკური რისკებისადმი ადაპტაციის შესაძლებლობებზე.

ამ კონტექსტში განსაკუთრებული ყურადღება ეთმობა ხელოვნური ინტელექტის, მონაცემთა ანალიტიკის, ციფრული პლატფორმებისა და ინტეგრირებული ლოგისტიკური სისტემების გამოყენებას, რომლებიც ქმნის სექტორის ფუნქციონირების უფრო მოქნილ და მონაცემებზე დაფუძნებულ მმართველობით გარემოს.

თანამედროვე კვლევითი მიდგომები მნიშვნელოვან როლს ანიჭებს პროგნოზირების, ოპტიმიზაციისა და სიმულაციური ანალიზის გამოყენებას, რადგან აღნიშნული ინსტრუმენტები უზრუნველყოფს სექტორში მიმდინარე პროცესების მრავალფაქტორულ შეფასებასა და განვითარების შესაძლო სცენარების მოდელირებას. აღნიშნული მეთოდოლოგიური მიდგომები შესაძლებლობას იძლევა შეფასდეს როგორც შიდა, ისე გარე რისკფაქტორების გავლენა საზღვაო ლოგისტიკის სისტემებზე, გაანალიზდეს ალტერნატიული ლოგისტიკური გადაწყვეტილებების ეფექტიანობა და განისაზღვროს სექტორის სტრატეგიული განვითარების ძირითადი მიმართულებები.

საბოლოოდ, კვლევის ფარგლებში შემუშავდა ეკონომიკურ-მათემატიკური მოდელირების თეორიულ-მეთოდოლოგიური საფუძველი, რომელიც ეფუძნება პროგნოზირების, ოპტიმიზაციისა და სიმულაციური ანალიზის ინტეგრირებულ გამოყენებას და უზრუნველყოფს საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის პროცესების კომპლექსურ შეფასებასა და განვითარების პროგნოზირებას.

კვლევის მეთოდოლოგია

კვლევის მეთოდოლოგია ეფუძნება სისტემურ, ინტერდისციპლინურ და კომპლექსურ მიდგომას, რომელიც აერთიანებს ეკონომიკური ანალიზის, ლოგისტიკური მართვის, ციფრული ტრანსფორმაციისა და ეკონომიკურ-მათემატიკური მოდელირების თანამედროვე მეთოდებს. აღნიშნული მიდგომა შესაძლებლობას იძლევა საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის პროცესები გაანალიზდეს როგორც ტექნოლოგიური, ისე ეკონომიკური, ინსტიტუციური და მეწარმეობრივი განვითარების ჭრილში.

კვლევის თეორიულ-მეთოდოლოგიურ საფუძველს წარმოადგენს ციფრული ეკონომიკის, პლატფორმული ეკონომიკის, ინოვაციური განვითარების, ლოგისტიკური სისტემებისა და მეწარმეობრივი საქმიანობის თანამედროვე კონცეფციები. კვლევის პროცესში გამოყენებულია ანალიზისა და სინთეზის, შედარებითი შეფასების, სისტემური მიდგომისა და სტრუქტურულ-ფუნქციური ანალიზის მეთოდები, რომელთა საშუალებითაც შეფასებულია ციფრული ტექნოლოგიების გავლენა საზღვაო ლოგისტიკის ეფექტიანობაზე, ოპერაციული პროცესების ოპტიმიზაციასა და სექტორის განვითარების ტენდენციებზე.

ეკონომიკურ-მათემატიკური ინსტრუმენტარიუმის ფარგლებში გამოყენებულია პროგნოზირების, ოპტიმიზაციისა და სიმულაციური ანალიზის მეთოდები. კერძოდ, კვლევაში გამოყენებულია წრფივი ტრანსპორტირების ამოცანა, რომლის საფუძველზეც ფორმალიზებულია ტვირთნაკადების ოპტიმალური გადანაწილების, საზღვაო მარშრუტების შერჩევისა და ლოგისტიკური დანახარჯების მინიმიზაციის პროცესი მოთხოვნის, მიწოდების, გამტარუნარიანობისა და რისკფაქტორების გათვალისწინებით. აღნიშნული მიდგომა შესაძლებლობას იძლევა შეფასდეს სხვადასხვა ლოგისტიკური ალტერნატივის ეფექტიანობა და განისაზღვროს რესურსების ოპტიმალური განაწილების მიმართულებები.

კვლევის ფარგლებში გამოყენებულია აგრეთვე სიმულაციური ანალიზის მიდგომა, რომელიც ეფუძნება სქემას – „ეკონომისტი – გლობალური ეკონომიკური შოკი“. აღნიშნული მიდგომის ფარგლებში ეკონომისტი განიხილება როგორც ანალიტიკური სუბიექტი, რომელიც ახორციელებს გლობალურ ეკონომიკურ გარემოში მიმდინარე პროცესების მონიტორინგს, რისკფაქტორების იდენტიფიცირებას, შესაძლო საფრთხეების პროგნოზირებასა და პრევენციული გადაწყვეტილებების ფორმირებას. თავის მხრივ, გლობალური ეკონომიკური შოკი წარმოდგენილია როგორც გარე მაკროეკონომიკური, გეოპოლიტიკური, ენერგეტიკული, პანდემიური ან ლოგისტიკური ფაქტორების ერთობლიობა, რომელიც გავლენას ახდენს საზღვაო

ლოგისტიკის სისტემების სტაბილურობასა და ფუნქციონირების ეფექტიანობაზე.

აღნიშნული სიმულაციური მიდგომა გამოყენებულია კრიზისული მოვლენებისა და ეკონომიკური რყევების პირობებში საზღვაო ლოგისტიკის სისტემების ადაპტაციის შესაძლებლობების, მდგრადობის ხარისხისა და განვითარების შესაძლო სცენარების შეფასებისათვის.

საბოლოოდ, გამოყენებული მეთოდოლოგიური და ეკონომიკურ-მათემატიკური ინსტრუმენტების ინტეგრირება ქმნის საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის პროცესების მრავალფაქტორული ანალიზისა და პროგნოზირების თეორიულ-მეთოდოლოგიურ საფუძველს.

ანალიზი და შედეგები

კვლევის ფარგლებში კომპლექსურად გაანალიზდა საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის პროცესების შავი ზღვის რეგიონის ქვეყნების მაგალითზე, კერძოდ: საქართველოს, თურქეთის, რუმინეთის, ბულგარეთისა და უკრაინის საზღვაო-ლოგისტიკური სისტემების კონტექსტში. კვლევის მიზანს წარმოადგენდა რეგიონში არსებული ციფრული განვითარების დონის, ლოგისტიკური ეფექტიანობის, გლობალური რისკფაქტორებისა და სისტემური მდგრადობის ურთიერთკავშირის შეფასება $I_{MERM_{AID}}$ ინდექსის გამოყენებით, რომელიც კვლევის ფარგლებში სპეციალურად შემუშავდა.

ანალიზისა და შედეგების ქვეთავში, კვლევის ფარგლებში შემუშავდა ლოგიკო-რეფლექსიური ციფრული საზღვაო ლოგისტიკის მდგრადობის ინტეგრირებული ეკონომიკურ-მათემატიკური მოდელი – LRDMLI (Logical-Reflexive Digital Maritime Logistics Index), რომლის მიზანია საზღვაო ლოგისტიკის სისტემების ციფრული ტრანსფორმაციის, ლოგისტიკური ეფექტიანობის, ეკონომიკური მდგრადობისა და გლობალური რისკების ურთიერთკავშირის კომპლექსური შეფასება.

მოდელი ეფუძნება ლოგიკო-რეფლექსიური მოდელირების პრინციპებს, რომლის მიხედვითაც თანამედროვე ხელოვნური ინტელექტის სისტემები ფუნქციონირებს ინფორმაციის, პროგნოზირების, უკუკავშირის, გამოცდილებისა და რეალურ დროში მიმდინარე ანალიტიკური პროცესების ინტეგრირებული გამოყენების საფუძველზე.

მოდელის ზოგადი ფორმა წარმოდგენილია შემდეგი სახით:

$$LRDMLI_i = \alpha AID_i + \beta LRD_i + \gamma LE_i + \delta ER_i + \lambda MERM_i \qquad (1)$$

კვლევის ფარგლებში მოდელის პრაქტიკული გამოყენების მიზნით განხორციელდა საქართველოს საზღვაო ლოგისტიკის სისტემის კომპონენტური შეფასება 0-დან 1-მდე შკალაზე. ექსპერტული შეფასებისა და სტატისტიკური ანალიზის საფუძველზე მიღებული იქნა შემდეგი შედეგები.

მიღებული შედეგი მიუთითებს, რომ საქართველოს საზღვაო ლოგისტიკის სისტე-

მა ამჟამად იმყოფება საშუალო-მოწყვლადობისა და ნაწილობრივი ციფრული ტრანსფორმაციის მდგომარეობაში.

ანალიზმა აჩვენა, რომ AID=0.5825 და LR=0.5975 კომპონენტები მიუთითებს ციფრული ინტეგრაციისა და პროგნოზირებადი მართვის შედარებით პოზიტიურ დონეზე, ხოლო LE=0.61 ასახავს საშუალო ლოგისტიკურ ეფექტიანობას. თუმცა, მაღალი MERM=0.666 მნიშვნელობა ადასტურებს, რომ გლობალური ეკონომიკური შოკები, რეგიონული გეოპოლიტიკური რისკები და მიწოდების ჯაჭვების შეფერხებები მნიშვნელოვნად ამცირებს სისტემის მდგრადობას.

კვლევის შედეგებმა დაადასტურა, რომ საქართველოს საზღვაო ლოგისტიკის მდგრადობის გასაზრდელად აუცილებელია Smart Port სისტემების გაფართოება, პროგნოზირებადი AI პლატფორმების ინტეგრაცია, მონაცემთა რეალურ დროში ანალიტიკა, ციფრული კოორდინაციის გაძლიერება და ლოგიკო-რეფლექსიური გადაწყვეტილების მხარდაჭერის სისტემების დანერგვა.

აღნიშნული მიდგომა ქმნის საზღვაო ლოგისტიკის სისტემების პროგნოზირებისა და სტრატეგიული მართვის ახალ თეორიულ-მეთოდოლოგიურ საფუძველს და უზრუნველყოფს სექტორის მდგრადი და კონკურენტუნარიანი განვითარების შესაძლებლობას თანამედროვე ციფრული ეკონომიკის პირობებში.

აღნიშნული ქვემოდელი ეფუძნება ლოგიკო-რეფლექსიური მოდელირების იმ მიდგომას, რომლის მიხედვითაც გადაწყვეტილების მიმღები სუბიექტი მუდმივად აფასებს სისტემის მდგომარეობას, აანალიზებს წარსულ გამოცდილებას და პროგნოზირებს შესაძლო მომავალ სცენარებს.

კვლევის შედეგებმა დაადასტურა, რომ საქართველოს საზღვაო ლოგისტიკის მდგრადობის გასაზრდელად აუცილებელია Smart Port სისტემების გაფართოება, პროგნოზირებადი AI პლატფორმების ინტეგრაცია, მონაცემთა რეალურ დროში ანალიტიკა, ციფრული კოორდინაციის გაძლიერება და ლოგიკო-რეფლექსიური გადაწყვეტილების მხარდაჭერის სისტემების დანერგვა. აღნიშნული მიდგომა ქმნის საზღვაო ლოგისტიკის სისტემების პროგნოზირებისა და სტრატეგიული მართვის ახალ თეორიულ-მეთოდოლოგიურ საფუძველს და უზრუნველყოფს სექტორის მდგრადი და კონკურენტუნარიანი განვითარების შესაძლებლობას თანამედროვე ციფრული ეკონომიკის პირობებში.

$I_{MERM_{AID}}$ (Maritime Economic Risk Management through Artificial Intelligence and Digitalization) ინდექსი, რომლის სტრუქტურა ეფუძნება ორ ძირითად კომპონენტს: MERM (Maritime Economic Risk and Management) – რომელიც ასახავს საზღვაო ლოგისტიკის სისტემაში არსებულ ეკონომიკურ, ლოგისტიკურ და გლობალურ რისკ-ფაქტორებს და AID (Artificial Intelligence and Digitalization) – რომელიც წარმოადგენს ხელოვნური ინტელექტისა და ციფრული ტექნოლოგიების საფუძველზე აღნიშნული პრობლემების გამოვლენის, კონტროლის, შემცირებისა და ეტაპობრივი აღმოფხვრის მექანიზმს.

კომპონენტი	მაჩვენებელი	აღნიშვნა	შინაარსობრივი განმარტება
MERM	გლობალური შოკები	(GS)	გეოპოლიტიკური კრიზისები, სამხედრო კონფლიქტები, პანდემიები და გლობალური ეკონომიკური რყევები
MERM	რისკფაქტორები	(RF)	ლოგისტიკური, ფინანსური, ოპერაციული და უსაფრთხოების რისკები
MERM	მიწოდების ჯაჭვების შეფერხება	(SC)	ტვირთნაკადების შეფერხება, მარშრუტების ცვლილება, პორტული გადატვირთვა
MERM	ეკონომიკური კრიზისები	(EC)	ინფლაცია, ენერგეტიკული კრიზისი, სავაჭრო შეზღუდვები და ეკონომიკური არასტაბილურობა
MERM	ოპერაციული მოწყვლადობა	(OV)	პორტებისა და ლოგისტიკური ინფრასტრუქტურის შეფერხებების მიმართ მგრძნობელობა
MERM	სადაზღვევო და სატრანსპორტო ხარჯების ზრდა	(IC)	საზღვაო გადაზიდვებთან დაკავშირებული დამატებითი ფინანსური დანახარჯები
AID	ხელოვნური ინტელექტის ინტეგრაცია	(AI)	AI-ზე დაფუძნებული პროგნოზირების, მონიტორინგისა და გადაწყვეტილების მხარდაჭერის სისტემები
AID	მონაცემთა ანალიტიკა	(DA)	Big Data და რეალურ დროში მონაცემთა დამუშავებისა და ანალიზის შესაძლებლობები
AID	ციფრული პლატფორმები	(DP)	ინტეგრირებული ლოგისტიკური და პორტული ციფრული სისტემები
AID	კიბერ-უსაფრთხოების სისტემები	(CS)	მონაცემთა, ინფრასტრუქტურისა და ციფრული ქსელების დაცვის მექანიზმები
AID	Smart Port ტექნოლოგიები	(SP)	ჭკვიანი პორტების მართვისა და ავტომატიზაციის სისტემები
AID	პროგნოზირებადი ანალიტიკა	(PA)	რისკების, ტვირთნაკადებისა და ლოგისტიკური შეფერხებების პროგნოზირების შესაძლებლობები
AID	ოპერაციული რეაგირების სისწრაფე	(OR)	კრიზისულ პირობებში სწრაფი კოორდინაციისა და ადაპტაციის უნარი
AID	ციფრული კოორდინაცია	(DC)	პორტებს, გადამზიდავებსა და ლოგისტიკურ ქსელებს შორის მონაცემთა ინტეგრირებული კავშირი

ანალიზმა აჩვენა, რომ შავი ზღვის რეგიონში საზღვაო ლოგისტიკის სისტემების განვითარებაზე მნიშვნელოვან გავლენას ახდენს გეოპოლიტიკური დაძაბულობა, მიწოდების ჯაჭვების შეფერხება, ენერგეტიკული რყევები და რეგიონული სამხედრო კონფლიქტები. განსაკუთრებით გამოიკვეთა უკრაინაში მიმდინარე სამხედრო პრო-

ცესების გავლენა საზღვაო მარშრუტების სტაბილურობაზე, სატრანზიტო ნაკადების გადანაწილებასა და სადაზღვევო რისკების ზრდაზე. აღნიშნულმა პროცესებმა არა მხოლოდ გაართულა რეგიონული საზღვაო-ლოგისტიკური ქსელების ფუნქციონირება, არამედ მნიშვნელოვნად გაზარდა ტრანსპორტირების დანახარჯები, ლოგისტიკური ოპერაციების დროითი გაურკვევლობა და საერთაშორისო სატრანზიტო მარშრუტების რისკიანობა.

ამასთან, რეგიონში არსებული არასტაბილური გარემო უარყოფი-თად აისახა პორტების ოპერაციულ ეფექტიანობაზე, ტვირთნაკადების უწყვეტობასა და მიწოდების ჯაჭვების კოორდინირებულ ფუნქციონირებაზე. განსაკუთრებით გამოიკვეთა ის გარემოება, რომ გლობალური და რეგიონული შოკების პირობებში ტრადიციული ლოგისტიკური მართვის მექანიზმები ნაკლებად ეფექტიანია სწრაფად ცვალებად გარემოსთან ადაპტაციის პროცესში. აღნიშნულმა ფაქტორებმა მნიშვნელოვნად გაზარდა რეგიონული ლოგისტიკური სისტემების მოწყვლადობა და წარმოაჩინა ციფრული მართვის, პროგნოზირებადი ანალიტიკური სისტემებისა და ხელოვნური ინტელექტის საფუძველზე მოქმედი ოპერატიული გადაწყვეტილებების მხარდაჭერის მექანიზმების აუცილებლობა.

ქვეყანა	MERM	AID	IMERMAID	შეფასება
თურქეთი	0.41	0.78	0.68	მაღალი ციფრული ადაპტაცია და ლოგისტიკური მდგრადობა
რუმინეთი	0.46	0.72	0.62	განვითარებული პორტული დიგიტალიზაცია და ოპერაციული ეფექტიანობა
საქართველო	0.55	0.58	0.51	საშუალო ტრანსფორმაციული პოტენციალი, მაღალი განვითარების შესაძლებლობა
ბულგარეთი	0.61	0.49	0.43	ზომიერი ციფრული ინტეგრაცია, გაზრდილი რეგიონული რისკები
უკრაინა	0.82	0.37	0.21	მაღალი გეოპოლიტიკური მოწყვლადობა და ლოგისტიკური შეფერხებები

ცხრილი N1

კვლევის შედეგებმა აჩვენა, რომ თურქეთი და რუმინეთი შედარებით მაღალი AID კომპონენტით გამოირჩევიან, რაც დაკავშირებულია პორტული ინფრასტრუქტურის დიგიტალიზაციის, მონაცემთა ანალიტიკის სისტემების გამოყენებისა და ინტეგრირებული ლოგისტიკური პლატფორმების განვითარების უფრო მაღალ დონესთან. აღნიშნულ ქვეყნებში ციფრული ტექნოლოგიების ინტეგრაცია მნიშვნელოვნად ზრდის საზღვაო-ლოგისტიკური პროცესების ოპერატიულობას, ამცირებს ინფორმაციულ დანაკარგებს და უზრუნველყოფს ტვირთნაკადების უფრო ეფექტიან მართვას. განსაკუთრებით გამოიკვეთა ის გარემოება, რომ მაღალი AID კომპონენტის მქონე სისტემები უკეთესად ახერხებენ ლოგისტიკური პროცესების კოორდინაციას, სატრა-

ნზიტო ნაკადების გადანაწილებასა და გარე რისკფაქტორებზე ოპერატიულ რეაგირებას.

საქართველოს შემთხვევაში კვლევამ აჩვენა, რომ ქვეყანას გააჩნია მნიშვნელოვანი სატრანზიტო და გეოეკონომიკური პოტენციალი, რაც განპირობებულია მისი სტრატეგიული მდებარეობითა და რეგიონული სატრანზიტო დერეფნების ფუნქციით. მიუხედავად ამისა, ციფრული ტრანსფორმაციისა და ინტეგრირებული ლოგისტიკური მართვის მიმართულებით კვლავ იკვეთება განვითარების საჭიროება. განსაკუთრებით მნიშვნელოვანია Smart Port სისტემების, ხელოვნური ინტელექტის საფუძველზე მოქმედი პროგნოზირების მექანიზმებისა და მონაცემთა ინტეგრირებული ანალიტიკის დანერგვა, რაც შესაძლებლობას შექმნის გაიზარდოს პორტების კონკურენტ-უნარიანობა, შემცირდეს ოპერაციული დანახარჯები და გაძლიერდეს რეგიონული ლოგისტიკური მდგრადობა.

ბულგარეთისა და უკრაინის შემთხვევაში გამოიკვეთა, რომ მაღალი MERM კომპონენტი მნიშვნელოვნად ამცირებს სისტემების ოპერაციულ ეფექტიანობას. მიწოდების ჯაჭვების შეფერხება, გლობალური შოკების ინტენსივობა, რეგიონული უსაფრთხოების რისკები და სამხედრო კონფლიქტებთან დაკავშირებული გაურკვევლობა ზრდის ლოგისტიკურ დანახარჯებს, აფერხებს სატრანზიტო ნაკადების სტაბილურობას და ამცირებს საზღვაო ინფრასტრუქტურის უწყვეტი ფუნქციონირების შესაძლებლობას. განსაკუთრებით გამოიკვეთა, რომ მაღალი რისკის პირობებში ტრადიციული ლოგისტიკური მართვის მექანიზმები ნაკლებად ეფექტიანია, რაც კიდევ უფრო ზრდის ციფრული და პროგნოზირებადი მართვის სისტემების მნიშვნელობას.

DEA (Data Envelopment Analysis) მეთოდის გამოყენებით განხორციელებულმა ეფექტიანობის შეფასებამ დაადასტურა, რომ მაღალი ციფრული მზაობისა და ინტეგრირებული ტექნოლოგიური მართვის მქონე საზღვაო-ლოგისტიკური სისტემები რესურსების გამოყენების შედარებით უფრო მაღალი ეფექტიანობით ხასიათდებიან. ანალიზის პროცესში გამოვლინდა, რომ ხელოვნური ინტელექტის, მონაცემთა ანალიტიკის, ციფრული პლატფორმებისა და კიბერუსაფრთხოების სისტემების ინტეგრირებული გამოყენება არსებით გავლენას ახდენს პორტების ოპერაციულ პროდუქტიულობაზე, ტვირთნაკადების კოორდინაციის ხარისხსა და რეაგირების სისწრაფეზე. ამასთან, დადგინდა, რომ მაღალი AID კომპონენტის მქონე სისტემები შედარებით უკეთ ახერხებენ გლობალური რისკფაქტორების ნეგატიური გავლენის შემცირებას, რაც განსაკუთრებით მნიშვნელოვანი აღმოჩნდა გეოპოლიტიკური დაძაბულობისა და მიწოდების ჯაჭვების შეფერხების პირობებში.

ქვეყანა	DEA	ეფექტიანობა	ძირითადი მახასიათებელი
თურქეთი	0.91	მაღალი ეფექტიანობა	განვითარებული Smart Port სისტემები და მაღალი ციფრული ინტეგრაცია
რუმინეთი	0.84	შედარებით მაღალი ეფექტიანობა	მონაცემთა ანალიტიკისა და ლოგისტიკური პლატფორმების აქტიური გამოყენება
საქართველო	0.73	საშუალო ეფექტიანობა	მზარდი სატრანზიტო პოტენციალი და ნაწილობრივი ციფრული ტრანსფორმაცია

ქვეყანა	DEA	ეფექტიანობა	ძირითადი მახასიათებელი
ბულგარეთი	0.65	საშუალოზე დაბალი ეფექტიანობა	რეგიონული რისკფაქტორების გავლენა და არასაკმარისი დიგიტალიზაცია
უკრაინა	0.48	დაბალი ეფექტიანობა	სამხედრო კონფლიქტით გამოწვეული მაღალი ლოგისტიკური და ოპერაციული რისკები

ცხრილი N2

ცხრილ N2-ში წარმოდგენილი DEA კოეფიციენტები, რომლებიც ასახავენ საზღვაო-ლოგისტიკური სისტემების შედარებით ეფექტიანობას ციფრული რესურსების, ტექნოლოგიური შესაძლებლობებისა და ოპერაციული შედეგების ურთიერთმიმართების საფუძველზე. მაღალი მაჩვენებელი მიუთითებს რესურსების უფრო ეფექტიან გამოყენებასა და სისტემური მდგრადობის უფრო მაღალ ხარისხზე.

კვლევის შედეგების საფუძველზე დადგინდა, რომ IMERMAID ინდექსი ეფექტიანად ასახავს შავი ზღვის რეგიონის საზღვაო ლოგისტიკური სისტემების ციფრული ტრანსფორმაციის, რისკფაქტორებისა და სისტემური მდგრადობის ურთიერთკავშირს. მოდელი შესაძლებლობას იძლევა განხორციელდეს რეგიონული განვითარების ალტერნატიული სცენარების პროგნოზირება, შეფასდეს გლობალური შოკების გავლენა და ჩამოყალიბდეს საზღვაო ლოგისტიკის სექტორის სტრატეგიული განვითარების ანალიტიკური საფუძველი. აღნიშნულმა ანალიზმა ასევე დაადასტურა, რომ ციფრული ტრანსფორმაციის მაღალი დონე პირდაპირ კავშირშია ლოგისტიკური ეფექტიანობის ზრდასთან, ოპერაციული დანახარჯების შემცირებასა და სისტემური მდგრადობის გაძლიერებასთან.

დასკვნა და რეკომენდაციები

კვლევის ფარგლებში შემუშავებულმა ინდექსმა დაადასტურა, რომ საზღვაო ლოგისტიკის ციფრული ტრანსფორმაცია თანამედროვე პირობებში აღარ წარმოადგენს მხოლოდ ტექნოლოგიური მოდერნიზაციის პროცესს და იგი გარდაიქმნება სექტორის სტრატეგიული მდგრადობის, პროგნოზირებადი მართვისა და ანტიკრიზისული ადაპტაციის ერთ-ერთ ძირითად საფუძვლად. დადგინდა, რომ გლობალური ეკონომიკური შოკების, რეგიონული სამხედრო კონფლიქტებისა და მიწოდების ჯაჭვების არასტაბილურობის პირობებში განსაკუთრებულ მნიშვნელობას იძენს ისეთი სისტემების ფორმირება, რომლებიც რეალურ დროში უზრუნველყოფენ მონაცემთა დამუშავებას, რისკების პროგნოზირებასა და ოპერატიული გადაწყვეტილებების მხარდაჭერას.

კვლევამ ასევე აჩვენა, რომ საზღვაო ლოგისტიკის სექტორის ეფექტიანი განვითარება დამოკიდებულია არა მხოლოდ ინფრასტრუქტურულ შესაძლებლობებზე, არამედ ინტეგრირებული ციფრული ეკოსისტემების ფორმირებაზე, სადაც ერთიან სისტემაში ფუნქციონირებს პორტები, ლოგისტიკური ოპერატორები, სატრანზიტო დერეფნები, მონაცემთა ანალიტიკური პლატფორმები და ხელოვნური ინტელექტის საფუძველზე მოქმედი მმართველობითი მექანიზმები. აღნიშნული გარემოება გან-

საკუთრებით მნიშვნელოვანია შავი ზღვის რეგიონისთვის, სადაც გეოპოლიტიკური და ეკონომიკური რისკები მნიშვნელოვნად ზრდის პროგნოზირებადი და მოქნილი ლოგისტიკური სისტემების აუცილებლობას.

კვლევის შედეგების საფუძველზე მიზანშეწონილია:

- საზღვაო ლოგისტიკის სექტორში ხელოვნური ინტელექტის საფუძველზე მოქმედი პროგნოზირებადი მართვის სისტემების ინტეგრირება;
- Smart Port კონცეფციის განვითარების ხელშეწყობა და პორტული ინფრასტრუქტურის ეტაპობრივი დიგიტალიზაცია;
- რეგიონული ციფრული ლოგისტიკური ქსელების ფორმირება შავი ზღვის ქვეყნებს შორის მონაცემთა ინტეგრირებული გაცვლისა და ოპერაციული კოორდინაციის მიზნით;
- ლოგისტიკური რისკების შეფასებისა და კრიზისული პროგნოზირების პროცესში ეკონომიკურ-მათემატიკური და სიმულაციური მოდელირების გამოყენების გაფართოება;
- კიბერუსაფრთხოების მექანიზმების გაძლიერება, როგორც საზღვაო-ლოგისტიკური სისტემების სტრატეგიული მდგრადობის ერთ-ერთი აუცილებელი კომპონენტის.

საბოლოოდ, ინდექსი შეიძლება განიხილებოდეს როგორც საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის შეფასებისა და პროგნოზირების ინტეგრირებული ანალიტიკური ინსტრუმენტი, რომელიც ქმნის სექტორის გრძელვადიანი განვითარების, რისკების მართვისა და სტრატეგიული დაგეგმვის თეორიულ-მეთოდოლოგიურ საფუძველს.

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საზღვაო ტერმინოლოგიასთან დაკავშირებული გამოწვევები

Challenges Related to Maritime Terminology

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თანამედროვე გლობალიზაციის პროცესში ტერმინოლოგიასთან დაკავშირებული გამოწვევები ერთ-ერთი აქტუალური და რთულად დასაძლევი პრობლემაა. აღნიშნული სირთულე განსაკუთრებით ეხება ტექნოლოგიებთან დაკავშირებულ საქმიანობასა და სწავლა-განათლებას. მათ შორის არის საზღვაო საქმიანობასთან დაკავშირებული ტერმინოლოგიის სპეციფიკა და თავისებურებები, რომლებიც იჩენს თავს როგორც საზღვაო საქმიანობაში, ასევე, ცხადია, საზღვაო განათლების მიღების პროცესში. გამომდინარე იქიდან, რომ საზღვაო სფერო სპეციფიკური და სტანდარტიზირებული ტერმინოლოგიის ზედმიწევნითი სიზუსტით გამოყენებას მოითხოვს, აღნიშნული ტერმინოლოგიის სიღრმისეული გააზრება და ადეკვატური გამოყენება აუცილებელია როგორც სრულფასოვანი კომუნიკაციის დასამყარებლად, ასევე უსაფრთხოების უზრუნველსაყოფად. როგორც ცნობილია, საზღვაო საქმიანობის ეფექტურად წარმართვისათვის დიდი მნიშვნელობა ენიჭება ტექნიკური და პროფესიული კომუნიკაციის სრულყოფილად ფუნქციონირებას, რაც დიდწილად დაკავშირებულია კომპლექსური ტექნიკური პროცესების სპეციფიკური ტერმინოლოგიით აღწერასთან. საზღვაო ტერმინოლოგიისა და მეზღვაურთა ლექსიკის, კომუნიკაციის ძირითადი საყრდენი არის ინგლისური ენა, ამდენად ქართულენოვანი სწავლების დროს გარკვეულ პრობლემებს ქმნის ამა თუ იმ ტერმინის ან ვრცელი ტექსტების ადეკვატური გააზრებისათვის. საზღვაო ტერმინოლოგიის ქართულ ენაში ინტეგრაცია არაერთ ფაქტორთანაა დაკავშირებული. აღნიშნული ტერმინები ქართულში გადმოდის როგორც თარგმანის, ისე ტრანსლიტერაციის გზით, რაც ზოგჯერ იწვევს ფორმათა აღრევასა და ნორმატიულ უზუსტობებს. პრობლემას ქმნის როგორც ფონეტიკური, ასევე ორთოგრაფიული და სემანტიკური თავისებურებები. უცხო ენიდან შემოსული ტერმინები ხშირად სხვადასხვა კონტექსტში გამოიყენება განსხვავებული სემანტიკური ნიუნსებით, რაც იმაზე მე-

ტყველებს, რომ არ არის ერთიანი და ზუსტი სტანდარტი. პროფესიულ და აკადემიურ კომუნიკაციაში ამგვარი სპეციფიკური შემთხვევები იწვევს გარკვეულ გადაცდენებს და ართულებს კომუნიკაციის ეფექტურად წარმართვას.

წინამდებარე სტატიის მიზანია საზღვაო ტერმინოლოგიასთან დაკავშირებული გამოწვევების შესწავლა და ანალიზი, რის საფუძველზეც შევეცდებით გარკვეული პრობლემის გადაჭრის გზების გამოვლენას, რაც ხელს შეუწყობს აღნიშნული პრობლემის საფუძვლიან შესწავლასა და მოგვარებას სამომავლოდ. კვლევაში ყურადღება გამახვილებულია საზღვაო ტერმინოლოგიის თარგმნის დროს წარმოშობილ სირთულეებსა და ბარიერებზე. გამომდინარე იქიდან, რომ საზღვაო ტერმინოლოგიის საკმაოდ დიდი ნაწილი ინგლისური ენიდან მომდინარეობს, ქართულ ენაზე მათი ზედმიწევნითი სიზუსტით გადმოტანა ძალიან რთული, შრომატევადი და საპასუხისმგებლო საქმეა. დროთა განმავლობაში უფრო და უფრო ცხადი ხდება, რომ სპეციფიკური ტერმინოლოგიისათვის ადეკვატური ეკვივალენტების არარსებობა ან მათი არაზუსტი მნიშვნელობით გადმოტანა-გამოყენება იწვევს მნიშვნელობის ნაწილობრივ ან სრულ დაკარგვას, რაც უარყოფითად მოქმედებს როგორც პროფესიულ, ასევე აკადემიურ საქმიანობაზე. აღნიშნული გარემოება შემაფერხებელ ფაქტორად რჩება და კიდევ უფრო იზრდება პრობლემის მასშტაბი, რამდენადაც ჩნდება ახალი ტექნოლოგიები, ვითრდება ციფრული ნავიგაცია, რაც იწვევს ახალი ტერმინების გაჩენას, რომელთა სტანდარტიზაცია და სწორი ფორმით დამკვიდრება ერთ-ერთი მთავარი ამოცანაა საზღვაო საქმიანობაში.

კვლევის პროცესში გამოვიყენეთ როგორც საკვლევ თემასთან დაკავშირებული ლიტერატურის მიმოხილვითი ანალიზის მეთოდი, ასევე კვლევის კვანტიტატიური და კვალიტატიური ანალიზის მეთოდები.

კვლევა წარმოადგენს ცდას, ხელი შევუწყოთ ისეთი მნიშვნელოვანი საკითხების გადაწყვეტას, როგორებიცაა საზღვაო ტერმინოლოგიასთან დაკავშირებულ გამოწვევებზე გამკლავება, ტერმინოლოგიის დახვეწის გზების გამოვლენა, ცნობიერების ამაღლების მიზნით ღონისძებების გატარება და ა.შ. ვინაიდან ტერმინოლოგიური პრობლემები საჭიროებს სისტემურ მიდგომას, ჩვენი სტატიის ფarგლებში, ცხადია, შეუძლებელია საკვლევი თემის ამომწურავად შესწავლა და პრობლემის გადაჭრა, თუმცა მსგავსი კვლევები ხელს შეუწყობს საზღვაო ტერმინოლოგიასთან დაკავშირებული ისეთი პრობლემების მოგვარებას, როგორებიცაა ტერმინთა ფონეტიკური სიზუსტე, სემანტიკური სანდოობა, საერთაშორისო სტანდარტებთან შესაბამისობა და სხვ. საბოლოოდ, აღნიშნული გამოწვევების დაძლევა ხელს შეუწყობს საზღვაო სფეროში უსაფრთხოების, ეფექტიანობისა და თანამშრომლობის გაუმჯობესებას.

კვლევის შედეგები აჩვენებს, რომ ზოგიერთი ტერმინი წარმატებითაა ინტეგრირებული ქართულ ენაში, ხოლო სხვები რჩება არასისტემურად. მაგალითად, „Shipment“ შეიძლება დაიწეროს როგორც ტრანსლიტერაციით „შიპმენტი“ ან ითარგმნოს როგორც „გადაზიდვა“, რაც ტექნიკურ დოკუმენტაციაში იწვევს არასანქცირებულ ინტერპრეტაციებს.

საკვანძო სიტყვები: საზღვაო ტერმინები, ტერმინთა ეკვივალენტურობა, სტანდარტიზაცია, ტრანსლიტერაცია.

ABSTRACT

In the process of modern globalization, the challenges related to terminology are one of the most urgent and difficult to overcome problems. This difficulty especially concerns activities related to technologies and learning and education. Among them are the specifics and peculiarities of terminology related to maritime activities, which manifest themselves both in maritime activities and, of course, in the process of receiving maritime education. Given that the maritime sphere requires the use of specific and standardized terminology with meticulous accuracy, a deep understanding and adequate use of this terminology is necessary both for establishing full-fledged communication and for ensuring safety. As is known, for the effective conduct of maritime activities, great importance is attached to the full functioning of technical and professional communication, which is largely related to the description of complex technical processes in specific terminology. The main basis of maritime terminology and seafarers' vocabulary and communication is the English language, thus creating certain problems during Georgian-language teaching for adequate understanding of a particular term or extensive texts. The integration of maritime terminology into the Georgian language is related to a number of factors. The mentioned terms are transferred to Georgian both through translation and transliteration, which sometimes leads to confusion of forms and normative inaccuracies. The problem is created by both phonetic and orthographic and semantic features. Terms imported from a foreign language are often used in different contexts with different semantic nuances, which indicates that there is no single and precise standard. Such specific cases in professional and academic communication cause certain deviations and complicate effective communication. The purpose of this article is to study and analyze the challenges related to maritime terminology, on the basis of which we will try to identify ways to solve certain problems, which will contribute to the thorough study and resolution of this problem in the future. The study focuses on the difficulties and barriers that arise during the translation of maritime terminology. Given that a fairly large part of maritime terminology comes from the English language, translating them into Georgian with meticulous accuracy is a very difficult, time-consuming and responsible task. Over time, it becomes more and more clear that the absence of adequate equivalents for specific terminology or their translation and use with an inaccurate meaning leads to a partial or complete loss of meaning, which negatively affects both professional and academic activities. This circumstance remains an obstacle and the scale of the problem is increasing, as new technologies emerge and digital navigation develops, which leads to the emergence of new terms, the standardization and establishment of which in the correct form is one of the main tasks in maritime activities.

In the research process, we used both the method of review analysis of literature related to the research topic, as well as quantitative and qualitative research analysis methods.

The study is an attempt to contribute to the resolution of such important issues as dealing with challenges related to maritime terminology, identifying ways to improve terminology, conducting awareness-raising activities, etc. Since terminological problems re-

quire a systematic approach, it is obviously impossible to comprehensively study the research topic and solve the problem within the scope of our article, however, such studies will help to solve such problems related to maritime terminology as phonetic accuracy of terms, semantic reliability, compliance with international standards, etc. Ultimately, overcoming these challenges will contribute to improving safety, efficiency and cooperation in the maritime sphere.

The results of the study show that some terms are successfully integrated into the Georgian language, while others remain unsystematic. For example, “Shipment” can be written as a transliteration of “shipment” or translated as “transportation”, which leads to unauthorized interpretations in technical documentation.

KEYWORDS: Maritime terms, Terminological equivalence, Standardization, Transliteration.

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ადამიანური კაპიტალის განვითარების აქტუალური საკითხები საზღვაო სისტემაში

Current Issues in Human Capital Development in the Maritime Sector

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აბსტრაქტი

ადამიანური კაპიტალი წარმოადგენს საზღვაო სისტემის განვითარების ერთ-ერთ უმნიშვნელოვანეს ფაქტორს, განსაკუთრებით ისეთი სტრატეგიული მნიშვნელობის მქონე რეგიონებში, როგორიცაა საქართველო და შავი ზღვა. თანამედროვე პირობებში საზღვაო სექტორი განიცდის დინამიკურ ტრანსფორმაციას, რაც განპირობებულია გლობალიზაციით, ციფრული ტექნოლოგიების ინტეგრაციითა და საერთაშორისო რეგულაციების გამკაცრებით. აღნიშნული პროცესები მნიშვნელოვნად ზრდის მოთხოვნას მაღალკვალიფიციურ, მოქნილ და მრავალკომპეტენტურ სამუშაო ძალაზე.

საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების პროცესს თან ახლავს რიგი გამოწვევები, მათ შორის პროფესიული უნარების დისბალანსი, განათლების სისტემისა და შრომის ბაზრის მოთხოვნებს შორის შეუსაბამობა, უწყვეტი პროფესიული განვითარების შეზღუდული შესაძლებლობები და კვალიფიციური კადრების მიგრაცია. არსებული პრობლემები აფერხებს დარგის კონკურენტუნარიანობას და ამცირებს მისი მდგრადი განვითარების პოტენციალს.

ტრადიციულად, საზღვაო სფეროში კადრების მომზადება ეფუძნება ფორმალურ განათლებასა და სერტიფიცირების სტანდარტებს, რომლებიც რეგულირდება ისეთი საერთაშორისო ორგანიზაციების მიერ, როგორიცაა International Maritime Organization. თუმცა, აღნიშნული მიდგომები სრულად ვერ პასუხობს თანამედროვე მოთხოვნებს, რომლებიც დაკავშირებულია ციფრულ უნარებთან, ეკოლოგიურ ცნობიერებასთან, კრიზისების მართვასთან და ინტერდისციპლინურ თანამშრომლო-

ბასთან. განსაკუთრებით აქტუალურია „ჭკვიანი პორტების“, ავტომატიზაციისა და მწვანე ტრანსპორტის განვითარებასთან დაკავშირებული ახალი კომპეტენციების დანერგვა.

ნაშრომში წარმოდგენილია ადამიანური კაპიტალის განვითარების ინტეგრირებული ანალიზის ჩარჩო საქართველოს საზღვაო სისტემისთვის შავი ზღვის რეგიონულ კონტექსტში. კვლევა ეფუძნება შრომის ბაზრის ანალიზს, კომპეტენციების შეფასებას, დაინტერესებული მხარეების გამოკითხვას და საერთაშორისო პრაქტიკის შედარებით ანალიზს. განსაკუთრებული ყურადღება ეთმობა საგანმანათლებლო პროგრამების მოდერნიზაციას, ინდუსტრიასა და აკადემიურ სექტორს შორის თანამშრომლობის გაღრმავებას და უწყვეტი განათლების სისტემების განვითარებას.

კვლევის შედეგები მიუთითებს, რომ ადამიანური კაპიტალის ეფექტიანი მართვა და განვითარება შესაძლებელია მხოლოდ სისტემური და კოორდინირებული პოლიტიკის ფარგლებში. რეკომენდაციები მოიცავს ციფრული სასწავლო პლატფორმების დანერგვას, პროფესიული გადამზადების პროგრამების გაფართოებას, საჯარო და კერძო სექტორებს შორის პარტნიორობის გაძლიერებას და შრომის ბაზრის მოთხოვნებზე ორიენტირებული საგანმანათლებლო მოდელების შექმნას.

მოსალოდნელი შედეგები გულისხმობს სამუშაო ძალის კონკურენტუნარიანობის ზრდას, დასაქმების შესაძლებლობების გაფართოებას, საზღვაო ოპერაციების უსაფრთხოებისა და ეფექტიანობის გაუმჯობესებას და საქართველოს პოზიციონირების გაძლიერებას საერთაშორისო საზღვაო სისტემაში.

საკვანძო სიტყვები: ადამიანური კაპიტალი, საზღვაო სისტემა, საქართველო, შავი ზღვა, შრომის ბაზარი, ციფრული უნარები

ABSTRACT

Human capital represents a critical driver of development and competitiveness in maritime systems, particularly in strategically important regions such as Georgia and the Black Sea basin. In recent decades, the maritime sector has undergone significant transformation driven by globalization, digitalization, and increasingly stringent international regulations. These trends have intensified the demand for a highly skilled, adaptable, and multidisciplinary workforce capable of operating in complex and technologically advanced environments.

The development of human capital in the Georgian maritime system faces several challenges, including skills mismatch, misalignment between education systems and labor market needs, limited access to lifelong learning opportunities, and migration of qualified professionals. These constraints hinder the sector's ability to achieve sustainable growth and maintain competitiveness in the regional and global maritime economy.

Traditionally, workforce development in the maritime sector has relied on formal education and certification systems governed by international standards, particularly those established by the International Maritime Organization. However, these frameworks do

not fully address emerging needs related to digital competencies, environmental sustainability, crisis management, and interdisciplinary collaboration. The growing importance of smart ports, automation, and green shipping technologies further emphasizes the need for updated training models and competency frameworks.

This paper presents an integrated analytical framework for assessing and enhancing human capital development in the Georgian maritime system within the Black Sea regional context. The research methodology combines labor market analysis, competency mapping, stakeholder surveys, and benchmarking against international best practices. Particular emphasis is placed on aligning educational programs with industry requirements, strengthening collaboration between academia and the maritime sector, and promoting lifelong learning systems.

The findings highlight the necessity of a coordinated and systemic approach to human capital development. Key recommendations include the integration of digital learning platforms, expansion of professional training programs, reinforcement of public-private partnerships, and the development of flexible, demand-driven education models. These measures aim to improve workforce adaptability and resilience in the face of rapid technological and economic changes.

Expected outcomes include increased labor market competitiveness, enhanced employment opportunities, improved safety and operational efficiency in maritime activities, and stronger integration of Georgia into the global maritime network. Ultimately, the study contributes to the formulation of evidence-based policies for sustainable development in the maritime sector of the Black Sea region.

KEYWORDS: human capital, maritime system, Georgia, Black Sea, labor market, digital skill.

შესავალი

თანამედროვე გლობალიზაციის, ტექნოლოგიური პროგრესისა და საერთაშორისო ეკონომიკური ინტეგრაციის პირობებში შავი ზღვის რეგიონი მნიშვნელოვან სატრანსპორტო და ლოგისტიკურ სივრცედ ჩამოყალიბდა. საქართველოსთვის, რომელიც შავი ზღვის აღმოსავლეთ სანაპიროზე მდებარეობს, საზღვაო ინდუსტრია წარმოადგენს ეროვნული ეკონომიკის, საერთაშორისო ვაჭრობისა და რეგიონული ინტეგრაციის ერთ-ერთ უმნიშვნელოვანეს მიმართულებას. ქვეყნის სატრანზიტო ფუნქცია, ფოთისა და ბათუმის პორტების სტრატეგიული მნიშვნელობა და საერთაშორისო სატრანსპორტო დერეფნებში მონაწილეობა განსაკუთრებულ მოთხოვნას აჩენს მაღალკვალიფიციური ადამიანური კაპიტალის მიმართ. მსოფლიო სავაჭრო ბრუნვის დაახლოებით 80-90% ხორციელდება საზღვაო ტრანსპორტის საშუალებით, რაც კიდევ ერთხელ უსვამს ხაზს საზღვაო სისტემის განსაკუთრებულ როლს საერთაშორისო ვაჭრობის, ლოგისტიკისა და ეკონომიკური განვითარების პროცესში. აღნიშნული გარემოებები ზრდის მოთხოვნას მაღალკვალიფიციურ, კონკურენტუნარი-

ან და თანამედროვე მოთხოვნებზე ადაპტირებულ ადამიანურ კაპიტალზე.

ადამიანური კაპიტალი თანამედროვე ეკონომიკურ მეცნიერებაში განიხილება როგორც საზოგადოების, ორგანიზაციისა და სახელმწიფოს განვითარების ერთ-ერთი უმნიშვნელოვანესი რესურსი. საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალის მნიშვნელობა განსაკუთრებით იზრდება, ვინაიდან ამ სფეროში დასაქმებულ პერსონალს უწევს მაღალი პასუხისმგებლობის, ტექნოლოგიური სირთულეების, საერთაშორისო სტანდარტებისა და უსაფრთხოების მოთხოვნების პირობებში საქმიანობა. საზღვაო სფეროში დასაქმებული სპეციალისტების პროფესიული ცოდნა, უნარები, გამოცდილება, კომუნიკაციის კულტურა და კრიზისულ სიტუაციებში მოქმედების უნარი პირდაპირ გავლენას ახდენს როგორც კონკრეტული კომპანიის ეფექტიანობაზე, ისე მთლიანად საზღვაო სექტორის უსაფრთხოებასა და მდგრადობაზე.

ბოლო წლებში საზღვაო ინდუსტრიაში მნიშვნელოვანი ცვლილებები შეინიშნება. ციფრული ტექნოლოგიების დანერგვა, ავტომატიზაცია, ხელოვნური ინტელექტის გამოყენება, ეკოლოგიური სტანდარტების გამკაცრება და საერთაშორისო რეგულაციების ცვლილება მნიშვნელოვნად ცვლის შრომის ბაზრის მოთხოვნებს. აღნიშნული პროცესები საჭიროებს არა მხოლოდ ტექნიკურ ცოდნას, არამედ მუდმივ გადამზადებას, უწყვეტ პროფესიულ განვითარებასა და თანამედროვე კომპეტენციების ფორმირებას.

განსაკუთრებული მნიშვნელობა ენიჭება საზღვაო განათლებისა და პროფესიული მომზადების სისტემის სრულყოფას. საერთაშორისო საზღვაო ორგანიზაციის (IMO) მოთხოვნები, STCW კონვენციის სტანდარტები და თანამედროვე საზღვაო პრაქტიკა განათლების სისტემისგან მოითხოვს ისეთი სპეციალისტების მომზადებას, რომლებიც შეძლებენ სწრაფად ცვალებად გარემოსთან ადაპტაციას და ინოვაციური ტექნოლოგიების ეფექტიან გამოყენებას.

საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების აქტუალობა განპირობებულია რამდენიმე ძირითადი ფაქტორით:

- გლობალური კონკურენციის ზრდა;
- ტექნოლოგიური ტრანსფორმაციის დაჩქარება;
- უსაფრთხოების საერთაშორისო სტანდარტების გამკაცრება;
- ეკოლოგიური მოთხოვნების ზრდა;
- კვალიფიციური კადრების დეფიციტი;
- ახალგაზრდების ინტერესის შემცირება საზღვაო პროფესიების მიმართ;
- პროფესიული გადამზადებისა და უწყვეტი განათლების აუცილებლობა.

განსაკუთრებით მნიშვნელოვანია ადამიანური რესურსების მართვის თანამედროვე მიდგომების დანერგვა საზღვაო კომპანიებსა და საგანმანათლებლო დაწესებულებებში. თანამედროვე პირობებში წარმატებული ორგანიზაციები ყურადღებას ამახვილებენ თანამშრომელთა მოტივაციაზე, კარიერულ განვითარებაზე, ინოვაციური სწავლების მეთოდების დანერგვასა და საერთაშორისო თანამშრომლობის გაღრმავებაზე.

საქართველოსთვის შავი ზღვის საზღვაო სივრცე წარმოადგენს ეკონომიკური განვითარების ერთ-ერთ სტრატეგიულ მიმართულებას. შავი ზღვის რეგიონში საქა-

რთველოს გეოპოლიტიკური მდებარეობა ქვეყანას მნიშვნელოვან როლს ანიჭებს საერთაშორისო სატრანსპორტო და ლოგისტიკურ ქსელებში. ფოთისა და ბათუმის პორტები მნიშვნელოვან ფუნქციას ასრულებენ ევროპისა და აზიის დამაკავშირებელ დერეფანში, რაც კიდევ უფრო ზრდის მოთხოვნას მაღალკვალიფიციურ ადამიანურ კაპიტალზე. თანამედროვე პირობებში საქართველოს საზღვაო სექტორის კონკურენტუნარიანობა პირდაპირ არის დაკავშირებული პროფესიონალი კადრების მომზადებასთან, საერთაშორისო სტანდარტებთან შესაბამისობასა და ინოვაციური განათლების სისტემის განვითარებასთან. ქვეყნის გეოგრაფიული მდებარეობა, შავი ზღვის სანაპირო და საერთაშორისო სატრანსპორტო დერეფნებში მონაწილეობა მნიშვნელოვან შესაძლებლობებს ქმნის საზღვაო სფეროს განვითარებისათვის. შესაბამისად, ადამიანური კაპიტალის ეფექტიანი მართვა და განვითარება მნიშვნელოვანი წინაპირობაა ქვეყნის კონკურენტუნარიანობის ზრდისა და საერთაშორისო საზღვაო სივრცეში ინტეგრაციისათვის.

ნაშრომის მიზანია საქართველოს საზღვაო სისტემასა და შავი ზღვის რეგიონში ადამიანური კაპიტალის განვითარების თანამედროვე ტენდენციების, პრობლემებისა და პერსპექტივების ანალიზი, ასევე იმ ფაქტორების გამოვლენა, რომლებიც გავლენას ახდენენ პროფესიული კომპეტენციების ფორმირებასა და საზღვაო სფეროში კადრების ეფექტიან მართვაზე.

კვლევის ძირითადი ამოცანებია:

- ადამიანური კაპიტალის თეორიული საფუძვლების განხილვა;
- საზღვაო სისტემაში ადამიანური რესურსების განვითარების თავისებურებების ანალიზი;
- თანამედროვე გამოწვევებისა და პრობლემების გამოვლენა;
- საერთაშორისო პრაქტიკის შესწავლა;
- რეკომენდაციების შემუშავება ადამიანური კაპიტალის ეფექტიანი განვითარებისათვის.

ძირითადი ნაწილი

ადამიანური კაპიტალის არსი და მნიშვნელობა საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალი წარმოადგენს ცოდნის, უნარების, გამოცდილების, პროფესიული კომპეტენციებისა და ინდივიდუალური შესაძლებლობების ერთობლიობას, რომელიც ზრდის შრომის პროდუქტიულობას და ქმნის ეკონომიკურ ღირებულებას. თანამედროვე ეკონომიკური თეორიების მიხედვით, ადამიანური კაპიტალი წარმოადგენს ორგანიზაციის ყველაზე მნიშვნელოვან სტრატეგიულ რესურსს.

საქართველოსა და შავი ზღვის რეგიონში ადამიანური კაპიტალის სპეციფიკა განპირობებულია დარგის განსაკუთრებული მახასიათებლებით. საზღვაო სფეროში დასაქმებული პერსონალი მუშაობს მაღალი რისკის პირობებში, სადაც პროფესიული შეცდომა შეიძლება გახდეს ეკოლოგიური, ეკონომიკური და ჰუმანიტარული კრიზისის მიზეზი.

საზღვაო სფეროში ადამიანური კაპიტალის ძირითადი კომპონენტებია:

კომპონენტი	შინაარსი	მნიშვნელობა
პროფესიული ცოდნა	ტექნიკური და თეორიული მომზადება	უსაფრთხოების უზრუნველყოფა
პრაქტიკული უნარები	ნავიგაცია, ტექნიკის მართვა	ოპერაციული ეფექტიანობა
კომუნიკაცია	მრავალეროვან ეკიპაჟთან ურთიერთობა	გუნდური მუშაობა
ლიდერობა	გადაწყვეტილების მიღება	კრიზისების მართვა
ინოვაციური უნარები	ახალი ტექნოლოგიების გამოყენება	კონკურენტუნარიანობა

საზღვაო სფეროში ადამიანური კაპიტალის განვითარების ეფექტიანობა მნიშვნელოვნად არის დამოკიდებული განათლების ხარისხზე, პრაქტიკულ გამოცდილებასა და უწყვეტ პროფესიულ განვითარებაზე.

1. საქართველოს საზღვაო განათლების თანამედროვე გამოწვევები

საქართველოში საზღვაო განათლება მნიშვნელოვანი ტრანსფორმაციის პროცესშია და დიდ გავლენას განიცდის შავი ზღვის რეგიონში მიმდინარე ეკონომიკური და ტექნოლოგიური პროცესებისგან. ტექნოლოგიური პროგრესი და საერთაშორისო რეგულაციების ცვლილება საგანმანათლებლო სისტემას ახალი გამოწვევების წინაშე აყენებს.

1.1. ციფრული ტექნოლოგიების გავლენა

ციფრული ტექნოლოგიების განვითარებამ მნიშვნელოვნად შეცვალა საზღვაო ინდუსტრიის ფუნქციონირების პრინციპები. თანამედროვე გემები აღჭურვილია ავტომატიზებული სისტემებით, ელექტრონული ნავიგაციის საშუალებებითა და ინტელექტუალური მართვის მექანიზმებით.

ეს გარემოება მოითხოვს შემდეგ კომპეტენციებს:

- ციფრული სისტემების მართვა;
- მონაცემთა ანალიზი;
- კიბერუსაფრთხოების ცოდნა;
- ავტომატიზებული ტექნოლოგიების გამოყენება;
- ტექნიკური პრობლემების სწრაფი დიაგნოსტიკა.

კვალიფიციური კადრების დეფიციტი საქართველოში

შავი ზღვის რეგიონში ჩატარებული კვლევების მიხედვით, საზღვაო სფეროში შეინიშნება მაღალკვალიფიციური ოფიცრებისა და ტექნიკური სპეციალისტების დეფიციტი. აღნიშნული პრობლემა გამოწვეულია:

- პროფესიის მაღალი სირთულით;
- ხანგრძლივი სამუშაო პერიოდებით;
- ფსიქოლოგიური დატვირთვით;
- ახალგაზრდების ინტერესის შემცირებით;
- კარიერული განვითარების შეზღუდული შესაძლებლობებით.

1.2. საერთაშორისო სტანდარტების გავლენა

საერთაშორისო საზღვაო ორგანიზაცია (IMO) და STCW კონვენცია განსაზღვრავენ საზღვაო განათლებისა და სერტიფიცირების ძირითად მოთხოვნებს. თანამედროვე პირობებში განსაკუთრებული მნიშვნელობა ენიჭება:

- პრაქტიკულ სწავლებას;
- სიმულატორების გამოყენებას;
- უსაფრთხოების კულტურის განვითარებას;
- ეკოლოგიური პასუხისმგებლობის ფორმირებას;
- საერთაშორისო კომუნიკაციის უნარებს.

კვლევის მეთოდოლოგია საქართველოსა და შავი ზღვის რეგიონის მაგალითზე

კვლევის მიზანს წარმოადგენდა საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების თანამედროვე მდგომარეობის, არსებული გამოწვევებისა და განვითარების პერსპექტივების შეფასება შავი ზღვის რეგიონის კონტექსტში. კვლევა ორიენტირებული იყო როგორც თეორიული, ისე პრაქტიკული ასპექტების ანალიზზე.

ნაშრომის მეთოდოლოგიური საფუძველი ეფუძნება ინტერდისციპლინურ მიდგომას, რომელიც აერთიანებს ეკონომიკური ანალიზის, განათლების მართვის, ადამიანური რესურსების მართვისა და საზღვაო უსაფრთხოების კვლევის კომპონენტებს.

კვლევის ფარგლებში განსაკუთრებული ყურადღება დაეთმო შემდეგ საკითხებს:

- საქართველოს საზღვაო განათლების სისტემის ეფექტიანობის შეფასებას;
- შავი ზღვის რეგიონში ადამიანური კაპიტალის განვითარების ტენდენციების შედარებით ანალიზს;
- საზღვაო სფეროში დასაქმებული კადრების პროფესიული კომპეტენციების შეფასებას;
- ტექნოლოგიური ტრანსფორმაციის გავლენას დასაქმებასა და პროფესიულ განვითარებაზე;
- საერთაშორისო სტანდარტებთან შესაბამისობის ანალიზს.

2. კვლევის მეთოდები

კვლევის პროცესში გამოყენებული იქნა როგორც თვისებრივი, ისე რაოდენობრივი კვლევის მეთოდები.

1. ლიტერატურის ანალიზი

გაანალიზდა საერთაშორისო საზღვაო ორგანიზაციის (IMO), UNCTAD-ის, ILO-სა და შავი ზღვის რეგიონული ორგანიზაციების ანგარიშები. ასევე გამოყენებული იქნა

საქართველოს საზღვაო ტრანსპორტის სააგენტოს, ეკონომიკის სამინისტროსა და საზღვაო აკადემიების მონაცემები.

2. შედარებითი კვლევის მეთოდი

საქართველოს საზღვაო სისტემის შეფასება განხორციელდა შავი ზღვის რეგიონის სხვა ქვეყნების – რუმინეთის, ბულგარეთისა და თურქეთის – მაგალითებთან შედარებით. შედარების ძირითადი კრიტერიუმები იყო:

კრიტერიუმი	**საქართველო**	**შავი ზღვის სხვა ქვეყნები**
საზღვაო განათლების ხარისხი	განვითარებადი	მაღალი
სიმულაციური ტექნოლოგიები	ნაწილობრივ განვითარებული	ფართოდ დანერგილი
საერთაშორისო სერტიფიცირება	მზარდი	სტაბილური
კვლევითი საქმიანობა	შეზღუდული	განვითარებული
პრაქტიკული სწავლება	არასაკმარისი	ინტენსიური

3. სტატისტიკური ანალიზი

გამოყენებული იქნა 2020–2025 წლების სტატისტიკური მონაცემები, რომლებიც ასახავდა:

- საზღვაო სფეროში დასაქმებულთა რაოდენობას;
- პროფესიული გადამზადების პროგრამებში ჩართულობას;
- საზღვაო სპეციალობებზე სტუდენტთა რაოდენობას;
- საერთაშორისო სერტიფიკაციის მაჩვენებლებს;
- ტექნოლოგიური უნარების განვითარების დონეს.

4. ექსპერტული შეფასების მეთოდი

კვლევის პროცესში გამოყენებული იქნა ექსპერტული შეფასებები საზღვაო განათლების, ლოგისტიკისა და ადამიანური რესურსების მართვის სფეროდან.

ექსპერტთა შეფასებით, საქართველოს საზღვაო სექტორის განვითარების მთავარ გამოწვევებად დასახელდა:

- პრაქტიკული სწავლების დეფიციტი;
- თანამედროვე ტექნოლოგიური ბაზის სიმცირე;
- კადრების გადინება უცხოურ ბაზრებზე;
- ინოვაციური პროგრამების არასაკმარისი განვითარება.

2.1. კვლევის ეტაპები

კვლევა განხორციელდა ოთხ ძირითად ეტაპად:

ეტაპი	შინაარსი	მიზანი
I ეტაპი	თეორიული ლიტერატურის შესწავლა	კონცეპტუალური საფუძვლის ჩამოყალიბება
II ეტაპი	სტატისტიკური მონაცემების ანალიზი	პრობლემების იდენტიფიცირება
III ეტაპი	რეგიონული შედარებითი კვლევა	საერთაშორისო გამოცდილების შეფასება
IV ეტაპი	რეკომენდაციების შემუშავება	პრაქტიკული მოდელის ფორმირება

2.2. კვლევის ძირითადი ჰიპოთეზები

კვლევის ფარგლებში ჩამოყალიბდა რამდენიმე ძირითადი ჰიპოთეზა:

- საქართველოს საზღვაო სექტორის კონკურენტუნარიანობა მნიშვნელოვნად არის დამოკიდებული ადამიანური კაპიტალის ხარისხზე;
- თანამედროვე ტექნოლოგიური კომპეტენციები განსაზღვრავს საზღვაო პერსონალის პროფესიულ ეფექტიანობას;
- შავი ზღვის რეგიონში წარმატებული საზღვაო სისტემები ეფუძნება უწყვეტ განათლებასა და ინოვაციურ სწავლების მოდელებს;
- ადამიანური კაპიტალის განვითარება პირდაპირ გავლენას ახდენს საზღვაო უსაფრთხოების ხარისხზე.

3. კვლევის შედეგები საქართველოს საზღვაო სექტორის მაგალითზე

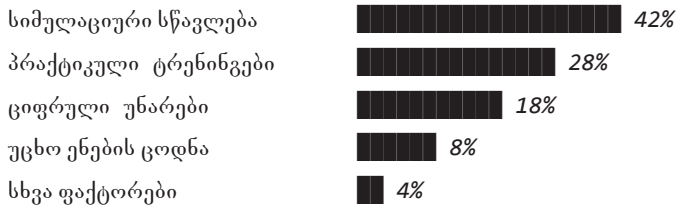
კვლევის შედეგად გამოიკვეთა, რომ საქართველოს საზღვაო სექტორში ადამიანური კაპიტალის განვითარების მიმართულებით მნიშვნელოვანი პოტენციალი არსებობს, თუმცა სისტემას კვლავ ახასიათებს რიგი სტრუქტურული პრობლემები.

3.1. პროფესიული განათლების გავლენა შრომით ეფექტიანობაზე

კვლევის შედეგებმა აჩვენა, რომ თანამედროვე ტექნოლოგიებზე დაფუძნებული სწავლება მნიშვნელოვნად ზრდის საზღვაო სფეროში დასაქმებულთა პროდუქტიულობას.

გამოკითხული სპეციალისტების 72%-მა აღნიშნა, რომ თანამედროვე სიმულატორების გამოყენება მნიშვნელოვნად აუმჯობესებს პრაქტიკულ უნარებს, ხოლო 68%-ის შეფასებით, ციფრული ტექნოლოგიების ცოდნა გახდა კარიერული განვითარების ერთ-ერთი მთავარი ფაქტორი.

დიაგრამა 1. პროფესიული განათლების გავლენა დასაქმების ეფექტიანობაზე



კვლევამ აჩვენა, რომ იმ სტუდენტებსა და სპეციალისტებს, რომლებიც საერთაშორისო სტანდარტების შესაბამის პროგრამებში იყვნენ ჩართული, დასაქმების მაჩვენებელი მნიშვნელოვნად მაღალი ჰქონდათ.

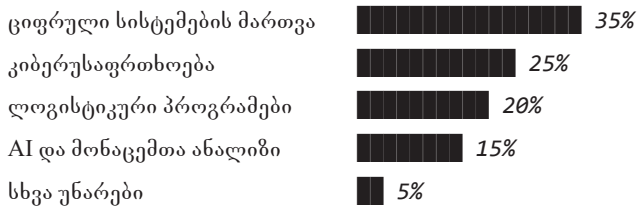
3.2. ტექნოლოგიური ტრანსფორმაციის გავლენა

საქართველოს საზღვაო სექტორში აქტიურად მიმდინარეობს ტექნოლოგიური მოდერნიზაცია. ფოთისა და ბათუმის პორტებში თანამედროვე ლოგისტიკური სისტემების დანერგვამ გაზარდა მოთხოვნა ციფრული უნარების მქონე სპეციალისტებზე.

კვლევის შედეგების მიხედვით:

- გამოკითხული რესპონდენტების 64% მიიჩნევს, რომ არსებული საგანმანათლებლო პროგრამები სრულად ვერ პასუხობს თანამედროვე ტექნოლოგიურ მოთხოვნებს;
- 71% აღნიშნავს, რომ საჭიროა კიბერუსაფრთხოების კომპონენტის გაძლიერება;
- 59% მიიჩნევს, რომ საზღვაო განათლებაში ხელოვნური ინტელექტისა და მონაცემთა ანალიზის ინტეგრაცია აუცილებელია.

დიაგრამა 2. თანამედროვე ტექნოლოგიური კომპეტენციების საჭიროება



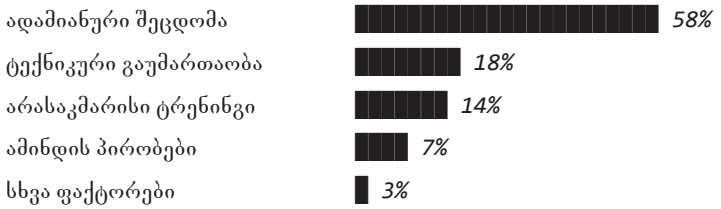
3.3. ადამიანური ფაქტორი და საზღვაო უსაფრთხოება

კვლევის ერთ-ერთი მნიშვნელოვანი მიმართულება იყო ადამიანური ფაქტორის გავლენა საზღვაო უსაფრთხოებაზე.

გამოკითხული სპეციალისტების 74%-მა აღნიშნა, რომ უსაფრთხოების ინციდენტების ძირითადი მიზეზი ადამიანური შეცდომაა, რაც დაკავშირებულია:

- არასაკმარის პრაქტიკულ გამოცდილებასთან;
- ფსიქოლოგიურ გადაღლასთან;
- ტექნოლოგიური სისტემების არასრულ ცოდნასთან;
- კომუნიკაციის პრობლემებთან.

დიაგრამა 3. უსაფრთხოების რისკების გამომწვევი ფაქტორები



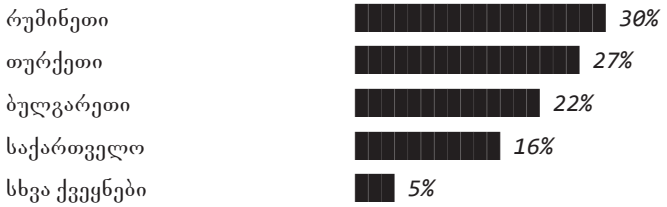
კვლევის შედეგებმა აჩვენა, რომ პრაქტიკული სწავლებისა და ფსიქოლოგიური მომზადების გაუმჯობესება მნიშვნელოვნად შეამცირებს უსაფრთხოების რისკებს.

3.4. შავი ზღვის რეგიონის შედარებითი ანალიზი

საქართველოს მონაცემების შედარებამ შავი ზღვის რეგიონის სხვა ქვეყნებთან აჩვენა, რომ:

- საქართველო სწრაფად ვითარდება საზღვაო განათლების მიმართულებით;
- რეგიონში კონკურენტუნარიანობის გასაზრდელად აუცილებელია ტექნოლოგიური ბაზის გაძლიერება;
- საერთაშორისო პარტნიორობა მნიშვნელოვან გავლენას ახდენს პროფესიული განვითარების ხარისხზე.

დიაგრამა 4. შავი ზღვის რეგიონის საზღვაო განათლების განვითარების დონე

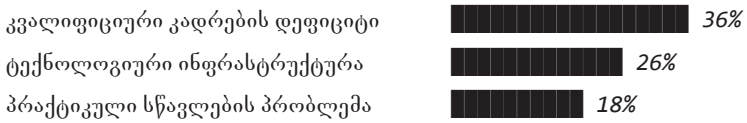


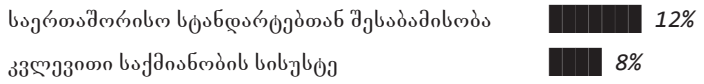
3.5. საქართველოს საზღვაო სექტორის ძირითადი პრობლემები

კვლევის ფარგლებში გამოვლინდა რამდენიმე მნიშვნელოვანი პრობლემა:

- თანამედროვე სიმულაციური ცენტრების სიმცირე;
- პრაქტიკული სწავლების არასაკმარისი დონე;
- კადრების გადინება უცხოურ ბაზრებზე;
- აკადემიური პერსონალის კვალიფიკაციის პრობლემა;
- კვლევითი საქმიანობის არასაკმარისი განვითარება;
- საერთაშორისო სერტიფიცირების დაბალი დონე.

დიაგრამა 5. საქართველოს საზღვაო სექტორის ძირითადი გამოწვევები





3.6. კვლევის ძირითადი მიგნებები

კვლევის შედეგად დადგინდა, რომ:

- ადამიანური კაპიტალის ხარისხი პირდაპირ განსაზღვრავს საქართველოს საზღვაო სექტორის კონკურენტუნარიანობას;
- ტექნოლოგიური ტრანსფორმაცია საჭიროებს ახალი პროფესიული კომპეტენციების ფორმირებას;
- პრაქტიკული სწავლების ხარისხი ერთ-ერთი მთავარი პრობლემაა;
- საერთაშორისო თანამშრომლობა მნიშვნელოვან როლს ასრულებს პროფესიული განვითარების პროცესში;
- შავი ზღვის რეგიონში საქართველოს პოზიციების გაძლიერება დამოკიდებულია ადამიანური რესურსების ეფექტიან მართვაზე.

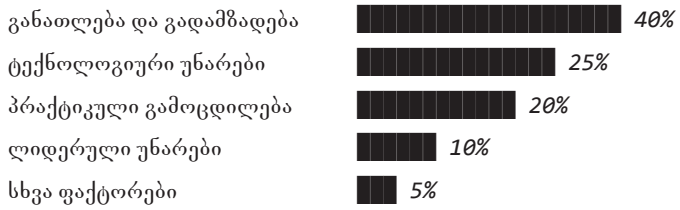
4. შავი ზღვის რეგიონისა და საქართველოს მაგალითის ანალიზი

საქართველოს საზღვაო სექტორისა და შავი ზღვის რეგიონის ანალიზის შედეგად გამოიკვეთა, რომ საზღვაო სისტემაში ადამიანური კაპიტალის განვითარებაზე მნიშვნელოვან გავლენას ახდენს რამდენიმე ძირითადი ფაქტორი.

4.1 საქართველოს საზღვაო განათლების ხარისხისა და შრომითი ეფექტიანობის კავშირი

კვლევის შედეგად დადგინდა, რომ თანამედროვე ტექნოლოგიებზე დაფუძნებული სწავლება მნიშვნელოვნად ზრდის პროფესიული მომზადების ხარისხს.

დიაგრამა 6. საქართველოს საზღვაო სექტორში ადამიანური კაპიტალის განვითარების ძირითადი ფაქტორები



ანალიზმა აჩვენა, რომ პროფესიული გადამზადების პროგრამებში მონაწილე სპეციალისტები უფრო ეფექტიანად ახერხებენ თანამედროვე ტექნოლოგიებთან ადაპტაციას.

4.2. ტექნოლოგიური ტრანსფორმაციის გავლენა შავი ზღვის რეგიონში

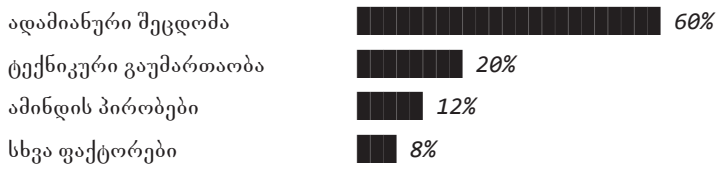
ავტომატიზაციისა და ციფრული სისტემების დანერგვამ მნიშვნელოვნად შეცვალა საზღვაო პერსონალის ფუნქციები. თანამედროვე სპეციალისტს მოეთხოვება არა მხოლოდ ტრადიციული საზღვაო ცოდნა, არამედ:

- IT კომპეტენციები;
- კიბერუსაფრთხოების ცოდნა;
- მონაცემთა დამუშავების უნარი;
- დისტანციური მართვის სისტემების გამოყენება.

4.3. უსაფრთხოების კულტურის მნიშვნელობა საქართველოს საზღვაო სივრცეში

კვლევამ აჩვენა, რომ ადამიანური ფაქტორი კვლავ რჩება საზღვაო ავარიების ერთ-ერთ ძირითად მიზეზად.

დიაგრამა 7. საზღვაო ავარიების გამომწვევი ფაქტორები



აღნიშნული მონაცემები მიუთითებს, რომ ადამიანური კაპიტალის ხარისხის გაუმჯობესება პირდაპირ უკავშირდება უსაფრთხოების დონის ზრდას.

5. შავი ზღვის რეგიონისა და საქართველოს მაგალითის ანალიზი

შავი ზღვის რეგიონი წარმოადგენს მნიშვნელოვან სატრანსპორტო, ეკონომიკურ და გეოპოლიტიკურ სივრცეს, სადაც საზღვაო სისტემის ეფექტიან განვითარებას განსაკუთრებული მნიშვნელობა ენიჭება. რეგიონში მოქმედი სახელმწიფოები – საქართველო, თურქეთი, რუმინეთი, ბულგარეთი და უკრაინა – აქტიურად არიან ჩართული საერთაშორისო საზღვაო გადაზიდვებსა და ლოგისტიკურ პროცესებში.

საქართველოსთვის შავი ზღვის სივრცე განსაკუთრებით მნიშვნელოვანია, რადგან ქვეყნის ეკონომიკური და სატრანზიტო ფუნქცია დიდწილად დამოკიდებულია საზღვაო ინფრასტრუქტურის ეფექტიან მუშაობაზე. ბათუმისა და ფოთის პორტები მნიშვნელოვან როლს ასრულებენ ტვირთბრუნვის, ენერგეტიკული პროექტებისა და საერთაშორისო სავაჭრო დერეფნების განვითარებაში.

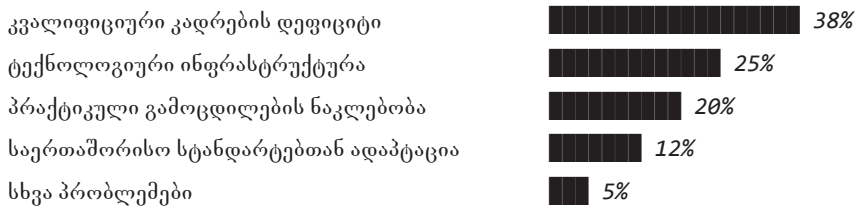
5.1. საქართველოს საზღვაო სექტორის თანამედროვე მდგომარეობა

საქართველოს საზღვაო სექტორში ადამიანური კაპიტალის განვითარების მიმართულებით ბოლო წლებში გარკვეული პროგრესი შეინიშნება. განსაკუთრებით მნიშვნელოვანია საზღვაო განათლების განვითარება, საერთაშორისო სტანდარტებთან ჰარმონიზაცია და პროფესიული გადამზადების პროგრამების დანერგვა.

საქართველოს საზღვაო სფეროს ძირითადი უპირატესობებია:

- სტრატეგიული გეოგრაფიული მდებარეობა;
- საერთაშორისო სატრანსპორტო დერეფნებში მონაწილეობა;
- საზღვაო განათლების განვითარების პოტენციალი;
- საერთაშორისო პარტნიორობის შესაძლებლობები.
- თუმცა, კვლავ რჩება რიგი პრობლემები:
- კვალიფიციური კადრების დეფიციტი;
- თანამედროვე ტექნოლოგიური ბაზის შეზღუდულობა;
- პრაქტიკული სწავლების არასაკმარისი დონე;
- ახალგაზრდა სპეციალისტების გადინება უცხოურ ბაზრებზე.

დიაგრამა 8. საქართველოს საზღვაო სექტორში ადამიანური კაპიტალის ძირითადი გამოწვევები



5.2. შავი ზღვის რეგიონის თანამშრომლობა

შავი ზღვის რეგიონში თანამშრომლობა მნიშვნელოვან გავლენას ახდენს ადამიანური კაპიტალის განვითარებაზე. საერთაშორისო პროექტები, გაცვლითი პროგრამები და ერთობლივი ტრენინგები ხელს უწყობს თანამედროვე პროფესიული სტანდარტების დანერგვას.

განსაკუთრებული მნიშვნელობა აქვს:

- რეგიონული სასწავლო ცენტრების განვითარებას;
- საერთაშორისო სერტიფიცირების პროგრამებს;
- საზღვაო უსაფრთხოების ერთობლივ სწავლებებს;
- ეკოლოგიური უსაფრთხოების მიმართულებით თანამშრომლობას.

5.3. საქართველოს საზღვაო განათლების პერსპექტივები

საქართველოს საზღვაო განათლების სისტემის განვითარება მნიშვნელოვან შესაძლებლობებს ქმნის ქვეყნის ეკონომიკური და საერთაშორისო ინტეგრაციისათვის.

პრიორიტეტულ მიმართულებებს წარმოადგენს:

- თანამედროვე სიმულატორების დანერგვა;

- ინგლისურენოვანი პროგრამების გაფართოება;
- საერთაშორისო აკრედიტაციის გაძლიერება;
- კერძო სექტორსა და უნივერსიტეტებს შორის თანამშრომლობა;
- ციფრული და ეკოლოგიური კომპეტენციების ინტეგრაცია.

6. შავი ზღვის რეგიონის საერთაშორისო პრაქტიკის ანალიზი

საერთაშორისო გამოცდილება ცხადყოფს, რომ წარმატებული საზღვაო სახელმწიფოები განსაკუთრებულ ყურადღებას უთმობენ ადამიანური კაპიტალის განვითარებას.

6.1. ნორვეგიის მოდელი

რუმინეთი ერთ-ერთ ლიდერ სახელმწიფოდ მიიჩნევა საზღვაო განათლების სფეროში. ქვეყნის წარმატება ეფუძნება:

- ინოვაციურ საგანმანათლებლო პროგრამებს;
- უნივერსიტეტებისა და ბიზნესის თანამშრომლობას;
- კვლევითი ცენტრების განვითარებას;
- თანამედროვე სიმულაციური ტექნოლოგიების გამოყენებას.

6.2. ბულგარეთის გამოცდილება

სინგაპური განსაკუთრებულ ყურადღებას უთმობს პროფესიული გადამზადებისა და უწყვეტი სწავლების სისტემას. ქვეყანაში ფუნქციონირებს სპეციალური ცენტრები, რომლებიც ორიენტირებულია:

- თანამედროვე ტექნოლოგიების სწავლებაზე;
- საერთაშორისო სერტიფიცირებაზე;
- ინოვაციური კვლევების მხარდაჭერაზე.

6.3. საქართველოს პერსპექტივები

საქართველოსთვის მნიშვნელოვანია საერთაშორისო გამოცდილების გათვალისწინება და ეროვნული სპეციფიკის შესაბამისად ადამიანური კაპიტალის განვითარების პოლიტიკის ჩამოყალიბება.

პრიორიტეტულ მიმართულებებს წარმოადგენს:

- საზღვაო განათლების ხარისხის გაუმჯობესება;
- პრაქტიკული სწავლების გაძლიერება;
- საერთაშორისო თანამშრომლობის გაფართოება;
- ციფრული ტექნოლოგიების ინტეგრაცია;
- ახალგაზრდების მოზიდვა საზღვაო პროფესიებში.

7. საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების სტრატეგიული მიმართულებები

თანამედროვე პირობებში ადამიანური კაპიტალის ეფექტიანი განვითარება საჭიროებს კომპლექსურ და გრძელვადიან მიდგომას.

7.1. უწყვეტი განათლების სისტემა

საზღვაო სფეროში ტექნოლოგიური ცვლილებების მაღალი ტემპი განსაზღვრავს უწყვეტი სწავლებისა და პროფესიული განვითარების აუცილებლობას.

უწყვეტი განათლების ძირითადი მიმართულებებია:

- პროფესიული გადამზადება;
- ონლაინ სწავლება;
- სიმულაციური ტრენინგები;
- საერთაშორისო გაცვლითი პროგრამები;
- პრაქტიკული სემინარები.

7.2. ინოვაციური ტექნოლოგიების ინტეგრაცია

სასწავლო პროცესში ინოვაციური ტექნოლოგიების გამოყენება მნიშვნელოვნად ზრდის სწავლების ეფექტიანობას.

დიაგრამა 9. ინოვაციური ტექნოლოგიების გამოყენების ეფექტიანობა

7.3. მოტივაციისა და კარიერული განვითარების სისტემა

ადამიანური კაპიტალის განვითარებისათვის მნიშვნელოვანი ფაქტორია თანამშრომელთა მოტივაცია.

ეფექტიანი მოტივაციის ძირითადი ელემენტებია:

- კონკურენტუნარიანი ანაზღაურება;
- კარიერული განვითარების შესაძლებლობა;
- სოციალური დაცვის მექანიზმები;
- პროფესიული აღიარება;
- უსაფრთხო სამუშაო გარემო.

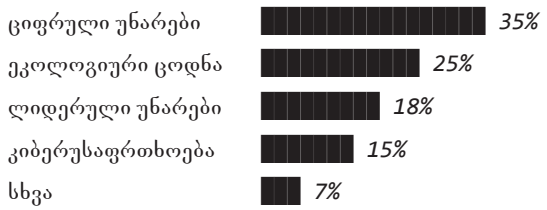
8. შავი ზღვის ეკოლოგიური გამოწვევები და ადამიანური კაპიტალი

შავი ზღვის რეგიონში საზღვაო ინდუსტრია აქტიურად არის ჩართული ეკოლოგიური მდგრადობის პროცესში. საერთაშორისო რეგულაციები მოითხოვს გარემოსდაცვითი სტანდარტების დაცვას და ნახშირბადის ემისიების შემცირებას.

აღნიშნული გარემოება ქმნის მოთხოვნას ახალ კომპეტენციებზე:

- მწვანე ტექნოლოგიების ცოდნა;
- ეკოლოგიური მართვის უნარები;
- ენერგოეფექტური სისტემების გამოყენება;
- გარემოსდაცვითი პასუხისმგებლობა.

დიაგრამა 10. მომავლის საზღვაო კომპეტენციები



9. საქართველოს საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების პრობლემები

საქართველოში საზღვაო განათლებისა და ადამიანური კაპიტალის განვითარების მიმართულებით გარკვეული პროგრესი შეინიშნება, თუმცა კვლავ არსებობს მნიშვნელოვანი გამოწვევები.

ძირითადი პრობლემებია:

- მატერიალურ-ტექნიკური ბაზის არასაკმარისი განვითარება;
- თანამედროვე სიმულატორების დეფიციტი;
- საერთაშორისო პრაქტიკასთან შეუსაბამობა;
- კვალიფიციური აკადემიური პერსონალის სიმცირე;
- კვლევითი საქმიანობის დაბალი დონე;
- სტუდენტთა პრაქტიკული მომზადების პრობლემები.

აღნიშნული პრობლემების გადაჭრა მოითხოვს სახელმწიფოს, საგანმანათლებლო დაწესებულებებისა და კერძო სექტორის კოორდინირებულ თანამშრომლობას.

დასკვნა

კვლევის საფუძველზე შეიძლება ითქვას, რომ ადამიანური კაპიტალი საქართველოს საზღვაო სისტემისა და შავი ზღვის რეგიონში საზღვაო განვითარების უმნიშვნელოვანეს ფაქტორს წარმოადგენს. გლობალიზაციის, ტექნოლოგიური პროგრესისა და საერთაშორისო კონკურენციის პირობებში საზღვაო სფეროს წარმატება მნიშვნელოვნად არის დამოკიდებული მაღალკვალიფიციური, ინოვაციურად მოაზროვნე და თანამედროვე კომპეტენციებით აღჭურვილი კადრების არსებობაზე.

კვლევამ აჩვენა, რომ თანამედროვე საზღვაო ინდუსტრია მნიშვნელოვანი ტრანსფორმაციის პროცესშია. ციფრული ტექნოლოგიების, ავტომატიზაციისა და ეკოლოგიური სტანდარტების განვითარება ქმნის მოთხოვნას ახალ პროფესიულ უნარებსა და კომპეტენციებზე. აღნიშნული გარემოება განსაკუთრებულ მნიშვნელობას ანიჭებს უწყვეტ განათლებას, პროფესიულ გადამზადებასა და თანამედროვე სასწავლო მეთოდების დანერგვას.

კვლევის შედეგად გამოვლინდა, რომ ადამიანური ფაქტორი კვლავ რჩება საზღვაო უსაფრთხოების ერთ-ერთ უმთავრეს გამოწვევად. შესაბამისად, პროფესიული განათლების ხარისხის გაუმჯობესება, უსაფრთხოების კულტურის ფორმირება და პრაქტიკული უნარების განვითარება უნდა გახდეს საზღვაო პოლიტიკის პრიორიტეტული მიმართულება.

შავი ზღვის რეგიონისა და საერთაშორისო გამოცდილების ანალიზმა აჩვენა, რომ წარმატებული საზღვაო სახელმწიფოები მნიშვნელოვან რესურსებს მიმართავენ ადამიანური კაპიტალის განვითარებაზე. აღნიშნული პრაქტიკა განსაკუთრებით მნიშვნელოვანია საქართველოსთვის, რომელიც შავი ზღვის რეგიონში მნიშვნელოვან სატრანზიტო და ლოგისტიკურ ფუნქციას ასრულებს.

ნაშრომის ფარგლებში შემუშავდა შემდეგი რეკომენდაციები:

- საზღვაო განათლების სისტემის მოდერნიზაცია;
- თანამედროვე სიმულაციური ტექნოლოგიების დანერგვა;
- საერთაშორისო პარტნიორობის გაძლიერება;
- უწყვეტი პროფესიული განათლების სისტემის განვითარება;
- ინოვაციური კვლევებისა და პრაქტიკული სწავლების მხარდაჭერა;
- ახალგაზრდების მოზიდვის პროგრამების განხორციელება;
- ეკოლოგიური და ციფრული კომპეტენციების განვითარება.

სამომავლოდ მნიშვნელოვანია საზღვაო სისტემაში ადამიანური კაპიტალის განვითარების საკითხების უფრო ღრმა კვლევა, განსაკუთრებით ხელოვნური ინტელექტის, კიბერუსაფრთხოების, მწვანე ტექნოლოგიებისა და დისტანციური მართვის სისტემების მიმართულებით.

ამრიგად, ადამიანური კაპიტალის ეფექტიანი განვითარება წარმოადგენს არა მხოლოდ ორგანიზაციული წარმატების, არამედ ეროვნული ეკონომიკური უსაფრთხოებისა და საერთაშორისო კონკურენტუნარიანობის მნიშვნელოვან წინაპირობას.

ბიბლიოგრაფია

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სავაჭრო ნაკადის სტრუქტურული ცვლილების დეტერმინანტები

Determinants of Structural Changes in Trade Flows

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აბსტრაქტი

სტატიაში განხილულია თანამედროვე საერთაშორისო ვაჭრობის ლიბერალიზაციის თეორია და პრაქტიკა, მათ შორის, მსოფლიო სავაჭრო ორგანიზაციის ფარგლებშიც, საჭიროებს სერიოზულ კორექტირებას, დიფერენცირებულ მიდგომას განვითარებადი ქვეყნებისა და გარდამავალი ეკონომიკის მქონე ქვეყნების ინტერესებზე მეტი ყურადღების მიქცევას.

საკვანძო სიტყვები: სავაჭრო ნაკადები, საერთაშორისო სავაჭრო ნაკადების სტრუქტურა, სავაჭრო ბრუნვა, ექსპორტი.

ABSTRACT

The article discusses the theory and practice of modern international trade liberalization, including within the framework of the World Trade Organization, which requires serious correction, a differentiated approach, and more attention to the interests of developing countries and countries with economies in transition.

KEEWORDS: trade flows, structure of international trade flows, trade turnover, export.

შესავალი

საერთაშორისო ვაჭრობა შედგება საქონლის ორი კონტრნაკადისგან – ექსპორტი და იმპორტი, რომელთაც ახასიათებს სავაჭრო ბალანსი და სავაჭრო ბრუნვა.

ექსპორტი არის საქონლის გაყიდვა, რომელიც გულისხმობს მის ექსპორტს საზღვარგარეთ. იმპორტი არის პროდუქტის შეძენა, რომელიც მოიცავს მის იმპორტს საზღვარგარეთიდან. სავაჭრო ბალანსი არის სხვაობა ექსპორტისა და იმპორტის ღირებულების მოცულობებს შორის („წმინდა ექსპორტი"). სავაჭრო ბრუნვა არის ექსპორტისა და იმპორტის ღირებულების ჯამი.

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ცხადია, რომ ქვეყნებისთვის ექსპორტი ძალზე მომგებიანია. 1950-1990 წლებში. გლობალური მთლიანი შიდა პროდუქტის წარმოება 5-ჯერ (მუდმივ ფასებში), ხოლო საქონლის ექსპორტი 11-ჯერ გაიზარდა. ამ პერიოდის განმავლობაში წარმოების დარგები 8-ჯერ გაფართოვდა დ მათი ექსპორტი 20-ჯერ გაიზარდა. გასული საუკუნის ბოლო ათწლეულის განმავლობაში, მშპ 1/4-ით გაიზარდა, საქონლის მსოფლიო ექსპორტი გაორმაგდა. შედეგად, საგარეო ვაჭრობის კვოტა, ე.ი. ყველა ქვეყნის ეკონომიკის დამოკიდებულება საგარეო ვაჭრობაზე, გამოითვლება როგორც საგარეო სავაჭრო ბრუნვის ღირებულების თანაფარდობა მშპ-ის ღირებულებასთან მსოფლიოში. 2022-24 წლებში ეს მაჩვენებლები (მუდმივ ფასებში) გაიზარდა 32-დან 40%-მდე (ცხრილი 4).

ცხრილი 4. საქონლისა და მომსახურების მსოფლიო ექსპორტი

მაჩვენებელი	ღირებულება, მლრდ. $			ზრდის საშუალო წლიური ტემპი,%		
	2022	2023	2024	2022	2023	2024
საქონელი	7274	8907	9600	6	16	21
მომსახურება	1763	2125	2500	7	12	18

განვიხილოთ გლობალური ვაჭრობის რამდენიმე მნიშვნელოვანი მახასიათებელი:

1. საერთაშორისო ვაჭრობა მოქმედებს როგორც საერთაშორისო რესურსების მობილობის შემცვლელი – თუ ადამიანური და მატერიალური რესურსები თავისუფლად ვერ გადაადგილდება ქვეყნებს შორის, მაშინ საქონლისა და მომსახურების მოძრაობა ეფექტურად ავსებს ამ ხარვეზს.
2. თითოეულ ქვეყანას აქვს საკუთარი ვალუტა და ეს გასათვალისწინებელია ექსპორტ-იმპორტის ოპერაციების განხორციელებისას.
3. საერთაშორისო ვაჭრობა ექვემდებარება ძლიერ პოლიტიკურ ჩარევას და კონტროლს.

ჩამოვთვლით ექსპორტის ძირითად სტიმულებს:

1. ჭარბი სიმძლავრის გამოყენება.
2. პროდუქციის ერთეულზე ღირებულების შემცირება.
3. მომგებიანობის გაზრდა მარკირების გაზრდის გზით (უნარი, გარკვეულ პირობებში, გავყიდოთ საკუთარი პროდუქცია უფრო დიდი მოგებით საზღვარგარეთ, ვიდრე ქვეყნის შიგნით).
4. გაყიდვების რისკის განაწილება.

იმპორტის ძირითადი სტიმულია:

1. საქონლის ან ნედლეულის იაფი მიწოდება.
2. დიაპაზონის გაფართოება.
3. საქონლის მიწოდების შეწყვეტის რისკის შემცირება.

ასევე შეგვიძლია გამოვყოთ საგარეო ვაჭრობისათვის ხელის შემშლელი გარკვეული დაბრკოლებები:

- არსებული შესაძლებლობების შესახებ ცოდნის ნაკლებობა,
- ინფორმაციის ნაკლებობა ვაჭრობის მექანიზმის შესახებ;
- რისკის შიში;
- სავაჭრო შეზღუდვები.

მსოფლიო ვაჭრობის სტრუქტურა ასახავს მონაწილე ქვეყნების ეკონომიკაში და ეკონომიკური ცხოვრების გლობალიზაციის პროცესში მომხდარ ძვრებს. მსოფლიო ექსპორტში წამყვანი ადგილი უკავია საწარმოო პროდუქციას, რომლის წილმა 2023 წელს 75%-ს მიაღწია (70% 2020 წელს). აქედან მანქანები, აღჭურვილობა და სატრანსპორტო საშუალებები შეადგენს დაახლოებით 40%-ს (36% ათი წლის წინ), რომელთა შორის ყველაზე დინამიურია საოფისე და სატელეკომუნიკაციო აღჭურვილობა – 13%-ზე მეტი, ხოლო საავტომობილო პროდუქციით ვაჭრობის მაჩვენებლი სტაბილიზებულია 9%-ზე. შემდეგი ყველაზე მნიშვნელოვანი სასაქონლო პუნქტი სამთო მრეწველობის პროდუქტებია – 12% (14%), რომელშიც მთავარი ადგილს მანგანუმის მადანი იკავებს. სასოფლო-სამეურნეო პროდუქციის მნიშვნელობა კვლავ მცირდება – 9%-ზე ნაკლებ (საბაზისო 12%-ის საპირწონედ), ასევე ქსოვილისა და ტანსაცმლის – 5%-ზე (6%-ის საპირწონედ).

მეოცე საუკუნის დასაწყისიდან მსოფლიო საქონლის ბაზრის სტრუქტურაში ორი „სართული“ გაჩნდა – ძირითადი საქონლის ბაზარი (საწვავი, მინერალური ნედლეული, სოფლის მეურნეობის პროდუქტები, ხე-ტყე) და მზა პროდუქციის ბაზარი. პირველი ტიპის საქონელს აწარმოებდნენ განვითარებადი და ყოფილი სოციალისტური ქვეყნები, რომლებიც სპეციალიზირებულნი იყვნენ რესურსების და შრომის ინტენსიური საქონლის ექსპორტზე. 132 განვითარებადი ქვეყნიდან 15 სპეციალიზირებულია ნავთობის ექსპორტზე, 43 მინერალური და სასოფლო-სამეურნეო ნედლეულის ექსპორტზე.

მეორე „სართული“ განვითარებული ინდუსტრიული და „პოსტინდუსტრიული“ ქვეყნების პრეროგატივაა. თანამედროვე საერთაშორისო ვაჭრობა ფართო, მრავალსაფეხურიანი სისტემაა. ქვედა სართული – ძირითადი საქონლის ბაზარი – შედგება სასოფლო-სამეურნეო და სამთო პროდუქტებისგან. საშუალო – ნახევარფაბრიკატები და შრომის ინტენსიური მზა პროდუქტები, ე.ი. დაბალი და საშუალო ტექნოლო-

გიების პროდუქტები (შავი მეტალურგია, სამშენებლო მასალები, ტექსტილი და სხვა მსუბუქი მრეწველობის პროდუქტები). საშუალო ტექნოლოგიური საქონელი მოიცავს ჩარხებს, სატრანსპორტო საშუალებებს, ძირითად ქიმიურ პროდუქტებს, რეზინისა და პლასტმასის ნაწარმს და ხის დამუშავების პროდუქტებს.

ბოლო წლების საერთაშორისო ვაჭრობის ყველაზე დინამიური სექტორი არის „მაღალი ტექნოლოგიების" ან ცოდნის ინტენსიური მრეწველობისა და არამატერიალური წარმოების სექტორების საქონლის გაცვლა. ეს არის მაღალტექნოლოგიური პროდუქტების ბაზარი, რომელიც დღეს გადამწყვეტია საოფისე და სატელეკომუნიკაციო აღჭურვილობის, ელექტრონიკას, ელექტრო აღჭურვილობის, ზუსტი საზომი ხელსაწყოების, კოსმოსური ტექნოლოგიების, კომპლექსურ სამედიცინო აღჭურვილობისა და ფარმაცევტულ ბაზარზე.

ძირითადი სავაჭრო ძალებს, როგორც ადრე, ეკონომიკურად მაღალგანვითარებული ქვეყნები, პირველ რიგში, აშშ, გერმანია, იაპონია, საფრანგეთი და დიდი ბრიტანეთი წარმოადგენენ.

განვითარებული ქვეყნების ლიდერობის შენარჩუნება საერთაშორისო ვაჭრობაში უზრუნველყოფილია, უპირველეს ყოვლისა, მაღალტექნოლოგიური პროდუქციისა და მასთან დაკავშირებული სერვისების ექსპორტით. მათზე მოდის ამ პროდუქციის მსოფლიო ექსპორტის თითქმის 3/4, რაც ღირებულებით 1 ტრილიონზე მეტ დოლარს შეადგენს.

საერთაშორისო ვაჭრობის სტრუქტურა ჩვეულებრივ განიხილება მისი გეოგრაფიული განაწილების (გეოგრაფიული სტრუქტურა) და პროდუქტის შინაარსის (სასაქონლო სტრუქტურის) თვალსაზრისით.

ბევრი განვითარებადი ქვეყანა კვლავაც დიდად არის დამოკიდებული სამთო მრეწველობის (ახლო აღმოსავლეთიდან ექსპორტის 75%) და სოფლის მეურნეობის (ლათინური ამერიკიდან და აფრიკიდან) ექსპორტზე.

თუმცა, განვითარებულ ქვეყნებს შორის არის საქონლის ექსპორტზე მაღალი დამოკიდებულების მაგალითები, რაც აიხსნება ბუნებრივი კონკურენტული უპირატესობებით (ნორვეგიის ექსპორტის 60% არის ნავთობი და გაზი, ავსტრალიისა და კანადის – მადნები და ლითონები, ხოლო ახალი ზელანდიის ექსპორტის 60% და ისლანდიის ექსპორტის 67% კი სასოფლო-სამეურნეო – ბუნებრივი საქონელია).

გარდამავალ ქვეყნებს შორის საგარეო სავაჭრო ტრანზაქციების ყველაზე დიდი მოცულობა დაფიქსირებულია ცენტრალური და აღმოსავლეთ ევროპის ქვეყნებში, თუმცა ზოგადად მათი წილი საერთაშორისო ვაჭრობაში კვლავ რჩება ძალიან მცირე (2023 წელს – 4%-ზე ნაკლები).

საერთაშორისო სავაჭრო სისტემაში ყველაზე მოკრძალებული პოზიცია უჭირავს ყველაზე ნაკლებად განვითარებული, 50 ღარიბი ქვეყანა, რომელთა წილი მსოფლიო ექსპორტში მხოლოდ 0,6%-ს შეადგენს. ამ ქვეყნების შემოსავლების სხვაობა განვითარებულ და მდიდარ ქვეყნებთან შედარებით არის დაახლოებით 1:150 და მათი მუდმივი მარგინალიზაცია სავსეა საშიშროებებით, რომლებიც მათ მსოფლიო ეკონომიკური გლობალიზაციის პროცესისთვის მოაქვთ.

მსოფლიო ვაჭრობის დამახასიათებელი თვისებაა სპეციალური ფასების სისტემის არსებობა – მსოფლიო ფასები. ისინი დაფუძნებულია წარმოების საერთაშორი-

სო ხარჯებზე, რომლებიც ეფუძნება ეკონომიკური რესურსების საშუალო მსოფლიო ხარჯებს ამ ტიპის საქონლის შესაქმნელად. წარმოების საერთაშორისო ხარჯები ფორმირდება იმ ქვეყნების გავლენის ქვეშ, რომლებიც მსოფლიო ბაზარზე წარმოადგენენ ამ ტიპის საქონლის ძირითადი მიმწოდებლებს. გარდა ამისა, მსოფლიო ბაზარზე მოცემული ტიპის პროდუქტზე მიწოდებისა და მოთხოვნის თანაფარდობა მნიშვნელოვან გავლენას ახდენს მსოფლიო ფასების დონეზე.

საერთაშორისო ვაჭრობას ახასიათებს ფასების მრავალგვარობა, ანუ ერთი და იგივე პროდუქტზე განსხვავებული ფასების არსებობა. მსოფლიო ფასები განსხვავდება წელიწადის დროის, ადგილმდებარეობის, საქონლის გაყიდვის პირობებისა და კონტრაქტის სპეციფიკის მიხედვით. პრაქტიკაში მსოფლიო ფასებად აღებულია მსოფლიო ვაჭრობის გარკვეულ ცენტრებში ცნობილი ფირმების – შესაბამისი ტიპის საქონლის ექსპორტიორების ან იმპორტიორების მიერ დადებული დიდი, სისტემატური და სტაბილური საექსპორტო ან საიმპორტო ოპერაციების ფასები. ბევრ საქონელზე (მარცვლეული, ბამბა, რეზინი და ა.შ.) მსოფლიო ფასები დგინდება მსოფლიოს უდიდეს სასაქონლო ბირჟებზე ვაჭრობის შედეგად.

საერთაშორისო ღირებულება, როგორც წესი, ნაკლებია შესაბამისი საქონლის ეროვნულ ღირებულებაზე, რადგან ყველაზე კონკურენტუნარიანი საქონელი, ანუ მსოფლიო ბაზარზე ჩვეულებრივ მიეწოდება ის, რაც წარმოებულია ყველაზე დაბალი დახარჯებით. მსოფლიო ფასებზე გავლენას ახდენს სხვა ფაქტორებიც: მიწოდებისა და მოთხოვნის თანაფარდობა, პროდუქციის ხარისხი და მონეტარული სფეროს მდგომარეობა. ამასთან, მსოფლიო ფასების ფორმირების გრძელვადიანი ტენდენციები თავს იჩენს, როგორც მსოფლიო ბაზარზე ღირებულების კანონის უნივერსალური მოქმედება.

საგარეო ვაჭრობის გავლენის რაოდენობრივი დასადგენად ქვეყნის ეროვნული შემოსავლისა და მშპ-ის ზრდაზე შემუშავდა და პრაქტიკაში გამოიყენება საგარეო ვაჭრობის მულტიპლიკატორი მოდელი. მისი გამოყენებით შეიძლება გამოთვლილ იქნას საგარეო ვაჭრობის მულტიპლიკატორის მოდელიც. ამავდროულად, ჩვენ მივიღებთ დაშვებას იმპორტისა და ექსპორტის დამოუკიდებელი გავლენის შესაძლებლობის შესახებ საგარეო ეკონომიკურ საქმიანობაში მონაწილე ქვეყნის ეროვნული ეკონომიკის განვითარებაზე. იმპორტის გავლენა ამ შემთხვევაში შეიძლება გაიგივდეს მოხმარებასთან, ხოლო ექსპორტის გავლენა – ინვესტიციებთან. შესაბამისად, მოხმარების ზღვრული მიდრეკილება ამ შემთხვევაში იღებს ზღვრული მიდრეკილების ფორმას იმპორტისადმი: $c = m = M/Y$, ხოლო დაზოგვის ზღვრული მიდრეკილება ექსპორტის ზღვრული მიდრეკილების ფორმას იღებს: $s = x = X/n$ (კეინსის მიხედვით).

რეალურ ცხოვრებაში ექსპორტი და იმპორტი ურთიერთდაკავშირებულია. ქვეყნის იმპორტი იმავდროულად კონტრაგენტის სახელმწიფოსთვის ექსპორტია. ასეთი ურთიერთდამოკიდებულება მნიშვნელოვნად ართულებს მულტიპლიკატორის მოდელს, რომელიც რეალური საგარეო სავაჭრო ურთიერთობების ასახვისთვის უნდა ითვალისწინებდეს მინიმუმ ორი ქვეყნის ურთიერთქმედებას.

WTO-ს ექსპერტების მიერ მომზადებული ანგარიში აანალიზებს და მსოფლიო ვაჭრობისა და გლობალური ფინანსური მაჩვენებლების სტატისტიკას და ადგენს მის ამომავლო პროგნოზებს, ასევე აფასებს რისკებს, რომლებიც დაკავშირებულია

თანამედროვე გეოპოლიტიკურ და ფინანსურ არასტაბილურობასთან. მათი პროგნოზით ვაჭრობის ზრდა, რომელიც თანდათან დაჩქარდა 2024 წელს, მიუხედავად რეგიონული კონფლიქტებისა, გეოპოლიტიკური დაძაბულობისა და წინა რყევებისა, განაგრძობს დაჩქარებას.

ბოლო წლების განმავლობაში, გლობალურ ვაჭრობაზე გავლენა იქონია არახელსაყრელი ფაქტორების ერთობლიობამ, რომლებსაც ერთად „პოლიკრიზისი" უწოდეს. ეს ფაქტორები მოიცავს მიწოდებისა და მოთხოვნის შოკებს, რომლებიც დაკავშირებულია COVID-19 პანდემიასთან, მიწოდების ჯაჭვის შეფერხებას და გეოპოლიტიკური მეტოქეობის ზეგავლენით გამოწვეული გაურკვევლობის ზრდას სავაჭრო პოლიტიკაში.

მიუხედავად ამ გამოწვევებისა, გლობალური ვაჭრობა საოცრად მდგრადი იყო ბოლო ოთხი წლის განმავლობაში. ამრიგად, 2023 წლის ბოლოსათვის საქონლით ვაჭრობის მოცულობა 2019 წელთან შედარებით 6,3%-ით გაიზარდა. გაიზარდა კომერციული სერვისებიც, მათ ღირებულებამ 2019 წლიდან 2023 წლამდე 21%-ით იმატა. 2023 წელს საქონლით ვაჭრობაში აშშ დოლარის გლობალური ღირებულება წინა წელთან შედარებით დაეცა 5%-ით (24,01 ტრილიონ დოლარი), მაგრამ კლება დიდწილად კომპენსირდება კომერციული სერვისებით ვაჭრობის ძლიერი ზრდით, რომელიც გაიზარდა 9%-ით (7,54 ტრილიონ დოლარი). საქონლის ექსპორტის შემცირება ნაწილობრივ გამოიწვია ისეთ საქონელზე ფასების დაცემა, როგორიცაა ნავთობი და გაზი. ამავდროულად, კომერციული სერვისებით ვაჭრობის ზრდა განაპირობა საერთაშორისო მოგზაურობის განახლებამ და ციფრული სერვისების ზრდამ.

საერთაშორისო ვაჭრობის აღდგენისა და განვითარების რისკები ძირითადად დაკავშირებულია გეოპოლიტიკურ დაძაბულობასთან და გაურკვევლობასთან.

არასახარბიელო სავაჭრო გარემო, რომელიც არსებობდა 2023 წელს, მოსალოდნელია, რომ გარკვეულწილად გაუმჯობესდება 2025 და 2026 წელს, რაც ხელს შეუწყობს საქონლის ვაჭრობის ზრდას ამ პერიოდში. ასევე მოსალოდნელია, რომ ინფლაცია 2025 წელს თანდათან შემცირდება, რაც განვითარებულ ეკონომიკაში შექმნის რეალურ შემოსავლების ზრდის საშუალებას, ეს კი გამოიწვევს წარმოებული საქონლის მოხმარების ზრდას. სავაჭრო საქონელზე მოთხოვნის აღდგენა 2024 წელს უკვე აშკარა იყო. ეს გამოწვეულია შინამეურნეობების მოხმარების გაზრდით, რაც თავის მხრივ დაკავშირებულია შემოსავლის გაუმჯობესებულ პერსპექტივასთან. თუმცა, გეოპოლიტიკურმა დაძაბულობამ და პოლიტიკურმა გაურკვევლობამ შეიძლება შეზღუდოს ვაჭრობის აღდგენის მასშტაბები. მიუხედავად იმისა, რომ ბევრ ქვეყანაში ექსპორტის ზრდა უნდა გაუმჯობესდეს საქონელზე გარე მოთხოვნის მატებასთან ერთად, საკვებისა და ენერგიის ფასები შესაძლოა კვლავ დაექვემდებაროს გეოპოლიტიკური მოვლენებით გამოწვეული შოკებს.

საპროცენტო განაკვეთების შესამცირებლად შესაბამისი ტემპის არჩევა ასევე გამოწვევა იქნება მოწინავე ეკონომიკის ცენტრალური ბანკებისთვის და ნებისმიერმა შეცდომამ 2025 წელს შეიძლება ფინანსური არასტაბილურობა გამოიწვიოს. ვაჭრობის აღდგენა შეიძლება ასევე შეაფერხოს სავაჭრო ხარჯების ზრდამ და გაურკვევლობამ საერთაშორისო ურთიერთობებში.

გლობალური ვაჭრობის მდგრადობა მოწმდება ასევე მსოფლიოს ორი მთავარი

სატრანსპორტო მარშრუტის, პანამის და სუეცის არხების შეფერხებით. მიუხედავად იმისა, რომ გასული წლის შუა რიცხვებისთვის გლობალური სატრანსპორტო ხარჯები დაუბრუნდა პანდემიამდელ დონეს, კონტეინერის გადაზიდვის ტარიფებმა კვლავ დაიწყო ზრდა.

WTO ასევე აღნიშნავს სავაჭრო ნაკადების ფრაგმენტაციის ადრეულ ნიშნებს, როდესაც ექსპორტი და იმპორტი გადამისამართებულია გეოპოლიტიკური პირობების მიხედვით. პირდაპირი უცხოური ინვესტიციები (FDI) ასევე სულ უფრო მეტად მიმართულია მეგობრად მიჩნეული ქვეყნებისკენ. საერთაშორისო სავალუტო ფონდის მონაცემების თანახმად, პირდაპირი უცხოური ინვესტიციების ნაკადები განვითარებად და დაბალ განვითარებულ ქვეყნებში არსებითად დაბალია გეოგრაფიულად უფრო შორეული პარტნიორებისთვის.

გეოპოლიტიკური დისტანციის მიმართ ეს მგრძნობელობა გაიზარდა 2018–2021 წლებში და განსაკუთრებით შესამჩნევია სტრატეგიულ სექტორებში, როგორიცაა ნახევარგამტარები, სატელეკომუნიკაციო აღჭურვილობა, მწვანე ეკონომიკაზე გადასვლისთვის საჭირო აღჭურვილობა, ფარმაცევტული ინგრედიენტები და კრიტიკული მინერალები.

მნიშვნელოვანია ინსტიტუციური ფაქტორების ზეგავლენაც: პოლიტიკური, ეკონომიკური, ფინანსური გლობალიზაცია და ლიბერალიზაცია. ბოლო დრომდე დაფიქსირებული საერთაშორისო ვაჭრობის სწრაფი ზრდა განპირობებული იყო მსოფლიოში პოლიტიკური, ეკონომიკური, ფინანსური გლობალიზაციისა და ლიბერალიზაციის პროცესებით. გლობალური და რეგიონული სივრცითი-დროებითი კონვერგენციის ინტენსიფიკაციამ გამოიხატება ახალი პოლიტიკური ინსტიტუტებისა და საერთაშორისო ორგანიზაციების შექმნაში, შრომის, კაპიტალის, ინფორმაციის ტრანსსასაზღვრო მოძრაობის ტემპის გაზრდაში, ტრანსნაციონალური კომპანიების როლის შემდგომ გაძლიერებაში. ტრანსნაციონალური კორპორაციები, როგორც მსოფლიო ვაჭრობის მთავარი ოპერატორები, ყველაზე შორეულ და, შესაძლოა, ადრე დახურულ ტერიტორიებზე.

განვიხილოთ ზემოქმედების ტექნიკური და ტექნოლოგიური ფაქტორები. ტექნიკური და ტექნოლოგიური ფაქტორები გახდა საერთაშორისო ვაჭრობის ამაჩქარებლები (აქსელერატორები): კომპიუტერიზაცია და, უფრო ფართო გაგებით, საინფორმაციო და საკომუნიკაციო ტექნოლოგიები (IT), ავტომატიზაცია, რობოტიზაცია, სატრანსპორტო ტრანსპორტის კონტეინერიზაცია, ახალი საინჟინრო და საკონსულტაციო ტექნოლოგიები, მომსახურება და სერვისები, რომლებიც წარმოიშვა ამის საფუძველზე. ასეთი ტექნოლოგიების ფართო გამოყენებამ გამოიწვია შრომისა და კაპიტალის პროდუქტიულობის შესამჩნევი ზრდა, წარმოების ეფექტიანობა და შრომის დანახარჯებისა და წარმოების ხარჯების შემცირება. ამრიგად, ინოვაციებმა სატრანსპორტო ტექნოლოგიებში გამოიწვია მნიშვნელოვანი სტრუქტურული ცვლილებები საერთაშორისო ტრანსპორტში და, შესაბამისად, მთელ მსოფლიო ვაჭრობაში. თუ 1970 წელს ტანკერების ფლოტი იკავებდა საზღვაო მიმოსვლის ლომის წილს (მთლიანი ტონაჟის 55%), 2017 წლისთვის იგი თითქმის ნახევარით შემცირდა და 29,4% შეადგინა. 1980 წლიდან მოყოლებული, ტანკერების გამოყენების საშუალო წლიური ტემპი მხოლოდ 1.4%-ით იზრდება, მშრალი ნაყარი გადამზიდავები 4.6%-ით.

კონტეინერის ტრანსპორტირება ყველაზე სწრაფად მზარდი სეგმენტია და 8.1% CAGR შეადგენს.

სივრცითი ფაქტორები. მსოფლიოს გეოგრაფიულ რუკაზე გამოჩნდა ახალი დიდი ქვეყნები (ჩინეთი, ინდოეთი, პოსტსაბჭოთა და პოსტსოციალისტური სივრცის სახელმწიფოები და ა.შ.) და რეგიონები (სამხრეთ-აღმოსავლეთ აზია, აღმოსავლეთ აზია, აზია-წყნარი ოკეანე, ცენტრალური და აღმოსავლეთი ევროპა, დსთ და ა.შ.), რომელთაც საკუთარი ბაზრებს გააჩნიათ.

ორგანიზაციული და მენეჯერული ფაქტორები – მოიცავს ტექნოლოგიურ და წარმოების პროცესების კონტროლის სისტემებს, მარკეტინგის, ლოგისტიკის, მართვის სისტემებს; სისტემებს წარმოების სრული ციკლისთვის ახალი პროდუქტების შემუშავებიდან საქონლის საბოლოო მომხმარებელთან მიწოდებამდე და ა.შ.

დასკვნა

ბიზნეს მოდელები, რაც მოიცავს სიღრმისეულ საერთაშორისო წარმოებაში თანამშრომლობას, წარმოების ფრაგმენტაციას, გლობალური ღირებულების ჯაჭვებს, საჯარო და კერძო პარტნიორობას, პერსონალიზაციას, ონლაინ ვაჭრობას.

ეროვნულმა მთავრობებმა აქტიური მონაწილეობა მიიღეს ეროვნული კომპანიების ინტერესების დაცვასა და ხელშეწყობაში გლობალურ ინდუსტრიულ და სასაქონლო ბაზრებზე, რომელთა საქმიანობა შეიძლება ჩაითვალოს კიდევ ერთ ფაქტორად, რომელმაც განსაზღვრა მსოფლიო ვაჭრობის თანამედროვე განვითარება. ბევრ ქვეყანაში სახელმწიფო დონეზე შემუშავდა და ყოველდღიურ პრაქტიკაში დაინერგა ექსპორტის პირდაპირი და არაპირდაპირი მხარდაჭერისა და სტიმულირების ღონისძიებები, რითაც გაზარდა ეროვნული მწარმოებლების, პირველ რიგში, ტრანსნაციონალური კომპანიების და საქონლის საერთაშორისო კონკურენტუნარიანობა.

მთავრობები ხელს უწყობდნენ საგარეო ეკონომიკურ აქტივობას მიზანმიმართული გრძელვადიანი პოლიტიკის გატარებით, აგრეთვე ინფრასტრუქტურული ობიექტების მშენებლობისა და მოდერნიზაციის დაფინანსებით, რომლებიც ემსახურება სახელმწიფო საკუთრებაში მყოფ საგარეო სავაჭრო ნაკადებს, ანდა შედის სახელმწიფოს უშუალო პასუხისმგებლობის სივრცეში (გზები და რკინიგზა, აეროპორტები, საზღვაო და მდინარის პორტები).

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სამედიცინო დაწესებულების მოტივაციის პრობლემის საერთო დიაგნოსტიკა

General Diagnosis of Motivation Problems in Medical Institutions

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აბსტრაქტი

არჩეული თემის აქტუალობა ნათელია, ვინაიდან იგი ეძღვნება საქმიანობას, რომელიც მიმართულია იმ ერთიანი მეთოდებისა და ოპერაციების არჩავასა და გამოყენებას, რომლებიც ემსახურება სამედიცინო დაწესებულების თანამშრომლებში მოტივების ფორმირებას, რაც თავის მხრივ მათში ქმნის მოტივაციას. თავის მხრივ მოტივირების პროცესი განაპირობებს მაღალ შედეგიანობას და ეფექტურობას, რომელიც წარმოადგენს საზოგადოებრივი ჯანდაცვის მნიშვნელოვან მიზანს. წარმოდგენილი ნაშრომი წარმოადგენს კომპლექსურ გამოკვლევას, რომელიც მიმართულია სამედიცინო კადრების მოტივაციის პროცესის მართვის მოდელის სამეცნიერო დასაბუთებაზე, სამედიცინო დახმარების ხარისხისა და ხელმისაწვდომობის დონის ამაღლებაზე.

საკვანძო სიტყვები: მოტივაცია, მმართველობითი ინოვაციები, მენეჯერების მოტივაცია, პიროვნული მახასიათებლები.

შესავალი

ჯანდაცვის სისტემის ფუნქციონირების სამედიცინო და სოციალური და ეკონომიკური ეფექტურობის ამაღლების და მოსახლეობისათვის სამედიცინო–პროფი-

ლაქტიკური დახმარების გაწევის საფუძველს წარმოადგენს ახალი ორგანიზაციული ტექნოლოგიების ძიება, შემუშავება, დანერგვა და სწორი გამოყენება. ქართული მედიცინის განვითარებაში გარღვევა შეიძლება უზრუნველყოფილი იყოს, უპირველეს ყოვლისა, მართვის სფეროში ინოვაციების დანერგვის გზით. გატარებული საბიუჯეტო და ჯანდაცვის რეფორმები არ იძლევა საჭირო ეფექტს იმის გამო, რომ პროფესიულ საზოგადოებებში ადგილი აქვს მათი შინაარსის არასრულ გააზრებას. ქართველი მკვლევარები აღნიშნავენ ხელმძღვანელების გაზრდილ ინტერესს შრომითი რესურსების მართვის ხარისხის სისტემების დანერგვაში. მეორე მხრივ, ამგვარი მუშაობის წარმართვის დაგროვებული დადებითი გამოცდილება არ არის ფართოდ გავრცელებული.

დისკუსია

1. ექიმებისა და მენეჯერების მოტივაციის შესწავლის შედეგები

შესწავლის ძირითად მეთოდს წარმოადგენდა კვლევის ამოცანებთან ადაპტირებული მეთოდიკის „მოტივაციური პროფილი“ შ. რიჩის და პ. მარტინის ავტომატიზირებული ვარიანტი. რესპოდენტების გამოკითხვამ გვიჩვენა, რომ ექიმებისა და ხელმძღვანელების ჯგუფებში შრომითი მოტივაციის ფაქტორების შესწავლას გააჩნია მსგავსებები და განსხვავებები. შესწავლილ იქნა შემდეგი ფაქტორები.

ფაქტორის შინაარსი და ნომერი:

1. მაღალი ხელფასის და მატერიალური ანაზღაურების საჭიროება, რესპოდენტის სურვილი ქონდეს სამუშაო კარგი შეღავათებით და მატერიალური დანამატების ჩამონათვალით.
2. კარგი სამუშაო პირობების და კომფორტული გარემოს არსებობის აუცილებლობა
3. მკაფიოდ სტრუქტურირებული სამუშაოს აუცილებლობა, უკუკავშირის და ინფორმაციის არსებობა, რომელიც საშუალებას იძლევა შეაფასო მუშაობის შედეგები. გაურკვევლობის შემცირების აუცილებლობა.
4. სოციალური კონტაქტების აუცილებლობა: ფართე წრის ადამიანებთან ურთიერთობა, სანდოობის მსუბუქი დონე, კოლეგებთან მჭიდრო კავშირი.
5. გრძელვადიანი და სტაბილური ურთიერთობების ფორმირების და შენარჩუნების აუცილებლობა, სამუშაოში კოლეგების მცირე რაოდენობა, ურთიერთობაში სიახლოვის მნიშვნელოვანი დონე და სანდოობა.
6. სხვა ადამიანების მხრიდან აღიარების მოპოვების საჭიროება იმაში, რომ გარემოცვამ დააფასოს ინდივიდუმის დამსახურება [ღვაწლი], მიღწევები და წარმატებები.
7. საკუთარი თავისთვის რთული და ამბიციური მიზნების დასახვის აუცილებლობა და მათი მიღწევა; ეს არის თვითმოტივაციის და დასახული მიზნების გაყოლის საჭიროების მაჩვენებელი.
8. გავლენიანობის და ძალაუფლების საჭიროება, მისწრაფება სხვების ხელმძღვანელობაზე, დაჟინებული მისწრაფება კონკურენციაზე და გავლენიანობაზე.

9. მოთხოვნილება მრვალფეროვნებაზე, ცვლილებებზე, მისწრაფება რუტინისა და მოწყენილობის თავიდან აცილებზე.
10. საჭიროებას წარმოადგენდა ახალი იდეებისადმი გახსნილი კრეატიული, ანალიტიკური და მოაზროვნე მუშაკი.
11. როგორც პიროვნების სრულყოფის, ზრდის და განვითარების საჭიროება.
12. საინტერესო და საზოგადოებრივად სასარგებლო საქმეში საკუთარი საჭიროების განცდის არსებობა.

2. წარმატებული ხელმძღვანელის პიროვნული მახასიათებლების შესწავლის ძირითადი შედეგები

კითხვარის „წარმატებული ხელმძღვანელის პიროვნული პროფილი" მიხედვით შესასწავლი პიროვნება 11 ქულას ანაწილებდა ჩამოთვლილი პასუხების სამ ვარიანტს შორის. ყოველ კითხვაში შეთავაზებული იყო პასუხების 3 ვარიანტი, ისინი აღწერდნენ პიროვნების თვისებებს და მათგან საჭირო იყო ამორჩეულიყო პასუხები, რომლებიც გამოკითხულის პირად წარმოდგენაში ყველაზე მეტად ახასიათებდნენ ხელმძღვანელის პიროვნულ ეტალონს („ჩემი იდეალი").

თუ გამოკითხულს ეჩვენებოდა, რომ ჩამოთვლილი პასუხებიდან ერთერთი ყველაზე უფრო მნიშვნელოვანია მას ანიჭებდა 11 ქულას; თუ თვლიდა, რომ პასუხი უმნიშვნელოა არ ანიჭებდა არც ერთ ქულას. სხვა შემთხვევებში დასმული კითხვის 3 შემოთავაზებულ პასუხებს შორის 11 ქულას ანაწილებდა თავისი შეხედულების მიხედვით. მნიშვნელოვანი პირობა იყო ყოველ კითხვაზე ყველა 11 ქულის მიკუთვნება. ქულები, რომლებიც ენიჭებოდა ცალკეულ ფაქტორს, შეტანილი უნდა ყოფილიყო პასუხების ცხრილში.

ამგვარად, ყველა გამოკითხული დამოუკიდებლად „წონიდა" ხელმძღვანელისათვის აუცილებელ ხასიათის თვისებებს, რომლებიც შემდგომში გავაერთიანეთ 3 ჯგუფად (3 კომპონენტი). პასუხების არჩევა განისაზღვრებოდა რესპოდენტის პირადი გამოცდილებით და ლიტერატურული წყაროების მონაცემების ანალიზის მიხედვით.

გარდა ამისა, წარმატებული ხელმძღვანელის პირადი პროფილის შედგენის დროს, მთავარი ექიმები გამოყოფენ პირადი თვისებების უფრო ფართო სპექტრს, რომელიც საჭიროა ეფექტური საქმიანობისაათვის; მიუთითებენ მათი მნიშვნელობების შედარებით თანაბარ დონეზე. ექიმები დიდ მნიშვნელობას ანიჭებენ ხელმძღვანელი პიროვნების ისეთ თვისებებს, როგორიცაა ტატქის გრძნობა და თვითკრიტიკულობა. მთავარ ექიმებში ხელმძღვანელის ხასიათის პრიორიტეტული თვისებების ამორჩევის იერარქია არ იყო დამოკიდებული სამუშაო სტაჟზე, ხოლო ექიმებში ასეთ დამოკიდებულებას ქონდა ადგილი. ხელმძღვანელის პირადი პროფილი პრაქტიკულად დაემთხვა მთავარ ექიმებისა და 5–9 წლის სტაჟის მქონე სპეციალისტების შეხედულებას. ახალგაზრდა ექიმები (სტაჟით 5 წლამდე) მიუთითებდნენ ხასიათი თვისებების უფრო მაღალ მნიშვნელობაზე, რომლებიც შეადგენდნენ სოციალიზაციის კომპონენტს (ზრდილობა, ოპტიმიზმი, ტაქტი). 10 წლის მუშაობის სტაჟის მქონე ექიმები აჩვენებდნენ რწმენის უფრო მაღალ დონეს იმაში, რომ წარმატებული მართვისათვის ყველაზე მნიშვნელოვანია ლიდერობის კომპონენტში შემავალი ხასიათის თვისებები.

3. საკუთარი პროფესიული საქმიანობით ექიმების კმაყოფილების მდგომარეობის შესწავლის ძირითადი შედეგები

კითხვარი „პროფესიული საქმიანობით კმაყოფილება“ არსებიათადაა სტრუქტურირებული. გამოკვლევაში ჩართულ რესპოდენტს მოეთხოვებოდა პასუხის აუცილებელი ამორჩევა, ცალკეულ შემთხვევებში პასუხებს მინიჭებული ქონდა მნიშვნელობები ქულებში. კითხვების სპექტრი ეხებოდა შემდეგ მიმართულებებს: „მიზნების დადგენა“, „ორგანიზაციის მართვა“, „ურთიერთობები კოლექტივში“, „შინაგანი მოტივაცია“ და „გარეგანი მოტივაცია“.

იდენტიფიცირებული იყო სამუშაო გარემოს სხვადსხვა მიმართულების ფაქტორთა გავლენა მოტივაციის პროცესზე. მოტივირების პროცესს აადვილებს ექიმების მიერ პოლიკლინიკის წინაშე არსებული მიზნებისა და ამოცანების გაცნობიერება, კოლექტივის მუშაობაში საკუთარი როლის მნიშვნელობის გაგება, სამუშაო ადგილის შეცვლის სურვილის არქონა, პირად ცხოვრებაზე პროფესიული საქმიანობის ნეგატიური გავლენის არარსებობა. მოტივაციის პროცესს აძნელებს შეღავათების და წახალისების გადანაწილების პროცესში ხელმძღვანელების მიმართ უნდობლობა, რწმენა, რომ არ არსებობს ურთიერთკავშირი ხელფასსა და საერთო საქმეში შეტანილ წვლილს შორის, არსებულ მოლოდინებთან მართვის სტილის შეუსაბამობა. კვლევაში ნაჩვენებია იმ რესპოდენტების წილი, რომლებმაც სტრუქტურირებულ კითხვარში აირჩიეს პასუხი (პოცენტებში გამოკითხვაში მონაწილე რესპოდენტების სრულ რაოდენობასთან). სამუშაო დროის შემდგომ ზენორმირებულ მუშაობაზე (მუშაობა შეთავსებით, მატერიალური წახალისების პირობით, საკუთარი სპეციალობით, დამატებითი სამუშაოს შესრულება) პრინციპული თანხმობა განაცხადა სოციოლოგიურ გამოკითხვაში მონაწილე ექიმების 61%–მა.

ამირჩეული წახალისების სტრუქტურაში პირველ სამ პოზიციას იკავებენ: პრემია (30,1%), დამატებითი სწავლება (16,5%), ინდივიდუალური მიზნობრივი წახალისება (16,5%). ყურადრებას იქცევს, რომ ექიმების ნახევარზე მეტი (რესპოდენტების 55%) მიუთითებს, რომ სპეციალობის აქტუალურ პრობლემებზე დამატებითი პროფესიული სწავლების უზრუნველყოფას ისინი განიხილავენ, როგორც წახალისების მნიშვნელოვან ფორმას.

ნაკლებად გავრცელებულ, მაგრამ საკმაოდ მნიშვნელოვან ფორმებში ექიმები გამოყოფენ ზოგიერთი კონკრეტული დამსახურებების აღიარებას და საერთო კრებაზე მადლობის გამოცხადებას (ყველა პოზიტიური პასუხის 12%). ამგვარი არჩევანი გააკეთეს რესპოდენტების 38%–მა. სერტიფიკატით დადასტურებული კონკრეტული დამსახურებების აღიარება აირჩიეს გამოკითხული ექიმების 10%. საყურადღებოა, რომ ექიმების იგივე რაოდენობა დადებითად აფასებს წახალისების ფორმას როგორიცაა ორგანიზაციის ხელმძღვანელთან ან მის მოადგილესთან პირადი შეხვედრის დროს მადლობის გადახდა.

პოლიკლინიკის ექიმებში, სტაჟისაგან დამოუკიდებლად, საკუთარი საქმიანობის ეფექტურობის თვითშეფასება რამდენადმე მაღალია (3,7 ±0,5 ქულა, ეს არის 92,5% მაქსიმალურად შესაძლებელი შეფასებიდან), ვიდრე მათი კოლეგების შეფასება. ექიმებმა სხვა კლინიკებში მომუშავე კოლეგების მუშაობის ეფექტურობა ასევე შეაფასეს, როგორც მაღალი (3,6 ± 0,6 ქულა, 90% მაქსიმალურად შესაძლებელიდან). სტა-

ციონარების ექიმების მუშაობის ეფექტურობა შეფასებული იყო, როგორც მნიშვნელოვნად უფრო დაბალი (2,8 ± 0,2 – 70% მაქსიმალურად შესაძლებელიდან, p <0,01). სპეციალისტების მუშაობის ეფექტურობა, რომლებიც მონაწილეობენ მაღალტექნოლოგიური სამედიცინო დახმარების გაწევაში, შეფასებულია 3,2±0,4 ქულით (80% მაქსიმალურად შესაძლებელიდან, p <0,05).

ოთხი რესპოდენტიდან სამი მიუთითებდა მნიშვნელოვან ფიზიკურ და ფსიქო–ემოციურ დატვირთვებზე (შესაბამისად 76,3% და 77,2%).

რესპოდენტებს შევთავაზეთ თავისუფალ წერილობით ფორმაში ეჩვენებინათ, ექიმების მატერიალური წაალისების მიზნით საქმიანობის ეფექტურობის რომელი მაჩვენებლები შეიძლება იქნას გამოყენებული. დასმულ კითხვაზე პასუხი გასცა 231 რესპოდენტიდან 80 ადამიანმა (34%). 26 ადამიანიდან 19 აღმოჩნდა 5 წლამდე სტაჟის მქონე (73,1%, ჯგუფი 1); 36 ადამიანიდან 5–9 წლის მუშაობის სტაჟის მქონე იყო – 34 (94%, ჯგუფი 2); 70 ადამიანიდან 10–19 წლის მუშაობის სტაჟის მქონე იყო 18 (25,7%, ჯგუფი 3); 99 ადამიანიდან 20 და მეტი ხნის სტაჟი ქონდა 9 (11,0%, ჯგუფი 4) ადამიანს.

საქმიანობის ეფექტურობის მაჩვენებლების ამორჩევასთან დაკავშირებით ექიმებისაგან შემოსული წინადადებებიდან რანჟირებული იყო ყველა. სურათი შემდეგია:

პირველი ადგილი: სააღრიცხვო დროის განმავლობაში ექიმთან ვიზიტების გეგმიური დავალებების გადაჭარბება სხვა ექიებთან შედარებით – 81,3% (80 ადამიანიდან 65);

მეორე ადგილი: საანგარიშო დროის განმავლობაში, იმავე პროფილის დანარჩენ ექიმებთან შედარებით ჩატარებული მომსახურებიდან მიღებული მაქსიმალური შემოსავალი – 63,5% (80 ადამიანიდან 50);

მესამე ადგილი: დანარჩენ ექომებთან შედარებით საანგარიშო დროის განმავლობაში, ელექტრონულ ვარიანტში, დიდი რაოდენობის ოქმებისა და სხვა საანგარიშგებო დოკუმენტების შევსება – 43,7% (80 ადამიანიდან 35);

მეოთხე ადგილი: საშუალო სამდიცინო პერსონალის დეფიციტის პირობებში მედდის დახმარების გარეშე მომუშავე ექიმების მატერიალური წახალისება;

მეხუთე ადგილი: ძირითადი სამუშაო დროის განმავლობაში მომიჯნავე თერაპიულ მონაკვეთებზე საუბნო თერაპევტის მუშაობა – 22,5% (80 ადამიანიდან 18 და 92% საუბნო თერაპევტებისა, რომლებმაც მონაწილეობა მიიღეს განხილვაში);

მეექვსე ადგილი: ექიმის აქტიური მონაწილეობა კოლექტივში კეთილგანწყობილი ფსიქოლოგიური კლიმატის მხარდაჭერაში, საწარმოო პროცესის ორგანიზაციულ საკითხებთან დაკავშირებულ კონფლიქტებში მონაწილეობის შემთხვევების არქონა – 13,7% (80 ადამიანიდან 11);

მეშვიდე ადგილი: დამატებითი სამუშაოების შესრულება, რომლებიც არ არის გათვალისწინებული თანამდებობრივი ინსტრუქციით და მოვალეობებით (მაგალითად სამედიცინო დახმარების ხარისხის ექსპერტად მუშაობა, საექიმო კომისიის დავალებით ამბულატორიული ავადმყოფების რუქების რეცენზირება და ა.შ.); მერვე ადგილი: სავალდებულო კონფერენციებზე და საწარმოო თათბირებზე აქტიური დასწრება – 17,5% (80 ადამიანიდან 14);

მერვე ადგილი: საანგარიშგებო დროის განმავლობაში, დახარჯული სამუშაო

დროის გათვალისწინებით, შრომითი კოლექტივის ყველა წევრს შორის მასტიმულირებელი/პრემიალური გადახდების თანაბარი წილების გადანაწილება. ასეთ დროს არ ხდება ცალკეული ინდივიდუალური მიღწევების გათვალისწინება – 17,5% (80 ადამიანიდა 14. მეათე ადგილზე იდგა განსხვავებული მაჩვენებლები, რომლებიც ძნელია გააერთიანო თემატურ ჯგუფებში – 23,7% (80 ადამიანიდან 21). ასეთი წინადადებები იყო 29.

„მოტივაციის პრობლემების საერთო დიაგნოსტიკის“ მიღებული შედეგები გამოყენებული იყო საბაზო პოლიკლინიკის მიზნების მიღწევისათვის პერსონალის მოტივირების სისტემის ფორმულირებაში. ფორმულირებულია ძირითადი მოტივაციური პრინციპები:

- სტიმულირების ოპტიმალური ფორმების არჩევა (მატერიალური და არამატერიალური სტიმულირება);
- ყველა მუშაკის თანამდებობრივი ინსტრუქციების, თანამდებობრივი და სამსახურებრივი მოვალეობების ზუსტი ფორმულირება;
- სამუშაო ადგილზე და მთლიანად ორგანიზაციაში, სტრუქტურული ქვედანაყოფების მიხედვით, მუშაკის წინაშე დასმული ყველა ამოცანების და მოვალეობების განაწილება; შედეგის შეფასება მაქსიმალური ობიექტურობით, საქმიანობის ეფექტურობის კრიტერიუმების არჩევა; დადგენილი კრიტერიუმებით „საუკეთესო შედეგი – საუკეთესო ანაზღაურება“ სამართლიანი შეფასებების გამოყენება;
- განსხვავებული მუშაობის სტაჟის მქონე ექიმების წარმატებული ხელმძღვანელის და მართვის სტილით კმაყოფილების დონის წარმოდგენების გათვალისწინებით, კადრების ხელმძღვანელობის ოპტიმალური სტრატეგიების არჩევა;
- მოტივირების სისტემის მონაწილეებს შორის ინფორმაციული გაცვლის ორგანიზება. ინფორმირების ფორმები: იდივიდუალური საუბრები, შედარების საფუძველზე „საუკეთესოების“ და „ცუდი“ მუშაკების და წახალისებების შესახებ ინფორმაციის მიწოდება, აგრეთვე ინფორმაცია განკარგულებების, ბრძანებების, კონფრენციებისა და საწარმოო თათბირების შესახებ;
- მათ საქმიანობაზე საზოგადოებრივი კონტროლის მიზნით მუშაკების წინაშე დამხმარე სამსახურების ანგარიშვალდებულება ჩატარებული სამუშაოს შესახებ; კმაყოფილების მოტივირების მიზნით ბლიც-გამოკითხვების ორგანიზება.

დასკვნა

სამედიცინი პერსონალის მოტივაციური საჭიროებების ღირებულებების მიხედვით მონიტორინგმა გვიჩვენა, რომ ექიმების და ხელმაძღვანელების პროფესიული საქმიანობა, შინაარსის მიხედვით, პოლიმოტივაციურია. ძირითად მოტივაციურ მოთხოვნილებას წარმოადგენს მაღალ ანაზღაურებადი სასარგებლო და საინტერესო სამუშაოს არსებობა. ექიმებს აქვთ სტრუქტურირებული შესასრულებელი სამუ-

შაოს მნიშვნელოვანი მოთხოვნილება, მათ ჭირდებათ ინფორმაცია, რომელიც საშუალებას იძლევა იმსჯელონ საკუთრი და მათი კოლეგების საქმიანობის შესახებ. 5 წლამდე მუშაობის სტაჟის მქონე ექიმებისათვის კომფორტულ პირობებში მუშაობა უფრო მნიშვნელოვანია.

წარმატებული ხელმაძღვანელის პიროვნული პორტრეტის შედარება, რომელიც შედგენილია ექიმების და მთავარი ექიმების შეხედულების შესწავლის დროს, აფართოებს კადრების მართვის ოპტიმალური კომბინაციის ამორჩევის შესაძლებლობებს და საშუალებას გვაძლევს ხელმძღვანელობის სტილი გამოვიყენოთ, როგორც მოტივაციური ფაქტორი. ექიმებმა გამოყვეს წარმატებული ხელმძღვანელის პიროვნებისადმი წაყენებული პრიორიტეტული მოთხოვნები: დისციპლინირებულობა, კანონმორჩილება, საკუთარ თავზე პასუხისმგებლობის აღების უნარი და პაციენტის ინტერესების დაცვის ერთგულება, ემოციური გაწონასწორებულობა. ექიმების მიერ წარმატებული ხელმაძღვანელის პიროვნების პრიორიტრტული თვისებების ამორჩევა დამოკიდებული იყო პროფესიულ სტაჟზე; მთავარი ექიმების შემთხვევაში ამგვარი დამოკიდებულება არ ვლინდებოდა.

ექიმების სოციოლოგიური გამოკითხვის შედეგებით დადგენილ იქნა საკუთრი პროფესიული საქმიანობით კმაყოფილების საერთო დონე. კმაყოფილები ან ნაწილობრივ კმაყოფილების არიან პოლიკლინიკის ექიმების – 48,1%. 70%–ზე მეტი რესპოდენტები თვლიან, რომ ესმით პოლიკლინიკის მიზნები და ამოცანები; თვლიან რომ შეაქვთ ღირსეული წვლილი საერთო საქმეში; აღნიშნავენ რომ კოლექტივში ქმნიან კეთილგანწყობილ [ხელსაყრელ] ფსიქოლოგიურ გარემოს; და უახლოეს მომავალში არ გეგმავენ სამუშაო დგილი შეცვლას. ექიმების უმეტესობა აღნიშნავდა შეღავათებისა და წახალისებების უსამართოლ გადანაწილებას (რესპოდენტების 72%), ხელმძღვანელობის სტილის მათ მოლოდინებთან შეუსაბამობას (81%), მათი შრომის მატერიალური შეუფასებლობას (72%). მოტივირების პროცესი ითვალისწინებს ღონისძიებებს, რომლებიც მიმართულია პოზიტიური ფაქტორების მხარდაჭერაზე, რომლებიც ამაღლებენ კმაყოფილებას და ახდენენ ნეგატიური პროცესების ნიველირებას.

დადგენილია ნორმაშემქმნელი ფაქტორები, რომლებიც გავლენას ახდენენ პოლიკლინიკის ექიმის სამუშაო დროის ბიუჯეტის ფორმირებაზე. მათ მიეკუთვნება სამუშაო ცვლების გარეგანი და შინაგანი დანაკარგები, ძირითადი საქმიანობის გარდა სამუშაო ცვლის შიგნით შესასრულებელი აუცილებელის სამუშაოები. წელიწადში, ერთ დაკავებულ განაკვეთზე, სამუშაო ცვლების ეფექტური ფონდი შეადგენს არაუმეტეს 189 ვცლას (ნორმატიულზე 11% ნაკლები). უბნის ექიმი თერაპევტის „ოპერატიული" დროის სტრუქტურაში (ამბულატორიული მიღება) ძირითდი საქმიანობა იკავებს 60,1%, დამხმარე საქმიანობა იკავებს – 30,2%, ორგანიზაციული წყვეტები კი – 5,5%. უბნის ექიმი თერაპევტის, ერთ დაკავებულ განაკვეთზე, სამუშაოზე გამოცხადებების წლიური სამუშაო დროის ფონდი შემცირდა არა ნაკლებ 2,7 სამუშაო ცვლაზე; აღნიშნული დაკავშირებული იყო ექიმი სპეციალისტის სავალდებულო თათბირებზე დასწრების აუცილებლობით – 3,3 სამუშაო ცვლა.

საქალაქო პოლიკლინიკის თანამედროვე სოციალურ–ეკონომიკური პირობებში ფუნქციონირების პირობებში, სამედიცინო დახმარების ხელმისაწვდომობისა და

ხარისხის ამაღლებისათვის, საექომო კადრების მოტივირების პროცესის მართვის შემუშავებული მოდელი წარმოადგენს სამედიცინო ორგანიზაციის ინოვაციური პოლიტიკის შემადგენელ ნაწილს. მოდელის დანერგვამ დაამტკიცა პოლიკლინიკის უნარი, გააუმჯობესოს საქმიანობის ეფექტურობა: ექიმ სპეციალისტებთან პირველად მიღებაზე ლოდინის ვადა შემცირდა 50%-ით, სამედიცინო დახმარების დაბალ ხელმისაწვდომობაზე დასაბუთებული მომართვების რიცხვი შემცირდა 2-ჯერ, ექიმების უცვლელი რაოდენობის პირობებში სამედიცინო დახმარების არასათანადო ხარისხზე მომართვები შემცირდა 2,4-ჯერ.

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უცხოური სამუშაო ძალის გავლენა საქართველოს შრომის ბაზრის სტრუქტურულ და ფუნქციურ ტრანსფორმაციაზე

The Impact of Foreign Labor on the Structural and Functional Transformation of Georgia's Labor Market

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აბსტრაქტი

სტატია იკვლევს უცხოელი მუშახელის შემოდინების გავლენას საქართველოს შრომის ბაზარზე. კერძოდ, მასში გაანალიზებულია როგორ გავლენას ახდენს ეს პროცესი დასაქმებაზე, ხელფასებზე და სექტორულ თუ რეგიონულ დიფერენციაციებზე.

კვლევის მიზანია შეაფასოს უცხოელი მუშახელის გავლენა ადგილობრივ დასაქმებულებზე, გამოიკვლიოს ხელფასების ცვლილება სხვადასხვა კვალიფიკაციის ჯგუფებში და გამოავლინოს რეგიონული ასიმეტრია ამ პროცესში.

საქართველოს შრომის ბაზარზე უცხოური სამუშაო ძალის გავლენის შესაფასებლად განხორციელდა რაოდენობრივი კვლევა ჰიბრიდულ რეჟიმში. კვლევის სამიზნე ჯგუფს წარმოადგენდა საქართველოს მასშტაბით დასაქმებული მოსახლეობა, ხოლო შერჩევის საერთო მოცულობამ შეადგინა 100 რესპონდენტი. რესპონდენტთა შერჩევა განხორციელდა შემთხვევითი შერჩევის პრინციპით, რაც უზრუნველყოფს შედეგების შედარებით ობიექტურობას. კვლევის ძირითად ინსტრუმენტად გამოყენებულ იქნა სტრუქტურირებული კითხვარი. კვლევის შედეგების ანალიზმა აჩვენა, რომ უცხოელი მუშახელის შემოსვლას სხვადასხვა სექტორსა და რეგიონში განსხვა-

ვებული ეფექტი აქვს. ერთი მხრივ, იგი ზრდის კონკურენციას განსაკუთრებით დაბალკვალიფიციური სამუშაო ძალის სეგმენტში; მეორე მხრივ კი, ხელს უწყობს პროფესიული დეფიციტების შემცირებას და შრომის ბაზრის მოქნილობის გაძლიერებას.

კვლევის საფუძველზე შესაძლებელია ითქვას, რომ უცხოური სამუშაო ძალის გავლენა საქართველოს შრომის ბაზარზე მრავალმხრივია და საჭიროებს ბალანსირებულ მართვას. შესაბამისად, წარმოდგენილი ნაშრომი აყალიბებს რეკომენდაციებს საქართველოს შრომითი პოლიტიკისთვის, განსაკუთრებით უცხოელი მუშახელის ეფექტიანი ინტეგრაციისა და ადგილობრივი დასაქმების ინტერესების დაცვითი ბალანსის უზრუნველყოფის მიმართულებით.

საკვანძო სიტყვები: შრომის ბაზრის ტრანსფორმაცია, უცხოური სამუშაო ძალა, მიგრაციის პოლიტიკა, ეკონომიკური ზრდა.

JEL კლასიფიკაცია: F6, F22, R23, M15, L86, M1

შესავალი

გლობალიზაცია და საერთაშორისო მიგრაცია მნიშვნელოვნად ცვლის შრომის ბაზრის სტრუქტურას მსოფლიოს სხვადასხვა ქვეყანაში. აღნიშნული საკითხი განსაკუთრებულ ყურადღებას იმსახურებს, როგორც ეკონომიკური პოლიტიკის, ასევე სოციალური განზომილების გათვალისწინებით. უცხოელი მუშახელი საქართველოში ძირითადად ჩართულია მშენებლობის, მომსახურებისა და მცირე საწარმოების სექტორებში, რაც ქმნის როგორც კონკურენციის, ასევე ბაზრის გაფართოების შესაძლებლობას ადგილობრივი დასაქმებულებისთვის.

მიგრაციის ეკონომიკური ეფექტების შესწავლა მნიშვნელოვანია იმისთვის, რომ დადგინდეს უცხოელთა შემოდინების გავლენა ადგილობრივთა დასაქმების შესაძლებლობებზე, ხელფასებზე და რეგიონულ თუ სექტორულ დიფერენციაციებზე. საერთაშორისო გამოცდილება აჩვენებს, რომ მიგრანტები ზოგჯერ კონკურენციას ქმნიან დაბალკვალიფიციურ სამუშაო ძალასთან მიმართებაში, თუმცა ამავდროულად ავსებენ ბაზრის დეფიციტურ პოზიციებს მაღალი კვალიფიკაციის პროფესიებში (Tkemaladze,I., 2021).

კვლევის მიზანია ემპირიულად შეფასდეს უცხოელი მუშახელის გავლენა საქართველოს შრომის ბაზარზე. ყურადღება გამახვილებულია დასაქმების მაჩვენებლებზე, ხელფასებზე, რეგიონულ და სექტორულ დიფერენციაციებზე.

კვლევა ემსახურება როგორც აკადემიურ მიზნებს, ასევე პოლიტიკის შემქმნელ დონეს, რომლის ფარგლებში ხდება უცხოელი მუშახელის შემოსვლის ეკონომიკური გავლენის წინასწარი შეფასება და შესაბამისი რეკომენდაციების შემუშავება ადგილობრივი დასაქმების ხელშეწყობისა და შრომის ბაზრის სტაბილური ბალანსის უზრუნველყოფის მიზნით.

შრომის ბაზრის მოდელები მიგრაციის კონტექსტში: თეორიული პერსპექტივები და ემპირიული მტკიცებულებები

შრომის ბაზრის ბალანსის მოდელის (Labor Market Equilibrium Model) მიხედვით უცხოელი მუშახელის შემოსვლა ზრდის სამუშაო ძალის საერთო მიწოდებას, რაც შესაძლოა აისახოს ხელფასების შემცირებით დაბალკვალიფიციურ დასაქმებულებზე. ამავდროულად იგი ამცირებს დეფიციტს კონკრეტულ პროფესიულ ჯგუფებში. მოდელის ძირითადი მიზანია განსაზღვროს სამუშაო ძალის ფასის (ხელფასის) და რაოდენობის (დასაქმების) პარამეტრები, რომლებიც უზრუნველყოფენ ბაზრის წონასწორობას.

მიწოდება (Ls) დამოკიდებულია ხელფასზე და სხვა ინდივიდუალურ ფაქტორებზე, როგორიცაა განათლება, გამოცდილება და რეგიონული პირობები:

$$L_s=f(W,X_s)$$

მოთხოვნა (Ld) დამოკიდებულია ხელფასზე, შრომის პროდუქტიულობაზე, კაპიტალზე, დამსაქმებლის პროდუქციის/მომსახურების პროდუქტის ფასის პარამეტრებზე, ტექნოლოგიებზე:

$$L_d=f(W,X_d)$$

მიგრაციის პროცესი მოქმედებს როგორც გარე შოკი, რომელიც ზრდის შრომის მიწოდებას კონკრეტულ რეგიონში ან სექტორში (Ls↑L^s). შედეგად შეიძლება გაჩნდეს შემდეგი ეფექტები:

კონკურენციის ეფექტი: მიწოდების ზრდა, განსაკუთრებით დაბალკვალიფიციურ პროფესიებში, იწვევს ხელფასების შემცირებას (w↓).

დეფიციტის შევსება: პროფესიულ დეფიციტში მიგრანტების შემოსვლა ზრდის დასაქმების შესაძლებლობას და პროდუქტიულობას შესაბამის პროფესიებში (Ls↑L^s), ხოლო ხელფასები რჩება სტაბილური ან მცირედ იზრდება (w≈სტაბილური/ზრდადი)

სექტორული და რეგიონული ასიმეტრია: ბაზრის ბალანსი შეიძლება განსხვავებულად წარმოიქმნას ურბანულ და სასოფლო რეგიონებში ან მშენებლობისა და მომსახურების სექტორებში.

ადამიანისეული კაპიტალის თეორიის მიხედვით (Human Capital Theory) – მიგრანტების შემოსვლამ შესაძლოა გაზარდოს კვალიფიციური და პროფესიული რესურსები ბაზარზე, რაც აამაღლებს ეკონომიკურ ეფექტიანობას. ადამიანისეული კაპიტალის თეორია განასახიერებს იდეას, რომ მუშაკის უნარები, ცოდნა და გამოცდილება პირდაპირ ზრდის პროდუქტიულობას, ხელფასებს და დასაქმების შესაძლებლობებს (Becker G. S., 1964). იმიგრანტთა შემოსვლა ცვლილებებს იწვევს ეროვნულ ბაზარზე შრომის მიწოდების კუთხით, რაც პირდაპირ უკავშირდება პროდუქტიულობის დიფერენციაციასა და დასაქმების პირობებს. მიგრანტები ხშირად განსხვავებულ ადამიანისეულ კაპიტალს ფლობენ, რომლითაც შეიძლება შეივსოს ამ მიმართულებით არსებული დეფიციტი. მაგალითად, დაბალკვალიფიციური მიგრანტები ზრდიან შრომის მიწოდებას დაბალკვალიფიციურ სექტორში, რაც გამოიწვევს მოკლევადიან პერიოდში სახელფასო ფონდის ოპტიმიზაციას დამსაქმებელთა დონეზე (Card, 1990). ამასთან, მაღალი კვალიფიკაციის მქონე მიგრანტები, რომლებიც ფლობენ იშვიათ

უნარებს, ზრდიან მთლიან შრომის პროდუქტიულობას და ხელს უწყობენ ტექნოლოგიურ განვითარებასა და ეკონომიკურ ზრდას (Becker, 1964) (Schultz, 1961). ჰოვარდ გარდნერის მრავალმხრივი ინტელექტის ხედვა ხაზს უსვამს, რომ მიგრანტებმა შეიძლება შემოიტანონ უნარები, რომლებიც შეიძლება არ არსებობდეს ადგილობრივად ცოდნის მარაგის სახით და მათი კულტურული, ენობრივი და ტექნიკური კომპეტენციები წვლილს შეიტანენ შრომის ბაზრის დივერსიფიკაციაში (Gardner, 1983). სპენსის სიგნალის თეორია (Spence, 1973) აჩვენებს, რომ განათლება და კვალიფიკაცია მიგრანტების შემთხვევაში წარმოადგენს სიგნალს დასაქმების პროცესში, რაც ეხმარება დამსაქმებლებს განსაზღვრონ პროდუქტის ფუნქციონირების შესაბამისი მუშაკები, განსაკუთრებით როდესაც ბაზარზე არსებობს ინფორმაციის ნაკლებობა. ბოულსისა და გინტისის ხედვა ხაზს უსვამს, რომ მიგრანტების ინტეგრაცია ეროვნულ შრომის ბაზარზე ასევე მოიცავს სოციალური და ორგანიზაციული ადაპტაციის უნარს, რაც მნიშვნელოვან როლს თამაშობს შრომის ჰომოგენური და სტაბილური ფუნქციონირების უზრუნველსაყოფად (Bowles, 1976).

შრომის მობილობის თეორია (Labor Mobility Theory) იკვლევს სამუშაო ძალის გადაადგილების პროცედურებს, მიზეზებს და ეფექტებს სხვადასხვა სამუშაო ადგილებსა და რეგიონებს შორის. ხაზს უსვამს მიგრანტების გავლენას რეგიონული შრომის ბაზრის ასიმეტრიაზე (Sjaastad, 1962). სამუშაო ძალის გადაადგილება გამოწვეულია ხელფასის დიფერენციაციით, სამუშაო პირობების ხარისხით, კარიერული ზრდის პერსპექტივებით და სოციალურ-ეკონომიკური მდგომარეობით. მუშაკები ხშირად არჩევენ სამუშაოს იმ მონაცემების მიხედვით, რაც აქვთ ხელფასების, დასაქმების პირობებისა და სხვა სარგებლის შესახებ (Chikobava et al., 2026). მეორე მხრივ, სამუშაოზე გადასვლა მოითხოვს დროს, სატრანსპორტო და სამოქალაქო თუ პროფესიულ ადაპტაციას, რაც ზღუდავს მობილურობას და განსაზღვრავს მიგრაციის ინტენსივობას (Todaro, 1969).

თეორიის მიხედვით სწორი მობილობა ზრდის შრომის ბაზრის ეფექტურობას, აუმჯობესებს შრომის განაწილების ხარისხს, ზრდის პროდუქტიულობას და ხელს უწყობს ინდივიდუალური შემოსავლების ზრდას. მუშაკები გადაადგილდებიან იქ, სადაც მათი უნარები ყველაზე მაღალ ფასეულობას იძენს. შესაბამისად ზრდის ინდივიდუალურ და საერთო პროდუქტიულობას (John R. Harris, 1970). შრომის მობილობა აუმჯობესებს რესურსების განაწილებას რეგიონებსა და სექტორებს შორის. თუმცა, მოკლევადიან პერიოდში შესაძლებელია ადგილი ჰქონდეს ადგილობრივი ხელფასების დონის დროებით შემცირებას და მერყეობას (Borjas, 2016). ამავე დროს, არასტრუქტურირებულმა მიგრაციამ შეიძლება წარმოქმნას შრომის ბაზრის დისბალანსი და სოციალური უთანასწორობა.

ნეოკლასიკური შრომის ბაზრის მოდელის მიხედვით, როდესაც შრომის მიწოდება იზრდება და მოთხოვნა უცვლელი რჩება, ხელფასების შემცირების ტენდენცია ჩნდება. სწორედ ამიტომ, უცხოელი მუშახელის ზრდა ზოგიერთ სექტორში იწვევს კონკურენციის გაძლიერებას და დაბალი კვალიფიკაციის მქონე მუშაკების ხელფასებზე ზეწოლას.

ეკონომიკური კვლევები აჩვენებს, რომ მიგრაციის გავლენა ხელფასებზე ერთმნიშვნელოვანი არ არის. ზოგიერთ შემთხვევაში უცხოელი მუშახელი ძირითადად

იკავებს იმ სამუშაო ადგილებს, რომლებზეც ადგილობრივი მოსახლეობა ნაკლებად არის დაინტერესებული. ასეთ შემთხვევაში ხელფასების შემცირება არ ხდება, იზრდება წარმოება და ეკონომიკური აქტივობა. კვლევაში „იმიგრანტ მუშაკებში აშშ-ში და უცხოეთში მიღებული შრომითი გამოცდილების ეკონომიკური ანაზღაურება“ (Vasheghanifarahani, 2025) ნაჩვენებია, რომ მიგრანტები ხშირად იწყებენ მუშაობას დაბალი ანაზღაურებით, მაგრამ გამოცდილების დაგროვების შემდეგ მათი შემოსავალი იზრდება. ეს ნიშნავს, რომ შრომითი მიგრაცია უფრო მეტად ცვლის შრომის ბაზრის სტრუქტურას, ვიდრე მხოლოდ ხელფასების დონეს.

აშშ-ს მაგალითზე ჩატარებულმა კვლევებმა აჩვენა, რომ დაბალი კვალიფიკაციის უცხოელი მუშახელის შემოსვლამ შეიძლება შეამციროს ადგილობრივი მუშახელის ხელფასები დაახლოებით 3–4%-ით, განსაკუთრებით სხვადასხვა თეორიულად ჰომოგენურ სექტორებში, მაგალითად სამშენებლო და მომსახურების ინდუსტრიებში (Borjas, 2003)

ევროპულ კონტექსტში გამოქვეყნებული კვლევა ხაზს უსვამს, რომ სტაბილური შემოსავალი და უცხოელი მუშახელის ზრდა გარკვეულ სექტორებში იწვევს ხელფასების დაბალანსებას. თუმცა ისინი აღნიშნავენ, რომ ზემოქმედება დიდწილად სექტორულია, ანუ ყველა სექტორზე არ გავრცელდება თანაბრად. პროფესიების მიხედვით კი განსაკუთრებით დაზარალებულია არიან დაბალი კვალიფიკაციის მქონე სამუშაო ძალა (Christian Dustmann and Tommaso Frattini, 2014)

თანამედროვე ეკონომიკურ ლიტერატურაში მიგრაციის გავლენა დასაქმებაზე შეფასებულია როგორც კომპლექსური და მრავალგანზომილებიანი პროცესი, რომლის შედეგები მნიშვნელოვნად არის დამოკიდებული შრომის ბაზრის სტრუქტურაზე, ინსტიტუციურ გარემოსა და ეკონომიკური განვითარების დონეზე (ტყემალაძე, 2023). უახლესი ემპირიული კვლევები მიუთითებს, რომ მოკლევადიან პერიოდში იმიგრაციის ზრდა შესაძლოა უარყოფითად აისახოს ადგილობრივი მოსახლეობის გარკვეული ჯგუფების დასაქმებაზე, განსაკუთრებით კი დაბალი კვალიფიკაციის მქონე მუშაკებში, თუმცა გრძელვადიან პერსპექტივაში აღნიშნული ეფექტი, როგორც წესი, სუსტდება ან სრულად ნეიტრალიზდება. ამასთანავე, საერთაშორისო ორგანიზაციების ანგარიშები ადასტურებს, რომ მიგრანტები მნიშვნელოვან როლს ასრულებენ შრომითი რესურსის გაფართოებაში და ხშირად ავსებენ დეფიციტურ სექტორებს, რაც ხელს უწყობს ეკონომიკური აქტივობის ზრდასა და დასაქმების საერთო მაჩვენებლების გაუმჯობესებას (OECD, 2025).

მნიშვნელოვანია, რომ რიგ კვლევებში გამოვლენილია მიგრაციასა და უმუშევრობის დონეს შორის ნეგატიური კორელაცია, რაც მიუთითებს, რომ იმიგრაციის ზრდა შეიძლება დაკავშირებული იყოს ადგილობრივი მოსახლეობის დასაქმების შესაძლებლობების გაფართოებასთან (Mohammad, 2025). ამასთან, ევროპულ კონტექსტში ჩატარებული კვლევები ხაზს უსვამს, რომ მიგრანტთა შრომით ბაზარზე ინტეგრაცია კვლავ გამოწვევად რჩება, რადგან მათი დასაქმების დონე საშუალოდ ჩამოუვარდება ადგილობრივ მოსახლეობას და ისინი ხშირად კონცენტრირებულნი არიან დაბალანაზღაურებად სექტორებში (European Parliament, 2024). დამატებით, უახლესი მაკროეკონომიკური კვლევები ადასტურებს, რომ მიგრაციის შემცირება შესაძლოა ნეგატიურად აისახოს დასაქმების ზრდის ტემპზე, რაც კიდევ ერთხელ

უსვამს ხაზს მიგრანტების მნიშვნელოვან როლს შრომის ბაზრის ფუნქციონირებაში (Francisco, 2026).

შრომითი მიგრაცია და მისი რეგულირება საქართველოში

მიგრაციის სფეროში სამართლებრივი ურთიერთობები რეგულირდება საქართველოს „შრომითი მიგრაციის შესახებ" კანონით. აღნიშნული კანონი განსაზღვრავს შრომით მიგრაციასთან დაკავშირებულ ურთიერთობებს, რომლებიც ერთი მხრივ მოიცავს საქართველოს მოქალაქეთა და საქართველოში მუდმივი ბინადრობის ნებართვის მქონე უცხოელთა ქვეყნის ფარგლებს გარეთ შრომით მოწყობასა და მათ მიერ შრომითი საქმიანობის განხორციელებას. ხოლო მეორე მხრივ, საქართველოში მუდმივი ბინადრობის ნებართვის არმქონე უცხოელთა საქართველოს ტერიტორიაზე დასაქმებასა და შრომითი საქმიანობის განხორციელებას ანაზღაურების ან სხვა სახის ფინანსური სარგებლის მიღების მიზნით.

2025 წლამდე საქართველო გამოირჩეოდა ერთ-ერთი ყველაზე ლიბერალური მიგრაციული რეჟიმით, რაც გამოიხატებოდა ფართო უვიზო მიმოსვლაში და ხანგრძლივი (1 წლის) ყოფნის უფლებით. უცხოელებს ქვეყანაში შემოსვლისა და დასაქმების შედარებით მარტივი შესაძლებლობა ჰქონდათ, რის შედეგადაც შრომითი მიგრაციისთვის დაბალი ბარიერი არსებობდა. დამსაქმებლებს არ ევალებოდათ ადგილობრივი კადრების უპირობო მოძიება. არასრული მიგრაციის და არასრული კონტროლის პირობებში სახელმწიფოს არ გააჩნდა ზუსტი სტატისტიკური მონაცემები დასაქმებული მიგრანტების რაოდენობისა და მათი სექტორული განაწილების შესახებ. აღნიშნულმა პირობებმა ხელი შეუწყო არაფორმალური დასაქმების ზრდას და გააუარესა შრომის ბაზრის მდგომარეობა.

2025 წელს საქართველოს პარლამენტმა „შრომითი მიგრაციის შესახებ" კანონში შეიტანა ცვლილებები, რომელიც ძალაში შევიდა 2026 წლის 1 მარტიდან. რეფორმის მიზნები მოიცავს: უცხოელი მუშახელის დასაქმების რეგულირებას, ადგილობრივი შრომითი ბაზრის დაცვას, მიგრაციის კონტროლის გამკაცრებას და ეკონომიკური უსაფრთხოების უზრუნველყოფას (საქართველოს პარლამენტი, 26/06/2025).

რეფორმის ერთ-ერთ უმნიშვნელოვანეს სიახლეს წარმოადგენს შრომითი საქმიანობის უფლების სავალდებულო მოპოვების მექანიზმი, რაც გულისხმობს D1 კატეგორიის საიმიგრაციო ვიზისა და შესაბამისი ბინადრობის ნებართვის მიღების აუცილებლობას. აღნიშნული ზომები მიზნად ისახავს უცხოელი მუშახელის რეგულირებას, სახელმწიფოს კონტროლის გამარტივებას და შრომითი ბაზრის სტრუქტურული დაცვის გაძლიერებას. ახალი მოთხოვნები გაჩნდა დამსაქმებლის მიმართაც. ცვლილებების მიხედვით დამსაქმებელმა უნდა დაასაბუთოს, რომ ადგილობრივი მუშახელი ვერ მოიძია. ვაკანსია უნდა განთავსდეს სახელმწიფო პორტალზე და მხოლოდ ამის შემდეგ შეიძლება უცხოელი სამუშაო ძალის დასაქმება საქართველოში. ასევე, გამოიკვეთა კონკრეტული სამუშაო ადგილები, სადაც ზოგიერთ სფეროში უცხოელებისთვის დაწესდა შეზღუდვები. მაგალითად, მუდმივი ბინადრობის არ მქონე უცხოელებს კურიერად, ტაქსის მძღოლად და გიდად მუშაობა ეკრძალებათ. გადაწყვეტილება ეფუძნება საქართველოს მთავრობის მიერ 2026 წლის 20 თებერვალს გამოცემულ დადგენილებას № 70 „შრომითი საქმიანობის უფლების გაცემის

წესის დამტკიცების შესახებ“, რომელიც წარმოადგენს მიგრაციისა და დასაქმების ახალი წესების ნაწილს. ეს დადგენილება მოქმედებს „შრომითი მიგრაციის შესახებ“ კანონთან ერთად და ითვალისწინებს დანართ №3-ის კვოტებს, სადაც გარკვეული პროფესიებისთვის – მათ შორის კურიერის, ტაქსის მძღოლისა (წლიური კვოტაა – 0) და ტურისტულ გიდის (წლიური კვოტა – 200) კვოტებია განსაზღვრული. რამაც ამ სფეროებში სამუშაოს განხორციელება უცხოელებისთვის ისე პროფესიონალური საქმიანობის უფლების ან D1 ვიზისა და ბინადრობის ნებართვის გარეშე ფაქტობრივად შეუძლებელი გახადა („შრომით იმიგრანტსა და თვითდასაქმებულ უცხოელზე შრომითი საქმიანობის უფლების გაცემის წესის დამტკიცების შესახებ“.

საქართველოს შრომის ბაზარზე უცხოური სამუშაო ძალის გავლენის დადგენის მიზნით ჩატარებული რაოდენობრივი კვლევის შედეგების ანალიზი

საქართველოს შრომის ბაზარზე უცხოური სამუშაო ძალის გავლენის დადგენის მიზნით ჩატარდა რაოდენობრივი კვლევა (ჰიბრიდულ რეჟიმში). კვლევის სამიზნე ჯგუფს წარმოადგენდა დასაქმებული მოსახლეობა საქართველოს მასშტაბით. ჯამურად გამოკითხულთა რაოდენობამ შეადგინა 100 დასაქმებული. რესპოდენტთა შერჩევა განხორციელდა შემთხვევითი შერჩევის პრინციპით. გამოკითხვის მთავარ ინსტრუმენტად გამოყენებულ იქნა კითხვარი.

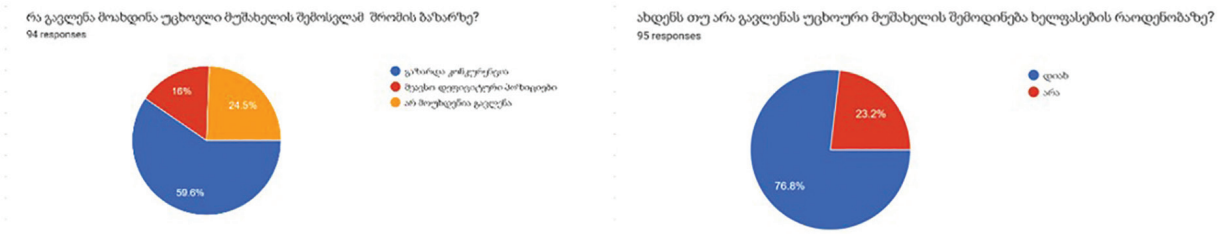
კვლევის მონაწილეების სოციალურ-დემოგრაფიული სურათი შემდეგნაირად გამოიყურება: ქალი 84,7%, ხოლო მამაკაცი 15,3%. 18-25 წლამდე ასაკის დასაქმებული პირები 14,3%, 26-35 წლის ასაკობრივი ჯგუფი – 14,3%, 36-45 წლის – 37,8%, 46-55 წელს გადაცილებული – 22,4%, 56 წლის და უფროსი ასაკის – 11,2% წარმოადგენს. გამოკითხულ რესპოდენტთა დიდ ნაწილს აქვს მაგისტრის ხარისხი (51,1%), ბაკალავრი ხარისხი აქვს – 28,6%, საშუალო განათლება – 10,2%, პროფესიული – 6,1%, დოქტორანტურა – 4,1%. რესპოდენტების 43,6% დასაქმებულია განათლების სფეროში, მომსახურების სფეროში – 10,6%, ჯანდაცვასა და სოციალურ მომსახურებაში – 8,5%, საფინანსო საქმიანობა და უძრავ ქონებასთან დაკავშირებული ოპერაციები – 6,4%, კომუნალური, სოციალური და სხვა მომსახურების გაწევაში – 3,2%, კერძო საოჯახო მეურნეობაში დასაქმებული – 5,3%, მშენებლობა – 2,1%, საბითუმო და საცალო ვაჭრობა, ავტომობილების, მოტოციკლების, საყოფაცხოვრებო ნაკეთობის, პირადი ნივთების რემონტის სფეროში – 5,3%, სასტუმროები და რესტორნები – 1,1%. გამოკითხულ რესპოდენტთა 87,6% თბილისის მაცხოვრებელია, იმერეთი – 2,1%, კახეთი – 1%, სამეგრელო – 1%, აჭარა – 1%.

გამოკითხულ რესპოდენტთა 58,2% აღნიშნავს, რომ მათი საქმიანობის სფეროში უცხოელი მუშახელი პრაქტიკულად არ არის. 26,5% თვლის, რომ მათი რაოდენობა მცირერიცხოვანია, 10,2% მოსაზრებით – საშუალო რაოდენობითა, 5,1% აზრით კი ბევრია.

უცხოელი მუშახელის შემოდინებამ ეროვნულ შრომის ბაზარზე რესპოდენტთა 59,6%-ის მოსაზრებით გაზარდა კონკურენცია, 16%-ის შეხედულებით შეავსო დეფიციტური პოზიციები და 24,5%-ის აზრით გავლენა არ მოუხდენია. გაზრდილი კონკურენცია აისახება ხელფასების რაოდენობაზე. რესპოდენტთა 76,8%-ის შეფასებით

ხელფასებზე გავლენა მაღალია, ხოლო 23,2% თვლის, რომ იმიგრაციას გავლენა არ მოუხდენია ხელფასებზე. შრომის ბაზრის გაჯერებამ შრომითი ემიგრაცია დააჩქარა. აღნიშნულ მოსაზრებას ეთანხმება რესპოდენტთა 67,7%.

სქემა 1. უცხოელი მუშახელის შემოსვლის გავლენა შრომის ბაზარზე



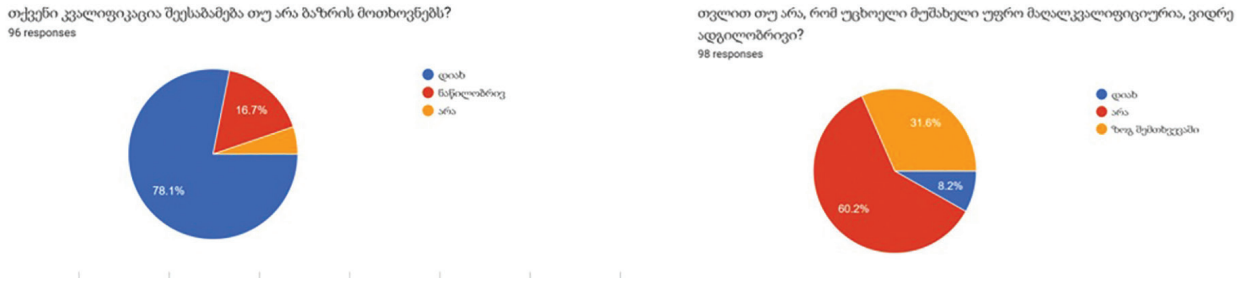
წყარო: შედგენილია ავტორთა კვლევის საფუძველზე

გამოკითხულთა დიდ ნაწილს (65,3%) ნეიტრალური დამოკიდებულება გააჩნია უცხოელი მუშახელისადმი, პოზიტიურად არის განწყობილი 18,4%, ხოლო ნეგატიურად – 16,3%.

გამოკითხულ რესპოდენტთა დიდი ნაწილი (78,1%) თვლის, რომ მისი კვალიფიკაცია სრულად შეესაბამება საქართველოს შრომის ბაზარზე არსებულ მოთხოვნებს. 16,7% – ნაწილობრივ შეესაბამება, ხოლო 5,2% აღიარებს მისი კვალიფიკაციის შეუსაბამობას.

გამოკითხულთა 60,2%-ს მიაჩნია, რომ ადგილობრივი სამუშაო ძალა აკმაყოფილებს შრომის ბაზრის მოთხოვნებს და უცხოელებთან მაღალი კვალიფიკაციითაც გამოირჩევიან. 8,2% ცალსახად აღიარებს უცხოელი მუშახელის მაღალკვალიფიციურობას.

სქემა 2. ადგილობრივი დაუცხოელი მუშახელის კვალიფიკაციის შესაბამისობა შრომის ბაზრის მოთხოვნებთან



წყარო: შედგენილია ავტორთა კვლევის საფუძველზე

ზოგადად, მიგრანტები საქართველოში ხელს უწყობენ ახალი ბიზნესების შექმნას, ინვესტიციების ზრდასა და მომხმარებელთა მოთხოვნის გაფართოებას, რაც პოზიტიურად აისახება ქვეყნის მთლიანი შიდა პროდუქტის ზრდაზე. ამასთან, კულტურული მრავალფეროვნება განიხილება როგორც მნიშვნელოვანი ფაქტორი,

რომელიც აძლიერებს საერთაშორისო ეკონომიკურ კავშირებს და ხელს უწყობს ინოვაციური იდეების გავრცელებას. მიუხედავად აღნიშნულისა, გამოკითხულ რესპონდენტთა 29,6%-ის მოსაზრებით, მიგრანტების შემოსვლას საქართველოში არ ჰქონია მნიშვნელოვანი დადებითი გავლენა ეკონომიკურ ზრდაზე. აღნიშნულ პოზიციას არ ეთანხმება გამოკითხულთა 25,5%, რომლებიც მიიჩნევენ, რომ მიგრაციის გავლენა ეკონომიკაზე აშკარად პოზიტიურია. მიუხედავად იმისა, რომ მიგრაციის სფერო რეგულირდება საქართველოს „შრომითი მიგრაციის შესახებ“ კანონით და 2025 წლიდან აღნიშნული საკანონმდებლო ჩარჩო დამატებითი რეგულაციების შემოღებით გადაიხედა. გამოკითხულ რესპონდენტთა უმრავლესობა (78,6%) მიიჩნევს, რომ მიგრაციის პოლიტიკა კვლავ საჭიროებს დამატებით გამკაცრებასა და რეგულაციების გაძლიერებას.

დასკვნა

გლობალიზაციის პირობებში უცხოური სამუშაო ძალის გავლენა საქართველოს შრომის ბაზარზე წარმოადგენს მრავალგანზომილებიან პროცესს, რომელიც ერთდროულად აისახება როგორც ეკონომიკურ ეფექტიანობაზე, ასევე შრომის ბაზრის სტრუქტურულ და ფუნქციურ ტრანსფორმაციებზე. ჩატარებული თეორიული და ემპირიული ანალიზის საფუძველზე გამოვლინდა, რომ მიგრაცია არ არის ერთმნიშვნელოვნად პოზიტიური ან ნეგატიური მოვლენა, არამედ მისი შედეგები მნიშვნელოვნად არის დამოკიდებული სექტორულ, რეგიონულ და კვალიფიკაციურ სპეციფიკაზე.

კვლევის შედეგების მიხედვით, უცხოელი მუშახელის შემოსვლა საქართველოს შრომის ბაზარზე ზრდის კონკურენციას, განსაკუთრებით დაბალკვალიფიციური სამუშაო ძალის სეგმენტში, რაც ნაწილობრივ აისახება ხელფასების დინამიკაზეც. ამავდროულად, იგი ასრულებს დეფიციტური პოზიციების შევსების ფუნქციას და ხელს უწყობს შრომის ბაზრის უფრო მოქნილ და ეფექტიან ფუნქციონირებას. ადამიანები, რომლებიც განიცდიან მაღალ სამუშაო კმაყოფილებას, მზად არიან პოზიტიურად მიუდგნენ შესასრულებელ სამუშაოს, რაც იწვევს შრომის ნაყოფიერების გაზრდას და საბოლოოდ აისახება ეკონომიკური ზრდის მაჩვენებლებზე (Chachua, 2025).

ემპირიული მონაცემების ანალიზმა ასევე აჩვენა, რომ საზოგადოებაში აღქმა უცხოური სამუშაო ძალის მიმართ არ არის ერთგვაროვანი. მიუხედავად გარკვეული პოზიტიური ეკონომიკური შეფასებებისა, რესპონდენტთა ნაწილი მიგრაციის გავლენას ეკონომიკურ ზრდაზე კრიტიკულად აფასებს, რაც მიუთითებს სოციალურ-ეკონომიკური აღქმის ჰეტეროგენულობაზე. ამასთან, კვლევის მნიშვნელოვანი მიგნებაა ის, რომ მოსახლეობის დიდი ნაწილი მხარს უჭერს მიგრაციის პოლიტიკის დამატებით რეგულირებასა და ინსტიტუციურ გაძლიერებას.

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ღვინის წარმოების ეკოლოგიური კვალი თელავის მუნიციპალიტეტში

Environmental Footprint of Wine Production in Telavi Municipality

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აბსტრაქტი

ღვინის წარმოება საქართველოს სოფლის მეურნეობისა და საკვები მრეწველობის ერთ-ერთი უმნიშვნელოვანესი დარგია, ხოლო კახეთის რეგიონი, განსაკუთრებით კი თელავის მუნიციპალიტეტი, მევენახეობა-მეღვინეობის ძირითად ცენტრს წარმოადგენს. აღნიშნული სექტორი მნიშვნელოვან როლს ასრულებს ქვეყნის ეკონომიკურ განვითარებაში, ადგილობრივი მოსახლეობის დასაქმებასა და კულტურული მემკვიდრეობის შენარჩუნებაში. ამავე დროს, ღვინის წარმოების პროცესი დაკავშირებულია ბუნებრივი რესურსების ინტენსიურ გამოყენებასთან და სხვადასხვა ტიპის ნარჩენების წარმოქმნასთან, რაც გარემოზე ზემოქმედების მნიშვნელოვან წყაროს წარმოადგენს. კლიმატის ცვლილების, წყლის რესურსებზე მზარდი ზეწოლისა და ეკოლოგიურად პასუხისმგებელი წარმოებისადმი გაზრდილი მოთხოვნის პირობებში, ღვინის წარმოების ეკოლოგიური კვალის შეფასება განსაკუთრებულ აქტუალობას იძენს.

ეკოლოგიური კვალი, მათ შორის ნახშირბადის, წყლისა და ეკოლოგიური ნაკვალევის ინდიკატორები, ფართოდ გამოიყენება როგორც კომპლექსური მაჩვენებელი საწარმოო სისტემების გარემოზე ზემოქმედების შესაფასებლად. ღვინის ინდუსტრიაში აღნიშნული მიდგომა სულ უფრო მეტად გამოიყენება სიცოცხლის ციკლის შეფასების (Life Cycle Assessment – LCA) მეთოდოლოგიის ფარგლებში, რომელიც საშუალებას იძლევა შეფასდეს გარემოზე ზემოქმედება წარმოების ყველა ეტაპზე – ნედლეულის გადამუშავებიდან დაწყებული, საბოლოო პროდუქტის ჩამოსხმასა და ნარჩენების მართვამდე. ევროპის ღვინის მწარმოებელ ქვეყნებში, როგორიცაა

იტალია, ესპანეთი და პორტუგალია, ჩატარებული კვლევები აჩვენებს, რომ ღვინის წარმოების ეკოლოგიურ ზემოქმედებაში განსაკუთრებული წილი მოდის ენერგიის მოხმარებაზე, წყლის გამოყენებასა და შეფუთვის მასალებზე.

კვლევის მიზანია თელავის მუნიციპალიტეტში ღვინის წარმოების ეკოლოგიური კვალის შეფასება და იმ ძირითადი ფაქტორების გამოვლენა, რომლებიც განსაზღვრავს რესურსების მოხმარებასა და გარემოზე ზემოქმედების დონეს ადგილობრივ ღვინის საწარმოებში. კვლევა მოიცავს რეგიონში მოქმედი შერჩეული ღვინის საწარმოების ტექნოლოგიური პროცესების ძირითად ეტაპებს, მათ შორის ყურძნის მიღება-გადამუშავებას, დუღილს, შენახვასა და ჩამოსხმას.

კვლევის მეთოდოლოგიური საფუძველი ეფუძნება საერთაშორისო პრაქტიკაში დამკვიდრებულ გარემოსდაცვით შეფასების მეთოდებს, განსაკუთრებით სიცოცხლის ციკლის შეფასების (LCA) მიდგომას და კვების მრეწველობაში გამოყენებულ გარემოსდაცვითი ეფექტიანობის ინდიკატორებს. მონაცემთა შეგროვება დაგეგმილია უშუალოდ ღვინის საწარმოებიდან და მოიცავს ინფორმაციას ენერგიის მოხმარების (ელექტროენერგია და ბუნებრივი აირი), წყლის გამოყენების, წარმოებული პროდუქციის მოცულობისა და ნარჩენების წარმოქმნისა და მართვის შესახებ. აღნიშნული მონაცემების საფუძველზე შეფასდება რესურსების გამოყენების ეფექტიანობა და გამოვლინდება ის ეტაპები, რომლებიც ყველაზე მეტად უწყობს ხელს გარემოზე ზემოქმედების ზრდას.

კვლევის შედეგები საშუალებას მოგვცემს პირველად განხორციელდეს თელავის მუნიციპალიტეტში ღვინის წარმოებასთან დაკავშირებული გარემოსდაცვითი ზეწოლის სისტემური შეფასება. მიღებული მონაცემები შესაძლებელს გახდის ადგილობრივი საწარმოო პრაქტიკის შედარებას ევროპულ კვლევებში აღწერილ მაჩვენებლებთან და ხელს შეუწყობს იმ მიმართულებების იდენტიფიცირებას, სადაც შესაძლებელია რესურსების მოხმარების ოპტიმიზაცია, ენერგოეფექტიანი ტექნოლოგიების დანერგვა და ნარჩენების მართვის თანამედროვე სისტემების გაუმჯობესება.

კვლევას აქვს არა მხოლოდ სამეცნიერო, არამედ პრაქტიკული მნიშვნელობაც. მისი შედეგები მნიშვნელოვანი იქნება როგორც ღვინის საწარმოების მენეჯერებისთვის, ისე ადგილობრივი თვითმმართველობისა და გარემოსდაცვითი პოლიტიკის განმსაზღვრელი სტრუქტურებისთვის, რადგან ხელს შეუწყობს გარემოსდაცვითად პასუხისმგებელი მართვის გადაწყვეტილებების მიღებას. საბოლოო ჯამში, კვლევა მიმართულია საქართველოს ღვინის სექტორის მდგრადი განვითარების ხელშეწყობისა და მისი საერთაშორისო სტანდარტებთან შესაბამისობაში მოყვანისკენ, რაც განსაკუთრებით მნიშვნელოვანია გლობალურ ბაზარზე კონკურენტუნარიანობის შენარჩუნებისა და გაზრდისთვის.

საკვანძო სიტყვები: ღვინის წარმოება; ეკოლოგიური კვალი; სიცოცხლის ციკლის შეფასება; წყლის მოხმარება; ენერგიის გამოყენება; ნარჩენების მართვა; მდგრადი განვითარება; თელავის მუნიციპალიტეტი.

ABSTRACT

The wine sector represents one of the most important branches of the agricultural and food industry in Georgia, with the Kakheti region and particularly Telavi Municipality serving as major centers of viticulture and winemaking. While the industry plays a crucial role in regional economic development, employment, and cultural heritage, wine production is also associated with intensive use of natural resources and generation of various types of waste. In the context of global climate change, increasing pressure on water resources, and growing demand for environmentally responsible production, the assessment of the environmental footprint of wine production has become an important scientific and practical issue.

The concept of environmental footprint, including ecological, water and carbon footprints, is widely used as an integrated indicator for evaluating the environmental impacts of production systems. In the wine industry, these indicators are increasingly applied within the framework of Life Cycle Assessment (LCA), which enables the identification of environmental pressures across all stages of the production process, from raw material processing to packaging and waste management. Studies conducted in European wine-producing countries such as Italy, Spain and Portugal demonstrate that energy consumption, water use and packaging materials are among the main contributors to the environmental impact of wine production.

The aim of this research is to assess the environmental footprint of wine production in Telavi Municipality and to identify the key factors that influence resource consumption and environmental pressure in local wineries. The study will focus on selected wine enterprises operating in the region and will analyze the main stages of the technological process, including grape processing, fermentation, storage and bottling.

The methodological framework of the study is based on internationally recognized approaches to environmental assessment, particularly the Life Cycle Assessment methodology and environmental performance indicators used in the food and beverage industry. Data collection will be carried out directly from wineries and will include information on energy consumption (electricity and natural gas), water use, characteristics of output products, and waste generation and management practices. These data will be used to evaluate the efficiency of resource use and to identify the stages of production that contribute most significantly to environmental impacts.

The study is expected to provide the first systematic assessment of environmental pressures associated with wine production in Telavi Municipality. The results will allow comparison of local production practices with those reported in European studies and will help identify opportunities for improving environmental performance through the implementation of energy-efficient technologies, water-saving measures and modern waste management strategies.

In addition to its scientific contribution, the research has practical significance for winery managers, local authorities and environmental policy makers. The findings may support the development of guidelines and recommendations aimed at reducing the en-

vironmental footprint of the wine sector and promoting sustainable production practices in one of Georgia's most important agricultural regions. Ultimately, the study contributes to the broader goal of aligning the Georgian wine industry with international sustainability standards and strengthening its competitiveness in global markets where environmental performance is becoming an increasingly important criterion.

KEEWORDS: wine production; environmental footprint; life cycle assessment; water consumption; energy use; waste management; sustainability; Telavi Municipality.

შესავალი

თანამედროვე მსოფლიოში მდგრადი განვითარების უზრუნველყოფა ერთ-ერთ უმნიშვნელოვანეს გამოწვევას წარმოადგენს. მოსახლეობის ზრდა, ბუნებრივი რესურსების ინტენსიური გამოყენება და სამრეწველო საქმიანობის გაფართოება მნიშვნელოვან ზეწოლას ახდენს გარემოზე და იწვევს ეკოსისტემების დეგრადაციას. რესურსების გადაჭარბებული მოხმარება დაკავშირებულია ისეთ გლობალურ პრობლემებთან, როგორიცაა კლიმატის ცვლილება, ბიომრავალფეროვნების შემცირება, ნიადაგის დეგრადაცია და წყლის რესურსების შემცირება. აღნიშნულ პირობებში განსაკუთრებულ მნიშვნელობას იძენს საწარმოო სისტემების ეკოლოგიური ეფექტიანობის შეფასება და ბუნებრივი რესურსების რაციონალური გამოყენება.

გარემოზე ზემოქმედების შეფასების ერთ-ერთ მნიშვნელოვან ინდიკატორს წარმოადგენს ეკოლოგიური კვალი, რომელიც ასახავს ბუნებრივი რესურსების მოხმარებისა და ნარჩენების წარმოქმნის შედეგად გარემოზე შექმნილ ზეწოლას. თანამედროვე კვლევებში ეკოლოგიური კვალი ფართოდ გამოიყენება აგროსასურსათო სექტორის, მათ შორის ღვინის ინდუსტრიის, გარემოსდაცვითი ეფექტიანობის შესაფასებლად (Ferrara and De Feo 2018). განსაკუთრებით აქტუალურია სიცოცხლის ციკლის შეფასების (Life Cycle Assessment – LCA) მეთოდოლოგია, რომელიც საშუალებას იძლევა შეფასდეს პროდუქტის გარემოზე ზემოქმედება წარმოების სხვადასხვა ეტაპზე – ნედლეულის მიღებიდან საბოლოო პროდუქტის წარმოებასა და ნარჩენების მართვამდე (Casolani et al. 2022).

ღვინის წარმოება საქართველოს ეკონომიკისა და აგროსასურსათო სექტორის ერთ-ერთი მნიშვნელოვანი მიმართულებაა. კახეთის რეგიონი, განსაკუთრებით კი თელავის მუნიციპალიტეტი, წარმოადგენს მევენახეობა-მეღვინეობის მნიშვნელოვან ცენტრს, სადაც ფუნქციონირებს როგორც მსხვილი, ასევე მცირე საოჯახო ტიპის ღვინის საწარმოები. ღვინის წარმოების პროცესი დაკავშირებულია ენერგიის, წყლისა და სხვადასხვა სახის მასალების ინტენსიურ გამოყენებასთან, აგრეთვე ორგანული და არაორგანული ნარჩენების წარმოქმნასთან, რაც გარემოზე ზემოქმედების მნიშვნელოვანი წყაროა.

საერთაშორისო კვლევები აჩვენებს, რომ ღვინის ინდუსტრიაში გარემოზე ზემოქმედების ძირითად ფაქტორებს წარმოადგენს ენერგიის მოხმარება, წყლის გა-

მოყენება, შეფუთვის მასალები და ტრანსპორტირება (Iannone et al. 2016). ამასთანავე, სხვადასხვა ტიპის ღვინის საწარმოთა შედარებითი ანალიზი მიუთითებს, რომ რესურსების ეფექტიან მართვასა და ნარჩენების გადამუშავებას მნიშვნელოვანი როლი აქვს ეკოლოგიური კვალის შემცირებაში (Jourdaine et al. 2020). შესაბამისად, ღვინის საწარმოების ეკოლოგიური კვალის შეფასება მნიშვნელოვან საფუძველს ქმნის რესურსების გამოყენების ოპტიმიზაციის, ნარჩენების მართვის გაუმჯობესებისა და ეკოლოგიურად მდგრადი წარმოების განვითარებისათვის.

საქართველოს გააჩნია მნიშვნელოვანი ბუნებრივი და ბიოტევადობის რესურსები, თუმცა მათი შენარჩუნება და მდგრადი გამოყენება ქვეყნის გარემოსდაცვითი უსაფრთხოების ერთ-ერთ მნიშვნელოვან წინაპირობას წარმოადგენს. ამდენად, ადგილობრივი საწარმოო სისტემების ეკოლოგიური ეფექტიანობის შეფასება მნიშვნელოვანია როგორც გარემოს დაცვის, ისე მდგრადი ეკონომიკური განვითარების თვალსაზრისით.

კახეთის რეგიონში მოქმედი ღვინის საწარმოები ინტენსიურად იყენებენ ბუნებრივ რესურსებს და წარმოქმნიან სხვადასხვა ტიპის ნარჩენებს, რაც გარემოზე ზემოქმედების მნიშვნელოვან წყაროს წარმოადგენს. კლიმატის ცვლილების, წყლის რესურსებზე მზარდი ზეწოლისა და ეკოლოგიურად პასუხისმგებელი წარმოებისადმი გაზრდილი მოთხოვნის პირობებში, ღვინის წარმოების ეკოლოგიური კვალის შეფასება განსაკუთრებულ აქტუალობას იძენს.

კვლევის მიზანია თელავის მუნიციპალიტეტში მოქმედი ღვინის საწარმოების ეკოლოგიური კვალის შეფასება ენერგიისა და წყლის მოხმარების, ნარჩენების მართვის პრაქტიკის, შეფუთვის მასალებისა და ტრანსპორტირების გარემოზე ზემოქმედების ანალიზის საფუძველზე.

ნაშრომში შესწავლილია თელავის მუნიციპალიტეტში მოქმედი შვიდი ღვინის საწარმო. კვლევის ფარგლებში განხორციელდა ღვინის საწარმოების დონეზე ენერგიის (ბუნებრივი აირი, ელექტროენერგია) და წყლის მოხმარების ანალიზი, ნარჩენების მართვის პრაქტიკის შეფასება, აგრეთვე ღვინის შეფუთვისა და ტრანსპორტირების ეკოლოგიური კვალის შესწავლა. განსაკუთრებული ყურადღება დაეთმო საწარმოო პროცესების იმ ეტაპების გამოვლენას, რომლებიც გარემოზე ზემოქმედების ძირითად წყაროებს წარმოადგენს.

კვლევის ამოცანებს წარმოადგენდა:

- ღვინის წარმოების სხვადასხვა ეტაპის (წარმოება, შეფუთვა, ტრანსპორტირება) ეკოლოგიური ზემოქმედების შეფასება;
- წყლის ეკოლოგიური კვალის განსაზღვრა 1 ლიტრ ღვინოზე;
- ენერგიის მოხმარების სტრუქტურის ანალიზი (ბუნებრივი აირი და ელექტროენერგია);
- ნარჩენების მართვის არსებული პრაქტიკის შეფასება ღვინის საწარმოებში.

კვლევის მეთოდოლოგია ეფუძნება საერთაშორისო პრაქტიკაში დამკვიდრებულ გარემოსდაცვითი შეფასების მეთოდებს და აერთიანებს რაოდენობრივ და ხარისხობრივ კვლევის მიდგომებს. კვლევის ფარგლებში გამოყენებული იქნა:

- რაოდენობრივი მონაცემები – წყლის, ენერგიისა და ნედლეულის მოხმარების მაჩვენებლები;

- ხარისხობრივი მონაცემები – ინტერვიუები და საველე დაკვირვებები;
- სიცოცხლის ციკლის შეფასების (Life Cycle Assessment – LCA) მეთოდოლოგია.

კვლევა ეყრდნობა გარემოზე ზემოქმედების შეფასების საერთაშორისო სტანდარტებს, კერძოდ:

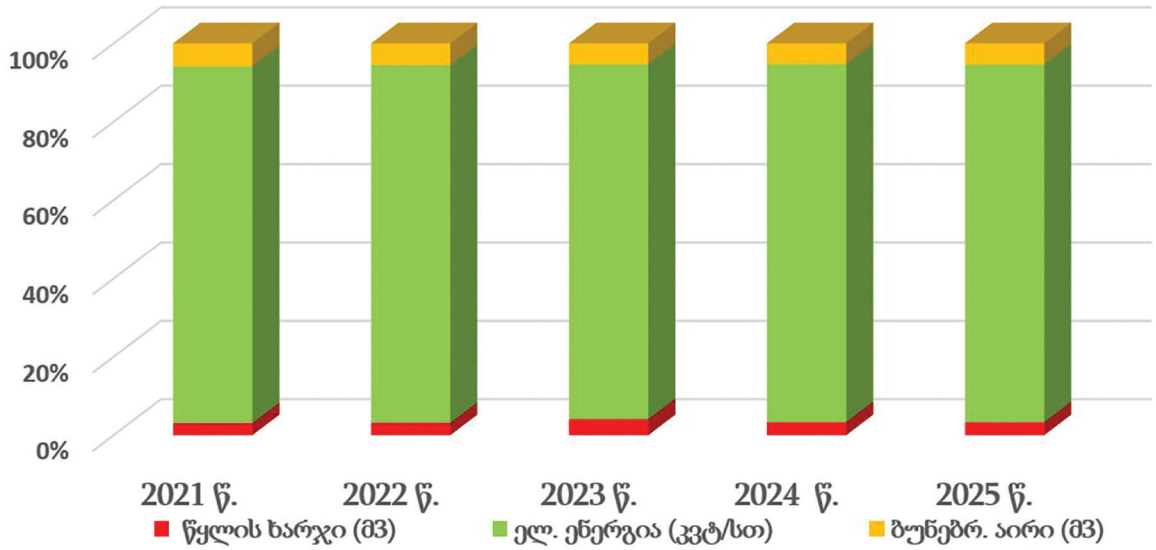
- ISO 14040 – სიცოცხლის ციკლის შეფასების პრინციპები და ჩარჩო;
- ISO 14044 – სიცოცხლის ციკლის შეფასების მოთხოვნები და სახელმძღვანელო პრინციპები.

კვლევის შედეგები. კვლევის ფარგლებში განხორციელდა თელავის მუნიციპალიტეტში მოქმედი ერთი საშუალო ზომის („შალაურის ღვინის მარანი") და ერთი მცირე ტიპის („საოჯახო მარანი წინანდალში") ღვინის საწარმოს რესურსების მოხმარებისა და ნარჩენების მართვის პრაქტიკის შედარებითი ანალიზი 2021–2025 წლების მონაცემების საფუძველზე.

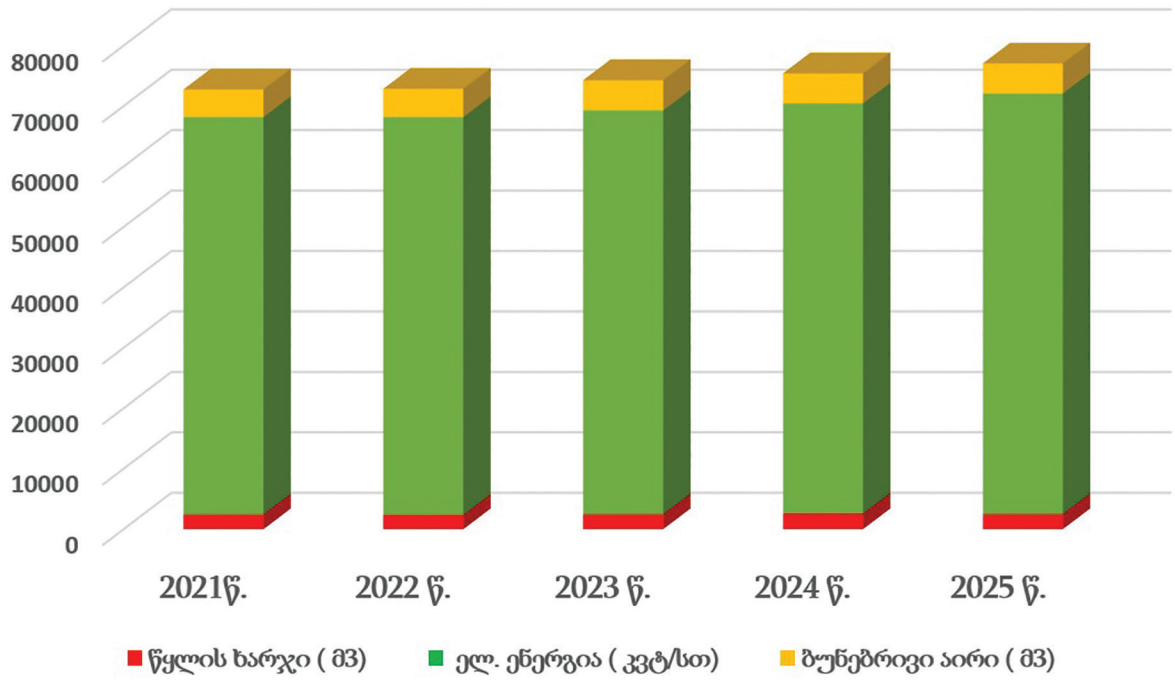
შალაურის ღვინის მარანში კვლევის პერიოდში შეინიშნებოდა ენერგიისა და წყლის მოხმარების თანდათან ზრდა. ელექტროენერგიის მოხმარება გაიზარდა 70,534 კვტ/სთ-დან 85,679 კვტ/სთ-მდე, წყლის მოხმარება – 2,345 მ³-დან 3,078 მ³-მდე, ხოლო ბუნებრივი აირის მოხმარება – 4,564 მ³-დან 5,038 მ³-მდე. აღნიშნული ცვლილებები დაკავშირებულია საწარმოს წარმოების მასშტაბის მნიშვნელოვან გაფართოებასთან. ამავე პერიოდში პროდუქციის მოცულობა დაახლოებით 101,000 ერთეულიდან 968,050 ერთეულამდე გაიზარდა, რაც წარმოების ინტენსიფიკაციაზე მიუთითებს.

მიუხედავად რესურსების აბსოლუტური მოხმარების ზრდისა, ერთეულ პროდუქტზე დანახარჯების შემცირება საწარმოს ეკოეფექტიანობის გაუმჯობესებაზე მიუთითებს. აღნიშნული ტენდენცია განსაკუთრებით მნიშვნელოვანია მდგრადი წარმოების თვალსაზრისით, რადგან წარმოების ზრდა თან ახლავს რესურსების გამოყენების შედარებით უფრო ეფექტიან მართვას.

დიაგრამა 1. შალაურის ღვინის მარნის წლიური ხარჯები



დიაგრამა 2. საოჯახო მარანი წინანდალში – წლიური ხარჯები



კვლევის შედეგად გამოვლინდა მნიშვნელოვანი ცვლილებები ნარჩენების მართვის პრაქტიკაშიც. 2021 წელს ყურძნის ჭაჭა არ ექვემდებარებოდა მეორეულ გამოყენებას და ძირითადად განთავსდებოდა როგორც ნარჩენი. 2022 წლიდან საწარმოში დაინერგა ჭაჭის გამოყენება ცხოველთა საკვებად, რაც წარმოადგენს წრიული ეკონომიკის პრაქტიკულ მაგალითს და ამცირებს ორგანული ნარჩენების გარემოზე ზემოქმედებას.

საოჯახო მარანში წინანდალში რესურსების მოხმარების მაჩვენებლები შედარებით სტაბილური იყო. ელექტროენერგიის მოხმარება 65,700 კვტ/სთ-დან 69,558 კვტ/სთ-მდე გაიზარდა, წყლის მოხმარება კი 2,468 $მ^3$-დან 2,506 $მ^3$-მდე შეიცვალა. ბუნებრივი აირის მოხმარება ასევე უმნიშვნელოდ გაიზარდა – 4,578 $მ^3$-დან 4,975 $მ^3$-მდე. პროდუქციის მოცულობის ზრდა შედარებით ზომიერი იყო და 15,000-დან 16,050 ერთეულამდე მერყეობდა, რაც მცირე მასშტაბის და შედარებით სტაბილურ საწარმოო პროცესზე მიუთითებს.

საოჯახო მარანში ნარჩენების მართვის პრაქტიკა კვლევის მთელი პერიოდის განმავლობაში ეფუძნებოდა ორგანული ნარჩენების მიწის განოყიერებისთვის გამოყენებას. კომპოსტირების და ორგანული მასის ნიადაგში დაბრუნების პრაქტიკა ხელს უწყობს ნიადაგის ნაყოფიერების შენარჩუნებას და ამცირებს ქიმიური სასუქების გამოყენების საჭიროებას.

ცხრილი 1. შედარებითი ანალიზი

მაჩვენებელი	**შალაურის ღვინის მარანი**	**საოჯახო მარანი წინანდალში**
წარმოების მასშტაბი	ძალიან დიდი	მცირე
რესურსების საერთო მოხმარება	მაღალი	საშუალო
ერთეულ პროდუქტზე რესურსების ხარჯი	დაბალი	შედარებით მაღალი
ნარჩენების მართვა	ცხოველთა საკვებად გამოყენება	ნიადაგის განოყიერება
ეკოეფექტიანობის დინამიკა	მკვეთრად გაუმჯობესებული	სტაბილური
წრიული ეკონომიკის ელემენტები	მაღალი	მაღალი

კვლევის შედეგებმა აჩვენა, რომ საშუალო და მცირე ზომის ღვინის საწარმოებს შორის განსხვავებულია როგორც რესურსების მოხმარების მასშტაბი, ისე ეკოლოგიური მართვის მიდგომები. საშუალო საწარმოში წარმოების ზრდასთან ერთად შეინიშნება რესურსების გამოყენების ეფექტიანობის გაუმჯობესება, ხოლო მცირე საწარმო უფრო მეტად ინარჩუნებს ეკოლოგიურად ტრადიციულ და დაბალინტენსიურ მართვის მოდელს.

დასკვნა

კვლევის შედეგებმა აჩვენა, რომ თელავის მუნიციპალიტეტში მოქმედი როგორც საშუალო, ისე მცირე ზომის ღვინის საწარმოები სხვადასხვა ფორმით ნერგავენ ეკოლოგიურად პასუხისმგებელ პრაქტიკებს, თუმცა განსხვავებული საწარმოო მოდელებისა და რესურსების მართვის სტრატეგიების ფარგლებში.

„შალაურის ღვინის მარანი" გამოირჩევა წარმოების მაღალი მასშტაბითა და რესურსების გამოყენების შედარებით მაღალი ეფექტიანობით. მიუხედავად იმისა, რომ კვლევის პერიოდში გაიზარდა ენერგიისა და წყლის აბსოლუტური მოხმარება, პროდუქციის მოცულობის მნიშვნელოვანი ზრდის ფონზე შემცირდა რესურსების დანახარჯი ერთეულ პროდუქტზე, რაც საწარმოს ეკოეფექტიანობის გაუმჯობესებაზე მიუთითებს. ამასთანავე, ნარჩენების მართვის პრაქტიკის ცვლილება, კერძოდ ყურძნის ჭაჭის მეორეული გამოყენება ცხოველთა საკვებად, წარმოადგენს წრიული ეკონომიკის ეფექტიან მაგალითს და ამცირებს ორგანული ნარჩენების გარემოზე ზემოქმედებას.

„საოჯახო მარანი წინანდალში" ინარჩუნებს მცირე მასშტაბის, შედარებით დაბალინტენსიურ და ეკოლოგიურად მდგრად საწარმოო მოდელს. საწარმოში რესურსების მოხმარება კვლევის მთელი პერიოდის განმავლობაში შედარებით სტაბილური იყო, ხოლო ორგანული ნარჩენების ნიადაგში დაბრუნების პრაქტიკა ხელს უწყობდა

ნიადაგის ნაყოფიერების შენარჩუნებას და ამცირებდა ქიმიური სასუქების გამოყენების საჭიროებას.

კვლევის შედეგები ადასტურებს, რომ ღვინის წარმოებაში ეკოლოგიური კვალის შემცირება შესაძლებელია რესურსების რაციონალური გამოყენების, ენერგოეფექტიანობის გაუმჯობესებისა და ნარჩენების მართვის თანამედროვე პრაქტიკების დანერგვის გზით. ამასთანავე, კვლევა აჩვენებს, რომ როგორც საშუალო, ისე მცირე ტიპის ღვინის საწარმოებს შეუძლიათ მნიშვნელოვანი წვლილის შეტანა მდგრადი განვითარების პრინციპების განხორციელებაში.

მიღებული შედეგები შეიძლება გამოყენებულ იქნეს ადგილობრივი ღვინის საწარმოების გარემოსდაცვითი მართვის გაუმჯობესებისა და ეკოლოგიურად მდგრადი საწარმოო პრაქტიკების განვითარებისათვის, რაც განსაკუთრებით მნიშვნელოვანია საქართველოს ღვინის სექტორის საერთაშორისო კონკურენტუნარიანობის ზრდის პირობებში.

გამოყენებული ლიტერატურა

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დანართი
კონფერენციის პროგრამა / Annex – Conference Program

კონფერენციაზე შემოსასვლელად გამოიყენეთ ბმული | To join the conference, please use the following link: https://tinywebs.site/POH7m1 | Meeting ID: 884 1119 9326 | Passcode: 776357

✅ **Time Reference for International Participants**

United Kingdom - 09:00; Belgium - 10:00; France- 10:00; Sweden - 10:00; Poland -10:00; Serbia - 10:00; Montenegro - 10:00; Croatia - 10:00; South Africa - 10:00; Lithuania - 11:00; Türkiye - 11:00; Ukraine - 11:00; Greece - 11:00; Georgia - 12:00; India - 13:30; Indonesia (Jakarta) - 15:00; China - 16:00; Philippines - 16:00; Malaysia - 16:00; Japan - 17:00; Republic of Korea - 17:00; Australia (Tasmania) - 18:00

შეგახსენებთ, რომ პროგრამაში ნაჩვენები ყველა დრო ემყარება GMT- ს (Greenwich Mean Time). შეგიძლიათ გამოიყენოთ Time Zone Converter ,რათა გადაიყვანოთ GMT თქვენს ადგილობრივ დროზე. | Please note that all times indicated in the program are based on GMT (Greenwich Mean Time). You may use a Time Zone Converter to convert GMT to your local time.

08:00 – 08:10	კონფერენციის გახსნა – „მოკლე ინფორმაცია კონფერენციის შესახებ“ გიორგი გაბედავა – საერთაშორისო ურთიერთობების სამსახურის ხელმძღვანელო; პროფესორი; ---------- Conference Opening – “Brief Information About the Conference” Professor George Gabedava – Head of the International Relations Service;
08:10 – 08:45	**მისალმება და კონფერენციის გახსნა** • პარმენ ხვედელიძე - ბნუ-ს რექტორი; პროფესორი, (საქართველო) • ივანე აბაშიძე - დირექტორი; საქართველოს ეკონომიკისა და მდგრადი განვითარების სამინისტროს საზღვაო ტრანსპორტის სააგენტო, (საქართველო) • იუსუკე მორი - აღმასრულებელი დირექტორის მოადგილე; საზღვაო უნივერსიტეტების საერთაშორისო ასოციაცია, (იაპონია) • მომოკო კიტადა - პროფესორი, საზღვაო განათლებისა და ტრენინგების მიმართულების ხელმძღვანელი; მსიფლიო საზღვაო უნივერსიტეტი, (შვედეთი) • ელიდა ხვედელიძე - ბნუ-ს რექტორის მოადგილე აკადემიური მიმართულებით; ასოცირებული პროფესორი, (საქართველო) • რიმა მიჩკევიჩინე - კლაიპედას უნივერსიტეტის საზღვაო ინჟინერიის დეპარტამენტის ხელმძღვანელი; პროფესორი, (ლიეტუვა) • რიმა მიკიენე - დირექტორის მოადგილე აკადემიურ საკითხებში; ლიეტუას საზღვაო აკადემია, (ლიეტუვა) • ლუკა ვუკიჩი - განვითარებისა და საერთაშორისო თანამშრომლობის დეკანის მოადგილე; ასოცირებული პროფესორი; საზღვაო ფაკულტეტი; სპლიტის უნივერსიტეტი, (ხორვატია) • მარიჯანა მლადენოვი - ვიცე-რექტორი საერთაშორისო თანამშრომლობის მიმართულებიღ; ნოვი სადის უნივერსიტეტის ბიზნეს აკადემია, (სერბეთი) • პელინ ბოლატ - ასოცირებული პროფესორი; სტამბოლის ტექნიკური უნივერსიტეტი (თურქეთი); • მურაი კოჯი – პროფესორი; ტოკიოს საზღვაო მეცნიერების და ტექნოლოგიების უნივერსიტეტის, (იაპონია) • ოქტავია პოსტოლაქ - საზღვაო დარგის ლექტორი; საფრანგეთის საზღვაო აკადემია, (საფრანგეთი) • ნიკიტას ნიკიტაკოს - პროფესორი ემერიტუსი; საზღვაო ვაჭრობისა და ტრანსპორტის დეპარტამენტი; ეგეოსის უნივერსიტეტი, (საბერძნეთი) • ნამ ჰიუნგსიკი – პროფესორი; ლოჯისტიკური სისტემების ინჟინერიის დეპარტამენტის ხელმძღვანელი, კორეის საზღვაო და ოკეანის უნივერსიტეტი, (კორეის რესპუბლიკა); ---------- Parmen Khvedelidze – BNU Rector; Professor, (Georgia) Ivane Abashidze – Director of Maritime Transport Agency of the Ministry of Economy and Sustainable Development of Georgia, (Georgia) Yusuke Mori – Deputy Executive Director, International Association of Maritime Universities (IAMU), (Japan) Momoko Kitada - Prof., Head of Maritime Education and Training, World Maritime University, (Sweden) Elida Khvedelidze – Vice-Rector for Academic Affairs, Associate Professor, (Georgia) • Rima Mickevičienė – Klaipeda University; Head of Department of Marine Engineering; EU-CONEXUS Management Board Member, Institutional Coordinator; Professor (Lithuania); • Rima Mickiene – VILNIUS TECH Lithuanian Maritime Academy; Vice Director for Academic Affairs (Lithuania); • LuKa Vukić - Vice Dean for Development and International Cooperation; Associate Professor; Faculty of Maritime Studies; University of Split (Croatia) • Marijana Mladenov -Vice Rector for International Cooperation; Professor; University Business Academy in Novi Sad (Serbia); • Pelin Bolat – Associate Professor; Istanbul Technical University (Turkey); • Murai Koji – Professor; Tokyo University of Marine Science and Technology (Japan); Capt. Octavian Postolache AFNI, Maritime Lecturer; French Maritime Academy (France); • Nikitas Nikitakos - Professor Emeritus; Department of Shipping Trade and Transport; University of the Aegean (GREECE) • Nam Hyungsik – Professor; Head of Department of Logistics System Engineering; Korea Maritime & Ocean University (Republic of Korea

ინგლისურენოვანი სექცია No1 / English-Language Section No1	**მოდერატორი: ასოცირებული პროფესორი ნინო ჭილაია; Moderator: Associate Professor Nino Tchilaia;**	
	ნაშრომი სათაური; ავტორ(ებ)ი / Paper Title; Author(s)	**უნივერსიტეტი / ქვეყანა - University / Country**
09:00 – 09:10	**„Implementation of SEEMP in Order to Evaluate the Operational Performance of LNG Vessels in the Indonesian Region"** **ავტორ(ებ)ი**/Author(s): Ronald Simanjuntak; Mutarin Dewi Mustafa; Derma Watty Sihombing; Nurindah Dwi Yani; Boedojo Wiwoho	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta, (Indonesia)
09:10 – 09:20	**„Present and Future Fuels for Sustainable Maritime Transportation: A Review of Opportunities and Challenges"** **ავტორ(ებ)ი**/Author(s): Aditya Kolakoti; Gargi Dangayach; Gauri Nandhana K.R	ინდოეთის საზღვაო უნივერსიტეტი, (ინდოეთი) Indian Maritime University, (India)
09:20 – 09:30	**„Sustainable Transport Systems and Maritime Logistics: Strategic Assessment of the Eastern Black Sea Logistics Hub"** **ავტორ(ებ)ი**/Author(s): Musa Gün	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
09:30 – 09:40	**„Modeling of Traffic Flows Taking into Account the Processes of Updating Components of Maritime Transport Infrastructure"** **ავტორ(ებ)ი**/Author(s)**:** Iryna Honcharova	ეროვნული სატრანსპორტო უნივერსიტეტის დუნაის წყლის ტრანსპორტის ინსტიტუტი**, (უკრაინა)** Danube Institute of Water Transport of National Transport University, (Ukrine)
09:40 – 09:50	**„Strategies for Enhancing the Competitiveness and Attractiveness of Georgia's Black Sea Ports"** **ავტორ(ებ)ი**/Author(s)**:** Ruslan Verdzadze; Levan Bolkvadze; Nino Beridze; **Master Student Beka Bolkvadze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
09:50 – 10:00	**„Approaches to Maritime Network Resilience: A State-of-the-Art Review and Future Research Directions"** **ავტორ(ებ)ი**/Author(s)**:** Jinendri Prasadika; Oanh Nguyen; Wenming Shi	ტასმანიის უნივერსიტეტი, (ავსტრალია) University of Tasmania, (Australia)
10:00 – 10:10	**„B2B Place Marketing and Strategic Positioning in Sustainable Supply Chains: A Conceptual Analysis Focusing on the İyidere Logistics Port"** **ავტორ(ებ)ი**/Author(s)**:** Mustafa Said AKIN; Abdülkadir ÖZTÜRK	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
10:10 – 10:20	**„STPA-Based Safety Analysis in Pilot Transfer Operations"** **ავტორ(ებ)ი**/Author(s)**:** Muhammed Ali Dönmez; Muhammed AYDIN	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
10:20 – 10:30	**„Temporal Changes and Operational Risk Factors in Maritime Container Loss Events"** **ავტორ(ებ)ი**/Author(s)**:** Mehmet KAPTAN	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
10:30 – 10:40	**„Improving the Interaction between Seaports and Rail Transport"** **ავტორ(ებ)ი**/Author(s)**:** Valerian Imnaishvili; Giorgi Kikvidze; **Master Student Mariam Gogitidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)

10:40 – 10:50	**„Risk Management in Global Energy Maritime Logistics under Geopolitical and Supply Chain Disruptions: A Review“** **ავტორ(ებ)ი**/Author(s)**:** K.M.Mahaboob Sheriff	**საზღვაო განათლებისა და მომზადების აკადემია** (AMET), (**ინდოეთი)** Academy of Maritime Education and Training (AMET), (India)
10:50 – 11:00	**Geopolitical risk and maritime logistics disruptions: The case of the Strait of Hurmuz** **ავტორ(ებ)ი**/Author(s)**:** Noa Klarić; Duje Delić; Luka Vukić	სპლიტის უნივერსიტეტი, (ხორვატია) University of Split, (Croatia)
11:00 – 11:10	**„Implementing Maritime Labour Convention 2006 in Cadet Education: A Seafarer Rights Awareness Model at STIP Jakarta“** **ავტორ(ებ)ი**/Author(s): Dr. Capt. Tri Cahyadi; Dr. Larsen Barasa; Capt. Natanael Suranta; Titis Ari Wibowo; Dr. Markus Yando; Nurul Wahyuni; Aji Permana	Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)** **ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)**
11:10 – 11:20	**„Blockchain-based Solution for Maritime Crew Certification: Sustainability Enhancement for Maritime Sector“** **ავტორ(ებ)ი**/Author(s): Thi Mai Phuong Pham; Anish Arvind Hebbar; Tafsir Matin Johansson	მსოფლიო საზღვაო უნივერსიტეტი, (შვედეთი) World Maritime University, (Sweden)
11:20 – 11:30	**„Object Detection in Marine Environment: Enhancing Indonesia Maritime Safety via Yolov8 Computer Vision and Kalman Filter“** **ავტორ(ებ)ი**/Author(s): Aditya Rinaldi; Larsen Barasa; Natanael Suranta	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)**
11:30 – 11:40	**A Multi LLM Analytical Prototype for Extracting Financial and Transition Risk Data from Port Reports** **ავტორ(ებ)ი**/Author(s): Mohammad Nawaz; Dr Chia-Hsun Chang	**ლივერპულ ჯონ მურსის უნივერსიტეტი, (გაერთიანებული სამეფო)** Liverpool John Moores University, (United Kingdom)
11:40 – 11:50	**„Predictive Analytics for SIRE Tanker Inspections Using Machine Learning: A Data-Driven Approach to Proactive Risk Management:** **ავტორ(ებ)ი**/Author(s): Toygar Tibet GENIS; Muhammet AYDIN	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
11:50 – 12:00	**„International Review of Emerging Technologies in Container Ports and Terminals: A Study of Asia-Pacific Region“** **ავტორ(ებ)ი**/Author(s): Pavan Kumar Amarvadi; Wenming Shi; Oanh Nguyen	ტასმანიის უნივერსიტეტი, (ავსტრალია) University of Tasmania, (Australia)
12:00 – 12:10	**„Information Systems for Logistics Management“** **ავტორ(ებ)ი**/Author(s): Viktoriia Smrkovska	ოდესის ეროვნული საზღვაო უნივერსიტეტი, (უკრაინა) Odesa National Maritime University, (Ukrine)
12:10 – 12:20	**„A Multi-Layer Approach to Event Prediction Using Semantic Network Models“** **ავტორ(ებ)ი**/Author(s): **Lia Shetsiruli; Natela Archvadze; Merab Pkhovelishvili**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)

12:20 – 12:30	**„A Combined Salt Spray and Cyclic Loading Test Protocol for Characterizing Weld Zone Corrosion in AH36 Steel"** **ავტორ(ებ)ი**/Author(s): **Anatoli Ripalevi**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
12:30 – 12:40	Forensic Evaluation of Systemic Failures in the Beirut Port Ammonium Nitrate Explosion under Maritime Risk Management Perspective **ავტორ(ებ)ი**/Author(s): Kasypi Mokhtar; Chahaya Alysa Ahmad Fuad; Siti Marsila Mhd Ruslan	**ტერენგანუს მალაიზიის უნივერსიტეტი,** (მალაიზია) Universiti Malaysia Terengganu, (**Malaysia)**
12:40 – 12:50	**Biodiesel Competency Framework for Engine Cadets to Support Indonesia's National Energy Mix** **ავტორ(ებ)ი**/Author(s): Dr. Larsen Barasa; Dr. Capt. Marihot Simanjuntak; Dr. Capt. Marihot Simanjuntak; Titis Ari Wibowo; Aditya Rinaldy	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)**
12:50	**ტრანსფერი მთავარი სესიის ოთახში** / Transfer to the Main Session Room	
ინგლისურენოვანი სექცია No2 / English-Language Section No2	**მოდერატორი: პროფესორი გიორგი გაბედავა** **Moderator: Professor George Gabedava**	
09:00 – 09:10	**„The Inaudible Catastrophe – Marine Noise Pollution"** **ავტორ(ებ)ი**/Author(s): Captain Pandian Mahadevan; Captain Dr. K. Rajesh	**საზღვაო განათლებისა და მომზადების აკადემია** (AMET), (**ინდოეთი)** Academy of Maritime Education and Training (AMET), (India)
09:10 – 09:20	**„Application of HAZOP Methodology for Risk Assessment in Chemical Tanker Tank Washing Operation"** **ავტორ(ებ)ი**/Author(s): Batuhan İnanc Erkan; Muhammet Aydin	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
09:20 – 09:30	**„The Effects of Climate Change on Human Physiology"** **ავტორ(ებ)ი**/Author(s): Elif ÖZDÜNDAR	**ართვინ ჩორუჰის უნივერსიტეტი, (თურქეთი)** Artvin Çoruh Üniversitesi, (Türkiye)
09:30 – 09:40	**„Prospects for Realizing the Transit Potential of the Eurasian Economic Union in the System of International Transport Corridors"** **ავტორ(ებ)ი**/Author(s): George Gabedava; Tengiz Aphkhazava; Nino Tchilaia, **Master Student Giorgi Davitadze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
09:40 – 09:50	**„Maritime Logistics, Climate Change and Housing Markets in Cities"** **ავტორ(ებ)ი**/Author(s): Haydar KARADAG	რეჯებ ტაიფ ერდოღანის უნივერსიტეტი, (თურქეთი) Recep Tayyip Erdoğan University, (Türkiye)
09:50 – 10:00	**„Maritime Value Chain towards Environmental Standards for Sustainable Growth from Malaysia Experience"** **ავტორ(ებ)ი**/Author(s): Kasypi Mokhtar	**ტერენგანუს მალაიზიის უნივერსიტეტი,** (მალაიზია) Universiti Malaysia Terengganu, (**Malaysia)**
10:00 – 10:10	**Integrating IMO's GHG Strategy into Engine Curriculum: A Green Simulation Module at STIP Jakarta** **ავტორ(ებ)ი**/Author(s): Dr. Meilinasari Nurhasanah Hutagaol; Jarot Delta Susanto; Muhammad Nurdin; Mochamad Ely Ridwan; Ardiansyah; Sursina; Fitri Mulyana	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)**

10:10 – 10:20	**„Dual Award Master's programme in Transport Technologies: Case of University of Plymouth and Kherson State Maritime Academy“** **ავტორ(ებ)ი**/Author(s): Alona Leshchenko; Alona Yurzhenko; Olena Kononova	**ხერსონის სახელმწიფო საზღვაო აკადემია, (უკრაინა)** **Kherson State Maritime Academy, (Ukrine)**
10:20 – 10:30	**„AI Literacy as an Emerging Non-Technical Competency in Maritime Officer Training: Implications for STCW and IMO Model Courses“** **ავტორ(ებ)ი**/Author(s): Bairamova Olena Viktorivna	ეროვნული სატრანსპორტო უნივერსიტეტის დუნაის წყლის ტრანსპორტის ინსტიტუტი**, (უკრაინა)** Danube Institute of Water Transport of National Transport University, (Ukrine)
10:30 – 10:40	**„Challenges Eco Port and Green Shipping : Overview of Current and Future Action“** **ავტორ(ებ)ი**/Author(s): Vidya Selasdini; Meilinasari Nurhasanah; Naomi Louhnapessy	ინდონეზიის საზღვაო ინსტიტუტი Maritime Institute Indonesia **(**Indonesia**)**
10:40 – 10:50	**„Human Factors and Their Impact on Maritime Safety and Operational Efficiency“** **ავტორ(ებ)ი**/Author(s): Tamar Diasamidze	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
10:50 – 11:00	**„Integrating AI Soft Skills into Maritime Engineering Education“** **ავტორ(ებ)ი**/Author(s): Natalia Ohorodnyk	**ხერსონის სახელმწიფო საზღვაო აკადემია, (უკრაინა)** **Kherson State Maritime Academy, (Ukrine)**
11:00 – 11:10	**„Logistics as a Scientific Tool for Managing Flow Processes“** **ავტორ(ებ)ი**/Author(s): George Gabedava, **Master Student Jambul Turmanidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
11:10 – 11:20	**„The Impact of Mobile OTG Resources on English Communicative Competence Onboard“** **ავტორ(ებ)ი**/Author(s): Litikova Oleksandra	**ხერსონის სახელმწიფო საზღვაო აკადემია, (უკრაინა)** **Kherson State Maritime Academy, (Ukrine)**
11:20 – 11:30	**„Virtual Reality for Contextual Maritime English Training: A Model for Situational Awareness at STIP Jakarta“** **ავტორ(ებ)ი**/Author(s): Dr. Marudut Bernadtua Simanjuntak; Niken Sitalaksmi Widjaja; Capt. Suhartini; Ikhwanuddin	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)**
11:30 – 11:40	**„The Impact of Logistics on Business Performance“** **ავტორ(ებ)ი**/Author(s): Ketevan Goletiani; Nino Tchilaia; Ekaterine Chikovani, **Master Student Ana Kekelidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
11:40 – 11:50	**„Optimizing EEOI Training for Deck and Engine Officers: A Collaborative Model for CII Compliance at STIP Jakarta“** **ავტორ(ებ)ი**/Author(s): Pargaulan Dwikora Simanjuntak; Rosna Yuherlina Siahaan; Susi Herawati; Derma Watty Sihombing	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta**, (**Indonesia**)**
11:50 – 12:00	**„Problems of Relations with the Eurasian Economic Union“** **ავტორ(ებ)ი**/Author(s): Levan Gvarishvili; Mirza Suknishvili; Giorgi Abashidze, **Master Student Bakur Kochalidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)

12:00 – 12:10	**„Enhancing ISM Code Compliance Through Simulation-Based Safety Culture Training for Cadets at STIP Jakarta"** **ავტორ(ებ)ი**/Author(s): Dr. Winarno; Capt. Natanael Suranta; Capt. Candra Purnama; Capt. Irfan Faozun; A. Nurfajri Irwan; Giovani B. Puteri	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta, **(**Indonesia**)**
12:10 – 12:20	**„Evaluating STCW-Based Maritime English Instruction on Deck and Engine Cadets' Operational Readiness at STIP Jakarta"** **ავტორ(ებ)ი**/Author(s): Dr. Marudut Bernadtua Simanjuntak; Capt. Suhartini; Tristanti; Yayu Nopriani Martha	**ჯაკარტის საზღვაო მეცნიერებების უმაღლესი სკოლა (STIP), (ინდონეზია)** Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta, **(**Indonesia**)**
12:20	**ტრანსფერი მთავარი სესიის ოთახში** / Transfer to the Main Session Room	
ქართულენოვანი სესია No3 / Georgian-Language Session No 3	**მოდერატორი: ასისტენტ - პროფესორი იმედა პაკსადზე** **Moderator: Assistant Professor Imeda Paksadze**	
09:00 – 09:10	**„საქართველოს სავაჭრო ნაკადების განმსაზღვრელები 3+3 ფორმატის ქვეყნებთან: ეკონომიკური, კულტურული და ლოგისტიკური ფაქტორების ანალიზი პანელური გრავიტაციის მოდელის გამოყენებით„** **„Determinants of Georgia's Trade Flows with the 3+3 Format Countries: An Analysis of Economic, Cultural, and Logistics Factors Using a Panel Gravity Model"** **ავტორ(ებ)ი**/Author(s): Imeda Paksadze; Ali Riza Sandalcilar	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
09:10 – 09:20	**„პირდაპირი უცხოური ინვესტიციების გავლენა ზღვის ტრასპორტისა და ლოჯისტიკის განვითარებაზე საქართველოში"** **„The Impact of Foreign Direct Investment on the Development of Maritime Transport and Logistics in Georgia"** **ავტორ(ებ)ი**/Author(s): Nino Kartvelishvili	საქართველოს უნივერსირტეტი, (საქართველო) **University of Georgia, (Georgia)**
09:20 – 09:30	**სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის ფორმირება და განვითარება საქართველოში** **„Formation and Development of Transport and Logistics Infrastructure in Georgia"** **ავტორ(ებ)ი**/Author(s): Parmen Khvedelidze; Nino Beridze; **Master Student Giorgi Shainidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
09:30 – 09:40	**„სატრანსპორტო და ლოგისტიკური ინფრასტრუქტურის როლი ტურისტული დანიშნულების ფორმირებაში: დუბაის განვითარების გამოცდილება"** **„The Role of Transport and Logistics Infrastructure in Shaping Tourist Destinations: The Experience of Dubai's Development"** **ავტორ(ებ)ი**/Author(s): Larisa Dolikashvili	საქართველოს ეროვნული უნივერსიტეტი, (საქართველო) **Georgian National University, (Georgia)**

09:40 – 09:50	**„საზღვაო ტრანსპორტის რისკების კლასიფიკაცია** **Classification of Maritime Transport Risks“** **ავტორ(ებ)ი**/Author(s): George Gabedava; Kristina Rzgoeva; **Master Student Anri Chkhaidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
09:50 – 10:00	**„სახელმწიფო ინვესტიციების როლი პორტების ოპტიმიზაციასა და ეფექტიანობაში და გავლენა რეგიონულ ეკონომიკურ განვითარებაზე“** **„The Role of Public Investment in Port Optimization and Efficiency and Its Impact on Regional Economic Development“** **ავტორ(ებ)ი**/Author(s): Daviti Grdzelishvili	**აკაკი წერეთლის სახელმწიფო უნივერსიტეტი, (საქართველო)** Akaki Tsereteli State University, (Georgia)
10:00 – 10:10	**„საზღვაო ლოგისტიკა და ნავსადგურების მართვა“** **„Maritime Logistics and Port Management“** **ავტორ(ებ)ი**/Author(s): Manana Laliashvili	საქართველოს ტექნიკური უნივერსიტეტი, (საქართველო) **Georgian Technical University, (Georgia)**
10:10 – 10:20	**„საზღვაო ინდუსტრიის უსაფრთხოების სტანდარტები და მათი რეგულირების მექანიზმები“** **„Safety Standards in the Maritime Industry and Their Regulatory Mechanisms“** **ავტორ(ებ)ი**/Author(s): Nato Saginadze	**ბათუმის შოთა რუსთაველის სახელმწიფო უნივერსიტეტი, (საქართველო)** **Batumi Shota Rustaveli State University, (Georgia)**
10:20 – 10:30	**„Digital Twin ტექნოლოგია როგორც ტრანსპორტისა და ლოგისტიკის ოპტიმიზაციის ინოვაციური ინსტრუმენტი“** **„Digital Twin Technology as an Innovative Tool for Transport and Logistics Optimization“** **ავტორ(ებ)ი**/Author(s): Tamila Kartsivadze	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
10:30 – 10:40	**„Digital Twin ტექნოლოგიის როლი თანამედროვე ლოგისტიკასა და საქართველოს სატრანზიტო პოტენციალის განვითარებაში“** **„The Role of Digital Twin Technology in Modern Logistics and the Development of Georgia's Transit Potential“** **ავტორ(ებ)ი**/Author(s): Nino Topuria; Elizbar Darchiashvili	საქართველოს ტექნიკური უნივერსიტეტი, (საქართველო) **Georgian Technical University, (Georgia)**
10:40 – 10:50	**„პორტის საქმიანობის ექსპლუატაციური მაჩვენებლების ანალიზი საბაზრო პირობებში“** **„Analysis of Port Operational Performance Indicators under Market Conditions“** **ავტორ(ებ)ი**/Author(s): Teimuraz Gograchadze; Tariel Paksadze; **Master Student Ilia Chkhaidze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)

10:50 – 11:00	**„საზღვაო ლოგისტიკის ციფრული ტრანსფორმაციის განვითარების პროგნოზირება საქართველოში"** **„Forecasting the Development of the Digital Transformation of Maritime Logistics in Georgia"** **ავტორ(ებ)ი**/Author(s): Irakli Gazdeliani; Tea Munjishvili	ივანე ჯავახიშვილის სახელობის თბილისის სახელმწიფო უნივერსიტეტი, (საქართველო) **Ivane Javakhishvili Tbilisi State University, (Georgia)**
11:00 – 11:10	**„საზღვაო ტერმინოლოგიასთან დაკავშირებული გამოწვევები"** **„Challenges Related to Maritime Terminology"** **ავტორ(ებ)ი**/Author(s): Tatia Tsetskhladze	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
11:10 – 11:20	**„ადამიანური კაპიტალის განვითარების აქტუალური საკითხები საზღვაო სისტემაში"** **„Current Issues in Human Capital Development in the Maritime Sector"** **ავტორ(ებ)ი**/Author(s): Nona Akhvlediani; Mariami Akhvlediani	**აკაკი წერეთლის სახელმწიფო უნივერსიტეტი, (საქართველო)** Akaki Tsereteli State University, (Georgia)
11:20 – 11:30	**„სავაჭრო ნაკადის სტრუქტურული ცვლილების დეტერმინანტები"** **„Determinants of Structural Changes in Trade Flows"** **ავტორ(ებ)ი**/Author(s): Givi Bakradze; Imeda Paksadze; Iago Beridze; **Master Student Giorgi Chkhikvadze**	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
11:30 – 11:40	**„სამედიცინო დაწესებულების მოტივაციის პრობლემის საერთო დიაგნოსტიკა"** **„General Diagnosis of Motivation Problems in Medical Institutions"** **ავტორ(ებ)ი**/Author(s): Elida Khvedelidze; Ekaterine Gvarishvili	ბათუმის ნავიგაციის უნივერსიტეტი, (საქართველო) Batumi Navigation University, (Georgia)
11:40 – 11:50	**„უცხოური სამუშაო ძალის გავლენა საქართველოს შრომის ბაზრის სტრუქტურულ და ფუნქციურ ტრანსფორმაციაზე"** **„The Impact of Foreign Labor on the Structural and Functional Transformation of Georgia's Labor Market"** **ავტორ(ებ)ი**/Author(s): Irma Tkemaladze; Teona Chachua; Nino Dokhturishvili; Gvantsa Eristavi	ივანე ჯავახიშვილის სახელობის თბილისის სახელმწიფო უნივერსიტეტი, (საქართველო) **Ivane Javakhishvili Tbilisi State University, (Georgia)**
11:50 – 12:00	**„ღვინის წარმოების ეკოლოგიური კვალი თელავის მუნიციპალიტეტში"** **„Environmental Footprint of Wine Production in Telavi Municipality"** **ავტორ(ებ)ი**/Author(s): Magda Davitashvili; Darejan Margalitashvili; Lamara Zuroshvili	იაკობ გოგებაშვილის სახელობის თელავის სახელმწიფო უნივერსიტეტი**, (საქართველო)** **Iakob Gogebashvili Telvai State University, (Georgia)**
12:00 – 12:15	**დასკვნითი სიტყვა და სამომავლო თანამშრომლობის შესაძლებლობები**	

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ISBN 978-9941-9995-4-3