GƏMİÇİLİK VƏ SU NƏQLİYYATININ İSTİSMARI

UOT 656.052

FROM CLASSROOM TO CARBON-NEUTRAL AND AUTONOMOUS VESSELS: PREPARING AZERBAIJAN'S MARITIME WORKFORCE FOR NEXT-GENERATION SHIPPING

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Xülasə. *Dənizçilik sektoru iki qlobal meqatrendin – dekarbonizasiya və avtomatlaşdırmanın təsiri ilə ciddi bir transformasiyadan keçir. Avtonom Dəniz Gəmiləri (MASS) və yaşıl texnologiyalar əməliyyat standartlarını dəyişdirir və dənizçilər, mühəndislər və sahil əsaslı personal üçün tələb olunan bacarıqları yenidən müəyyənləşdirir. Bu dəyişikliklər, rəqəmsal sistemlər, süni intellekt, ətraf mühit tələbləri və uzaqdan idarəetmə sahəsində bacarıqlı yeni bir dənizçi nəslinin hazırlanmasını tələb edir.*

Bu xülasədə Azərbaycan üçün bu dəyişikliklərə necə cavab verilə biləcəyi araşdırılır və gələcəyə hazır dənizçilik işçi qüvvəsinin formalaşdırılması yolları təklif olunur. Qlobal standartlara uyğun Dəniz Təhsili və Təlimi (MET), kursant hazırlığında süni intellekt və kibertəhlükəsizliyin inteqrasiyası, və Bakı Gəmiqayırma Zavodu kimi resursların innovasiya və bacarıq inkişafında istifadəsi vurğulanır. Təhlil beynəlxalq çərçivələrə, MASS sahəsində lider ölkələrin təcrübəsinə və qlobal işçi qüvvəsi hazırlığı müqayisələrinə əsaslanır.

Abstract. *The maritime sector is undergoing a major shift driven by two global megatrends: decarbonization and automation. Maritime Autonomous Surface Ships (MASS) and green technologies are reshaping operational standards and redefining the skills needed for seafarers, engineers, and shore-based personnel. These changes call for a new generation of maritime professionals skilled in digital systems, AI, environmental compliance, and remote operations.*

This abstract examines how Azerbaijan can respond to these changes by building a future-ready maritime workforce. It emphasizes aligning Maritime Education and Training (MET) with global standards, integrating AI and cybersecurity into cadet training, and leveraging assets like Baku Shipyard for innovation and skill development. The analysis draws on international frameworks, lessons from MASS pioneers, and global workforce readiness comparisons.

Аннотация. *Морской сектор переживает значительные преобразования под влиянием двух глобальных мегатрендов: декарбонизации и автоматизации. Автономные суда (MASS) и экологически чистые технологии меняют стандарты эксплуатации и переопределяют требования к компетенциям моряков, инженеров и берегового персонала. Эти изменения требуют появления нового поколения морских специалистов, обладающих навыками в области цифровых систем, искусственного интеллекта, экологического регулирования и удалённого управления.*

Данная аннотация рассматривает, как Азербайджан может ответить на эти вызовы, сформировав кадровый потенциал, готовый к будущему. Акцент сделан на приведении морского образования и подготовки (MET) в соответствие с международными стандартами, интеграции искусственный интеллект и кибербезопасности в подготовку курсантов, а также использовании таких активов, как Бакинский судостроительный завод, для инноваций

и развития навыков. Анализ основан на международных рамках, опыте лидеров в области MASS и глобальных сравнениях готовности рабочей силы.

***Açar sözlər**: dənizçilik işçi qüvvəsi, avtonom dəniz gəmiləri, gəmiçiliyə süni intellektin tətbiqi, dəniz təhsili, Azərbaycan, dekarbonizasiya, avtomatlaşdırma, rəqəmsal təlim*

***Key words:** maritime workforce, MASS, AI in shipping, maritime education, Azerbaijan, decarbonization, automation, digital training*

***Ключевые слова**: морская рабочая сила, автономные суда (MASS), искусственный интеллект в судоходстве, морское образование, Азербайджан, декарбонизация, автоматизация, цифровое обучение*

1. Introduction. The shipping industry faces growing pressure to transition to low-emission operations while embracing digital tools, AI systems, and autonomous technologies. Global regulatory bodies, particularly the International Maritime Organization (IMO), have introduced frameworks such as the MASS regulatory roadmap and interim guidelines to support this shift [1, 8].

For Azerbaijan, these developments highlight the urgent need to adapt its maritime workforce strategy. Future seafarers must be equipped not only with traditional navigational skills but also with the ability to operate AI-assisted systems, engage with data platforms, and interact with remote operation centers (ROCs). As vessels move toward cleaner fuels and smarter operations, workforce readiness will be essential for safety, efficiency, and international alignment

2. Historical Context of Maritime Workforce Development. The development of maritime workforce systems has historically followed technological and geopolitical shifts. In the 20th century, the primary focus of seafarer training revolved around manual navigation, engineering proficiency, and hierarchical shipboard roles. The introduction of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) in 1978 and its 1995 and 2010 amendments sought to harmonize global standards for safety and competence.

However, these frameworks were largely reactive and have proven insufficient in the face of automation, cyber-risk, and green shipping mandates. STCW regulations still do not address core competencies related to artificial intelligence (AI), autonomous ship handling, or data-driven decision-making. As such, many MET institutions—particularly in post-Soviet regions—continue to teach curricula anchored in legacy models of seafaring.

In Azerbaijan, this legacy is particularly pronounced. Maritime training institutions emerged under Soviet doctrine, which emphasized mechanical skill mastery and command structure over innovation or cross-functional adaptability. While this has created technically proficient officers, the system remains slow to adapt to the rapidly evolving global maritime landscape. Furthermore, training infrastructures—such as simulators, assessment systems, and faculty development pathways—have not kept pace with trends in digitalization or decarbonization.

By revisiting the assumptions underlying traditional workforce development and aligning training with the realities of Maritime Autonomous Surface Ships (MASS), Azerbaijan can modernize its maritime human capital pipeline and enhance its relevance on the international stage**.**

3. The Global Push Toward Autonomous and Sustainable Shipping. Maritime nations are rapidly advancing automation and climate-focused innovation. The International Maritime Organization (IMO) introduced a four-tier MASS framework classifying ships by autonomy—from automated decision support to fully crewless vessels [1]. This structure is driving regulatory adaptation and vessel innovation globally.

Leading countries have launched strategic pilots. Norway's Yara Birkeland, the first zero-emission, fully autonomous container ship, showcases AI integration, remote control centers, and electric propulsion [4]. Japan's e5 Lab, supported by NYK Line and Mitsui O.S.K. Lines, is developing autonomous electric vessels with machine-learning navigation [1][4].

In the U.S., public-private research via the META program and Department of Defense supports crewless ship testbeds in Virginia and San Diego [10]. Singapore's Maritime Digitalization Blueprint and MASS test zone near Tuas Port facilitate live autonomous trials and port-call optimization [15].

Simultaneously, regulatory pressure is mounting to decarbonize. The IMO's revised GHG Strategy targets 70% emissions cut by 2040 (from 2008 levels), prompting adoption of alternative fuels like ammonia, hydrogen, and methanol—each with unique operational challenges [4].

These shifts demand a new skillset: digital dashboard operation, predictive maintenance, emissions compliance, and hybrid seafaring-engineering expertise.

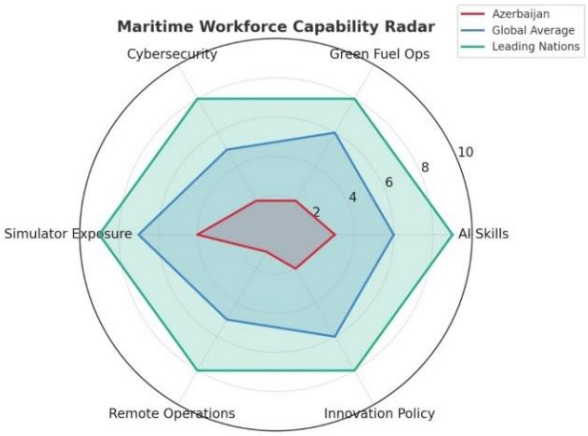
While Azerbaijan lags in MASS deployment and alternative fuel use, its Caspian Sea location and growing Baku Shipyard capabilities position it well. By adapting global trends to local needs, Azerbaijan can close workforce gaps and become a regional leader in smart, sustainable shipping.

4. Azerbaijan's Current Position. While countries like Norway, Japan, Singapore, and the U.S. are advancing autonomous vessel operations and aligning workforce strategies with digital and environmental standards, Azerbaijan remains in an exploratory phase. Its strategic location on the Caspian Sea and legacy in oil shipping and offshore engineering offer both opportunities and challenges amid maritime transformation.

Azerbaijan's main maritime training center—the Azerbaijan State Maritime Academy—still focuses on traditional navigation and engineering. Modern tools like autonomous bridge simulators, digital twins, or AI-based navigation are largely absent. Most instruction remains lecture-based, with limited exposure to remote operations or machine learning in maritime contexts.

Baku Shipyard, the country's most advanced infrastructure asset, has adopted Industry 4.0 techncv ologies such as robotic welding, predictive maintenance, and AI-enhanced design modeling [6]. However, the skills needed to support these innovations are not yet taught in MET programs, leading to a disconnect between education and industry needs. Regulatory progress is also limited. Although Azerbaijan is an IMO member with access to the MASS roadmap, its maritime authorities have not yet updated STCW standards to include digital skills, decarbonization, or ROC certification. Legal frameworks for autonomous vessel trials remain undeveloped.

Nonetheless, Azerbaijan has strong potential. A digitally inclined youth population, solid technical education institutions, and regional partnerships via TRACECA can support pilot projects and upskilling. With focused policy reform, investments in simulation and AI-based training, and tighter alignment between industry and education, Azerbaijan could position itself as a regional hub for smart and sustainable maritime innovation.



Maritime Workforce Capability Radar

The chart compares Azerbaijan's readiness with global and leading standards across six key areas. It highlights significant gaps in AI, remote operations, and cybersecurity—underscoring the need for focused workforce development

5. Skills Gap and Perception Challenges. Azerbaijan's maritime sector faces a critical skills mismatch between what future shipping demands and what current Maritime Education and Training (MET) systems provide. While not unique to Azerbaijan, this gap is especially concerning in the era of autonomous and low-emission vessels.

International surveys show over 60% of maritime cadets feel unprepared to work with AI-assisted systems, low-emission technologies, or onboard cybersecurity protocols [2][12]. In Azerbaijan, limited access to digital simulators, outdated assessment methods, and a lack of real-world MASS case studies amplify this issue. Practical training remains focused on conventional bridge and engine room operations, leaving cadets underexposed to data analytics, software-driven navigation, and alternative propulsion systems.

Faculty readiness is another challenge. Instructors often lack training in modern maritime technologies. Many are experienced in traditional methods but unfamiliar with digital twins, remote operations, and MASS behavior [5]. Without continuous professional development, even advanced equipment may go underused or misapplied.

Cultural perceptions also hinder progress. Maritime careers in Azerbaijan are still seen as physically demanding, male-dominated, and rigid. This limits recruitment from digitally native youth and underrepresents women in maritime leadership. The IMO and World Maritime University stress that diversity and inclusion are vital for a resilient workforce [13].

Employers increasingly report graduates are unprepared for hybrid roles involving remote monitoring, diagnostics, and AI. Yet these competencies are missing from most local MET curricula. Without stronger feedback loops between industry and academia, the gap will likely widen.

Ultimately, Azerbaijan's skills gap is not only technical but also structural and cultural. Closing it requires a multifaceted strategy—faculty retraining, tighter industry-academic collaboration, and a reframing of maritime careers as innovative, tech-driven, and inclusive.

6. Policy Innovation and Curriculum Reform. Azerbaijan's maritime sector stands at a pivotal moment where policy reform and curriculum modernization must converge. The current governance model—rooted in traditional STCW compliance—does not reflect the rapid shifts brought by MASS technologies and climate regulations.

Globally, policy innovations have accelerated workforce transformation. Singapore created a MASS regulatory sandbox and incorporated digital skills into its SkillsFuture roadmap. South Korea launched a Smart Maritime Education Framework that ties simulator-based learning to national R&D funding. Both conduct curriculum audits every 3–5 years to stay current with technological developments [15][16].

In contrast, Azerbaijan lacks a coordinated maritime human capital strategy. While some MET institutions are updating programs, there is no standardized, government-led framework for incorporating AI, automation, remote operations, or alternative fuels. The absence of a national accreditation system for simulation and digital training centers further limits certification in these emerging areas.

Reform should prioritize a shift from theory-heavy teaching to practice-based, competency-driven learning. MET curricula must include digital navigation, diagnostics, cybersecurity, emissions reporting, and MASS operations across all levels. Initiatives like the MT24 Consortium provide models for hybrid, simulation-based education [9].

Incentives are also key. Faculty development, industry fellowships, and joint research funding can help modernize instruction. Scholarships and tax credits can support students pursuing digital maritime careers.

Regulatory updates must include remote operator licenses, MASS simulator endorsements, and digital competency assessments aligned with IMO guidelines. These changes are crucial for maintaining international relevance.

Ultimately, policy and curriculum reform are not optional—they are essential for ensuring Azerbaijan's maritime workforce can meet the demands of next-generation shipping.

7. Recommendations. To prepare Azerbaijan's maritime workforce for carbon-neutral and autonomous shipping, coordinated action is needed across institutional, policy, and human capital domains. This paper outlines six key recommendations:

1. **Modernize MET Curricula**. MET institutions should integrate modules on:
   - MASS operations
   - AI-based decision systems
   - Onboard cybersecurity
   - Alternative fuels and emissions compliance (e.g., LNG, ammonia)
   - Environmental auditing and digital reporting

   These should be embedded across undergraduate and graduate programs and taught through case-based and simulation-driven methods, as seen in Norway and the Netherlands [16,17].
2. **Establish ROC Training and Certification**. Introduce national standards for Remote Operations Center (ROC) training in line with IMO and EMSA frameworks. Training should include simulation exercises, real-time protocols, and inter-operator communication strategies for managing autonomous and semi-autonomous vessels [18].
3. **Create a Maritime Innovation Hub**. Transform Baku Shipyard into a center for:
   - MASS system testing
   - AI and IoT application development
   - Industry-academia pilot projects

   This hub could attract international partnerships and establish Azerbaijan as a regional smart shipping R&D center.
4. **Build Global Talent Exchange Networks**. Form bilateral partnerships with top MET institutions in Singapore, Japan, the U.S., and the EU. Exchange programs should include student mobility, faculty fellowships, and collaborative research tied to real-time MASS operations and regulatory best practices [10,15].
5. **Promote Youth and Gender Inclusion**. Launch scholarships, mentoring programs, and outreach campaigns to attract youth and women into maritime careers. Participation in IMO's Women in Maritime initiative and partnerships with youth tech platforms will broaden the talent pool [13].
6. **Institutionalize Industry-Education Panels**. Create formal advisory panels linking port authorities, shipping companies, and MET faculty. These panels should guide curriculum development, identify emerging skill demands, and influence regulatory updates to ensure implementation and accountability [19].

8. Conclusion. As global shipping moves toward decarbonization, digitalization, and autonomy, human capital is becoming a strategic priority. The rise of Maritime Autonomous Surface Ships (MASS), climate imperatives, and complex ship systems require a fundamental rethinking of how maritime professionals are trained, certified, and supported.

This paper highlights that while Azerbaijan has strong assets—a solid MET foundation, an innovative Baku Shipyard, and a digitally savvy youth—its workforce strategies are not yet aligned with global trends. Curriculum gaps, outdated policies, and limited industry-academia collaboration risk leaving the country behind in a rapidly evolving maritime landscape.

Yet, this challenge offers a clear opportunity. By modernizing curricula, launching national ROC certifications, investing in innovation infrastructure, and fostering global partnerships, Azerbaijan can build a future-ready maritime workforce.

The maritime professionals of tomorrow will be defined not just by technical ability, but by their agility with hybrid systems, digital fluency, and commitment to sustainable practices. Azerbaijan's willingness to embrace this future will determine its competitiveness and its role in shaping a smarter, greener maritime industry.

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Məqalə qəbul olunub: 25.04.25
Tövsiyə edib: prof. Rüstəmov Z.Ə.