Varazdin Development and Entrepreneurship Agency and
Faculty of Maritime Studies, University of Split, Croatia

In cooperation with:
Maritime department University of Zadar, Croatia
Faculty of Management University of Warsaw, Poland
Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco
Ecole Nationale de Commerce et de Gestion de Tanger - Abdelmalek Essaadi University, Morocco
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Book of Proceedings

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Editors:
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ISBN 978-953-6125-37-1

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Publishing Editor ■ Domagoj Cingula

Publisher ■ **Design** ■ Varazdin Development and Entrepreneurship Agency / Faculty of Maritime Studies, University of Split, Croatia / Maritime department University of Zadar, Croatia / Faculty of Management University of Warsaw, Poland / Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco / Ecole Nationale de Commerce et de Gestion de Tanger - Abdelmalek Essaadi University, Morocco / GOVCOPP - University of Aveiro, Portugal.

Printing ■ Online Edition

ISBN 978-953-6125-37-1

The Book is open access and double-blind peer reviewed.
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Contributions in Croatian

FOREIGN TRADE AND GREEN ENERGY ASPECTS OF ECONOMIC RELATIONS EU WITH AZERBAIJAN AND CENTRAL ASIA COUNTRIES

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ABSTRACT

This study allows seeing the strategic role trade and energy cooperation between EU and Central Asia region. Suggested that trade and energy cooperation may transforming and resulting in regional effects. The approach comprises the three elements of relations (trade, Partnership and Cooperation Agreement and green projects). The economic development for the region countries hinges on the structure of economy, human capital, resource productivity and regional cooperation. The trade and green energy cooperation depend on different factors driving. For Azerbaijan, Kazakhstan and Uzbekistan, the model of economic development demonstrated good forecast for trade, green energy and agreement with EU, indicating positive dynamics for relations with EU. Particularly increased participation around sustainable development. Ensuring green projects initiatives and economic sustainability is crucial for implementing the transregional economic projects between European Union (EU) countries, Azerbaijan and Central Asia. In this article, we provide a summary of the most commonly available economic tendency, especially trade and green aspects of development cooperation EU with Azerbaijan-Central Asian republics nations—Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The purpose of this paper is to explore the trade, green energy and common interest aspects of the transregional relations with the EU and their economic integration prospect. The aim of the article is to explore the role foreign trade and green energy aspects of economic development of Azerbaijan and Central Asia countries, focusing on tools economic cooperation with EU.

Keywords: *economic relations; green energy; sustainable development; trading partners; transregional projects.*

1. INTRODUCTİON

Main fossil energy consumers of the developed world, have been revising their national energy strategies, and substantiating their strategy especially for Caucasus and Central Asian countries. EU and other OECD countries motivated to foster their roles in energy transition across Central Asia after Russia's invasion of Ukraine in 2022. Green transition policy of EU highlighted the importance of securing alternative (non-Russian) conventional energy supplies and access to energy transition resources, making Central Asian countries desirable partners for them (Elena Shadrina 2025). With vast human and natural resources, Central Asia economies have srtategic regional economic persperctives. Yet Central Asia is a region of enormous disparity in income levels, living standards, and socioeconomic conditions. Azerbaijan and the Central Asian states are situated at “the crossroads of Asia” on the route of the Silk Road. Economically the area represents a transition zone between EU and Chine. In the region, several global and regional actors compete for influence. Azerbaijan and Central Asia countries is one of the largest agrefood and cotton-producing areas in the world, and it contains substantial deposits of oil, gas, and non-ferrous metals and other nature minerals.

Rising globalization and regional cooperation facilitates the technological transfers across the nations. More specifically in EU, green technology promotes economic growth of an economy by lowering carbon emissions. Green energy transition plays a vital role in mitigating climate change. Accordingly, EU partner countries are strengthening their institutional frameworks for renewable energy to attract foreign direct investment and accelerate green energy projects whith Azerbaijan and Central Asia.

2. LITERATURE REVIEW

Diversification of trade relations is an important component of the development of oil and gas produced nations of Caspian and Central Asia region. The reason for this is the increase in the country's resilience to external stimuli, the study of the possibilities of diversifying the economy is very relevant, especially in today's geopolitical conditions (Guliyev, M. & Azizov, T., 2022). Improving energy resilience is significant for climate change mitigation, and green transition. To move toward a more sustainable economy, suggestions include enacting green taxes, luring in foreign direct investment, and bolstering green finance (Yonghong Zhang et al. 2025). The world has witnessed significant economic growth in many economies, driven by large amounts of FDI between nations. However, FDI has questionable effects in terms of reducing pollution and supporting green energy (Marco Túlio Dinali Viglioni et.al.2025). Azerbaijan and Central Asia has already demonstrated its capacity for collaboration with international energy projects.

The planned green energy corridors connecting Kazakhstan, Uzbekistan, Azerbaijan, Türkiye, and the EU could bring together diverse renewable sources, delivering low-cost, sustainable power across borders (Ufuk Alparslan,2024).Both regions need independence in terms of energy supplies from Russia, the second-largest supplier of natural gas and oil in the world (Chiara Gaffuri,2024). The need for energy security can be intertwined and lead to cooperation between the EU and Central Asia. A comparative analysis of the trade and green strategies of global corporations in European and Chinese industrial multinational corporations identifies differences in approaches and similarities in the pursuit of competitiveness (Mushfig Guliyev et.al. 2025). Such a study provides valuable insight into contributing bringing innovation to the Azerbaijan economy and Central Asia's region market. The EU Green Energy Initiative is wide, it will include actions at continental and different regional level. Since the launch of the EU-Africa Global Gateway Investment Package, the first 30 national and regional actions and projects under the Africa-EU Green Energy Initiative have been approved by the European Commission, for a total budget of €540 million (EU-Africa: Global Gateway Investment Package –Green Energy Initiative, 2023). The EU, Azerbaijan and Kazakhstan have complementary interests for a mutually beneficial cooperation in the energy sector, where international consortia had built pipelines to bring gas and oil to Western markets (Renata Mantel, 2015). In the context of its strategy of energy supply diversification, region countries are a welcome supplier for the EU independent from Russia and the Middle East.

3. PROBLEM STATEMENT

Highlights the role trade relations and green energy corridors in strengthening regional connectivity and enabling cost-effective expansion prospect of cooperations.COP29 host Azerbaijan and its neighbors are still largely fossil dependent. Diversification of trade realations and regional collaboration around renewables could usher in a new era in economic and sustynaible development Azerbaijan and Central Asia regions nations. The region has much to gain from enhancing these efforts by tapping into the EU investment.

4. MAIN RESULTS OF THE RESEARCH

Transforming regional economy and Energy Landscape: Azerbaijan and Central Asia region countries towards open and fair world-wide trade: the role cooperation with EU. The European Union is one of the most outward-oriented trade bloc in the world and world's largest single regional market area. Free trade one of the EU's founding principles, and it is committed to developing up regional trade with neighbours regions countries. The EU actively engages with Central Acia countries to negotiate trade agreements. These agreements have a strategic role for these countries. They grant mutually-beneficial access to the markets of both the EU and the countries concerned. Especially EU companies can grow their business, and can also more easily import the raw materials they use to make their products. The EU has boosted its bilateral and regional relations with most African, Caribbean and Pacific (ACP) and including countries Central Asia, implement or have signed Economic Partnership Agreements with the EU. The EU looks at 'behind-the-border issues' such as technical, social and environmental matters when creating such types of agreements with a view to making trade policy contribute to the development and cooperation of those countries or regions (European Union, Support for developing countries). The convergence of regional economies and support for sustainable development are strategically important today and are global challenges of the new era. Economic Partnership Agreements (EPAs) and other trade agreements with Azerbaijan and Central Asia countries bring them mutual benefits. Table 1 shoes the figures and latest developments EU trade with the region's nations.

	Import 2023	Export 2023	Total 2023	Total trade with EU 27 % World	Annual average growth rate, % import/export 2019 - 2023
Azerbaijan	19,065	2,340	21,405	48.6	15.8 / 6.2
Kazakhstan	30,287	12,120	42,407	27.9	13.3/19.6
Kyrgyz Republic	116	2,730	2,846	5.9	2.5/ 69.7
Tadjikistan	174	326	500	7.1	40.8/18.1
Turkmenistan	1,204	670	1,875	11.4	33.8/4.8
Uzbekistan	780	4,352	5,132	12.0	42.4 /14.9

Table 1. European Union trade with Azerbaijan, Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and Turkmenistan (Mio euros)
(Source: Compiled by the author based on data from EU trade relationships by country/region. From official website of the European Union, https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region_en)

The EU is region's main trading partner, accounting for around 48.6 % of Azerbaijan's, 27.9% of Kazakhstan's, 12.0% of Uzbekistan's, 11.4% of Turkmenistan's total trade. The EU continues to be Azerbaijan's biggest export market, and is now its third-biggest import market, with a 64% share of Azerbaijan's exports and a 17.4% share of Azerbaijan's imports. EU imports from Azerbaijan chiefly consist of mineral fuels, lubricants and related materials. EU exports to Azerbaijan are dominated by machinery and transport equipment. Other EU exports to Azerbaijan include mainly chemicals and related products, manufactured goods and articles (Azerbaijan, EU trade relationships by country/region). Since 1999 EU-Azerbaijan trade relations are based on a Partnership and Cooperation Agreement (PCA).

It should be noted that, the agreement does not include tariff preferences, but it eliminates trade quotas between the EU and Azerbaijan, with the aim of drawing Azerbaijan's standards closer to those of the EU. According to the European Commission Kazakhstan is the first Central Asian partner to have concluded an EPCA with the EU. The Enhanced Partnership and Cooperation Agreement (EPCA 2020), governs trade and economic relations between the European Union and Kazakhstan. The EU is Kazakhstan's biggest overall trading partner, as the destination for 37% of total Kazakh exports and representing 27.9% of its total trade in 2023. The EU is also the biggest foreign investor in Kazakhstan, providing €54.8 billion of total foreign direct investment (FDI) stock in 2022 (Kazakhstan, EU trade relationships by country/region). Studying development macroeconomic levels and processes is an important aspect of learning about regional relations Central Asia. The region contains countries different range of developmental levels. The Kyrgyz Republic benefits from the EU Generalised Scheme of Preferences plus (GSP+), the special incentive arrangement for sustainable development and good governance (GSP+). It allows the Kyrgyz Republic to strengthen its economy by exporting products to the European Union with no tax duties regime (The European Union and the Kyrgyz Republic). EU-Tajikistan development cooperation for the 2021-2027 period has in public finance management, water, energy and agriculture, while stepping up support on managing natural resources and greening the economy. According to the European Commission (EU-Tajikistan relations, March 2025), EU bilateral development assistance allocation for 2021-2024 was €91 million, and as for the allocation for 2025-2027 is €51 million, following 3 priority areas: inclusive green and digital economy, human development, natural resources management, efficiency and resilience. The EU has accepted Uzbekistan as the country of the special incentive arrangement for sustainable development and good governance (GSP+) under the unilateral Generalised Scheme of Preferences (GSP). From 2021, the EU started applying preferential tariffs for products imported from Uzbekistan under this arrangement. As is shown in table 1, the main import product group from Uzbekistan to EU are chemicals and related product (38,4%), manufactured goods classified chiefly by material (32.0%) and textiles (14.9%). EU's Generalised Scheme of Preferences plus (GSP+) gives Uzbekistan tariff-free quotation access to the EU market for the majority of tariff lines. To benefit from GSP+, Uzbekistan has committed to the implementation of 27 core international conventions on: support to democratic governance and digital transformation, inclusive, digital, and green growth, development of a smart and eco-friendly agro-food sector. As part of its Multi-annual Indicative Programme for Uzbekistan (2021-2027), the EU has allocated €76 million in 2021-2024 (EU-Uzbekistan relations, March 2025). The EU Strategy and green energy cooperation on Azerbaijan and Central Asia. The EU is one of the biggest oil and gas consumers in the world economy. As the European Union moves away from Russian energy recourse actively seeks to diversify its energy supply. The EU sees Azerbaijan and Kazakhstan as a very important oil and gas supplier. İn the mid-term European nations could begin purchasing "green energy" from the traditional energy-rich Caspian and Central Asian region countries. The European Union hopes two strategic positions (Timothy Rooks, 2023): pooling its gas demands will keep prices down through greater bargaining power. The coordinated effort is an attempt to make up for lost Russian gas and use infrastructure more efficiently. The bloc hopes guarantee a new stable supply while keeping energy prices down. EU aims to ensure alternative energy supplies, to help Azerbaijan and Kazakhstan develop its renewable sector in the near future. Germany, as the largest EU economy, is already involved in the green hydrogen production in Kazakhstan. Kazakhstan aim to produce 2 million tons of hydrogen annually starting in 2032, with the export-oriented production beginning in 2030. The EU and Azerbaijan's strategic energy cooperation has shown all its dynamism. If in 2019, there was only nature gas on the horizon, now The Southern Gas Corridor has evolved to become a forum for cooperation also on green energy.

According to European politicians, this is an extraordinary result and is proof of how this project is forward looking and made clean energy a key part of EU-Azerbaijan bilateral relations (EU steps up renewable energy cooperation with Azerbaijan, 4 March 2024). The Black Sea electric cable is a new transmission route full of opportunities and new form green energy cooperation. Especially this project could also help bring electricity to Moldova and the Western Balkans. The Black Sea electric cable partnership have dinamizm and more countries have signaled interest in joining this initiative. The partnership becomes consolidated and moves to transitions to tackle new work together:

- December 2022, Governments of Azerbaijan, Georgia, Romania and Hungary signed agreement on strategic partnership in the field of green energy in Bucharest;
- June 2023, Bulgaria, Serbia and Moldova announced its intention to join the project;
- May 2024 energy operators from Azerbaijan, Romania, Georgia and Hungary signed a memorandum to establish a joint venture as part of the Black Sea Energy implementation (EU following Black Sea green cable project from Azerbaijan with great interest, January 30, 2025).

In late 2024, TEN-E Regulation (Regulation (EU) 2022/869 sets out new guidelines for the development and interoperability of European Union (EU)-wide energy infrastructure corridors bringing them in line with the European Green Deal. The new Regulation, among others, aims to: conform the infrastructure development to reflect the climate mitigation's targets; promote the integration of renewable and of clean energy technologies into the energy system; continue to connect isolated regions; strengthen existing cross-border interconnections and promote cooperation with partner countries. The Black Sea Energy project is included as a strategic project under the EU Global Gateway strategy, which opens new opportunities and prospects for EU funding under instrument of international green energy cooperation. It should be noted that, Azerbaijan and Kazakhstan seeks to enhance green energy cooperation not only with EU nations, already eyes joint green energy projects with China. In Azerbaijan Since 2020, cooperation on renewable energy projects has begun with a large number of corporations, as Masdar, ACWA Power, bp, Fortescue Future Industries, China Gezhouba Group Overseas Investment, Total Energies, Nobel Energy, A-Z Czech Engineering and Baltech (The Use of Renewable Energy Resources in Azerbaijan, 06-03-2024). Kazakhstan it also plans to attract at least $150 billion FDI by 2029, a significant portion of this investment will be directed towards Kazakh renewables (Nikola Mikovic, 2024). Should be added about The Trans-Caspian Pipeline project was first suggested in 1996 by the United States. The project never progressed. This pipeline gains renewed significance. In 2023 Turkmenistan signed its first deal to supply natural gas to the EU. With Ukraine indicating it won't continue as a transit route for Russian gas to EU, Hungary is redirecting its focus to the Caspian region for improved energy security (Haley Nelson, 2023). However, this transition is exposing constraints in the current energy infrastructure and reviving discussions about the feasibility of the Trans-Caspian pipeline. Human rights are an essential aspect of bilateral relations with Turkmenistan. The EU and Turkmenistan hold an annual Human Rights Dialogue and democratization (EU-Turkmenistan relations). The EU Action "EU for a green Turkmenistan: Policy Dialogue and Climate Action 2024 – 2028" contributes to the Team Europe Initiative on Water, Energy and Climate Change in Central Asia (Green Central Asia). There is also an increasing understanding that the climate-related challenges cannot be tackled individually. In this respect, the project will support to realize Turkmenistan's policy objectives for sustainable green growth by applying EU best practices and standards. The EU also supports Uzbekistan's sustainable development, in line with the EU Strategy for Central Asia. There are several key initiatives. The EU signed a Memorandum of Understanding for cooperation on Critical Raw Materials with Uzbekistan in 2024 (Uzbekistan, International Partnerships).

The actions build on inclusive green economy, and improvements to the living conditions in the Central Asia region. The EU is dedicated to improving transport connectivity along the Trans-Caspian Corridor with Central Asia, including with Uzbekistan. Uzbekistan plays an important role securing critical raw materials, which are crucial for strategic technologies used for the green and other sectors.

5. ANALYSIS OF RESULTS

Three basic interrelated strategies can be used to development regional cooperation in such a way as to cover a variety of differences between countries. First, Regional Cooperation and Integration Strategy, Including Regional Cross-Border Infrastructure, it can refer to some region countries achievements. A second strategy is to rely on a trade diversification and Investment Cooperation. In terms of trade liberalization, the EU and WTO-led process of multilateral trade negotiation is the most important mechanism for Azerbaijan and Central Asia, as the region's economic future depends to a significant extent on the openness of global markets. The third strategy is to have EU identifies green transformation as a strategic priority. Green energy cooperation is one of the key instruments that EU will use to reduce poverty. It is therefore not an end in itself but a means to achieve a poverty-free Central Asia. EU provides a transregional platform that complements national policies and programs aimed at socioeconomic development and poverty reduction.

6. CONCLUSION

The tendency mutual trade cooperation with EU and development economy policy emphasizes that these countries should have increasing coordination, diversification and development strategies. They need to implement trade policies and make necessary domestic reforms to stimulate trade and investment, ensure that benefit from trade-led growth, and make sure their economic development is for the long term. In case of integration strategies, the countries have a choice to move in the value chain by adopting forward and backward integration. In this regard diversification strategy is another strategic alternative available for region countries to expand cooperation with the EU and economy grow.

7. FUTURE WORK

Future works can include aspects on matters such as intellectual property, sustainable development and human capital. We need learn how global trends like tech innovation and green transition will transform jobs, skills, and workforce strategies in The Future of cooperation EU with Azerbaijan and Central Asia region nations. And discuss ways in which these and other factors can be addressed when studying about present and future development in the South Caucus and Central Asia region.

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UPDATING MARINA OPERATIONS AND TRAFFIC FLOW THROUGH DIGITALIZATION

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ABSTRACT

The integration of digital technologies into marina operations presents both notable challenges and promising avenues for advancing nautical tourism. This paper aims to assess the progress in digital uptake among nautical ports, pinpointing key obstacles and prospects for future growth. Nautical ports are cornerstones of the nautical industry, bringing together diverse stakeholders across the manufacturing and service sectors. Data were collected via surveys administered to marina management personnel in Croatia. The results reveal that most marinas have implemented only foundational digital solutions, such as internet connectivity and reservation platforms, whereas more sophisticated technological applications remain underutilized. While user satisfaction with current offerings is broadly favorable, substantial opportunities exist to enhance and expand digital platforms. The insights from this paper offer valuable guidance for shaping strategies that sustain the industry's enduring competitiveness and sustainability.

Keywords: *Nautical ports, Tourism industry, Digital technologies, Traffic flow, Sustainable development*

1. INTRODUCTION

Nautical tourism represents a highly dynamic and vital segment of the Croatian tourism market. The nautical tourism sector is a pivotal element of coastal and maritime tourism in Europe and on inland waterways, but it still has potential to grow sustainably (European Boating Industry - EBI, n.d.). To harness its full potential, the sector is increasingly turning to digitalization, which facilitates more efficient management, optimized resource utilization, and an enhanced customer experience. Marinas particularly face growing customer expectations, and to stay competitive and keep up with global market shifts, they have to advance towards delivering an optimal client experience while improving business efficiency and social and environmental responsibility, i.e., overall sustainability. Thus, marinas must become smart to keep up with the global trend (ICOMIA Marinas Group, 2023). Smart ports understand that optimizing their performance (operational, social, and environmental) is imperative to their competitive advantage in the global market (Port Technology, 2023). The integration of digital and smart technologies is pivotal in transforming traditional marinas into intelligent, digitally managed systems, thereby boosting their competitiveness and contributing to sustainable development (Jović et al., 2019). The application of digital technologies enables marinas to use resources more efficiently, protect the marine environment, and create value for the community. Innovamarina (2023) highlights that interconnected, accessible assets pave the way for digitally managed, smart, data-driven marina operations.

Adopting smart technologies for communication with customers and partners, and interconnecting marinas and stakeholders across the industry value chain, is vital to addressing the sustainability challenges ahead for the nautical sector (Innovamarina, 2023; Port Technology, 2023). This evolution towards smart tourism is characterized by the adoption of artificial intelligence (AI) and the Internet of Things (IoT), enabling advanced applications such as digital berth reservations, real-time vessel tracking, and energy consumption optimization (Chun et al., 2023). However, the digital transformation of nautical ports faces significant headwinds. Many marinas operate with limited technological capacities, a situation often complicated by the differing contexts of private and public ownership. Key challenges include substantial technical and financial barriers, a shortage of trained personnel, organizational resistance to change, and concerns regarding data security. Consequently, a successful digital transition is contingent not only on modern infrastructure but also on cultivating employee readiness and strategic oversight. Organizations that navigate these challenges effectively can achieve significant gains in operational efficiency, security, and overall user experience (Buhalis and Amaranggana, 2015).

2. DIGITALIZATION OF NAUTICAL TOURISM PORTS

The development of ports can be divided into four phases: cargo ports, industrial ports, logistics ports, and smart ports (Gretzel et al., 2015; Yigit et al., 2023). A smart port (or *smartport)* is generally defined as a technologically advanced seaport that incorporates digitalization, automation, and data-driven solutions to optimize logistics, improve efficiency, enhance safety, and reduce environmental impact (Barten, 2020). Smart ports utilize modern technologies such as sensors, blockchain, and 5G networks to enable more efficient management and reduce costs (Favro and Mužinić, 2023; Gretzel et al., 2015).

Figure 1: Characteristics of a smartport – Smart marina (Source: Adjusted from Sinay, 2021)

Figure 1 provides a visual representation of the key functional pillars that characterize a smart port. The infographic overlays an aerial view of a modern port with three central domains (Sinay, 2021): Smart Environment Monitoring, Smart Operations, and Smart Assets Management. These domains are presented as interconnected elements, reflecting the integrated approach required for efficient digital port management. Each domain represents a core area in which data-driven systems enhance coordination, safety, and environmental performance. The figure also highlights the foundational technologies that support these capabilities, including artificial intelligence, big data analytics, IoT sensor networks, blockchain applications, and 5G connectivity. Together, these technologies illustrate how smart ports can optimize operations, strengthen sustainability, and enhance overall competitiveness (Sinay, 2021).

The main obstacles include high implementation costs, a lack of trained personnel, and limited financial resources (Buhalis and Leung, 2018). Solutions suggest better utilization of EU funds (Digital Europe, Interreg Italy–Croatia) and staff training. In the long term, digital transformation increases operational efficiency, safety, and business sustainability (Barten, 2020; Innovamarina, 2023). ICOMIA (2023) defines smart marinas as interconnected boating facilities that are easily accessible through digital platforms and physical data-collection sources, while maintaining safety and data privacy, and that can be further enhanced by linking to surrounding services and communities. Smart Marina processes can enable marinas to generate, analyze, and utilize data to automate operations, predict future market behavior, and independently address boaters' operational needs (ICOMIA, 2023). In Croatia, a successful example of digitalization is Marina Punat, which employs the Sense4Boat IoT system to monitor vessel safety parameters. Ultimately, the smart port represents an evolutionary step in port development, integrating advanced technology to promote sustainable growth (Lesniewska et al., 2021; Ivanov and Webster, 2017). Digital transformation of marinas includes (EBI, n.d.): a) digital transformation through roll-out of 5G, Wi-Fi and digital infrastructure allowing for connected boating, smart marinas, improved land-sea connectivity, Internet of Things, digital connectivity and automatized customer interaction technology; b) research and innovation investment: connected boats, autonomous boats, and improvement of on-board safety, citizen science, smart marinas, and c) investigation and pilot projects between universities, research institutions and marinas as means to develop new projects in close connection with experts (equally valuable for environmental transformation).
Figure 2 presents a glimpse of the future in the marina industry.

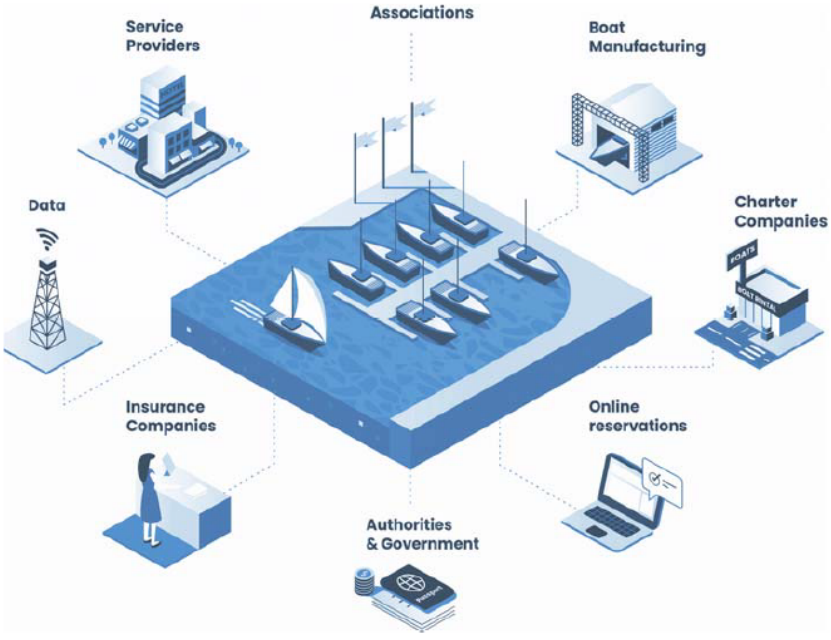

Figure 2: Future of marinas
(Source: ICOMIA Marinas Group, 2023)

Figure 2 illustrates the envisioned structure of future marina ecosystems, presenting the marina as a central hub surrounded by a network of interconnected stakeholders (ICOMIA, 2023). The core of the image shows a stylized marina basin with several moored vessels, representing the operational nucleus of the nautical tourism sector.

Surrounding this central area are the key actors expected to interact digitally with marinas in the coming years, including service providers, charter companies, boat manufacturers, insurance companies, governmental authorities, and industry associations. Digital components such as online reservation platforms and data infrastructures are also highlighted. The figure emphasizes the transition toward a more integrated, data-driven operational model in which marinas function as connected nodes within a broader digital service environment. Through this depiction of interconnectivity and information exchange, the visual underscores how smart marina development is expected to enhance efficiency, user experience, and sustainability across the nautical tourism sector.

3. RESEARCH METHODOLOGY

This research surveyed managers at Croatian marinas using a structured questionnaire distributed via email to a sample of 55 marinas, with 17 valid responses received (N=17). The questionnaire consisted of 18 closed-ended questions, divided into thematic sections on the digitalization of marinas: (1) the current level of digitalization, (2) the types of digital technologies implemented, (3) perceived obstacles to further digital adoption, and (4) future development, investment plans, and digital solutions. The data were analyzed using descriptive statistics and advanced visual analytical techniques to uncover underlying patterns and relationships, including a digital maturity matrix, a heatmap, a radar chart, and a technology adoption pathway network.

4. RESULTS AND DISCUSSION

The results indicate that Croatian marinas are still in the early stages of digital transformation. Most marinas rely primarily on basic digital solutions, particularly those directly visible to end users. Figure 3 shows the extent to which different digital tools are used in Croatian marina management and operations.

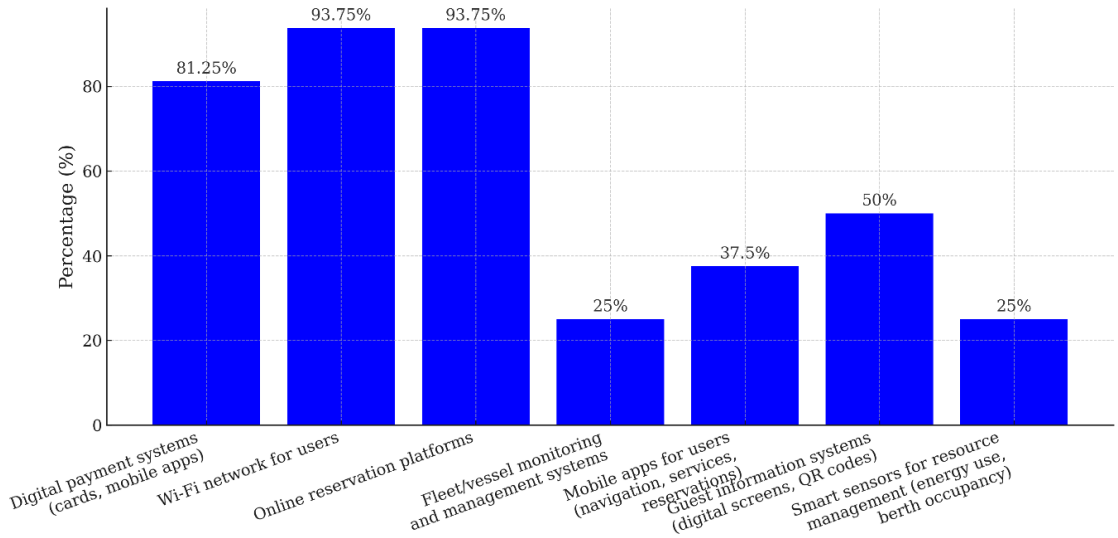

Figure 3: Use of digital tools in marina management and operations (Source: Authors)

The results (Figure 3) indicate that marinas predominantly rely on basic digital solutions, with Wi-Fi networks and online reservation platforms achieving the highest adoption rates (93.75%). Digital payment systems are also well established, with 81.25 percent of marinas implementing them. By contrast, the adoption of more advanced technologies remains limited.

Only 25 percent of marinas use vessel or fleet monitoring systems, and smart sensors for resource management show similarly low uptake. Mobile applications for navigation and service access are used by 37.5 percent of respondents, while guest information systems, such as digital displays or QR codes, are present in half of the marinas. These findings correspond with broader industry observations that marinas tend to prioritize user-facing tools over operational digital solutions, leaving advanced management technologies underutilized (Ahmad, 2025). Overall, the figure illustrates a clear divide between widely adopted basic systems and the slow integration of more sophisticated digital infrastructure. Figure 4 presents the key challenges that restrict the adoption of advanced digital technologies in Croatian marinas. The results show that the most significant barrier to digitalization is the lack of qualified personnel, as perceived by 93.75 percent of respondents. The European Boating Industry (n.d.) reports that a vital challenge for the nautical tourism sector is a shortage of workforce and skills. However, it also highlights that the European Commission is actively involved in addressing this issue. The Commission can support Member States in developing relevant educational programmes in the industry, as well as provide funding for cooperation between industry and educational bodies, offering a reassuring solution to workforce challenges in nautical tourism, such as digital transformation. Technical complexity and system maintenance represent the second major obstacle (62.5 percent), followed by the need for additional employee and user training (56.25 percent). Financial constraints affect 25 percent of marinas, particularly smaller facilities that prioritize essential infrastructure over digital investment. Poor internet availability, although less common (12.5 percent), still limits progress in some locations. The European Boating Industry (n.d.) underscores that nautical tourism services, such as marinas, are often small-and medium-sized enterprises (SMEs) that are unable to sustain the investment required to address key challenges related to digitalization and sustainability. EU funding, such as research and innovation or regional funds, should target this investment gap and provide the necessary support for the sustainable development of the industry (EBI, n.d.). Overall, the findings indicate that skill shortages, technical challenges, and limited financial capacity are the primary factors slowing the adoption of advanced digital solutions in Croatian marinas.

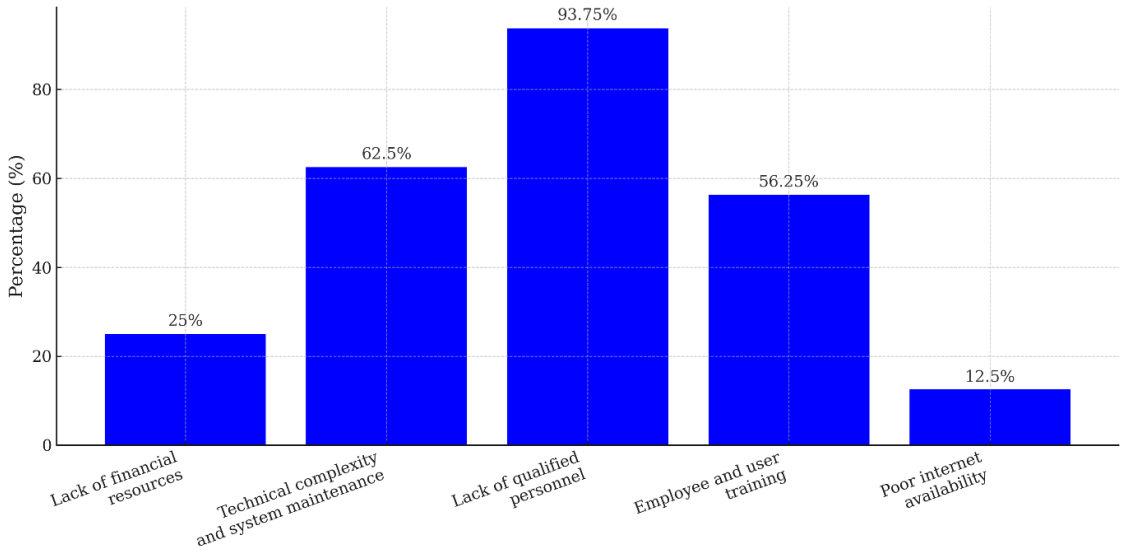

Figure 4: Challenges in implementing digitalization in marinas (Source: Authors)

Figure 5 shows the current level of digitalization in Croatian marinas. The results show that only 6.25 percent of respondents rate their level of digitalization as high, while most consider it moderate (75 percent) or low (25 percent). This distribution highlights uneven progress across the sector, with some marinas advancing more quickly than others. Despite these differences, managers generally view digitalization as essential for improving service efficiency and maintaining competitiveness. At the same time, the findings reveal a gap between recognizing the value of digital transformation and implementing it in practice, as few marinas have developed concrete plans to adopt advanced technologies. The results suggest that digital tools are often introduced reactively rather than as part of a long-term strategy, which may slow sector-wide progress and disadvantage smaller marinas.

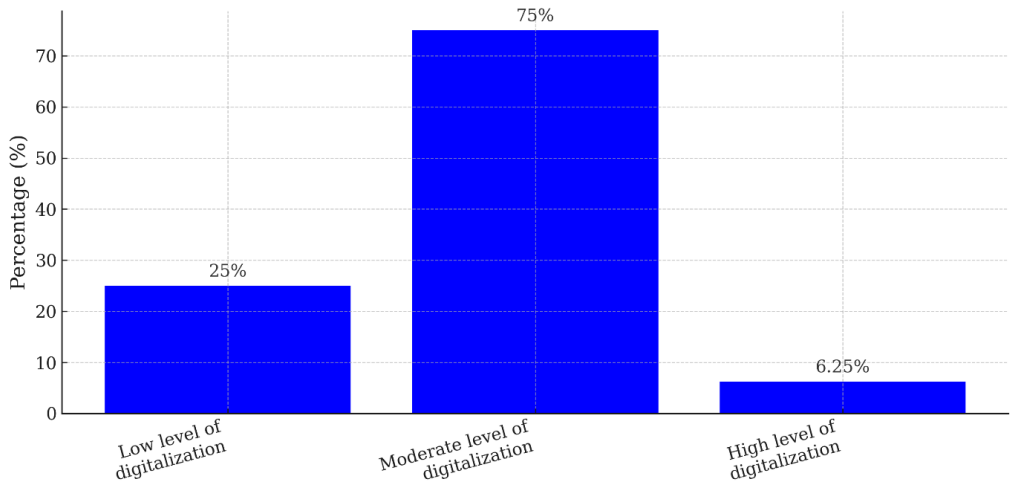

Figure 5: Level of digitalization in marinas
(Source: Authors)

Figure 6 shows the Digital Maturity Matrix: Technology vs. Investment for the Croatian marinas. The Digital Maturity Matrix shows how marinas differ in their adoption of advanced technologies and their readiness to invest in digital development. The horizontal axis represents *Investment Aggressiveness* (from no plans to concrete plans), while the vertical axis shows the *Number of Advanced Technologies Used*. Each bubble represents a marina, with its size indicating the number of berths, its color representing the geographic region, and its shape denoting network affiliation. In the top-right quadrant, *The Digital Leaders* combine high technology usage with firm investment plans. These are typically large marinas, often based in Dalmatia, and include both network-affiliated and independent operators. They are driving digital transformation and setting the pace for the wider industry. The top-left quadrant, *The Capable but Hesitant*, includes marinas with strong existing digital capabilities but limited future investment plans. Usually medium to large in size, they may be waiting to see results from the leaders or facing internal barriers to further commitment. The bottom-right quadrant, *The Ambitious Starters*, represents marinas with low current digitalization but concrete plans to invest. This group often includes smaller or network-affiliated marinas that aim to leapfrog by aggressively adopting digital technologies. Networks play a crucial role in enabling their progress. The bottom-left quadrant, *The Digital Laggards*, consists of smaller, independent marinas with low technology use and no clear investment plans. Without strategic action, they risk being left behind as the sector advances. The matrix provides a clear picture of the industry's digital landscape. It identifies leaders driving innovation, followers preparing to catch up, and those at risk of digital stagnation, offering a valuable framework for strategic decision-making across the marina sector.

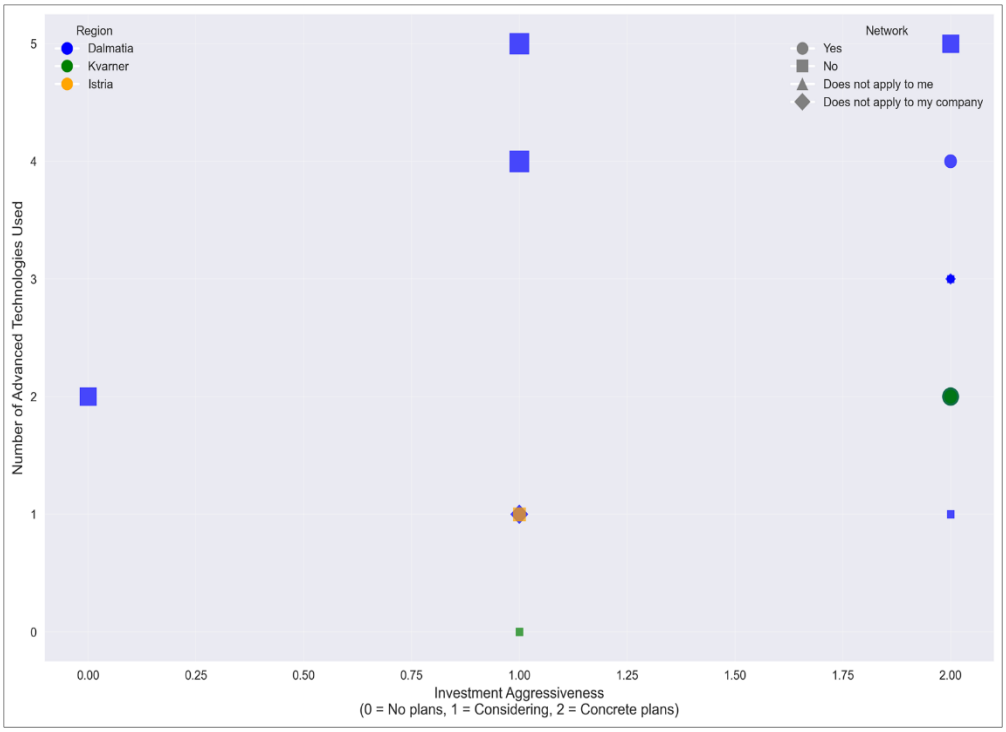

Figure 6: Digital Maturity Matrix: Technology vs. investment
(Source: Authors)

Figure 7 shows the gap between digitalization and reality for Croatian marinas (heatmap analysis).

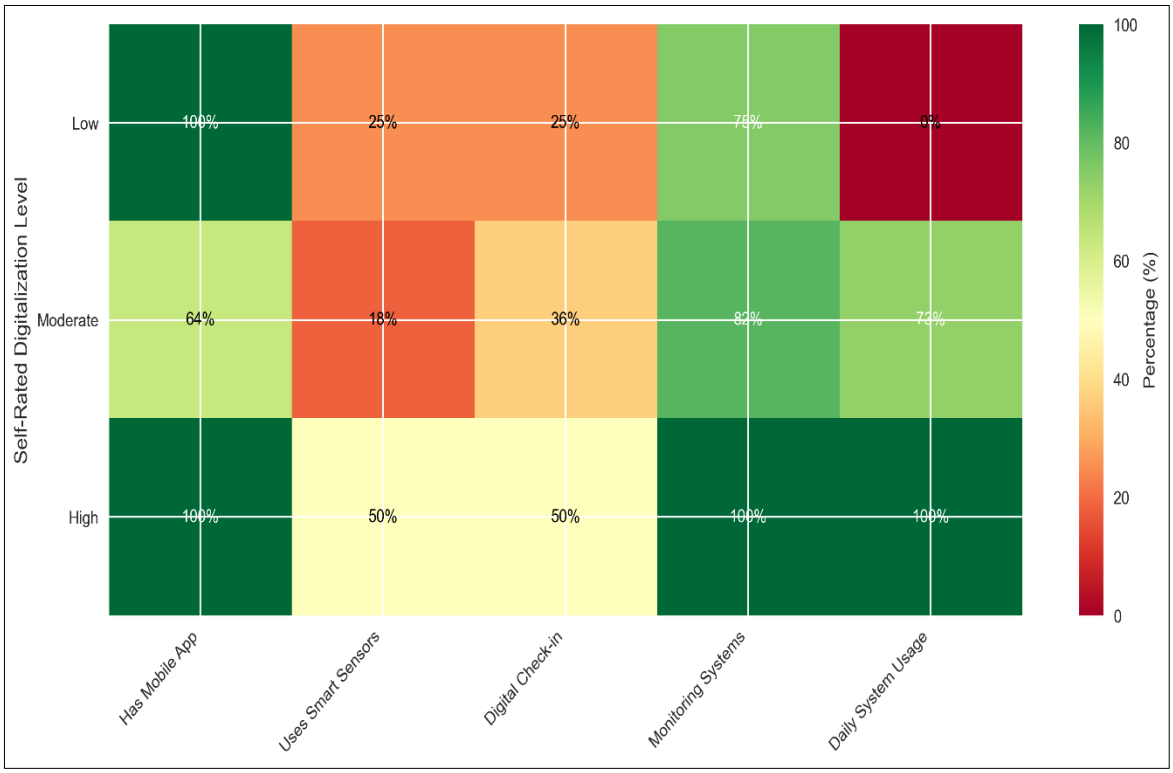

Figure 7: Digitalization vs. reality (percentage of marinas with each technology)
(Source: Authors)

The heatmap analysis (Figure 7) compares marinas' self-rated digitalization levels (Y-axis) with their actual technology adoption metrics (X-axis). Each cell shows the percentage of marinas in each category that use specific technologies, color-coded for clarity: green (70-100%) indicates strong alignment between perception and reality, yellow (30-70%) suggests moderate alignment, and red (0-30%) highlights a significant disconnect. Marinas that rated themselves as High in digitalization show strong alignment, with 100% using mobile apps, smart sensors, monitoring systems, and daily digital tools. However, only 50% have digital check-in, suggesting that even advanced marinas struggle with automation. Moderate marinas show the most significant perception gap: only 11% use smart sensors and 33% use digital check-in, suggesting overconfidence in their digital maturity. Low self-rated marinas, meanwhile, are fairly accurate in their self-assessment, with limited use of digital tools and 0% smart sensor adoption. Key insights include the Moderate Mirage, where mid-level marinas overestimate their progress; digital check-in as a reliable maturity indicator; and the finding that monitoring systems are now a baseline feature across all categories. Smart sensors clearly distinguish digital leaders. Figure 8 shows the Investment Decision Driver Analysis for Croatian marinas (heatmap).

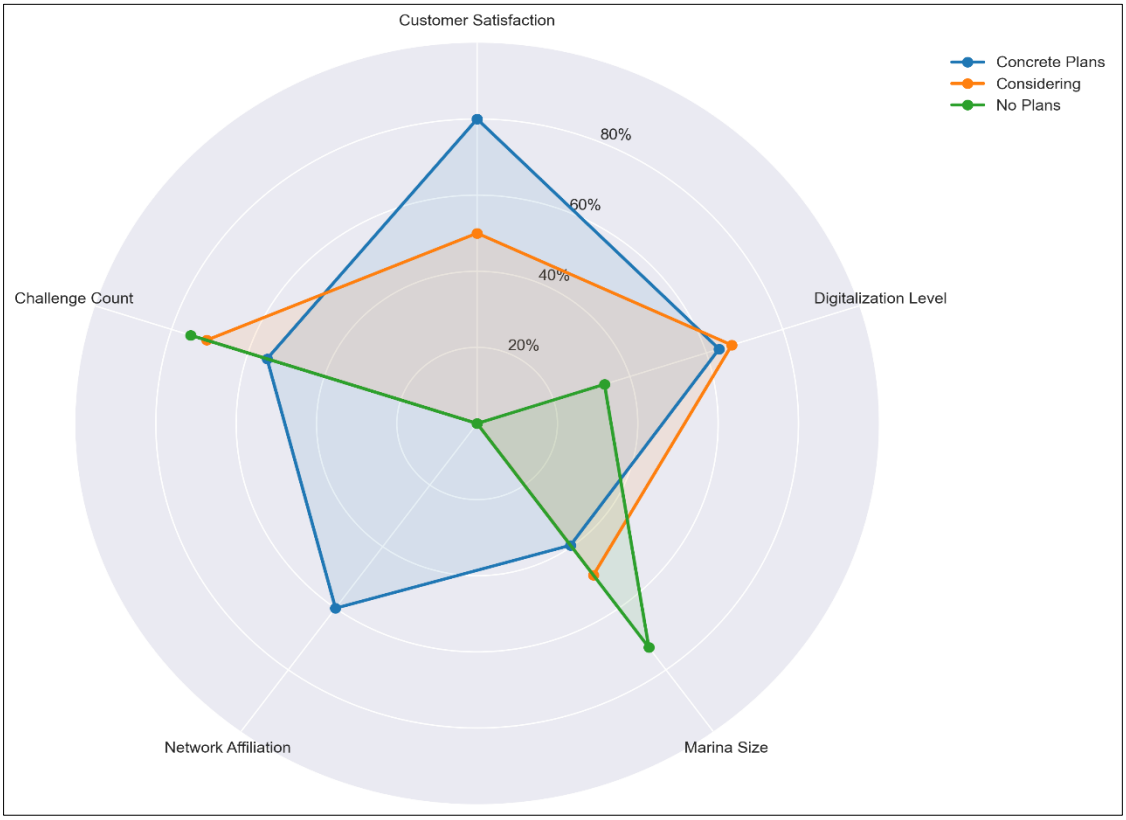

Figure 8: Investment Decision Driver Analysis
(Source: Authors)

The radar analysis (Figure 8) reveals three distinct investment personas within the marina sector. The *Ambitious Challengers* (Concrete Plans group) are large, network-affiliated marinas actively investing to address challenges and sustain growth. They score highest in size, network affiliation, and challenge awareness, reflecting a proactive and strategic approach to digital transformation. The *Cautious Middle-Ground* (Considering group) consists of smaller, independent marinas with solid digital capabilities but limited scale or support, resulting in hesitation to invest further.

The *Complacent or Constrained* (No Plans group) are small, disconnected marinas with low satisfaction and minimal digital maturity, showing no intent to improve. The results highlight that network membership and size are the strongest drivers of digital investment, while customer satisfaction has little influence. Those facing more challenges tend to act more decisively, suggesting that awareness, resources, and collaboration, rather than contentment, determine digital progress in the marina industry. Figure 9 shows the Technology Adoption Pathway Network for Croatian marinas (heatmap).

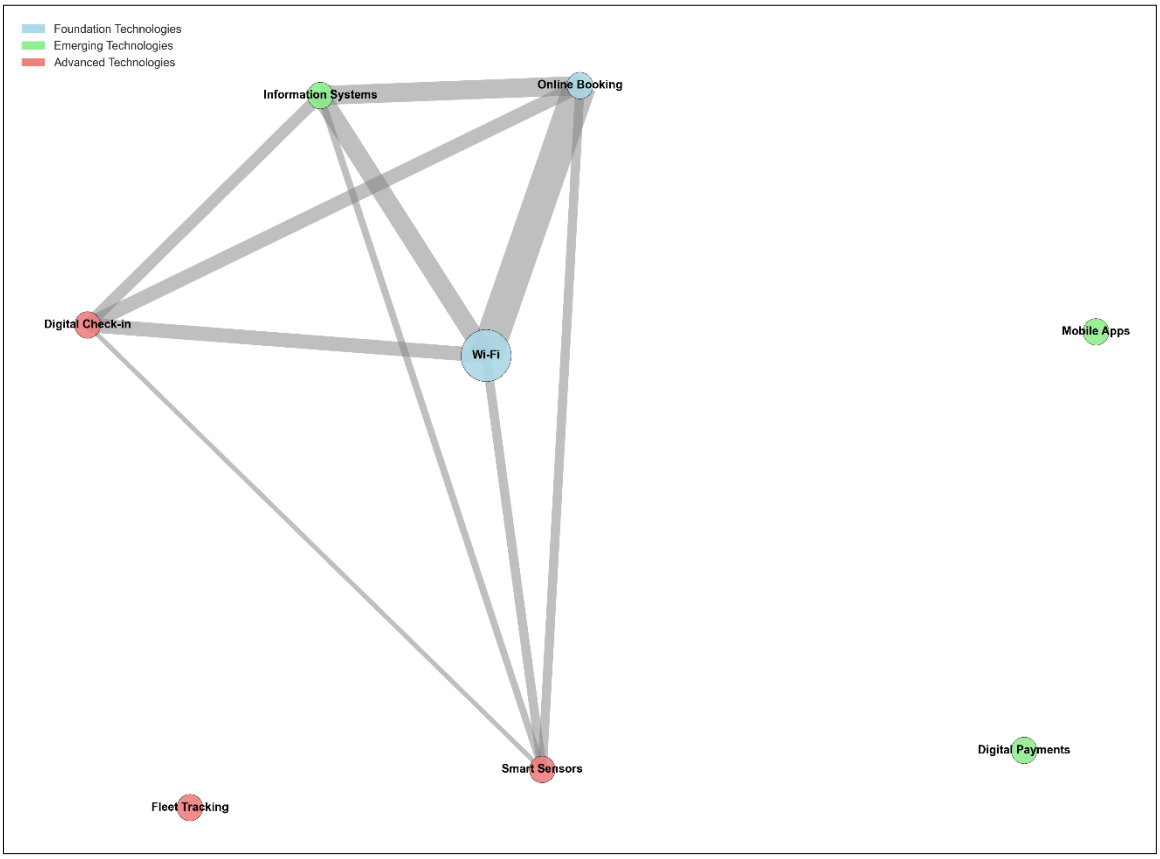

Figure 9: Technology Adoption Pathway Network (Node size - planned adoption frequencies/Edge thickness - Co-occurrence)
(Source: Authors)

As seen from Figure 9, the technology network analysis illustrates how digital solutions interconnect within marinas, highlighting three distinct tiers of technological maturity. Foundation technologies such as Wi-Fi and online booking form the core infrastructure, appearing as large, centrally positioned nodes with thick connections, reflecting near-universal adoption and interdependence. Emerging technologies, including digital payments, information systems, and mobile apps, show strong planned adoption and multiple links to foundational systems. These tools enhance customer experience and are rapidly becoming standard rather than optional. Advanced technologies, such as fleet tracking, smart sensors, and digital check-in, occupy more peripheral positions with thinner connections, indicating selective, specialized adoption. While less common, they represent the next frontier in operational efficiency and data-driven management. This network reveals a clear progression from essential connectivity toward integrated, intelligent systems, illustrating how marinas are evolving from basic digital functionality to advanced, performance-oriented ecosystems.

5. RESEARCH LIMITATIONS

Although the research provides valuable insights into the state of digitalization in Croatian marinas, it has certain limitations. First, the focus is primarily on basic digital services, such as Wi-Fi networks and electronic reservations. In contrast, more advanced technologies, such as berth management systems, sensors, and energy-efficiency monitoring software, are not sufficiently analyzed. Second, the small, selective sample of respondents, particularly from smaller, privately owned marinas, limits the generalizability of the findings to all Croatian marinas. The study largely relies on marina managers' perceptions and opinions, without objective data on the actual impact of digitalization on operational efficiency, financial performance, or user experience. It also does not provide insight into the long-term dynamics of digitalization, making it difficult to assess the effectiveness of strategies over time. Despite the identified obstacles (high costs, lack of staff training, and management resistance), the research does not analyze their underlying causes in detail. Moreover, the analysis of digitalization lacks sufficient integration into the broader context of national tourism strategies, sustainable development, and international standards, which is vital for long-term strategic planning. Despite these limitations, the study provides a valuable foundation for further analysis and policy development that can accelerate the digital transformation of Croatian marinas.

6. CONCLUSION

The research shows that the digitalization of marinas in Croatia is still in its early stages. Most facilities use basic digital technologies, while advanced solutions are only beginning to be implemented. Key challenges remain high costs, a lack of skilled personnel, and the absence of a long-term strategy. Investment in staff education, funding through EU programs, and the development of integrated smart marina management systems are recommended. Digital transformation should become an integral part of the sustainable development strategy for Croatian nautical tourism. Advanced solutions, such as berth management systems, smart sensors, and energy-efficiency monitoring software, are not yet widely implemented in practice. Current efforts, therefore, focus on short-term service improvements rather than long-term strategic transformation. The main barriers to digitalization are high implementation costs, insufficiently trained personnel, and management resistance to new technologies, particularly in small marinas with limited financial and organizational capacity. Despite these challenges, most marina managers recognize the potential of digitalization to enhance competitiveness, operational efficiency, and user satisfaction. To accelerate digital transformation, a strategic vision and planning are necessary. Previously mentioned include the gradual introduction of advanced systems, continuous staff training, and the shift from individual services to integrated platforms that enable automated berth management, billing, and monitoring through IoT technologies. Public policies and financial support, especially for small- and medium-sized marinas, are crucial to success, while establishing industry clusters and forums can promote knowledge exchange and accelerate sector development. Digitalization should therefore not be viewed merely as a technical issue, but as a strategic imperative for the development of Croatian nautical tourism. With a coordinated strategy, marinas can significantly increase efficiency, improve user experience, and ensure long-term competitiveness in the global market.

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INNOVATION HORIZONS OF DIGITAL TRANSITION IN MARITIME INDUSTRY

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ABSTRACT

Digital transformation is becoming a key driver of change in global maritime transport, opening new horizons for innovation and shaping the foundations for more competitive, efficient, and sustainable operations. The integration of advanced technologies, including artificial intelligence (AI), the Internet of Things (IoT), big data analytics, blockchain, autonomous systems, and additive manufacturing, is redefining the way shipping and port operations are planned, executed, and monitored. These technologies enable the optimization of logistic chains, increased transparency in information exchange, reduction of operational costs, and more precise resource management, thus creating the preconditions for smart and green shipping of the future. The paper focuses on a systematic presentation of the key innovation directions and development trends of the digital transformation of the maritime sector. Special attention is devoted to the transformation of business models, the development of digital platforms, and the implementation of smart solutions in ports and shipping companies. Digitalization is regarded not merely as technological modernization but as a strategic process involving changes in organizational culture, knowledge management, and data-driven decision-making. An overview of relevant literature and practical examples highlights the increasing importance of digital innovations in strengthening the resilience of maritime systems and promoting sustainable development and the green transition. The need for an integrated approach linking technological, economic, and regulatory aspects is emphasized to unlock the full potential of digital solutions in global maritime transport. This paper contributes to a better understanding of the innovation horizons of digital transition and provides a theoretical foundation for future research aimed at developing efficient, sustainable, and technologically advanced maritime systems.

Keywords: *digital transition, innovations, maritime transport, competitiveness, sustainability*

1. INTRODUCTION

Digital transition represents one of the most significant drivers of change in the global maritime industry, acting as a catalyst for innovation, process optimization, and the development of new business models. The integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain has stimulated the development of smart shipping and intelligent port concepts, transforming traditional operational and economic patterns within the sector. As highlighted by Jović et al. (2022), the digital transformation of the maritime sector extends well beyond mere technical modernization, as it involves the creation of digital strategies and business models that enhance the efficiency, transparency, and competitiveness of logistics chains.

The introduction of digital solutions has strong economic implications, influencing cost structures, productivity, and the market position of shipping and port enterprises, while opening opportunities for the implementation of sustainable and energy-efficient business practices. According to Munim and Schramm (2018), improvements in port infrastructure quality and logistics performance positively affect maritime trade and economic growth, indicating long-term benefits associated with more efficient resource utilization and reduced operational costs. These findings confirm that the digital transition represents more than a purely technical process; it constitutes a strategic framework that fosters the convergence of technological, organizational, and economic innovations across the maritime system. Despite growing interest and accelerated adoption of digital technologies, scientific research on the digital transition in maritime transport remains fragmented and unevenly distributed across regions. The lack of a comprehensive approach hinders the understanding of development trends and innovation priorities driving the sector's transformation. Based on a review of professional literature and institutional reports, the paper synthesizes existing knowledge to present the key innovation directions of the digital transition in the maritime sector and places them within the context of sustainability and resilience objectives. Special attention is given to the European context and the potential for developing strategic guidelines aimed at accelerating digital adaptation and fostering the green transition of the maritime sector.

2. OPERATIVE AND INSTITUTIONAL CHALLENGES OF THE DIGITAL TRANSITION OF THE MARITIME SECTOR

The digital transition of maritime transport is taking place in a complex environment characterized by numerous technical, organizational, regulatory, economic, and social challenges. Although advanced technologies present considerable potential to improve efficiency, safety, and sustainability, their adoption is constrained by numerous challenges that impede the sector's alignment with global digital transformation trends (Heilig et al., 2017). One of the fundamental challenges relates the technical and infrastructural aspects of the digital transition. In many shipping companies and ports, the digital infrastructure is still insufficiently developed to enable full system interoperability, advanced data analytics, and automation of operational processes. Furthermore, outdated information systems, limited integration of digital platforms, and restricted broadband network availability, particularly in island and peripheral regions, hinder the application of solutions based on artificial intelligence, the Internet of Things (IoT), and predictive management systems (Sanchez-Gonzalez et al., 2019). Infrastructure and organizational challenges of digital modernization are particularly pronounced in the context of European Mediterranean and Adriatic ports, where the digital transition process is progressing more slowly due to limited investment capacities and the need to strengthen institutional and technical cooperation. At the MEDports Forum (2022), the importance of developing joint digital initiatives and sharing best practices among ports in the region was emphasized to accelerate the implementation of digital solutions and enhance the resilience of the maritime sector. Another major challenge relates to the organizational and managerial aspects of the digital transition. The transformation of business models, the adaptation of organizational structures, and the development of a digital culture within maritime organizations represent a long-term process that requires strategic planning and systematic investment in human resources. Despite the recognized importance of digital competencies, many maritime institutions and enterprises still operate according to traditional hierarchical decision-making and communication patterns, thereby constraining the flexibility and innovativeness needed for effective digital process management. Research indicates that, despite the availability of technologies and concepts, the level of their practical implementation remains low, pointing to a gap between technological potential and actual application (Fruth & Teuteberg, 2017).

Regulatory and security challenges also have a significant impact on the pace of digital adaptation. The establishment of unified standards, interoperable protocols, and harmonized legal frameworks within the European Union and international maritime organizations is progressing slowly, creating uncertainty among stakeholders. At the same time, the digitalization of maritime transport opens the door to new types of threats, especially in the field of cybersecurity and data protection. With the increasing connectivity of ships, ports, and logistics networks, the risks of cyber incidents are becoming more prominent, making information security one of the key prerequisites for a successful digital transition (IMO, 2025; EMSA, 2023). The economic aspects pose an additional barrier, as the digital transition requires substantial investment in infrastructure, technology, and employee training. The return on investment in digital solutions is often difficult to quantify in the short term, discouraging particularly small and medium-sized shipping companies from initiating digital modernization processes. Munim and Schramm (2018) found that investment in port infrastructure quality and logistics performance yields long-term economic benefits through improved efficiency and reduced operational costs; however, these positive effects tend to diminish as countries reach higher levels of technological and economic maturity. In addition, the lack of financial instruments, rising costs, and limited national co-financing make project implementation more difficult, with more pronounced challenges in smaller (comprehensive) ports (ESPO, 2024). The challenges associated with the digital transition in maritime transport must be considered within the broader framework of sustainable development and the green transition. The adoption of digital technologies in the maritime sector holds substantial potential to reduce greenhouse gas emissions, optimize energy consumption, and support the creation of circular business models. Nevertheless, in the absence of coordinated policies, unified standards, and ongoing human resource development, the digital transition risks becoming fragmented and inconsistently implemented.Therefore, its successful implementation requires an integrated approach that links technological innovation with regulatory reforms, financial incentives, and the development of competencies necessary for effective change management.

3. INNOVATION AND INVESTMENT DIRECTIONS OF THE DIGITAL TRANSITION IN EUROPEAN MARITIME TRANSPORT

Despite numerous technical and institutional constraints, the European maritime sector is gradually moving from a phase of adaptation to a phase of systemic transformation. Investments in digital infrastructure, the development of smart ports, and the application of innovative technologies confirm that the process of digital transformation is increasingly recognized as a strategic framework for the modernization and sustainable restructuring of the maritime economy. Global digitalization trends further reinforce this dynamic. The global maritime digitalization market was valued at USD 167.7 billion in 2022 and is projected to grow to USD 367.7 billion by 2031, with an average annual growth rate of 9.3% (Transparency Market Research, 2023). This growth reflects the intensified adoption of technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, blockchain, and autonomous systems, which drive innovation in the planning, monitoring, and optimization of shipping and port operations. The rapid expansion of the market is also driven by regulatory requirements set by the International Maritime Organization (IMO), which encompass digital data exchange, decarbonization, and improvements in energy efficiency. Simultaneously, increasing investments in autonomous vessels, robotics, smart ports, and energy management systems (EnMS) are promoting new forms of integration between technology, business processes, and sustainable operational practices. Particular emphasis is placed on the growing importance of cybersecurity and data management, as the digital transition increases exposure to risks associated with cyber threats and information protection.

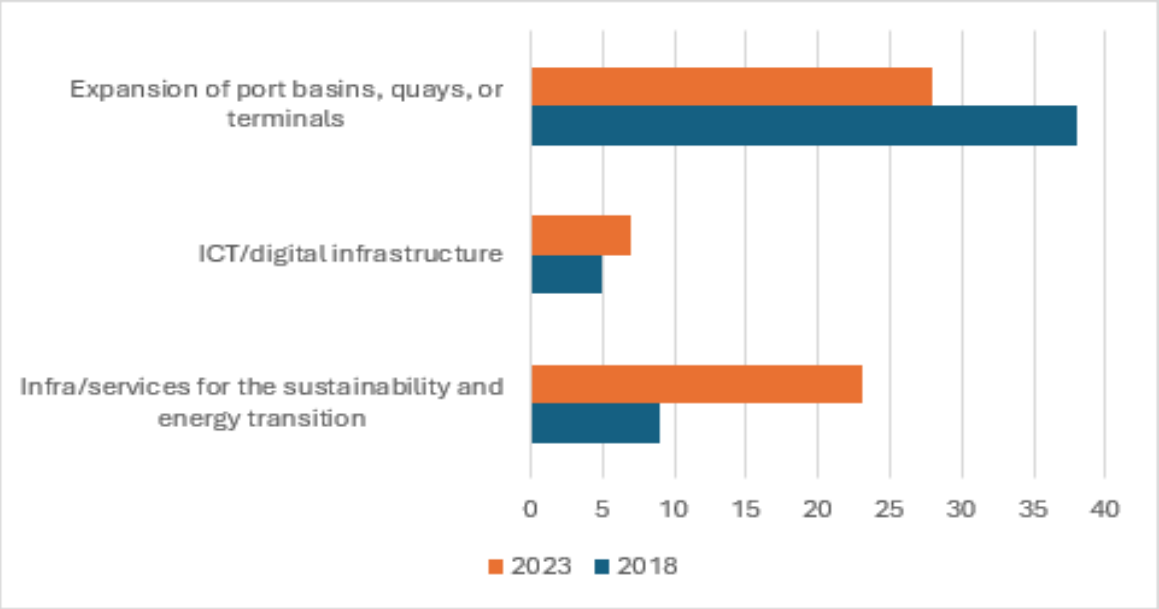
As a result, the digital and green transitions are increasingly interlinked, jointly shaping emerging models of port, energy, and logistics management. To provide a structured overview of the main directions of digital transition in European maritime transport, the following section identifies the key innovation areas that characterize the sector's current development trends.

Innovation Area	Application in the European Context	Expected Effects
Internet of Things (IoT)	Sensor networks for monitoring environmental and logistical parameters	Sensor networks for monitoring environmental and logistical parameters
Data Analytics and Artificial Intelligence (AI)	Predictive maintenance, traffic optimization, and energy management	Improved efficiency, cost reduction, and data-driven decision-making
Digital Logistics	Data integration between ports, shipping companies, terminals, and logistics chains	Transparency, interoperability, and enhanced supply chain security
Onshore Power Supply (OPS) and Clean Energy	Electrification of berths, development of hydrogen and LNG infrastructure, and digital energy consumption management	Decarbonization, emission reduction, and sustainability of energy systems
Cybersecurity	Digital risk management and protection of information systems	Resilience, data protection, and business continuity
Digital Twin	Virtual modeling and simulation of port operations	Predictive management, process optimization, and reduction of environmental footprint

Table 1: Key Innovation Directions in the Digital Transition of the EU Maritime Sector (Source: EMSA, 2023; ESPO, 2024; European Investment Bank, 2023; Port Technology International, 2023).

Table 1 presents the core technological and strategic areas shaping the sector's transformation. The analysis of the presented areas indicates that the process of digital transformation in European maritime transport simultaneously encompasses technological, organizational, and energy innovations. IoT facilitates real-time monitoring of environmental and operational parameters, while AI and Data Analytics enhance efficiency through predictive maintenance, traffic optimization, and energy management. Digital Logistics strengthens data integration and interoperability across ports, shipping companies, and supply chains, improving transparency and security. At the same time, OPS and clean energy technologies contribute to decarbonization and sustainable energy use. Ensuring Cybersecurity is essential for protecting digital infrastructures and maintaining operational resilience, whereas Digital Twin technologies support predictive management, process optimization, and reduced environmental impact. Collectively, these innovation directions illustrate how digital and green transitions are advancing together to create a more efficient, resilient, and sustainable EU maritime sector.

In the context of European maritime policy, the port is no longer viewed solely as a transport and infrastructure system, but as an integrated energy, digital, and industrial hub where global supply chains, technological innovations, and EU climate policies intersect (ESPO, 2024). European ports are becoming key actors in the implementation of the European Green Deal and the Fit for 55 strategy, which requires substantial investment in energy infrastructure, digital systems, and sustainable technologies. Over the past decade, ports have transformed from traditional logistical hubs into innovation environments where digital technologies support decarbonization, resource optimization, and increased operational efficiency. According to ESPO (2024), European ports are increasingly acting as centers of energy, industry, and the circular economy, thereby assuming a broader societal role in energy transition and strengthening geopolitical resilience. In this context, digital infrastructure is becoming the foundation of modern port management: the integration of sensor networks, IoT systems, advanced analytics, and artificial intelligence enables predictive maintenance, emission monitoring, and transparent energy management. The ESPO Port Investments Study 2024, which included 84 European Port Managing Bodies (PMBs) and 467 projects planned for the period 2024–2034, shows a significant shift in investment priorities compared to the 2018 study. The most pronounced trend relates to the increase in investments in energy transition and sustainability, while investments in berth and terminal expansion have declined.



Graph 1. Projected Share of Planned Investments by European Ports by Category (%) (Source: ESPO, 2024)

As highlighted by ESPO findings, European ports are emerging as centers of technological and energy innovation; however, fully realizing this potential requires addressing several persistent challenges. The most notable among them include complex permitting procedures, rising costs due to inflation, and limited access to financial resources. According to ESPO (2024), European ports largely rely on public funding sources and European programs, particularly the Connecting Europe Facility (CEF), confirming that institutional support remains crucial for the implementation of the digital and energy transformation of the maritime sector. This financial framework indicates that European ports are unlikely to sustain the costs of digital transition on their own, underscoring the need for structured institutional support and streamlined administrative procedures.

The implementation of digital solutions in European maritime transport shows that the digital transition goes beyond technical modernization and increasingly takes the form of a strategic transformation of the sector. The Port of Rotterdam (the Netherlands) serves as an example of systematic digital infrastructure integration and public–private cooperation. Through the PortXchange platform, real-time data sharing between shipping companies, terminals, and logistics operators has been enabled, representing a tangible example of how the digital economy reshapes port efficiency and environmental performance (Port of Rotterdam, 2023). Similarly, the Port of Hamburg (Germany), through its SmartPORT concept, demonstrates the potential of IoT technology and data analytics to enhance energy efficiency and reduce traffic congestion, thereby directly contributing to the objectives of the European Green Deal (Hamburg Port Authority, 2023). The Port of Antwerp–Bruges (Belgium) is a frontrunner in the application of Digital Twin systems, enabling predictive management and simulation of port operations, while the Mediterranean Port of Valencia (Spain), through the ValenciaportPCS platform, demonstrates how digital solutions can streamline administrative processes and increase supply chain transparency.

Aspect	Current Challenges and Dependencies	Examples of Successful Implementation	Strategic Implications
Institutional and Financial Framework	European ports depend heavily on public funding and EU programs (e.g., CEF). Complex permitting procedures, inflation, and limited access to capital hinder progress.	—	Institutional and financial support are essential to ensure continuity and scalability of digital and energy initiatives.
Technological Integration	Digital transition is often fragmented and limited by administrative and financial barriers.	Port of Rotterdam (NL) – Integrated digital infrastructure through PortXchange, enabling real-time data sharing among stakeholders.	Demonstrates how systematic digitalization improves operational efficiency and environmental performance.
Energy and Sustainability Focus	Ports face challenges in aligning digital efforts with decarbonization goals due to cost and infrastructure constraints.	Port of Hamburg (DE) – SmartPORT initiative uses IoT and analytics to improve energy efficiency and traffic management.	Shows the link between digitalization and the Green Deal, emphasizing sustainability through innovation.

Use of Advanced Digital Tools	Limited adoption of Digital Twin systems and data-driven management.	Port of Antwerp–Bruges (BE) – Implements Digital Twin for predictive management and simulation of operations.	Highlights the shift toward data-driven decision-making and proactive port management.
Administrative Digitalization	Administrative and customs processes remain time-consuming and paper-based in many ports.	Port of Valencia (ES) – ValenciaportPCS platform digitalizes administrative workflows, improving transparency and efficiency.	Demonstrates how digital platforms can streamline procedures and strengthen supply chain connectivity.
Governance and Strategic Capacity	Slower adaptation linked to weak strategic planning and low digital competency investment.	Successful ports show strong public–private collaboration, clear strategic vision, and skills development programs.	Effective governance integrates technological, institutional, and human factors to sustain transformation.
Overall Trend	Digitalization still viewed by some as technical modernization rather than strategic reform.	Leading ports combine digital and green investments, recognizing their mutual reinforcement.	Digital and energy transitions are becoming interconnected pillars of EU maritime policy, driving sustainability, competitiveness, and resilience.

Table 2: Comparison of Digital Transition Challenges and Innovation Practices in European Ports
(Source: Authors)

Taken together, these examples confirm that the digital restructuring of European maritime transport is not a linear process but a dynamic transformation requiring the integration of technological innovation with institutional and organizational reforms. The key difference between successful and slower cases lies in the level of strategic planning, investment in digital competencies, and the capacity for cross-sectoral cooperation. This process is shaping a new concept of port governance, in which digital and green transitions become inseparable components of European maritime policy. Investments in digital infrastructure (ICT, sensors, analytics) directly contribute to the development of smart ports, while investments in energy transition (OPS systems, renewable sources, hydrogen, clean fuels) form the foundation of an integrated green transition. It is increasingly recognized that digital and energy investments are mutually complementary, as digital tools enable precise measurement, monitoring, and optimization of energy efficiency.

These trends confirm the growing interconnection between digital transformation and the goals of the green transition and circular economy, opening the way for a deeper analysis of its strategic implications and effects on the sustainability, competitiveness, and resilience of maritime systems.

4. DISCUSSION AND RECOMMENDATIONS

The digital transition represents one of the most significant transformative forces in contemporary maritime transport. However, its implementation across European Union member states remains uneven. Northern European ports – such as Rotterdam, Hamburg, and Antwerp–Bruges – have evolved into advanced digital and energy hubs, while many Mediterranean and Adriatic ports are still developing the institutional, technical, and financial capacities needed for a comprehensive digital transformation. This disparity highlights the need for a coordinated European approach that ensures balanced progress across all maritime regions. Based on the analysis of relevant literature, reports from European institutions (ESPO, EMSA, EIB), and examples of good practice, four key areas of action can be identified to accelerate and harmonize the digital transition of the EU maritime sector. The first area concerns governance and regulatory coordination. Effective digital transformation requires coherent governance and stable regulatory frameworks. Establishing a unified European system for the interoperability of digital platforms would enable standardized data exchange among ports, shipping companies, and logistics operators. At present, the fragmentation of information systems limits efficiency and integration. To overcome this, the European Commission and EMSA should develop common technical standards, cybersecurity protocols, and data exchange guidelines, ensuring consistent application across the sector. Simplifying administrative procedures for approving digital projects is equally important, as complex permitting and procurement processes often cause multi-year delays. The introduction of digital regulatory sandboxes—controlled environments for testing new technologies—could facilitate faster innovation while maintaining compliance with safety and regulatory standards. The second area relates to financing and institutional support. The digital transformation of maritime transport requires substantial investment in ICT infrastructure, sensor networks, artificial intelligence, and energy management systems (OPS, LNG, hydrogen). Reducing dependence on public funding necessitates greater engagement of the private sector through public–private partnerships (PPPs) and specialized investment platforms for maritime innovation. EU funding programs such as the Connecting Europe Facility (CEF) and InvestEU should allocate a larger share of resources to digital and green technologies, with priority support for ports with lower levels of digital readiness. The European Investment Bank (EIB) could play a pivotal role by establishing Smart Port Funds to co-finance projects involving digital twins, predictive analytics, and autonomous systems. Furthermore, transnational cooperation among ports, universities, and technology centers should be strengthened to reduce costs and promote interoperability. The third area focuses on human capital and digital competencies. Successful digital transformation depends not only on technology but also on the skills and adaptability of the maritime workforce. It is essential to establish a European framework for digital education and certification in collaboration with maritime universities, academies, and professional organizations. Continuous professional development programs should target employees in ports and shipping companies, while digital competencies—including data analytics, cybersecurity, and automation—should become integral parts of maritime curricula. Alongside technical expertise, managerial skills such as strategic planning, risk assessment, and data-driven decision-making are vital for effective digital governance and innovation management. The final area emphasizes the integration of digital and green transitions within a unified development framework.

Digital and environmental transformation should not be treated as separate processes, as digital tools—such as IoT networks, AI, and digital twins—enable precise monitoring of energy consumption, emissions, and logistics efficiency, directly supporting the objectives of the European Green Deal. Developing integrated Smart & Green Port strategies would allow ports to combine digitalized emission monitoring, resource optimization, and port electrification (OPS) with renewable energy and circular business models. In this way, digital transformation becomes not only a technological advancement but also a central mechanism for achieving sustainability, resilience, and competitiveness in the European maritime sector. In light of the discussion, it is evident that the success of the digital transition in the EU maritime sector depends on a coordinated and long-term strategy that integrates governance, financing, human capital, and sustainability dimensions. Establishing a unified European framework for interoperability and regulatory stability should be accompanied by stronger institutional and financial support mechanisms, particularly for ports with lower levels of digital readiness. Investment in digital competencies must become a central component of maritime education and training, ensuring that technological progress is matched by the development of human capabilities. Finally, aligning digital and green transitions within a single strategic framework will allow ports to function as drivers of innovation, sustainability, and resilience, strengthening the overall competitiveness of the European maritime system.

4. CONCLUSION

The digital transition in European maritime transport can be viewed as a test of institutional maturity and the capacity to adapt to complex global changes. The success of its implementation depends not only on technology but also on the coherence of policies, coordination among stakeholders, and a shared development vision. The examples of Rotterdam, Hamburg, and Antwerp–Bruges demonstrate that digital transformation can simultaneously enhance competitiveness, resilience, and sustainability—but only when supported by a long-term strategy, investment in human capital, and an open system of cooperation. For other ports and emerging maritime systems, establishing this strategic triad – technology, finance, and competence – is a prerequisite for integration into the digital future of European maritime transport. The next development phase therefore requires an integrated approach to digital and green transition, ensuring that innovation is not confined to the technical domain but becomes a driver of sustainable economic and social progress. By promoting collaboration, system standardization, and human capital development, the European maritime sector can gradually build a resilient and competitive digital–green infrastructure. This approach represents not merely the modernization of the industry, but an evolution of maritime governance models, in which digital transformation is affirmed as a key instrument of sustainable development and global connectivity.

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COASTAL LINER PASSENGER TRANSPORT AS A DETERMINANT OF SOCIOECONOMIC DEVELOPMENT OF CROATIAN ISLANDS

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ABSTRACT

The islands' isolation and poor transport connections are often stated as the main challenges to their economic and social development, however, the aforementioned topic is still insufficiently researched in the academic literature. The Republic of Croatia, with its 1244 islands, islets, rocks and reefs, is the second largest archipelago in the Mediterranean and has significant spatial and development potential. However, the permanently inhabited islands are confronted with numerous socio-economic constraints due to their geographical isolation. A key factor in shaping the socio-economic conditions on the islands is coastal liner passenger transport, which determines the level of connectivity to the mainland on most islands and thus has a direct impact on economic activity, the availability of public services and the general quality of life of the island population. This paper analyses the economic and social trends on the Croatian islands and examines the correlation between transport connectivity and their development. It also provides basic recommendations for improving coastline transport. The research shows that insufficient and unreliable connectivity to the mainland represents a major obstacle to sustainable development, while improving transport infrastructure and route organisation can act as a multiplier for economic and social development. This paper also contributes to the debate on island development policies by emphasising the need for improved transport connectivity as a fundamental prerequisite for long-term sustainability.

Keywords: *coastal liner passenger transport, Croatian islands, development policies, socioeconomic development*

1. INTRODUCTION

Islands are distinct geographical, economic, and social entities whose development largely depends on the quality and availability of transport connections with the mainland and other islands. In conditions of spatial isolation, regular maritime passenger transport plays an important role in ensuring population mobility, the exchange of goods, and access to basic public services. Island development is inextricably linked to the frequency and availability of transport connections that enable functional integration with urban centres on the mainland. In this context, regular maritime transport serves as a key determinant of the availability of the labor market, educational and health institutions, as well as cultural and tourist flows. Reliable and frequent services stimulate economic activities, while their volatility and unreliability often lead to depopulation, reduced investment, and a weakening of the local economy. The Croatian islands form a spatial entity comprising 1,244 individual spatial units — islands, islets, rocks, and reefs—making the Republic of Croatia one of the leading countries in the world and Europe in terms of the number and diversity of islands. In Croatia, scheduled maritime passenger transport is a prerequisite for achieving social cohesion, economic development, and territorial integration of island communities (Stupalo et al., 2012). For this reason, the Republic of Croatia, through transport policy measures, seeks to establish the right to special transport for island populations on state maritime routes, even when there is no commercial interest from shipowners in maintaining the route, in order to support island development and reduce depopulation.

As transport services in island areas are often subsidised and organised as a public service, the analysis of scheduled maritime transport extends beyond purely transport-economic considerations. It also encompasses regional policy, sustainable development, and social justice. In this context, understanding the role of maritime passenger routes as a determinant of island development is essential for designing effective transport and development policies.

2. THE ROLE OF COASTAL LINER PASSENGER TRANSPORT IN CROATIA

Maritime passenger transport in the Republic of Croatia is one of the fundamental segments of the national transport system and a key link between the mainland and the islands. Due to the pronounced indentation of the Adriatic coast and the existence of more than fifty inhabited islands, this form of transport plays a strategic role in maintaining territorial cohesion and the functional integration of the national territory (Stupalo et al., 2012; Milković, 2020). In addition to ensuring basic physical connectivity, maritime transport also has a broader developmental dimension, as it supports economic activity, stimulates tourism, and mitigates the negative demographic trends of island depopulation (Naletina et al., 2018; Jugović et al., 2021). The system of regular maritime passenger transport in Croatia is organised to increase the mobility of the island population, reduce socio-economic differences between the islands and the mainland, and achieve the long-term sustainability of island communities. Public maritime transport is provided by shipowners who conclude public service contracts with the competent authorities, with individual lines grouped for economic, demographic, or traffic reasons (Official Gazette 80/13; 56/16, 2016). This model enables more equitable availability of services, even on lines that are not economically viable, thus confirming the status of maritime transport as a public service of general economic interest. Maritime passenger transport in Croatia goes beyond its basic transport function. It enables the supply of island communities with basic goods, supports economic activities, and contributes to the development of tourism, which is the dominant economic sector in coastal and island areas. In this way, transport accessibility becomes one of the key determinants of regional development, as better connectivity with the mainland contributes to more favourable demographic and economic trends. Maritime transport, therefore, acts not only as transport infrastructure but also as an instrument of national policy for balanced territorial development and regional cohesion. In addition to its economic function, maritime passenger transport also has a distinct social function. Maintaining regular lines throughout the year allows equal access to public goods and services, regardless of the geographical location of the population. Especially outside the tourist season, when lines are often economically unprofitable, their operation is ensured through state subsidies and concession agreements. This confirms that public maritime transport is not only an economic but also a social issue of strategic importance for the preservation of island life (Jugović et al., 2021). Despite its recognised importance, the coastal liner transport system faces a number of structural and operational challenges. The most pronounced of these relates to the seasonality of traffic. During the summer months, there is a marked increase in demand, while in winter period there is a significant decrease in the number of passengers and lines. Such unevenness makes capacity planning, rational use of the fleet, and the economic sustainability of the lines difficult. The economic unsustainability of those routes connecting less populated islands, where traffic volume is insufficient for self-sustaining operations, is particularly problematic and requires permanent subsidies and long-term strategic support from the state. The analysis contained in the National Plan for the Development of Coastal Liner Maritime Transport until 2030 indicates deficiencies in the state of island port infrastructure. It has been observed that many maritime passenger ports on islands have below-average ratings for technical equipment, and in some cases do not meet basic safety standards. In some ports, the safety of passengers, crew, and ships is at risk, which directly affects the reliability and quality of transport services, as well as the life of the local community.

Such findings indicate the need for greater investment in the modernization and improvement of port infrastructure, with the aim of increasing safety, efficiency, and the resilience of the system to seasonal and climate fluctuations. It can be concluded that maritime passenger transport in Croatia has integration, economic, and social functions of national importance. It connects geographically fragmented areas, stimulates economic activities, ensures social equity, and contributes to the sustainability of island communities. Its further development should be directed towards models that combine market efficiency and public interest, with clearly defined criteria for sustainability, regional balance, and environmental protection.

3. SOCIOECONOMIC FACTORS OF ISLAND DEVELOPMENT

Understanding economic processes on islands is very important for the development of specific development policies that can improve the sustainability and quality of life of the island population. When examining the dynamics of island economies, it is necessary to consider their specific characteristics within a broader social and economic context in order to gain a deeper understanding of the interaction between local factors and the wider environment. This approach enables a more accurate assessment of the capacities and development trends of the Croatian islands and their position within the national economy.

3.1. Social indicators of island development

Demographic trends and the educational structure of the population are fundamental social indicators that shape the development potential of island communities. Limited natural resources, geographical isolation, and the seasonality of economic activities make demographic processes on islands particularly sensitive.

3.1.1. Demographic trends on the Croatian islands

Economic and social development is closely linked to demographic development, as illustrated by the example of the Croatian islands (Lajić & Mišetić, 2013). The long-standing emigration process in the island region and unfavourable demographic trends have become the main limiting factors of development and the primary cause of social and economic decline.

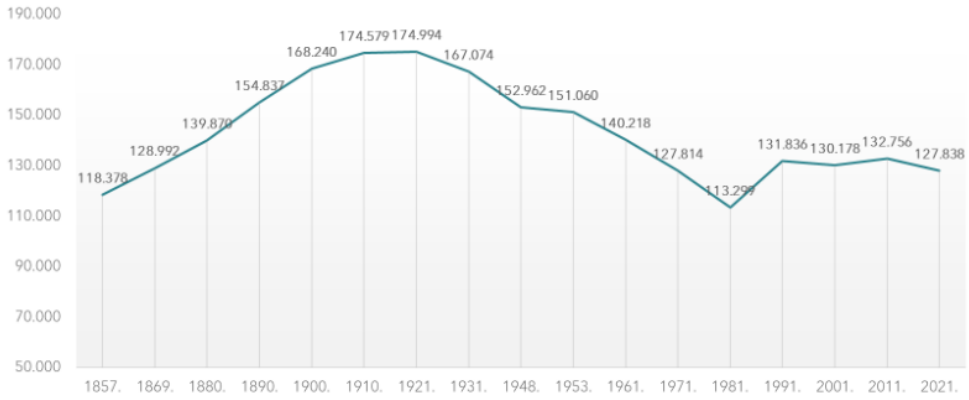


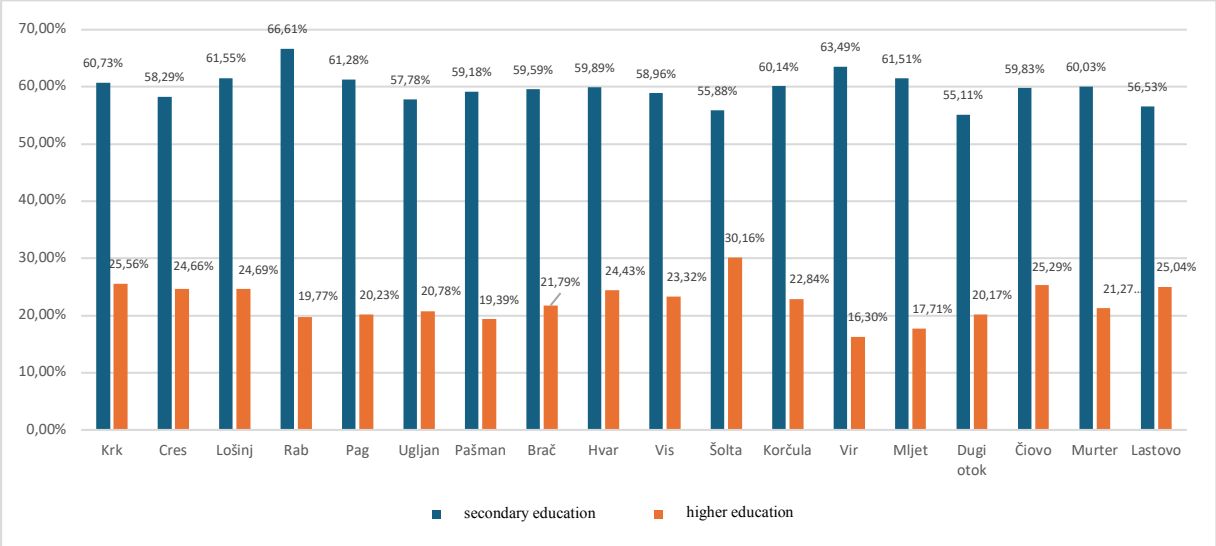
Figure 1: Population movement for the period from 1857 to 2021 (Source: Government of the Republic of Croatia 2023, p.118)

The population of the Croatian islands ranges from just a few inhabitants on smaller islands to several thousand on larger islands. Chart 1 shows that the first significant migrations of island inhabitants began in the 1880s and continued until World War I as a result of various, interconnected economic and demographic factors. Despite the 35.25% decline in population on the islands, visible in Chart 1, from 1921 to 1981, from 174,994 inhabitants in 1921 to 113,299 inhabitants in 1981, the island population remained fairly constant from 1991 to 2021, with variations of 5,000 inhabitants. In the period from 2001 to 2011, the total population on the islands increased.

This can be interpreted as a consequence of the development of tourism and all the economic activities it encompasses. Also, a certain number of residents of cities on the Croatian mainland who own houses, flats and apartments in tourist resorts are registered as living there because of the lower taxes and surtaxes paid in those places. This is precisely why the number of registered residents is higher than the actual number. Additionally, some residents of mainland Croatian cities who own houses, flats or apartments in tourist resorts register as living there to benefit from lower taxes and surtaxes. For this reason, the number of registered residents is higher than the actual number.

2.1.2. Education of the Croatian island population

One of the fundamental prerequisites for social development is raising the educational level of the population. Education drives social, economic and other changes, as well as the overall progress of the country (Keeley 2007; Vican 2013). Graph 2 below shows the share of the population with secondary education and the share of those with higher education on 18 most populated islands, calculated according to the latest Population census from 2021. The data indicate that the population with secondary education is predominant on the Croatian islands. The highest share of the population with secondary education is recorded on the island of Rab (66.61%), followed by Vir (63.49%), Lošinj (61.55%) and Pag (61.28%), while Dugi otok (55.11%) and Šolta (55.88%) have the lowest proportions. The share of the population of Dugi Otok with higher education is 20.11%, and when considering both secondary and higher education levels, it is evident that Dugi otok has the least favourable educational structure among the islands analysed. Compared to other islands, it has a higher share of residents who have completed only primary school. The island of Šolta has the highest share of highly educated residents (30.16%), which at the same time, according to the latest Population census (2021), also has the highest ageing index (532). It can be assumed that older, highly educated individuals, after completing their working lives, choose to return to live on the islands. This trend is not unique to Šolta, but generally characterises most Croatian islands. According to data from the Central Bureau of Statistics of the Republic of Croatia in 2021, the share of highly educated people was 24.1%.



Graph 2: Share of population with secondary and higher education by islands (Source: author's creation based on the Population census, 2021)

Analysis of the data from Graph 2 shows that, along with Šolta, the islands of Krk, Cres, Lošinj, Hvar, Čiovo, and Lastovo are above the national rate, while Rab, Pag, Ugljan, Pašman, Brač, Vis, Korčula, Vir, Dugi otok, and Murter are below. Given current knowledge of the economic structure of the islands, the need for a significant share of highly educated residents could be questioned. However, the limited spatial capacity and the numerous challenges faced by the islands will likely encourage a partial reorientation of islanders towards professions that require innovative solutions and higher education in the long term.

3.2.1. Economic indicators of island development

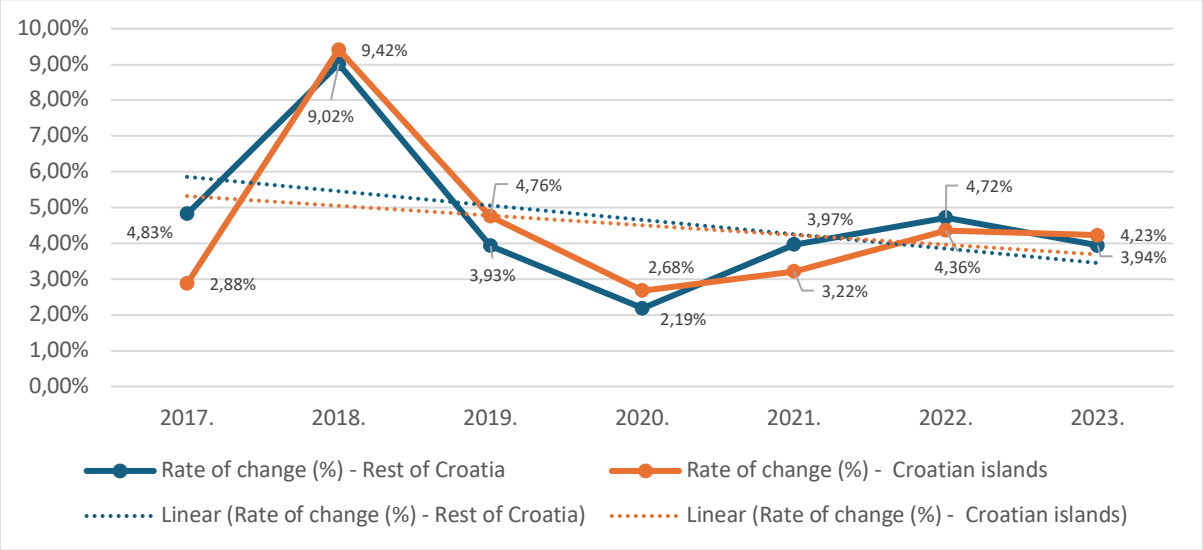
The number of employees and entrepreneurs are frequently used economic indicators that provide insight into the state and dynamics of the economy and enable the analysis of economic trends. They serve as a starting point for shaping development policies aimed at stimulating economic growth and reduce unemployment. Table 1 shows the total number of entrepreneurs on the islands and employees in companies on the islands from 2017 to 2023.

Year	Total number of entrepreneurs	Number of employees in companies on the islands	Average number of employees per entrepreneur
2017	4322	21542	4,98
2018	4729	22801	4,82
2019	4954	23174	4,68
2020	5087	21640	4,25
2021	5251	23034	4,39
2022	5480	25729	4,70
2023	5712	27479	4,81

Table 1: Number of entrepreneurs on the islands and employees in companies on the islands in the period from 2017 to 2023 (Source: author's creation based on data FINA – Registar godišnjih financijskih izvješća 2016 – 2023)

The data in Table 1 show a continuous increase in the number of entrepreneurs in the economy, suggesting a strengthening entrepreneurial spirit and more favourable conditions for starting a business on the Croatian islands. Comparing 2017 and 2023, the number of entrepreneurs on the islands has increased by almost 32%. This is partly due to various support programmes for entrepreneurs that are being implemented, as well as the gradual development of digitalisation, which makes it easier to start and run a business. At the same time, the number of employees is also increasing, though with occasional fluctuations. An analysis of the number of employees shows that in 2020 there was a slightly larger decline, which is also a consequence of the COVID-19 pandemic. The pandemic caused major disruptions in the economy, including temporary business closures, reduced demand, and layoffs. However, the island labor market has shown resilience, so by 2021 the number of employees was growing continuously until 2023, when it reached a record 27,479. This indicates the adaptability of entrepreneurs and employees and the relatively rapid recovery of economic activity. Analyzing the ratio of employees per entrepreneur on the islands, a slight decrease is observed from 4.99 employees per entrepreneur in 2017 to 4.81 in 2023. This decrease may indicate changes in the structure of entrepreneurship, with a higher share of small businesses or self-employed persons. An increasing number of entrepreneurs work independently or employ fewer people, especially in service industries. In 2020, a significant decrease in the ratio to 4.25 employees per entrepreneur is evident, clearly reflecting the impact of the pandemic, while in subsequent years the ratio

gradually stabilizes. Looking at the Croatian islands as a whole, the data indicate a positive long-term trend in the growth of entrepreneurship and employment.
However, the decrease in the average number of employees per entrepreneur raises the question of how to further support entrepreneurs in employing more workers, especially in sectors with high potential for job creation. Diversification of the economy and the development of sectors that require a larger workforce could contribute to a more stable relationship between entrepreneurs and employees. Graph 3 below shows the growth rates of the number of entrepreneurs on “Croatian Islands” and the “Rest of Croatia”.



Graph 3: Growth rates of the number of entrepreneurs in "Croatian islands" and "Rest of Croatia" (Source: author's creation based on data FINA – Registar godišnjih financijskih izvješća, 2016. - 2023.)

It can be seen that the most significant increase was recorded in 2018, when growth rates reached 9.02% in " Croatian islands" and 9.42% in the "Rest of Croatia". This can be linked to increased incentives for self-employment provided by the Croatian Employment Service, tax breaks for entrepreneurs resulting from tax reforms in 2017 and 2018, and the stable economic growth of the Republic of Croatia after emerging from recession. Additionally, grants from European funds played an important role, enabling financing for the start-up and development of businesses, especially in tourism and innovative activities. In the following years, growth in both regions slowed but remained positive, with the "Rest of Croatia" recording somewhat more stable annual growth rates. Despite these positive trends, the relatively slower development of island entrepreneurship compared to the mainland is often highlighted as a challenge for the national economy. This is a consequence of geographical isolation, poorer transport connections, and a smaller population on the islands, which makes it more difficult for entrepreneurs to access the market and increases business costs. Island entrepreneurship is also characterized by a heavy dependence on tourism, leading to seasonality and reduced diversification of the economic structure, while entrepreneurship in the "Rest of Croatia" is more evenly distributed across different economic activities. This is also largely due to the smaller spatial capacity of the islands and the fact that the island population is gradually abandoning primary and secondary activities in favour of service and “light” activities. This trend is not characteristic only of the Croatian islands but is also present on other islands worldwide (United Nations, 2022). The current growth in the number of entrepreneurs on “ Croatian islands” can also be linked to development initiatives and economic policy measures

aimed at stimulating areas with specific development characteristics. However, additional efforts are needed to reduce the gap between island and mainland areas.
Targeted measures, such as better connecting islands to the mainland, encouraging diversification of the economic structure, and increasing and simplifying access to financial support, could ensure even faster development of entrepreneurship on the islands. Although the Republic of Croatia has been continuously investing in various segments of the islands for years, further development requires new, more focused and simpler investment models, as well as easier access to incentives for the local island population. In addition, it should be borne in mind that sources of funds from European funds will generally decrease in the future, and for long-term, stable development, a dominant reliance on various forms of state aid is not desirable. This, in turn, raises the question of local and regional policies regarding the attraction of private investments, particularly those fully aligned with the principles of sustainable development of islands.

3. RELATIONSHIP BETWEEN ACCESSIBILITY OF MARITIME PASSENGER TRAFFIC AND SOCIO-ECONOMIC FACTORS OF ISLAND DEVELOPMENT

Island areas are specific spatial and social systems characterized by physical separation, limited resources, and strong dependence on transport connections with the mainland. Unlike mainland areas, their spatial isolation increases the importance of maritime transport, which is a fundamental prerequisite for the social integration and economic vitality of island communities. The intensity, structure, and dynamics of maritime passenger transport are therefore not only technical indicators of transport activity but also reliable indicators of the general socio-economic state of the island. The degree of transport connection with the mainland directly affects the availability of public services, the labour market, education, and healthcare, which indirectly determines the quality of life of the island population. At the same time, socio-economic factors such as the number of inhabitants, the level of education, the level of economic activity, and the unemployment rate significantly shape the demand for maritime transport. An analysis of the interconnection between maritime passenger transport and the socio-economic characteristics of islands therefore allows a deeper understanding of development processes in island environments. Due to the lack of data, the sample included only islands with local self-government units on their territory. Islands connected to the mainland by a bridge (Krk, Čiovo, Pag, Murter, and Vir) were excluded, as the bridge connection makes them physically fully integrated spatial units with the mainland, thus losing the fundamental island property of spatial discontinuity (Marinković, 2018). The accessibility of the island, previously calculated based on data from the Coastal Liner Maritime Transport Agency by the author (Aksentijević, 2025), was used as an indicator of transport connectivity, while the other selected indicators were calculated as aggregated values of selected indicators of island local self-government units.

	Accessibility	N_entrepreneurs	craftsper100	S_education	H_eudcation	Population	Unemployment
Accessibility	1.0000						
N_entrepreneurs	-0.3023	1.0000					
Craftsper100	0.6392	-0.0917	1.0000				
S_education	-0.3547	0.3240	0.2689	1.0000			
H_eudcation	0.2081	0.0744	-0.1322	-0.4087	1.0000		
Population	-0.3535	0.9375	-0.0947	0.4221	-0.0324	1.0000	
Unemployment	0.5989	0.0448	0.0755	-0.2969	0.5723	0.0392	1.0000

Table 2: Correlation matrix
(Source: Author's calculation)

Table 2 presents an analysis of the correlations between the accessibility of islands—defined by the level of development of maritime passenger transport—and selected indicators of socio-economic development. It highlights the multi-layered and varied effects of transport integration on island communities. The results indicate that maritime accessibility does not have a linear effect on economic and social aspects of development; rather, certain effects are conditioned by the structure of the local economy, demographic trends, and the functional connectivity of the island with the mainland. The weak negative correlation between the number of entrepreneurs and the accessibility of islands ($r = -0.3023$) suggests that increased transport connectivity does not necessarily result in greater entrepreneurial activity. This relationship can be interpreted through the process of functional centralization, where improved transport infrastructure facilitates access for the island population to markets and business opportunities on the mainland, potentially leading to the relocation of entrepreneurial activities outside the island area. On the other hand, the density of crafts shows a strong positive correlation with transport accessibility ($r = +0.6392$), confirming that better connectivity with the mainland encourages the development of local crafts and smaller businesses. More frequent maritime lines and shorter travel times enable more efficient supply, easier market access, and reduced transaction costs. This result aligns with theories on the role of transport infrastructure as a factor in regional convergence and integration (Puljiz, 2010). Regarding educational structure, the positive correlation between the share of highly educated population and accessibility ($r = +0.2081$) indicates that better transport connectivity enables greater mobility of educated groups and facilitates daily migration for work and education purposes. This encourages so-called circular mobility, contributing to knowledge exchange and the increase of human capital on the islands. The negative correlation between the secondary education level and accessibility ($r = -0.3547$) can be interpreted as a consequence of some larger Croatian islands having secondary schools, eliminating the need for daily migrations to the mainland. Also, despite the economic structure of the islands is dominated by tourism-related activities, i.e. accommodation and food services—which do not require a high proportion of highly educated people, the negative correlation between the secondary educated population and accessibility may also indicate the initial phase of structural transformation towards sectors requiring higher levels of education and digital competences. Although somewhat surprising, the number of inhabitants shows a moderate negative correlation with accessibility ($r = -0.3535$), suggesting that better transport connections do not necessarily lead to an increase in the permanent population on the islands. This result can be explained by the fact that increased accessibility often facilitates daily and occasional migration towards urban centres on the mainland, where educational and work opportunities are more diverse. Transport integration reduces isolation but simultaneously increases spatial dependence on mainland centers. This makes the islands functionally integrated into the wider spatial system, but at the risk of losing demographic vitality. The relatively high positive correlation between the unemployment rate and accessibility ($r = +0.5989$) points to a complex relationship between transport connectivity and the labour market. The positive correlation suggests that increased transport connectivity does not necessarily lead to a decrease in unemployment, but that the two phenomena can move in the same direction. The local economy on islands often does not generate enough new jobs to meet the growing needs of the working-age population. On islands strongly oriented towards tourism, transport integration additionally accentuates seasonal oscillations in employment, with periods of intense demand for labour alternating with periods of stagnation outside the tourist season. At the same time, increased accessibility enables greater mobility of the population towards mainland centers, but some of the population who temporarily work or reside outside the island remain administratively registered as unemployed.

It can be concluded that the positive correlation between accessibility and the unemployment rate does not reflect direct causality, but rather a complex interdependence of transport integration, the structure of the island economy, and migration movements. The results of the analysis confirm that maritime passenger transport plays a multiple and complex role in the socio-economic development of islands. Improved accessibility has a positive impact on economic dynamics, the development of crafts, and the educational structure of the population, while it can also lead to more intensive migration flows and increased dependence on mainland economic centers.

4. DISCUSSION & CONCLUSIONS

Maritime passenger transport is a key factor in the socio-economic development of island areas, especially in countries with numerous islands under their territorial jurisdiction and a dispersed population, such as the Republic of Croatia. As the primary form of transport connectivity, it enables the integration of island communities into regional and national economic flows and creates the prerequisites for sustainable economic and social development. Maritime passenger transport serves as a generator of economic vitality and an instrument of social cohesion and territorial integration. This paper conducts a correlation analysis confirming that maritime passenger transport plays a multiple and complex role in the socio-economic development of islands. Improved transport connectivity and accessibility positively affect economic dynamics, the development of crafts, and the educational structure of the population, but can also lead to more intensive migration flows and increased dependence on mainland economic centers. Additionally, it is important to highlight the connection between maritime transport and the development of tourism, which is the dominant economic sector on most islands. High-quality transport connections provide easier access to tourist destinations, increase the competitiveness of island entrepreneurs, and contribute to the diversification of the local economy. Reliable and regular shipping lines increase the availability of the labor market, educational and health services, encourage the circulation of people and goods, and strengthen local economies. Over time, maritime transport has been affirmed as a strategic element of regional policy, with effects manifested through employment growth, improved living standards, and the preservation of demographic stability. From the perspective of increasing transport accessibility, which in this research is expressed as time, the optimal and most concrete solution for economic policymakers should be to increase the number of high-speed ferry lines. However, high-speed lines are also the most expensive in regular maritime passenger transport and require higher costs for the shipowner, raising questions about the profitability of increasing such lines with a public service obligation. Although this would contribute to greater transport accessibility, it is more likely that a smaller shipowner will opt for a commercial high-speed ferry line during the tourist season when demand is uniform and higher. In the context of island development, liner shipping goes beyond its transport function and must be viewed as a complex system that shapes the spatial, economic, and social patterns of island areas. Its role in the long-term sustainability of islands requires an interdisciplinary approach, coordinated planning, and continuous adaptation to contemporary development challenges.

ACKNOWLEDGEMENT: *This paper was supported under the project line ZIP UNIRI of the University of Rijeka, for the project [UNIRI-ZIP-2103-5-22] and under the project line ZIP UNIRI of the University of Rijeka, for the project [ZIP-UNIRI-2023-2].*

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MAPPING SMALL AND MEDIUM ENTERPRISES IN CROATIA'S BLUE ECONOMY: ALIGNMENT WITH SMART SPECIALISATION STRATEGIES (S3)

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ABSTRACT

The Republic of Croatia has seen increasing interest in the Blue Economy as a strategic way to promote sustainable growth, protect the environment, and foster social inclusion in recent years. Its extensive coastline and maritime heritage give its marine industries (such as fisheries, mariculture, maritime transport, and nautical tourism) great potential for job creation and innovation. Nonetheless, these sectors face challenges like vulnerability to external shocks, low digitalisation, and partial alignment with Smart Specialisation Strategies (S3). This study examines the small and medium-sized enterprises (SMEs) within Croatia's Blue Economy, emphasising their contribution to sustainable development and adherence to S3 principles in the South-eastern Adriatic region. A survey among Croatian SMEs across various Blue Economy sectors evaluated employment trends, innovation ability, and participation in digital and green transitions. The findings aim to highlight growth opportunities, foster collaboration, and inform policy measures, supporting cross-border cooperation and transformative pathways. The research was funded by the BLUESLINKS project, which seeks to strengthen innovation networks, develop matchmaking platforms, and encourage sustainable employment in traditional Blue Economy industries through the integration of S3 frameworks and smart services.

Keywords: *Blue Economy, Nautical sector, Marine sustainability, Cross-border cooperation, Innovation*

1. INTRODUCTION

In Croatia, interest in the concept of the blue economy has grown in recent years. The sustainable use and management of marine resources for economic growth, social inclusion, and environmental preservation present huge potential for job creation and economic diversification (Kovačić, Perinić and Kerčević, 2021). The Croatian coastline is full of natural resources and offers a wide range of employment opportunities in the blue economy, including fisheries and aquaculture, maritime transport, tourism, and renewable energy.

One of its most important elements is the fishery sector. The fishing industry in Croatia employs a portion of the labour force, especially in coastal regions, providing jobs in fishing, processing, and distribution (The World Bank, 2024). Alongside the small-scale fishing industry, mariculture has a long tradition in Croatia, focusing on the cultivation of fish and shellfish, and has a historical significance in Europe (The World Bank, 2024). However, the mariculture industry has suffered significant job losses due to the COVID-19 pandemic, especially among small and medium enterprises. Nevertheless, microcompanies have shown resilience, indicating diverse impacts across the sector (Pećarević et al, 2023). The maritime transport industry, including all its pertinents, is another vital element of the Croatian blue economy. International ports and related logistical activities, such as cargo handling, ship repair, and maintenance, create a considerable number of jobs (The World Bank, 2024). The sea-related job market in Croatia is multifaceted, and each sector has unique employment trends and challenges influenced by both local and global dynamics. While the Croatian sea related job market is promising, it is also vulnerable to external shocks and requires strategic development to reach its full potential (Ivanić, Perić Hadžić and Mohović, 2018). It is of utmost importance to map the landscape of Small and Medium-sized Enterprises (SMEs) in the blue economy, highlight opportunities for growth and collaboration, and align with regional strategic frameworks. The insights gained will help stakeholders to understand the current state of the sector better and inform policy and support measures tailored to the needs of these enterprises. The Smart Specialisation Strategy (S3) framework should be mentioned here, as it encourages regional innovation by bringing together stakeholders in the blue economy focused on digital and green priorities, thereby supporting knowledge exchange and the necessary skills development (Fontana, Bisogni and Renwick, 2023). To address these issues and enhance the sustainable use of marine resources in fisheries, mariculture, and the nautical sector, the Blue Economy New Skills (BLUESLINKS) project was developed. Related to the aforementioned, the BLUESLINKS project has the following objectives:

- "To create a cross-border network favouring the adoption of the key principles of S3 specialisation strategies in the Blue Economy traditional sectors and seajobs.
- To provide innovative and smart services to SMEs of traditional Blue Economy Sectors and seajobs to foster transformative paths.
- To activate three continuous match-making mechanisms aimed at enhancing the employment capacity in Blue Economy traditional sectors and seajobs at the cross-border level."

Furthermore, the project's main outputs are to activate the BLUES S3 Innovation Hub Network, supporting 80 SMEs with a catalogue of innovative IT business solutions/services; three matchmaking mechanisms, including an online platform for SMEs and job seekers in Blue Economy Domains; engage young generations in three hackathons and three cross-border open job fairs thereby linking labour supply and demand in traditional sectors of the Blue Economy. (BLUESLINKS, 2025).

2. METHODOLOGY

In order to obtain a broader and clearer picture of the state of SMEs involved in the south eastern Croatian region, a cross-border consortium consisting of 8 partners related to small-scale fishery, aquaculture and the nautical sectors, developed a questionnaire to assess the actual needs in terms of demand and supply of marine jobs and evaluate current level of innovation and alignment of SMEs with the regional smart specialization strategies (S3). The survey was distributed to a diverse group of small and medium-sized enterprises (SMEs) in the above mentioned sectors of the blue economy.

It was designed to help identify key SMEs, assess their demand/supply of jobs, check their level of compliance with the S3 strategy in the Croatian Adriatic regions and identify innovative solutions they use or plan to use in the future. The results analysis gives insight into Croatian SMEs related to the Blue Economy and helps develop measures that will facilitate the transition to sustainable business, including facilitating employment and increasing the usage of environmentally friendly solutions, materials and renewable energy sources to reduce impact.

3. RESULTS AND DISCUSSION

A total of 25 SME's participated in the survey, most of which (22) were from Dubrovnik Neretva County, with the exception of 2 participants from the Šibenik region and one registered on the island of Rab. The results show that the majority of participants have SMEs registered in Dubrovnik, followed by Ston (Figure 1). A smaller proportion of participants fell into the "other" category and were essentially evenly distributed in the region of Dubrovnik-Neretva County.

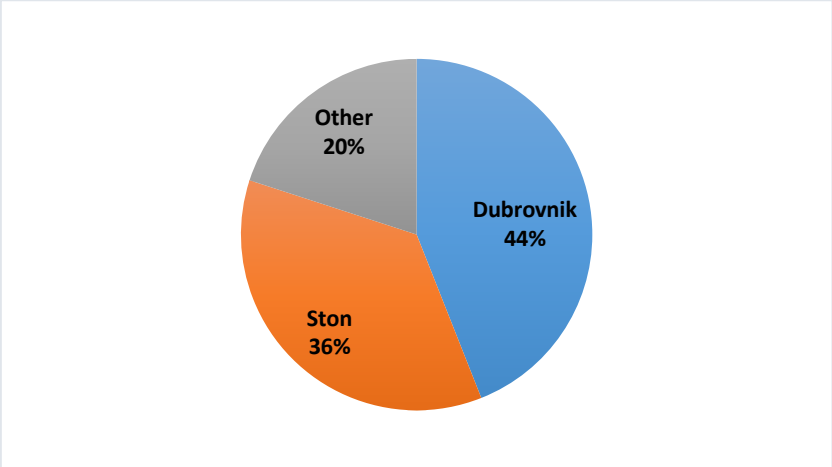

Figure 1: Location of the company's headquarters within surveyed SME's
(Source: Authors)

In terms of sectors of operation, the distribution of participants in the aquaculture, nautical and small-scale fishery sectors is fairly balanced, indicating a well-represented diversity (Figure 2).

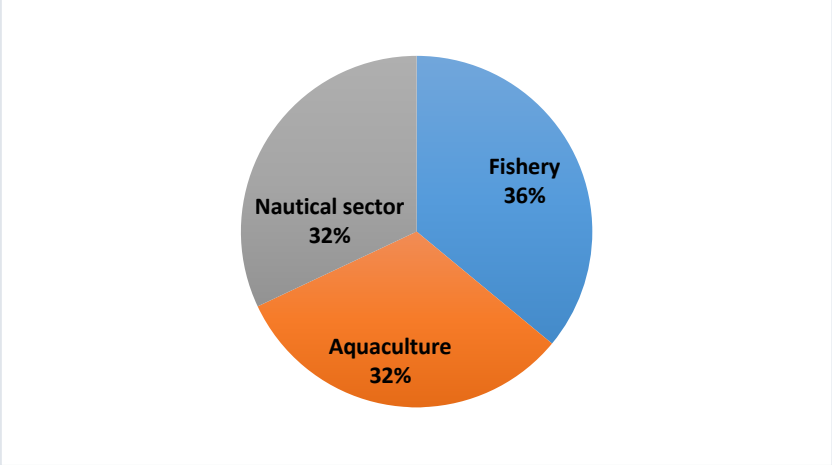

Figure 2: Sector of Operation within surveyed SME's
(Source: Authors)

The survey results show that 26% of respondents are not looking to hire employees. Of those actively hiring, 19% were looking for nautical service providers, 13% for tourism coordinators, 10% for fisheries technicians, and another 10% for fishermen (Figure 3). This distribution highlights the different employment needs across blue economy sectors and identifies specific areas where labour development and training initiatives could be beneficial.

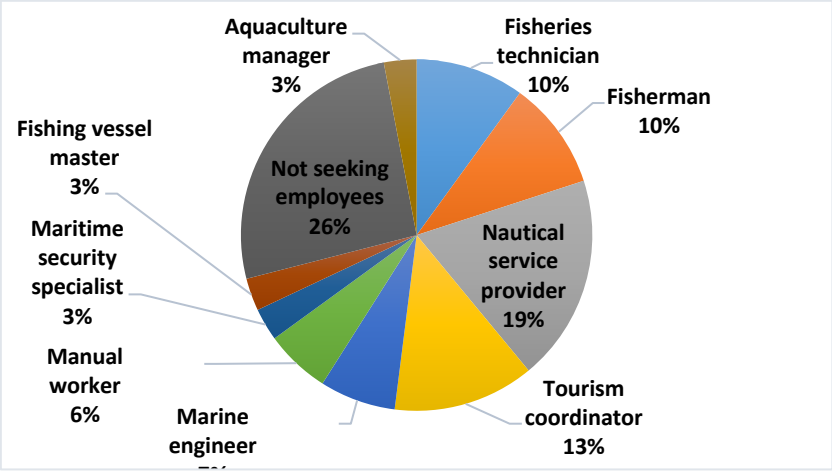

Figure 3: Types of jobs that are currently in high demand within surveyed SME's
(Source: Authors)

In terms of the key skills required for these jobs, findings revealed that the majority of SMEs are in demand of workers with technical skills (47%). The other categories had a balanced distribution, with the highest percentage at 12% and the lowest at 8%. One respondent highlighted that workers required diligence and skilfulness to navigate the complexities of these jobs (Figure 4).

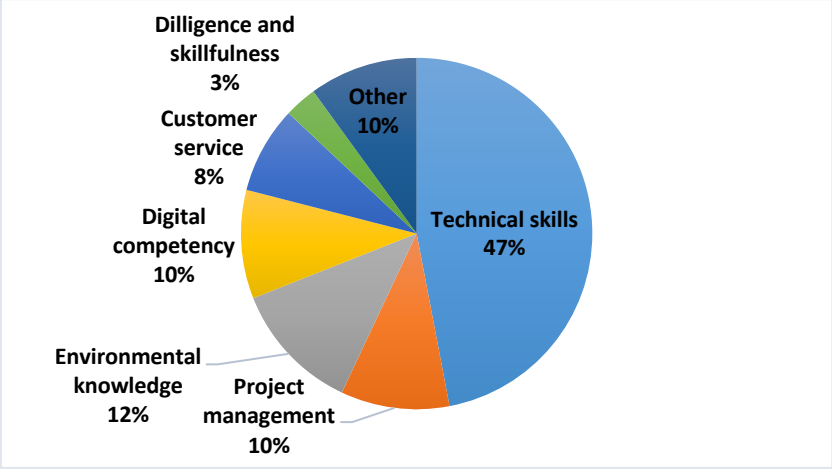

Figure 4: The key skills required for these seajobs within surveyed SME's
(Source: Authors)

When asked whether it is difficult for them to find qualified labour for work at sea, the majority answered 'No' (68 %). Of those who said 'Yes' (32 %), the majority found that the labour market lacks qualified applicants (65 %) (Figure 5).

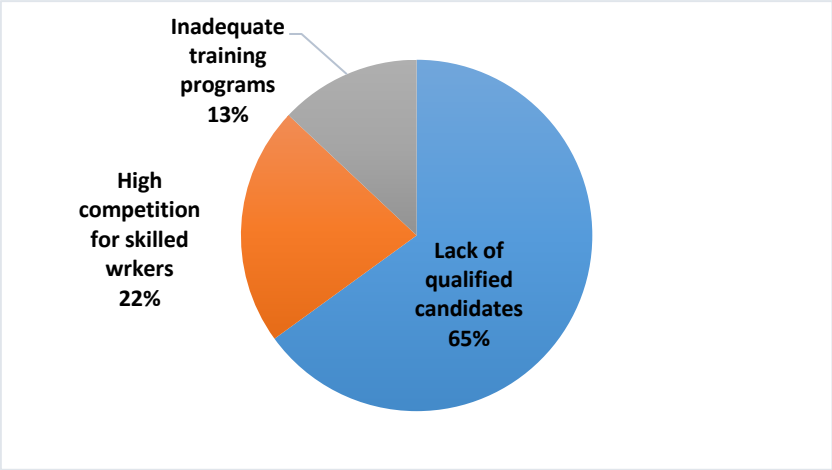

Figure 5: Specific challenges in finding skilled workers for seajobs within 32% of surveyed SME's
(Source: Authors)

The majority (85%) of participants stated that their company does not offer specific training programmes to improve employees' skills. Of the four SMEs that answered positively to this question, three provided training programmes to enhance technical skills and one offered management training. The survey provided valuable insights into the challenges faced by companies in the fisheries and aquaculture sector. The fact that regulatory issues were highlighted as a top concern (35%) suggests that compliance, licencing and changing regulations could significantly impact business. A significant portion of respondents (23%) highlighted market competition as a challenge (Figure 6).

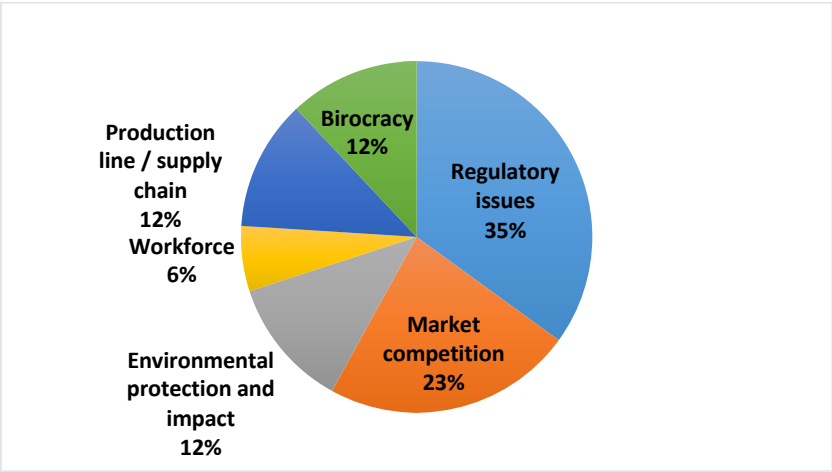

Figure 6: The major challenges companies face in the fisheries/aquaculture sector, within surveyed SME's
(Source: Authors)

In the nautical sectors, results indicating that both regulatory issues and market competition each account for 46% of the challenges suggest a significant dual focus for these businesses (Figure 7).

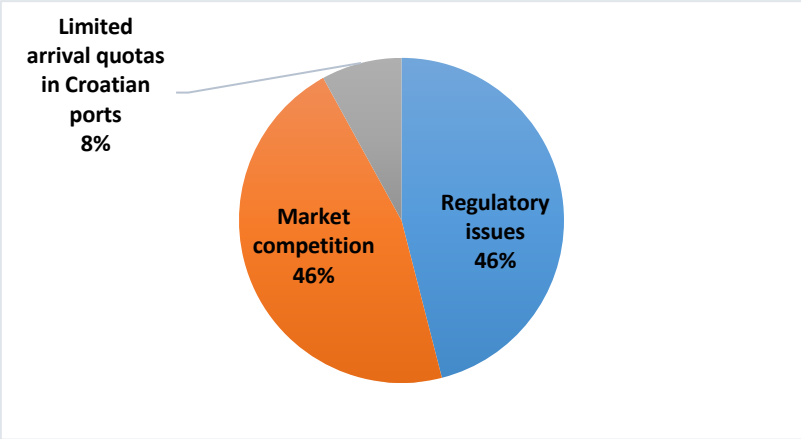

Figure 7: The major challenges companies face in the nautical sector, within surveyed SME's
(Source: Authors)

When asked about future growth potential, 76% of respondents in the fisheries and aquaculture sector see medium growth potential for companies, despite the challenges they face. It is an encouraging fact that suggests optimism and confidence in the industry's resilience and adaptability. High and low growth potential was expected by 12% of respondents (each). The survey results show that a significant majority (72%) of respondents are not familiar with the Smart Specialisation Strategies (S3/S4) for the Adriatic region (Figure 8). This indicates a potential gap in awareness and understanding of strategic initiatives that could drive innovation and economic development in these sectors. Therefore, there is a need for greater education and outreach to help companies take advantage of available resources and opportunities.

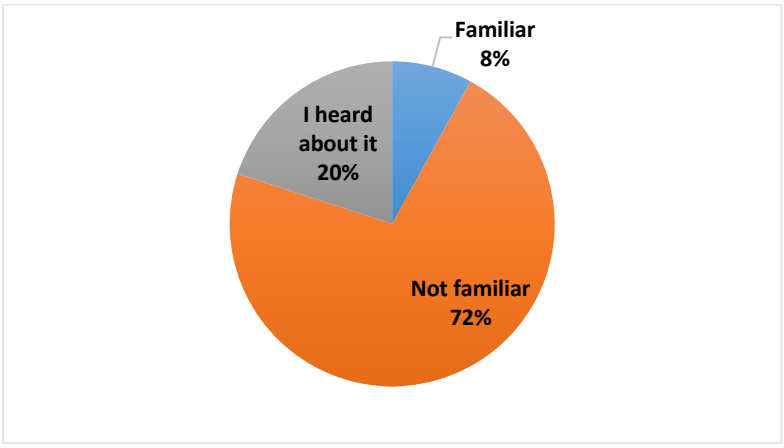

Figure 8: Familiarity with the Smart Specialisation Strategies (S3/S4) in the Adriatic regions
(Source: Authors)

28% of respondents who were aware of these strategies and had heard of them are committed to collaborating with research institutions (Figure 9). Collaboration with research institutions is promising because it can improve companies' access to new technologies, best practices, and expertise, which is critical to remaining competitive and compliant with regulations.

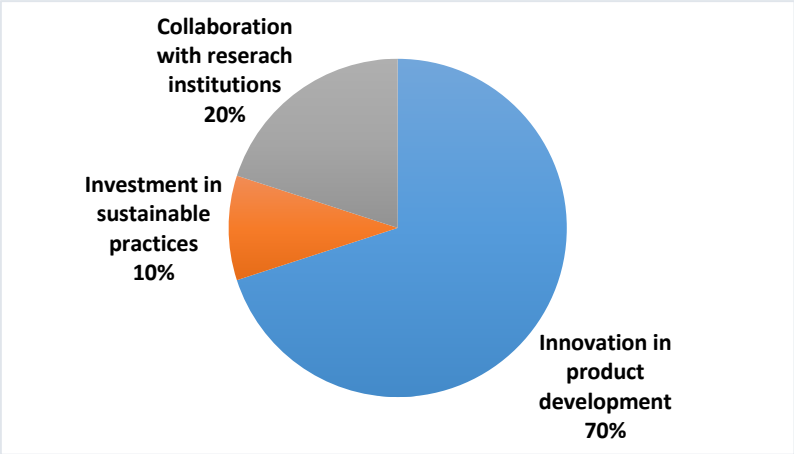

Figure 9: The Company's adherence to the principles of the S3 or S4 strategy within 28% of surveyed SME's
(Source: Authors)

The responses on the innovative solutions and technologies companies are using to align with S3 and S4 strategies provide valuable insights into their diverse approaches. A significant portion of SMEs (28%) are implementing sustainability through the use of environmentally friendly materials. Almost a quarter of respondents use digital tools and platforms. The use of digital tools indicates a shift towards modernisation and efficiency. This can include everything from management software to advanced data analytics, helping companies optimise operations and decision-making. Companies are investing in innovation (16%), improving products and operational efficiencies, keeping them competitive in the market. The use of renewable energy (12%) is lower, but reflects a growing commitment to reducing carbon footprints and promoting sustainable practices (Figure 10). There is an overall optimistic atmosphere showing a proactive approach to aligning with the S3 frameworks, emphasising sustainability and technological advancement.

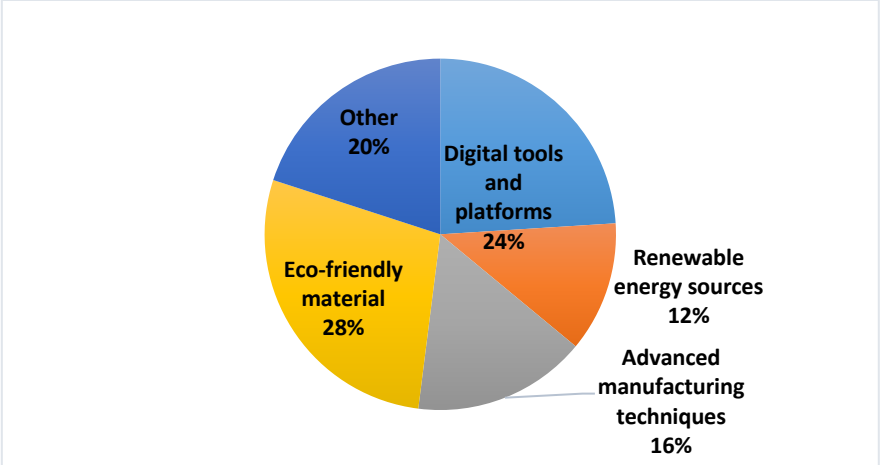

Figure 10: Innovative solutions aligned with the S3 strategy
(Source: Authors)

The fishing sector in Croatia is characterised by a complex interplay between small-scale and industrial fishing, which has a significant impact on the local economy and sustainability (Matić-Skoko et al, 2017). Despite its historical importance, the sector faces challenges in terms of management, trade and legal framework. Much of the fishing in the coastal zone is small and micro fishing (80%).

Small and micro enterprises have developed in a very specific socio-economic and historical context. They are vital for coastal communities, contribute to food supply and the local economy, but are underrepresented in official statistics. The fishing fleet is still smaller than that of neighbouring countries, which indicates potential for growth and development (FAO, 2023). The national strategic development plan aims to adapt to EU regulations and promote sustainable practices in mariculture and fisheries. Fishermen are dissatisfied with national and EU policies and feel excluded from decision-making, undermining their resilience and the sustainability of the sector. While the Croatian fisheries sector has potential for growth, it requires improved management strategies and greater involvement of local fishermen to improve sustainability and economic viability. Even though Mariculture in Croatia has a long tradition, it is facing many challenges, especially in recent times. The decline has been most pronounced since the COVID-19 pandemic (Pećarević et al., 2023).

The European Union has opened up opportunities for the development of mariculture in Croatia, aligning with the Common Fisheries Policy. The National Strategic Development Plan for Fishing and Aquaculture (2021-2027) outlines guidelines for sustainable aquaculture. Mariculture supports employment in sensitive island communities and enhances tourism (Volarić, Kolanović and Poletan Jugović, 2019). Consumer perceptions of farmed fish are generally negative compared to those of wild fish, despite their stable nutritional values. Challenges in Croatian mariculture include the absence of shellfish nursery grounds and underdeveloped infrastructure. The integration of mariculture and tourism is seen as beneficial for economic growth, as it promotes local seafood products. Future prospects for Croatian mariculture include leveraging EU funds for sustainable practices and improving infrastructure (Volarić, Kolanović and Poletan Jugović, 2019). The maritime transport system in Croatia is projected to show a positive correlation between employment and the number of vessels (Pupavac et al., 2019). This sector is crucial for the national economy, linking labour market indicators to the freight transport dynamics. Nautical tourism is underutilised in terms of promotional activities, which affects job creation in marinas. Effective marketing strategies could enhance the relationship between supply and demand, potentially increasing employment opportunities in this sector. By focusing on specific areas, there is a need to map the landscape of SMEs in the blue economy in Croatia, highlighting opportunities for growth, collaboration, and alignment with regional strategic frameworks. The insights gained should aim to help stakeholders better understand the current state of the sector and inform policy and support measures tailored to the needs of these enterprises.

4. CONCLUSION

The ways to encourage the adoption of innovative and sustainable practices that will offer equal opportunities for employment in the sector should be identified. Regarding education and training, workshops and seminars should be organised to inform stakeholders (companies) about the benefits of S3 strategies, an environmentally friendly approach, the use of digital tools, big data, and renewable energy. Financial incentives in the form of grants or subsidies should be offered to SMEs that invest in sustainable practices and innovative technologies. Furthermore, tax incentives should be introduced for SMEs that utilise environmentally friendly materials or renewable energy solutions in their everyday businesses.

Networking opportunities should be encouraged, such as creating platforms for SMEs and other stakeholders to share best practices, collaborate and create partnerships with research institutions. In addition, industry forums or conferences should be organised to facilitate stakeholder learning and the sharing one ideas and approaches to improvement.

Access to funding opportunities for projects that align with S3 strategies should be provided and facilitated. Guidelines for SMEs on online resources or toolkits for implementing innovative practices should be developed and encouraged. The 2021–2027 European programming cycle presents major opportunities for the Blue Economy to grow and shift toward sustainable, digitally driven production models, supporting the EU's green and digital transitions and aligning with the UN 2030 Sustainable Development Goals and cohesion objectives.

ACKNOWLEDGEMENT: *This research was funded by the IT-HR INTERREG, BLUESLINKS project.*

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GENERAL CLASSIFICATION OF CARGO OPERATIONS ON LIQUEFIED NATURAL GAS CARRIERS

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ABSTRACT

Maritime transport, as the most important branch of goods transportation, includes a wide range of cargoes, among which natural gas holds a special role. Due to its low density, natural gas must be cooled to reach a liquid state suitable for transport. Liquefied Natural Gas (LNG) enables the economically viable transport of large quantities of gas over long distances with specially designed LNG carriers playing a key role. These ships perform complex cargo operations that differ significantly from those of bulk or oil carriers, primarily because of the extremely low temperatures and flammability of the cargo. This paper classifies the sequence and characteristics of cargo operations on LNG carriers throughout their service life. All the general and specific cargo operations are identified and grouped into three main categories: standard cargo operations, drydock preparation operations, and gas management operations onboard. The research provides a detailed description of cooling, loading, loaded voyage, discharging, and ballast voyage procedures, as well as heating, inerting, drying, purging, aeration and gas handling processes. The paper emphasises the importance of understanding the properties, technical and technological characteristics of LNG carriers for safe operational handling. Proper management of these operations ensures the safe transport of LNG. This paper contributes to the understanding of LNG carrier operations by providing an overview of cargo-handling procedures.

Keywords: *LNG carriers, liquefied natural gas, LNG management, cargo operations, maritime safety*

1. INTRODUCTION

Maritime transport is one of the most significant branches of freight transportation. It deals with a wide range of different types of cargo. One of these cargoes is natural gas. The specific characteristic of all gases is their extremely low density. To enable the transport of reasonable quantities of natural gas, its density must be increased. Generally, the increase in density, that is, the reduction of volume, is achieved by compressing gases. However, since large quantities of natural gas are transported in ship tanks, such pressure would be extremely high, and the tanks would need to be made smaller, which is economically less favorable. Instead of compression, the approach taken is to cool the natural gas. By cooling, natural gas increases its density to a level that makes transport economically viable.

Because this cargo is at an extremely low temperature, its loading, unloading, and transportation differ from those of other cargoes. Special procedures are required to ensure the safe handling of LNG. These cargo operations are much more complex compared to cargo operations on bulk carriers or container ships. In addition to the problems caused by the extremely low temperature of the cargo, it must also be remembered that LNG is explosive, which requires specific procedures similar to those carried out on ships transporting crude oil, oil products, and flammable chemicals in bulk (Belamarić, 2012).

Natural gas is one of the main non-renewable energy sources today, along with crude oil and its derivatives, as well as solid fuels (such as coal). The advantage of natural gas over other non-renewable energy sources lies in the fact that it is non-toxic, produces lower carbon dioxide (CO_2) emissions, thereby reducing greenhouse gas emissions, burns almost completely without producing ash, has higher energy efficiency, and, through liquefaction, allows for the transport and use of larger quantities (Sutlović, 2011).

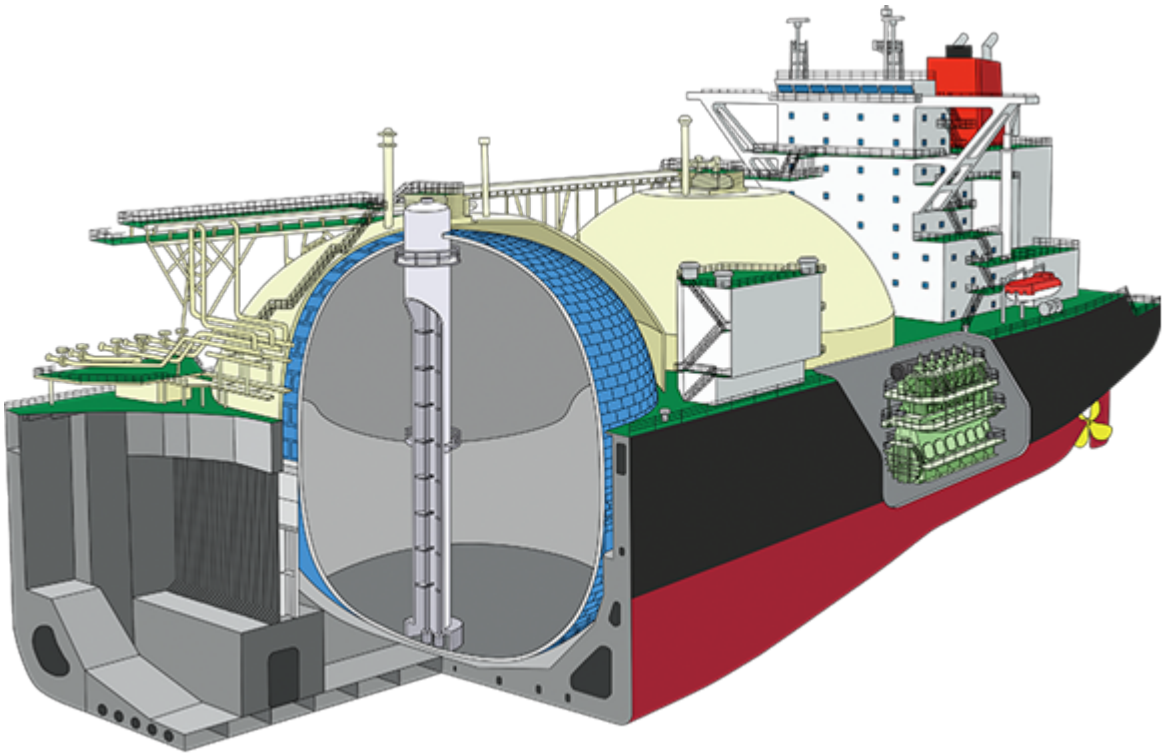

Figure 1: Cross-section of an LNG carrier
(Source: Answers Kawasaki, 2017)

Natural gas is a mixture of gases that, at ambient pressure and temperature, exist in a gaseous state. It is colorless, odorless, and non-toxic. The largest portion of this mixture consists of hydrocarbons, the most abundant of which is methane. Natural gas also contains gases that are not hydrocarbons (Komadina et al., 1992). In Figure 2, there is a more detailed chemical composition distribution of LNG given.

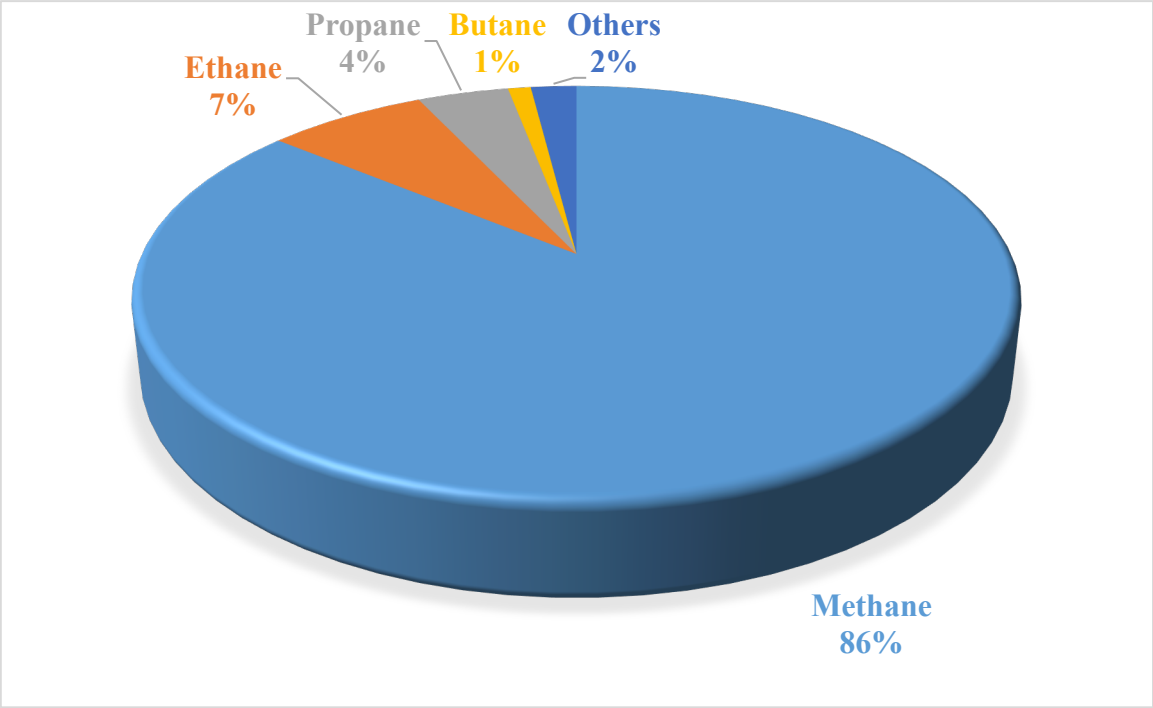

Figure 2: Chemical composition of natural gas
(Source: authors)

In order for natural gas to be practical for transportation, its volume needs to be reduced, which is achieved by liquefaction, resulting in the so-called LNG. This is a high-pressure gas that has been cooled to as low a temperature as possible to obtain a liquid state. Natural gas is cooled to a temperature of minus 161.5 °C and takes on the properties of a colorless liquid that has no odor or taste. LNG reduces its volume by 600 times compared to natural gas at ambient pressure and temperature, making it very suitable for transportation by tankers specially designed for the transport of LNG carriers (Bošnjak, 2020). This paper is divided into 5 chapters. Chapter 1 is an introduction that gives an overview of natural gas and LNG carriers in general. The structure of this paper is also presented in this chapter. Chapters 2, 3, and 4 give a general classification and an overview of cargo operations onboard LNG carriers, standard cargo operations, preparation for drydock operations, and LNG management onboard operations, respectively. Chapter 5 is the conclusion, and it gives final notes and results of the study are briefly discussed and commented on. This paper used scientific research methods of description, classification, compilation, as well as deductive and inductive methods.

2. STANDARD CARGO OPERATIONS

In this classification, standard cargo operations, usually called “normal operation” onboard, refer to the operations a vessel is performing when not in preparation to or leaving drydock, nor cargo management operations on board during ballast or laden voyage. The result is the following cargo operations:

- Loading
- Unloading/discharging

2.1. Loading

Before the loading operation, safety procedures must be established between the ship and the terminal, typically guided by detailed checklists. Special attention is given to safety valves, high-pressure alarms, remotely controlled valves, liquefaction systems, gas detection systems, loading rates, and ship or terminal limitations.

The terminal provides all essential cargo data, and the crew must be familiar with cargo characteristics and safety measures. The cargo plan ensures safe loading while maintaining ship strength and stability during both loading and navigation. All operations are monitored from the Cargo Control Room (CCR), which controls trim, heel, and tank pressures. LNG loading and deballasting occur simultaneously to maintain uniform tank filling and stability. Tanks are filled from the bottom, and vapor above the liquid condenses on tank walls, but rapid volume reduction in later stages can cause pressure spikes.

A topping-up procedure is followed near the end, keeping the ship on an even keel. Loading is staggered between tanks, and the terminal is notified in advance to reduce the loading rate. Cargo can be loaded through direct lines, vapor return lines, or both. Excess pressure is managed via tank-top sprayers, emergency shut-down (ESD) systems, or gas combustion, and tank pressure should not exceed 90% of the safety valve activation pressure. Cargo levels are monitored by floats or radar/ultrasonic sensors, and after loading, pipelines are drained and purged with vapor.

Deballasting starts by gravity until tanks near the waterline, then pumps complete the process, maintaining a slight aft trim. Free surfaces in tanks affect ship stability, shifting the center of gravity and reducing the GZ lever. Sloshing from cargo movement is considered in tank design, and loading never occurs in the 10–80% tank range to reduce risks. Safety valves are set above maximum vapor pressures to prevent LNG spills during fire scenarios. The final cargo amount depends on valve settings and maximum allowable pressure, ensuring the operation remains within safe limits throughout loading, transit, and unloading (Bošnjak, 2020; McGuire, 2000).

2.2. Unloading/discharging

Upon arrival at the unloading terminal, cargo tank pressures and temperatures must meet terminal requirements. Before unloading, standard information exchange, safety and checklist verification, and implementation of all safety measures are required. Unloading methods vary depending on ship type and terminal capabilities, with three main methods commonly used.

The first method uses the cargo evaporator, where the liquid cargo evaporates and the vapor is discharged under high pressure from the tank, or vapor suction compressors can be used. This method does not require pumps, but the terminal must reliquefy the LNG, and gas return lines are not used, so the terminal tank pressure must be lower than the ship tank pressure. The second method relies on centrifugal pumps, often with booster pumps in series or independently. Pumps operate in parallel, but multiple pumps can heat the cargo, generating excess vapor that is reliquefied at the terminal. If compressors cannot maintain desired terminal tank pressures, unloading speed is reduced, which must be carefully monitored to avoid problems with pump operation.

The third method uses centrifugal pumps with heated suction lines. Cargo is heated to equalize pressure between the ship and terminal tanks before pumping, while booster pumps maintain intermediate pressure. Seawater flow through heaters must be stabilized and gradually cooled to reach target temperatures. Sufficient liquid cargo must be present for proper pump operation. Heating carries the risk of freezing seawater, so heater temperatures must be continuously monitored to ensure safe unloading (McGuire, 2000).

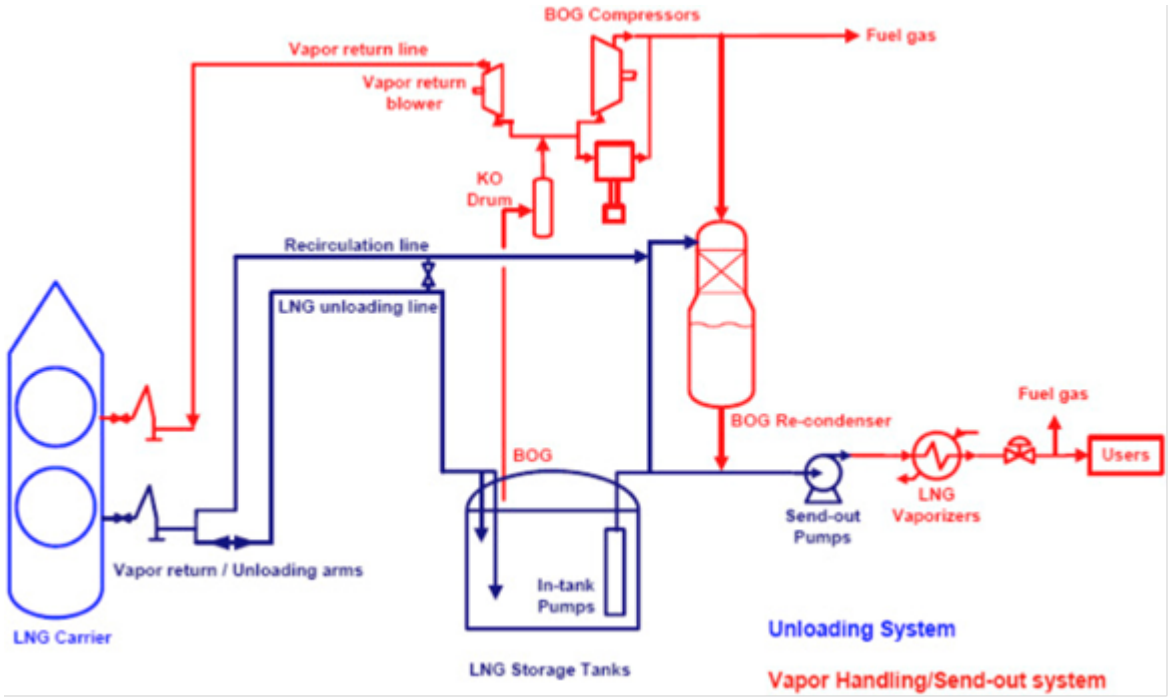

Figure 3: Diagram of unloading operation on a shore terminal (Source: Shearer and Tusiani, 2007)

During the unloading operation, attention must be paid to the ship's stability and hull stresses. Ballasting operations are carried out to maintain satisfactory trim and overall ship stability. Unloading gas from the cargo space can cause pressure changes in the barrier spaces, so this pressure must be monitored throughout the entire unloading process. The so-called boil-off effect, caused by heat transfer through the tank insulation, is usually insufficient to maintain tank pressure as it drops due to liquid pumping. This depends on the pumping rate, and for a normal pumping speed, vapor must be added to the tanks to maintain the rate. This vapor is supplied either through the vapor return line from the shore or by redirecting part of the liquid being unloaded into the evaporator. After unloading is complete, the sequence of operations is the same as at the end of loading: pipeline drainage, disconnection from the shore, and calculation of remaining liquid and vapor. The amount of cargo unloaded is calculated by subtracting the quantity remaining after unloading from the quantity at arrival in port.

3. OPERATIONS PRIOR AND AFTER THE DRY DOCK

Cargo operations that take place before and after the vessel is going to dry dock (which is ordinarily once in 2 years) are classified as "dry dock operations". These include:

- Stripping off
- Warming up
- Inerting
- Gassing up
- Aeration
- Cooling down

Preparing an LNG carrier for a dry dock is an extensive operation that requires ensuring the cargo tanks are safe for entry and/or safe to work around. This involves adjusting the tank atmosphere and temperature affected by the LNG. To achieve this condition, it is necessary to remove any remaining liquid, heat the tanks, inert the tanks, and ventilate the tanks.

3.1. Stripping the cargo

Depending on the type of tank, the removal of remaining cargo in tanks can be done using pressurization (no longer used on modern LNG carriers), classical stripping, or by using heaters. Removing residual cargo from tanks and other cargo units is the first operation to perform before entering the dry dock. Removing cargo residues using heaters takes the most time but is the most common method on LNG carriers, as many vessels only have this option. Caution is required because rapid vaporization consumes large amounts of latent heat, causing a sudden temperature drop that can lead to brittle fracture inside the tank. Heating is performed using coils that warm the LNG. As the vapor evaporates from the tank, it passes through a compressor, where compression heat increases the evaporation temperature. The heated cargo then returns to the remaining cargo, gradually warming it. Once sufficient temperature for evaporation is reached, the cargo is directed to a deck tank for later unloading or can be unloaded directly to the terminal. If the ship lacks heating coils, hot vapor from the compressor is returned to the remaining cargo through openings at the tank bottom. This method is even slower than using coils because compressors cannot heat the cargo as quickly as coils, so it is rarely used except on small LNG ships not equipped with heating coils (Mokhatab et al., 2014).

3.2. Warming up

After the remaining cargo has been removed, cargo vapor remains in the cargo system, and the system is still subcooled. The tanks need to be heated using this vapor in a way that avoids thermal stress on the material. Tanks are heated by circulating heated LNG vapor, which is reheated using a compressor or a steam heater. Initially, the hot vapor is introduced through the cargo lines to the bottom of the tank to facilitate evaporation of any remaining liquid. In the next step, once temperatures start to stabilize, the hot vapor is introduced through the top of the tank via the vapor line. At sea, excess vapor generated during heating is vented to the atmosphere or burned in boilers. When the ship is moored, the vapor can be returned to shore. Initially, tank temperatures rise slowly as LNG continues to evaporate, accompanied by significant vapor formation and ventilation. After evaporation is complete, the tank temperature increases rapidly, and the circulation rate decreases. Heating should continue until the vapor temperature in the tank reaches between +5ºC and +10ºC. It is important that the tank temperature remains above the dew point of the inert gas introduced after this phase. If this is not ensured, water condensation may occur on the tank side when inert gas is introduced (McGuire, 2000; Mokhatab et al., 2014).

3.3. Inerting

The purpose of inerting tanks and cargo systems is to prevent the formation of explosive concentrations of cargo vapor and air. To achieve this, the oxygen content must be reduced to below 5%, although a lower concentration is usually preferred. Unlike some other cargoes prone to forming explosive vapor-air mixtures, LNG is handled so that the cargo never comes into contact with air, making the risk of fire or explosion very low or negligible. Inert gas is an exhaust gas that does not support combustion and is non-flammable. It is produced either by special inert gas generators or from the ship's propulsion system. To maintain LNG purity, nitrogen generators are often used. Nitrogen generators extract nitrogen from air, which is primarily nitrogen, by forcing air under increased pressure through filters that separate nitrogen from other air components. Nitrogen is delivered through one outlet, while the remaining air is expelled through another. Nitrogen generators are usually located on the ship's deck.

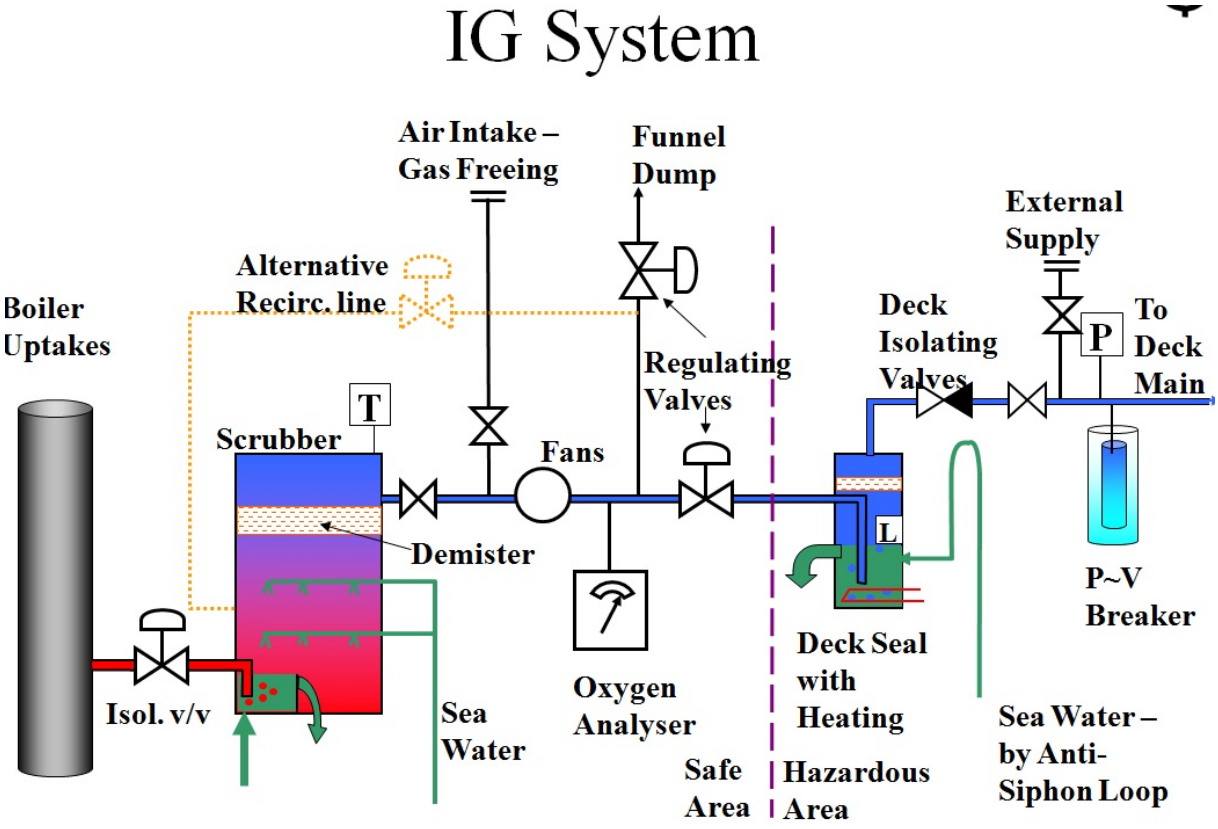

Figure 4: Diagram of inerting operation on LNG carrier
(*Source: MarineSite.Info, 2016*)

Inert gas for LNG tanks is produced using low-sulfur fuel and consists mainly of nitrogen, with small amounts of carbon dioxide, oxygen (0.5–3%), and water vapor. Oxygen levels are controlled, and water vapor is removed before injection. The gas is used to purge methane from tanks and maintain an inert atmosphere in storage and surrounding spaces. Because carbon dioxide freezes at –56ºC, tanks are first heated to near ambient temperature to prevent freezing and thermal stress. Tanks can be inerted by displacement or dilution. In displacement, gas is injected slowly at the top, pushing methane out through a bottom vent, which uses less inert gas and is preferred for standard operations. In dilution, gas is injected quickly at the top to accelerate inerting, though it consumes more gas. Inerting continues until cargo levels are below dry dock limits, after which tanks are ventilated until oxygen reaches 21%, making them safe for inspection and work.

3.4. Aeration

After flammable vapors have been removed through inerting, cargo tanks can be ventilated with air. Air is supplied via the ventilation system from the inert gas system, which includes a built-in air compressor and an air-drying unit. Ventilation is carried out until the oxygen level reaches 21%, and hydrocarbon vapors must be completely eliminated to prevent fire or explosion. It is also necessary to determine the level of possible carbon monoxide, which can be hazardous during entry. It is extremely important that no parts of the tank remain subcooled during ventilation, as condensation of water vapor could cause problems during loading and prolong some of the subsequent processes (McGuire, 2000).

3.5. Gassing up

Gassing up refers to the process of replacing inert gas with cargo vapors. Before starting the gassing-up procedure, it must be ensured that all gas detection equipment (fixed and portable) is functioning correctly and calibrated according to the manufacturer's instructions. Gassing up is necessary to remove all gases from cargo spaces that freeze at –161°C, mainly CO_2. The solidification point of CO_2 is around –70°C, and at the temperature at which LNG is transported, dry ice could form, potentially blocking filters, nozzles, and similar equipment. Gassing up can be carried out using cargo already in a dedicated deck tank or via the terminal. Typically, this cargo is in liquid form and must be sent through an evaporator before starting the tank gassing procedure. LNG vapor from the evaporator has a temperature of approximately 20°C and must be directed through the vapour header into each tank via the vapour dome. At the start, the piping system and evaporator can become blocked by vapor, and care must be taken to ensure LNG does not leak into the evaporator. LNG vapor is lighter than inert gas, allowing the inert gas in the cargo tank to rise to the top of the tank filling line. The inert gas is then vented into the atmosphere through the vent.

When about 5% methane is detected at the vent (the exact value is determined by the terminal or port authority), the exhaust gas is directed to shore via compressors or to boilers through the gas pipeline. This part of the operation can be carried out without compressors if return pressure requirements are met. If possible, compressors should be avoided to prevent turbulence in the tanks. Some terminals require the operation to end with all exhaust gas returned to shore. Returned methane is usually sent for combustion, as venting is prohibited because methane is a greenhouse gas.

Under certain circumstances, the procedure can be considered complete when methane content measured at the top of the cargo filling line exceeds 80%, though a value close to 100% is preferred. Target levels for N_2 and CO_2 are equal to or less than 1%, depending on terminal requirements. The exact sequence of operation and ignition must be discussed and agreed with the terminal before starting. All agreed procedures should be fully documented and signed by both parties (Shearer and Tusiani, 2007).

3.6. Cooling down

As previously mentioned, LNG is supercooled to –161°C during handling. To avoid thermal stress on tank walls, pipelines, and handling equipment, the entire LNG loading system must be gradually cooled before cargo transfer begins. Without this pre-cooling, heat from the surroundings could cause gas expansion, increasing pressure and potentially activating safety valves, leading to cargo vapor loss. Pre-cooling is achieved using LNG itself, typically at a rate of up to 10°C per hour. The process starts with a small flow of liquid LNG from the terminal to cool the pipelines and check for leaks.

Vapor produced during evaporation is returned to the terminal or sent to the ship's reliquefaction system. On LNG carriers, the pre-cooling operation usually takes around 12 hours, with temperatures at the bottom of tanks reaching –130°C and at the top –90°C. Cooling continues until liquid LNG begins forming at the bottom, confirmed by temperature sensors, and LNG is delivered via spray nozzles or cargo pipelines. Evaporated vapor is returned through a vapor line to the terminal for reliquefaction.

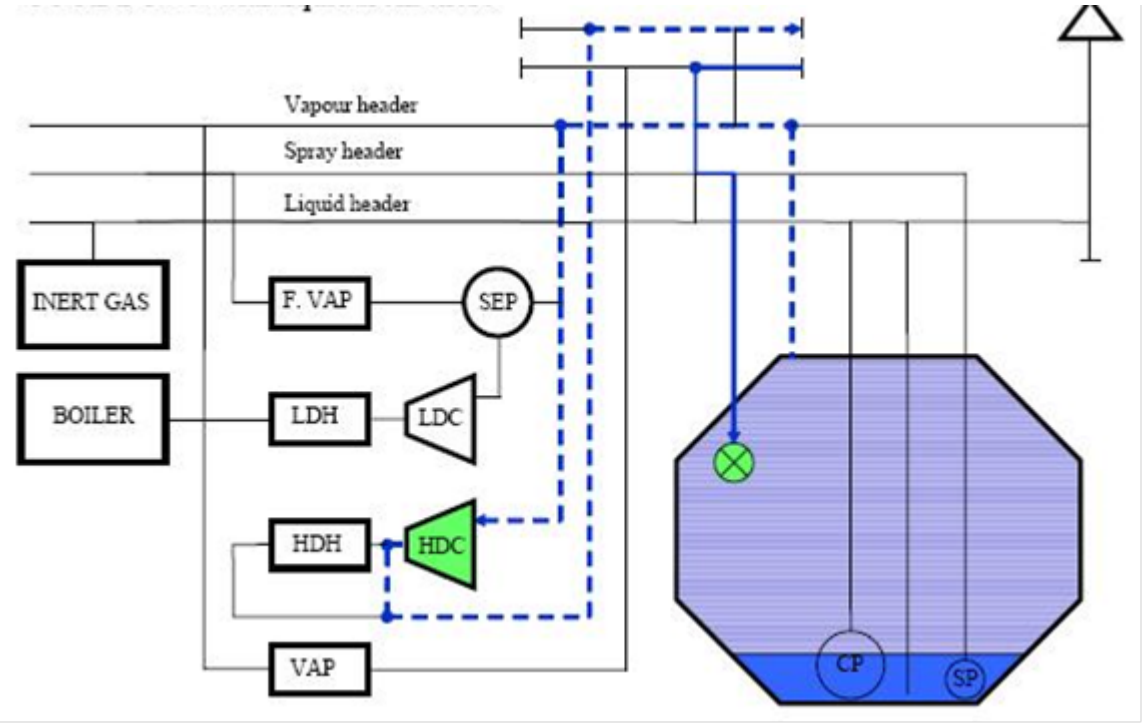

Figure 5: Diagram of cooling down operation (*Source: Bošnjak, 2020*)

There are two types of reliquefaction systems: two-stage and cascade. In the two-stage system, the condenser is cooled by seawater, requiring a dual compressor to raise the pressure from atmospheric to about 15 bar. In the cascade system, a Freon 22 refrigeration unit is used: Freon is condensed using seawater, stored in a Freon tank, and then evaporated in the cargo condenser via a thermostatic expansion valve, removing heat from the system. Large cargo compressors pull vapor from the tanks into the Freon-cooled condenser, and the thermostatically controlled Freon cycle continuously removes the latent and sensible heat from the cargo. The cascade system is efficient because the same refrigerant can be used for all cargoes, with seawater temperature being the only variable. Typically, all tanks are cooled simultaneously, but if condensate distribution is uneven, it is returned to one tank at a time to balance levels (Mokhatab et al., 2014; Shearer and Tusiani, 2007; Šeparović, 2015).

4. CARGO MANAGEMENT DURING VOYAGE

Cargo operations that are done when the vessel is underway, wheter it is during ballast or laden condition are classified as “cargo management operations”. These include:

- Reliquefaction
- Boil-off gas (BOG)

4.1. Reliquefaction

As a cooling medium, nitrogen is used, which remains in its gaseous phase throughout the entire cooling process and is produced using a nitrogen generator. The nitrogen present in boil-off natural gas cannot be recondensed, which results in a decrease in its concentration within the natural gas. Unliquefied nitrogen is removed by combustion in the gas burning chamber. The IGC Code provides some basic guidelines for system design, such as that the system’s capacity must be sufficient to condense all the boil-off gas under normal conditions, and that the liquefaction system must be equipped with 100% redundancy as required by the IGC Code. The gas combustion chamber must be installed as a complete alternative to the liquefaction system.

The system must also be equipped with automatic capacity control and must have the ability to shut down the liquefaction system during cargo pump operation, which eliminates the need for an additional generator (Komadina et al., 1992).

4.2. Boil-off gas

When designing a liquefied gas carrier, the choice of propulsion system takes into account the vessel's efficiency, size, and the method of handling boil-off gas. On average, the use of cargo vapors as fuel amounts to about 0.2% of the total cargo per day. For a long time, steam turbines were the primary choice for the propulsion of liquefied gas carriers. Steam turbines have a thermal efficiency of approximately 30%, whereas modern two-stroke slow-speed diesel engines can achieve efficiencies of up to 50%. For this reason, and due to fuel savings, diesel engines remain a key focus in the maritime industry. Modern engines can operate on up to three different types of fuel. Therefore, the conventional propulsion system for LNG carriers is the steam engine. Steam engines are proven, highly reliable, and have low maintenance costs. They are used on LNG carriers because part of the boil-off gas that naturally evaporates during transport due to heat ingress into the tanks can be used as fuel. The main disadvantage of the steam engine, however, is its low efficiency (Huan et al., 2019).

5. CONCLUSION

Handling LNG is far more demanding than handling other types of cargo, so the crew must be aware of all possible hazards during loading. The cooling operation is a key procedure to ensure that materials and equipment in contact with the cold LNG do not suffer brittle fractures caused by thermal stress. Depending on the ship's size and type, the cooling equipment may vary. LNG loading has its own specific procedures, but is generally performed using loading tables. Typical challenges include ship stability, longitudinal strength during loading (due to uneven stress distribution), and local stress around loading openings. Before cooling begins, the atmosphere in the tanks must be inert and dry. Inerting on LNG carriers is done using inert gas generators or nitrogen generators. However, since LNG is stored at extremely low temperatures (−161°C), CO_2 would solidify, creating handling problems. Therefore, before cooling, the inert gas must be replaced with warm cargo vapors that contain no oxygen, eliminating explosion risks. Discharging LNG is somewhat more demanding than loading and depends largely on the terminal's equipment. Although it can be discharged as a gas, this is rare because it takes longer; typically, cargo pumps are used. During discharge, in addition to stability and structural strength, the main concern is vacuum formation. Near the end of discharge, the rate must be reduced and a return line maintained to prevent vacuum conditions. When a ship is preparing for dry docking or tank inspection, the tanks must be emptied and made safe for entry. This involves removing cargo residues, gradually warming the system to avoid sudden temperature or pressure spikes (which could cause brittle fractures), then inerting the tanks to remove explosion risk before ventilating them for inspection. During transport, LNG slowly warms and produces BOG, which helps maintain temperature through latent heat consumption. These vapors are used as fuel for steam turbine boilers, though diesel engines are also used for maneuvering due to better efficiency. LNG carriers rarely reliquefy vapors back into cargo tanks; if excess vapor cannot be used as fuel, it is burned off in a flare and released into the atmosphere. By analyzing all cargo operations, it can be concluded that LNG transport is a complex process requiring advanced equipment and a highly trained crew. The crew's skill and experience are crucial since most cargo operations are specific to each ship and terminal.

ACKNOWLEDGEMENT: *This paper is based on the bachelor's thesis of Vice Milin supervised by prof. Rino Bošnjak at the University of Split, Faculty of Maritime Studies.*

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NON-STANDARD FORMS OF EMPLOYMENT

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ABSTRACT

Non-standard forms of employment have become one of the defining features of the contemporary labour market. In the context of rapid technological progress and the expansion of artificial intelligence, traditional employment models are increasingly being replaced by flexible but also insecure forms of work. This paper examines the historical and legal framework of the right to work, classifies non-standard employment types, and analyses their impact on the labour market and workers' mental health. Using analytical-descriptive and comparative methods, the paper draws upon data from the Croatian Employment Service and Eurostat between 2017 and 2022, as well as relevant academic studies in sociology, economics, and management. The results show that although non-standard forms of work provide greater flexibility, they simultaneously increase the risks of insecurity, stress, and mental health deterioration. It is concluded that future labour policies should balance labour market flexibility with social security to ensure sustainable and dignified employment conditions.
Keywords: *non-standard employment, labour market, digital economy, mental health, artificial intelligence*

1. INTRODUCTION

The right to work is one of the fundamental human rights guaranteed by both international and national legislation. [1] In the globalised and digitalised economy, the concept of work is undergoing significant transformation. Traditional employment, characterised by permanent contracts and collective rights, is increasingly giving way to flexible arrangements that bring both advantages and risks. [2]

With the rise of artificial intelligence and digital platforms, the boundaries between standard and non-standard work are becoming blurred. The aim of this paper is to examine the development of non-standard employment in Croatia, analyse its causes and consequences, and highlight the psychological and social implications arising from contemporary labour market trends. [3]

2. THEORETICAL BACKGROUND

2.1. Historical and Legal Context of the Right to Work

The right to work is defined by the *Universal Declaration of Human Rights* (1948) and the *European Social Charter* (1961), and in Croatia it is guaranteed by the Constitution (Art. 55) and the Labour Act. [1][4][5] Historically, the industrial revolution created the basis for the protection of workers' rights, but globalisation and technological progress in the 20th and 21st centuries have caused fragmentation of the labour market. [6]

Beck argues that modern society has become a "risk society" in which individuals must adapt to unstable market conditions, while Standing describes the emergence of the *precariat*. [6][3]

2.2. Standard and Non-Standard Forms of Work

Standard employment is characterised by permanent contracts, full-time working hours, and social protection. In contrast, non-standard forms of work include temporary employment, part-time work, seasonal jobs, freelancing, outsourcing, and digital platform-based work. [2][3][8]

De Stefano highlights that platform-based employment redefines the employment relationship, as digital platforms (e.g., Uber, Wolt, Glovo) act as de facto employers without formal obligations. [8] Sennett stresses that such trends alter the worker's identity, as employment loses its stability and becomes a short-term survival mechanism. [7]

2.3. Artificial Intelligence and Digital Transformation of Work

Artificial intelligence (AI) accelerates automation and reshapes work organisation. According to the OECD, by 2030, 14% of jobs will be fully automated and an additional 30% will undergo substantial changes. [10] Castells notes that the digital network society creates new forms of work but simultaneously deepens inequality between the "digitally skilled" and the "labour periphery". [9]

3. METHODOLOGY

The research presented in this paper is based on a qualitative and quantitative analytical framework, combining descriptive, comparative, and interpretative methods to examine the phenomenon of non-standard forms of employment in Croatia within the broader European context. The methodological approach ensures both empirical accuracy and theoretical depth, enabling the integration of statistical data with socio-economic and psychological interpretations.

3.1. Research Objectives and Questions

The main objective was to identify and analyse trends in non-standard employment in Croatia between 2017 and 2022, with emphasis on socio-economic and psychological implications. The research sought to answer:

1. What structural trends define non-standard employment in Croatia?
2. How do these trends compare with EU labour patterns?
3. What socio-economic and psychological effects emerge from flexible and platform-based models?

3.2. Data Sources

The study uses secondary data from:

- *Croatian Employment Service (CES)* – employment and self-employment statistics;
- *Eurostat* – EU-27 labour market indicators;
- *Croatian Bureau of Statistics (CBS)* – sectoral employment data;
- *Eurofound* and *OECD* – data on remote and platform work.

Qualitative data include publications by Beck, Standing, Sennett, Kalleberg, Supiot, De Stefano, and Castells, alongside policy documents and national reports. [6][3][7][19][13][8][9]

3.3. Analytical Procedures

The descriptive method was used to illustrate structural evolution, while the comparative method enabled analysis between Croatia and the EU.

The interpretative approach connected statistical data with theoretical concepts such as the "risk society" and "precariat". Findings were synthesised into summary tables for clarity and temporal comparison.

3.4. Research Design and Limitations

The research employs a longitudinal comparative design, covering 2017–2022, capturing pre-pandemic and post-pandemic transformations. Due to limited data on platform work, multiple sources (Eurofound, CES, OECD) were triangulated for validity. Qualitative national studies, such as IDI (2021), were incorporated for contextual understanding. Limitations include partial statistical coverage and standardisation challenges; however, triangulated evidence ensures analytical reliability.

3.5. Ethical Considerations and Relevance

All data are publicly available and cited according to academic standards. The interdisciplinary methodology integrates economic, legal, and psychological perspectives, treating employment not only as an economic construct but as a social and human experience affecting well-being and identity.

4. RESULTS

The analysis reveals major structural changes in Croatia's labour market between 2017 and 2022, driven by digitalisation, platform work, and remote work expansion. [2][14][15]

Indicator	2017	2022	Change (%)	Source
Fixed-term employment	22.0	18.1	-3.9	Eurostat
Self-employment	10.4	12.0	+1.6	CES
Part-time employment	4.7	6.5	+1.8	CBS
Platform-based work (est.)	2.3	5.6	+3.3	Eurofound
Remote work (≥1 day per week)	9.1	28.7	+19.6	OECD

Table 1. Trends in Non-Standard Forms of Employment in Croatia, 2017–2022
Source: Author's compilation based on Eurostat, CES, CBS, and Eurofound (2017–2022).

A clear shift from traditional to flexible employment structures is evident. While unemployment declined, the quality of employment changed significantly. [14][15] The rise in self-employment and remote work reflects digital transformation, yet platform work exhibits rapid growth and precarious conditions. [2][20]

Sectoral data show concentration of flexible jobs in ICT, tourism, and logistics, while gender disparities persist – women occupy 58% of temporary and part-time roles. [20] Younger workers dominate platform-based labour, confirming trends toward labour precarity. [20]

Though flexible employment expands participation and opportunity, it also increases insecurity, weakens collective representation, and blurs work-life boundaries. The psychological impact includes stress, burnout, and digital fatigue, aligning with WHO and IDI findings that insecure jobs correlate with anxiety and reduced well-being. [11][16][22]

Overall, results highlight a dual dynamic: digitalisation enhances economic adaptability but generates psychosocial and legal challenges demanding systemic policy responses. [13][23]

5. DISCUSSION

The findings support previous research that labour flexibility promotes innovation yet can undermine social cohesion. [6][3] Bauman frames this as a symptom of "liquid modernity", where individuals face continuous adaptation. [12] Supiot warns of regulatory lag in protecting digital workers, while Harvey links neoliberalism with transferring risk from institutions to individuals. [13][17]

Psychologically, insecurity manifests as emotional exhaustion, especially in remote and gig workers exposed to algorithmic control. [21] For Croatia, this dynamic accentuates gender and generational divides and exposes the need for an integrated approach combining social policy, labour law, and mental health promotion. [20][22]

6. CONCLUSION

Non-standard forms of employment are now a permanent feature of the modern economy. While they expand flexibility, inclusiveness, and entrepreneurial opportunities, they simultaneously increase exposure to insecurity, income volatility, and stress. The future of work in Croatia must therefore rest on three key pillars:

1. Legislative reform – Modernising labour law to recognise platform and freelance workers as part of the social protection system.
2. Institutional adaptation – Strengthening active labour market policies, upskilling programs, and public support for digital literacy.
3. Psychosocial resilience – Implementing mental health strategies in workplaces and ensuring access to psychological support.

Artificial intelligence and automation should serve as instruments of empowerment, not exclusion. The pursuit of *decent work*—defined by stability, dignity, and mental well-being—must remain at the heart of policy-making and corporate governance. Ultimately, sustainable employment requires balancing flexibility and security while preserving the social and human dimension of labour. The future of work depends not only on technological innovation but on the ethical responsibility to ensure that progress benefits people as much as productivity.

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CRISIS MANAGEMENT, INNOVATION AND HUMAN RESOURCES AS THE FOUNDATIONS OF ORGANIZATIONAL RESILIENCE IN HOTEL ORGANIZATIONS

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ABSTRACT

Contemporary hotel enterprises must continuously adapt to global crises, economic instability, technological advancement, and social change. This stems from the growing recognition that organizational resilience is essential for long-term survival and competitiveness. Organizational resilience implies not only the ability to withstand upcoming crises but also the ability to learn from them, adapt, and evolve into a more innovative, stable, and adaptable organization. The aim of this paper is to examine the relationship between crisis management, innovation, and human resource development and to clarify how their synergy promotes the creation of more resilient hotel organizations. Crisis management is a methodical way of identifying, planning, responding to, and recovering from crises. For hotel management to manage a crisis well, it is necessary to plan in advance, anticipate, and respond promptly because it is capable of making quick decisions. However, the structure of crisis management alone is not enough; a hotel organization needs competent employees and their ability to generate new ideas. Innovations are a key way in which organizations adapt during crises. They help hotel organizations create more innovative offerings, services, and processes that meet new market conditions. A crisis often serves as a catalyst for innovation and a driving force for digital transformation and reconfiguration of business models. The most important factor in any hotel business is its employees. Their knowledge, experience, emotional strength, and motivation are extremely important for successful recovery and long-term stability. The difference between organizations that remain the same and those that emerge stronger from a crisis lies in how they manage their employees. They achieve this through continuous learning, skills development, idea sharing, and the cultivation of trust. Based on previous scientific research and published papers, it can be said that the combination of crisis management, innovation, and human resource development creates a framework that helps hotel enterprises cope with uncertainty, ensure business continuity, and gain a long-term advantage over competitors. Organizational resilience thus becomes a dynamic process of learning, change, and growth.

Keywords: *hotel organization, crisis management, innovation, human resources, organizational resilience*

1. INTRODUCTION

Hotel companies operate in a very unstable and changing environment where markets often change, global crises exist, consumer habits change, and technology advances rapidly. In recent years, especially after the COVID-19 pandemic, it has become clear that hotel systems are not stable financially or in the market, but also that management must be able to manage crises well, encourage new ideas, and find and retain good employees (according to Sučević, 2016; Jugo, 2017; Cerović, 2010). Organizational resilience means that an organization can notice, accept, and adapt to changes and continue to operate during and after a crisis, maintaining important functions and values. In the hotel industry, resilience means quickly changing the way of working, maintaining high service quality, and motivating employees (according to Čavlek et al., 2011; Kerum, 2025). Bahtijarević-Šiber (2014) claims that people are the main drivers of change and innovation in organizations.

Sikavica (2011) and Buble (2009) believe that a good organizational structure and leadership enable hotel organizations to respond quickly in times of crisis and after it. In hotel business, crisis management must be proactive and based on collaboration. Jugo (2017) emphasizes the necessity of crisis communication to protect reputation, while Sučević (2016) highlights the importance of preparation for crisis situations in business, readiness, and making quick decisions based on risk assessments. Innovation, which includes the development of new services, digital solutions, and sustainable business practices, enables hotel enterprises to maintain competitiveness and achieve long-term survival in the market (Kerum, Šipić, and Vuković, 2025; Garrido-Moreno et al., 2024). Hospitality is one of the most sensitive elements of tourism, so it is evident that it will be exposed to various types of crises. Cerović (2010) emphasizes the importance of managerial competencies in ensuring organizational stability, while McCloskey (1994) highlights the role of communication and a team approach as key factors in shaping economic and organizational decisions in hotel companies. In this context, fostering an organizational culture that encourages trust, creativity, and shared responsibility is crucial for resilience (Bahtijarević-Šiber, Sikavica & Pološki Vokić, 2008). This study aims to examine the interconnections between crisis management, innovation processes, and human resource development as key components of organizational resilience in hotel business. Managers need to keep up with new management trends that combine communication, corporate culture, and employee knowledge (Kerum, 2025), and their application in achieving sustainable and resilient hotel business.

2. THEORETICAL FRAMEWORK OF ORGANIZATIONAL RESILIENCE

Organizational resilience is a key concept in modern management, especially within service industries characterized by rapid market fluctuations and significant unpredictability. Resilience refers to the ability of a group to prepare for crises, respond effectively to them, and emerge from them stronger and more adaptable (Bahtijarević-Šiber, Sikavica, and Pološki Vokić, 2008). The commitment of management to maintaining consistent operational standards, providing high-quality service, and preserving guest trust, especially in challenging circumstances, demonstrates the resilience of the hotel industry (Cerović, 2010; Čavlek et al., 2011). Resilience is built through innovation, crisis management, and human resource development. Sučević (2016) emphasizes that crisis management must be a proactive, organized process that allows a business to react quickly and recover. According to Jugo (2017), communication is crucial for preserving reputation and public trust in times of crisis. On the other hand, Sikavica (2011) and Buble (2009) highlight the importance of leadership, coordination, and organizational structure that allows flexible decision-making, while Bahtijarević-Šiber (2014) claims that human resources are the main factor of organizational stability. Crisis management is one of the important components of resilience. Bahtijarević-Šiber, Sikavica, and Pološki Vokić (2008) claim that organizations that encourage employee innovation and creativity have improved adaptability to market changes. In the hotel industry, new ideas come in the form of digital solutions, personalized services, and environmentally friendly practices that make guests more satisfied and help hotels stay ahead of the competition (Kerum, Šipić, and Vuković, 2025; Garrido-Moreno, García-Morales, and Martín-Rojas, 2024). When management integrates new ideas into the culture of the organization, they create a system that constantly changes and learns from its mistakes. Hotel organizations rely heavily on their human resources. According to Bahtijarević-Šiber (2014), a culture of trust and cohesion is developed through employee development, which is encouraged by education, incentives, and active engagement. In doctoral research, Kerum (2025) confirms that the integration of internal marketing, organizational culture, and internal communication directly improves the quality of hotel service and resilience. Hotels can quickly adapt to changes and maintain their competitiveness over time through this type of managerial approach.

A study conducted by Rozkwitalska-Welenc, Borzyszkowski, Basińska, Okumus, and Karatepe (2024) shows that the ability to integrate information, technology, and human resources within sustainable business models serves as the main source of resilience in tourism and hospitality industries. The authors emphasize that a strong company culture and a shared set of values are key to navigating through challenging periods. Edeh, Islam, Nwali, Ugboego, and Nwokeiwu (2024) claim that organizational learning and staff flexibility are key factors of corporate resilience in developing economies. The development of human resources, innovation, and crisis management are integrated to establish a framework for organizational resilience. This allows hotels to use crises as opportunities for growth while ensuring their survival and further development. Therefore, resilience is not considered a fixed organizational characteristic but an evolving process that integrates leadership, knowledge, and experience. Hotel companies that follow this approach become more competitive, stable, and long-lasting (Kerum, 2025; Rozkwitalska-Welenc et al., 2024; Edeh et al., 2024).

3. CRISIS MANAGEMENT IN HOTEL ORGANIZATIONS

When a crisis occurs in a hotel that could threaten the safety of guests or workers, the reputation of the organization, or both, the staff takes steps to identify the problem, contain it, and mitigate its impact. According to Sučević (2016), effective crisis management relies on timely preparation, risk assessment, and decisions that enable quick reactions and recovery. Crisis management is a dual approach that strengthens the company and responds to potential threats. For Jugo (2017), a crisis is primarily a matter of communication within the hotel industry, as it directly affects guests' perception of service quality and their trust in it. Communicating with someone in an open, honest, and understandable way is crucial for maintaining hotel credibility in such circumstances. Buble (2009) and Sikavica (2011) believe that good crisis management requires emotionally stable staff who work as a team and are capable of making decisions in stressful circumstances. Bahtijarević-Šiber (2014) claims that participants are the most important element of any effective crisis response. When employees are trained, motivated, and well-informed, they behave more responsibly and help maintain business stability. According to the study by Kerum and Vuković (2021), it was found that Croatian hotels that implemented crisis communication strategies, digitalized their operations, and promoted teamwork among employees during the COVID-19 pandemic recovered faster and gained greater guest trust. Kerum and Vuković (2022) and Kerum, Vuković, and Hunjet (2021) emphasize the importance of timely addressing customer concerns and maintaining honesty to increase revenue and improve reputation. Effective and timely management is key to the recovery of hotel business from crises. According to McCloskey (1994), proper economic decision-making requires not only thorough logical analysis but also the ability to persuade, build trust, and maintain constant interaction with stakeholders. Kerum (2025) claims that hotels that nurture a culture of transparency, collaboration, and two-way communication are more likely to overcome challenges and improve employee satisfaction. Crisis management is not just something that happens when things go wrong; it is also an important part of the culture and strategy of the organization. When hotels invest in employee education, crisis training, and improving communication skills, crises become opportunities to strengthen the organizational community and professional development (Rozkwitalska-Welenc, Borzyszkowski, Basinska, Okumus & Karatepe, 2024). In this way, crisis management becomes one of the most important factors for the long-term success and survival of hotels.

4. INNOVATION AND ORGANIZATIONAL RESILIENCE IN HOSPITALITY

Innovations in the hotel industry are important for resilience because they help companies stay ahead of the competition, improve the quality of their services, and adapt to market changes. Hotels need to find new ways of doing business and solving problems if they want to survive in the long term.

This is because problems with the economy, employee turnover, and the environment are becoming more common. Bahtijarević-Šiber, Sikavica, and Pološki Vokić (2008) claim that innovations embody corporate culture and knowledge, while Buble (2009) emphasizes the key role of managers in encouraging employee participation in innovation processes. Kerum, Šipić, and Vuković (2025) claim that the integration of corporate culture, internal communication, and human resources is key to the innovative potential of Croatian hotel enterprises. The authors emphasize that hotels that regularly educate their staff and encourage creativity are more capable of adapting and recovering from catastrophic outcomes. Garrido-Moreno, García-Morales, and Martín-Rojas (2024) claim that an organization's operations should have a permanent orientation towards innovation, rather than serving as a temporary solution to problems. Dryglas, Lis, and Suder (2024) claim that hotel resilience stems from a combination of innovative capabilities, effective leadership, and socially responsible business practices. Their research shows that hotels that incorporate strategic planning, staff development, and sustainability achieve improved growth and increased resilience to market fluctuations. Ledi, Dumeda, Bandoma, and Ameza-Xemalordzo (2024) come to the same conclusion: strategic thinking and innovative ideas are key guidelines for hotel companies facing significant challenges. The authors emphasize that innovations go beyond new technologies as they involve transforming the mindset and behavior of hotel team members. Rozkwitalska-Welenc, Borzyszkowski, Basińska, Okumus, and Karatepe (2024) claim that innovations in tourism and hospitality arise from organizational resilience and the management's ability to learn from previous challenges. It is often said that innovations are not the ultimate goal as they serve as a means to improve the organization's readiness for future challenges. Research conducted in developing countries confirms that organizational learning and knowledge sharing among employees act as drivers of innovative behavior and resilience (Edeh, Islam, Nwali, Ugboego, and Nwokeiwu, 2024). For effective innovation management within hotels, managers must foster a culture of collaboration, transparency, and idea sharing. Employees can exchange ideas and take responsibility for improvement when internal communication, internal marketing, and organizational culture are effectively integrated. This approach enhances the overall organization, allowing it to learn, share information, and collaborate effectively when challenges arise. When employees are empowered, educated, and motivated, they become carriers of organizational resilience, and their commitment becomes the main source of stability, innovation, and long-term business sustainability.

5. HUMAN RESOURCE AS THE FOUNDATION OF ORGANIZATIONAL RESILIENCE

Employees are the most important part of any business. Service quality is directly related to how motivated, skilled, and connected employees are to the hotel organization. When it comes to assessing the strength of an organization, employees who implement plans are just as important as the organization's structure and strategy. Companies that use systematic human resource management are better able to deal with crises and know how to emerge stronger than before. According to Bahtijarević-Šiber (2014), sustainable management includes staff development, training, and decision-making. This approach enables the creation of a corporate culture that values cooperation, honesty, and openness to new ideas. Successful human resource management includes not only formal education and training, but also the systematic strengthening of employees' communication and emotional competencies, which is crucial in the hotel industry. Employee resilience is related to their emotional stability, ability to learn, and adapt. Xie, Zhu, and Chen (2023) found that the resilience of hotel employees directly affects their job satisfaction and therefore their intention to stay in the organization, and thus the quality of the service provided.

When hotel management encourages teamwork, a sense of purpose in each employee, trust in the organization, and mutual respect, employees develop greater commitment and willingness to face challenges. Such an organizational climate reduces staff turnover and strengthens internal team stability. Organizational culture plays a crucial role in strengthening resilience and innovation. Georgescu, Bocean, and Vărzaru (2024) argue that a culture based on trust, flexibility, and shared values creates an environment in which employees can freely express ideas and take responsibility. Ledi, Dumeda, Bandoma, and Ameza-Xemalordzo (2024) argue that strategic thinking and investing in employee competencies increase organizational resilience by enabling rapid adaptation to changes in the business environment. Research by Edeh, Islam, Nwali, Ugboego, and Nwokeiwu (2024) shows that organizational learning and knowledge exchange among employees act as drivers of resilience. Hotels that develop a system of continuous learning, teamwork, and experience sharing are more effective in responding to unforeseen circumstances and creating innovative solutions to crisis situations. Such practices contribute to the creation of collective resilience, due to the organization's ability to learn, adapt, and strengthen through the experience of its employees. Hotels manage their employees based on strategic planning, appropriate communication, and skill development. A hotel company can achieve competitiveness in the market if it has empowered, educated and motivated employees. Their responsibility towards their work and commitment to what they do is what keeps the organization strong, creative and capable of achieving continuity and long-term sustainability in business.

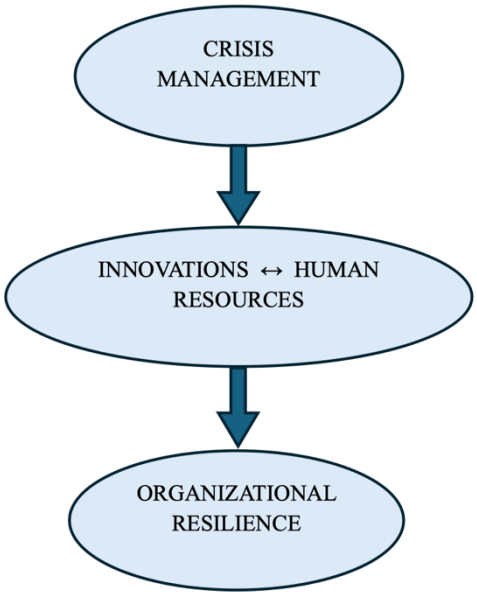
6. MODEL OF ORGANIZATIONAL RESILIENCE OF HOTEL ORGANIZATIONS

Based on a review of the relevant literature and an analysis of the connection between crisis management, innovation and human resources development, a conceptual model of the organizational resilience of hotel organizations can be formed. The model shows how resilience variables are linked and how a comprehensive plan can help hotel organizations weather uncertain market circumstances. Crisis management represents the starting point in the implementation of the organizational resilience model because it ensures the readiness of employees, facilitates mutual communication and allows them to react quickly in unforeseen circumstances. The role of crisis management is not only solving problems, but establishing prevention and learning with the aim of preventing crisis situations or adequately dealing with them. Planned crisis management creates the foundations for innovative thinking and flexible employee behavior. Innovations in the model act as mediators between crisis management and resilience. They make it possible to meet guests' needs by focusing on transforming challenges into opportunities, encouraging new ideas and enabling hotels to adapt their offer and service to market demands. Innovations include technological, organizational and marketing changes that arise as a response to experiences from the crisis. A successful hotel organization recognizes innovation as a continuous process, not as a one-time reaction.

Human resources represent the connected segment of this model because they enable the implementation of all plans and strategies. Through the development of competences, communication and a culture of cooperation, employees become the bearers of the organization's resilience. Their ability to learn, adapt and act collectively enables crisis situations to be turned into opportunities for learning and organizational development.

By integrating these three areas, a dynamic system is created in which crisis management ensures readiness, innovation drives adaptation, and human resources enable sustainability and development. The result of this process is organizational resilience, i.e. the hotel's ability to maintain itself, adapt and progress despite changes and crises.

Figure 1. Conceptual model of organizational resilience of a hotel organization



Source: Author's work

The model shows that resilience cannot be built in just one area. Successful hotel companies plan how to align crisis management, innovation and employee development. In this relationship, employees learn and adapt, and each new crisis is an opportunity for progress. This strategy suggests a modern understanding of resilience as a skill that changes over time and includes not only endurance but also organizational transformations through knowledge and experience.

7. CONCLUSION

The resilience of hotel organizations stems from their ability to simultaneously manage crises, foster innovation and develop human resources. In the modern tourism environment characterized by dynamic market changes, crises and growing guest demands, resilience becomes a key competency of every successful hotel. Crisis management, when implemented systematically and strategically, enables not only an effective response to unforeseen circumstances but also the creation of an organizational culture that learns from experience and prepares for future challenges. In this context, innovation acts as a bridge between crisis and adaptation. It turns uncertainty into an opportunity for growth and enables the creation of new value through digital transformation, sustainability and personalized services. The introduction of innovation requires an open organizational climate, a willingness to change and managerial leadership that encourages creativity. Through an innovative approach, hotels not only improve competitiveness but also strengthen the resilience of the entire system. Human resource is the fundamental strength that connects all aspects of resilience. Quality employee management, investment in their education and building trust allow hotels to turn crisis situations into opportunities for professional development and collective learning. Organizations that systematically develop the competencies of their employees create teams ready to cooperate, adapt and make decisions in conditions of uncertainty. The proposed model of organizational resilience for hotel organizations shows that crisis management, innovation and human resources are interconnected elements that make up a dynamic and self-sustaining system. Resilience is not built linearly but through continuous learning, knowledge exchange and adaptation to change.

This approach enables hotels not only to weather the storms, but also to use them to their advantage by strengthening their market position, improving interactions with guests and creating a more environmentally friendly business environment.To better understand the variations in resilience levels and identify the most important elements of success, future research should test this model in other hotel companies and locations. Rather than viewing resilience as a one-time strategy, hotel managers should view it as a continuous process that connects learning, creativity, and employee development. Such an approach allows hotel organizations to remain stable, competitive, and socially responsible in an environment of constant change and uncertainty.

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MEDIA CONSUMPTION AND SINGLE-SOURCE MEASUREMENT: LONGITUDINAL EVIDENCE FROM CROATIA

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ABSTRACT

This paper examines the transformation of media consumption in Croatia through the framework of single-source audience measurement. Using data from two national surveys conducted in 2019 (N=1,816) and 2023 (N=1,831), it provides a comparative, longitudinal analysis of media reach, information-seeking behavior, and cross-media engagement. Bivariate statistical tests (two-proportion z-tests) reveal significant shifts in audience habits over the five-year period. Internet and mobile media show the most substantial growth in reach (+12 and +11 percentage points), while television and radio display moderate declines (–3 to –4 pp). The Internet has become the dominant information source (+10 pp), replacing interpersonal channels and partially displacing television. Findings support the reinforcement hypothesis rather than substitution: audiences expand their overall media repertoire by combining traditional and digital platforms. Trust in media remains higher for traditional channels, but daily reliance has shifted decisively toward digital media. The study emphasizes the need for continuous, person-centered single-source measurement to capture convergent media use and guide future policy and advertising strategies in Croatia and similar small markets.

Keywords: *single-source measurement; media convergence; cross-media behavior; digital transformation; media reach; audience measurement; Croatia*

1. INTRODUCTION

The transformation of media consumption in the digital era has fundamentally reshaped how audiences interact with information.The convergence of traditional and digital media has altered both the technological and sociocultural landscape of communication, making it increasingly difficult to understand media behavior through single-platform measurement systems. In Croatia, as in most European markets, each medium is measured separately — television by Nielsen, radio and print by MEDIA puls, and digital media by Dotmetrics. While these systems provide valuable insights within their own domains, they are fragmented and lack integration, preventing a holistic understanding of audience behavior across media.The emergence of single-source audience measurement seeks to address this gap by integrating multiple types of media exposure and engagement from a single respondent base. This approach enables the simultaneous tracking of television, radio, print, and online usage, including overlaps, substitution patterns, and cross-media reinforcement.

The goal of this research is to present a comparative longitudinal analysis of media consumption and perception in Croatia, combining theoretical insights and empirical data from two survey waves, 2019 and 2023, and to illustrate the implications of the single-source model for understanding audience convergence in a small media market context.

2. THEORETICAL FRAMEWORK

2.1 Digital Transformation and Media Convergence

The concept of media convergence encompasses the technological, industrial, and cultural merging of communication channels. Digitalization has blurred the boundaries between previously distinct media systems, creating hybrid forms of content production and audience engagement. Television now extends to on-demand and streaming services; print journalism has migrated to online portals; and radio is consumed via mobile apps and smart devices. This transformation produces what Henry Jenkins (2006) termed participatory culture, where audiences are no longer passive consumers but active participants, curators, and distributors of content. In this converged environment, time and attention have become scarce resources, and audiences shift fluidly between screens and platforms, creating complex, multi-modal patterns of media behavior. From the perspective of audience research, this transformation challenges traditional definitions of "viewers," "readers," or "listeners." The boundaries between these categories have dissolved — contemporary audiences are users, who navigate across content and platforms in ways that defy the logic of linear measurement.

2.2 Uses and Gratifications Theory

The Uses and Gratifications (U&G) Theory provides a psychological foundation for understanding why individuals engage with multiple media. According to Katz, Blumler, and Gurevitch (1973), media use is goal-oriented, and audiences choose media that best satisfy their personal needs informational, entertainment, social, or escapist.

2.3 Media Dependency and Trust

Media Dependency Theory (Ball-Rokeach & DeFleur, 1976) suggests that the more an individual depends on media to achieve certain goals, the greater the media's influence. However, in the era of fragmented communication, this dependency is distributed across multiple platforms. A key dimension of this dependency is trust. As audiences are exposed to a flood of information from diverse sources, credibility has become a crucial determinant of media choice.

2.4 Engagement and Cross-Media Experience

The Engagement Theory (Van Doorn et al., 2010) expands this understanding by linking emotional and cognitive involvement with behavioral loyalty. Engagement is not limited to exposure. It encompasses attention, motivation, and emotional resonance. Cross-media engagement occurs when audiences interact with content across platforms, such as watching a TV show while following its discussion on social media. In this sense, engagement represents the dynamic process that binds users to brands, programs, or topics across multiple touchpoints. Single-source data are essential for capturing this complexity because they allow researchers to measure engagement in integrated, person-centered ways.

2.5 The Single-Source Measurement Approach

Single-source audience measurement emerged as a methodological response to the fragmentation of audience data. It combines behavioral data (viewing, reading, listening, clicking) across platforms for the same individuals.

This approach provides several benefits: it eliminates duplication in audience estimates, reveals patterns of cross-media reinforcement (e.g., how TV and digital campaigns complement each other), allows trend analysis across time, as in the Croatian case, comparing 2019 and 2023. In Croatia, the implementation of such a system remains in early stages. Yet the growing need for integrated planning and cross-platform advertising effectiveness makes the single-source model not only desirable but necessary for the transparency and accuracy of media measurement.

3. METHODOLOGY

The study integrates data from two national research waves on media usage and attitudes in Croatia, conducted in 2019 and 2023. Both datasets derive from the VAL (Value of Advertising and Media) research initiative, conducted by leading Croatian market research agencies. The surveys use a stratified random sampling method, representative of the Croatian adult population by region, gender, and age group. Sample sizes are comparable across both waves (N_1 = 1,816; N_2 = 1,831), allowing reliable statistical comparison.

3.1 Data Collection and Variables

The questionnaire covers multiple thematic blocks, including media usage frequency and duration (television, radio, print, Internet, YouTube, social media, cinema, outdoor), information-seeking behavior (primary channel used to find information), media trust and credibility perceptions and cross-media consumption and device usage patterns. For the purposes of this study, two core indicators were extracted and analyzed longitudinally: primary information source, the channel respondents most frequently use to obtain information and potential reach, the proportion of the population reached by each medium within a reference period.

3.2 Analytical Procedure

A bivariate analysis was conducted to compare percentage differences between 2019 and 2023 for each category.The statistical test applied is the two-proportion z-test, equivalent to the chi-square test for two independent samples. Results are reported as difference in percentage points between 2023 and 2019, standardized test statistic and p-value, probability of observing the difference under the null hypothesis of no change. The significance threshold is set at $p < .05$.

4. RESULTS

This section presents the empirical findings of the study, based on comparative analysis of the 2019 and 2023 survey waves. The results are organized into thematic subsections addressing information-seeking behavior, media reach, and cross-media engagement, providing an integrated view of evolving audience patterns in Croatia.

4.1 Information-Seeking Behavior

The first subsection focuses on information-seeking behavior and identifies shifts in the primary channels through which Croatian audiences access news and information. *Table 1* displays the comparative distribution of these channels between 2019 and 2023.

Channel	2019 (%)	2023 (%)	Δ (pp)	z	p-value
Internet	71.36	81.43	+10.07	7.16	< .001
Television	11.80	9.68	–2.12	–2.07	.039
Radio	1.17	1.47	+0.30	0.84	.399
Print	1.05	1.92	+0.87	2.16	.031
Friends/family	13.46	5.17	–8.29	–8.58	< .001
Other	3.96	1.86	–2.10	–3.79	< .001
No answer	0.23	1.48	+1.25	4.13	< .001

Table 1: Changes in the primary channel used to find information between 2019 and 2023 (Source: Author's analysis based on Brandpuls data)

Figure 1 visually complements these results, illustrating the consolidation of the Internet as the dominant source of information and the corresponding decline of interpersonal and traditional communication channels.

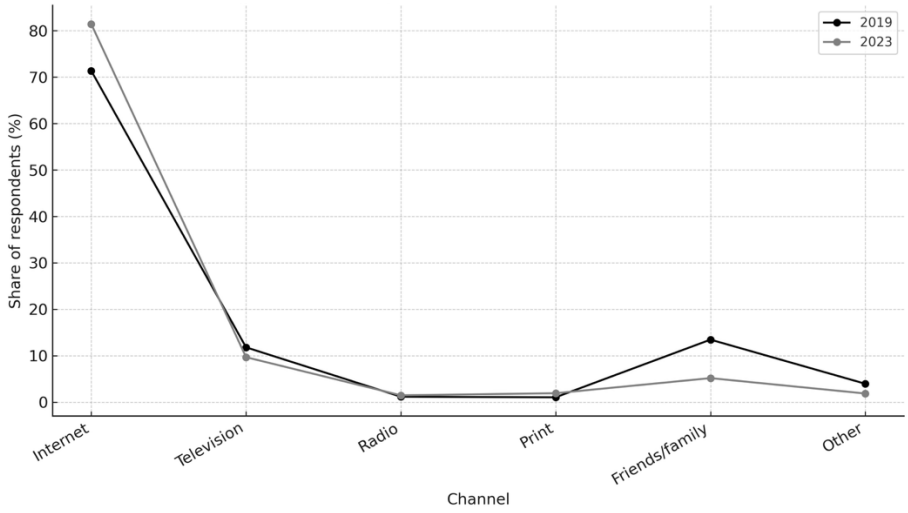

Figure 1: Comparison of primary information sources in Croatia between 2019 and 2023 (Source: Author's analysis based on Brandpuls data)

The Internet has solidified its role as the dominant channel for information retrieval, growing by more than 10 percentage points in five years. Television's role has decreased slightly but remains relevant as a secondary channel. A significant decline is observed in interpersonal information exchange (–8.3 pp), suggesting that individuals increasingly rely on digital search and media platforms instead of social networks in the traditional sense as shown in *Table 1.* and *Figure 1.*

4.2 Potential Reach of Media Channels

The second subsection examines the potential reach of major media channels, comparing audience exposure across traditional and digital platforms. *Table 2* summarizes the longitudinal changes in media reach between 2019 and 2023, together with statistical indicators of significance.

Medium	2019 (%)	2023 (%)	Δ (pp)	z	p-value
Internet	84.22	96.29	+12.08	12.32	< .001
Mobile Internet	82.00	92.96	+10.95	10.01	< .001
YouTube	79.47	89.69	+10.22	8.55	< .001
Magazines	51.66	64.97	+13.30	8.17	< .001
Television	92.92	89.61	–3.31	–3.50	< .001
Radio	77.86	73.91	–3.95	–2.80	.005
Cinema	70.01	78.98	+8.96	6.22	< .001
Outdoor (OOH)	81.30	80.13	–1.16	–0.89	.376

Table 2: Comparative reach of major media channels in Croatia between 2019 and 2023 (Source: Author's calculation based on Brandpuls data)

Figure 2 provides a graphical overview of these results, emphasizing the steady expansion of digital media reach and the moderate contraction of traditional mass media, particularly television and radio.

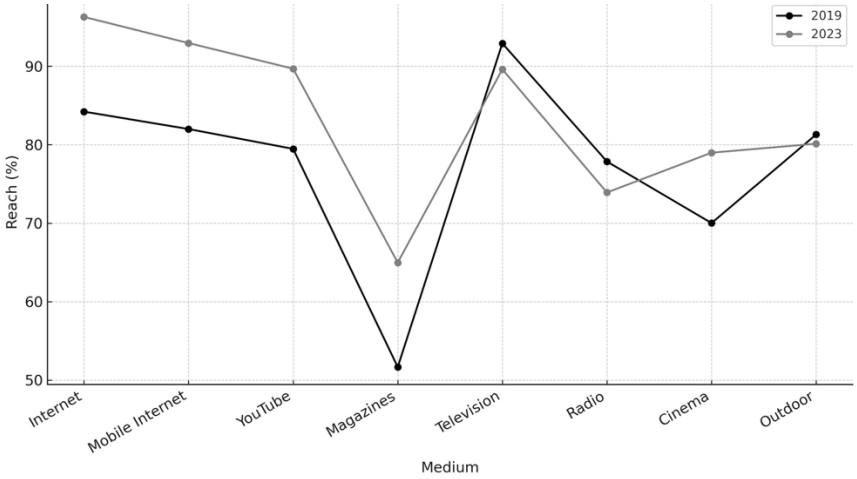

Figure 2: Potential media reach by mediumin Croatia between 2019 and 2023
(Source: Author's analysis based on Brandpuls data)

The reach of digital channels (Internet, YouTube, and mobile Internet) has grown significantly, while traditional mass media show slight declines. Television remains the broadest-reaching medium in absolute terms (nearly 90%), but its relative dominance has eroded. Radio displays modest decline, reflecting generational shifts and increased streaming use. Cinema and magazines show notable increases, suggesting partial revival of traditional and experiential media through digital synergy as shown in *Table 2.* and *Figure 2.*

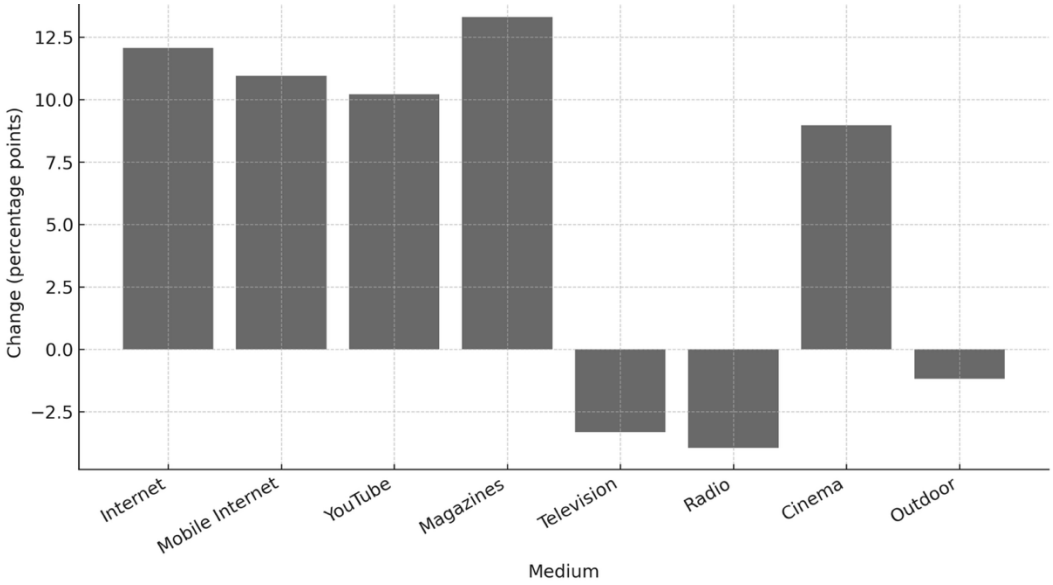

Figure 3: Five-year change in potential media reach
(difference in pp, between 2019 and 2023)
(Source: Author's analysis based on Brandpuls data)

As depicted in *Figure 3*, the overall trend confirms a continued shift toward digital media consumption, accompanied by the relative stabilization of traditional channels. This pattern reflects the broader dynamics of media convergence observed in the Croatian market over the past five years.

4.3 Trust and Perception (Qualitative Summary)

Although detailed quantitative trust data are unavailable in identical format across both waves, qualitative summaries indicate consistent trends: trust decline across all media types, especially digital platforms; television remains the most trusted medium, followed by radio; social media and online portals are perceived as least credible. These findings align with previous Croatian and European studies (Ham et al., 2020; EBU, 2023) indicating that while consumption migrates online, credibility remains anchored in traditional media institutions.

4.4 Cross-Media Behavior

The data support the notion of media reinforcement rather than substitution. Daily simultaneous use of Internet and television increased by approximately 8 percentage points, while radio and print maintain smaller yet stable overlaps with digital channels. This pattern highlights audience multitasking, the tendency to consume multiple media concurrently rather than sequentially, an essential feature of convergent media environments.

5. DISCUSSION

The comparative results between 2019 and 2023 clearly demonstrate the continuing digitalization and convergence of Croatian media consumption. The most striking finding is the growth in Internet and mobile usage as the dominant modes of media access. This transformation is consistent with European media trends, yet it has specific local characteristics: Croatian audiences continue to show loyalty to television, particularly for national and live content. Radio and print retain relevance among older segments, driven by habitual and trust-related factors. The Internet and YouTube serve as central hubs for younger audiences, where entertainment, social interaction, and information blend seamlessly. These results reinforce the reinforcement hypothesis: digital media expand the overall media ecosystem rather than displacing traditional channels. This aligns with the argument of Enoch and Johnson (2010), who showed that cross-media users tend to consume more total media time, not less. From the perspective of Uses and Gratifications, these findings confirm that media are used to satisfy distinct but complementary needs immediacy and convenience through digital, credibility and shared experience through traditional channels. Meanwhile, Media Dependency Theory explains the diversification of dependency: audiences no longer depend on one dominant source but distribute attention across multiple platforms according to context and content type. At the same time, the trust deficit remains a critical challenge. As audiences migrate to digital channels, they increasingly face misinformation, algorithmic bias, and reduced editorial oversight. While consumption has shifted online, trust continues to be rooted in legacy media, a paradox that underscores the complexity of media literacy and public communication in transitional markets.

6. IMPLICATIONS FOR MEDIA PRACTICE AND POLICY

The results have multiple implications for stakeholders in the Croatian and broader regional media markets:

For Advertisers and Agencies

Integrated planning must be based on cross-platform audience measurement, enabling consistent frequency management and campaign optimization.

The reinforcement of traditional and digital media underscores the value of hybrid strategies, combining reach (TV/radio) with engagement (online/video).

For Publishers and Broadcasters
Media houses should leverage their brand trust to strengthen digital presence. Cross-media storytelling and platform synchronization (e.g., social media extensions of TV formats) can increase engagement and monetization opportunities. Investment in first-party data collection will become vital under privacy regulations (GDPR) and the decline of third-party cookies.

For Policy and Research
The Croatian market lacks an official single-source audience measurement framework.The implementation of such a system would improve transparency in advertising valuation, ensure methodological comparability across media, and malign Croatia with international standards (e.g., UK BARB, Dutch NMO). Public institutions should therefore prioritize developing a national, multi-platform audience measurement model that captures cross-media reach, duplication, and engagement.

7. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

While this study provides valuable insights into longitudinal audience behavior, it has several limitations: self-reported data may introduce recall bias and social desirability effects, the structure of the survey differs slightly between waves, constraining comparability for certain indicators (e.g., media trust). The analysis is limited to bivariate proportions; more advanced techniques (e.g., logistic regression or time-series modeling) could explore causal relationships and predictive trends. Future research should integrate passive measurement technologies (e.g., digital meters, cookies, app tracking) with traditional surveys to build a unified database of real-time media behavior. Such integration would enable Croatia to participate in the emerging global trend of total audience measurement, a unified framework for understanding audiences holistically across all screens and devices.

8. CONCLUSION

The longitudinal comparison of Croatian media consumption between 2019 and 2023 reveals a rapidly digitalizing yet persistently convergent media ecosystem. The Internet has become the central channel for information seeking (+10 pp), while traditional media such as television and radio maintain stabilized but declining reach. YouTube, mobile Internet, and online video platforms are expanding their dominance, particularly among younger audiences. Rather than replacing traditional media, digital platforms have expanded the media repertoire, allowing users to multitask, interact, and personalize their experience.This confirms the reinforcement model of media consumption and emphasizes the continued social and emotional role of traditional channels. In the Croatian context, these results underline the urgent need for integrated single-source measurement systems, capable of accurately tracking cross-platform usage and audience overlaps. Such systems are essential for evidence-based media policy, advertising efficiency, and the preservation of pluralism in a rapidly evolving communication landscape.

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DIGITAL TRANSFORMATION IN THE MARITIME INDUSTRY

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ABSTRACT

Digitalization and emerging developments in the domains of artificial intelligence, blockchain, the Internet of Things, and automation are assuming increasing relevance within the maritime industry. These advancements facilitate the simplification of extant processes, the generation of novel business opportunities, and the reconfiguration of supply chains alongside trade geographies. Notwithstanding the substantial potential, opportunities, and benefits proffered by these technologies, they concomitantly entail risks and prospective costs for maritime stakeholders in developing nations. Consequently, the establishment of equitable conditions is imperative. This paper elucidates the pivotal role of global digital standards, the exigency of fostering technological innovations while averting monopolistic ramifications, and the imperative to align digitalization with the objectives of sustainable development.

Keywords*: digitalization, digital transformation, intersectoral strategy*

1. INTRODUCTION

The management of vessels across all size categories is progressively mediated through digital technologies. Retrospective examination of such technologies reveals that merely 50 years ago, they were regarded exclusively as experimental. Contemporaneously, digital systems underpin the governance of the largest vessels. Data analytics and intelligent processing ameliorate executive functions. Maritime enterprises can thereby discern augmented insights pertaining to their fleets. Maritime communications engendered paradigmatic shifts midway through the twentieth century; however, the contemporary influx of data into administrative offices and shipyards frequently surpasses the situational awareness of onboard personnel. Intelligent maritime transport amalgamates digital technologies into operational paradigms to optimize performance metrics, attenuate expenditures, and augment safety protocols. Several catalysts propel digital transformation within the maritime sector:

- **Global trade imperatives:** The maritime industry constitutes the cornerstone of international commerce, with over 80% of global merchandise transported via sea routes. As trade volumes escalate, exigencies for enhanced efficiency and sustainability intensify correspondingly.
- **Regulatory imperatives:** Mandates from the International Maritime Organization (IMO), such as the 2020 sulfur emission caps and decarbonization targets for 2030 and 2050, compel cleaner and more efficacious maritime practices.
- **Technological advancements:** Expeditious progress in domains including the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain furnishes unprecedented avenues for elevating operational efficacy and curtailing costs.
- **Stakeholder expectations:** Contemporary clientele demand expeditious, translucent, and dependable delivery modalities, thereby impelling the maritime sector to assimilate digital solutions in fulfillment thereof.

Ports serve as pivotal nodes within the maritime supply chain, wherein their operational efficacy exerts direct influence upon overarching logistical performance. While the salubrious ramifications of digital transformation in the maritime industry are manifest, myriad challenges and impediments necessitate resolution.

- **Substantial inaugural investments:** The pecuniary outlays attendant to digital technology deployment are formidable, encompassing acquisitions of novel hardware and software, alongside personnel capacitation for proficient utilization.
- **Cybersecurity vulnerabilities:** Augmented dependence upon digital apparatuses renders the maritime sector susceptible to cyber incursions. The promulgation of resilient cybersecurity protocols is indispensable for safeguarding proprietary data and preserving operational coherence.
- **Amalgamation with obsolescent systems:** A preponderance of maritime entities persist in reliance upon antiquated infrastructures and protocols. The assimilation of emergent digital paradigms with such legacies engenders complexity and protracted timelines.
- **Regulatory conformance:** Vigilance over proliferating statutes and accreditation exigencies poses formidable hurdles. Digital transformation endeavors must harmonize with extant and prospective regulatory frameworks to obviate juridical and fiscal sanctions.
- **Proficiency deficits:** The maritime domain confronts a paucity of adept practitioners versed in avant-garde digital modalities. Strategic investments in pedagogical and developmental initiatives are paramount to surmounting this lacuna and harnessing the plenitude of digital transformation's dividends.

Upon ingress and egress from ports, indispensable intelligence must be disseminated among sundry terrestrial entities. Port administrations, navigational pilots, maritime regulatory bodies, and sanitary authorities require particulars concerning vessel specifications, cargoes, hazardous materials, crew complements, passengers, inter alia, predicated upon imperatives of security, safeguarding, and ecological stewardship. The modality of such intelligence dissemination is germane. Digitalization emerges as instrumental, not solely in error mitigation but also in elevating the caliber of exchanged intelligence. Commencing in 2019, the IMO has mandated electronic interchange of data germane to customs clearance for vessels, cargoes, and personnel among declarants—including masters, agents, and proprietors—and port authorities. Effective January 1, 2024, the institution of a singular window is obligatory across all ports. Via the maritime single window, data are tendered through a unitary portal sans redundancy, thence apportioned to pertinent authorities.

Digital transformation is inaugurating a revolution within the maritime industry, tendering profound boons in efficiency, security, and sustainability. Notwithstanding extant challenges, the sector persists in confronting these exigencies to embrace a digitized trajectory. As technological evolution persists, the maritime industry shall burgeon in interconnectivity, automation, and resilience, thereby charting a course for perennial expansion and ingenuity in forthcoming epochs. The transposition to a digitalized inspectorial regimen aspires to consummate seamless coalescence with preexistent maritime data architectures. This engenders interoperability and efficacious data reciprocity among constituencies. Such normalization cultivates an augmented, collaborative ethos vis-à-vis international maritime security and adherence.

2. INTERSECTORAL STRATEGY

The intersectoral strategy subsumes sundry facets of the IMO's endeavors, fomenting a wholly interlinked, consonant, and automated global maritime milieu. To shepherd this trajectory, the Facilitation Committee has instituted a Correspondence Group tasked with delineating the strategy's ambit, cardinal objectives, and implementational scaffold. Over the ensuing annum, the Group shall assay extant and nascent technologies, norms, and methodologies conducive to maritime digitalization, whilst ensuring consonance across disparate IMO committees. The IMO's maritime digitalization strategy constitutes a revolutionary endeavor toward fluid, unencumbered, and perspicacious navigation. It shall facilitate vessel-port integration, logistical refinement, and itinerary optimization, concomitant with attenuation of greenhouse gas effluvia. Collaborative imperatives dictate that the strategy redound to universal benefit (*The International Maritime Organization is a specialized United Nations agency charged with maritime transport safety and security, alongside prophylaxis against marine and atmospheric pollution from shipping. IMO's labors buttress the United Nations Sustainable Development Goals).*

3. REALIZING DIGITAL TRANSFORMATION

During its convocation in London from March 10 to 14, the IMO's Facilitation Committee (FAL) formulated an operational schema for the elaboration of the IMO's Maritime Digitalization Strategy, slated for adoption by the Organization's paramount administrative organ—the IMO Assembly—by terminus 2027.[2] This intersectoral strategy shall encompass multifarious IMO operational spheres, engendering a fully interlinked, consonant, and automated global maritime sector. To helm this procession, the Facilitation Committee has convened a Correspondence Group for circumscription of the strategy's scope, principal aims, and executory framework. Over the proximate annum, the Group shall identify extant and emergent technologies, standards, and methodologies supportive of maritime digitalization, whilst safeguarding inter-committee consonance, and tender a report for perusal at the succeeding Facilitation Committee session (FAL 50) – (*The Facilitation Committee convened at IMO headquarters in London for its 49th session /FAL 49/ from March 10 to 14 /hybrid modality/. Presided by Mr. Watchara Chiemanukulkit /Thailand/, with Mr. Mohamed AlKaabi /United Arab Emirates/ as vice-chair).*

“The IMO's maritime digitalization strategy represents a revolutionary pursuit of seamless, frictionless, and astute navigation. It shall abet vessel-port amalgamation, logistical amelioration, and navigational optimization, whilst mitigating greenhouse gas emissions. Collaboration is sine qua non to ensuring the strategy's equitable service to all.” The International Maritime Organization (IMO) is inaugurating measures toward a holistic strategy harnessing emergent technologies to exalt efficiency, security, and sustainability within the shipping domain.

4. DEVELOPMENTAL CONCEPT AND DIGITALIZATION INITIATIVES

This strategy accretes upon antecedent milestones, inclusive of the antecedent annum's mandatory stipulations for the Single Maritime Window (MSW), mandating vessels and ports to employ a unitary digital platform for informational reciprocity and port-admission procedural simplification. At the 49th Facilitation Committee session, sundry cardinal digital initiatives advanced, inter alia:

- **Revised IMO Compendium on Facilitation and Electronic Business:** Sanctioned is a novel iteration incorporating supplementary data ensembles to enhance standardization and interoperability across maritime informatics systems.

- **Augmented Guidelines for the Single Maritime Interface (MSW):** Approved emendations and adjuncts to establishment guidelines, inaugurating verificatory functionalities, attenuating manual administrative encumbrances, and excising superfluous validations by disparate entities.
- **Cybersecurity for the Single Maritime Window:** Instituted is a novel deliverable for cybersecurity measure elaboration, safeguarding digital maritime operations against incursions.
- **Guidelines for Electronic Certificates:** Conjoint FAL-LEG-MEPC-MSC directives on electronic certificates have been ratified and remitted for concurrent approbation by IMO's Marine Environment Protection Committee, Maritime Safety Committee, and Legal Committee.

5. EXPOSITION OF IMO'S MARITIME DIGITALIZATION STRATEGIES: OPERATIONAL SCHEMA

The IMO Committee has ratified an operational schema for the confection of an indigenous, comprehensive maritime digitalization strategy, oriented toward leveraging nascent technologies to augment efficiency, security, and sustainability in shipping. This intersectoral stratagem shall subsume diverse IMO operational domains and anticipates adoption by the IMO Assembly by close of 2027, at its 35th convocation. The Committee has empaneled a Correspondence Group to prosecute delineation of the strategy's purview, paramount objectives, and implementational armature. Over the impendent annum, the Group shall assay extant and emergent technologies, norms, and methodologies propitious to maritime digitalization, whilst ensuring committee-wide consonance, tendering a report for deliberation at Facilitation Committee session FAL 50. To secure precocious stakeholder enlistment in strategy conformation, the Marine Environment Protection Committee (MEPC) and Maritime Safety Committee (MSC) are exhorted to galvanize member states and international organizations toward Correspondence Group affiliation. The Committee concurred that strategy elaboration pivots upon multifarious inputs from member states and international organizations, encompassing security and environmental salients.

6. DIGITAL TRANSFORMATION AND MARITIME METAMORPHOSES

Digitalization within the shipping industry has transmuted paradigms of security and prophylaxis. Assimilation of digital technologies into enterprise architectures facilitates risk appraisal, preparedness, and responsiveness. Electronic navigational apparatuses—such as GPS and the Electronic Chart Display and Information System (ECDIS)—furnish real-time locational and orientational intelligence, abetting itinerary contrivance whilst forestalling exigencies and retardations. Automatic Identification Systems (AIS) and Very High Frequency (VHF) radio buttress this via interlocutory conduits betwixt vessels and littoral operatives. Such apparatuses expedite incident remediation and operational perpetuity. Inaugurations including digital simulacra and prognosticative maintenance modalities further undergird vessel security and functionality. Digital simulacra constitute virtual replicas of corporeal entities or processes, instrumental in apparatus surveillance, performance chronometry, and preemptive sustentation antecedent to anomaly manifestation. Leveraging such, enterprises can refine vessel kinetics, attenuate unanticipated cessations and sustentative outlays, culminating in secure, dependable logistical matrices - prognosticative maintenance harnesses data analytics and IoT sensoria for perpetual apparatus condition chronometry. Data assayment identifies and redresses latent anomalies antecedent to derangement, attenuating quiescence and sustentative fiscal burdens. This methodology elongates apparatus longevity.

Digital technology assimilation concomitantly proffers data prophylaxis prioritization and security augmentation. Stalwart cybersecurity protocols—including firewalls, data cryptograph, multifactor authentication, and audit regimes—insulate against cybernetic menaces, whilst edifying brand fiduciary and client certitude. Automation and robotic deployments have likewise exalted operational quotient. Shipping automation informatics streamline modalities such as container manipulation, inventory stewardship, vessel chronometry, and berthage systems. Ergo, enterprises evince accelerated, prolific, and emulous market postures. Automated and robotic paradigms attenuate laborative, errative, and inefficacious vectors, assuring robust vessel governance with optimized fiscal and resursive apportionments. Within maritime carriage, itinerary optimization yields profound ecological boons: efficacious routing attenuates combustible depletion, effluvia, and carbonic imprints. Conjoined with celerity refinement and data-derived environmental perspicuities (e.g., meteorology, currents, zephyrs), enterprises palliate ecological incidences whilst maximizing operational yields. Digitalization within maritime and shipping milieus is pivotal to contemporaneous commerce. Electronic consignment modalities, instantaneous chronometry, automation, and robotics edify translucent interrelations, tender dependable and secure consignments, and facilitate perspicacious arbitrations predicated upon veracious intelligence.

7. IMPEDIMENTS TO DIGITALIZATION IN MARITIME CARRIAGE

Maritime carriage and the industry writ large have yet to attain the 52% acceleration in AI adoption schemas responsive to the pandemic. This lacuna stems not from antiquarianism—contrary to external detractors—but from the sector's perduring innovativeness, among the world's preeminent. Three principal impediments currently circumscribe AI assimilation, forestalling exploitation of its prodigious yields in efficiency, prolificacy, and revenue augmentation:

Data accession: AI predicates upon data; aggregation and assayment persist as cardinal barriers. Decennially, vessel data—evolving from narrations to sensoria—have accrued, yet holistic comprehension eludes. The crux resides not in procurement but in real-time analyticity furnishing decisional affordances. Sundry systems evince incommunicability or contextual penury, obfuscating praxis.

Vessel-littoral intercourse: Vessel kinetics evince escalated intricacy. As naval architects fabricate augmented "mega-vessels"—eclipsing quinquagenarian capacities—crews stagnate or contract amid amplified fiduciary. Diurnal operations transpire in labyrinthine, industrial ambits, manipulating ponderous mechanica, executing reparations and sustentation, and contriving navigation—aloof from terrestrial succor. To optimize AI investitures, universal data accession among constituencies is requisite; dissociated analytics vitiate collaborative decisional praxis.

Maritime exigencies mandate augmented vessel-littoral synergy, enabling synchronous informational accession and collaborative amelioration. Augmented visibility and translucency exalt performance, tendering augmented client value and operational facility.

8. WORKFORCE GOVERNANCE AND CAPACITATION OPTIMIZATION

This facilitates operators in judicious crew apportionment and centralized digital certification repositories upon technologically sophisticated workforce governance platforms. Automated advisories ensure regulatory consonance. Virtual reality (VR) and augmented reality (AR) modalities engender immersive, hazardless experiential capacitation. Such encounters with neoteric technologies inaugurate proficiency exaltation conduits.

The salience of human resourcing elaboration within the maritime sector—attendant to its labyrinthine, altitudinous-risk complexion—defies hyperbole. Maritime human resourcing elaboration subsumes a panoply of preparative and developmental operations cultivating superlative, pliant personnel. Constitutive activities encompass training, pedagogy, competency valuation, and career trajectorying. Within a domain wherein security, consonance, and efficiency paramountize, seafarer and terrestrial personnel expertise and eudaimonia constitute fulcrums. The salience of human resourcing elaboration within the maritime sector—attendant to its labyrinthine, altitudinous-risk complexion—defies hyperbole. Maritime human resourcing elaboration subsumes a panoply of preparative and developmental operations cultivating superlative, pliant personnel. Constitutive activities encompass training, pedagogy, competency valuation, and career trajectorying (Khang et al.). Maritime Resource Management (MRM) denotes efficacious coordination and mobilization of operational constituents—including human resourcing, technics, apparatus, and ambient factors. MRM's telos resides in operational quotient exaltation, security buttressing, and global regulatory consonance, per IMO stipulations. MRM accentuates navigational prophylaxis, workforce challenge governance, combustible optimization, and ecological attenuation, assuring untrammeled, sustainable kinetics (*Pass, S., & Ridgway, M. (2022). / Piwowar-Sulej, K. (2021.) / Khang, A., Jadhav, B., & Birajdar, S. (2023.).*

9. CONCLUDING REFLECTIONS

Ultimately, neoteric technologies exact exactions—fiscal in novel hardware/software installations, and human-capital in acclimation. "Digital transformation" connotes plenary maritime operational revision toward digital oriens. Yet, AI assimilation ought attenuate, not transmute, extant praxis. Technological investitures necessitate quotidian utility perspicuity and informational requisites for fleet governance. Ergo, interrogatives obtain:

- Are routine sustentations intercalated appropriately?
- What temporal quantum attends vessel circumvolution in specified ports?
- Which fleet constituents evince superlative efficacy, and whence their distinction?

Answering such—even amid optimal technics—exigencies neoteric proficiency capacitation, including data analytics. The maritime sector shall metamorphose across proximate decades, impelled by technologic application, climatic vicissitudes, and geopolitico-macroeconomic intensifications. Global maritime tendencies redress exigencies for robust transformational drivers. A holistic assault upon labyrinthine maritime conundrums yields perspicuous, data-anchored visibilities of impendence. Comprehensive analytic propulsion founds futuric maritime scenaria, abetting directorial and policy decisional perspicacity (*Global Maritime Trends 2050* Report by Economist Impact).*

Instantaneous chronometry apparatuses tender perpetual vessel locational, cargo status, and itinerarial visibilities. Such empowers expeditious, perspicacious arbitrations, retardance evasion, and combustible economization. Instantaneous chronometry augments client satiety via veracious consignment advisories, exalting translucency and fiduciary. It likewise palliates port congestion via optimized ingress/egress coordination.

Notwithstanding digital transformation's prodigious latency within maritime milieus, consummation exigencies impediment circumscription. A salient impediment resides in data security trepidation. Digitalization assimilation elevates cybernetic threat prophylaxis for proprietary intelligence. Maritime entities must invest in stalwart cybersecurity—including firewalls, cryptograph, access regimentation, and periodic audits—to insulate data. Crew resistive vectors to mutation constitute another. Traditional manual praxis habitués may demur neoteric assimilation. Countervailing stratagems encompass communicative efficacy, holistic

capacitation regimes, and incentivizing mechanisms to foment participatory and innovatory cultures. Chronometry shall engender ameliorated decisional praxis and prognosticative sustentation, exalting operational dependability and security. Autonomous vessels: Developmental and implementational momentum for autonomous vessels shall accrue, portending human errancy and operational fiscal attenuation. Equipped with avant-garde navigational apparatuses and sensoria, such vessels shall kineticize with minimal anthropic intercession, inaugurating maritime operational revolutions.

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Contributions in Croatian

THE ROLE OF NAUTICAL PORT DEVELOPMENT IN SHAPING DESTINATION SUSTAINABILITY: A LOCAL COMMUNITY PERSPECTIVE

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ABSTRACT

Seaports are an important factor in the socio-economic development of coastal tourism areas. Planning the construction of new ports entails various positive and negative effects in the context of sustainable tourism development and the local economy, the community's quality of life, and the preservation of the natural environment. The growth of tourist traffic in coastal destinations—reflected in the increasing number of vessels, boaters, and transit passengers, as well as the expansion of complementary nautical-tourism services—affects the frequency of traffic congestion, passenger dissatisfaction, and a decline in the quality of life of local residents. By constructing new ports, tourist destinations establish the prerequisites for sustainable socio-economic development and for the long-term enhancement of competitiveness and resilience. At the same time, the development of complex maritime infrastructure can disrupt the marine environment and threaten natural resources. Therefore, the aim of this paper is to investigate residents' perceptions of the economic, social, and environmental effects of seaport construction in a nautical tourism destination. The study was conducted through an online survey on a sample of residents and non-residents of the city of Omiš (Croatia). Statistical analysis of the collected data was carried out using SPSS. The results indicate a relationship between respondents' level of awareness of the port construction project and their attitudes toward the importance of the port's development, as well as their views on its effects on the local community. Furthermore, differences were identified in the perceived economic, social, and environmental impacts depending on respondents' level of awareness of the project and their age group. The study highlights the importance of timely public communication about all aspects of seaport development projects and the need to consider the socio-economic needs of the local community while protecting natural resources.

***Keywords**: seaport, sustainable development, socio-economic effects, environmental impact, nautical tourism*

KAKO IZGRADNJA NAUTIČKIH LUKA OBLIKUJE ODRŽIVI RAZVOJ DESTINACIJA IZ PERSPEKTIVE LOKALNE ZAJEDNICE

SAŽETAK

Morske luke važan su čimbenik društveno-ekonomskog razvoja obalnih turističkih područja. Planiranje izgradnje novih luka pretpostavlja različite pozitivne i negativne učinke u kontekstu održivog razvoja turizma i lokalne ekonomije, kvalitete života zajednice te očuvanja prirodnog okruženja. Porast turističkog prometa u obalnim destinacijama, vidljiv kroz rast broja plovila, nautičara i putnika u tranzitu, te širenje komplementarnih nautičko-turističkih sadržaja utječe na učestalost prometnih gužvi, nezadovoljstvo putnika i snižavanje kvalitete života lokalnog stanovništva. Izgradnjom novih luka, turističke destinacije stvaraju preduvjete za održivi društveno-ekonomski razvoj, te dugoročno povećanje konkurentnosti i otpornosti. Istodobno, izgradnja složene morske infrastrukture može narušiti morski okoliš i ugroziti prirodne resurse. Stoga je cilj rada istražiti percepcije lokalnog stanovništva o ekonomskim, društvenim i ekološkim učincima izgradnje morske luke u nautičkoj destinaciji. Istraživanje je provedeno on-line anketiranjem na uzorku rezidenata i nerezidenata grada Omiša (Hrvatska). Statistička obrada prikupljenih podataka provedena je korištenjem programa SPSS. Rezultati pokazuju da postoji povezanost između informiranosti ispitanika o projektu izgradnje luke i njihovog stava prema važnosti izgradnje luke, te prema učincima izgradnje luke na lokalnu zajednicu. Nadalje, utvrđene su razlike u percepcijama ekonomskih, društvenih i ekoloških učinaka s obzirom na razinu informiranosti ispitanika o projektu i njihovu dobnu skupinu. Istraživanje ističe važnost pravodobnog informiranja javnosti o svim aspektima projekata izgradnje morskih luka te nužnosti uvažavanja društveno-ekonomskih potreba lokalne zajednice, uz zaštitu prirodnih resursa.

Ključne riječi: *morska luka, održivi razvoj, društveno-ekonomski učinci, ekološki utjecaj, nautički turizam*

1. UVOD

Razvoj obalnih i otočnih destinacija diljem svijeta usko je povezan sa rastom turističke industrije, osobito sa širenjem nautičkog turizma koji zbog potreba za odgovarajućom pomorskom infrastrukturom ima značajan ekonomski, društveni i ekološki utjecaj. Broj turista nautičara i plovila u stalnom je porastu na globalnoj razini (Martin Rojo, 2009; Cardoso i sur., 2023), što rezultira izgradnjom novih nautičkih luka i širenjem ponude raznovrsnih proizvoda i usluga, te potiče ekonomski i društveni razvoj destinacija. Djelatnost nautičkih luka i sektor nautičkog turizma imaju značajnu ulogu u razvoju radnih mjesta, poduzeća i lokalnog poduzetništva, te u rastu zapošljavanja, investicija i plave ekonomije (European Commission - EC, 2014, 2017; Lam-González i sur., 2019; Centre for Economics and Business Research - Cebr 2022a, 2022b; Santos i sur., 2022).

Nautički turizam smatra se vrstom obalnog i morskog turizma koji igra značajnu ulogu u plavoj ekonomiji Europske Unije (EC, 2017), predstavljajući glavni ekonomski sektor u zemljama s atraktivnom obalom (Tonazzini i sur., 2019). Nautički sektor ključan je za ekonomsku održivost i prosperitet brojnih primorskih mjesta fokusiranih na turizam jer, između ostaloga, omogućuje postizanje dužeg razdoblja aktivne sezone, te posljedično ostvarivanje većih prihoda i povrata investiranog kapitala u odnosu na druge sektore (EC, 2014, 2017; Jugović i sur., 2016; Lam-González i sur., 2019; Moreno i Otamendi, 2017; Ivanić i sur., 2018; Santos i sur., 2022). Nadalje, sektor nautičkog turizma ima snažno naglašenu pomorsku komponentu, što dodatno ističe njegov višefunkcionalni karakter i složenost, te snažniji društveno-ekonomski i okolišni utjecaj na obalne destinacije, na lokalnoj i regionalnoj razini (Martin Rojo, 2009; Luković, 2013; Gon i sur., 2016; Gračan i sur., 2016; Moreno i Otamendi, 2017; Ivanić i sur., 2018).

Uz mnoge pozitivne učinke razvoja nautičkog sektora, obalne destinacije se suočavaju s brojnim izazovima koje uzrokuje povećanje nautičko-turističkog prometa i potražnje. Primjerice, nedostatak odgovarajućih nautičkih vezova, nekontrolirano sidrenje plovila u osjetljivim morskim zonama, onečišćenje morskog okoliša, prometne gužve i rast cijena nekretnina u destinaciji, dovode u pitanje održivost rasta turističkog sektora. Rješavanje nekih od prethodno istaknutih problema moguće je putem ulaganja u rekonstrukciju postojećih i/ili izgradnju novih nautičkih luka i povezanih nautičkih kapaciteta.

Luke su vitalne za opstojnost i razvoj obalnih područja zbog ekonomske povezanosti s brojnim dionicima duž lanca vrijednosti nautičkog sektora, te omogućuju stvaranje vrijednosti za ostale sektore plave ekonomije, kao što je prijevoz robe, turizam, ribarstvo i drugo (Martínez-Vázquez i sur., 2022; Marušić i sur., 2024). Izgradnja nove luke predstavlja strateški projekt koji lokalnoj zajednici omogućuje postizanje efikasnije kontrole turističkih tijekova, odgovornije ponašanje turista-nautičara i nautičkih poduzeća, te razvoj različitih poslovnih aktivnosti na širem području lokacije luke.

Razvijanjem nautičke infrastrukture i povezanih nautičko-turističkih kapaciteta, obalna destinacija stvara dodatne preduvjete za postizanje pozitivnih ekonomskih, ekoloških i društvenih učinaka. Osim toga, investicije u nautičke luke potiču razvoj pripadajuće regije (Ivanić i sur., 2018). Uz rast turizma i lokalne ekonomije, izgradnja nove luke omogućuje podizanje standarda i kvalitete života lokalne zajednice, te očuvanje prirodnih resursa i ekološkog integriteta destinacije.

Dobro osmišljene nautičke luke potiču stvaranje novih javno dostupnih prostora, sadržaja i mjesta (primjerice, šetnice, biciklističke staze, uređenje plaže, zeleni i tematski parkovi) pogodnih za različite društveno-kulturne, sportske i druge aktivnosti lokalnog stanovništva i posjetitelja (Gračan i sur., 2016; Jugović i sur., 2021; Cebr, 2022a, 2022b; Innovamarina, 2023). S druge strane, izgradnja i djelatnost nautičke luke, uz povezane prometne i druge aktivnosti u destinaciji mogu izazvati brojne probleme u zajednici i morskom ekosustavu.

Primjerice, značajne fluktuacije u zaposlenosti i ekonomskim aktivnostima tijekom cijele godine zbog sezonskog karaktera turizma, te značajan porast cijena stambenog prostora i istiskivanje lokalnog stanovništva iz gradskih središta zbog kontinuiranog rasta potražnje za nekretninama u atraktivnim gradskim zonama (Broads Authority, 2008; Kizielewicz i Luković, 2013; Cebr, 2022a, 2022b).

Nadalje, kretanje i privez plovila, kao i uporaba fosilnih goriva, zaštitnih boja za trupove i kemikalija, te ispuštanje otpadnih voda s plovila predstavljaju prijetnju za bioraznolikost i integritet morskog okoliša (Innovamarina, 2023). U infrastrukturnom smislu, morske luke predstavljaju važan element razvoja priobalnih područja, te europske, nacionalne i lokalne politike sve više potiču razvoj luka u skladu s načelima održivog razvoja, integriranog upravljanja obalnim područjima (ICZM), uz primjenu zelenih tehnologija i mjera prilagodbe klimatskim promjenama (UNEP/MAP, 2015).

Uspješnost prihvaćanja i realizacije projekta izgradnje nautičke luke, kao i uspješnost upravljanja lukom, izravno su povezani s razinom informiranosti i uključenosti lokalne zajednice u cjelokupni proces, od planiranja i izgradnje do neposrednog korištenja nautičko-turističkih sadržaja. Održivi razvoj nautičkog turizma pretpostavlja uključivanje i osnaživanje lokalnih zajednica (EC, 2017; Tonazzini i sur., 2019; Innovamarina, 2023).

Stoga su percepcije članova lokalne zajednice o koristima i izazovima izgradnje morske luke, te dostupnost relevantnih informacija o takvom projektu izrazito važne. Razumijevanje stavova i mišljenja lokalne zajednice neophodno je za održivi razvoj nautičkog turizma (Ravikumar i sur., 2022; Tonazzini i sur., 2019), te je neophodno provoditi znanstvena istraživanja navedene problematike.

Mediteranske zemlje smatraju se najtraženijim nautičkim destinacijama na globalnoj razini (Balaguer i sur., 2011; Kovačić i sur., 2015; Moreno i Otamendi, 2017; Ivanić i sur., 2018; Martínez-Vázquez i sur., 2022, Sanotos i sur., 2022), pri čemu raste popularnost Hrvatske kao jedne od najpoželjnijih (Luković, 2013). Cardoso i sur. (2023) ističu potencijale nautičkog turizma koji istovremeno može generirati ekonomski rast i služiti kao poluga za održivi razvoj turizma u obalnim destinacijama. U radu se istražuju percepcije članova lokalne zajednice o ekonomskom, društvenom i ekološkom utjecaju izgradnje luke na održivi razvoj nautičke destinacije. Istraživanje se provodi na primjeru izgradnje nove luke u gradu Omišu (Hrvatska).

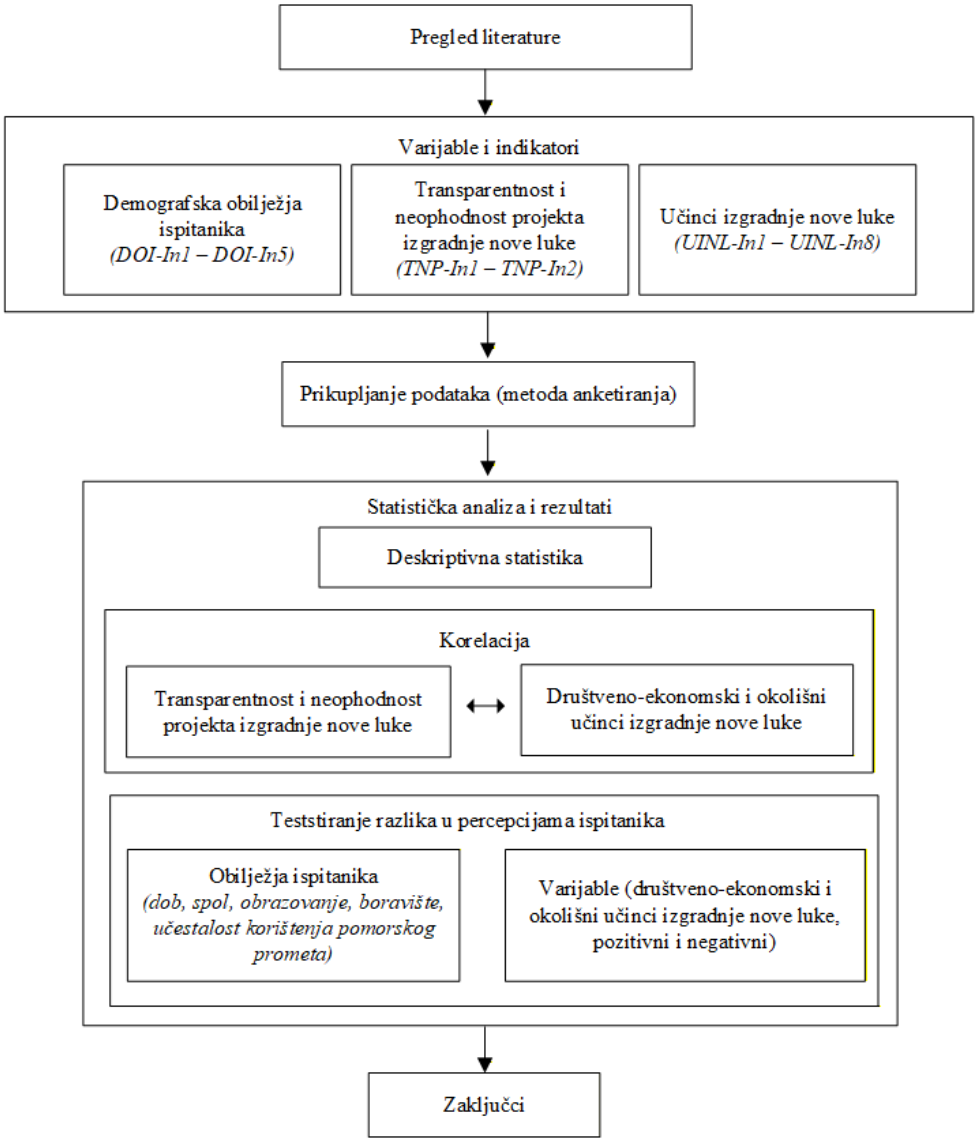
2. MATERIJALI I METODE

Rad istražuje percepcije lokalnih stanovnika o ekonomskim, društvenim i ekološkim učincima gradnje pomorske luke na primjeru nautičke destinacije. Uzorak populacije (N=219) uključuje rezidente i nerezidente grada Omišu. Model istraživanja rada prikazan je na slici 1, a varijable i indikatori istraživanja u tablici 1.

Demografska obilježja ispitanika	
DOI-In1	*Spol ispitanika*
DOI-In2	*Dob ispitanika*
DOI-In3	*Obrazovanje*
DOI-In4	*Boravište Stavovi i ponašanje ispitanika*
DOI-In5	*Učestalost korištenja pomorskog prijevoza /putovanja*
Transparentnost i neophodnost projekta	
TNP-In1	*Dostupnost relevantnih informacija o projektu izgradnje nove luke*
TNP-In2	*Neophodnost izgradnje nove luke za razvoj destinacije*
Učinci izgradnje nove luke	
UINL-In1	*Utjecaj na razvoj turizma i lokalne ekonomije*
UINL-In2	*Utjecaj na rast broja turista i turističkog prometa*
UINL-In3	*Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva*
UINL-In4	*Utjecaj na autentičnost, prepoznatljivost i konkurentnost destinacije*
UINL-In5	*Utjecaj na prometnu povezanost destinacije*
UINL-In6	*Utjecaj na povećanje kvalitete života lokalne zajednice*
UINL-In7	*Utjecaj na rast prometnih gužvi*
UINL-In8	*Utjecaj na onečišćenje mora i degradaciju morskih resursa*

Tablica 1: Istraživačke varijable i indikatori
(Izvor: Autori)

Za operacionalizaciju percepcije lokalne zajednice o projektu identificirane su dvije skupine indikatora (tablica 1): 1) indikatori transparentnosti i neophodnosti projekta (*TNP-In1* - *TNP-In2*) i 2) indikatori učinaka izgradnje nove luke (*UINL-In1* - *UINL-In8*).



Slika 1: Model istraživanja
(Izvor: Autori)

Model istraživanja rada uključuje (slika 1): i) pregled literature, ii) identificiranje varijabli i indikatora o projektu gradnje luke i učincima gradnje luke na lokalnu ekonomiju, iii) prikupljanje podataka, iv) statistička analiza, i v) zaključak. Podaci su prikupljeni on-line anketiranjem, uz korištenje strukturiranog upitnika sastavljenog od tri djela: i) demografska obilježja ispitanika, ii) percepcije ispitanika o dostupnosti informacija i neophodnosti projekta, iii) učinci izgradnje luke na promatranu destinaciju. Za mjerenje indikatora korištena je Likertova ljestvica sa 5 stupnjeva. Statistička analiza provedena je korištenjem paketa *IBM SPSS Statistics* (verzija 20) i sastoji se od deskriptivne statistike, Spearman-ovog testa korelacije i testiranja razlika u percepcijama ispitanika o projektu i učincima projekta, s obzirom na njihova demografska obilježja.

3. REZULTATI I DISKUSIJA

3.1. Deskriptivna statistika

U tablici 2 prikazani su rezultati deskriptivne statistike, te rezultati ispitivanja normalnosti distribucije primjenom Kolmogorov-Smirnov testa. Rezultati testa pokazuju da podaci nisu normalno distribuirani te će se za daljnje statističke analize koristiti neparametrijski testovi.

Indikator	Krat.	Srednja vrijednost		Std. devij.	Kolmogorov-Smirnov		
		Sred.	Std. greš.		Vrijed.	df	Sig.
Učestalost korištenja pomorskog prijevoza /putovanja	*DOI-In5*	2,32	,077	1,143	,235	219	,000
Dostupnost relevantnih informacija o projektu izgradnje nove luke	*TNP-In1*	**4,31**	,068	1,014	,326	219	,000
Neophodnost izgradnje nove luke za razvoj destinacije	*TNP-In2*	**2,58**	,078	1,163	,184	219	,000
Utjecaj na razvoj turizma i lokalne ekonomije	*UINL-In1*	**4,26**	,066	,991	,320	219	,000
Utjecaj na rast broja turista i turističkog prometa	*UINL-In2*	3,86	,073	1,083	,206	219	,000
Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva	*UINL-In3*	**2,83**	,086	1,278	,154	219	,000
Utjecaj na autentičnost, prepoznatljivost i konkurentnost destinacije	*UINL-In4*	3,36	,086	1,282	,162	219	,000
Utjecaj na prometnu povezanost destinacije	*UINL-In5*	3,82	,082	1,227	,231	219	,000
Utjecaj na povećanje kvalitete života lokalne zajednice	*UINL-In6*	**2,67**	,070	1,041	,269	219	,000
Utjecaj na rast prometnih gužvi	*UINL-In7*	3,36	,083	1,234	,166	219	,000
Utjecaj na onečišćenje mora i degradaciju morskih resursa	*UINL-In8*	3,57	,079	1,178	,164	219	,000

Tablica 2: Deskriptivna statistika
(Izvor: Autori)

Ispitanici su dodijelili (tablica 2) visoku prosječnu ocjenu (4,26) indikatoru *UINL-In1 (Utjecaj na razvoj turizma i lokalne ekonomije*), te značajno nižu ocjenu (2,83) indikatoru *UINL-In3* (*Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva)*. Rezultati impliciraju da ispitanici ne povezuju rast turizma i lokalne ekonomije sa rastom novih radnih mjesta i lokalnog poduzetništva. Za razliku od percepcije lokalne zajednice na području grada Omiša, Europska komisija (EC, 2014, 2017) ističe važnost obalnih područja u stvaranju radnih mjesta, posebno za mlade ljude, uz podatak da gotovo polovica turističkih radnika (45%) pripada dobnoj skupini od 16 do 35 godina. Obalna područja privlače više od trećine ukupnog turističkog poslovanja u Europi (EC, 2014, 2017), a nautičke luke potiču razvoj lokalnog turizma i poduzetništva (Martínez-Vázquez i sur., 2022). Rezultati pokazuju relativno niske ocjene koje su ispitanici dodijelili indikatoru *UINL-In6* (*Utjecaj na povećanje kvalitete života lokalne zajednice*), uz prosječnu ocjenu 2,67.

Prosječna ocjena za indikator *TNP-In2* (*Neophodnost izgradnje nove luke za razvoj destinacije*) iznosi 2,58, što pokazuje nedostatnu neprepoznavanje pozitivnih učinaka gradnje luke u kontekstu rješavanja određenih društveno-ekonomskih i ekoloških problema (npr. nekontrolirano sidrenje plovila), odnosno održivom razvoju lokalne zajednice. S druge strane, dosadašnja istraživanja (npr. Santos i sur., 2022, Martínez-Vázquez i sur., 2022) ukazuju na potencijale nautičkog sektora da potiče održivi razvoj obalnih destinacija. Sukladno tomu, pretpostavlja se da diseminacija informacija u široj javnosti o koristima izgradnje nautičke infrastrukture i sustavnog razvoja sektora u kontekstu društveno-ekonomskog i ekološkog otiska ima važnu ulogu.

Nadalje, vrijednosti prosječnih ocjena kod ostalih indikatora kreću se od 3,36 (UINL-In4) do 3,86 (UINL-In2), pokazujući neutralan stav ispitanika prema istraženim učincima. Unatoč visokoj vrijednosti (4,31) indikatora *TNP-In1* (*Dostupnost relevantnih informacija o projektu izgradnje nove luke*) prethodno navedeni rezultati impliciraju mogućnost nedovoljne upoznatosti ispitanika kao članova lokalne zajednice sa relevantnim koristima i mogućim posljedicama gradnje u ekonomskom, društvenom i ekološkom smislu.

3.2. Koeficijenti korelacije

Rezultati Spearman-ovog testa korelacije prikazani u tablici 3 i tablici 4. Rezultati pokazuju da postoji umjerena, statistički značajna pozitivna korelacija između indikatora *DOI-In5* (*Učestalost korištenja pomorskog prijevoza/putovanja*) i slijedećih indikatora (tablica 3): i) *TNP-In2* (*Neophodnost izgradnje nove luke za razvoj destinacije*, 0,141), ii) *UINL-In3* (*Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva*, 0,177) i iii) *UINL-In6* (*Utjecaj na povećanje kvalitete života lokalne zajednice*, 0,235). Ispitanici koji češće koriste pomorski prijevoz dodjeljuju više vrijednosti kod indikatora *TNP-In2* (*Neophodnost izgradnje nove luke za razvoj destinacije*), kao i kod pojedinih indikatora utjecaja izgradnje luke na lokalnu ekonomiju i kvalitetu života u destinaciji.

Indikatori	*DOI-In5*	*TNP-In1*	*TNP-In2*	*UINL-In1*	*UINL-In2*	*UINL-In2*
DOI-In5	1,000					
TNP-In1	,049	1,000				
TNP-In2	**,141***	,122	1,000			
UINL-In1	,071	**,491****	**,227****	1,000		
UINL-In2	,123	**,339****	**,215****	,668**	1,000	
UINL-In3	**,177****	**,155***	**,293****	,389**	,587**	1,000

* Korelacija je značajna na razini 0,05 (2-tailed); ** Korelacija je značajna na razini 0,01 (2-tailed)

Tablica 3: Koeficijenti korelacije između učestalosti korištenja pomorskog prometa, dostupnosti informacija, neophodnosti izgradnje i ekonomskih učinaka
(Izvor: Autori)

Indikatori	*DOI-In5*	*TNP-In1*	*TNP-In2*	*UINL-In4*	*UINL-In5*	*UINL-In6*	*UINL-In7*	*UINL-In8*
DOI-In5	1,000							
TNP-In1	,049	1,000						
TNP-In2	**,141***	,122	1,000					
UINL-In4	,050	**,457****	**,322****	1,000				
UINL-In5	,106	**,238****	**,319****	,352**	1,000			
UINL-In6	**,235****	,085	**,354****	,170*	,211**	1,000		
UINL-In7	-,050	**-,308****	-,054	-,333**	-,073	-,083	1,000	
UINL-In8	-,014	**-,338****	**-,225****	-,431**	-,293**	-,131	,417**	1,000

* Korelacija je značajna na razini 0,05 (2-tailed); ** Korelacija je značajna na razini 0,01 (2-tailed)

Tablica 4: Koeficijenti korelacije između učestalosti korištenja, dostupnosti informacija, neophodnosti izgradnje te društvenih i ekoloških učinaka
(Izvor: Autori)

Rezultati pokazuju da postoji statistički značajna, pozitivna korelacija između indikatora *TNP-In1* (*Dostupnost relevantnih informacija o projektu izgradnje nove luke*) sa slijedećim indikatorima (koeficijenti korelacije su navedeni uz indikatore, tablica 4): i) *UINL-In1* (*Utjecaj na razvoj turizma i lokalne ekonomije,* 0,491), ii) *UINL-In2 (Utjecaj na rast broja turista i turističkog prometa*, 0,339), iii) *UINL-In3 (Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva, 0,155)*, iv) *UINL-In4* (*Utjecaj na autentičnost, prepoznatljivost i konkurentnost destinacije,* 0,457), te v) *UINL-In5* (*Utjecaj na prometnu povezanost destinacije,* 0,238).

Indikator *TNP-In1* (*Dostupnost relevantnih informacija o projektu izgradnje nove luke*) negativno korelira sa dva indikatora: i) *UINL-In7* (*Utjecaj na rast prometnih gužvi,* -0,308), te ii) *UINL-In8* (*Utjecaj na onečišćenje mora i d*egradaciju morskih resursa, -0,338). Ispitanici koji percipiraju višu razinu dostupnosti relevantnih informacija o projektu izgradnje nove luke, vrednovali su višim ocjenama čimbenike pozitivnog, a nižim ocjenama indikatore negativnog ekonomskog, društvenog i ekološkog utjecaja gradnje luke na destinaciju. Dosadašnja istraživanja i studije ističu kako značajan rast turizma i ljudskih aktivnosti općenito značajno uništavaju prirodne resurse i okoliš (Tonazzini i sur., 2019; Ravikumar i sur., 2022; EC, 2014, 2017).

Indikator *TNP-In2* (*Neophodnost izgradnje nove luke za razvoj destinacije*) pozitivno je i statistički značajno koreliran sa slijedećim indikatorima (tablica 4): i) *UINL-In1* (*Utjecaj na razvoj turizma i lokalne ekonomije*, 0,227), ii) *UINL-In2* (*Utjecaj na rast broja turista i turističkog prometa*, 0,215), iii) *UINL-In3* (*Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva*, 0,293), iv) *UINL-In4* (*Utjecaj na autentičnost, prepoznatljivost i konkurentnost destinacije*, 0,322), v) *UINL-In5* (*Utjecaj na prometnu povezanost destinacije*, 0,319), te vi) *UINL-In6* (*Utjecaj na povećanje kvalitete života lokalne zajednice*, 0,354). Istodobno, indikator *TNP-In2* (*Neophodnost izgradnje nove luke za razvoj destinacije*) negativno je koreliran sa indikatorom *UINL-In8* (*Utjecaj na onečišćenje mora i degradaciju morskih resursa*, -0,225). Ispitanici koji percipiraju višu razinu neophodnosti izgradnje nove luke za razvoj destinacije, percipiraju i višu razinu pozitivnih, te nižu razinu negativnih učinaka nove luke za sve istražene indikatore.

3.3. Testiranje razlika u percepcijama ispitanika o učincima izgradnje s obzirom na demografske varijable

3.3.1. Testiranje razlika u percepcijama ispitanika s obzirom na spol

Testiranje razlika u percepcijama ispitanika o dostupnosti relevantnih informacija o projektu, neophodnosti izgradnje nove luke za razvoj destinacije i učincima izgradnje nove luke, s obzirom na spol ispitanika, napravljeno je primjenom Mann Whitney U testa za nezavisne uzorke.

Indikator	Spol	N	Srednja vrijednost	Std. dev.	Std. greš.	Sig.
Dostupnost relevantnih informacija o projektu izgradnje nove luke	Muški	82	4,49	,959	,106	,013
	Ženski	139	4,21	1,032	,088	
Neophodnost izgradnje nove luke za razvoj destinacije	Muški	82	2,18	1,079	,119	,000
	Ženski	138	2,83	1,152	,098	
Utjecaj na rast prometnih gužvi	Muški	81	3,07	1,302	,145	,011
	Ženski	137	3,52	1,170	,100	
Utjecaj na onečišćenje mora i degradaciju morskih resursa	Muški	82	3,16	1,262	,139	,000
	Ženski	139	3,81	1,062	,090	

Tablica 5: Deskriptivna statistika i Mann Whitney U Test – Spol ispitanika (Izvor: Autori)

Rezultati testa (tablica 5) pokazuju da se ispitanici različitog spola razlikuju u percepcijama o: i) dostupnosti relevantnih informacija o projektu, ii) neophodnosti izgradnje nove luke za razvoj destinacije, iii) utjecaju izgradnje nove luke na rast prometnih gužvi te iv) utjecaju na onečišćenje mora i degradaciju morskih resursa. Muškarci su u prosjeku, u odnosu na žene, dodijelili više ocjene za dostupnost relevantnih informacija o projektu izgradnje nove luke. S druge strane, žene u odnosu na muškarce, percipiraju višu razinu neophodnosti izgradnje nove luke za razvoj destinacije, ali i snažniji negativni utjecaj izgradnje luke na rast prometnih gužvi te onečišćenje mora i degradaciju morskih resursa. Između percepcija ispitanika različitog spola u ostalim indikatorima nisu zabilježene statistički značajne razlike.

3.3.2. Testiranje razlika u percepcijama ispitanika s obzirom na dobnu skupinu

Testiranje razlika u percepcijama ispitanika o učincima izgradnje nove luke, s obzirom na dob ispitanika (tablica 6), napravljeno je primjenom Kruskal Wallis testa za nezavisne uzorke.

Indikator	Dob	N	Srednja vrijednost	Std. dev.	Std. greš.	Sig.
Utjecaj na razvoj turizma i lokalne ekonomije	18-25	23	4,39	,722	,151	,015
	26-35	53	4,64	,623	,086	
	36-45	61	4,23	1,039	,133	
	46-55	53	4,06	1,064	,146	
	> 55	32	3,94	1,243	,220	
Utjecaj na rast broja turista i turističkog prometa	18-25	23	4,17	,887	,185	,020
	26-35	53	4,13	,921	,126	
	36-45	61	3,90	1,106	,142	
	46-55	53	3,70	1,049	,144	
	> 55	32	3,34	1,285	,227	
Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva	18-25	23	3,52	1,310	,273	,008
	26-35	53	3,02	1,217	,167	
	36-45	61	2,66	1,263	,162	
	46-55	53	2,85	1,246	,171	
	> 55	31	2,29	1,216	,218	
Utjecaj na prometnu povezanost destinacije	18-25	23	4,30	,822	,171	,000
	26-35	53	4,34	,919	,126	
	36-45	61	3,75	1,220	,156	
	46-55	53	3,47	1,339	,184	
	> 55	32	3,31	1,355	,239	

Tablica 6: Deskriptivna statistika i Kruskal Wallis Test – Dobna skupina (Izvor: Autori)

Rezultati testa pokazuju da se ispitanici iz različitih dobnih skupina razlikuju u percepcijama o utjecaju izgradnje luke na: i) razvoj turizma i lokalne ekonomije, ii) rast broja turista i turističkog prometa, iii) rast novih radnih mjesta i lokalnog poduzetništva te iv) utjecaj na prometnu povezanost destinacije. Mlađi ispitanici, dodijelili su više ocjene u indikatorima utjecaja izgradnje nove luke na ekonomiju i turizam općenito, ali i za utjecaj izgradnje luke na prometnu povezanost destinacije. Razlike u percepcijama ispitanika iz različitih dobnih skupina kod ostalih indikatora nisu statistički značajne.

3.3.3. Testiranje razlika u percepcijama ispitanika s obzirom na boravište

Testiranje razlika u percepcijama ispitanika o dostupnosti relevantnih informacija o projektu, neophodnosti izgradnje nove luke za razvoj destinacije i učincima izgradnje nove luke, s obzirom na prebivalište ispitanika, napravljeno je primjenom Mann Whitney U testa za nezavisne uzorke. Rezultati testa pokazuju da se rezidenti i nerezidenti razlikuju u percepcijama o utjecaju izgradnje nove luke na rast novih radnih mjesta i lokalnog poduzetništva (tablica 7).

Indikator	Boravište	N	Srednja vrijednost	Std. dev.	Std. greš.	Sig.
Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva	Rezidenti	153	2,65	1,290	,104	,001
	Nerezidenti	68	3,24	1,161	,141	

Tablica 7: Deskriptivna statistika i Mann Whitney U Test – Boravište ispitanika (Izvor: Autori)

Nerezidenti percipiraju snažniji utjecaj izgradnje luke na nova radna mjesta i lokalno poduzetništvo, u odnosu na rezidente (tablica 7). Percepcije rezidenata i nerezidenata u ostalim indikatorima se statistički ne razlikuju.

3.3.4. Testiranje razlika u percepcijama ispitanika s obzirom na učestalost korištenja pomorskog prijevoza

Testiranje razlika u percepcijama ispitanika o učincima izgradnje nove luke, s obzirom na učestalost korištenja pomorskog prijevoza ispitanika, napravljeno je primjenom Kruskal Wallis testa za nezavisne uzorke (tablica 8).

Indikator	Učestalost korištenja	N	Srednja vrijednost	Std. dev.	Std. greš.	Sig.
Utjecaj na rast novih radnih mjesta i lokalnog poduzetništva	Vrlo rijetko	57	2,58	1,209	,160	,008
	Rijetko	81	2,69	1,221	,136	
	Ponekad	54	3,04	1,317	,179	
	Često	12	3,92	1,084	,313	
	Vrlo često	17	2,88	1,409	,342	
Utjecaj na povećanje kvalitete života lokalne zajednice	Vrlo rijetko	57	2,35	1,110	,147	,000
	Rijetko	81	2,63	,968	,108	
	Ponekad	54	2,83	,966	,132	
	Često	12	3,33	1,231	,355	
	Vrlo često	17	3,00	,935	,227	

Tablica 8: Deskriptivna statistika i Kruskal Wallis Test – Korištenje pomorskog prijevoza (Izvor: Autori)

Rezultati testa (tablica 8) pokazuju da ispitanici koji češće koriste pomorski prijevoz percipiraju snažniji pozitivan utjecaj izgradnje nove luke na: i) rast novih radnih mjesta i lokalnog poduzetništva te ii) povećanje kvalitete života lokalne zajednice.

Percepcije ispitanika s obzirom na učestalost korištenja pomorskog prijevoza, u ostalim se kategorijama statistički ne razlikuju. Također nisu zabilježene ni razlike u percepcijama ispitanika sa različitom razinom obrazovanja.

Investicije u nautičkom sektoru i projekti izgradnje luka osnovica su za održivi razvoj i prosperitet obalnih destinacija (Santos i sur., 2022), unatoč brojnim negativnim učincima s kojima se susreću lokalne zajednice (EC, 2017; Tonazzini i sur., 2019). Percepcija pozitivnih i negativnih učinaka rasta nautičkog sektora u velikoj mjeri zavisna je o dostupnosti relevantnih informacija vezanih za ekonomske, društvene i ekološke aspekte. Rezultati provedenog istraživanja u ovom radu otkrivaju da ispitanici koji su visoko ocijenili dostupnost relevantnih informacija imaju pozitivniji stav prema koristima od izgradnje nove luke u destinaciji u odnosu na ispitanike koji smatraju da informacije o projektu nisu dovoljno dostupne.

Brojni izvori (npr., Jugović i sur., 2011; Gračan i sur., 2016; Ivanić i sur. 2018) ističu važnu ulogu sektora nautičkog turizma u ekonomskom rastu i razvoju Republike Hrvatske, osobito ako se uzme u obzir široki raspon turističkih i pomorskih aktivnosti koje sektor obuhvaća (Tonazzini i sur., 2019; Santos i sur., 2022), uz činjenicu da nautičke luke predstavljaju temeljnu infrastrukturu i djelatnost sektora. Santos i sur. (2022) naglašavaju da konkurentnost nautičkih destinacija zavisi o razvijenosti i kvaliteti nautičke infrastrukture. Međutim, tržišna aktualizacija novih luka i njihova uspješna integracija u nautičke destinacije pretpostavlja određeno vremensko razdoblje koje u značajnoj mjeri zavisi o uključivanju lokalne zajednice u sve etape njihovog razvoja.

4. ZAKLJUČAK

Izgradnja nautičkih luka i unaprjeđenje infrastrukturnih kapaciteta od vitalne su važnosti za razvoj i održivo upravljanje obalnim destinacijama. Projekt izgradnje nautičke luke koji uspostavlja ravnotežu između ekonomskog rasta s utjecajem na dobrobit lokalne zajednice i očuvanje morskog okoliša, omogućuje održivi razvoj destinacija. Izgradnja nautičko-turističke infrastrukture istodobno rezultira pozitivnim i negativnim društveno-ekonomskim i ekološkim učincima. Razvoj industrije turizma i nautičkog turizma, osnaživanje lokalnog poduzetništva, ali i doprinos rastu životnog standarda i kvaliteti života u destinaciji predstavljaju samo neke od pozitivnih učinaka, dok se povećanje prometnih gužvi i onečišćenje morskog okoliša ističu kao negativni učinci. Uspjeh infrastrukturnih projekata u nautičkom turizmu značajno zavisi o potpori i uključenosti lokalne zajednice, kao i o njezinoj percepciji pozitivnih i negativnih učinaka projekta. Stoga je važno istraživati percepciju članova lokalne zajednice o utjecaju izgradnje morske luke na održivi razvoj destinacije uz sagledavanje ekonomskih, društvenih i ekoloških aspekata. Istraživanje percepcije o transparentnosti projekta i dostupnosti relevantnih informacija, te o neophodnosti izgradnje nautičke luke i njezinim ekonomskim, društvenim i ekološkim utjecajima provedeno je na uzorku članova lokalne zajednice u nautičkoj destinaciji. Rezultati provedenog istraživanja pokazuju da ispitanici, u prosjeku, percipiraju dostupnost relevantnih informacija o projektu, te značajnost utjecaja izgradnje luke na turizam i lokalnu ekonomiju. S druge strane, ispitanici ne percipiraju značajan utjecaj luke na nova radna mjesta, lokalno poduzetništvo i kvalitetu života. Rezultati također pokazuju da pojedina demografska obilježja ispitanika utječu na njihovu percepciju istraženih varijabli. U odnosu na muškarce, žene percipiraju veći značaj izgradnje luke za razvoj destinacije, ali i veći negativni utjecaj luke na okoliš i lokalnu zajednicu. Također, mlađi ispitanici više percipiraju pozitivni utjecaj izgradnje luke na rast i razvoj turizma i lokalne ekonomije u odnosu na ispitanike koji pripadaju starijim dobnim skupinama. Konačno, ispitanici koji smatraju da su relevantne informacije o projektu dostupne, te da je projekt neophodan za razvoj destinacije, u većoj mjeri percipiraju pozitivne u odnosu na negativne učinke izgradnje nautičke luke.

Temeljem prethodno navedenog, nalazi rada ukazuju da je transparentnost projekta i dostupnost relevantnih informacija o izgradnji nautičke infrastrukture moguće promatrati kao važne preduvjete za dobivanje podrške od strane lokalne zajednice. Ograničenja ovog rada odnose se na relativno mali broj indikatora korištenih za procjenu promatranih varijabli, te bi buduća istraživanja trebala uključiti širi raspon društveno-ekonomskih i ekoloških indikatora utjecaja izgradnje nautičke luke i njezinih poslovnih operacija. Osim toga, istraživanja ove problematike trebala bi koristiti različite istraživačke metode u svrhu objektivnijeg sagledavanja problema istraživanja.

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FINANCIAL PERFORMANCE ANALYSIS IN MARITIME ORGANIZATIONS: THE CASE OF THE PORT OF RIJEKA

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ABSTRACT

The aim of this paper is to analyze the role and application of financial indicators in maritime organizations, with a particular focus on a case study of the Port of Rijeka. The paper explores the theoretical aspects of financial operations and key indicators of liquidity, profitability, efficiency, and indebtedness, along with an analysis of their relationship to operational performance and strategic management. The Port of Rijeka was selected as a representative example of the Croatian maritime industry due to its geostrategic position, diverse revenue structure, and strong investment cycle. An analysis of the financial statements for the period 2020–2024 shows stable revenue growth, improved liquidity, and increased profitability, alongside reduced indebtedness and enhanced operational efficiency. A comparison with competing ports in the region confirms the Port of Rijeka's competitive position in terms of profitability and capital management. The results highlight the importance of systematic monitoring of financial indicators for strategic decision-making, business process optimization, and strengthening resilience to market risks. The paper contributes to a deeper understanding of the financial dynamics within the maritime sector and may serve as a foundation for further research on sustainable development and port competitiveness within European transport corridors.

Keywords: *Competitiveness, Efficiency, Financial indicators, Liquidity, Maritime organizations, Port of Rijeka, Profitability*

ANALIZA FINANCIJSKIH POKAZATELJA U POMORSKIM ORGANIZACIJAMA: STUDIJA SLUČAJA LUKE RIJEKA

SAŽETAK

Cilj ovog rada jest analizirati ulogu i primjenu financijskih pokazatelja u pomorskim organizacijama, s posebnim naglaskom na studiju slučaja Luke Rijeka. U radu se istražuju teorijski aspekti financijskog poslovanja te ključni pokazatelji likvidnosti, profitabilnosti, učinkovitosti i zaduženosti, uz analizu njihove povezanosti s operativnim rezultatima i strateškim upravljanjem. Luka Rijeka odabrana je kao reprezentativan primjer hrvatske pomorske industrije zbog svog geostrateškog položaja, raznovrsne strukture prihoda i snažnog investicijskog ciklusa. Analiza financijskih izvještaja za razdoblje 2020.–2024. pokazuje stabilan rast prihoda, poboljšanje likvidnosti i porast profitabilnosti, uz smanjenje zaduženosti i povećanje operativne učinkovitosti. Usporedba s konkurentskim lukama u regiji potvrđuje konkurentnu poziciju Luke Rijeka u pogledu profitabilnosti i upravljanja kapitalom. Rezultati naglašavaju važnost sustavnog praćenja financijskih pokazatelja za strateško odlučivanje, optimizaciju poslovnih procesa i povećanje otpornosti na tržišne rizike. Rad doprinosi razumijevanju financijske dinamike pomorskog sektora i može poslužiti kao temelj za daljnja istraživanja održivog razvoja i konkurentnosti luka unutar europskih prometnih koridora.

Ključne riječi: *Pomorske organizacije, Luka Rijeka, Financijski pokazatelji, Likvidnost, Profitabilnost, Učinkovitost, Konkurentnost*

1. UVOD

Pomorska industrija ima ključnu ulogu u globalnom gospodarstvu jer omogućuje nesmetan protok robe i povezuje međunarodna tržišta (Brčić i dr., 2022). U tom kontekstu, luke djeluju kao čvorišta multimodalnog prometa i pokretači gospodarskog razvoja (Herz i Flämig, 2014). Luka Rijeka, najveća hrvatska teretna luka, ima strateško značenje ne samo za nacionalno gospodarstvo nego i za cijeli prometni koridor koji povezuje Srednju Europu s Mediteranom (Naletina, Baković i Damić, 2017). Cilj rada je analizirati financijske pokazatelje poslovanja Luke Rijeka – likvidnost, zaduženost, profitabilnost i učinkovitost – te ih usporediti s pokazateljima drugih jadranskih luka kako bi se procijenila njezina financijska stabilnost i konkurentnost (Barić, Devčić i Valenčić, 2008; Zanne i Borkowski, 2021). Istraživanje se temelji na kombinaciji teorijskog i empirijskog pristupa, koristeći podatke iz godišnjih financijskih izvještaja Luke Rijeka (Rudić, Hirnig i Rudić, 2007; Zagreb Stock Exchange, 2025) te metode horizontalne, vertikalne i omjerske analize uz primjenu benchmarkinga (Batur i Nikolić, 2015; Munitić, 2019). Takav pristup omogućuje prepoznavanje glavnih snaga i slabosti poslovanja te pruža osnovu za oblikovanje strateških preporuka i budući razvoj luke (Rudić i Gržin, 2020).

2. FINANCIJSKI POKAZATELJI U UPRAVLJANJU

2.1. Značaj financijskih pokazatelja

Financijski pokazatelji predstavljaju kvantitativne instrumente koji omogućuju procjenu uspješnosti, stabilnosti i učinkovitosti poslovanja. Temelje se na podacima iz financijskih izvještaja i služe menadžerima, investitorima i dionicima kao temelj za donošenje racionalnih odluka (Barić, Devčić i Valenčić, 2008). Njihova vrijednost leži u sposobnosti da kompleksne financijske podatke pretvore u sažete informacije koje omogućuju brzu procjenu stanja poduzeća. Pokazatelji profitabilnosti mjere učinkovitost korištenja resursa, dok pokazatelji likvidnosti ukazuju na sposobnost podmirenja kratkoročnih obveza.

Također, imaju važnu internu funkciju – kao alat menadžmenta za planiranje i kontrolu – ali i eksternu, jer pomažu bankama, investitorima i regulatorima u procjeni rizika i kreditne sposobnosti poduzeća (Herz i Flämig, 2014). U pomorskom sektoru, koji je kapitalno intenzivan i globalno izložen, njihova važnost dodatno raste jer osiguravaju transparentnost i smanjuju neizvjesnost poslovanja.

2.2. Uloga financijske analize

Financijska analiza koristi pokazatelje, usporedbe i trendove kako bi se procijenila profitabilnost, zaduženost i likvidnost poduzeća. Njome se identificiraju prednosti i slabosti poslovanja te podržava donošenje strateških odluka (Batur i Nikolić, 2015). Analiza ima preventivnu funkciju jer omogućuje rano prepoznavanje rizika, te korektivnu, jer pomaže u pravodobnom prilagođavanju poslovanja. Osim interne, financijska analiza ima i vanjsku dimenziju – banke je koriste za procjenu kreditne sposobnosti, a investitori za procjenu isplativosti ulaganja (Brčić i dr., 2022). U pomorskim organizacijama transparentnost financijskih izvještaja ključna je za održavanje povjerenja i privlačenje kapitala. Stoga financijska analiza u ovom sektoru ima i operativnu i stratešku ulogu, osiguravajući dugoročnu održivost poslovanja (Herz i Flämig, 2014).

2.3. Specifičnosti financijskog poslovanja pomorskih organizacija

Pomorske organizacije, poput luka i brodarskih kompanija, posluju u složenom međunarodnom okruženju obilježenom velikim ulaganjima, dugoročnim ugovorima i globalnim rizicima (Brčić i dr., 2022). Njihovo poslovanje karakteriziraju visoki fiksni troškovi, potreba za održavanjem infrastrukture i osjetljivost na promjene u globalnoj trgovini, cijenama energenata i geopolitičkim uvjetima. Financijsko upravljanje u takvom okruženju zahtijeva precizno praćenje novčanih tokova i duga, jer veliki infrastrukturni projekti često uključuju značajna kreditna sredstva (Herz i Flämig, 2014). Uz to, regulatorni zahtjevi i ekološki standardi stvaraju dodatne financijske obveze, što povećava važnost sustavne analize financijskih pokazatelja u ocjeni dugoročne održivosti poslovanja.

3. FINANCIJSKI POKAZATELJI I NJIHOVA PRIMJENA

3.1. Likvidnost i solventnost

Likvidnost predstavlja sposobnost poduzeća da podmiri kratkoročne obveze raspoloživim sredstvima, dok solventnost označava dugoročnu sposobnost otplate duga (Islam, 2015). Pokazatelji poput tekućeg i brzog omjera mjere kratkoročnu stabilnost, dok omjer duga i kapitala te pokriće kamata procjenjuju dugoročnu održivost. U pomorskom sektoru, gdje su investicije u infrastrukturu značajne, solventnost postaje presudna za očuvanje povjerenja ulagača i kreditora (Kolanović, 2007). Uspostavljanje ravnoteže između likvidnosti i solventnosti ključno je jer nedostatak jednog od ta dva elementa povećava rizik poslovanja, osobito u lukama koje ovise o sezonskim tokovima i globalnim tržišnim promjenama.

3.2. Pokazatelji profitabilnosti

Profitabilnost odražava sposobnost organizacije da ostvaruje dobit i stvara vrijednost za dioničare. Mjeri se pokazateljima poput neto profitne marže, povrata na imovinu (ROA) i povrata na kapital (ROE) (Hlača, Rudić i Gržin, 2014). U pomorskim organizacijama, visoka profitabilnost pokazuje sposobnost efikasnog korištenja resursa i privlačenja investitora, dok niska profitabilnost može ugroziti tržišni položaj i otežati financiranje razvoja. Luka Rijeka koristi analizu profitabilnosti kako bi prepoznala mogućnosti za modernizaciju i digitalizaciju, čime smanjuje ovisnost o vanjskim izvorima kapitala (Islam, 2015). Pokazatelji profitabilnosti stoga omogućuju istodobnu procjenu prošlih rezultata i budućih potencijala rasta.

3.3. Pokazatelji zaduženosti

Pokazatelji zaduženosti prikazuju u kojoj mjeri poduzeće koristi tuđi kapital za financiranje poslovanja. Najčešće korišteni su omjer duga i kapitala te omjer pokrića kamata (Kolanović, Dundović i Jugović, 2011). U pomorskom sektoru, visok stupanj zaduženosti često proizlazi iz kapitalno intenzivnih projekata, poput proširenja terminala ili ulaganja u logističku infrastrukturu. Iako zaduženost može povećati prinos na kapital, pretjerano oslanjanje na vanjsko financiranje povećava rizik insolventnosti i smanjuje sposobnost privlačenja novih ulaganja. Optimalna struktura kapitala podrazumijeva ravnotežu između vlastitih i tuđih izvora financiranja, čime se osigurava stabilnost i fleksibilnost poslovanja (Kolanović, 2007). Učinkovito upravljanje dugom tako predstavlja jedan od temelja dugoročne održivosti luka i brodarskih kompanija.

3.4. Pokazatelji aktivnosti (učinkovitosti)

Pokazatelji aktivnosti mjere koliko učinkovito poduzeće koristi raspoložive resurse za stvaranje prihoda. Među njima su najvažniji promet imovine, promet potraživanja i promet zaliha, dok u pomorskim organizacijama dodatno uključuju iskorištenost skladišnih i terminalskih kapaciteta (Munitić, 2019). Visoka stopa prometa imovine ukazuje na učinkovito korištenje infrastrukture i optimizaciju kapaciteta, dok niska može signalizirati operativne neefikasnosti. Luka koja postiže dobar promet imovine ostvaruje niže troškove po jedinici tereta i veći povrat na ulaganja. Redovito praćenje ovih pokazatelja omogućuje pravovremeno prepoznavanje uskih grla u poslovanju i poboljšanje likvidnosti te ukupne operativne učinkovitosti (Kolanović, Dundović i Jugović, 2011).

3.5. Tržišni pokazatelji

Tržišni pokazatelji prikazuju vrijednost poduzeća iz perspektive tržišta kapitala i investitora. Najčešće korišteni su omjer cijene i zarade (P/E), omjer cijene i knjigovodstvene vrijednosti (P/B) te prinos na dividendu (Munitić, 2019). U pomorskim organizacijama ti pokazatelji odražavaju percepciju tržišta o budućoj profitabilnosti i rizicima poslovanja. Visoki tržišni omjeri sugeriraju stabilne prihode i povjerenje investitora, dok niži mogu ukazivati na rizik ili pad konkurentnosti. Za luke, posebno one koje planiraju dodatna ulaganja, tržišni pokazatelji predstavljaju ključan alat u privlačenju kapitala i partnerstava. Oni služe i kao veza između stvarnih financijskih performansi i tržišnih očekivanja (Kolanović, 2007).

3.6. Analitički alati i metode

Procjena financijskih pokazatelja provodi se različitim analitičkim metodama, među kojima su najčešće horizontalna i vertikalna analiza, analiza trendova te benchmarking – usporedba s najboljim praksama u industriji (Munitić, 2019). Horizontalna analiza prati promjene kroz vrijeme, vertikalna analizira strukturu financijskih izvještaja, a benchmarking omogućuje usporedbu s konkurentskim lukama i brodarskim kompanijama. U novije vrijeme sve više se primjenjuju modeli koji integriraju financijske i nefinancijske pokazatelje, uključujući održivost i ESG kriterije (Kolanović, Dundović i Jugović, 2011). Digitalizacija financijske analize povećava preciznost, dostupnost podataka i brzinu donošenja odluka, čime luke poput Rijeke mogu učinkovitije reagirati na tržišne promjene. Time suvremeni analitički alati postaju ključni instrument dugoročne konkurentnosti i otpornosti pomorskih organizacija.

4. LUKE KAO POMORSKE ORGANIZACIJE

4.1. Uloga luka u međunarodnoj trgovini

Luke imaju presudnu ulogu u međunarodnoj trgovini jer omogućuju prijenos robe između kontinenata i održavanje globalnih lanaca opskrbe (Naletina, Baković i Damić, 2017).

One su središta logističke aktivnosti, distribucije i dodane vrijednosti, a njihova učinkovitost izravno utječe na konkurentnost izvoznika i uvoznika. Učinkovita luka smanjuje troškove transporta i skraćuje vrijeme isporuke, dok neučinkovita može ograničiti gospodarski rast i razvoj regije. Osim ekonomskog značaja, luke imaju i širu društvenu ulogu jer potiču zapošljavanje, ulaganja i razvoj lokalne infrastrukture. Financijski pokazatelji luka stoga ne odražavaju samo njihovu internu uspješnost, već i širi doprinos regionalnom i nacionalnom gospodarstvu (Rudić i Gržin, 2020).

4.2. Organizacijska struktura luka

Organizacijska struktura luka ovisi o veličini, vrsti tereta i vlasničkom modelu. Veće luke obično imaju kompleksne organizacije s više odjela – operativnim, logističkim, financijskim, sigurnosnim i tehničkim (Rudić i Gržin, 2020). U manjim lukama funkcije su češće objedinjene, što omogućuje fleksibilnost, ali smanjuje specijalizaciju. Uspješnost poslovanja ovisi o usklađenosti organizacijske strukture sa strateškim ciljevima. Privatne luke uživaju veću autonomiju u odlučivanju, dok javne djeluju u okviru zakonskih propisa i državnog nadzora (Rudić, Hirnig i Rudić, 2007). Prilagodljiva i učinkovita struktura ključna je za optimalno korištenje resursa i povećanje profitabilnosti.

4.3. Upravljanje i poslovni modeli luka

Upravljanje lukom podrazumijeva koordinaciju svih operativnih, financijskih i logističkih aktivnosti, pri čemu poslovni model značajno utječe na učinkovitost i rezultate (Zanne i Borkowski, 2021). Postoje tri osnovna modela: javni, privatni i mješoviti. Javni model usmjeren je na strateške ciljeve i razvoj infrastrukture, dok privatni naglašava tržišnu orijentaciju, profitabilnost i fleksibilnost. Mješoviti model kombinira prednosti oba pristupa, omogućujući ravnotežu između javnog interesa i tržišne učinkovitosti (Naletina, Baković i Damić, 2017). Financijski pokazatelji u ovom kontekstu služe za praćenje operativne učinkovitosti, profitabilnosti i održivosti ulaganja. Dobro upravljanje omogućuje dugoročnu stabilnost i konkurentnost luke.

4.4. Regulatorni okviri i zakonodavstvo

Pomorske luke djeluju u kompleksnom regulatornom sustavu koji obuhvaća međunarodne konvencije, nacionalne zakone i standarde sigurnosti te zaštite okoliša (Rudić i Gržin, 2020). Na razini EU, direktive i norme Međunarodne pomorske organizacije (IMO) definiraju minimalne standarde sigurnosti, ekologije i transparentnosti. Poštivanje propisa često zahtijeva dodatna ulaganja, ali istodobno povećava održivost i povjerenje poslovnih partnera (Zanne i Borkowski, 2021). Nepoštivanje regulativa može uzrokovati kazne, gubitak koncesija ili reputacijske štete, što izravno utječe na financijske pokazatelje i stabilnost poslovanja.

4.5. Financijski izvori i investicije u lukama

Razvoj luka zahtijeva značajna financijska sredstva za infrastrukturu, tehnologiju i logističke sustave. Najčešći izvori su vlastita sredstva, zajmovi, državne subvencije i privatna ulaganja (Malenica, 2007). Optimalna kombinacija ovih izvora smanjuje rizik i omogućuje dugoročno održivo financiranje. Državna potpora često je usmjerena u projekte od strateškog značaja, dok privatna ulaganja donose kapital i znanje. Ulaganja u modernizaciju, digitalizaciju i ekološku infrastrukturu povećavaju učinkovitost i poboljšavaju pokazatelje profitabilnosti i povrata na kapital (Rudić, Hirnig i Rudić, 2007).

4.6. Rizici poslovanja luka

Lučko poslovanje suočeno je s brojnim rizicima – financijskim, operativnim, regulatornim i tržišnim. Financijski rizici uključuju promjene u likvidnosti, kamatnim stopama i kreditnoj sposobnosti; tržišni rizici odnose se na fluktuacije potražnje i cijena energenata; regulatorni pak proizlaze iz promjena zakonskih okvira i ekoloških zahtjeva (Zanne i Borkowski, 2021). Upravljanje rizicima zahtijeva sustavno planiranje, osiguranje i ulaganje u sigurnosne sustave (Malenica, 2007). Proaktivan pristup rizicima povećava otpornost luke, štiti njezinu reputaciju i osigurava održivost poslovanja.

5. STUDIJA SLUČAJA: LUKA RIJEKA

5.1. Povijest i razvoj Luke Rijeka

Zbog svog strateškog položaja na Jadranskom moru i važnosti u međunarodnoj trgovini, Luka Rijeka ima dugu povijest razvoja koja seže nekoliko stoljeća unatrag. Tijekom 20. stoljeća, uslijed industrijalizacije i rasta svjetske trgovine, luka je doživjela ubrzanu ekspanziju, uz kontinuirana ulaganja u terminale, mehanizaciju i pristanišnu infrastrukturu (Zagreb Stock Exchange, 2025). U novijem razdoblju, Luka Rijeka provodi intenzivnu modernizaciju kroz digitalizaciju poslovanja, automatizaciju lučkih procesa i ulaganja u održivu infrastrukturu. Rezultati tih investicija vidljivi su kroz stabilan rast prihoda, povećanje profitabilnosti te poboljšanje likvidnosti, uz umjereno smanjenje razine duga (Rajsman, 2012). Ova ulaganja potvrđuju njezinu važnost ne samo kao operativnog centra, već i kao generatora gospodarskog razvoja u regiji i Hrvatskoj.

5.2. Struktura i organizacija Luke Rijeka

Organizacijska struktura Luke Rijeka odražava složenost njezinih operacija. Sastoji se od odjela za operacije, logistiku, financije, ljudske resurse, sigurnost i održavanje infrastrukture. Financijski odjel ima središnju ulogu u praćenju pokazatelja profitabilnosti, likvidnosti i duga, dok operativni odjel upravlja terminalima i koordinira promet (Zagreb Stock Exchange, 2025). Luka Rijeka djeluje prema mješovitom modelu upravljanja, u kojem su prisutni i javni i privatni elementi. Takav model omogućuje stabilnost i učinkovitost, ali zahtijeva pažljivo upravljanje rizicima i kapitalom (Krpan, Furjan i Maršanić, 2014). Struktura Luke Rijeka prilagođena je dugoročnim ciljevima modernizacije, ekološke održivosti i povećanja konkurentnosti na regionalnom tržištu.

5.3. Financijski pokazatelji Luke Rijeka

Analiza financijskih pokazatelja Luke Rijeka za razdoblje 2020.–2024. pokazuje stabilan i održiv rast poslovanja. Ukupni prihodi povećali su se s 70 milijuna EUR (2020.) na 99 milijuna EUR (2024.), dok je neto dobit porasla s 10 na 19 milijuna EUR. Najveći udio prihoda ostvaruje se iz rukovanja teretom i koncesijskih naknada, dok dodatni prihodi dolaze od zakupa i logističkih usluga (Rudić, Hirnig i Rudić, 2007). Likvidnost je zabilježila pozitivan trend – tekući omjer porastao je s 1,5 na 1,9, a omjer ukupnog duga i kapitala smanjen je na 0,45, što ukazuje na povećanu financijsku stabilnost. Profitabilnost je također u porastu: neto marža iznosi 19 %, a ROE 10,5 % u 2024. godini. Ovi rezultati ukazuju na rast učinkovitosti i dobru ravnotežu između ulaganja i zaduženosti. U usporedbi s lukama Koper, Ploče i Bar, Luka Rijeka bilježi konkurentne rezultate – posebno u pogledu povrata na imovinu i obrtaja kapaciteta – čime potvrđuje svoj status vodeće luke hrvatskog dijela Jadrana (Rudić, Hirnig i Rudić, 2007).

5.4. Investicije i razvojni projekti

Ulaganja u infrastrukturu, modernizaciju terminala i digitalne tehnologije predstavljaju temeljnu komponentu strategije Luke Rijeka.

Ključni projekti uključuju modernizaciju kontejnerskog terminala, automatizaciju logističkih sustava i implementaciju ekoloških rješenja u skladu s europskim standardima (Rajsman, 2012). Ova ulaganja povećavaju kapacitet i učinkovitost, ali zahtijevaju odgovorno upravljanje zaduženjem i likvidnošću. Financijski pokazatelji, posebno ROI, koriste se za procjenu isplativosti projekata (Malenica, 2007). Ekološki projekti, iako ne stvaraju izravne prihode, smanjuju regulatorne rizike i jačaju imidž Luke Rijeka kao održive i odgovorne organizacije.

5.5. Analiza rizika i izazova

Poslovanje Luke Rijeka izloženo je brojnim rizicima – od operativnih i financijskih do tržišnih i regulatornih. Operativni rizici obuhvaćaju kvarove opreme, kašnjenja i incidente, dok financijski rizici uključuju oscilacije kamatnih stopa i valutnih tečajeva (Krpan, Furjan i Maršanić, 2014). Tržišni rizici povezani su s promjenama globalne potražnje i cijenama energenata, dok regulatorni rizici proizlaze iz usklađivanja s međunarodnim propisima (Rudić, Hirnig i Rudić, 2007). Luka Rijeka primjenjuje diversifikaciju prihoda, investicije u sigurnosne sustave i preventivne mjere za upravljanje rizicima, čime osigurava stabilnost i otpornost poslovanja.

5.6. Perspektive razvoja

Razvojne perspektive Luke Rijeka temelje se na digitalnoj transformaciji, proširenju kapaciteta i održivom poslovanju (Rudić i Gržin, 2020). Planirani projekti uključuju izgradnju novih terminala, digitalne sustave za praćenje prometa i ulaganja u obnovljive izvore energije (Malenica, 2007). Osim tehnoloških ulaganja, naglasak je na razvoju ljudskog kapitala kroz edukaciju zaposlenika i menadžerske kompetencije. Korištenje financijskih pokazatelja omogućuje kontinuirano praćenje rezultata, identifikaciju odstupanja i pravovremeno prilagođavanje strategije. Takav integrirani pristup pridonosi dugoročnoj održivosti i jačanju pozicije Luke Rijeka u okviru europskih prometnih koridora.

6. TEORIJA FINANCIJSKIH POKAZATELJA U POMORSKIM ORGANIZACIJAMA

6.1. Specifičnosti financijskog poslovanja pomorskih organizacija

Financijski pokazatelji u pomorskim organizacijama predstavljaju ključne alate za ocjenu uspješnosti, učinkovitosti i stabilnosti poslovanja. Njihova uloga nije ograničena na internu kontrolu, već obuhvaća i komunikaciju s investitorima, regulatorima i partnerima (Zagreb Stock Exchange, 2025). U kapitalno intenzivnim sustavima poput luka, praćenje pokazatelja likvidnosti, profitabilnosti i zaduženosti nužno je za postizanje ravnoteže između kratkoročnih operativnih ciljeva i dugoročnih ulaganja (Rudić i Gržin, 2020). Benchmarking prema drugim lukama omogućuje identifikaciju najboljih praksi i jačanje konkurentnosti (Rudić, Hirnig i Rudić, 2007). Sustavna primjena financijskih pokazatelja time postaje temelj učinkovitog strateškog upravljanja.

6.2. Likvidnost i solventnost u pomorskim organizacijama

Likvidnost pokazuje sposobnost luke da podmiri kratkoročne obveze, dok solventnost mjeri dugoročnu održivost i sposobnost financiranja kapitalnih projekata (Malenica, 2007). Redovito praćenje tekućeg i brzog omjera omogućuje pravodobno planiranje novčanih tokova, a analiza omjera duga i kapitala te pokrića kamata osigurava održivost poslovanja (Zanne i Borkowski, 2021). Ravnoteža između likvidnosti i solventnosti preduvjet je stabilnog financijskog upravljanja u pomorskom sektoru, osobito u razdobljima tržišnih nestabilnosti.

6.3. Profitabilnost i analiza prihoda u lukama

Profitabilnost je ključni pokazatelj uspješnosti poslovanja jer mjeri sposobnost generiranja dobiti kroz različite izvore – od lučkih naknada do koncesija i zakupa (Rajsman, 2012). Pokazatelji kao što su neto marža, ROA i ROE omogućuju uvid u učinkovitost korištenja kapitala i resursa. U lukama poput Rijeke, profitabilnost je izravno povezana s operativnom učinkovitošću, optimizacijom troškova i diversifikacijom prihoda (Krpan, Furjan i Maršanić, 2014). Sustavna analiza profitabilnosti time doprinosi dugoročnoj održivosti i investicijskoj privlačnosti.

6.4. Učinkovitost i promet imovine u pomorskom sektoru

Pokazatelji učinkovitosti i prometa imovine mjere sposobnost luke da koristi svoju imovinu u stvaranju prihoda (Naletina, Baković i Damić, 2017). Visok promet imovine ukazuje na racionalno korištenje kapaciteta i dobru organizaciju poslovanja. Optimizacija procesa pretovara, smanjenje zastoja i digitalno praćenje prometa izravno povećavaju povrat na imovinu (ROA) i povrat na ulaganja (ROI). Time se jača ukupna produktivnost i konkurentnost luke (Zanne i Borkowski, 2021).

6.5. Zaduženost i financijska struktura luka

Financijska struktura luka odražava odnos između vlastitog i tuđeg kapitala te ravnotežu kratkoročnih i dugoročnih obveza. Pretjerana zaduženost povećava rizik, dok preniska može ograničiti rast i investicije (Herz i Flämig, 2014). Optimalna struktura osigurava fleksibilnost i solventnost te omogućuje financiranje kapitalno zahtjevnih projekata bez ugrožavanja stabilnosti poslovanja. Integrirana analiza zaduženosti s pokazateljima profitabilnosti i učinkovitosti ključna je za dugoročno održivo upravljanje (Rudić i Gržin, 2020).

6.6. Benchmarking i usporedba s drugim lukama

Benchmarking omogućuje usporedbu financijskih i operativnih pokazatelja među lukama radi identifikacije najboljih praksi i povećanja učinkovitosti (Naletina, Baković i Damić, 2017). Uključuje analizu ključnih pokazatelja – profitabilnosti, likvidnosti, učinkovitosti i zaduženosti – te operativnih metrika poput prometa tereta i iskorištenosti terminala. Usporedba s regionalnim lukama, poput Kopra i Trsta, omogućuje Luki Rijeka da prepozna svoje konkurentske prednosti i područja za unaprjeđenje. Rezultati benchmarkinga doprinose strateškom planiranju i predstavljaju dokaz transparentnosti i stabilnosti (Zanne i Borkowski, 2021; Zagreb Stock Exchange, 2025).

7. ZAKLJUČAK

Financijski pokazatelji predstavljaju temeljni alat za razumijevanje i upravljanje poslovanjem pomorskih organizacija. Njihova primjena omogućuje kvantitativnu procjenu uspješnosti, učinkovitosti i stabilnosti poslovanja te pruža osnovu za strateško odlučivanje. Studija slučaja Luke Rijeka pokazala je da sustavno praćenje pokazatelja – likvidnosti, profitabilnosti, solventnosti, učinkovitosti i zaduženosti – omogućuje jasnu procjenu financijskog položaja i razvojnih potencijala. Luka Rijeka bilježi stabilan rast prihoda, poboljšanje likvidnosti i profitabilnosti te smanjenje razine duga, što ukazuje na uspješnost njezine strategije upravljanja i otpornost na tržišne promjene. Rezultati potvrđuju snažnu povezanost između financijskih pokazatelja i strateškog menadžmenta. Njihova pravilna primjena omogućuje pravovremeno prepoznavanje rizika, optimizaciju operacija i učinkovitije upravljanje investicijama. U budućnosti, daljnji razvoj luka trebao bi se temeljiti na digitalizaciji financijske analize, uključivanju održivosti u procjene učinkovitosti i jačanju transparentnosti poslovanja. Zaključno, financijska analiza u pomorskim organizacijama nije samo instrument izvještavanja, već ključni alat strateškog odlučivanja i dugoročne konkurentnosti.

Luka Rijeka dokaz je da se odgovornim upravljanjem i sustavnom primjenom financijskih pokazatelja može osigurati stabilan rast, otpornost na promjene i jačanje pozicije hrvatskog pomorskog sektora unutar europskog prometnog sustava.

NAPOMENA: *Ovaj je članak proizašao iz diplomskog rada studenta Grge Milanovića izrađenog i obranjenog na Pomorskom fakultetu Sveučilišta u Splitu.*

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ECONOMIC ASPECTS OF MARITIME HEALTH: A LITERATURE REVIEW

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ABSTRACT

Maritime health, which encompasses medical care for seafarers, fishers, offshore oil platform workers, and passengers, represents an important yet often overlooked component of global health. This literature review summarizes the available evidence on the clinical, economic, and regulatory aspects of healthcare at sea. Particular attention is given to the costs of providing medical services, the economics of preventive medicine, and the impact on global trade and maritime regulations. The findings emphasize that effective maritime health systems should be regarded as an essential factor in the economic sustainability and resilience of global supply chains.

Keywords: *Maritime health, Seafarers, Telemedicine, Preventive medicine, Health economics*

EKONOMSKI ASPEKTI POMORSKOG ZDRAVSTVA: PREGLED LITERATURE

SAŽETAK

Pomorsko zdravstvo, koje obuhvaća medicinsku skrb za pomorce, ribare, radnike na naftnim platformama i putnike, predstavlja važnu, ali često zanemarenu komponentu globalnog zdravstva. Upravo ovaj pregledni rad sažima dostupne dokaze o kliničkim, ekonomskim i regulatornim aspektima zdravstvene zaštite na moru. Posebna pažnja posvećena je troškovima pružanja zdravstvene skrbi, ekonomici preventivne medicine te utjecaju na globalnu trgovinu i pomorske propise. Zaključci ističu da se učinkoviti pomorski zdravstveni sustavi moraju promatrati kao neizostavan čimbenik ekonomske održivosti i otpornosti globalnih opskrbnih lanaca.

Ključne riječi: *Pomorsko zdravstvo, Pomorci, Telemedicina, Preventivna medicina, Zdravstvena ekonomika*

1. UVOD

Pomorska industrija, koja pokreće više od 90% svjetske trgovine i zapošljava milijune radnika, ovisi o zdravlju i sigurnosti svoje radne snage. Pružanje zdravstvene skrbi na moru suočeno je s brojnim izazovima koji proizlaze iz geografske izoliranosti, ograničenih medicinskih resursa i ovisnosti o telemedicinskoj podršci. Posljedično, ekonomski čimbenici, izravni i neizravni, snažno utječu na organizaciju i financiranje zdravstvene skrbi.

Pomorsko zdravstvo obuhvaća preventivnu, hitnu i profesionalnu zdravstvenu zaštitu osoba koje rade ili borave na moru. Procjenjuje se da oko 1,9 milijuna pomoraca radi u globalnoj trgovačkoj floti, zajedno s milijunima radnika u ribarstvu, kruzing industriji i naftnim postrojenjima. Njihova izolacija, ekstremni uvjeti rada i multikulturalne posade čine medicinske i organizacijske izazove iznimno složenima.

2. ZDRAVSTVENI PROFIL POMORACA

Pomorci se suočavaju sa specifičnim profesionalnim i osobnim rizicima, koji značajno utječu na njihovo zdravlje. Najčešći zdravstveni problemi uključuju kardiovaskularne bolesti, mišićno-koštane poremećaje i ozljede te mentalne poremećaje. Među pomorcima je zabilježena i veća učestalost metaboličkog sindroma, pretilosti, pušenja i konzumacije alkohola u odnosu na opću populaciju. Nadalje, poremećaji spavanja, kronični umor i stres učestali su zbog neredovitih smjena i dugotrajne izolacije, a ograničene mogućnosti rekreacije i socijalne interakcije dodatno pogoršavaju psihološko stanje posade. Negativne posljedice ovih psihosocijalnih čimbenika vidljive su u smanjenoj radnoj učinkovitosti, narušenoj sigurnosti i slabijim ekonomskim rezultatima.

Sigurnost i zaštita zdravlja na radu ključni su elementi pomorske medicine. Pomorska radna konvencija (MLC 2006) postavlja minimalne standarde zdravstvene zaštite i prevencije nesreća. Unatoč tome, pomorci se i dalje susreću s brojnim profesionalnim opasnostima, uključujući padove, izloženost kemikalijama, buku, toplinski stres i ozljede zbog klizavih površina. Također, dugotrajni boravak na moru, kulturne razlike i ograničena komunikacija doprinose umoru i smanjenju koncentracije, što povećava rizik od ljudske pogreške i nesreća. Stoga, mentalno zdravlje ima izrazitu medicinsku i ekonomsku važnost.

2.1. Organizacija zdravstvene skrbi

Većina brodova nema brodskog liječnika, pa medicinsku skrb pružaju časnici obučeni za hitnu pomoć, uz podršku centara Telemedical Maritime Assistance Service (TMAS). TMAS službe, pod nadzorom Međunarodne pomorske organizacije (IMO), dostupne su 24 sata dnevno putem radija, e-maila ili satelitske komunikacije. Razvoj telemedicine uvelike je unaprijedio dostupnost i kvalitetu skrbi. Videokonzultacije, elektronički kartoni i sustavi za daljinsko praćenje zdravlja povećavaju sigurnost i brzinu reakcije.

Ipak, izazovi poput ograničene povezanosti, troškova satelitske komunikacije i razlika u razini digitalne pismenosti i dalje su prisutni, osobito u zemljama s nižim dohotkom. Zatvoreni brodski prostori i globalne rute pogoduju širenju zaraznih bolesti. Pandemija COVID-19 pokazala je ranjivost pomorskog sektora, kada su kruzeri postali žarišta infekcije, a tisuće pomoraca blokirani u lukama. Prevencija uključuje cijepljenje, higijenske mjere, izolaciju oboljelih i suradnju s lučkim zdravstvenim službama. Međunarodni zdravstveni propisi (IHR 2005) i smjernice Svjetske zdravstvene organizacije naglašavaju potrebu za globalnim nadzorom i brzim protokolima djelovanja u slučaju epidemija. Pomorska medicina sve se više oslanja na digitaliziraciju. Nosivi uređaji, umjetna inteligencija i elektroničke zdravstvene iskaznice pomoraca omogućuju kontinuirano praćenje i rano otkrivanje zdravstvenih problema. Automatizacija i analiza podataka i dalje će omogućavati prediktivno upravljanje rizikom i smanjenje nesreća povezanih sa zdravljem.

2.1.1. Pravni i regulatorni okvir

Pravni i regulatorni okvir pomorskog zdravstva uređen je nizom međunarodnih konvencija:

- Pomorska radna konvencija (MLC 2006) – minimalni standardi zdravstvene skrbi i zaštite pomoraca
- Konvencija o standardima izobrazbe i ovlaštenja pomoraca (STCW) – propisuje zahtjeve za medicinsku obuku posade
- Međunarodni zdravstveni propisi (IHR 2005) – propisuju nadzor zaraznih bolesti te suradnju luka i država

Nacionalni zakoni i standardi

- Većina zemalja implementira međunarodne konvencije u vlastite zakone, prilagođavajući ih lokalnim uvjetima i potrebama
- Primjeri uključuju standarde za lučke zdravstvene službe, pravila za medicinsku njegu na kopnu i uvođenje digitalnih sustava za praćenje zdravlja pomoraca

Regulativni izazovi i budući razvoj

- Potreba za usklađivanjem različitih nacionalnih propisa s međunarodnim standardima radi učinkovitije zaštite zdravlja
- Uvođenje elektroničkih zdravstvenih iskaznica i sustava za nadzor zdravlja zahtijeva stroge sigurnosne mjere i međunarodnu suradnju
- Razvijanje protokola za brzo djelovanje u slučaju epidemija i drugih hitnih medicinskih situacija na moru

3. EKONOMSKI ASPEKTI POMORSKOG ZDRAVSTVA

Pružanje zdravstvene skrbi na moru ima značajne izravne i neizravne ekonomske posljedice za brodarske tvrtke, osiguravatelje i države.

1. Izravni troškovi

Obuhvaćaju nabavu medicinske opreme i potrošnog materijala, ugovore s TMAS centrima (procjenjuje se 5.000,00 – 20.000,00 € godišnje po brodu), obuku posade iz prve pomoći te hitne medicinske evakuacije koje mogu koštati 10.000,00 – 100.000,00 €.

2. Neizravni troškovi

Neizravni troškovi uključuju odstupanje od planirane rute, kašnjenja, povećane premije osiguranja i smanjenje produktivnosti zbog bolesti ili umora. Procjenjuje se da gubici uzrokovani zdravstvenim problemima čine 3 – 5% godišnje globalne produktivnosti u pomorstvu.

3. Preventivne mjere i telemedicina

Ulaganja u prevenciju i telemedicinu pokazuju visoku isplativost. Sustavi video telemedicine mogu smanjiti potrebu za evakuacijama do 40%, a programi promocije zdravlja posade povećavaju zadovoljstvo i smanjuju fluktuaciju radnika. Povrat ulaganja u preventivne programe procjenjuje se na četiri do šest puta veći u odnosu na troškove hitne skrbi.

4. Makroekonomske posljedice

Zdravlje pomoraca izravno utječe na stabilnost globalne trgovine. Epidemije i zdravstvene krize mogu paralizirati luke i uzrokovati velike financijske gubitke. Tijekom pandemije COVID-19 procijenjeni globalni gubici u pomorskom sektoru premašili su 350 milijardi USD.

5. Implikacije za politiku

Ekonomska logika nalaže uključivanje pomorskog zdravstva u nacionalne zdravstvene sustave, stvaranje poticaja za ulaganje u prevenciju te financijsku podršku zemljama s nižim dohotkom za razvoj telemedicinske infrastrukture. Zdravlje na moru mora se promatrati kao strateško ulaganje, a ne trošak.

4. ZAKLJUČAK

Prijelaz pomorskog zdravstva s modela hitne intervencije na preventivnu, tehnološki naprednu medicinu ključan je za budućnost industrije. Sustavna ulaganja u digitalnu infrastrukturu, kontinuiranu edukaciju posade i aktivnu promociju zdravih navika donose dugoročne ekonomske i društvene koristi.

Konačno, prepoznavanje zdravstvene zaštite pomoraca kao strateške gospodarske vrijednosti zahtijeva suradnju država, brodskih kompanija i javnozdravstvenih institucija. Takav integrirani pristup ne samo da štiti zdravlje pomoraca, već i jamči stabilnost globalnih opskrbnih lanaca.

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ECONOMIC AND LEGAL ASPECTS OF PROTECTING AI-ASSISTED INVENTIONS

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ABSTRACT

The protection of intellectual property—particularly patent protection as one of its key forms—significantly contributes to stimulating investment in research and development, and thus to economic growth. Patent protection, especially in the context of inventions created with the help of artificial intelligence (AI), is becoming increasingly important, and the protection of such inventions requires an approach that incorporates economic, legislative, and ethical considerations. The development of legal frameworks and intellectual property protection strategies is crucial for fostering innovation in the field of AI and related technologies. The aim of this paper is to examine and explain the economic and legislative aspects of protecting inventions generated using AI, as well as their impact on economic growth and competitiveness. The analysis is based on secondary data drawn from relevant databases of Eurostat, WIPO, and the EPO, while data on AI were sourced from the "AI Index Report." The analysis was conducted at the macroeconomic level and includes selected highly developed EU member states. The results indicate a positive impact of patent protection for AI-related inventions on countries' economic growth and competitiveness, observed through increases in GDP per capita, the number of granted AI-related patents, R&D expenditure, and the number of newly established AI-driven companies. The findings also point to the need for continuous alignment and harmonization of the legislative framework governing the application of AI and the protection of AI-generated inventions, with particular emphasis on questions of inventorship and ownership. Future research should focus on analyzing the correlation between the growth of AI-related patenting and increases in GDP per capita, taking into account variations among EU member states and factors such as economic size, the specific characteristics of individual industrial sectors, and levels of development within the EU. Such an approach would provide a deeper understanding of the influence of AI technology development on the economic growth and competitiveness of EU countries.

Keywords: *economic growth, artificial intelligence, intellectual property protection, patent*

EKONOMSKI I PRAVNI ASPEKTI ZAŠTITE IZUMA STVORENIH POMOĆU UMJETNE INTELIGENCIJE

SAŽETAK

Zaštita intelektualnog vlasništva, osobito zaštita izuma patentom kao jednim od oblika zaštite, značajno doprinosi poticanju ulaganja u istraživanje i razvoj, a time i gospodarskom rastu. Patentna zaštita, posebno u kontekstu izuma stvorenih uz pomoć umjetne inteligencije (UI), postaje sve važnija, a zaštita takvih izuma zahtijeva pristup koji obuhvaća ekonomske, zakonodavne i etičke aspekte. Razvoj zakonskih okvira i strategija zaštite intelektualnog vlasništva ključan je za poticanje inovacija u području UI i srodnih tehnologija. Cilj ovog rada jest istražiti i objasniti ekonomske i zakonodavne aspekte zaštite izuma nastalih pomoću UI te njihov učinak na gospodarski rast i konkurentnost. Za potrebe analize korišteni su sekundarni podaci preuzeti iz relevantnih baza podataka Eurostata, WIPO-a, EPO-a, dok je za analizu podataka o UI korišten „AI Index Report." Analiza je provedena na makroekonomskoj razini i uključuje odabrane visokorazvijene zemlje članice Europske unije. Rezultati provedenog istraživanja ukazuju na pozitivan utjecaj patentne zaštite izuma povezanih s UI na gospodarski rast i konkurentnost zemalja, promatrano kroz povećanje BDP-a po stanovniku, broj odobrenih patenata vezanih uz UI, izdvajanja za istraživanje i razvoj te broj novoosnovanih tvrtki koje koriste UI. Također, rezultati upućuju na potrebu kontinuiranog usklađivanja i harmonizacije zakonodavnog okvira primjene UI i zaštite izuma stvorenih pomoću UI, s naglaskom na pitanja izumiteljstva i vlasništva nad takvim izumima. Fokus budućih istraživanja trebao bi staviti naglasak na analizu korelacije između rasta broja patenata vezanih uz UI i rasta BDP-a po stanovniku, uzimajući u obzir varijacije među državama članicama Europske unije te čimbenike poput veličine gospodarstva, specifičnosti pojedinih industrijskih sektora i stupnja razvijenosti zemalja unutar EU-a, kako bi se bolje razumio utjecaj razvoja tehnologija UI na gospodarski rast i konkurentnost zemalja EU-a.

Ključne riječi: *gospodarski rast, umjetna inteligencija, zaštita intelektualnog vlasništva, patent*

1. UVOD

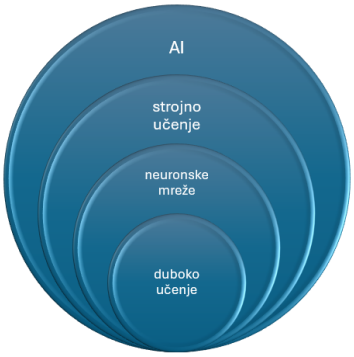
Umjetna inteligencija (en. Artificial Intelligence - AI) (u daljnjem tekstu: UI) jedno je od najznačajnijih tehnoloških dostignuća 21. stoljeća. U današnjem brzo razvijajućem tehnološkom okruženju, sve veća pažnja pridaje se potencijalu UI da preoblikuje društvo, gospodarstvo i svakodnevni život. UI je područje računarstva koje se bavi razvojem sposobnosti računala da obavljaju zadatke koji su tradicionalno zahtijevali ljudsku inteligenciju. UI predstavlja simulaciju ljudske inteligencije u računalima koja su programirana da „razmišljaju" poput ljudi i oponašaju njihove radnje. Razvoj UI donosi značajne promjene u načinu stvaranja i zaštite izuma te stoga patentna zaštita izuma stvorenih pomoću UI postaje sve relevantnija u kontekstu brzine tehnološkog razvoja te gospodarskog rasta i konkurentnosti koju ona omogućuje. Automatizacija istraživačkih i razvojnih procesa primjenom UI smanjuje vrijeme i troškove potrebne za stvaranje izuma. S druge strane, izumi stvoreni pomoću UI mogu otvoriti nova tržišta i poslovne prilike kroz razvoj novih proizvoda i usluga. Patentima zaštićeni izumi postaju vrijedna imovina i povećavaju tržišnu vrijednost tvrtki. Napredak u području UI značajno je utjecao na suvremeno tržište rada. Integracija UI u razvojne i poslovne procese donosi promjene u prirodi poslova, potrebnim vještinama i načinu funkcioniranja organizacija (Santana i Díaz-Fernández, 2022). UI preuzima ponavljajuće i vremenski zahtjevne zadatke dok poboljšanje proizvodnih procesa i logistike optimizira poslovanje i smanjuje troškove (Bonadio, 2021). Sve veća primjena UI u industriji dovela je do prepoznavanja njezinog potencijala i porasta potražnje za sustavima UI.

To potiče daljnji razvoj i usavršavanje tehnologije UI te kreiranje novih sustava UI što posljedično doprinosi jačanju izvoza sustava UI iz tehnološki razvijenih zemalja te pozitivno utječe na njihov gospodarski rast i globalni tehnološki napredak (Soni, 2020). Zaštita prava intelektualnog vlasništva, osobito patenti, ima ključnu ulogu u poticanju inovacija i razvoju novih proizvoda obzirom da osigurava pravnu zaštitu nematerijalne imovine koju je stvorila pojedina organizacija ili tvrtka. Zemlje članice Europske unije, kao i većina razvijenih zemalja, aktivno ulažu u zaštitu intelektualnog vlasništva, razvijajući politike zaštite s posebnim naglaskom na patentnu zaštitu. Osim toga, ove zemlje kontinuirano ulažu u istraživanje i razvoj novih tehnologija, naglašavajući njihov ključni utjecaj na inovacije i gospodarski rast. Ulaganja u istraživanje i razvoj važan su čimbenik u stvaranju novih znanja i tehnologija, koje je potrebno zaštititi odgovarajućim oblicima zaštite intelektualnog vlasništva, ponajprije patentima, kako bi se pretvorila u konkretne proizvode i usluge (Bezić i Karanikić, 2014). Unatoč visokim troškovima, ulaganja u istraživanje i razvoj ključna su za gospodarski rast. Primjena UI u različitim industrijama otvorila je raspravu o zakonodavnim aspektima zaštite izuma stvorenih pomoću UI. Iako UI pozitivno utječe na gospodarski rast, postoji i potreba za pravnom zaštitom izuma stvorenih putem UI. Relevantnost gospodarskih aktivnosti vezanih uz primjenu UI istovremeno zahtijeva razvoj odgovarajućeg zakonodavnog okvira sustava zaštite prava intelektualnog vlasništva te zakonodavnog okvira koji se odnosi na izume stvorene umjetnom inteligencijom. Cilj ovog rada je pružiti teorijski okvir te analizirati ekonomske i zakonodavne aspekte zaštite izuma stvorenih umjetnom inteligencijom i njihov utjecaj na gospodarski rast i konkurentnost s osvrtom na izabrane visokorazvijene zemlje članice Europske unije. Istraživačko pitanje ovog rada jest na koji način izumi stvoreni uz pomoć UI, uz analizu pratećeg zakonodavnog okvira njihove zaštite, utječu na gospodarski rast i konkurentnost. Za potrebe analize osim pregleda dostupne literature koristili su se i podaci dostupni u relevantnim bazama podataka Svjetske organizacije za intelektualno vlasništvo (en. World Intellectual Property Organization - WIPO), Europskog patentnog ureda (en. European Patent Offoce - EPO) i Statističkog ureda Europske unije (en. Statistical office of the European Union - Eurostat). Za analizu podataka o UI korišten je „AI Index“ kojeg na godišnjoj razini objavljuje Stanford University's Human-Centered AI Institute te pruža sveobuhvatan pregled i analizu napretka u području UI. Rad je organiziran u pet dijelova. U uvodnom dijelu razrađuje se tema istraživanja. Drugi dio definira umjetnu inteligenciju i njezine značajke. Treći dio objašnjava ulogu UI u stvaranju izuma i njihove zaštite. Četvrti dio analizira ekonomske i zakonodavne učinke zaštite izuma stvorenih pomoću UI na gospodarski rast i konkurentnost visokorazvijenih zemalja članica Europske unije. Završni dio rada, zaključak, sažima relevantne nalaze temeljem dostupne literature i provedene analize te predlaže smjernice za buduća istraživanja.

2. POJMOVNO DEFINIRANJE UMJETNE INTELIGENCIJE

Umjetna inteligencija predstavlja jedno od najznačajnijih tehnoloških dostignuća 21. stoljeća. UI je područje računarstva koje se bavi razvojem sposobnosti računala da obavljaju zadatke koji su tradicionalno zahtijevali ljudsku inteligenciju. Simulacija ljudskih radnji u računalima može se postići na dva načina. Prvi pristup nastoji omogućiti računalima da „razmišljaju“ i „ponašaju se“ kao ljudi, odnosno da njihova izvedba bude usporediva s ljudskom. Drugi pristup fokusira se na to da računala „razmišljaju“ i „ponašaju se“ racionalno, odnosno da teže idealnoj izvedbi donoseći ispravne odluke bez obzira na dostupne informacije (Russell i Norvig, 2010). UI se može klasificirati u dvije glavne skupine: uska (slaba) UI i opća (jaka) UI. Slaba UI dizajnirana je za obavljanje specifičnih zadataka. Ona ne posjeduje svijest i ne razumije širu problematiku izvan okvira za koji je programirana. Primjeri slabe UI uključuju algoritme na platformama koji korisnicima preporučuju sadržaj temeljen na njihovim prethodnim preferencijama, glasovne asistente u automobilima i mobilnim telefonima, te mnoge druge primjene UI u svakodnevnom životu.

S druge strane, jaka UI još uvijek je u fazi teorijskog razvoja. Ova vrsta UI ima sposobnost razumijevanja, učenja i obavljanja intelektualnih zadataka na razini ljudskih bića. Iako još nije ostvarena, jaka UI predstavlja krajnji cilj istraživanja u ovom području (Russell i Norvig, 2010). Da bi sustavi UI postigli ljudsku izvedbu, oni se „uče“ izlaganjem velikim količinama podataka. Većina sustava UI temelje se na metodama strojnog učenja pri čemu to učenje može biti nadzirano, djelomično nadzirano ili nenadzirano, ovisno o tome jesu li sustavi izloženi skupovima podataka s unaprijed definiranim rješenjima ili ne. Prepoznavanjem obrazaca među dostupnim informacijama, sustavi donose „zaključke“ koji se potom empirijski koriste za pristup novim zadacima (Müller, 2020). Složeno međudjelovanje sustava, dobivenih rješenja i načina na koji se UI uči i nadograđuje otežava preciznu klasifikaciju i određivanje što pripada podskupini, a što se odnosi na specifične funkcionalnosti. Strojno učenje, duboko učenje i neuronske mreže smatraju se glavnim podskupinama UI, što je prikazano na Slici 1.



Slika 1 Podgrupe umjetne inteligencije
Prilagođeno prema IBM, 2025., What is Generative AI, (online). Dostupno na:
https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-generative-ai
(pristupljeno 10. listopada 2025.)

Strojno učenje, kao najšire područje UI, temelji se na stvaranju modela za učenje trendova i primjeni tih modela za rješavanje problema. Uža podgrupa, duboko učenje, može obraditi neuređene podatke u njihovom izvornom obliku, poput teksta ili slika. Iz dubokog učenja razvila su se specifična područja kao što su obrada prirodnog jezika i računalni vid i koja su danas u širokoj upotrebi. Temelj za razvoj dubokog učenja kao najnaprednijeg područja UI bio je napredak u neuronskim mrežama. Ovaj model, inspiriran ljudskim mozgom, koristi složene procese koji oponašaju način na koji biološki neuroni surađuju kako bi prepoznali uzorke, analizirali opcije i donosili odluke. Generativna umjetna inteligencija (en. Generative Artificial Intelligence - GenAI) obuhvaća algoritme i podskupine UI koji stvaraju novi sadržaj, kao što su audio, slike, video, tekstualni sadržaj i programski kod. Korisnici unose upute u tekstualnom obliku, ponekad u kombinaciji s određenim podacima, čime je pristup ovoj tehnologiji omogućen širem krugu korisnika. Razvoj GenAI rezultat je kontinuiranog napretka na polju strojnog učenja i neuronskih mreža. Amari-Hopfield mreža (Amari, 1972. i Hopfield, 1982.) je vrsta neuronske mreže s asocijativnom memorijom koja se smatra osnovom za razvoj GenAI. To je prvi sustav koji je demonstrirao kako mreže mogu prepoznavati i pohranjivati uzorke, slično procesima ljudske memorije. Razvoj GenAI modela, poput ChatGPT-a, zahtijeva ogromne količine podataka i resursa (npr. treniranje GPT-3, njegove naprednije verzije, uključivalo je oko 45 terabajta podataka uz troškove u milijunima dolara). Ovakva velika ulaganja čine razvoj GenAI modela izazovnim i dostupnim samo najvećim i financijski snažnim tvrtkama.

Primjena modela UI omogućuje donošenje boljih poslovnih odluka kroz analizu podataka i predviđanje trendova te na taj način poboljšava kvalitetu proizvoda i usluga u realnom vremenu prilagođavajući ih prema potrebama krajnjih korisnika. Na taj način UI omogućuje razvoj novih poslovnih modela i doprinosi razvoju inovacija i novih rješenja, te samim time i većoj profitabilnosti poslovanja (Bonadio, 2021).

3. ULOGA UMJETNE INTELIGENCIJE U PROCESU STVARANJA I ZAŠTITE IZUMA

Digitalno doba donijelo je novo doba razvoja inovacija, a inovacije temeljene na UI čine ključni dio inovacijskog procesa te se stoga pojavila potreba za njihovom pravnom zaštitom putem zaštite prava intelektualnog vlasništva (IV). Sustav zaštite prava IV predstavlja institucionalni okvir koji potiče inovacije i gospodarski razvoj (Karanikić, 2023). Trenutni sustav zaštite prava IV osmišljen je kako bi poticao ljudsku inovaciju i stvaralaštvo. Međutim, razvoj umjetne inteligencije mijenja ljudski element u samom procesu inoviranja. Patent, kao jedan od oblika zaštite prava IV predstavlja pravo priznato za izum koji nudi novo rješenje određenog tehničkog problema. Patent se može odnositi na proizvod, postupak ili primjenu, a stječe se priznanjem ovlaštenog tijela nakon ispitivanja patentne prijave koja opisuje izum. Izumiteljem se smatra fizička osoba ili skupina pojedinaca koja je stvorila izum koristeći svoje intelektualne i kreativne sposobnosti (DZIV, 2025). Uz izumitelje, u kontekstu patentnog prava izdvaja se i nositelj prava na patent, koji je najčešće sam izumitelj ili skupina pojedinaca, ali može biti i pravna osoba (tvrtka ili organizacija). Patentna zaštita ostvaruje se ako izum zadovoljava tri zakonski propisana uvjeta: novost, inventivnu razinu i industrijsku primjenjivost.

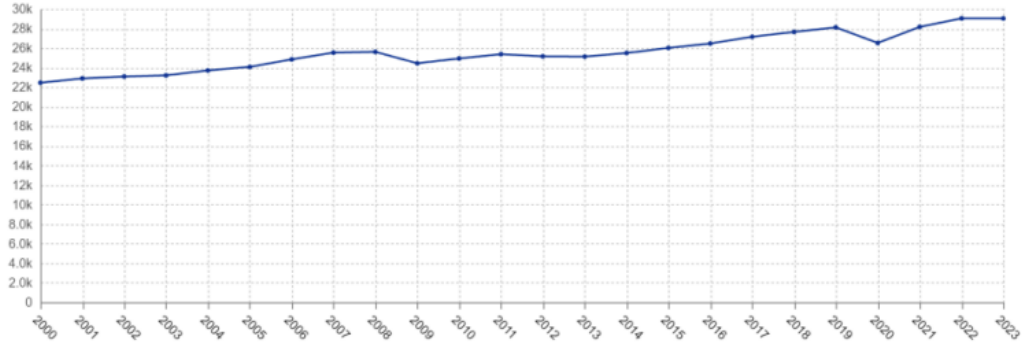
Trajanje zaštite patentom obično iznosi dvadeset godina od dana podnošenja patentne prijave, a zaštita se može ostvariti na nacionalnoj i međunarodnoj razini. Patentna zaštita izuma omogućuje nositeljima prava privremeni monopol na korištenje izuma kroz određeni vremenski period te na taj način povratiti sredstva uložena u istraživanje i razvoj (Hall i Harhoff, 2012). Europska patentna organizacija (EPO, 2023) klasificira izume prema ulozi UI u njihovom stvaranju u tri glavne kategorije: izumi stvoreni uz pomoć UI za verifikaciju, gdje istraživači koriste UI za provjeru i validaciju rezultata tijekom razvoja izuma; izumi u kojima fizička osoba koristi UI za pronalaženje rješenja, prepoznavanje problema i potom koristi UI kao alat za razvijanje rješenja; te izumi koje stvara UI gdje UI samostalno identificira probleme i predlaže rješenja bez ljudske intervencije. U prve dvije kategorije sustavi UI se koriste kao alat ljudskim izumiteljima, pomažući njihovom inovativnom procesu. Ipak, potpuno neovisni izumi stvoreni putem UI još uvijek nisu priznati u kontekstu postojeće regulative vezane uz patentnu zaštitu.
Prema Svjetskoj organizaciji za intelektualno vlasništvo (WIPO, 2024) uloga UI u stvaranju izuma podijeljena je u četiri kategorije: novi modeli UI ili algoritmi, izumi nastali uz pomoć UI (en. AI-assisted inventions), izumi temeljeni na UI (en. AI-based inventions) te izumi stvoreni tehnologijom UI (en. AI-generated inventions). Prva kategorija obuhvaća nove modele UI i algoritme koji unapređuju postojeće metode ili razvijaju nove tehnike, no njihova zaštita može biti izazovna zbog ograničenja zaštite softvera i matematičkih metoda putem patenta. Druga kategorija odnosi se na izume nastale uz pomoć UI, gdje UI služi kao alat za optimizaciju procesa i analizu podataka u razvoju izuma. Treća kategorija obuhvaća izume temeljene na UI, u kojima UI predstavlja ključnu sastavnicu izuma i omogućava patentnu zaštitu. Četvrta kategorija razmatra izume stvorene tehnologijom UI, gdje je UI u potpunosti odgovorna za identifikaciju problema i razvoj rješenja i upućuje na mogućnost UI kao samostalnog stvaratelja izuma što još nije tehnički izvedivo, ali bi moglo postati stvarnost u budućnosti. Generativni sustavi umjetne inteligencije zahtijevaju pristup velikim količinama podataka što može dovesti do povrede prava intelektualnog vlasništva i prava na privatnost.

Kao odgovor na ove izazove, Europska unija donijela je Uredbu (EU) 2024/1689 o utvrđivanju usklađenih pravila o umjetnoj inteligenciji koja je stupila na snagu u kolovozu 2024., a koja uspostavlja ujednačen zakonodavni okvir za razvoj i primjenu sustava UI unutar Unije kako bi se osigurala sigurna, etička i transparentna primjena tehnologije UI u gospodarstvu i društvu. Također, pokrenuta je dobrovoljna inicijativa Europske komisije kao podršku provedbi tih pravila i promicanje odgovorne upotrebe tehnologija UI na globalnoj razini. Izum se definira kao novo rješenje određenog tehničkog problema, a u kontekstu umjetne inteligencije obuhvaća elemente poput algoritama, softvera, hardvera i uređaja. Budući da UI pripada računalnim znanostima, izumi koji je uključuju klasificiraju se kao računalno implementirani izumi (RII). Iako Europska patentna konvencija (en. European Patent Convention - EPC) isključuje računalne programe "kao takve" iz patentne zaštite, RII mogu biti patentibilni ako imaju tzv. tehnički karakter. Patenti se odobravaju kada UI doprinosi rješavanju određenog tehničkog problema, poput primjene neuronskih mreža u medicinskim uređajima, čime se omogućuje zaštita izuma stvorenih pomoću UI i koji imaju praktičnu primjenu u različitim tehnološkim područjima. Poznati slučaj DABUS (en. Device for the Autonomous Bootstrapping of Unified Sentience) doveo je u pitanje postojeći zakonodavni okvir za izume stvorene samostalno putem UI. Europska patentna konvencija zahtijeva da izumitelj bude fizička osoba, a ne stroj ili UI, jer izumitelj mora snositi određene pravne učinke što UI kao takva ne može. S ciljem poticanja ulaganja u razvoj inovacija temeljenih na UI, Ured za patente i žigove Sjedinjenih Američkih Država (en. United States Patent and Trademark Office - USPTO) objavio je u veljači 2024. smjernice koje podržavaju ljudski doprinos u procesu stvaranja izuma pomoću UI. Iako izumi u cijelosti stvoreni pomoću UI još uvijek nisu patentibilni ove zakonske izmjene omogućuju patentnu zaštitu izuma koji su djelomično stvoreni pomoću UI uz navođenje fizičkih osoba koje su značajno doprinijele procesu stvaranja izuma. USPTO i EPO imaju slične pristupe u patentnoj zaštiti izuma stvorenih umjetnom inteligencijom jer oba zahtijevaju da izumitelj bude fizička osoba. Oba ureda dopuštaju doprinos UI u stvaranju izuma čak i kada je UI ključna za samo stvaranje, ali ne priznaju navođenje UI kao izumitelja te je stoga potrebno navesti fizičku osobu kao izumitelja kako bi se ispunili pravni zahtjevi koje patentna zaštita zahtijeva.

4. ANALIZA EKONOMSKOG I ZAKONODAVNOG ASPEKTA PRIMJENE UMJETNE INTELIGENCIJE

4.1. Ekonomski aspekt primjene umjetne inteligencije

Glavni pokazatelji gospodarskog rasta i konkurentnosti određene zemlje obično uključuju bruto domaći proizvod (BDP) te BDP po stanovniku, pokazatelje zaštite prava intelektualnog vlasništva i ulaganja u istraživanje i razvoj (I&R). Na Slici 2 prikazan je trend rasta ukupnog BDP-a po stanovniku Europske unije za 27 zemalja članica u razdoblju od 2000. do 2023. godine.



Slika 2 Trend rasta ukupnog BDP-a po stanovniku Europske unije u promatranom razdoblju od 2000. do 2023. (u tisućama Eur)
(Izvor: Eurostat; Obrada: Autori)

Bruto domaći proizvod po stanovniku u Europskoj uniji u 2023. dosegnuo je razinu od gotovo 30.000 eura, što predstavlja relevantan pokazatelj gospodarske aktivnosti i životnog standarda u zemljama članicama. Međutim, detaljnija analiza pokazuje značajne razlike među državama članicama EU. Prema podacima Eurostata (Eurostat, 2023), promatrajući BDP po stanovniku Europske unije u razdoblju od 2018. do 2023. godine, visoko razvijene zemlje poput Švedske, Luksemburga, Norveške, Islanda, Austrije, Njemačke i Finske bilježe znatno viši BDP po stanovniku u usporedbi s prosjekom EU, čime se potvrđuje njihova veća razina ekonomske razvijenosti te samim time i konkurentnosti. Unatoč neujednačenom gospodarskom razvoju između članica EU ukupni trend BDP-a po stanovniku u EU pokazuje stabilan i postupan rast, što implicira pozitivne makroekonomske učinke. Industrije koje intenzivno koriste prava intelektualnog vlasništva su industrije s iznadprosječnim brojem registriranih prava intelektualnog vlasništva po zaposleniku u usporedbi s ostalim industrijama koje ih također koriste. Analiza provedena od strane Europskog patentnog ureda (en. European Patent Office – EPO) i Ureda Europske unije za intelektualno vlasništvo (en. European Union Intellectual Property Office – EUIPO) iz 2022. godine pokazuje da su industrije koje intenzivno koriste prava intelektualnog vlasništva u promatranom razdoblju između 2017. i 2019. generirale gotovo trećinu svih radnih mjesta u Europskoj uniji (29,7%). Učinak ovih industrija je značajan budući da su generirale više od 47,1% ukupnog BDP-a EU, a njihova gospodarska snaga očituje se i u međunarodnoj razmjeni obzirom da su ove industrije ključne za makroekonomsku stabilnost EU te čine 80% ukupnog uvoza i izvoza EU. Podaci prikazani u Tablici 1 jasno ukazuju na snažnu korelaciju između intenzivnog korištenja zaštite intelektualnog vlasništva i važnih makroekonomskih pokazatelja EU.

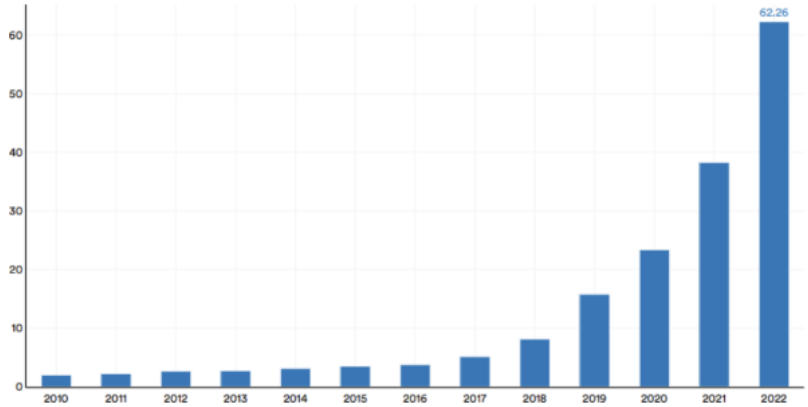
Ekonomski pokazatelji (EU27)	Studija 2013 (2008-2010)	Studija 2016 (2011-2013)	Studija 2019 (2014-2016)	Studija 2022 (2017-2019)
Zaposlenost	28,6%	28,5%	28,9%	29,7%
BDP	46,2%	46,1%	46,2%	47,1%
Izvoz dobara i usluga	76,6%	78,4%	79,1%	80,1%

Tablica 1 Doprinos industrija koje intenzivno koriste prava intelektualnog vlasništva na ekonomske pokazatelje Europske unije u promatranom razdoblju od 2008. do 2022. (Izvor: EPO i EUIPO (2022); Obrada: Autori)

Podaci iz četiri uzastopne studije EPO-a i EUIPO-a (2013., 2016., 2019. i 2022.) ukazuju na važnu uloge industrija koje intenzivno koriste prava intelektualnog vlasništva na gospodarstvo Europske unije obzirom da tri ključna makroekonomska pokazatelja: zaposlenost, BDP i izvoz pokazuju njihov stabilan rast kroz analizirana promatrana razdoblja. Primjena UI u procesu istraživanja i razvoja (I&R) ima značajnu ulogu u poticanju stvaranja inovacija te samim time i broja patenata. Untaoč tome što se UI ne navodi kao sudionik u procesu stvaranja izuma prilikom podnošenja patentne prijave, ona ima široku primjenu u aktivnostima istraživanja i razvoja što ukazuje na važnu ulogu UI u tehnološkom napretku.

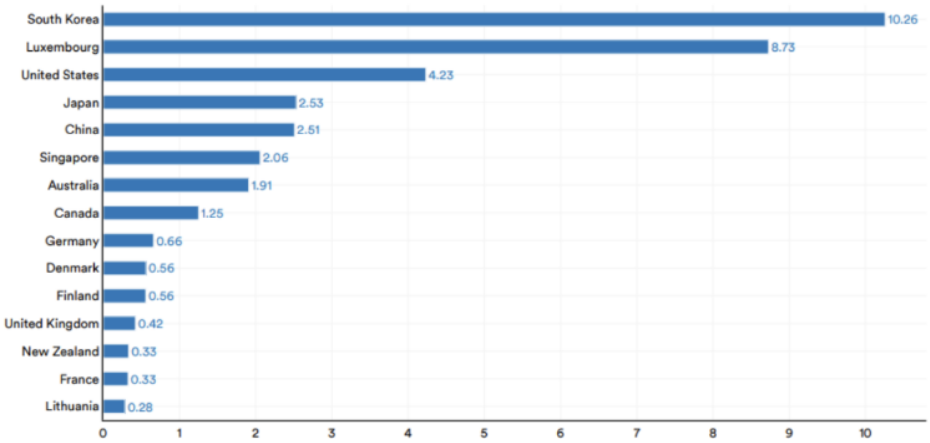
Prema podacima Eurostata (2023) za 2023. korištenje i primjena UI u istraživanju i razvoju i inovacijskim aktivnostima bila je najveća kod velikih poduzeća (24,3 %), dok je taj postotak manji kod srednjih (19,6%) i malih (16,3%) poduzeća što sugerira da aktivnosti istraživanja i razvoja zahtijevaju značajna ulaganja te su često rezervirana prvenstveno za one industrije koje s najvećim raspoloživim financijskim resursima (npr. farmaceutska industrija). Umjetna inteligencija postaje sve važnija u razvoju inovacija što je vidljivo kroz kontinuirani porast broja prijavljenih i odobrenih patenata u ovom području.

Jedan od najrelevantnijih izvora podataka o UI - AI Index, kojeg na godišnjoj razini objavljuje Stanford University's Human-Centered AI Institute, pruža sveobuhvatan pregled i analizu napretka u području UI. Cilj ovog indeksa je pratiti, dokumentirati i analizirati ključne trendove i dostignuća u području UI kako bi se pratio i analizirao učinak UI na društvo, ekonomiju i različite industrije koje koriste UI. Na Slici 3 vidljiv je jasan uzlazni trend u broju odobrenih patenata vezanih uz UI prema AI Index-u u razdoblju od 2010. do 2022. godine.



Slika 3 Broj odobrenih patenata vezanih uz UI u promatranom razdoblju od 2010. do 2022. (u tisućama)
(Izvor: AI Index (2024); Obrada: Autori)

Prema podacima AI Indexa za 2024. godinu, između 2010. i 2014. godine, ukupan rast broja odobrenih patenata vezanih uz UI bio je 56,1%, dok je samo u razdoblju od 2021. do 2022. godine taj postotak porastao za 62,7%. Broj odobrenih patenata vezanih uz UI u 2022.g. bio je 62,264, a broj neodobrenih patenata iznosio je 128,952. Ovi podaci jasno sugeriraju da je umjetna inteligencija postala ključna tehnologija koja potiče inovacije, a njezina primjena u industrijama značajno raste iz godine u godinu. Europske visokorazvijene zemlje nalaze se među vodećima prema broju odobrenih patenata vezanih uz UI na 100 000 stanovnika za 2022. što je prikazano na Slici 4. Među 15 zemalja u svijetu s najvećim brojem odobrenih patenata vezanih uz UI smjestile su se i određene visokorazvijene zemlje EU, kao što su Luksemburg, Njemačka, Danska, Finska i Francuska, što je istovremeno i odraz i njihovih značajnih ulaganja u istraživanje i razvoj te samim time i njihove uloge u globalnoj tehnološkoj konkurenciji.



Slika 4 Broj odobrenih patenata vezanih uz UI po državama u 2022. (na 100 000 stanovnika)
(Izvor: AI Index (2024); Obrada: Autori)

Te visokorazvijene zemlje, prema podacima Eurostata (Eurostat, 2023) ujedno imaju i visok BDP po stanovniku kao i velika ulaganja u aktivnosti istraživanja i razvoja što je prikazano u Tablicama 2 i 3.

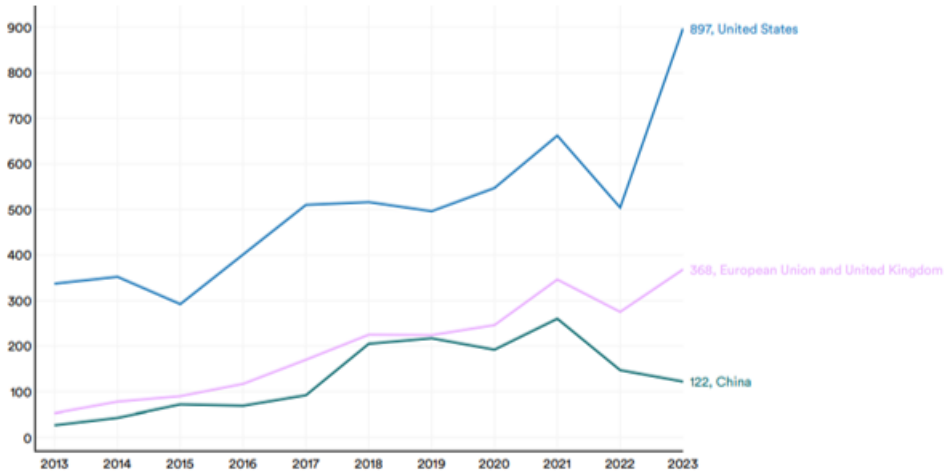
DRŽAVA/GODINA	2018.	2019.	2020.	2021.	2022.
Luksemburg	96.460	95.740	96.520	94.180	99.360
Njemačka	38.430	38.690	39.020	37.500	38.670
Danska	50.150	50.830	51.500	50.470	53.970
Finska	40.710	41.120	41.580	40.540	41.610
Francuska	33.920	34.320	34.880	32.170	34.260

Tablica 2 BDP po glavi stanovnika za odabrane zemlje Europske unije u promatranom razdoblju od 2018. do 2022. (u Eur)
(Izvor: Eurostat (2023), Obrada: Autori)

DRŽAVA/GODINA	2018.	2019.	2020.	2021.	2022.
Luksemburg	1,17	1,18	1,10	1,04	0,98
Njemačka	3,11	3,17	3,13	3,13	3,13
Danska	2,97	2,94	2,97	2,76	2,89
Finska	2,76	2,80	2,91	2,99	2,95
Francuska	2,20	2,19	2,27	2,22	2,18

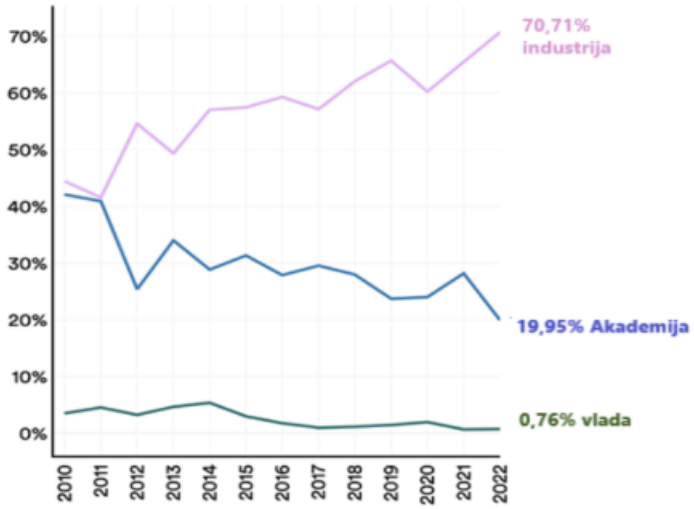
Tablica 3 Bruto domaći izdaci za istraživanje i razvoj (I&R) odabranih zemalja Europske unije u promatranom razdoblju od 2018. do 2022. (% BDP)
(Izvor: Eurostat (2023), Obrada: Autori)

Ove zemlje uz visok BDP po stanovniku imaju i visok broj odobrenih patenata na 100 000 stanovnika što ukazuje na snažnu povezanost između gospodarske snage i mogućnosti ulaganja u istraživanje i razvoj tih zemalja. Visok BDP po stanovniku omogućava ovim zemljama i veća ulaganja u obrazovanje, infrastrukturu i razvoj novih tehnologija što se posljedično manifestira kroz povećan broj patenata vezanih uz UI te samim time i konkurentnost u globalnoj tehnološkoj utrci što posljedično ima pozitivan učinak na njihov gospodarski razvoj. Ulaganja u razvoj tehnologija UI rezultira pozitivnim trendom broja novoosnovanih UI tvrtki u svijetu. UI tvrtke su tvrtke specijalizirane za integraciju rješenja temeljenih na UI kako bi pomogla drugim poduzećima da unaprijede svoje poslovanje i ostanu konkurentna u svojoj industriji. Europska unija, SAD i Kina su vodeće zemlje po broju novoosnovanih UI tvrtki što je prikazano na Slici 5.



Slika 5 Broj novoosnovanih UI tvrtki u svijetu u promatranom razdoblju od 2013. do 2023.
(Izvor: AI Index (2024); Obrada: Autori)

Značajan porast u broju novoosnovanih UI tvrtki u svijetu odražava brzi razvoj i rast sektora UI. Navedeno sugerira veliku potražnju za razvojem tehnologija UI u različitim sektorima i samim time stvaranje novih radnih mjesta što pozitivno doprinosi gospodarskom rastu. Ulaganja u razvoj UI i njezinu implementaciju predstavljaju značajan gospodarski čimbenik u EU obzirom da ovakva ulaganja omogućuju tehnološki napredak i oblikuju budućnost globalne ekonomije. Podaci o ulaganjima u UI u Europskoj uniji (AI Watch, 2022) u promatranom razdoblju od 2018. i 2020. ukazuju na stratešku podjelu resursa između različitih sektora i kategorija. Sektor istraživanja i razvoja čini najveći udio među investicijama u UI s 29,7% ukupnih ulaganja, što odražava ključnu važnost ovog sektora za daljnji napredak u tehnologije UI. Javni sektor u EU najveći dio svojih ulaganja usmjerava na tzv. "ulaganja u vještine" što obuhvaća obrazovanje i obuku korisnika tehnologija UI. Ova ulaganja iznosila su više od 3,6 milijardi EUR, odnosno činila su 22% ukupnih ulaganja u UI što ukazuje na važnost razvoja ljudskog kapitala u kontekstu sve bržeg razvoja tehnologija UI. Prema izvješću AI Indeksa za 2024. godinu vidljiv je kontinuiran rast broja doktoranada specijaliziranih za tehnologije UI u različitim sektorima što je prikazano na Slici 6 što ukazuje da obrazovni sustavi diljem svijeta odgovaraju na rastuće potrebe tržišta za stručnjacima u području UI.



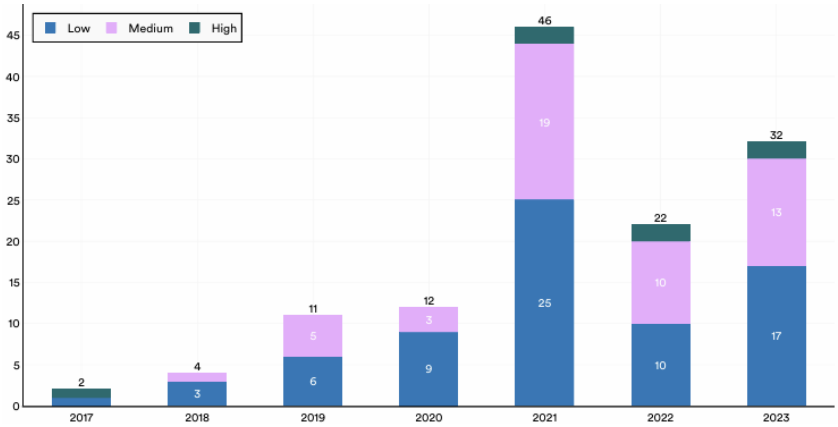
Slika 6 Zaposlenost doktoranada iz područja UI po sektorima (% od ukupnog broja) (Izvor: AI Index (2024); Obrada: Autori)

Trend zapošljavanja stručnjaka iz područja UI u industriji bilježi značajan porast, s vrhuncem dosegnutim 2022. kada je 70,71 % stručnjaka iz područja UI bilo zaposleno upravo u industriji.

4.2. Zakonodavni aspekt primjene umjetne inteligencije

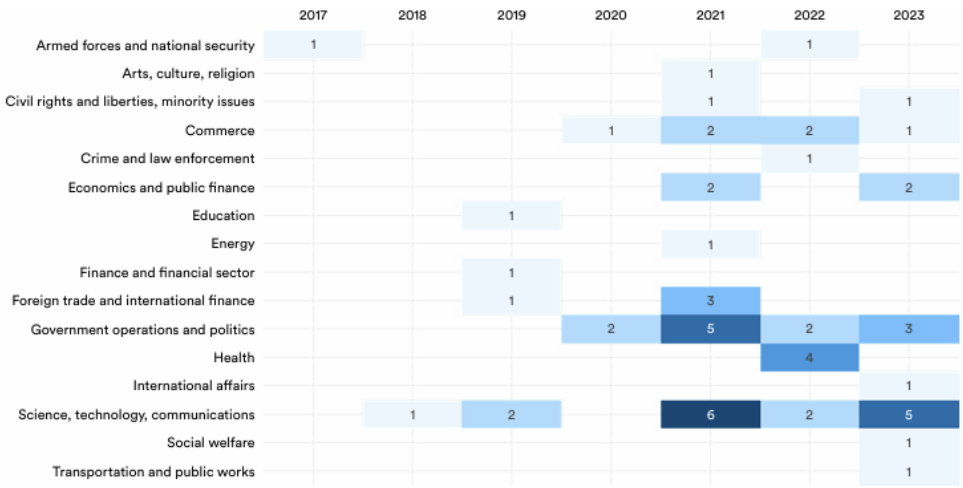
U trećem poglavlju detaljno je prezentirana i elaborirana uloga umjetne inteligencije u procesu stvaranju izuma i njegove zaštite i prateći zakonodavni okvir. Međutim, postoje i drugi propisi koji uređuju i reguliraju korištenje UI. Usvajanje Uredbe (EU) 2024/1689 o utvrđivanju usklađenih pravila o umjetnoj inteligenciji naglašava važnost regulacije sigurne i odgovorne primjene UI. Obzirom da UI postaje važan čimbenik gospodarskog rasta i konkurentnosti potreban je snažan zakonodavni okvir koji potiče inovacije, ali istovremeno i štiti društvo od mogućih rizika njezine primjene. Broj zakonskih propisa povezanih s UI koje je donijela Europska unija porastao je s 22 u 2022. na 32 u 2023., a broj propisa povezanih s umjetnom inteligencijom dosegnuo je vrhunac 2021., kada ih je doneseno 46. Ovi propisi uključuju pravne akte, međunarodne sporazume i konsolidirane tekstove povezanih s UI (AI Index, 2024). Uvođenje novih propisa povezanih s UI, osobito onih visoke relevantnosti, ukazuju na sve veću potrebu za jasno definiranim pravilima koja osiguravaju sigurnu i etičku primjenu tehnologija UI.

Europska unija je 2021. usvojila svoje prve i relevantne propise povezane s UI, a upravo su ti propisi uspostavili Program za digitalnu Europu i Obzor Europa, okvirni program za istraživanje i inovacije. Prema podacima AI Indeksa, od 32 propisa donesenih 2023., dva su bila visoko relevantna za umjetnu inteligenciju, 13 je imalo srednju relevantnost, a 17 nisku relevantnost što je vidljivo na Slici 7.



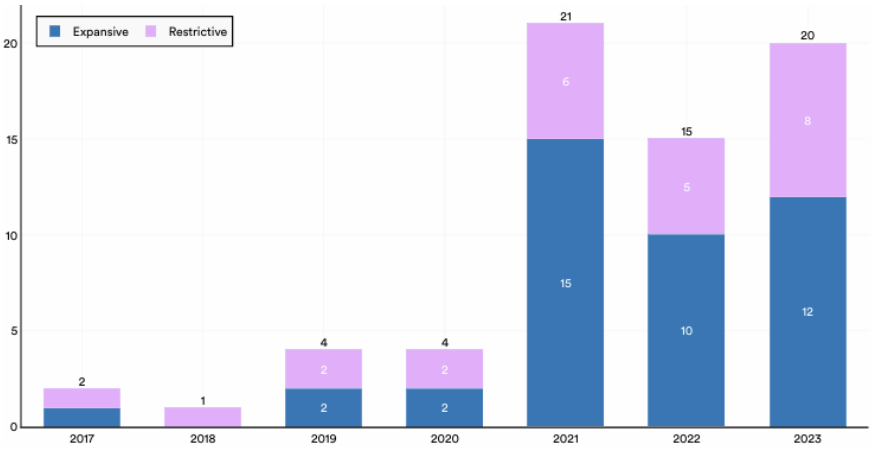
Slika 7 Broj propisa povezanih s UI u Europskoj uniji prema relevantnosti za UI u promatranom razdoblju od 2017. do 2023.
(Izvor: AI Index (2024), Obrada: Autori)

Obzirom da UI postaje ključna komponenta razvoja različitih industrija i gospodarstva općenito, može se očekivati daljnji rast i prilagodba zakonodavnog okvira primjene UI kako bi se odgovorilo na buduće izazove i potrebe koje ova tehnologija donosi. Na Slici 8 prikazan je broj propisa povezanih s UI u EU prema području regulacije u razdoblju od 2017. do 2023. Vidljivo je da je najveći broj propisa, njih 16, u području znanosti, tehnologije i komunikacije što upućuje na važnost kontinuiranog donošenja odnosno unapređenja zakonodavnog okvira primjene UI u tom području kroz pozitivan učinak na gospodarski rast vidljiv u prethodnoj analizi pokazatelja gospodarskog rasta i konkurentnosti.



Slika 8 Broj propisa povezanih s UI u Europskoj uniji prema predmetu regulacije u promatranom razdoblju od 2017. do 2023.
(Izvor: AI Index (2024, Obrada: Autori)

Promatrajući trenutni zakonodavni okvir i propise povezane s primjenom UI u Europskoj uniji od 2017. do 2023. postoje dva pristupa: ekspanzivni i restriktivni. Ekspanzivni pristup fokusira se na širenje i razvoj novih propisa povezanih s UI koje omogućuju rast i primjenu tehnologija UI u različitim industrijama, dok restriktivni pristup postavlja ograničenja i stvara smjernice za odgovorno korištenje UI kako bi se zaštitili pojedinci i društvo od potencijalnih negativnih učinaka. Na Slici 9 prikazan je odnos između ekspanzivnog i restriktivnog pristupa.



Slika 9 Broj novih propisa povezanih s UI u Europskoj uniji prema ekspanzivnom i restriktivnom pristupu u promatranom razdoblju od 2017. do 2023.
(Izvor: AI Index (2024); Obrada: Autori)

Razvidno je da EU nastoji održati ravnotežu između poticanja inovacija kroz ekspanzivnu regulativu i osiguravanja sigurnosti, etičnosti i kontrole kroz restriktivnu regulativu. Ovaj pristup omogućuje Europskoj uniji da podrži razvoj i implementaciju UI, dok istovremeno postavlja jasne smjernice koje sprječavaju potencijalne negativne društvene, ekonomske i sigurnosne utjecaje. Ovaj balans ključan je za održivu i odgovornu primjenu UI u EU.

5. ZAKLJUČAK

Inovacije su važan čimbenik gospodarskog rasta i razvoja jer omogućuju razvoj novih tehnologija, a primjena UI u istraživanju i razvoju se nameće kao ključni pokretač razvoja inovacija. Unatoč tome što se UI ne može formalno navoditi kao izumitelj u patentnim prijavama njezin njihov konkretan doprinos u procesu stvaranja izuma je neosporan. UI omogućuje bržu obradu velikih količina podataka, automatizaciju analitičkih procesa te generiranje rješenja koji vode do stvaranja inovacija čime se značajno obrzava proces od ideje do komercijalno primjenjivog rješenja. Značajan rast broja odobrenih patenata povezanih s UI kao alata u razvojnom procesu potvrđuje da UI postaje neizostavni dio tehnološke infrastrukture u inovacijskom ekosustavu. Buduća integracija UI u proces istraživanja i razvoja povećat će ukupnu učinkovitost i produktivnost, ali i transformirati načine na koje se znanje temeljeno na rezultatima znanstvenih istraživanja komercijalno eksploatira. Industrije koje intenzivno koriste prava intelektualnog vlasništva, posebno patentna prava, jedan su od ključnih pokretača gospodarskog rasta i konkurentnosti Europske unije. Njihova sposobnost generiranja visoke dodane vrijednosti potvrđuje važnost sustavne potpore inovacijama i njihovoj pravnoj zaštiti. U tom kontekstu, daljnji razvoj tehnologija UI, zajedno s odgovarajućim zakonodavnim okvirom koji se odnosi na zaštitu izuma stvorenih uz pomoć UI, od ključne je važnosti za poticanje inovacija i održivog gospodarskog rasta i razvoja. Rezultati provedene analize ukazuju na snažan i sve veći utjecaj UI na stvaranje inovacija, gospodarski rast i jačanje konkurentnosti kako na europskoj tako i na globalnoj razini.

Poseban značaj ima uloga patentne zaštite u osiguravanju ekskluzivnih prava na eksploataciju izuma povezanih s UI čime se dodatno potiču ulaganja u istraživanje i razvoj. Vidljiv je kontinuirani rast broja odobrenih patenata povezanih s UI, porast broja novoosnovanih UI tvrtki te povećana zaposlenost stručnjaka iz područja UI u industriji. Europske zemlje s višim BDP-om po stanovniku prednjače u broju odobrenih patenata vezanih uz UI što dodatno potvrđuje povezanost između ulaganja u istraživanje i razvoj, inovativnosti i gospodarskog rasta i razvoja. Međutim, izazovi ostaju u području zakonodavnog okvira, a osobito u vezi s izumiteljstvom i pravima na izume koji su potpuno ili djelomično stvoreni uz pomoć UI. Rezultati analize upućuju na rastuću potrebu za usklađivanjem i harmonizacijom zakonodavnog okvira upravo u području zaštite izuma koji su stvoreni pomoću UI, a potrebno je adresirati pravna i etička pitanja koja se odnose na izumiteljstvo i vlasništvo nad takvim izumima. Postojeći pravni sustavi (poput onih u SAD-u i EU) priznaju isključivo fizičke osobe kao izumitelje. Stoga je nužno otvoriti raspravu o mogućim prilagodbama tih sustava u kontekstu zaštite izuma stvorenih uz pomoć UI kao ključnog preduvjeta za daljnji razvoj i primjenu tehnologija UI kao pokretača gospodarskog i društvenog razvoja. Glavni izazov u nadolazećem razdoblju predstavljat će etički aspekt primjene tehnologije UI kao i postizanje ravnoteže između ekspanzivnih i restriktivnih propisa s ciljem uravnoteženog pristupa koji će poticati razvoj inovacija, a istovremeno štiti interese svih dionika u inovacijskom procesu. Provedena analiza u okviru ovog rada ima određena ograničenja. Analiza je provedena na razini EU i na makroekonomskoj razini, s osvrtom na određene visokorazvijene zemlje EU. Fokus budućih istraživanja trebao bi biti na analizi korelacije između rasta broja patenata vezanih uz UI i rasta BDP-a po stanovniku, uzimajući pritom u obzir varijacije među državama članicama Europske unije. S obzirom na sve veći broj prijava patenata vezanih uz UI potrebno je usporediti ekonomske pokazatelje zemalja s velikim brojem odobrenih patenata u industrijama koje intenzivno koriste prava intelektualnog vlasništva s onima koje bilježe manji broj takvih patenata. Također, u buduća istraživanja trebalo bi uključiti i čimbenike poput veličine gospodarstva, specifičnosti pojedinih industrijskih sektora i razvijenost zemalja unutar EU. Takva usporedba omogućila bi bolje razumijevanje utjecaja razvoja tehnologija UI na gospodarski rast i konkurentnost zemalja EU.

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PREDICTIVE ANALYSIS OF COMPANY PROFITABILITY USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Early identification of unprofitable companies is a key element of financial risk management, as it allows timely loss mitigation and informed business decision-making. The aim of this study was to develop a predictive model based on artificial neural networks to classify Croatian companies according to their profitability. The sample included indicators of liquidity, profitability, capital structure, and financial stability, while redundant variables were excluded to improve model accuracy. The model was evaluated using precision, recall, F1-score, and the area under the ROC curve (AUC), with particular emphasis on recall, which measures the model's ability to correctly identify unprofitable companies. The results indicate that neural networks can effectively distinguish between profitable and unprofitable companies, with financial stability ratio, credit rating, and quick liquidity ratio identified as the most important predictors of unprofitability. The findings contribute to the development of early warning systems and the enhancement of data-driven financial decision-making.

Keywords: *Neural networks, Company unprofitability, Financial risk management, Predictive analysis*

PREDIKTIVNA ANALIZA PROFITABILNOSTI PODUZEĆA PRIMJENOM UMJETNIH NEURONSKIH MREŽA

SAŽETAK

Rana identifikacija neprofitabilnih poduzeća važan je element upravljanja financijskim rizicima jer omogućuje pravovremeno ograničavanje gubitaka i donošenje informiranih poslovnih odluka. Cilj ovog istraživanja bio je razviti prediktivni model temeljen na umjetnim neuronskim mrežama za klasifikaciju hrvatskih poduzeća prema njihovoj profitabilnosti. Korišteni uzorak uključivao je pokazatelje likvidnosti, profitabilnosti, kapitalne strukture i financijske stabilnosti, dok su redundantne varijable isključene radi poboljšanja točnosti modela. Model je evaluiran pomoću metrika preciznosti, odziva, F1-mjere i površine ispod ROC krivulje (AUC), uz poseban naglasak na pokazatelj odziva koji mjeri sposobnost modela da pravilno prepozna neprofitabilna poduzeća. Dobiveni rezultati ukazuju da neuronske mreže mogu učinkovito razlikovati profitabilna i neprofitabilna poduzeća te da su koeficijent financijske stabilnosti, kreditni rejting i koeficijent ubrzane likvidnosti najvažniji prediktori neprofitabilnosti. Rezultati istraživanja doprinose razvoju sustava ranog upozoravanja i unapređenju financijskog odlučivanja temeljenog na podacima

Ključne riječi:*, Neuronske mreže, Neprofitabilnost poduzeća Upravljanje financijskim rizicima, Preditktivna analiza*

1. UVOD

Profitabilnost poduzeća jedan je od temeljnih pokazatelja njegove dugoročne uspješnosti i financijske stabilnosti. Iako sama profitabilnost ne jamči apsolutnu sigurnost poslovanja, njezin izostanak često predstavlja rani signal neučinkovitosti, smanjene konkurentnosti i potencijalnih financijskih poteškoća. U uvjetima dinamičnog i globalnog poslovanja, pravovremeno prepoznavanje poduzeća koja pokazuju znakove neprofitabilnosti postaje važan preduvjet za učinkovito upravljanje rizicima, optimizaciju resursa i donošenje informiranih poslovnih odluka. Tradicionalne metode financijske analize temelje se na interpretaciji pokazatelja profitabilnosti, likvidnosti, zaduženosti i stabilnosti poslovanja. Međutim, njihova sposobnost predviđanja budućih trendova često je ograničena zbog pretpostavki o linearnosti odnosa među varijablama te nemogućnosti prepoznavanja složenih obrazaca u podacima. Metode strojnog učenja omogućuju uočavanje skrivenih struktura i nelinearnih odnosa u financijskim podacima, čime se povećava točnost predviđanja i poboljšava kvaliteta poslovnog odlučivanja. U skladu s navedenim, ovo je istraživanje usmjereno na ranu detekciju neprofitabilnih poduzeća s ciljem omogućavanja pravovremenog i preventivnog djelovanja prije pojave financijskih problema.

Cilj ovog istraživanja je razvoj modela strojnog učenja koji omogućava klasifikaciju poduzeća prema njihovom statusu profitabilnosti te identifikaciju financijskih čimbenika koji najviše utječu na neprofitabilnost poduzeća. Poseban naglasak stavljen je na usporedbu performansi modela prema više evaluacijskih metrika (*preciznost, odziv, F1 mjera i ROC-AUC*), kao i na analizu značajnosti varijabli koje najviše doprinose razlikovanju profitabilnih i neprofitabilnih poduzeća. Navedenim se omogućuje dublje razumijevanje utjecaja financijskih pokazatelja poput povrata na kapital (ROE), koeficijenta zaduženosti, omjera likvidnosti i drugih na ukupnu uspješnost poslovanja. Dobiveni rezultati mogu pridonijeti razvoju sustava ranog upozoravanja u poslovnom sektoru, čime se menadžerima, investitorima i financijskim institucijama omogućuje donošenje učinkovitijih i pravovremenih odluka temeljenih na podacima.

2. PRETHODNA ISTRAŽIVANJA

U područjima financija, računovodstva i poslovnog upravljanja profitabilnost poduzeća se promatra kao jedan od ključnih pokazatelja uspješnosti poduzeća. Različiti pokazatelji poput ROE, povrata na imovinu (ROA), dobit prije kamata i poreza (EBIT), dobit prije kamata, poreza, amortizacije i deprecijacije (EBITDA), neto profitne marže, omjera duga i kapitala te omjera likvidnosti pružaju procjene operativne učinkovitosti i financijskog zdravlja poduzeća (Henry i sur., 2012). S obzirom na važnost financijskih pokazatelja u procjeni uspješnosti poduzeća, sve češće se primjenjuju metode strojnog učenja koje omogućuju dublju analizu i prediktivno modeliranje temeljem tih varijabli. U istraživanju Delen i sur. (2013) za identifikaciju ključnih financijskih omjera i predviđanje uspješnosti poduzeća koristili su faktorsku analizu i stabla odlučivanja. Rezultati su pokazali da su modeli CHAID i C5.0 ostvarili najveću točnost predviđanja, pri čemu su omjer dobiti prije oporezivanja i kapitala te neto marža dobiti bili najvažniji pokazatelji uspješnosti. Anand i sur. (2019) analizirali su mogućnost preciznijeg predviđanja promjena u profitabilnosti pomoću stabala odlučivanja u odnosu na tradicionalne statističke modele. Predviđali su smjer promjene (rast ili pad) za pet pokazatelja profitabilnosti (ROE, ROA, RNOA, CFO i FCF), pri čemu su klasifikacijska stabla postigla točnost od 57% do 64%. Utvrđeno je da su novčani pokazatelji (CFO i FCF) najpouzdaniji, a da je prediktivna sposobnost modela stabilna i na petogodišnjem razdoblju. Alam i sur. (2020) u svom istraživanju koristili su 64 financijska pokazatelja povezana s profitabilnošću, likvidnošću, zaduženošću i solventnošću te primijenili pet metoda strojnog učenja za predviđanje stečaja poduzeća. Modeli temeljeni na stablima odlučivanja i algoritmu Slučajnih šuma pokazali su se najučinkovitijima, potvrđujući potencijal strojnog učenja u ranoj detekciji financijskih poteškoća.

Nadalje, istraživanje Magrinia (2025), provedeno na velikom uzorku talijanskih poduzeća usmjereno je na predviđanje neprofitabilnosti poduzeća i rizika od stečaja korištenjem financijskih omjera te modela logističke regresije s adaptivnom LASSO regularizacijom i algoritom Slučajne šume. Rezultati su pokazali visoku točnost klasifikacije, potvrđujući učinkovitost strojnog učenja u analizi financijske stabilnosti. U svom istraživanju, Cozgarea i sur. (2023) analizirali su profitabilnost rumunjskih poduzeća te utvrdili da nadzirani algoritmi strojnog učenja, uključujući višeslojni perceptron (MLP) i Slučajne šume, mogu učinkovito predviđati profitabilnost poduzeća. Autori zaključuju da takvi modeli imaju potencijal za razvoj održivih sustava podrške menadžerskom odlučivanju. D'Amato i sur. (2023) istražili su utjecaj ESG pokazatelja na profitabilnost poduzeća, mjereno EBIT-om, koristeći modele strojnog učenja i interpretacijske alate poput Shapley vrijednosti. Rezultati pokazuju da ESG score može biti značajan prediktor profitabilnosti, često učinkovitiji od tradicionalnih računovodstvenih pokazatelja. Vuković i sur. (2023) analizirali su čimbenike koji utječu na profitabilnost maloprodajnih poduzeća koristeći panel podatke za 551 poduzeće. Navedeni autori usporedili su regresijske metode s pojedinačnim i naprednim algoritmima strojnog učenja (*DNN, LSTM, Slučajne šume, ensemble modeli*). Rezultati su pokazali da prethodna profitabilnost, rast prodaje i web promet imaju pozitivan utjecaj na buduću profitabilnost, dok su modeli strojnog učenja nadmašili regresijske metode u točnosti predviđanja. Pregled literature pokazuje da metode strojnog učenja, poput stabala odlučivanja, Slučajnih šuma i neuronskih mreža, postižu visoku točnost u predviđanju profitabilnosti i financijske stabilnosti poduzeća. U skladu s tim, ovo istraživanje usmjereno je na razvoj prediktivnog modela temeljenog na umjetnoj neuronskoj mreži (MLP) za klasifikaciju hrvatskih poduzeća prema njihovoj profitabilnosti, koristeći financijske pokazatelje na uzorku od 6.579 poduzeća.

3. METODOLOGIJA

U ovom istraživanju za modeliranje profitabilnosti poduzeća primijenjena je metoda strojnog učenja – umjetne neuronske mreže (engl. *Artificial Neural Networks – ANN*). ANN su jedan od najvažnijih pristupa u prediktivnoj analitici, a temelje se na načinu funkcioniranja ljudskog mozga: svaki neuron prima ulazne informacije, ponderira ih i prosljeđuje dalje kroz mrežu (Walczak, 2018). Korišteni model temelji se na višeslojnoj perceptronskoj mreži (engl. *Multi-Layer Perceptron – MLP*), koja se sastoji od ulaznog sloja, jednog ili više skrivenih slojeva i izlaznog sloja. Ulazni sloj prima vrijednosti ulaznih varijabli modela, dok skriveni slojevi obavljaju transformacije tih podataka pomoću nelinearnih aktivacijskih funkcija, a izlazni sloj generira konačnu klasifikaciju; u ovom slučaju, procjenu vjerojatnosti da je poduzeće možemo označiti kao profitabilno ili neprofitabilno. Proces treniranja mreže provodi se pomoću algoritma propagacije pogreške unatrag (engl. *backpropagation*), koji omogućuje prilagodbu težinskih koeficijenata između neurona s ciljem minimizacije razlike između predviđene i stvarne vrijednosti izlaza (Rumelharti sur., 1986; Walczak, 2018). Matematički, MLP s dva skrivena sloja može se prikazati sljedećim izrazom (Zekić-Sušac i sur., 2021):

$$y_c = f_2\left(\sum_{j=1}^{m} f_1\left(\sum_{i=1}^{n} w_i^{(1)} x_i\right) w_j^{(2)}\right)$$

gdje je y_c izračunati izlaz, x_i su elementi ulaznog vektora, $w_i^{(1)}$ težine prvog skrivenog sloja, $w_j^{(2)}$ težine drugog sloja, dok su f_1 I f_2 aktivacijske funkcije u pojedinim slojevima. Početne težine nasumično su odabrane iz intervala [-1,1] te se tijekom učenja iterativno prilagođavaju pomoću propagacije pogreške kako bi se minimizirala ukupna funkcija gubitka (Zekić-Sušac i sur., 2021). Optimizacijski algoritmi imaju ključnu ulogu u treniranju neuronskih mreža jer utječu na brzinu konvergencije, točnost i stabilnost učenja (Barve i sur., 2025).

Optimizacijski algoritmi služe za pronalaženje optimalne težinske koeficijente (engl. *weights*) koji minimiziraju pogrešku modela. Najčešće korišteni optimizacijski algoritmi uključuju: stohastički gradijentni spust (engl. *Stochastic Gradient Descent – SGD*), Adam, LBFGS i Nadam (Ruder, 2016; Zaheer i Shaziya, 2019; Barve i sur.,2025). Metode regularizacije također su važan parameter neuronskih mreža, a omogućuju bolju generalizacijsku sposobnost modela i sprečavaju pretreniranje (engl. *overfitting*), odnosno, stanje u kojem model dobro radi na podacima za treniranje, ali ne uspijeva dobro generalizirati na neviđenim podatcima (Salman i Liu, 2019).

Postoje brojne tehnike regularizacije koje se primjenjuju u procesu treniranja, a među kojima se najčešće koristi *L2* regularizacija, kojom se ograničavaju prevelike vrijednosti težina mreže; *dropout* odnosno nasumično isključivanje jedinica (neurona) i njihovih veza tijekom treninga kako bi se spriječilo prekomjerno adaptiranje neurona (Srivastava i sur., 2014.). Dodatno, primjenjuje se i metoda ranog zaustavljanja (engl. *Early Stopping*) kojom se treniranje prekida u trenutku kada se pogreška na validacijskom skupu prestane smanjivati, čime se sprječava degradacija performansi modela (Ying, 2019).

U skrivenim slojevima neuronskih mreža koriste se različite aktivacijske funkcije koje omogućuju modelu učenje nelinearnih odnosa među varijablama. Najčešće korištene aktivacijske funkcije uključuju ReLU (engl. *Rectified Linear Unit*) zbog brze konvergencije i stabilnosti gradijenata, Leaky ReLU koja je poboljšana inačica ReLU-a, a omogućava male negativne vrijednosti za ulaze manje od nule, hiperbolnu tangens funkciju koja transformira vrijednosti u raspon od –1 do 1, te sigmoidnu funkciju koja se često koristi u izlaznim slojevima kod binarnih klasifikacijskih problema jer generira izlaz u rasponu između 0 i 1 (Shama i sur., 2017). Za evaluaciju modela najčešće se koriste metrike (Skansi, 2018): točnost (engl. *Accuracy)*, preciznost (engl. *Precision*), odziv (engl. *Recall*), F1 i AUC (engl. *Area Under the ROC Curve*).

S obzirom na neuravnotežen uzorak točnost modela nije uzeta kao primarni pokazatelj uspješnosti. Pozornost je posvećena pokazatelju odziva (engl. *Recall*), koji mjeri sposobnost modela da pravilno identificira neprofitabilna poduzeća koja su u fokusu ovog istraživanja. U ovom su istraživanju navedeni pristupi i funkcije primijenjeni s ciljem postizanja optimalne kombinacije hiperparametara i najveće moguće točnosti u klasifikaciji profitabilnih i neprofitabilnih poduzeća, uz zadržavanje stabilnosti i interpretabilnosti modela.

3.4. Podaci

Uzorak korišten za modeliranje prikupljen je iz baze Financijske agencije (FINA) koja prikuplja i objavljuje službene poslovne i financijske izvještaje poduzeća u Republici Hrvatskoj. Korišten uzorak obuhvaća 6.579 poduzeća iz hrvatskog IT sektora (aktivna poduzeća s potpunim financijskim izvještajima za 2024. godinu), a obuhvaća djelatnosti računalnog programiranja, savjetovanja i srodnih usluga.

Odabrani sektor predstavlja jedno od najbrže rastućih područja hrvatskog gospodarstva, obilježeno visokom razinom inovativnosti i značajnim doprinosom digitalnoj transformaciji. U ulaznom prostoru nalazi se devet nezavisnih varijabli koje obuhvaćaju ključne aspekte poslovanja i koje su predstavljene u Tablici 1.

	Prosjek	Minimalna	Maksimalna vrijednost	Standardna devijacija
Starost	9.08	1	45	8.54
Koeficijent ubrzane likvidnosti	27,04	0	18044.25	417.93
EBIT	79127.70	-4.100.93	29.260.27	587544.30
Koeficijent financijske stabilnosti	0.41	0	137.25	2.95
Koeficijent zaduženosti	137.79	0	270841	5080.29
Koeficijent vlastitog financiranja	0.63	0	1	0.34
Koeficijent financiranja	2.25	0	2652.56	38.22
ROE	0.63	0	792.61	10.74
Kreditni rejting	Klasa A: 3422	Klasa B: 2942	Klasa CD: 215	

Tablica 1: Varijable u ulaznom prostoru
(Izvor: Vlastita izrada autora)

Ciljna varijabla definirana je kao binarna i označava profitabilnost poduzeća:

- vrijednost 1 označava neprofitabilno poduzeće (neto dobit < 0),
- vrijednost 0 označava profitabilno poduzeće (neto dobit ≥ 0).

U uzorku dominiraju profitabilna poduzeća, odnosno 5.184 slučaja *klase 0* (profitabilna poduzeća) i 1.395 slučaja *klase 1* (neprofitabilna poduzeća). U fazi pripreme uzorka su uklonjene varijable s visokim stupnjem korelacije ($r > 0{,}80$). Sve numeričke varijable su standardizirane korištenjem *Min–Max* normalizacije, čime su vrijednosti skalirane u raspon od 0 do 1. Kategorijalna varijabla je kodirana metodom one-hot encoding. Skup podataka podijeljen je u 80% podataka za treniranje i 20% za testiranje, uz stratificiranu podjelu (*random_state=42*) radi očuvanja proporcionalne zastupljenosti klasa s obzirom na neuravnotežen uzorak. Hiperparametri modela optimizirani su primjenom *GridSearchCV* metode uz stratificiranu 5-struku unakrsnu validaciju na skupu za treniranje, s ciljem postizanja maksimalne prediktivne točnosti. Evaluacija modela provedena je na izdvojenom testnom skupu. Sve analize provedene su u programskom jeziku Python, korištenjem biblioteke *scikit-learn.*

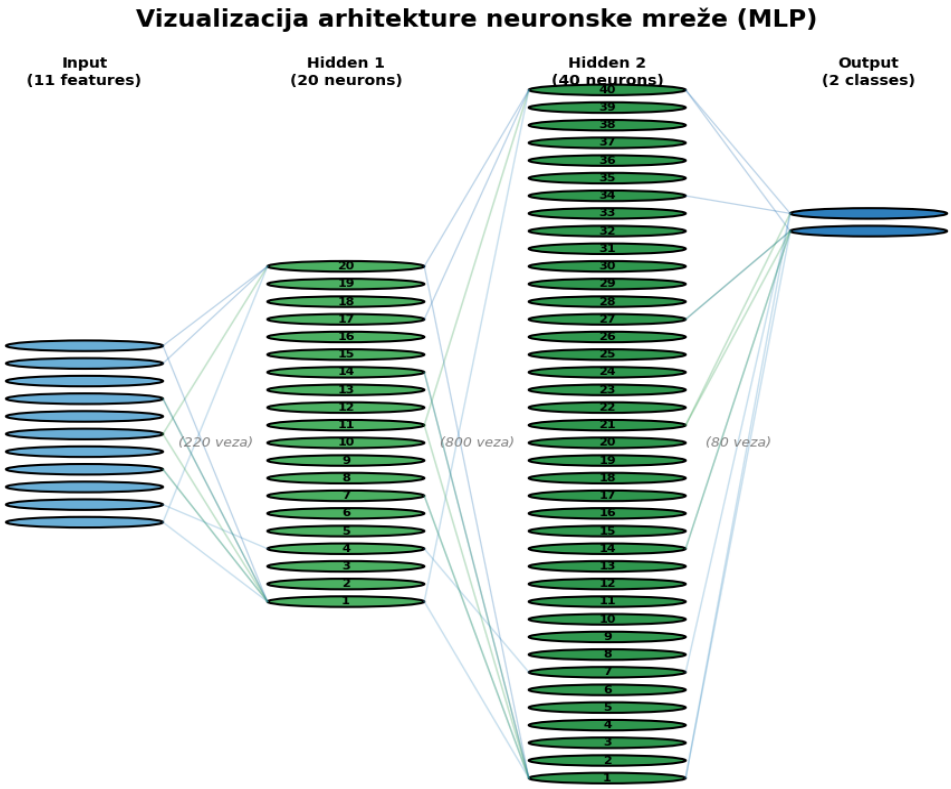
4. REZULTATI I RASPRAVA

Prilikom izrade modela za klasifikaciju profitabilnih i nepofitabilnih poduzeća s naglaskom na prepoznavanju neprofitabilnih poduzeća testirano je nekoliko arhitektura umjetne neuronske mreže (MLP) s ciljem pronalaska optimalne kombinacije hiperparametara koje će omogućiti što točnije prepoznavanje neprofitabilnih poduzeća. Testirane su i uspoređene različite aktivacijske funkcije (*ReLU*, *tanh, logistic*), optimizacijski algoritmi (*Adam*, *sgd* i *lbfgs*), te različiti brojevi neurona u skrivenim slojevima; od jednostavnijih struktura (20 neurona, 50 neurona) do dvoslojnih arhitektura (20 do 40 neurona, 40 do 60 neurona). S obzirom na neuravnoteženost uzorka, tijekom treniranja modela primijenjeno je stratificirano uzorkovanje. Optimizacija hiperparametara provedena je metodom *GridSearchCV* uz petostruku stratificiranu unakrsnu validaciju.

Najbolji rezultati postignuti su sljedećom kombinacijom parametara:

- aktivacijska funkcija: *tanh*,
- optimizator: *lbfgs*,
- regularizacijski parameter (alpha): 0.0001,
- struktura mreže: dva skrivena sloja s 20 i 40 neurona,
- maksimalan broj iteracija: 200.

Na Slici 1 prikazana je i struktura optimalnog modela neuronske mreže dobivenog optimizacijom hiperparametara.



Slika 1: Arhitektura optimalnog modela neuronske mreže
(Izvor: Vlastita izrada autora)

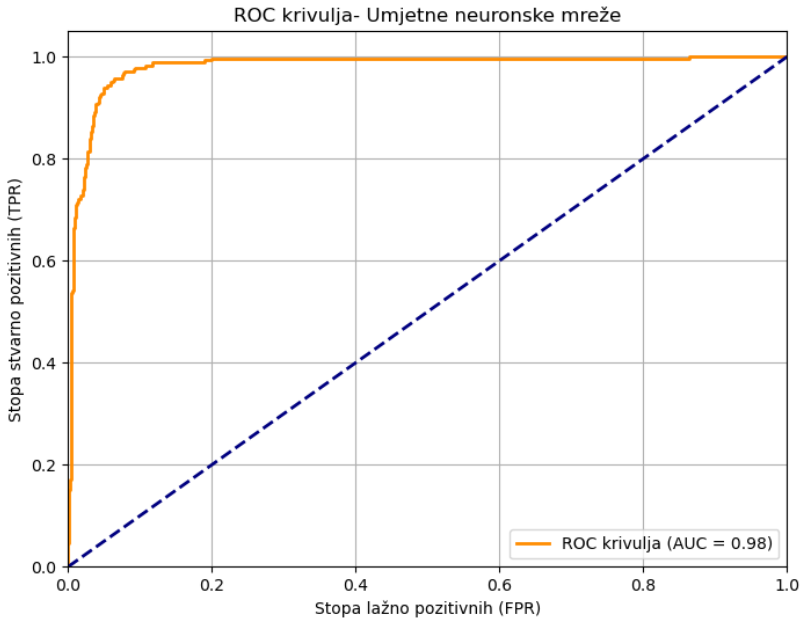
Model se sastoji od ulaznog sloja s 11 neurona, što odgovara broju ulaznih varijabli. Kod varijabli s kategorijalnim vrijednostima, svaka kategorija predstavlja zaseban neuron. Skriveni dio mreže čine dva sloja – prvi sa 20, a drugi sa 40 neurona. Izlazni sloj sastoji se od jednog neurona koji generira binarni izlaz, klasificirajući poduzeće kao profitabilno ili neprofitabilno. U skrivenim slojevima mreže korištena je aktivacijska funkcija hiperbolna tangens (tanh), dok je za optimizaciju težinskih koeficijenata primijenjen algoritam LBFGS (*Limited-memory Broyden–Fletcher–Goldfarb–Shanno*). Ovaj optimizacijski algoritam posebno je prikladan za manje i srednje velike mreže jer omogućuje brzu i stabilnu konvergenciju (LeCun i sur., 2015). Stopa učenja dinamički se prilagođavala tijekom procesa treniranja, ovisno o promjenama pogreške. Vrijednost regularizacijskog parametra postavljena je na $\alpha = 0.0001$, čime se učinkovito sprječavalo prekomjerno učenje modela (engl. *overfitting*). Prikazana arhitektura MLP sadrži 1.162 parametra (težine i pristranosti – engl. *bias)*, koji su tijekom procesa treniranja iterativno prilagođavani. Takav broj parametara ukazuje na umjerenu složenost modela; dovoljno visoku da može prepoznati nelinearne obrasce, ali i dovoljno ograničenu da se izbjegne pretreniranje.

Ova arhitektura pokazala se učinkovitom u prepoznavanju nelinearnih odnosa između financijskih pokazatelja (ulaznih varijabli) i statusa profitabilnosti poduzeća, čime se potvrđuje opravdanost primjene neuronskih mreža u modeliranju ovog problema. Kako bi se utvrdila uspješnost modela isti je testiran različitim evaluacijskim metrikama koje su prikazane u Tablici 2.

Pokazatelj	**Preciznost** (engl. Precision)	**Odaziv** (engl. Recall)	**F1 vrijednost** (engl. F1 score)	**AUC**	**Točnost** (engl. Accuracy
	0,87	0,88	0,88	0,98	0,95

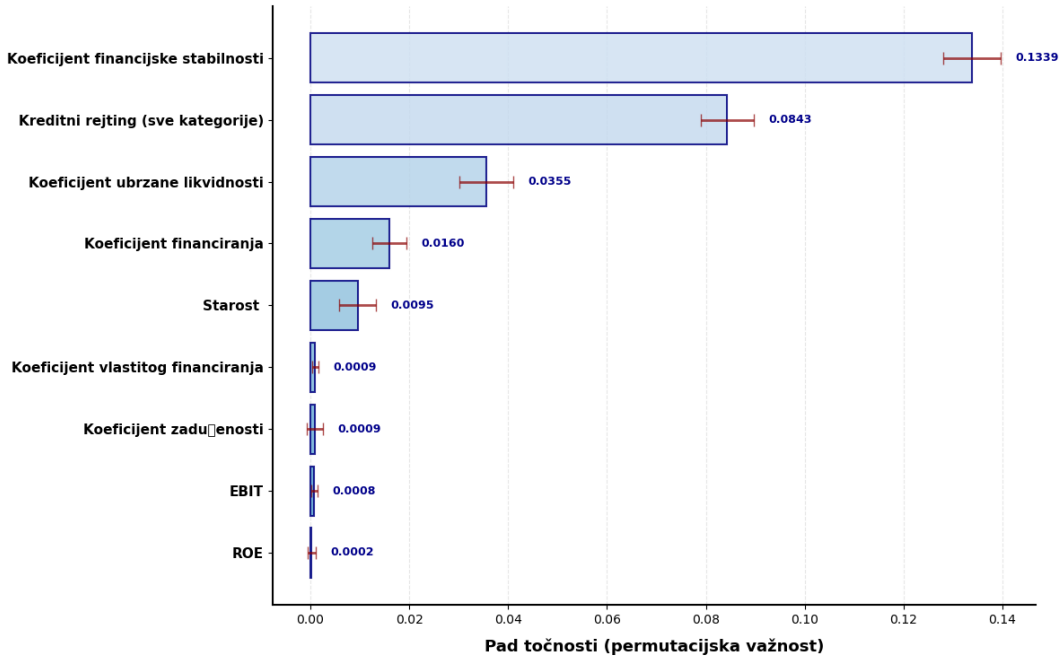
Tablica 1: Evaluacija optimalnog modela MLP
(Izvor: Vlastita izrada autora)

Poseban naglasak stavljen je na sposobnost modela da ispravno identificira neprofitabilna poduzeća, budući da su ona od najvećeg interesa za ranu detekciju poslovnih poteškoća. Preciznost (engl. *Precision*) mjeri udio ispravno klasificiranih neprofitabilnih poduzeća među svim poduzećima koja je model predvidio kao neprofitabilna. Visoka vrijednost od 87% preciznosti pokazuje da model rijetko pogrešno označava profitabilna poduzeća kao neprofitabilna, odnosno da generira mali broj lažno pozitivnih klasifikacija. Odaziv (engl. *Recall*) prikazuje sposobnost modela da prepozna sva stvarno neprofitabilna poduzeća u uzorku. Odaziv od 88% ukazuje da je model uspio identificirati većinu poduzeća koja doista ostvaruju negativan rezultat, što je ključno u kontekstu ranog upozoravanja na financijske poteškoće. F1 vrijednost od 88% pokazuje da model postiže dobar kompromis između točnosti predviđanja i sposobnosti prepoznavanja svih neprofitabilnih poduzeća. Točnost (engl. *Accuracy*) prikazuje udio svih ispravno klasificiranih poduzeća (profitabilnih i neprofitabilnih) u ukupnom uzorku. Međutim, s obzirom na neuravnoteženost klasa, točnost nije uzeta kao glavni pokazatelj uspješnosti modela, već je naglasak stavljen na pokazatelj odaziva (engl. *Recall*) koji bolje odražava sposobnost modela u prepoznavanju neprofitabilnih poduzeća.
Na Slici 2. Prikazana je ROC krivlja dobivenog optimalnog modela.



Slika 2: ROC krivulja višeslojne perceptronske neuronske mreže (MLP)
(Izvor: Vlastita izrada autora)

ROC krivulja prikazuje odnos između stope točno pozitivnih klasifikacija (engl. *True Positive Rate - TPR*) i stope lažno pozitivnih klasifikacija (engl. *False Positive Rate - FPR*) pri različitim pragovima odlučivanja modela. Površina ispod krivulje (engl. *Area Under the Curve-AUC*) predstavlja ukupnu sposobnost modela da razlikuje profitabilna od neprofitabilnih poduzeća. Vrijednosti AUC bliže 1 ukazuju na visoku razdvojnu moć modela, odnosno njegovu sposobnost da s velikom točnošću klasificira poduzeća u ispravnu kategoriju. Predloženi model neuronske mreže postigao je AUC vrijednost od 98%, što ukazuje na izrazito visoku razinu prediktivne točnosti i sposobnost modela da učinkovito prepoznaje neprofitabilna poduzeća.



Slika 3: Najznačajnije varijable višeslojne perceptronske neuronske mreže (MLP) (Izvor: Vlastita izrada autora)

Na Slici 3 prikazana je važnost pojedinih financijskih pokazatelja u predloženom modelu neuronske mreže (MLP), mjerenu metodom permutacijske važnosti. PFI (engl. *Permutation Feature Importance*) predstavlja tehniku neovisnu o vrsti modela, kojom se kvantificira doprinos pojedine varijable ukupnoj učinkovitosti modela. Temelji se na mjerenju smanjenja performansi modela nakon što se vrijednosti jedne varijable nasumično permutiraju unutar skupa podataka (Khan i sur., 2025). Vrijednosti prikazane na osi x (Slika 3) predstavljaju pad točnosti modela uzrokovan permutacijom pojedine varijable, čime se procjenjuje njezina relativna važnost. Veći pad točnosti ukazuje na veću relevantnost varijable u procesu klasifikacije, odnosno na njezin značajniji doprinos donošenju odluka modela. Rezultati pokazuju da su *koeficijent financijske stabilnosti, kreditni rejting* i *koeficijent ubrzane likvidnosti* najznačajnije varijable u modelu, jer njihova permutacija dovodi do najvećeg smanjenja točnosti klasifikacije. Ove varijable odražavaju sposobnost poduzeća da održava financijsku ravnotežu i servisira obveze, što izravno utječe na njegovu profitabilnost. S druge strane, pokazatelji poput *EBIT-a* i *ROE-a*, iako tradicionalno važni u financijskoj analizi, u ovom modelu imaju relativno mali doprinos točnosti. Drugim riječima, vrijednost 0,1339 za varijablu *Koeficijent financijske stabilnost* znači da bi točnost modela pala za približno 13,39% ako bi se vrijednosti te varijable permutirale, dok bi utjecaj varijable *ROE* bio gotovo zanemariv (pad točnosti manji od 0,03%).

Takvi rezultati mogu upućivati na činjenicu da su profitabilni i neprofitabilni slučajevi (poduzeća) u uzorku slični prema ovim pokazateljima, dok stabilnost, likvidnost i struktura financiranja pružaju snažniji signal o statusu profitabilnosti. Dobiveni rezultati u ovom istraživanju potvrđuju zaključke prethodnih istraživanja o važnosti financijskih pokazatelja povezanih sa stabilnošću, likvidnošću i strukturom kapitala u predviđanju profitabilnosti poduzeća, ali i da metode strojnog učenja mogu doseći vrlo visoku prediktivnu točnost pri klasifikaciji profitabilnih i neprofitabilnih poduzeća.

5. ZAKLJUČAK

Rezultati dobiveni ovim istraživanjem potvrđuju da razvijeni model višeslojne perceptronske neuronske mreže (MLP) ostvaruje vrlo dobre performanse u klasifikaciji poduzeća prema profitabilnosti, s osobitom sposobnošću pravovremenog prepoznavanja neprofitabilnih subjekata. Visoke vrijednosti evaluacijskih metrika (F1 = 0,88, AUC = 0,98) ukazuju na to da model učinkovito razlikuje profitabilna od neprofitabilnih poduzeća te da se može koristiti kao pouzdan alat za rano otkrivanje financijskih poteškoća. Navedeno potvrđuje da primjena neuronskih mreža može značajno unaprijediti tradicionalne metode analize i predviđanja poslovne uspješnosti. Analiza značajnosti varijabli pokazala je da su pokazatelji stabilnosti i likvidnosti najznačajniji prediktori profitabilnosti poduzeća. Koeficijent financijske stabilnosti imao je najveći utjecaj na točnost modela, dok su kreditni rejting, koeficijent ubrzane likvidnosti i koeficijent financiranja dodatno potvrdili važnost uravnoteženog odnosa između vlastitih i tuđih izvora kapitala. S druge strane, tradicionalni pokazatelji dobiti poput EBIT-a i ROE-a imali su manji doprinos klasifikaciji, što može ukazivati da oni odražavaju posljedicu, a ne uzrok smanjenja profitabilnosti. Predloženi model je pokazao da su upravo varijable koje odražavaju financijsku stabilnost i likvidnost rani indikatori poslovnih poteškoća, što ga čini posebno korisnim za razvoj sustava ranog upozoravanja. Takvi sustavi mogu pomoći menadžerima, investitorima i financijskim institucijama u donošenju utemeljenih odluka i pravovremenom poduzimanju mjera za smanjenje rizika. Iako rezultati potvrđuju visoku točnost modela neuronske mreže, istraživanje ima nekoliko ograničenja. Uzorak obuhvaća samo hrvatska IT poduzeća, što ograničava mogućnost generalizacije na druge sektore. Model se temelji isključivo na financijskim pokazateljima, bez uključivanja nefinancijskih čimbenika. Iako je neuravnoteženost podataka u MLP modelu djelomično ublažena primjenom stratificiranog uzorkovanja, postoji prostor za dodatna poboljšanja primjenom naprednijih tehnika uravnoteženja koje bi mogle dodatno povećati točnost i stabilnost modela. Proširenje analize na različite sektore te uključivanje nefinancijskih pokazatelja, poput inovativnosti, digitalne zrelosti i održivosti, može pridonijeti većoj robusnosti i interpretabilnosti modela. Osim toga, usporedba neuronskih mreža s drugim algoritmima strojnog učenja, poput slučajnih šuma (engl. *Random Forest*) omogućila bi procjenu konzistentnosti prediktivnih rezultata. Takva proširenja mogu doprinijeti razvoju sveobuhvatnih sustava ranog upozoravanja te unaprijediti donošenje informiranih odluka u području financijskog upravljanja i analize rizika.

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THE RELATIONSHIP BETWEEN FINANCIAL PERFORMANCE MANAGEMENT AND ENERGY COSTS

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ABSTRACT

In recent years, numerous global events have had significant consequences worldwide. Among them, the energy crisis caused by the military conflict between Russia and Ukraine stands out, resulting in financial repercussions for businesses across the globe. Companies in many sectors, such as construction—which is the focus of this study—are particularly exposed to the risks associated with fluctuations in energy prices. In such an environment, businesses may resort to manipulative practices to present their financial performance as more stable than it actually is. More specifically, financial difficulties act as an incentive for companies to engage in earnings management. The primary aim of this study is to analyze the relationship between earnings management and the share of energy costs in the assets of companies. The sample includes joint-stock companies operating in the construction sector in Croatia from 2021 to 2024. Statistical modeling was performed using panel regression analysis. The intensity of earnings management was estimated using the modified Jones model. Descriptive statistics indicate that in the year the war began, the share of energy costs in the assets of the companies under review increased significantly. This trend is likely due to rising energy prices, which affected the companies' financial positions. Two years later, the share of energy costs in assets declines sharply, which may be attributed to reduced business activity or earnings management. Regression analysis results suggest a positive relationship between earnings management and changes in the share of energy costs. Based on these findings, it can be concluded that rising energy prices incentivize earnings management.

Keywords*: Earnings management, Energy costs, Financial reporting quality*

POVEZANOST UPRAVLJANJA FINANCIJSKIM REZULTATOM I TROŠKOVA ENERGIJE

SAŽETAK

Posljednjih godina nastali su brojni događaji čije posljedice je osjetio čitavi svijet. Među njima se može izdvojiti energetska kriza uzrokovana ratnim aktivnostima između Rusije i Ukrajine koja je rezultirala financijskim reperkusijama za poslovne subjekte diljem svijeta. Poslovanje trgovačkih društava u mnogim djelatnostima, poput građevinarstva koje je analizirano u ovom istraživanju, znatno je izloženo rizicima promjene cijena energenata. U takvom okružju poslovni subjekti mogu pribjeći manipulativnim aktivnostima kako bi vlastito poslovanje prikazali stabilnijim nego što jest. Preciznije rečeno, financijske poteškoće djeluju kao poticaj poslovnim subjektima za upravljanje financijskim rezultatom. Temeljni cilj ovog istraživanja je analiza odnosa upravljanja financijskim rezultatom i udjela troškova energije u imovini trgovačkog društva. U uzorak istraživanja uključena su dionička društva koja su poslovala u građevinskoj djelatnosti na području Republike Hrvatske u razdoblju od 2021. do 2024. Statističko modeliranje provedeno je s pomoću panel regresijske analize. Intenzitet upravljanja financijskim rezultatom procijenjen je s pomoću modificiranog Jones modela. Deskriptivna statistika upućuje na to da se tijekom godine u kojoj je rat započeo udio troškova energije u imovini razmatranih društava znatno povećao. Za pretpostaviti je da su takva kretanja uzrokovana porastom cijena energenata koje su se reflektirale na financijsko stanje društava. Dvije godine nakon toga dolazi do intenzivnog pada vrijednosti udjela troškova energije u imovini, što se može pripisati padu poslovne aktivnosti ili upravljanju financijskim rezultatom. Rezultati regresijske analize upućuju na postojanje pozitivne povezanosti upravljanja financijskim rezultatom i promjene udjela troškova energije. Temeljem toga moglo bi se zaključiti da porast cijena energenata poticajno djeluje na upravljanje financijskim rezultatom.

Ključne riječi: *upravljanje zaradom, trošak energije, kvaliteta financijskog izvještavanja*

1. UVOD

Nedavna energetska kriza, koja je trajala od 2021. do 2023., rezultat je sinergijskog djelovanja krize uzrokovane koronavirusom i krize uzrokovane ratnim sukobom Rusije i Ukrajine (Agram & Rahal, 2024, str. 66). Reperkusije energetske krize odnosile su se na „inflaciju, sprječavanje rasta BDP-a i oskudne javne financije“ (Agram & Rahal, 2024, str. 66). Osim na stanovništvo, ova kriza znatno je utjecala i na poslovni sektor, ugrožavajući financijsku uspješnost trgovačkih društava. Financijske krize su „jedinstvena prilika za proučavanje učinaka krize na kvalitetu financijskog izvještavanja“ (Kousenidis, Ladas & Negakis, 2013, u Franceschetti, 2020, str. 27). “Energetski šokovi imaju duboke implikacije na financijsko zdravlje i operativne performanse trgovačkih društava” (The Bank for the Accounts of Companies Harmonized Working Group, 2023, str. 2). U takvom okružju kod trgovačkih društava stvaraju se poticaji za upravljanje financijskim rezultatom. Slijedom toga, u ovom istraživanju nastoji se pružiti odgovor na pitanje o povezanosti upravljanja zaradom i promjene udjela troškova energije u trgovačkim društvima. Znanstveni doprinos ovog istraživanja uključuje istraživanje povezanosti upravljanja financijskim rezultatom i udjela troškova energije u imovini trgovačkih društava za vrijeme energentske krize koje je provedeno na uzorku trgovačkih društava koja su poslovala u građevinarskoj djelatnosti u Republici Hrvatskoj. Prema saznanju autora, navedeni odnos prethodno nije bio predmetom znanstvenih istraživanja. Također, provedena je analiza kretanja intenziteta upravljanja financijskim rezultatom i udjela troškova energije u imovini trgovačkih društava tijekom kriznog razdoblja u Republici Hrvatskoj. Pružen je uvid u financijske informacije trgovačkih društava iz djelatnosti građevinarstva koja u velikoj mjeri ovisi o cijeni energenata.

2. PREGLED LITERATURE

Koliko je autorima poznato, istraživanja povezanosti troškova energije i upravljanja financijskim rezultatom u ovom obliku nisu ranije provođena, stoga postoji potreba da se ovo područje detaljnije istraži. Zbog manjka istraživanja navedene tematike, u ovom poglavlju prikazana su istraživanja iz srodnog područja koje u odnos stavlja troškove energije i financijske performanse trgovačkih društava. Tako primjerice Herman, Nistor i Jula (2023, p. 1) istražuju povezanost profitabilnosti i cijena energije na uzorku europskih država i tvrde da "porast cijena energije utječe na rizik da trgovačka društva ostvare negativnu profitabilnost u 2022. u usporedbi s 2018., mjereno s povećanjem broja trgovačkih društava koja objavljuju dobit manju ili jednaku nuli". The Bank for the Accounts of Companies Harmonized Working Group (2023, p. 2) istraživali su odnos profitabilnosti i fluktuacija troškova također na uzorku europskih država i utvrdili kako "njihova preliminarna analiza općenito ističe negativnu korelaciju porasta cijena energije i pokazatelja profitabilnosti trgovačkog društva". U takvom okružju negativnog utjecaja cijena energije na performanse trgovačkih društava stvaraju se poticaji za upravljanje financijskim rezultatom. Stoga se postavlja sljedeća istraživačka hipoteza: ***Postoji pozitivna povezanost upravljanja financijskim rezultatom i udjela troškova energije u imovini trgovačkog društva***.

3. METODOLOGIJA

3.1. Uzorak istraživanja

Uzorak istraživanja sastoji se od svih aktivnih dioničkih društava u djelatnosti F – Građevinarstvo sukladno Odluci o nacionalnoj klasifikaciji djelatnosti 2025. – NKD 2025. (Narodne novine, 2024). Navedena djelatnost odabrana je zbog njezine visoke ovisnosti o troškovima energije. U uzorak je uključeno 60 dioničkih društava i njihovi financijski podaci tijekom četiri poslovne godine, od 2021. do 2024. Podaci su prikupljeni iz financijskih izvještaja dostupnih u bazi podataka Fina Info.BIZ koju vodi Financijska agencija (Fina, n.d.).

3.2. Model istraživanja

Za potrebe istraživanja formiran je sljedeći model:

$$aDOS_i = \beta_0 + \beta_1 * EUA_i + \beta 2 * KTL_i + \beta 3 * KZ_i + \beta 3 * RVK_i + e_i \quad (2)$$

Varijable uključene u model su sljedeće: aDOS je apsolutna vrijednost diskrecijskih obračunskih stavki izračunana s pomoću formule za modificirani Jones model sukladno pristupu kojeg su koristili Khunkaew i Qingxiang (2019), EUA predstavlja omjer troškova energije i ukupne imovine, KTL je koeficijent tekuće likvidnosti, KZ je koeficijent zaduženosti, RVK je rentabilnost vlastitog kapitala (Fina, n.d.).

Pokazatelj	Kratica	Formula	
		Brojnik	Nazivnik
Omjer troškova energije i ukupne aktive	EUA	Troškovi energije	Ukupna aktiva
Koeficijent tekuće likvidnosti	KTL	Kratkotrajna imovina	Kratkoročne obveze
Koeficijent zaduženosti	KZ	Dugoročne obveze + kratkoročne obveze	Ukupna aktiva
Rentabilnost vlastitog kapitala (ROE)	RVK	Dobit ili gubitak razdoblja	Kapital i rezerve

Tablica 1: Pregled pokazatelja uključenih u analizu
(Izvor: Fina, n.d.)
Napomena: Vrijednost pokazatelja RVK pomnožena je sa 100.

Zavisna varijabla je vrijednost diskrecijskih obračunskih stavki koja se često koristi za procjenu razine upravljanja financijskim rezultatom, a testna varijabla su troškovi energije čija povezanost s upravljanjem financijskim rezultatom je temeljno pitanje ovog znanstvenog rada. Pod troškovima energije podrazumijevaju se "obračunani troškovi energije potrošene u obavljanju djelatnosti poslovnog subjekta" (Fina, 2024, str. 8). "Uključeni su troškovi električne energije, plina, pare, goriva, motornog ulja, mazuta, ulja za loženje, ugljena, drva i sl. Isključuju se energetski proizvodi kupljeni kao sirovina ili kao roba za daljnju prodaju u nepromijenjenu stanju" (Fina, 2024, str. 8). Kao kontrolne varijable uključeni su pokazatelji koji predstavljaju likvidnost, zaduženost i profitabilnost o kojima znantno ovisi motivacija menadžmenta da se upusti u upravljanje financijskim rezultatom.

3.3. Statistička metodologija

Za potrebe prikaza rezultata istraživanja korištena je deskriptivna statistika, korelacijska analiza i regresijska analiza. S obzirom na to da su korišteni podaci za četiri poslovne godine, korištena je panel regresijska analiza. Statističke obrade su provedene s pomoću programa za statističku analizu PAST 4.03 (Hammer i sur., 2001) i R language and environment for statistical computing (R Core Team, 2024). Uz program R korišteni su njegovi paketi poput the plm Package (Croissant & Millo, 2008; Croissant & Millo, 2018), the stargazer (Hlavac, 2022), the lm test (Zeileis & Hothorn, 2002) i the car package (Fox & Weisberg, 2019).

4. REZULTATI

Rezultati obuhvaćaju deskriptivnu statistiku, korelacijsku analizu i regresijsku analizu. Radi potencijalnog utjecaja na vrijednost modela, uklonjeno je 5 % ekstremnih pozitivnih vrijednosti, odnosno stršećih varijabli (eng. *outliera*).

Godina	aDOS	Pr_EUA
2021.	0,19	0,15
2022.	0,16	0,61
2023.	0,17	0,05
2024.	0,22	-0,17

Tablica 1: Prosječne vrijednosti zavisne i testne varijable po godinama
(Izvor: Analiza autora)
Legenda: aDOS = apsolutna vrijednost diskrecijskih obračunskih stavki izračunana modificiranim Jones modelom, Pr_EUA = promjena omjera troškova energije i ukupne imovine.

Deskriptivna statistika sadržana u tablici 1 upućuje na to da je tijekom ratne godine došlo do znantnog povećanja udjela troškova energije u imovini građevinskih dioničkih društava. U sljedećoj godini dolazi do drastičnog smanjenja ovog pokazatelja, odnosno prisutan je tek blagog porasta, da bi u 2024. došlo do pada vrijednosti ovog udjela. Ovakav intenzivan pad vrijednosti mogao bi biti naznaka smanjenja poslovne aktivnosti. Ako se podaci sagledaju zajedno s apsolutnom vrijednošću diskrecijskih obračunskih stavki za tu godinu, vidljivo je da je porasla razina upravljanja financijskim rezultatom pa bi se dio tog pada mogao pripisati i upravljanju financijskim rezultatom.

Korelacijska analiza obuhvaća izračun korelacijskih koeficijenata između zavisne varijable, testne varijable i kontrolnih varijabli (Tablica 2). Ako se granična vrijednost od 0,8 koristi kao referentna vrijednost procjene postojanja problema multikolinearnosti, može se konstatirati da nije prisutan problem multikolinearnosti između varijabli uključenih u korelacijsku matricu (Kennedy, 2008, u Enomoto, Kimura & Yamaguchi, 2018, str. 190).

	aDOS	Pr_EUA	KTL	KZ	RVK
aDOS	1				
Pr_EUA	0,12*	1			
KTL	0,17**	-0,03	1		
KZ	0,09	0,16**	-0,02	1	
RVK	0,11*	-0,03	-0,01	-0,005	1

Tablica 2: Korelacijska matrica
(Izvor: Analiza autora)
Legenda: aDOS = apsolutna vrijednost diskrecijskih obračunskih stavki izračunana modificiranim Jones modelom, Pr_EUA = promjena omjera troškova energije i ukupne imovine, KTL = koeficijent tekuće likvidnosti, KZ = koeficijent zaduženosti, RVK = rentabilnost vlastitog kapitala (ROE).

Varijabla	FIV
Pr_EUA	1,0384
KTL	1,0014
KZ	1,0375
RVK	1,0013

Tablica 3: Faktor inflacije varijance
(Izvor: Analiza autora)
Legenda: Pr_EUA = promjena omjera troškova energije i ukupne imovine, KTL = koeficijent tekuće likvidnosti, KZ = koeficijent zaduženosti, RVK = rentabilnost vlastitog kapitala (ROE).

Vrijednosti faktora inflacije varijance u Tablici 3 znatno su ispod referentne vrijednosti 3,4 (Doupnik, 2008, str. 332) te potkrjepljuju zaključke dobivene temeljem korelacijske matrice, odnosno upućuju na to da nije prisutan problem multikolinearnosti.

Varijabla	Zavisna varijabla: aDOS
Pr_EUA	0,019**
	(0,009)
KTL	0,0005**
	(0,0002)
KZ	0,001
	(0,001)
RVK	0,001*
	(0,001)
Constant	0,174***
	(0,012)

Tablica 4: Regresijska analiza
(Source: Analiza autora)
Legenda: aDOS = apsolutna vrijednost diskrecijskih obračunskih stavki izračunana modificiranim Jones modelom, Pr_EUA = promjena omjera troškova energije i ukupne imovine, KTL = koeficijent tekuće likvidnosti, KZ = koeficijent zaduženosti, RVK = rentabilnost vlastitog kapitala (ROE).

Rezultati regresijske analize u Tablici 4 upućuju na pozitivan odnos apsolutne vrijednosti diskrecijskih obračunskih stavki i promjene omjera troškova energije i ukupne imovine. Temeljem rezultata Hausmanovog testa u panel analizi primijenjen je model sa slučajnim efektima. Statističkim testovima je utvrđeno odsutstvo autokorelacije i heteroskedastičnosti.

5. ZAKLJUČAK

Krizna događanja u posljednjim godinama rezultirala su porastom cijena energenata. S obzirom na to da rastući troškovi energenata mogu djelovati kao snažan poticaj za upravljanje financijskim rezultatom, temeljni cilj ovog istraživanja je analiza odnosa troškova energije i upravljanja financijskim rezultatom. Rezultati su pokazali pozitivan odnos upravljanja financijskim rezultatom i promjene udjela troškova energije u ukupnoj imovini građevinskih dioničkih društava, odnosno istraživačka hipoteza je potvrđena. Sukladno očekivanjima, tijekom ratne godine došlo je do znantnog povećanja udjela troškova energije u imovini građevinskih dioničkih društava, ali u 2024. dolazi do intenzivnog pada vrijednosti vrijednosti ovog pokazatelja koji bi mogao biti naznaka smanjenja poslovne aktivnosti. Djelomično bi se taj pad mogao pripisati i upravljanju financijskim rezultatom. S obzirom na to da je razina upravljanja financijskim rezultatom u djelatnosti građevinarstava u godinama koje su uključene u uzorak bila relativno visoka, preporučljivo je da se u budućnosti analiziraju i druge djelatnosti. Također, u ovom istraživanju analizirana su isključivo dionička društva za koje se može pretpostaviti da bi zbog svoje veličine trebala biti otpornija na energetske šokove. Stoga bi u uzorak trebalo uključiti i manja trgovačka društva.

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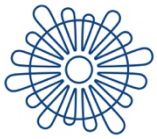

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