

SuTra2026

International Conference on Sustainable Transport

Book of Conference Contributions

Research Abstracts, Project Summaries,
Invited Lectures, and Expert Panel Overviews

Opatija, Croatia • 4 – 6 November 2026



SuTra2026

International Conference on Sustainable Transport

Opatija, Croatia • 4 – 6 November 2026

Book of Conference Contributions

Research Abstracts, Project Summaries,
Invited Lectures, and Expert Panel Overviews

Organised by



University of Rijeka
FACULTY OF MARITIME STUDIES



**University
North**

Conference Partner



**FACULTY OF TRANSPORT
AND TRAFFIC SCIENCES**

SuTra 2026 Book of Conference Contributions:

Research Abstracts, Project Summaries, Invited Lectures, and Expert Panel Overviews

Published by

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Address: Faculty of Maritime Studies, Studentska 2, 51000 Rijeka, Croatia

Phone: +385 (0)51 338 411, URL: <http://www.pfri.uniri.hr/>, E-mail: dekanat@pfri.uniri.hr

University North, Koprivnica, Croatia

Address: University North, Trg dr. Žarka Dolinara 1, 48000 Koprivnica, Croatia

Phone: +385 (0)48 499 923, URL: <https://www.unin.hr/>, E-mail: info@unin.hr

For the Publisher

Prof **Ana Perić Hadžić**, PhD, Dean, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Prof **Damir Vusić**, PhD, Rector, University North, Koprivnica, Croatia

Editors

Assoc Prof **David Brčić**, PhD, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Asst Prof **Nikola Lopac**, PhD, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Proofreading

Jana Kegalj, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Mirjana Borucinsky, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Visual Concept and Graphic Design

David Brčić and Tempora, Rijeka

Typesetting and Layout

Tempora, Rijeka

Printing

Tiskara Sušak, Rijeka

Printing Support

University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia

Conference Partner of SuTra 2026

Editorial note: Selected editorial, analytical and visualisation tasks were supported by generative AI and computational tools. Final editorial decisions and responsibility for the preparation of the volume remained with the editors. The content of individual contributions remains the responsibility of the respective authors, including the accuracy, originality and appropriate citation of the material presented, as well as compliance with applicable ethical and publication standards. The views, interpretations and conclusions expressed in individual contributions do not necessarily reflect those of the editors or the publisher.

Technical organiser



Vivid Original

Copyright © 2026 University of Rijeka, Faculty of Maritime Studies

Published in 2026

ISBN 978-953-165-151-6

International Scientific, Programme and Organising Committee

Conference Chairs

Ana Perić Hadžić, University of Rijeka, Faculty of Maritime Studies, Croatia

Damir Vusić, University North, Croatia

Conference Coordinator & Programme Chair

David Brčić, University of Rijeka, Faculty of Maritime Studies, Croatia

Programme Committee

Predrag Brlek, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia

Jasmin Čelić, University of Rijeka, Faculty of Maritime Studies, Croatia

Neven Grubišić, University of Rijeka, Faculty of Maritime Studies, Croatia

Luka Liker, University of Rijeka, Faculty of Maritime Studies, Croatia

Nikola Lopac, University of Rijeka, Faculty of Maritime Studies, Croatia

Miljenko Mustapić, University North, Department for logistics and sustainable mobility, Croatia

Goran Vukelić, University of Rijeka, Faculty of Maritime Studies, Croatia

Scientific Committee

Chair: Nikola Lopac, University of Rijeka, Faculty of Maritime Studies, Croatia

Borna Abramović, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia

• Dea Aksentijević, University of Rijeka, Faculty of Maritime Studies, Croatia • Dario Babić, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • Svetlana Bačkalić, University of Novi Sad, Faculty of Technical Sciences, Serbia • Maja Bakran Marcich, DG MOVE, EC, Belgium • Nebojša Bojović, University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia • David Brčić, University of Rijeka, Faculty of Maritime Studies, Croatia • Predrag Brlek, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • Dalibor Brnos, Port Authority of Pula, Croatia • Juraj Bukša, ACI dd, Rijeka, Croatia • Krešimir Buntak, University North, Department for logistics and sustainable mobility, Croatia • Jasmin Čelić, University of Rijeka, Faculty of Maritime Studies, Croatia • Verica Dancevska, Faculty of Technical Sciences, Department of Traffic and Transport, North Macedonia • Miroslav Drljača, University North, Department for logistics and sustainable mobility, Croatia • Renato Filjar, University of Applied Sciences Hrvatsko Zagorje Krapina, Croatia • Ana Globočnik Žunac, University North, Koprivnica, Croatia • Neven Grubišić, University of Rijeka, Faculty of Maritime Studies, Croatia • Rajko Horvat, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • Špiro Ivošević, University of Montenegro, Faculty of Maritime Studies, Montenegro • Mladen Jardas, University of Rijeka, Faculty of Maritime Studies, Croatia • Dragan Jovanović, University of Novi Sad, Faculty of Technical Sciences, Serbia • Alen Jugović, University of

Rijeka, Faculty of Maritime Studies, Croatia • **Goran Kos**, Institute for Tourism, Zagreb, Croatia • **Aleksandra Kostić-Ljubisavljević**, University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia • **Tomislav Krljan**, PTV Group (PTV Planung Transport Verkehr GmbH), Vienna, Austria • **Ljudevit Krpan**, University North, Department for logistics and sustainable mobility, Croatia • **Luka Liker**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Robert Maršanić**, University North, Department for logistics and sustainable mobility, Croatia • **Ivana Martinčević**, University North, Department for logistics and sustainable mobility, Croatia • **Xavier Martinez de Oses**, Faculty of Nautical Studies of Barcelona, Technical University of Catalonia, Barcelona, Spain • **Jakša Mišković**, University of Split, Faculty of Maritime Studies, Croatia • **Miljenko Mustapić**, University North, Department for logistics and sustainable mobility, Croatia • **Nina Nesterova**, Breda University of Applied Sciences, Breda, Netherlands • **Luka Novačko**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Renato Oblak**, Adria Polymers d.o.o, Omišalj, Croatia • **Matija Orešković**, University North, Department for Civil Engineering, Croatia • **Luminita Parv**, Transilvania University Brasov, Faculty of Technological Engineering and Industrial Management, Romania • **Ana Perić Hadžić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Dalibor Pešić**, University of Belgrade, Faculty of Transport and Traffic, Engineering, Serbia • **Saša Petar**, University North, Department for logistics and sustainable mobility, Croatia • **Radoslav Radonja**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Biserka Rukavina**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Donald Schiozzi**, Port Authority of Rovinj, Croatia • **Vesna Sesar**, University North, Department for logistics and sustainable mobility, Croatia • **Nenad Sikirica**, Krapina University of Applied Science, Krapina, Croatia • **Milan Simeunović**, Faculty of Technical Sciences, University of Novi Sad, Serbia • **Merica Slišković**, University of Split, Faculty of Maritime Studies, Croatia • **Zlatko Sovreski**, Faculty of Technical Sciences, Department of Traffic and Transport; Faculty of Transportation Sciences, Czech Republic • **Katarina Stojanović**, Faculty of Economics and Engineering Management in Novi Sad, University Business Academy in Novi Sad, Serbia • **Marko Strabić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Senka Šekularac Ivošević**, University of Montenegro, Faculty of Maritime Studies, Montenegro • **Marko Šoštarić**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Robert Ulewicz**, Czestochowa University of Technology, Poland • **Sanjin Valčić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Pero Vidan**, University of Split, Faculty of Maritime Studies, Croatia • **Siniša Vilke**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Goran Vizentin**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Šime Vučetić**, University of Zadar, Maritime Department, Croatia • **Goran Vukelić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Dražen Žgaljić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Martina Žuškin**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Srđan Žuškin**, University of Rijeka, Faculty of Maritime Studies, Croatia

Organising Committee

Chair: David Brčić, University of Rijeka, Faculty of Maritime Studies, Croatia

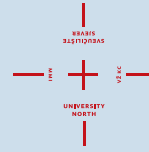
Dea Aksentijević, University of Rijeka, Faculty of Maritime Studies, Croatia • **Saša Aksentijević**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Dario Babić**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Mirjana Borucinsky**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Predrag Brlek**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Dalibor Brnos**, Port Authority of Pula, Croatia • **Juraj Bukša**, ACI dd, Rijeka, Croatia • **Krešimir Buntak**, University North, Department for logistics and sustainable mobility, Croatia • **Ivan Cvitković**, University North, Department for logistics and sustainable mobility, Croatia • **Jasmin Čelić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Nives Domjan Kačarević**, University North, Department for logistics and sustainable mobility, Croatia • **Neven Grubišić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Rajko Horvat**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Andrea Ivanišević**, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia • **Špiro Ivošević**, University of Montenegro, Faculty of Maritime Studies, Montenegro • **Mladen Jardas**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Jasmina Jelčić Čolakovac**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Alen Jugović**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Jana Kegalj**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Ante Klečina**, University North, Department for logistics and sustainable mobility, Croatia • **Goran Kolarić**, Ministry of Science and Education • **Maja Križanec Cvitković**, University North, Department of Media and Communication, Croatia • **Tomislav Krlijan**, PTV Group (PTV Planung Transport Verkehr GmbH), Vienna, Austria • **Ljudevit Krgan**, University North, Department for logistics and sustainable mobility, Croatia • **Fitim Kurti**, University North, Department for logistics and sustainable mobility, Croatia • **Luka Likar**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Nikola Lopac**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Marijana Marijanović**, University of Rijeka, Faculty of Engineering, Croatia • **Ivana Martinčević**, University North, Department for logistics and sustainable mobility, Croatia • **Gea Miščević**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Jakša Mišković**, University of Split, Faculty of Maritime Studies, Croatia • **Miljenko Mustapić**, University North, Department for logistics and sustainable mobility, Croatia • **Renato Oblak**, Adria Polymers d.o.o, Omišalj, Croatia • **Matija Orešković**, University North, Department for Civil Engineering, Croatia • **Ana Perić Hadžić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Radoslav Radonja**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Biserka Rukavina**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Donald Schiozzi**, Port Authority of Rovinj, Croatia • **Vesna Sesar**, University North, Department for logistics and sustainable mobility, Croatia • **Karlo Severinski**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Nenad Sikirica**, University of Applied Sciences Hrvatsko Zagorje Krapina, Croatia • **Marko Strabić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Valentina Strabić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Ivana Šabanović-Uzelac**, Vivid Original d.o.o., Zagreb, Croatia • **Marko Šoštaric**, University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia • **Sanjin Valčić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Šime Vučetić**, University of Zadar, Maritime Department, Croatia • **Pero Vidan**, University of Split, Faculty of Maritime Studies, Croatia • **Siniša Vilke**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Goran Vizontin**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Goran Vukelić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Dražen Žgaljić**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Martina Žuškin**, University of Rijeka, Faculty of Maritime Studies, Croatia • **Srđan Žuškin**, University of Rijeka, Faculty of Maritime Studies, Croatia

Organisers



University of Rijeka
FACULTY OF MARITIME STUDIES

University of Rijeka, Faculty of Maritime
Studies, Rijeka, Croatia
<http://www.pfri.uniri.hr/>



**University
North**

University North, Koprivnica, Croatia
<https://www.unin.hr/>

Conference Partner



**FACULTY OF TRANSPORT
AND TRAFFIC SCIENCES**

University of Zagreb, Faculty of Transport
and Traffic Sciences (FPZ)
<https://www.fpz.unizg.hr>

With the support of

HGK



HRVATSKA
GOSPODARSKA
KOMORA

Croatian Chamber of Economy,
County Chamber Rijeka
<https://www.hgk.hr/zupanijska-komora-rijeka>



JANAF

JANAF
<https://janaf.hr>

VECTRINO



Vectrino
<https://www.vectrino.eu>



JADROLINIJA

Jadrolinija
<https://www.jadrolinija.hr/en>



**GRAD
OPATIJA**

Conference Patron

City of Opatija

<https://opatija.hr>



Tourist Board of the City of Opatija
<https://www.visitopatija.com/en/>



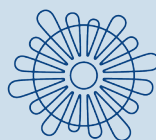
**Dezinsekcija®
RIJEKA**

Dezinsekcija d.o.o. Rijeka
<https://www.dezinsekcija.hr>



UNIVERSITY OF RIJEKA
FACULTY OF ECONOMICS

University of Rijeka,
Faculty of Economics and Business (EFRI)
<https://efri.uniri.hr>



University of Zadar

University of Zadar, Maritime Department
<https://www.unizd.hr>



Rijeka Gateway
<https://rijekagateway.com>

RIJEKA PLUS
d.o.o., Blaža Polića 2, Rijeka

RIJEKA plus
<https://www.rijeka-plus.hr>



Dragon Maritime Adria d.o.o.
<https://dragonmaritime.net>



MEP
<https://www.mep.hr>

Institutional support



University of Rijeka
<https://uniri.hr>

Selected conference activities are
supported by the University of Rijeka
through institutional funding.

Preface

Sustainable transport is easy to support as an idea, a concept. However, achieving sustainability requires knowledge, technology, investment and regulation, but also something harder to measure: a willingness to work across disciplines, institutions, sectors and borders. It means questioning established practices, testing new solutions, sharing what works, acknowledging what does not, and accepting responsibility for the systems we help to create. This is where we see our role.

SuTra was never intended to belong to a single transport mode, discipline or professional community. Transport does not work that way. Maritime, road, rail, air and inland waterway transport are parts of interconnected systems in which infrastructure, energy, digital technologies, logistics, safety, human behaviour, policy and the environment continuously intertwine, and influence one another. Sustainability therefore cannot be reduced to a single technology, type of fuel, indicator or policy target. It is a shared challenge and, more importantly, a collective task.

The contributions gathered in this book reflect that understanding. They move from artificial intelligence, data-driven systems and the resilience of navigation and critical infrastructure to maritime decarbonisation, alternative technologies, coastal development and the blue economy; from logistics, supply chains and intermodal transport to smart mobility, transport planning and the social dimensions of sustainability. Across these themes run questions of safety, human judgement, digital transformation and our ability to make increasingly complex transport systems more efficient, resilient and responsible. The work presented here comes from different countries, institutions, disciplines and professional backgrounds, approaching transport from different perspectives and at different scales. It includes scientific research, methodological advances, professional experience, technological solutions, project results and ideas still under development. Student contributions, invited contributions, project presentations and expert panel discussions extend that conversation further. For that reason, this volume goes beyond the conventional format of a book of abstracts. It captures the intellectual landscape of SuTra 2026 and, with it, the work of the people who shaped it.

Behind every contribution is an author or a team willing to share their work. Behind every session are reviewers, chairs and colleagues who dedicate their time and expertise. Behind the conference itself stands a much larger group of organisers, partners, institutions and supporters whose work may not always be visible, but without whom neither the conference nor this book would exist.

That effort matters because the challenges we address do not stop at institutional, disciplinary or national borders. Supply chains cross continents. Transport systems connect jurisdictions. Digital systems exchange information across networks. Environmental consequences are shared, as are questions of safety, resilience, energy, accessibility and mobility.

A conference cannot solve these challenges, nor should it pretend to. What it can do is create a place where people who might otherwise work separately meet, compare evidence, challenge assumptions and see familiar problems from another perspective. It can connect a young researcher with an experienced colleague, a scientific idea with an operational problem, or a project with a future partner. Sometimes, a discussion that begins in a session continues long after the conference has ended. Those may appear to be small outcomes. We do not think they are. To sustain is, after all, also to endure.

Sustainability is built in much the same way: through accumulated decisions, improvements, collaborations and changes in practice. Researchers shape it through the questions they choose to investigate. Universities through the people they educate. Industry through the technologies and practices it develops. Public institutions through the frameworks they create. And all of us through the choices we make about how, and with whom we work. SuTra is one small part of that process. We believe it is a meaningful one.

SuTra 2026 is also another step in the development of the conference itself. Each edition brings new people together, institutions and topics, while many colleagues return and continue conversations that began at previous meetings. That continuity is perhaps one of the most valuable things a conference can achieve. This book is therefore not only a record. It is also an invitation: to read beyond one's own field, continue a discussion started in Opatija, turn an idea into cooperation, bring students into that conversation, and return with new questions, results and partners.

To all authors, participants, reviewers, invited speakers, panellists, project teams, partners, sponsors, colleagues and friends who contributed to SuTra 2026, thank you. This conference and this book exist because you chose to take part.

We are proud to present the *SuTra 2026 Book of Conference Contributions*. More importantly, we look forward to seeing what emerges from it.

Editors

At a Glance

60

Contributions

143

Authors

12

Countries

Presentation formats

41 Oral presentations

19 Posters

38

Full-paper submissions

Contribution types

47 Research and professional

13 Student

Additional book content

8

Project summaries

2

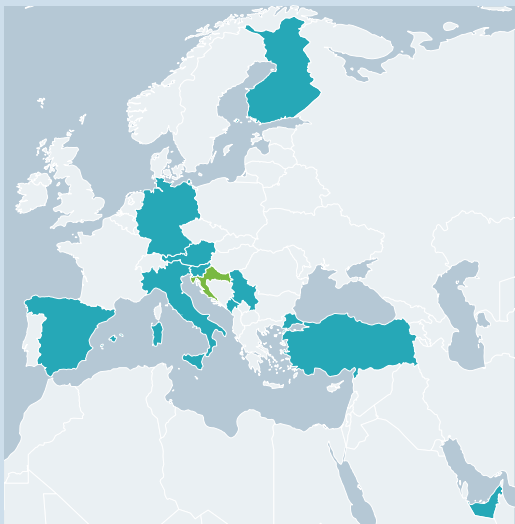
Invited contributions

3

Panel contributions

Themes and International Reach

International reach

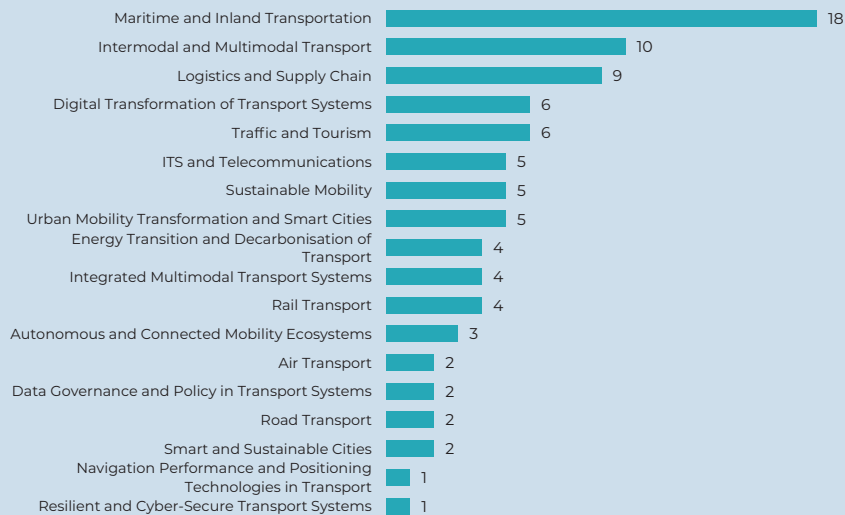


Authors by country

Croatia	112
Spain	6
Italy	4
Montenegro	4
Serbia	4
Slovenia	4
Türkiye	4
Austria	1
Finland	1
Germany	1
North Macedonia	1
United Arab Emirates	1

Thematic coverage

89 assignments



An abstract may address more than one theme.

Contents

Preface	8
PART I • Invited and Special Contributions	17
Jakov Karmelić From Maritime Wind Heritage to Wind-Powered Futures: Lessons for Sustainable Maritime Transport.....	19
Irena Jurdana Submarine Fibre-Optic Networks as Critical Infrastructure: Balancing Connectivity, Security, and Marine Environmental Protection	21
Robert Baždarić AI, Human Judgment and the Limits of Machine Intelligence: The Mirror of Delusion: Why AI Generates Our Hallucinations and How I Hover Above the Machine as a System Creator	23
PART II • Panel and Round Table Contributions	25
PANEL 1: Opening Panel of the SuTra Conference, Powered by the Horizon Europe INNO2MARE Project.....	27
PANEL 2: Resilient Infrastructure of the Future: AI, Cybersecurity and Critical Systems Protection.....	30
PANEL 3: Transport Models for the Digital Transformation of Cities and Citizen Mobility Information Services.....	32
PART III • Research and Professional Abstracts	37
Marija Jović Mihanović, Edvard Tijan, Saša Aksentijević Artificial Intelligence in Maritime Transport and Seaport Operations: A Literature Review.....	39
Zdravko Paladin, Nexhat Kapidani, Žarko Lukšić, Rasim Mujalović, Elson Thana Leveraging Artificial Intelligence Applications for Maritime Safety and Logistics Challenges: A Feature-Based Analysis	42
Nermin Hasanspahić, Maro Car, David Brčić Human Readiness for the Digital Transformation of Maritime Navigation	45
Luigia Mocerino, Maria Acanfora, Davor Šakan, David Brčić A Multi-Layer Validation Framework for AIS-Derived Mooring Episodes in Port Environments	47
Marijana Marjanović, Jasna Prpić-Oršić, Marko Valčić Neural Network-Based Ship Performance Prediction for Intelligent Autonomous Navigation Systems.....	49
Karlo Severinski, Jonatan Lerga, Nikola Lopac Analysis of Individual Ship-Motion Components for Attention-Based Sea-State Classification.....	51

Karlo Severinski, Ivan Otulić, Jonatan Lerga, Nikola Lopac On the Influence of Observation-Window Length in Sea-State Classification from Vessel Motions Using Attention-Based Machine Learning	53
David Brčić, Lovro Čović, Mario Bakota, Serđo Kos Is Accuracy Not Enough? Elevation Mask Angle Effects on GPS L1 Solution Availability in Maritime Positioning	55
Đani Mohović, Marko Šuljić, Antonio Blažina, Matej Šuper Determining Actions for Collision Prevention between Ships in a Close-Quarters Situation Using Simulated Avoiding Strategies	57
Ana Globočnik Žunac, Maja Križanec Cvitković, Ivana Perkušić Communication Safety: Reframing Communication as a Core Dimension of Transport Safety	59
Matej Šuper, Marko Strabić, Vlado Frančić, Đani Mohović The Contribution of Fatigue to Human Error in Maritime Accidents	61
Urban Pegan, Elen Twrđy, Danijela Tuljak-Suban A Multi-Criteria Assessment of Green Strategies for Achieving IMO Net-Zero Transition Goals: A Review	63
Marko Novaselić, Tomislav Bukša, Marko Valčić Fleet-Renewal Strategy for Decarbonising Small Passenger Vessels under the EU Maritime Decarbonisation Framework	65
Ivan Chetyrbok, Josip Orović Decarbonisation of Shipping with Alternative Fuels Technology Simulators	67
Ana Gundić, Astrid Zekić, Mateo Ivanac, Jasna Pletikosić Comprehensive Identification and Analysis of Key Challenges in the Blue Economy Sectors	69
Saša Petar, Božo Smoljan, Zoran Kobeščak Climate Risk in the Rhine–Danube–Sava Inland Waterway Corridor	71
Augustine-Moses Gaavwase Gbagir, Irena Jurdana A Remote Sensing Framework for Environmental Monitoring of Sustainable Coastal and Submarine Infrastructure Systems: A Pilot Study of a Cable-Landfall Coastal Area in Dubrovnik, Croatia	73
Mia Šarić, Astrid Zekić, Ana Gundić, Petra Radobuljac Alcedo Sustainable Coastal Management in Zadar County: Public Perceptions	77
Luka Vukić, Gorana Jelić Mrčelić Pursuing Standardization: Identifying Operational Criteria for Effective Beach Safety Flag Management	79
Elide Alinovi, Martí Puig, Rosa Mari Darbra Integrated Transport and Mobility Analysis to Improve Marina Planning: The Case of Sestri Levante (Italy)	81
Ana Perić Hadžić, Šime Vučetić, Ljiljana Peričin Calculation of Correlation and CAGR in Nautical Tourism: A Case Study of the Republic of Croatia	83
Luka Grbić, Mate Barić, Šime Vučetić Analysis of Trends in the Offer of Yacht Charter Agencies	85

Miljenko Mustapić, Davor Grgurević, Petra Tišler	
Global Supply Chain Disruptions and Import Resilience: Evidence from Croatia, 2015–2024	88
Atilla Cifter, N. Baris Vardar, Gul Esin Delipinar	
Which Sectors Benefit Most from Logistics Improvements in Africa? Evidence from Firm-Level Data	90
Gul Esin Delipinar, Ibrahim Uzpeder	
Intermodal Transportation and Green Logistics in Türkiye	92
Dea Aksentijević, Mateo Crnković	
From Paper to Interoperability: NSCP as a Model for Secure and Resilient Digitalization of Freight Transport	94
Marko Vukšić, Jasmin Ćelić, Ivan Panić, Aleksandar Cuculić	
Connected Reefer Containers for Perishable Cargo Supervision: LSTM-Based Early Warning of Microclimate Conditions Associated with Accelerated Ripening	96
Vice Milin, Marko Šundov, Oleg Zaretskiy	
Suspended Steel-Wheel String-Rail Complexes as a Second-Level Freight Transport Mode: A Comparative Techno-Economic and Environmental Assessment	98
Siniša Vilke, Josip Knežević, Bariša Rašić	
Reconstruction of the Rijeka Railway Junction as a Prerequisite for the Development of the Port of Rijeka	100
Tanja Poletan Jugović, Dražen Žgaljić, Anastazija Jakovac	
Cargo Consolidation Strategies and Documentation Flow in LCL Logistics	102
Svjjetlana Hess, Mirano Hess, Teo Tomulić	
Optimization of Delivery Vehicle Allocation and Routing Using Free Open-Source Tools: A Case Study of Express Parcel Delivery in Rijeka, Croatia	104
Marko Gulić, Neven Grubišić, Srđan Žuškin, Tonći Biočić	
Comparative Analysis of Energy Efficiency in Metaheuristic Algorithms for the Container Relocation Problem	106
Nives Domjan Kačarević, Ante Klečina, Ivan Cvitković	
Evidence-Based Urban Mobility Planning Using Multi-Source Transport Data: A Case Study of Opatija, Croatia	108
Nikola Kožul, Luka Novačko, Borna Abramović, Tomislav Fratrović	
Expert and User Perceptions of Multimodal Public Transport Attributes: A Comparative Analysis for Stated Preference Design	110
Neven Grubišić, David Brčić, Tomislav Krljan	
A Survey-Driven Digital Framework for Planning Demand Responsive Transport in Rural Areas: A Tour-Based Simulation Approach	112
Nikola Biškup, Ante Klečina, Nives Domjan Kačarević, Ivan Cvitković	
Assessing the Impact of Real-Time Passenger Information Systems on Perceived Bus Transport Service Quality: A Systematic Literature Review	114
Ante Klečina, Tanja Poletan Jugović, Dražen Žgaljić, Nives Domjan Kačarević	
From Service Standards to Infrastructure Needs: A Transferable Model for Suburban and Regional Railway Network Planning	116

Predrag Brlek, Luka Novačko, Karlo Babojelić, Zlatko Sovreski Analysis of Cycling Infrastructure and Road Accidents Involving Cyclists in the European Union	118
Paula Čaklec, Miljenko Mustapić, Nikola Biškup Mobile Eye Tracking as a Tool for Behaviour Analysis of Vulnerable Road Users	120
Nives Domjan Kačarević, Ante Klečina, Ivan Cvitković, Paula Čaklec Video-Based Assessment of Spatial Driver Behaviour in a Speed Enforcement Zone: A Case Study from Northern Croatia	122
Tomislav Krljan, Neven Grubisic, Luka Novačko, Marko Gulić Simulation-Based Generation of Traffic State Datasets for Machine Learning-Based Decision Support in Centralized Traffic Management.....	124
Katarina Stojanović, Andrea Ivanišević, Slađana Milovanović, Ksenija Orlandić Osmajić, Robert Maršanić Generative Infrastructure: Redefining Sustainable Mobility through AI Urbanism	126
Aythami Santana-Padrón, Lorenzo Masiero, Matias Manuel González Hernández, Javier de León Operational and Environmental Inefficiency in Air Transport: A By-Production Approach with Tourism Dependence	128
Carmelo J. León, Aythami Santana-Padrón, Javier de León Beyond Frontiers: A Symmetric Dual-Method Framework for Technical and Environmental Efficiency in European Aviation	130
Ivana Martinčević, Ana Globočnik Žunac, Ivona Huđek Kanižaj ESG Reporting as a Driver of Green Logistics: A Systematic Literature Review	132
Karlo Knežević, Vesna Sesar Gender and Age Differences in Citizens' Perceptions of Sustainable Urban Logistics and Quality of Life.....	134
PART IV • Student Contributions	137
Sara Kučiš, Nives Domjan Kačarević Analysis of Pedestrian Behaviour in Relation to Traffic Infrastructure around University North in Varaždin: A Case Study of Vinka Međerala Street	139
Mihaela Niković, Petra Bedeković, Marina Premužak, Nives Domjan Kačarević Analysis of Pedestrian Desire Lines in Relation to Traffic Infrastructure in the University North Campus Area: A Case Study of Peteranska Road, Koprivnica.....	141
Helena Luketić, Luka Novačko, Borna Abramović Sustainable Mobility in the Railway Sector	143
Šimun Šabijan, Saša Petar Last-Mile Delivery Solutions for Sustainable Urban Logistics	146
Luka Liker, Mladen Jardas, Ana Perić Hadžić Simulation-Based Evaluation of Urban Freight Delivery Flows: A Case Study of Rijeka, Croatia	148
Bor Petrovčić, Elen Twrdy Port-City Relationships in the Context of Sustainable Development.....	150

Eva Mlinar Mikuličić, Alen Jugović, Siniša Rajačić, Juraj Bukša Legal and Economic Comparison of Charterparty Agreements and Contracts for the Carriage of Individual Consignments with Particular Reference to Seaports	152
Marko Kopačić, Radoslav Radonja Nuclear Propulsion for Maritime Decarbonization: Challenges and Prospects	154
Mišo Kucelj From Regulatory Requirements to Operational Practice: The Environmental Officer's Role in Sustainable Cruise Ship Operation	156
Tomislav Mavra, Antonija Mišura, Astrid Zekić, Ana Gundić Environmental Pressure Associated with Blackwater at Nautical Anchorages: A Case Study of Zadar County.....	159
Roko Brečić, Tomislav Sunko, Toni Mišković, Vilim Đura Review of Emerging Sensor Fusion Technologies Integrating Electro-Optical and Advanced Radar Systems in the Maintenance of National Security	161
Pia Biondić, Neven Grubišić Feasibility Assessment of UAV Delivery Logistics in the UTM/U-space Environment.....	163
Domagoj Stojanović, Igor Rudan, Davor Šakan With the Wind at our Backs: Implications of Wind-Assisted Propulsion Systems for Maritime Training and Navigational Safety.....	165
PART V • Project Summaries	167
Zorica Đurović Digital Education for Maritime Communication	169
Ana Perić Hadžić, Dario Ogrizović, Irena Jurdana, Renato Ivče, Jasmin Čelić, Marko Vukić, Antonio Blažina, Luka Liker Multimedia Interactive Simulation Systems in the Maritime Sector	171
David Brčić, Jasmin Čelić, Sanjin Valčić, Serđo Kos, Mario Bakota, Nermin Hasanspahić, Maro Car Research on Dynamic Impacts and the Proposal of Modular Solutions for the Complex Electronic Navigation Environment	173
Mario Muštra, Edouard Ivanjko, Tomislav Radišić, Niko Jelušić, Jasna Leder Horina, Marijana Greblički, Luka Kramarić, David Brčić, Franc Dimc, Danijel Šugar Improving Localization Accuracy and Resilience of Global Navigation Satellite Systems Positioning.....	175
Nikola Lopac Sea State Estimation from Wave-Induced Ship Response Using Advanced Deep Learning Methods	177
Edvard Tijan, Saša Aksentijević, Gea Mišćević, Marija Jović Transformation of Maritime Transport: Digital Technologies and Alternative Fuels (TRANSMAR)	179
Marko Gulić, Neven Grubišić, Srđan Žuškin, Marko Valčić, Tonći Biočić Application of Energy-Efficient Metaheuristics to Optimisation Problems in Maritime Container Transport	181
Mladen Jardas Optimization of Urban Delivery Models through Simulation Analysis	183





From Maritime Wind Heritage to Wind-Powered Futures: Lessons for Sustainable Maritime Transport

Jakov Karmelić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Former IMO Ambassador

E-mail: jakov.karmelic@pfri.uniri.hr

Abstract

The traditional use of wind as a propulsion resource, deeply rooted in the heritage of wooden shipbuilding and sailing, demonstrates that the maritime sector historically operated with a fully decarbonised form of propulsion. The earliest evidence of sail use in the Mediterranean dates to c. 3100 BC, found on an Egyptian ceramic vessel, attests to the long history of harnessing wind as a source of maritime propulsion. As the need arose to build larger vessels with greater cargo capacity, and with the development of industrial shipbuilding, the introduction of iron and steel, and the transition to steam and diesel engines, wind was gradually abandoned as the primary source of energy.

Confronted with the negative emissions associated with fossil fuels and the requirements of the IMO's decarbonisation objectives, the contemporary maritime sector is once again opening space for a technologically advanced reinterpretation of wind through *Wind Propulsion Technology* (WPT) systems. This confirms that wind – once the sole means of propulsion and today an alternative one – remains a constant in maritime transport. Modern *wind-assist* and *primary-wind* systems, based on advanced materials, automation and digitalisation, are now being demonstrated on more than 107 large commercial vessels worldwide. Research (IWSA, 2023) indicates that *wind-assist* technologies will play a significant role in the

energy mix by 2030, while the combined uptake of *primary wind* and *wind-assist* systems is expected to be comparable to other low and zero-emission fuels by 2050.

Nevertheless, the introduction of WPT systems faces technical, operational, economic and regulatory barriers that limit their perception as an equivalent propulsion option. It is therefore essential to analyse wind-based technologies within the same holistic framework as other alternative fuels (LNG, methanol, ammonia, biofuels, hydrogen, battery systems and nuclear options), to clearly understand their complementary role in the sustainable transformation of the maritime sector.

Returning to wind, not out of nostalgia but out of necessity, is increasingly recognised as an equal and sustainable option within the future energy mix, symbolically closing the historical arc from traditional sail-based heritage to a technologically advanced and decarbonised maritime future – reaffirming that history remains a constant source of inspiration for modern solutions, *historia magistra vitae*.

Keywords: maritime heritage; wind propulsion technology; decarbonisation pathways; alternative fuels; sustainable maritime transport

Submarine Fibre-Optic Networks as Critical Infrastructure: Balancing Connectivity, Security, and Marine Environmental Protection

Irena Jurdana

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: irena.jurdana@pfri.uniri.hr

Abstract

Submarine fibre-optic cable networks constitute one of the most critical components of global communication infrastructure, carrying more than 99% of international digital data traffic and supporting modern economies, public services, and global communications. As demand for high-capacity broadband services continues to grow, the expansion of submarine telecommunications networks has become essential for maintaining global connectivity, digital sovereignty, and socio-economic development. Despite their relatively small physical footprint, activities associated with the planning, installation, operation, maintenance, and repair of submarine cables may affect sensitive marine and coastal ecosystems. Disturbances of seabed habitats, particularly in ecologically vulnerable areas, highlight the importance of integrating environmental considerations throughout the entire lifecycle of submarine cable systems. Sustainable management and protection of marine environments are therefore essential for the long-term resilience and acceptance of submarine telecommunications infrastructure. At the same time, submarine fibre-optic networks are increasingly recognised as strategic and critical infrastructure. Many islands, outermost regions, and overseas territories rely heavily on submarine cable connectivity for access to digital services and international communications. Growing geopolitical tensions, cybersecurity concerns, and repeated incidents involving cable damage have drawn attention to the vulnerability of

these networks to both natural hazards and human-induced threats, including fishing activities, anchoring, accidents, sabotage, and coordinated attacks.

Protecting submarine cable infrastructure while preserving sensitive marine environments represents a significant challenge for policymakers, regulators, infrastructure operators, and environmental stakeholders. Addressing this challenge requires coordinated technical, regulatory, and environmental measures aimed at strengthening network resilience across the entire resilience cycle, including prevention, detection, response, and recovery. Particular emphasis is placed on best practices that support secure cable deployment, effective risk management, and environmentally responsible operation. The findings emphasise that enhancing the resilience of submarine fibre-optic networks and protecting marine ecosystems are complementary objectives that contribute to sustainable digital connectivity and the development of secure, reliable, and environmentally responsible communication infrastructure.

Keywords: submarine fibre-optic cables; critical infrastructure; network resilience; marine environmental protection; digital sovereignty; sustainable connectivity

AI, Human Judgment and the Limits of Machine Intelligence

The Mirror of Delusion: Why AI Generates Our Hallucinations and How I Hover Above the Machine as a System Creator

Robert Baždarić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: robert.bazdasic@uniri.hr

Abstract

In contemporary discourse surrounding Smart Mobility, Autonomous Systems, and Data-Driven Transportation, the term “hallucination” is frequently used to dismiss erratic AI outputs as mere statistical glitches. This presentation introduces a fundamental epistemic correction to this narrative. AI does not hallucinate. The machine operates as a flawless mathematical mirror, reflecting the deep, systemic “hallucinations” embedded within modern engineering logic [1]. The real delusion lies in the dogmatic belief that data density, hyper-optimization, and algorithmic dominance can out-calculate a nonlinear universe [2]. The current paradigm often uses AI as a digital miracle drug to force infrastructure into operational extremes, attempting to “win” an evolutionary game where nature only respects a homeostatic draw [3]. When the system fractures, it is not a coding bug, it is the logical consequence of a flawed architectural premise. Through my work with unsupervised decision-making, this session moves beyond the superficial lens of the observer’s eyes. By standing above the AI and operating from the creator’s perspective, true autonomous control is revealed not as a quest to micro-manage data signals or chase more complex controllers. Instead, it requires designing architectures that enforce localized causal boundaries, protect internal equilibrium, and reject the

fiction of the optimal win. Ultimately, there is no external entity out there to produce the questions that need to be answered; it is us. We must simultaneously provide the understandable questions and the answers. If we do not create the question ourselves, we will never truly know if the machine's answer is correct. This presentation invites us to look into the mirror, confront the structural flaws in our current logic, and retake our role as the foundational authors of systemic equilibrium.

Keywords: epistemic thought; ontic truth, homeostasis; natural equilibrium; algorithm

References

- [1] Von Neumann, J., & Kurzweil, R., 2012. *The computer and the brain*. Yale university press.
- [2] Bellman R. E., Dreyfus S.E., 2015. *Applied dynamic programming*. Princeton University Press.
- [3] Turing, Alan Mathison, 1990. *The chemical basis of morphogenesis*. Bulletin of mathematical biology. 52, no. 1, 153-197.





SuTra2026

International Conference on Sustainable Transport

Opatija, Croatia • 4 – 6 November 2026

PART II • Panel and Round Table Contributions

Panel#1

Discussion Flow

Opening Panel of the SuTra Conference, Powered by the Horizon Europe INNO2MARE Project

Panelists:

Prof. **Nikolina Brnjac**, PhD, member of the EU parliament and an ECF rapporteur

David Smith, PhD, director general of the Ruđer Bošković Institute and an EIT Water representative

Prof. **Nikola Mišković**, PhD, Head, Center of Excellence in Maritime Robotics and Technologies

Mr. **Ivić Vodopija**, East Europe Managing Director at Maersk Line

Ms. **Roberta Padovan**, M.A.R.E. Technology Cluster FVG

Prof. **Ana Perić Hadžić**, PhD, Dean, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Moderator:

Prof. **Alen Jugović**, PhD, University of Rijeka, Faculty of Maritime Studies, Rector's Assistant for Investment and Economy

Discussion frame

Where do we sail from here

The SUTRA conference opens with a panel devoted to the question that will shape the next decade of the European maritime domain: how research and innovation in the sector will be funded in the 2028–2034 period.

The new financial framework brings two turning points. The first is FP10, the tenth framework program for research and innovation, which remains a stand-alone program but is closely linked to the new European Competitiveness Fund (ECF), particularly through its second pillar. The second is the ECF itself, an instrument

designed to translate research results more quickly into industrial application and market deployment. For the maritime sector that is spread across transport, industry, energy, and marine protection, this raises very concrete questions: where research ends, and industrial investment begins, how the two instruments will actually connect in practice, and whether maritime research will have a recognizable place in the new architecture or will fall between budget lines. The panel also follows the Commission's Industrial Maritime Strategy and European Ports Strategy, which announced a reinforcement of public-private cooperation under the 2028–2034 framework program, building on the achievements of the current zero-emission waterborne transport partnership, making the question of what will succeed that partnership one of the central ones.

Six perspectives on the same process will meet at the table: a European legislator leading rapporteurship work on the financial instruments for the new programming period; the national ministry responsible for the sea, transport and infrastructure, which carries those negotiations in the Council; a European industrial technology platform and the shipbuilding industry, which articulate the sector's research priorities; a global shipping operator, as the end user and buyer of innovation; a center of excellence in maritime robotics, grown out of the widening program; and the new European knowledge and innovation community for water, marine and maritime sectors.

The panel is also the closing event of the INNO2MARE project, which spent four years connecting the innovation ecosystems of Adriatic Croatia and western Slovenia. The discussion, therefore, does not remain at the level of budget figures, but it asks what the new framework means for regions that built their maritime research capacity through European programs, and how the experience of such ecosystems can be translated into messages that Brussels will hear while decisions are still open.

On the table:

The ECF merges a range of existing programs into a single fund, with national and regional partnership plans. **How to ensure that maritime affairs, which do not belong to one clear policy area, get a recognizable window and a visible allocation, rather than being scattered across other priorities?**

The new instruments require national co-financing and institutional capacity. **Does Croatia have a mechanism to bring well-evaluated maritime projects that miss out on European funding to realization anyway?**

Co-programmed or institutionalized partnership — which model gives industry the predictability it needs to plan development cycles that run a decade or more?

Over the past decade, where has European research delivered a measurable effect on operations, and where has it lagged behind what the industry needs?

Participation gaps between older and newer member states remain stubborn despite a series of measures. **What would actually move the needle: quotas, mandatory inclusion of partners, investment in people, or something else entirely?**

The knowledge and innovation community model assumes a gradual reduction in European funding and a path towards financial self-sufficiency. **How feasible is that in maritime, where development cycles are long and capital requirements are high?**

Panel#2

Discussion Flow

Resilient Infrastructure of the Future: AI, Cybersecurity and Critical Systems Protection

Panelists:

Mr. **Tomislav Bronzin**, CITUS LLC, Zagreb, Croatia

Mr. **Arian Stipić**, CITUS LLC, Zagreb, Croatia

Prof. **Marko Horvat**, PhD, University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia

Mr. **Marko Gulan**, Astera Advisory, Zagreb, Croatia

Prof. **Luka Mihanović**, PhD, Dr. Franjo Tuđman Defense and Security University, Zagreb, Croatia

Moderator:

Prof. **Dario Ogrizović**, PhD, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Discussion frame

The speed asymmetry

Critical infrastructure is becoming faster, smarter and more connected. It may also be becoming less governable. Attacks, failures and false signals can spread across connected information technology, operational technology and AI-enabled systems in seconds. Response still depends on human approval, divided authority and procedures designed for slower threats.

That is the speed asymmetry.

AI can strengthen detection and response, but it also raises an uncomfortable question: must a system sometimes act before a human fully understands what is happening? In critical infrastructure, waiting can be dangerous. Acting too quickly

can be worse. An automated defensive decision can stop machinery, close a terminal, interrupt power or disable an essential service. The response can become the incident. Resilience is not proven by preventing every compromise. It is tested when prevention fails. Can the system retain control, preserve essential functions and operate safely when data, communications and automated decisions can no longer be fully trusted?

On the table:

Can autonomous defence be trusted with a kill switch on physical systems?

Who authorises its activation, who can override it, and who is accountable when the defensive action causes the outage?

What is the minimum viable degraded mode for a port, a grid, a fleet or another critical system?

Which functions must remain operational, which can be sacrificed, and has that boundary ever been tested under realistic conditions?

Where does the human stay in the loop, and where is that insistence now a liability?

When does human judgement protect the system, and when does approval delay make an effective response impossible?

What fails first in a converged IT, OT and AI environment?

The technology, the data, communications, organisational coordination or the authority to decide?

Are we building operational resilience, or only faster and more complex systems?

Do current AI, cybersecurity and compliance investments improve the ability to operate while compromised, or merely expand dependencies, attack surfaces and false confidence?

Discussion Flow

Transport Models for the Digital Transformation of Cities and Citizen Mobility Information Services

Panelists:

Mr. **Ivan Oleksa**, Ernst & Young Consulting, Zagreb, Croatia

Tomislav Krljan, PhD, PTV Austria Planung Transport Verkehr GmbH, Vienna, Austria

Mr. **Saša Vojvodić**, Ericsson Nikola Tesla, Zagreb, Croatia

Mr. **Sanjin Kuljanić**, Technical Innovation and Fleet Development Department, Jadrolinija, Rijeka, Croatia

Mr. **Aleksandar Saša Milaković**, PhD, Deputy Mayor of the City of Rijeka, Rijeka, Croatia, representing Mayor Iva Rinčić

Moderators:

Prof. **Neven Grubišić**, PhD, University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

Prof. **Luka Novačko**, PhD, University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia

Discussion frame

Digital ambition without digital foundations

Cities are increasingly expected to become data-driven, predictive and responsive. Digital twins, real-time traffic management, AI-supported mobility services and personalised travel information are becoming part of the language of urban transport policy. But these systems depend on something much more basic: reliable, accessible and, wherever possible, open data, together with models that accurately represent how the transport system actually works. In many Croatian cities, transport

data collection is still fragmented, irregular and often project-based. Traffic counts, origin-destination data, public transport information, cycling and pedestrian data, parking data and other mobility datasets are collected by different institutions, with different methodologies and for different purposes. In addition, these datasets are often not easily accessible or available for reuse by other public authorities, researchers, service providers or citizens.

Transport models are often developed for a specific study or infrastructure project and are rarely maintained as continuously updated decision-support systems. That creates a fundamental mismatch.

We are discussing digital twins and predictive mobility services while, in many cases, the basic digital representation of the transport system is still incomplete, fragmented or inaccessible. Transport models could become the connecting layer between data, planning, traffic management and services provided directly to citizens. But this requires a shift from one-off studies towards permanent, integrated and continuously updated modelling environments, supported by open, interoperable and reusable transport data.

The question is therefore not only how advanced our models should become. It is whether cities have the data, institutional capacity and governance structures needed to make those models useful—and whether the data on which they depend are sufficiently open and accessible to all those who can use them to improve transport planning, research and mobility services.

On the table:

Are we discussing digital twins before we have built the digital basics?

Can cities realistically introduce predictive traffic management and real-time mobility services when systematic and continuous transport data collection is still missing?

What happens when traffic information starts changing the traffic it is trying to predict?

If all users receive the same recommended route or mode, can the system remain stable, and how should the model respond to behaviour that it has itself helped to trigger?

Should Croatia first invest in better data or better models?

Or is this a false choice, and should data collection, modelling and mobility information services be developed as one integrated urban digital infrastructure?

Do Croatian cities actually know how their transport systems perform on a daily basis?

Without permanent traffic monitoring and regularly updated transport models, how confidently can cities assess congestion, accessibility, modal split, infrastructure investments or the impacts of transport policies?

Are transport models still treated as project deliverables instead of permanent decision-support systems?

How do we move from models developed for individual studies towards living models that are continuously updated and used in everyday urban planning and traffic management?

Who should own and maintain the transport model of a city?

Should responsibility lie with city administrations, national authorities, public transport operators, universities, technology providers – or should Croatia develop a common national framework for transport data and modelling?

Can a city provide reliable mobility information to citizens if the city itself does not have a complete picture of its transport system?

When most real-time travel information comes from commercial platforms, does the public sector risk losing both the data and the ability to actively manage mobility?

Can smaller Croatian cities realistically build sophisticated transport modelling capabilities on their own?

Would shared national or regional modelling platforms, common data standards and centralised technical support provide a more realistic pathway to digital transformation?

Three System Questions

Three panels, three levels of governing systems in transition

The three SuTra 2026 panels approach transition from different scales: the European research ecosystem, critical infrastructure, and the urban mobility system. Each begins with an open question rather than a predetermined answer.

01

THE EUROPEAN SYSTEM

Where do we sail from here?

Opening panel · Horizon Europe INNO2MARE closing event

How do we move from building maritime research capacity to sustaining it in the next European funding architecture?

FP10 · ECF · partnerships · deployment · widening · capacity

02

THE CRITICAL SYSTEM

The speed asymmetry

Resilient Infrastructure of the Future

How do we retain control when connected critical systems can react faster than institutions?

autonomy · degraded mode · authority · accountability · resilience

03

THE URBAN SYSTEM

Digital ambition without digital foundations

Transport Models for the Digital Transformation of Cities

How do cities build predictive mobility services when the data, models and governance needed to support them remain fragmented?

data · models · feedback · monitoring · ownership · governance







Artificial Intelligence in Maritime Transport and Seaport Operations: A Literature Review

Marija Jović Mihanović¹, Edvard Tijan^{2,*}, Saša Aksentijević²

¹ Institute of Shipping Economics and Logistics, Bremen, Germany
E-mail: jovic@isl.org

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: edvard.tijan@pfri.uniri.hr; sasa.aksentijevic@pfri.uniri.hr

Abstract

Artificial intelligence (AI) has become a key driver of digital transformation in the maritime transport sector by supporting safer, more efficient, and more sustainable maritime operations. As research in this field continues to expand, a comprehensive synthesis of current knowledge is needed to identify the main areas of AI application and emerging research trends. This study presents a systematic literature review of recent research on artificial intelligence in maritime transportation and seaports. The review is based on peer-reviewed publications indexed in the Web of Science database and is complemented by recent industry reports and other relevant practice-oriented documents to provide additional context on current developments in the maritime sector. The literature search was performed in the Web of Science using the Topic field (titles, abstracts, author keywords, and Keywords Plus®). The search employed the keywords ("artificial intelligence" OR AI) AND ("maritime transport" OR shipping OR seaport OR vessel OR fleet management OR marine logistics). The selected studies were analysed to identify application areas and the opportunities and challenges associated with AI implementation. The findings indicate that current research primarily focuses on smart ports and port

* Corresponding/presenting author

operations [1–4] autonomous navigation and maritime safety and security [5–7], predictive maintenance and fleet management [8, 9], sustainable shipping and operational optimisation [10, 11], and governance, and human factors [1, 12]. While the reviewed literature demonstrates considerable potential for improving operational performance, safety, and environmental sustainability, it also highlights certain challenges. The main challenges include technical and infrastructure limitations, such as integrating AI with existing systems, ensuring data quality and interoperability, and enabling reliable real-time data processing [13]. In addition, AI adoption is constrained by cybersecurity and regulatory issues [7], as well as organisational barriers such as resistance to change [14].

Keywords: artificial intelligence; AI, maritime transport; seaport; literature review

Acknowledgments: This paper was funded under the project line 581 NPOO of the University of Rijeka, for the project uniri-iz-25-13.

References

- [1] Lee, J., Sim, M., Kim, Y., Lim, H. and Lee, C., 2025. Strategizing Artificial Intelligence Transformation in Smart Ports: Lessons from Busan's Resilient AI Governance Model. *J Mar Sci Eng* 13(7), 1276. doi: 10.3390/jmse13071276
- [2] Castro, M., Sabino, M.R., Cabrita, M. do R., Mendes, A. and Pinho, T., 2026. From Smart Ports to Sustainable Port Ecosystems: The Transformative Role of Artificial Intelligence. *Systems* 14(2), 187. doi: 10.3390/systems14020187
- [3] Teixeira, P., Lopes, R.B. and Teixeira, L., 2026. The Integration of Artificial Intelligence in Seaports' Smart Gate Processes: Evidence Based on a Systematic Literature Review. *Results Eng* 29, 108919. doi: 10.1016/j.rineng.2025.108919
- [4] Fernandes, A., Pequeno, V., Teodoro, P. and Batista, M., 2026. Applications of Artificial Intelligence in Port Management and Operations: A Prisma-Based Review. *Naše more* 73(1), pp. 31–42. doi: 10.17818/NM/2026/1.1
- [5] Dalaklis, D., 2025. Artificial Intelligence (AI) Applications and the Shipping Industry. *TransNav* 19(1), pp. 325–330. doi: 10.12716/1001.19.01.38
- [6] Bi, J., Cheng, H., Zhang, W., Bao, K. and Wang, P., 2024. Artificial Intelligence in Ship Trajectory Prediction. *J Mar Sci Eng* 12(5), 769. doi: 10.3390/jmse12050769
- [7] Miller, T., Durlik, I., Kostecka, E., Sokołowska, S., Kozłowska, P. and Zwolak, R., 2025. Artificial Intelligence in Maritime Cybersecurity: A Systematic Review of AI-Driven Threat Detection and Risk Mitigation Strategies. *Electronics* 14(9), 1844. doi: 10.3390/electronics14091844
- [8] Potdar, P.R. and Parikh, S.M., 2026. Internet of Things (IoT) and Artificial Intelligence (AI) Enabled Framework for Smart Fleet Management. *OPSEARCH* 63(2), pp. 1343–1375. doi: 10.1007/s12597-025-00961-7
- [9] Savran, M. and Kafalı, M., 2025. Artificial Intelligence-Based Modelling and Optimization of Multi-Deck Passenger Ships Structural Parameters for Minimum Stress Distribution. *J ETA Marit Sci* 13(4), pp. 334–350. doi: 10.4274/jems.2025.12754

- [10] Wang, K. et al., 2026. Artificial Intelligence and Machine Learning for Green and Intelligent Shipping: Methods, Applications and Challenges. *Comput Ind Eng* 211, 111647. doi: 10.1016/j.cie.2025.111647
- [11] Alamaniotis, M. and Ipiotis, K., 2025. Artificial Intelligence as Enabler for Adoption of Sustainable Nuclear-Powered Maritime Ships: Challenges and Opportunities. *Sustainability* 17(8), 3654. doi: 10.3390/su17083654
- [12] Lasse, R.T.N., Gurning, R.O.S., Baihaqi, I. and Wiradanti, B., 2025. Investigating Digital Collaboration: Human Factors in Artificial Intelligence-Driven Collaboration Platforms for Resilient Port. *Oper Supply Chain Manag*, pp. 185–200. doi: 10.31387/oscm0610465
- [13] Durlík, I., Miller, T., Kostecka, E. and Tuński, T., 2024. Artificial Intelligence in Maritime Transportation: A Comprehensive Review of Safety and Risk Management Applications. *Appl Sci* 14(18), 8420. doi: 10.3390/app14188420
- [14] Fani, V., 2025. Assessing the Adoption of Artificial Intelligence in the Maritime Transport Industry: An Empirical Exploration in the Port of Rotterdam. *Marit Econ Logist*. doi: 10.1057/s41278-025-00333-4

Leveraging Artificial Intelligence Applications for Maritime Safety and Logistics Challenges: A Feature-Based Analysis

Zdravko Paladin^{1*}, Nexhat Kapidani¹, Žarko Lukšić¹,
Rasim Mujalović², Elson Thana³

¹ Maritime Safety Administration of Montenegro, Montenegro
E-mail: zdravko.paladin@pomorstvo.me; nexhat.kapidani@pomorstvo.me;
zarko.luksic@pomorstvo.me

² Jadroagent Bar
E-mail: rasi@t-com.me

³ Transport Community
E-mail: elsonth@yahoo.com

Abstract

Ensuring all conditions of maritime safety is a key priority for coastal states with a strong interest in providing flawless maritime traffic and shipping in their waters. At the same time, advances in information and communication technologies have significantly enhanced the accuracy and scope of the operational maritime picture, enabling ship management and shore authorities to exercise more effective and comprehensive oversight of shipping activities [1–2]. Therefore, this paper aims to make an analytical overview of the application of Artificial Intelligence (AI)-supported technologies in three main fields with relevant challenges for maritime safety: autonomous shipping, reduction of risks of ship collisions, navigational operations and advanced global logistics solutions [3–5]. Maritime autonomous ships are widely regarded as a new chapter in future maritime transportation and it

* Corresponding author

is expected that through integrated machine learning (ML) models, new autonomous ships will be capable of avoiding collisions, responding rapidly and effectively to emergency situations, optimise navigation routes, reduce human error and enhance overall operational and situational awareness [6]. These capabilities have direct implications for maritime safety and resources optimisations. Collision risk may also be reduced through the integration of existing technologies for raising maritime safety based on e.g. Automatic Identification System (AIS) data [7]. The application of classification and clustering algorithms to AIS data can support the detection of maritime anomalies, facilitate the timely identification of potential collision risks, and strengthen anticipatory risk management in infrastructure contexts [8]. Following the mentioned issues in the maritime safety and logistics field, the main applications of AI-based technologies and its features are focused on analysis of vast amount of Big Data using the methods of ML and deep learning to provide better operational picture. For example, clustering and classification algorithms can be used to group vessel trajectories and vessel types, predict ship trajectories and destination ports, estimate arrival times, calculate deviations from expected routes, and detect anomalous behaviour [9–12]. To summarize, current disruptive AI developments in maritime context enable four main applications: in predictive analytics for forecasting future states, in protection of maritime infrastructure against collision, cyber and other risks, in decision support through the provision of accurate information, and increased operational automation. These applications can contribute to improvements in functions such as cargo handling and autonomous vessel concept development [13].

Keywords: maritime safety; AI; collision risks; autonomous shipping; Big Data

References

- [1] Paladin Z., Scrima P., Vosinakis G., Hajduch G., Moutzouris M., Bolakis, C., et al. (2022). Maritime information sharing environment deployment using the advanced multilayered Data Lake capabilities: EFFECTOR project case study. *Sci. J. of Maritime Research*, 36(2), 291-304. doi.org/10.31217/p.36.2.13.
- [2] Avensys Consulting. (2025). Artificial Intelligence in Integrated Maritime Risk Assessment: A Strategic Framework for Maritime Leaders. Avensys Consulting White Paper. Available at <https://aven-sys.com/ai-agents-for-industry/>.
- [3] Maceiras, C., Cao-Feijó, G., Pérez-Canosa, J., Orosa, J. (2024). Application of Machine Learning in the Identification and Prediction of Maritime Accident Factors. *Journal Applied Sciences*, 14, 7239. doi.org/10.3390/appl14167239.
- [4] Gómez Ruiz, M. Á., de Almeida, I. & Pérez Fernández, R. (2023). Application of Machine Learning Techniques to the Maritime Industry. *Journal of Marine Science and Engineering*, 11(9), Article 1820. doi.org/10.3390/jmse11091820.
- [5] Knapp, S., & van de Velden, M. (2024). Exploration of machine learning methods for maritime risk predictions. *Maritime Policy & Management*, 51(7), 1443–1473. doi:10.1080/03088839.2023.2209788.

- [6] PCCG GmbH, DLR, HB, ISL. (2023). Internationale Umfeldanalyse zu Anwendungsfällen von Autonomen Maritimen Systemen (AMS). Deutsches Maritimes Zentrum e.V. Available at <https://dmz-maritim.de/entwicklung-des-marktes-fuer-autonome-maritime-systeme-ams/>
- [7] Berbić, I., Stupalo, V., Kavran, N., & Bukljaš, M. (2023). Overview of machine learning methods in maritime traffic monitoring based on Automatic Identification System. *Transportation Research Procedia*, 73, 220–226. doi: 10.1016/j.trpro.2023.11.911.
- [8] Cahyadi, T., Winarno, M., Faozun, I., & Barasa, L. (2026). Artificial intelligence and machine learning applications in maritime shipping: Predictive analytics, decision support systems, and operational automation. *Fundamental and Applied Management Journal*, 4(1), 1–12. doi. org/10.66314/famj.v4i1.276.
- [9] Diaz, R., Ungo, R., Smith, K., Haghnegahdar, L., Singh, B., & Phuong, T. (2024). Applications of AI/ ML in maritime cyber supply chains. *Procedia Computer Science*, 232, 3247–3257. doi.org/10.1016/j.procs.2024.02.140.
- [10] Muthukumar, R., & Vinitha Mary, S. (2025). Ship Safety using Machine Learning. *International Journal of Multidisciplinary Research in Science, Engineering and Technology*, 8(7), 11421–11433. doi:10.15680/IJMRSET.2025.0807051.
- [11] Pham, T.-A., Do, V.-D., Dang, X.-K., Pham, T.-D. A., & Koboević, Ž. (2023). Maritime data mining for marine safety based on deep learning: Southern Vietnam case study. *Naše more: Znanstveno-stručni časopis za more i pomorstvo*, 70(2), 114–125. doi.org/10.18690/um.fov.4.2026.15.
- [12] Munim, Z. H., Sørli, M. A., Kim, H., & Alon, I. (2024). Predicting maritime accident risk using Automated Machine Learning. *Reliability Engineering & System Safety*, 248, Article 110148. doi. org/10.1016/j.res.2024.110148.
- [13] Pohontu, A. (2020). A Review over AI Methods Developed for Maritime Awareness Systems. *Scientific Bulletin of Naval Academy*, 23(2), 287–299. doi: 10.21279/1454-864X-20-12-107.

Human Readiness for the Digital Transformation of Maritime Navigation

Nermin Hasanspahić^{1,*}, Maro Car¹, David Brčić²

¹ University of Dubrovnik, Faculty of Maritime Studies, Dubrovnik, Croatia
E-mail: nermin.hasanspahic@unidu.hr; mcarl@unidu.hr

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: david.brcic@pfri.uniri.hr

Abstract

As maritime navigation becomes increasingly digitalised and automated, seafarers require new competencies to effectively operate, supervise and interact with advanced systems [1]. Although the IHO S-100 framework, IMO e-Navigation and Sea Traffic Management have received considerable attention, fewer studies have examined how these developments are perceived by seafarers in everyday navigation [2, 3]. The experience gained from mandatory ECDIS implementation indicates that technological advances alone do not guarantee their effective use in practice, highlighting the importance of understanding seafarers' perceptions and educational needs before introducing new digital navigation concepts [4]. Therefore, this study explores the human dimension of maritime digitalisation by investigating awareness, perceptions and educational needs related to emerging digital navigation technologies. Particular attention is given to knowledge of the S-100 framework, perceptions of the strategic priorities of the e-Navigation concept, cyber security awareness and attitudes towards future professional development. The study highlights existing knowledge gaps and identifies areas considered essential for the successful future navigation systems implementation. The findings

* Corresponding/presenting author

suggest that maritime stakeholders broadly recognise the importance of digital transformation but simultaneously indicate a need for a more systematic education and competency development. The successful implementation of digital navigation technologies will depend not only on technological advances but also on appropriate education, competency development and organisational support.

Keywords: maritime digitalisation; digital navigation and e-concepts; human factor; S-100; e-navigation, sustainable navigation

Acknowledgments: Funded by the European Union – NextGenerationEU – DYNAMO_SCENE – uniri-iz-25-143.

References

- [1] Palbar Misas, J. D., Hopcraft, R., Tam, K., & Jones, K. (2024). Future of maritime autonomy: cybersecurity, trust and mariner's situational awareness. *Journal of Marine Engineering & Technology*, 23(3), 224–235. <https://doi.org/10.1080/20464177.2024.2330176>
- [2] Palma, V., Giglio, D., & Tei, A. (2023). Investigating the introduction of e-navigation and S-100 into bridge related operations: The impact over seafarers. *WMU Journal of Maritime Affairs*, 22(1), 37–58. <https://doi.org/10.1007/s13437-022-00286-y>
- [3] Hagen, J. E. (2017). *Implementing e-navigation*. Artech House.
- [4] Hasanspahić, N., Brčić, D., Car, M., & Žuškin, S. (2025). From paper to digital: The impact and hidden challenges of mandatory ECDIS on maritime safety and seafarer practice. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 19(1), 57–66. <https://doi.org/10.12716/1001.19.01.08>

A Multi-Layer Validation Framework for AIS-Derived Mooring Episodes in Port Environments

Luigia Mocerino^{1*}, Maria Acanfora¹, Davor Šakan², David Brčić²

¹ University of Naples Federico II, Department of Industrial Engineering, Naples, Italy
E-mail: luigia.mocerino@unina.it; maria.acanfora@unina.it

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: davor.sakan@pfri.uniri.hr; david.brcic@pfri.uniri.hr

Abstract

Automatic Identification System (AIS) data are widely used for maritime traffic analysis, vessel monitoring, and safety-related research, supported by international AIS performance and technical standards [1], [2]. Recent AIS research has addressed trajectory preprocessing, anomaly handling, route extraction, and maritime traffic analytics, while recognising persistent challenges associated with temporal continuity, spatial consistency, and data quality [3], [4]. Previous research on berthed vessels has shown that AIS-derived positions may satisfy maritime positioning requirements while exhibiting greater variability than GNSS-based (Global Navigation Satellite System) reference solutions [5]. However, AIS messages recorded as *moored vessel* conditions have received comparatively limited attention as structured spatio-temporal units for assessing reported positional stability. This paper presents a multi-layer validation framework for mooring episode analysis in port environments, based on AIS data. The framework was applied to an analytical dataset comprising 101,957 AIS records from 64 MMSI (Maritime Mobile Service Identity),

* Corresponding/presenting author

from which 126 retained mooring episodes were identified. The study used terrestrial AIS data, covering the Port of Naples (Italy) from 24 May to 14 June 2021 [6], [7]. Episodes were extracted using AIS moored navigational status, speed-over-ground below 0.3 kn, a minimum duration of 12 h, and a maximum gap percentage of 5%. As this is an initial methodological prototype, the detailed presentation focuses on two contrasting episodes considered significant and identified as the most stable and most dispersed cases according to a composite instability score derived from standardised spatial indicators. The proposed framework integrates temporal filtering, spatial consistency assessment, episode-level profiling, and harbour-context interpretation into a systematic and reproducible procedure for identifying and comparing patterns of reported positional stability. Observed AIS-derived variability should not be interpreted as direct evidence of GNSS error or signal degradation. The proposed methodology provides a reproducible basis for evaluating AIS-derived mooring behaviour and supports future integration with georeferenced harbour infrastructure for quantitative berth-validation applications.

Keywords: AIS; mooring episode; multi-layer validation; positional stability; port environment; spatial dispersion; maritime data analysis; harbour

Acknowledgments: Funded by the European Union – NextGenerationEU – DYNAMO_SCENE – uniri-iz-25-143.

References

- [1] International Maritime Organization. (2024). Performance standards for a universal shipborne automatic identification system (AIS) (Resolution MSC.570(109)).
- [2] International Telecommunication Union. (2026). *Recommendation ITU-R M.1371-6: Technical characteristics for VHF automatic identification system using time division multiple access in the maritime mobile service*. ITU.
- [3] Zhao, L., Shi, G., & Yang, J. (2018). Ship trajectories pre-processing based on AIS data. *The Journal of Navigation*, 71(5), 1210–1230. <https://doi.org/10.1017/S0373463318000188>
- [4] Huang, I.-L., Lee, M.-C., Chang, L., & Huang, J.-C. (2024). Development and application of an advanced Automatic Identification System (AIS)-based ship trajectory extraction framework for maritime traffic analysis. *Journal of Marine Science and Engineering*, 12(9), 1672. <https://doi.org/10.3390/jmse12091672>
- [5] Brčić, D., Šakan, D., Žuškin, S., & Kos, S. (2025). *Assessment of AIS-derived positioning accuracy in port environment: Case study of the Port of Copenhagen*. Presented at the 16th International Conference on Marine Navigation and Safety of Sea Transportation, TransNav 2025, Gdynia, Poland.
- [6] Spire Global, Inc. (2021). Historical Automatic Identification System data extract for the Port of Naples, 24 May to 14 June 2021 [Proprietary data set]. Spire Maritime.
- [7] Toscano, D., Murena, F., Quaranta, F., & Mocerino, L. (2022). Impact of ship emissions at a high receptor point in the port of Naples. *Atmospheric environment*, 286, 119253.

Neural Network-Based Ship Performance Prediction for Intelligent Autonomous Navigation Systems

Marijana Marjanović^{1*}, Jasna Prpić-Oršić¹, Marko Valčić²

¹ University of Rijeka, Faculty of Engineering, Rijeka, Croatia
E-mail: marijana.marjanovic@riteh.uniri.hr; jasnapo@riteh.hr

² University of Zadar, Department of Mechatronics and Robotics, Zadar, Croatia
E-mail: mvalcic@unizd.hr

Abstract

The development of Maritime Autonomous Surface Ships (MASS) requires intelligent onboard modules capable of assessing vessel performance in real time under varying environmental conditions. This paper presents a wide neural network (WNN) architecture for data-driven ship performance prediction, designed as a core component of autonomous navigation decision-making. The model estimates attainable ship speed as a function of significant wave height, wave period, encounter angle, and engine settings. It is trained on comprehensive datasets covering five sea-state categories and 13 encounter-angle configurations generated from validated hydrodynamic simulations [1]. The proposed architecture achieves prediction accuracy of $R^2 = 0.9990$, with robust generalisation across the full operational envelope. It includes extreme conditions beyond the training domain. The model also captures directional sensitivity, as head seas cause a 36% reduction in ship speed while following seas allow a 6% speed increase under identical wave heights [2]. Integrated seakeeping safety constraints based on slamming probability, deck

* Corresponding/presenting author

wetness frequency, and propeller emergence criteria ensure that the prediction module respects vessel structural integrity, functioning as hard constraints within an autonomous decision-making loop. The computational efficiency of the deployed NNs enables sub-second prediction suitable for real-time implementation within optimisation loops required for MASS operations. Furthermore, the modular architecture supports transfer learning, allowing adaptation to similar vessels using only limited additional data.

Keywords: maritime autonomous surface ships; neural network; ship performance prediction; attainable ship speed; seakeeping safety constraints

Acknowledgments: This work was supported by the Croatian Science Foundation under the project HRZZ-IP-2022-10-2821. This work was also supported by the University of Rijeka (PROJECTS no. PU-17 uniri-iz-25-10 - Funded by the European Union – NextGenerationEU).

References

- [1] Marjanović, M.; Valčić, M.; Prpić-Oršić, J.; Barić, M. 2026. A data-driven framework for attainable ship speed uncertainty under stochastic weather conditions. *Brodogradnja* 77, 77108. doi: 10.21278/brod77108
- [2] Marjanović, M.; Prpić-Oršić, J.; Valčić, M. 2026. Waypoint-sequencing model predictive control for ship weather routing under forecast uncertainty. *J. Mar. Sci. Eng.* 14, 118. doi: 10.3390/jmse14020118

Analysis of Individual Ship-Motion Components for Attention-Based Sea-State Classification

Karlo Severinski^{1,2}, Jonatan Lerga^{2,3}, Nikola Lopac^{1,2,*}

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: karlo.severinski@pfri.uniri.hr; nikola.lopac@pfri.uniri.hr

² University of Rijeka, Center for Artificial Intelligence and Cybersecurity, Rijeka, Croatia

³ University of Rijeka, Faculty of Engineering, Rijeka, Croatia
E-mail: jonatan.lerga@riteh.uniri.hr

Abstract

Reliable sea-state classification plays a crucial role in enhancing maritime safety, supporting route planning, and enabling autonomous vessel operation [1]. Although wave buoys, wave radars, and satellite imagery provide valuable data for sea-state estimation (SSE) and classification, these methods are often constrained by high costs and limited practical applicability [2]. Consequently, the wave buoy analogy (WBA), also known as the ship-as-a-wave-buoy (SAWB) method, has been introduced as an approach for estimating sea-state parameters, including wave height, period, and direction, while also supporting the classification of sea-state codes [3–5]. Building on previous work in which an attention-based neural network was applied to sea-state classification from ship-motion responses across common multi-degree-of-freedom (DOF) configurations [6], this paper extends the analysis by examining the relevance of individual ship-motion components. Simulated vessel responses were generated under irregular JONSWAP wave conditions using the MSS Toolbox package [7] and then classified into five sea-state classes. The attention-based classifier was evaluated using the full 6DOF ship-motion input,

* Corresponding/presenting author

individual single-DOF configurations, post-hoc channel-occlusion analysis, and speed-dependent performance evaluation. The results indicate that pitch and heave are the most relevant motion components for sea-state classification, but their importance varies across evaluation settings. Heave achieved the highest standalone classification performance, indicating strong independent discriminative capability, whereas pitch made the largest contribution within the full 6DOF model. Across vessel speeds, the complete 6DOF configuration achieved the highest overall performance, while pitch and heave consistently remained the most influential individual motion components. This suggests that reduced-input classification models based on the most relevant motion components may provide a practical balance between performance and system complexity. These findings show that ship-motion components contribute unequally to sea-state classification and highlight pitch and heave as particularly important signals for efficient ship-motion-based classification configurations.

Keywords: sea-state estimation; sea-state classification; ship-motion components; degrees of freedom; attention-based neural network; wave buoy analogy

Acknowledgments: Funded by the European Union – NextGeneration EU – SEALEARN – uniri-mz-25-49. This work was also supported by the European Regional Development Fund, grant no. PK.1.1.13.0083 (Collaborative scientific research aimed at increasing coastal traffic safety using machine learning)

References

- [1] Lopac, N., Severinski, K., Palaić, D., & Lerga, J. (2026). Machine learning for ship-motion-based sea-state estimation. *Ocean Engineering*, 362, 126362. <https://doi.org/10.1016/j.oceaneng.2026.126362>
- [2] Severinski, K., Lopac, N., & Lerga, J. (2025). Advancing Sea State Estimation: Current Techniques and Emerging Methodologies. In *Book of Abstracts of the 9th Annual PhD Conference on Engineering and Technology MFC 2025* (pp. 22). Rijeka: University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia.
- [3] Cheng, X., Wang, K., Liu, X., Yu, Q., Shi, F., Ren, Z., & Chen, S. (2023). A Novel Class-Imbalanced Ship Motion Data-Based Cross-Scale Model for Sea State Estimation. *IEEE Transactions on Intelligent Transportation Systems*, 24(12), 15907-15919. <https://doi.org/10.1109/TITS.2023.3315674>
- [4] Mittendorf, M., Nielsen, U. D., Bingham, H. B., & Storhaug, G. (2022). Sea state identification using machine learning—A comparative study based on in-service data from a container vessel. *Marine Structures*, 85, 103274. <https://doi.org/10.1016/j.marstruc.2022.103274>
- [5] Selimović, D., Hržić, F., Prpić-Oršić, J., & Lerga, J. (2023). Estimation of sea state parameters from ship motion responses using attention-based neural networks. *Ocean Engineering*, 281, 114915. <https://doi.org/10.1016/j.oceaneng.2023.114915>
- [6] Severinski, K., Lerga, J., Otulić, I., & Lopac, N. (2026). Sea-State Classification Based on Vessel-Motion Responses Using an Attention-Based Neural Network. In 2026 International Symposium ELMAR. IEEE.
- [7] Fossen, T. I. (2011). *Handbook of Marine Craft Hydrodynamics and Motion Control*. John Wiley & Sons. <https://doi.org/10.1002/9781119994138>

On the Influence of Observation-Window Length in Sea-State Classification from Vessel Motions Using Attention-Based Machine Learning

Karlo Severinski^{1,2}, Ivan Otulić³, Jonatan Lerga^{2,4}, Nikola Lopac^{1,2,*}

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: karlo.severinski@pfri.uniri.hr, nikola.lopac@pfri.uniri.hr

² University of Rijeka, Center for Artificial Intelligence and Cybersecurity, Rijeka, Croatia

³ Ototrak, Kraljevica, Croatia
E-mail: ivan.otulic@ototrak.hr

⁴ University of Rijeka, Faculty of Engineering, Rijeka, Croatia
E-mail: jonatan.lerga@riteh.uniri.hr

Abstract

Sea-state estimation (SSE) is a key component of safe and efficient maritime transport, supporting route planning, vessel operation, and decision-making in changing ocean environments [1]. In particular, real-time SSE is essential for enabling timely operational responses and improving the reliability of intelligent maritime systems [1, 2]. Although current wave-measurement methods provide a reasonable balance between accuracy and practicality, they are often limited by their response times. Wave radars and wave buoys require sufficient observation time to estimate sea-state parameters reliably, while satellite-based measurements are typically delayed due to their remote-sensing nature. Following the previous evaluation, present work evaluates the influence of ship-motion signal duration on the classification performance of an attention-based neural-network framework for SSE [3, 4]. Simulated six-degree-of-freedom (6DOF) vessel-motion responses were produ-

* Corresponding/presenting author

ced at five vessel forward speeds under irregular JONSWAP sea conditions and subsequently assigned to five sea-state classes based on global wave-statistics parameters [4–6]. For each original 30-minute record, reduced-duration input sets were created by retaining only the initial 2, 5, 10, 15, 20, 25, or 30 minutes of data, while maintaining identical dataset splits and sample distributions across all experiments. Beyond the overall performance assessment, a speed-dependent analysis was conducted to determine whether the effect of observation-window length remained consistent across different vessel forward speeds. The results indicate that classification performance generally improved with increasing observation-window length, confirming the importance of signal duration for reliable sea-state classification. The best average performance was obtained using the 25-minute input window, while the 30-minute configuration provided no further improvement, suggesting performance saturation in the 20–30-minute range. The speed-based analysis showed broadly consistent trends across vessel forward speeds, indicating that the influence of observation-window length is not strongly speed-dependent. Although not the most accurate configuration, the 10-minute window provided a practical compromise between accuracy and latency, substantially reducing the required observation time while maintaining competitive classification performance.

Keywords: sea-state estimation; sea-state classification; vessel-motion responses; observation-window length; attention-based neural network

Acknowledgments: Funded by the European Union – NextGeneration EU – SEALEARN – uniri-mz-25-49. This work was also supported by the European Regional Development Fund, grant no. PK.1.1.13.0083 (Collaborative scientific research aimed at increasing coastal traffic safety using machine learning).

References

- [1] Lopac, N., Severinski, K., Palaić, D., & Lerga, J. (2026). Machine learning for ship-motion-based sea-state estimation. *Ocean Engineering*, 362, 126362. <https://doi.org/10.1016/j.oceaneng.2026.126362>
- [2] Severinski, K., Lopac, N., & Lerga, J. (2025). Advancing Sea State Estimation: Current Techniques and Emerging Methodologies. In *Book of Abstracts of the 9th Annual PhD Conference on Engineering and Technology MFC 2025* (pp. 22). Rijeka: University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia.
- [3] Selimović, D., Hrčić, F., Prpić-Oršić, J., & Lerga, J. (2023). Estimation of sea state parameters from ship motion responses using attention-based neural networks. *Ocean Engineering*, 281, 114915. <https://doi.org/10.1016/j.oceaneng.2023.114915>
- [4] Severinski, K., Lerga, J., Otulić, I., & Lopac, N. (2026). Sea-State Classification Based on Vessel-Motion Responses Using an Attention-Based Neural Network. In 2026 International Symposium ELMAR. IEEE.
- [5] Price, W. G. (1974). *Probabilistic Theory of Ship Dynamics*. Chapman and Hall, 157-163.
- [6] Fossen, T. I. (2011). *Handbook of Marine Craft Hydrodynamics and Motion Control*. John Wiley & Sons. <https://doi.org/10.1002/9781119994138>

Is Accuracy Not Enough? Elevation Mask Angle Effects on GPS L1 Solution Availability in Maritime Positioning

David Brčić^{1,*}, Lovro Čović², Mario Bakota³, Serđo Kos¹

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: david.brcic@pfri.uniri.hr; serdjo.kos@pfri.uniri.hr

² Jadrolinija, Rijeka, Croatia
E-mail: lovro.covic@hotmail.com

³ University of Split, Faculty of Maritime Studies, Split, Croatia
E-mail: mbakota@pfst.hr

Abstract

Global Navigation Satellite Systems (GNSS) are widely used as the primary Electronic Position Fixing System (EPFS) in maritime navigation, where reliable positioning supports safe, efficient, and digitally assisted transport operations [1]. Their operational value depends not only on positioning accuracy, but also on the continuous availability of valid positioning solutions [2]. This study assesses single-frequency GPS L1 positioning performance under different elevation mask settings using four datasets from three coastal or near-coastal reference stations. The data were processed using a consistent RINEX-based RTKLIB single point positioning strategy [5, 6], with elevation mask angles tested from 0° to 45° in 5° increments. Performance was evaluated through horizontal and three-dimensional positioning error, satellite geometry indicators, number of valid satellites, and solution availability. Operational acceptability was assessed using IMO-based criteria combining horizontal accuracy and availability [3, 4]. The results show that positioning accuracy remained acceptable

* Corresponding/presenting author

across a broad range of configurations, while solution availability and compliance showed clear threshold-type behaviour. Stable compliance was observed between 5° and 20°, 25° represented a transitional regime, and elevation mask angles of 30° and above resulted in systematic non-compliance. These findings indicate that accuracy-only assessment is insufficient for evaluating maritime GNSS usability. Elevation mask angle selection should be treated as a trade-off between excluding low-elevation observations, which are more susceptible to multipath and atmospheric effects, and preserving sufficient satellite geometry for continuous positioning [7, 8]. The study provides a practical basis for interpreting GNSS positioning reliability in electronic navigation systems, especially when availability, rather than accuracy, becomes the limiting operational factor. In the context of sustainable maritime transport, the results support safer and more reliable digital navigation through improved operational understanding of GNSS performance.

Keywords: maritime navigation; GPS L1; elevation mask angle; solution availability; satellite geometry; IMO requirements

Acknowledgments: Funded by the European Union – NextGenerationEU – DYNAMO_SCENE – uniri-iz-25-143.

References

- [1] Bowditch, N. (2019). The American practical navigator. National Geospatial-Intelligence Agency. <https://msi.nga.mil/Publications/APN>
- [2] Kaplan, E. D., & Hegarty, C. J. (Eds.). (2006). Understanding GPS: Principles and applications (2nd ed.). Artech House.
- [3] International Maritime Organization. (2001). Revised maritime policy and requirements for a future Global Navigation Satellite System (GNSS) (Resolution A.915(22)). <https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.915%2822%29.pdf>
- [4] International Maritime Organization. (2011). Worldwide Radionavigation System (Resolution A.1046(27)). <https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1046%2827%29.pdf>
- [5] International GNSS Service. (2015). RINEX: The Receiver Independent Exchange Format, version 3.03. <https://files.igs.org/pub/data/format/rinex303.pdf>
- [6] Takasu, T. (2009). RTKLIB: Open source program package for RTK-GPS. FOSS4G 2009, Tokyo, Japan. https://gpspp.sakura.ne.jp/paper2005/foss4g_2009_rtklib.pdf
- [7] Won, D. H., Ahn, J., Lee, S.-W., Lee, J., Sung, S., Park, H. W., Park, J. P., & Lee, Y. J. (2012). Weighted DOP with consideration on elevation-dependent range errors of GNSS satellites. *IEEE Transactions on Instrumentation and Measurement*, 61(12), 3241–3250. <https://doi.org/10.1109/TIM.2012.2205512>
- [8] Anđić, D. M., & Đurović, R. (2022). Dependence of epoch-wise two-way nested ANOVA estimates of variances of unmodeled effects present in relative GPS positioning on satellite elevation cutoff angle and PDOP mask. *Geodesy and Geodynamics*, 13(5), 489–500. <https://doi.org/10.1016/j.geog.2022.02.005>

Determining Actions for Collision Prevention between Ships in a Close-Quarters Situation Using Simulated Avoiding Strategies

Đani Mohović*, Marko Šuljić, Antonio Blažina, Matej Šuper

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: dani.mohovic@pfri.uniri.hr; marko.suljic@student.uniri.hr; antonio.blazina@pfri.uniri.hr;
matej.super@pfri.uniri.hr

Abstract

The International Regulations for Preventing Collisions at Sea (COLREGs) refer to the concept of a *close-quarters situation*. As this term is not precisely defined, various interpretations and definitions have emerged in the literature and in judicial practice, based on court proceedings and judgments. In practice, many officers and masters rely primarily on their professional experience when determining whether a close-quarters situation exists. However, differing interpretations among seafarers, maritime experts, and even court-appointed experts may lead to potentially adverse consequences [1]. This study adopts the proposed definition of a close-quarters situation as the minimum distance at which a collision can still be avoided through the action of only one vessel [2]. Based on this definition, a series of navigational simulations was conducted using the TRANSAS NTPRO 5000 navigational simulator to determine the minimum distances and times at which a stand-on vessel can still initiate effective collision-avoidance action when the give-way vessel fails to comply with the COLREGs. A total of 168 simulations were performed using different scenario combinations of fine-form and full-form vessels, loading conditions, target

* Corresponding/presenting author

vessel speeds, and course angles. The results show that the minimum distance and time required to avoid a collision are primarily influenced by vessel maneuvering characteristics, relative speed, and the angle of intersection, confirming previous findings regarding the importance of maneuvering performance in collision avoidance [3]. The most critical situations were identified for course angles between 115° and 150°, for which substantially greater distances and longer reaction times were required to avoid collision. The findings provide practical guidance for navigators, Vessel Traffic Service (VTS) operators, and the development of autonomous collision-avoidance systems by defining the operational limits within which effective avoiding action can still prevent a collision between vessels.

Keywords: close-quarters situation; COLREGs; action to avoid a collision; last opportunity to avoid collision; use of navigational simulator

References

- [1] He, Y., Jin, Y., Huang, L., Xiong, Y., Chen, P. and Mou, J., 2017. Quantitative Analysis of COLREG Rules and Seamanship for Autonomous Collision Avoidance at Open Sea. *Ocean Engineering*, 140, pp. 281–291. doi: <https://doi.org/10.1016/j.oceaneng.2017.05.048>
- [2] Mohovic, D., Mohovic, R., Suljic, M. and Njegovan, M., 2021. Reducing the Risk of Collision Between Ships in a Close-Quarters Situation by Simulating Collision Avoidance Actions. *The Journal of Navigation*, 74(3), pp. 558–573. doi: <https://doi.org/10.1017/S0373463320000795>
- [3] Krata, P. and Montewka, J., 2015. Assessment of a Critical Area for a Give-Way Ship in a Collision Encounter. *Archives of Transport*, 34(2), pp. 51–60. doi: <https://doi.org/10.5604/08669546.1160923>

Communication Safety: Reframing Communication as a Core Dimension of Transport Safety

Ana Globočnik Žunac^{1,*}, Maja Križanec Cvitković¹, Ivana Perkušić²

¹ University North, Croatia

E-mail: agzunac@unin.hr; mkcvitkovic@unin.hr

² Faculty of Humanities and Social Sciences, Josip Juraj Strossmayer University of Osijek, Croatia

E-mail: iperkusic@ffos.hr

Abstract

Transport safety has traditionally been understood through three dominant dimensions: technical reliability, infrastructure quality, and human factors. Although communication plays a central role in virtually every transport process—from operational coordination and decision-making to incident reporting and passenger information—it is rarely conceptualised as an independent dimension of transport safety. Instead, communication is usually treated as one of the human factor components, limiting a broader understanding of its systemic influence [1, 2]. This paper introduces the concept of Communication Safety, defined as the ability of a transport system to ensure accurate, timely, understandable, and actionable information exchange among all relevant stakeholders, including operators, managers, maintenance personnel, emergency services, passengers, and increasingly intelligent digital systems. The proposed framework argues that communication quality directly influences situational awareness, operational coordination, organisational learning, risk management, resilience, and safety culture [1–4]. Drawing

* Corresponding/presenting author

upon literature from organisational communication, safety management, human factors, and transport systems, the paper develops a conceptual model that identifies the principal dimensions of communication safety, including information accuracy, timeliness, feedback mechanisms, communication climate, digital communication support, and organisational openness. Particular attention is given to the growing role of artificial intelligence and digital communication technologies in supporting or, in some circumstances, complicating communication processes within transport organisations [4, 5]. The paper's main contribution lies in positioning communication not merely as a supporting organisational process but as a fundamental determinant of transport safety. Establishing communication safety as a distinct analytical concept may provide researchers and practitioners with a broader perspective for understanding accidents, improving organisational resilience, strengthening safety management systems, and designing communication-centred safety strategies in increasingly complex transport environments [2, 3, 6, 7].

Keywords: communication safety; transport safety; organisational communication; safety culture; human factors; risk management; transport systems; digital communication

References

- [1] Zara, J., Nordin, S. M., Isha, A.S.N., 2023. *Influence of communication determinants on safety commitment in a high-risk workplace: A systematic literature review of four communication dimensions*. *Frontiers in Public Health* 11, 1225995. doi:10.3389/fpubh.2023.1225995. Available online: <https://www.frontiersin.org/articles/10.3389/fpubh.2023.1225995/full>, accessed 20 July 2026.
- [2] Nævestad, T. O., Phillips, R. O., 2023. *The limits of soft safety regulation: Does successful work with safety culture require Safety Management System implementation?* *Transportation Research Interdisciplinary Perspectives* 17, 100733. doi:10.1016/j.trip.2022.100733. Available online: <https://doi.org/10.1016/j.trip.2022.100733>, accessed 20 July 2026.
- [3] Xu, Z., Chopra, S. S., 2023. *Interconnectedness enhances network resilience of multimodal public transportation systems for Safe-to-Fail urban mobility*. *Nature Communications* 14, 4291. doi:10.1038/s41467-023-39999-w. Available online: <https://www.nature.com/articles/s41467-023-39999-w>, accessed 20 July 2026.
- [4] Bach, T. A., Kristiansen, J. K., Babic, A., Jacovi, A., 2023. *Unpacking Human-AI Interaction in Safety-Critical Industries: A Systematic Literature Review*. arXiv:2310.03392. Available online: <https://arxiv.org/abs/2310.03392>, accessed 20 July 2026.
- [5] Rizkalla, S., Kliks, A., Bagheri, N., et al., 2026. *Communication Technologies for Intelligent Transportation Systems: From Railways to UAVs and Beyond*. arXiv:2601.14106. Available online: <https://arxiv.org/abs/2601.14106>, accessed 20 July 2026.
- [6] Hollnagel, E., 2014. *Safety-I and Safety-II: The Past and Future of Safety Management*. Ashgate Publishing, Farnham, UK.
- [7] International Civil Aviation Organization (ICAO), 2022. *Safety Management Manual (SMM), 5th ed. (Doc 9859)*. Montreal, Canada. Available online: <https://www.icao.int/safety/SafetyManagement>, accessed 20 July 2026.

The Contribution of Fatigue to Human Error in Maritime Accidents

Matej Šuper*, Marko Strabić, Vlado Frančić, Đani Mohović

Faculty of Maritime Studies, University of Rijeka, Rijeka, Croatia

E-mail: matej.super@pfri.uniri.hr; marko.strabic@pfri.uniri.hr; vlado.francic@pfri.uniri.hr;
dani.mohovic@pfri.uniri.hr

Abstract

Numerous studies have identified human error as the leading cause of maritime accidents, therefore, understanding it is essential for improving navigational safety [1]. Fatigue is recognized as one of the most significant factors contributing to human error [2]. According to data from the International Transport Workers' Federation (ITF), fatigue is associated with up to 25% of all maritime accidents [3]. By impairing cognitive and physical abilities, fatigue can lead to navigational errors, communication failures, impaired judgement and various other issues that may result in serious maritime accidents [4]. Based on an analysis of 521 maritime accidents related to fatigue [2], it was concluded that fatigue was the cause of 41% ship collisions. To better understand the significance of fatigue in shipping, this study conducted a survey to assess the level of fatigue experienced by seafarers upon resuming their duties on board. The survey involved 103 experienced deck officers; the largest group comprised second and third deck officers (56.3%), followed by chief officers and masters (43.7%). The results reveal a concerning level of fatigue (50%) among seafarers, highlighting the need for appropriate measures.

Keywords: human error; maritime accidents; fatigue; survey

* Corresponding/presenting author

References

- [1] Hasanspahić, N, et al., 2021. The Role of the Human Factor in Marine Accidents. *Journal of Marine Science and Engineering*, 9(3), 261. doi: <https://doi.org/10.3390/jmse9030261>
- [2] Moreno, F, et al., 2026. Fatigue as a latent risk factor in maritime safety systems: A systematic review and implications for reliability analysis. *Reliability Engineering & System Safety*, vol 267. doi: <https://doi.org/10.1016/j.ress.2025.111930>
- [3] International Transport Workers' Federation, 2026. Fatigue. Available online: <https://www.itfseafarers.org/en/resources/fatigue>, accessed 6 July
- [4] EInav. 2025. Why Seafarers' Fatigue Is Unique and More Dangerous Than in Other Transport Sectors. Available online: <https://elnav.ai/why-seafarers-fatigue-is-unique-and-more-dangerous-than-in-other-transport-sectors/>

A Multi-Criteria Assessment of Green Strategies for Achieving IMO Net-Zero Transition Goals: A Review

Urban Pegan*, Elen Twrdy, Danijela Tuljak-Suban

University of Ljubljana, Faculty of Maritime Studies and Transport, Ljubljana, Slovenia

E-mail: urban.pegan@fpp.uni-lj.si; elen.twdry@fpp.uni-lj.si; danijela.tuljak@fpp.uni-lj.si

Abstract

The transition toward environmentally sustainable ports and maritime transport is a crucial step in achieving the objectives of the International Maritime Organization (IMO), particularly in reducing greenhouse gas emissions and improving energy efficiency across the maritime sector. Although ports play a central role in the global economy and international trade, they are also associated with substantial environmental impacts [1]. The findings show that maritime transport accounts for approximately 2%-3% of global greenhouse gas emissions. With a projected annual growth rate of 2.1% over the coming years, the maritime industry is under increasing pressure to reduce its emissions. In response, the IMO has developed a strategy that targets a 20% reduction in net emissions by 2030, a further 70% reduction by 2040, and the achievement of net-zero emissions by 2050, relative to 2008 levels. In this context, the selection of appropriate green technologies in maritime transport constitutes a complex decision-making problem, as it requires the simultaneous consideration of environmental, economic, technical, and social dimensions, as well as the interests of multiple stakeholders [2–5]. Due to this complexity, multi-criteria decision-making (MCDM) methods are increasingly being adopted as effective tools

* Corresponding/presenting author

to support decision-making for the implementation of green technologies in ports and maritime transport. This paper provides a comprehensive review of the scientific literature on the application of MCDM methods in the selection of green technologies within the maritime sector, with a particular focus on solutions such as alternative fuels, shore-side electricity supply systems, energy-efficient port equipment, and emission reduction technologies. The analysis encompasses the MCDM methods employed, decision criteria, application areas, and methodological approaches. The results reveal prevailing research trends, as well as the strengths and limitations of existing methodologies, and highlight key research gaps, particularly in addressing uncertainty and in practical implementation within real maritime environments. Furthermore, the findings indicate that existing studies tend to focus either on challenges at the port level or on those faced by ship operators, resulting in limited interoperability of approaches to addressing the transition to zero emissions. This fragmentation represents a significant challenge and, at the same time, an opportunity for future research.

Keywords: GHG emissions; ship; port; MCDM

References

- [1] Halpe, P. et al., 2025. Challenges and opportunities for ports in achieving net-zero emissions in maritime transport. *Transportation Research Interdisciplinary Perspectives*, 30, 101379. doi: <https://doi.org/10.1016/j.trip.2025.101379>
- [2] Styhre L., Rogerson S., Santén V., 2026. Sustainable shipping on the horizon: Environmental requirements and institutional pressures in maritime decarbonisation, *Research in Transportation Business & Management*, 67, 101687, <https://doi.org/10.1016/j.rtbm.2026.101687>
- [3] Jin, J., Meng, L., Wang, X., & He, J., 2024. Carbon emission reduction strategy in shipping industry: A joint mechanism. *Advanced Engineering Informatics*, 62, 102728. <https://doi.org/10.1016/j.aei.2024.102728>
- [4] Satta, G., Vitellaro, F., Njikatoufon, A.G. et al. Green strategies in ports: a stakeholder management perspective. *Marit Econ Logist* 27, 96–122 (2025). <https://doi.org/10.1057/s41278-024-00294-0>
- [5] Su, Z., Liu, Y., Gao, Y., Park, K.-S., & Su, M., 2024. Critical Success Factors for Green Port Transformation Using Digital Technology. *Journal of Marine Science and Engineering*, 12(12), 2128. <https://doi.org/10.3390/jmse12122128>

Fleet-Renewal Strategy for Decarbonising Small Passenger Vessels under the EU Maritime Decarbonisation Framework

Marko Novaselić¹, Tomislav Bukša², Marko Valčić^{3,*}

¹ Jadrolinija, Management Board, Rijeka, Croatia
E-mail: marko.novaselic@jadrolinija.hr

² Jadrolinija, Department for Technical Innovations and Fleet Development, Rijeka, Croatia
E-mail: tomislav.buksa@jadrolinija.hr

³ University of Zadar, Department of Mechatronics and Robotics, Zadar, Croatia
E-mail: mvalcic@unizd.hr

Abstract

Maritime transport is entering a critical phase of decarbonisation, driven by the greenhouse gas (GHG) targets of the International Maritime Organization (IMO) [1] and reinforced by an increasingly stringent European framework. Its core instruments, the EU Emissions Trading System (EU ETS) [2] and the FuelEU Maritime Regulation [3], currently apply primarily to vessels above 5,000 GT, a threshold below which a substantial proportion of Croatia's national passenger fleet operates. Under the derogations granted for domestic island connections, these smaller vessels remain outside the full scope of both instruments until the end of the decade. The resulting window is a narrow one, and easily wasted: compliance pressure is modest today, yet it will rise sharply once the derogations expire and ageing vessels approach the end of their service life. This paper treats that window not as a reprieve but as a planning horizon, linking the regulatory trajectory to concrete decarboni-

* Corresponding/presenting author

sation pathways for the sub-5,000 GT passenger segment [4]. Two complementary levers are examined. For the existing fleet, neat biodiesel (FAME B100) is assessed as a near-term retrofit fuel [5, 6], and for prospective newbuildings, other alternative fuels are considered. Rather than evaluating these options solely in terms of compliance at a specific point in time, the analysis considers their well-to-wake (WtW) GHG intensity, technical feasibility, and durability under the tightening limits ahead. On this basis, the paper proposes a conceptual fleet-renewal strategy for sub-5,000 GT passenger ships that translates these considerations into a structured decision logic, aligning compliance horizons, emission-reduction potential, and propulsion choices throughout the transition from retrofit to newbuilding. For operators, shipbuilders, and national authorities alike, it offers a transparent basis for sequencing investment, so that the derogation period becomes an opportunity to prepare decarbonisation rather than a pretext to defer it.

Keywords: maritime decarbonisation; passenger vessels; fleet renewal; FAME biodiesel; EU ETS; FuelEU Maritime

Acknowledgements: This work was supported by the Croatian Science Foundation under the projects' numbers HRZZ-IP-2025-02-4779 and HRZZ-IP-2022-10-2821.

References

- [1] International Maritime Organization, 2023. *2023 IMO Strategy on Reduction of GHG Emissions from Ships. Resolution MEPC.377(80)*. IMO, London.
- [2] European Union, 2023. Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system. *Off J Eur Union L* 130, 134-202.
- [3] European Union, 2023. Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC (FuelEU Maritime). *Off J Eur Union L* 234, 22.9.2023, 48-100.
- [4] Ampah, J.D., Yusuf, A.A., Afrane, S., Jin, C., Liu, H., 2021. Reviewing two decades of cleaner alternative marine fuels: Towards IMO's decarbonization of the maritime transport sector. *J Clean Prod* 320, 128871. doi: 10.1016/j.jclepro.2021.128871
- [5] Jo, K.-S., Kong, K.-J., Han, S.-H., 2025. Optimizing Fuel Efficiency and Emissions of Marine Diesel Engines When Using Biodiesel Mixtures Under Diverse Load/Temperature Conditions: Predictive Model and Comprehensive Life Cycle Analysis. *J Mar Sci Eng* 13(6), 1192. doi: 10.3390/jmse13061192
- [6] Chountalas, T.D., Founti, M., Hountalas, D.T., 2023. Review of Biofuel Effect on Emissions of Various Types of Marine Propulsion and Auxiliary Engines. *Energies* 16(12), 4647. doi: 10.3390/en16124647

Decarbonisation of Shipping with Alternative Fuels Technology Simulators

Ivan Chetyrbok¹, Josip Orović^{2,*}

¹ Wartsila Corporation, Simulation R&D
E-mail: ivan.chetyrbok@wartsila.com

² University of Zadar, Maritime Department, Zadar, Croatia
E-mail: jorovic@unizd.hr

Abstract

The decarbonisation of shipping is one of the main topics nowadays and it cannot be achieved without a large-scale transition to alternative fuels. Each of them introduces operational risks: toxicity, wide flammability limits, cryogenic temperatures, and substantially altered bunkering and emergency response procedures. Although the global fleet companies are adopting new fuels, personnel training cannot always keep up with these changes. Under these conditions, technology simulators are becoming not an auxiliary training resource, but a crucial factor of the energy transition. Simulators make it possible to reproduce a wide range of scenarios – from introductory exercises to highly complex operational situations – while doing so in a significantly safer and more cost-effective way. The use of a realistic human-machine interface combined with 3D graphics and even augmented reality, including rolling, vibrations, sound and light effects, allows for immersion in the realistic environment in which a person would work on a ship [1, 2]. Recent examples of these solutions are MethanolPAC [3] and AmmoniaPAC(3D), developed by Wärtsilä. Reproducing specific circumstances which led to accidents, followed by

* Corresponding/presenting author

reflection and structured debriefing, can also form an integral part of the training programme. Wärtsilä TechSim platform, in addition to type-specific simulators for methanol, ammonia and HVO, contains all tools required for such scenario-based training and debriefing [4]. Even before the first crew member boards the ship, digital models can enable crew familiarisation and type-specific training. Throughout the asset's lifecycle they can serve as a platform for scientific research, refresher training, competence assessment and the rehearsal of emergency procedures, training operators to work with new fuels and their associated systems in a safe virtual environment [5]. At the same time, the modelling of failure modes and human-machine interaction helps to identify, reduce and manage operational risks before they materialise at sea. Simulators should no longer be viewed as a stand-alone training product, but as a standard part of the equipment delivery, used for continuous operation and product/ship lifecycle improvement.

Keywords: technology simulators; decarbonisation; alternative fuels; crew training

References

- [1] International Maritime Organization, 2020. *Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel*. (MSC.1/Circ.1621) Available online: <https://futurefuels.imo.org/safety-guidelines/>, accessed 1 July 2026
- [2] International Maritime Organization, 2025. *Interim Guidelines for the Safety of Ships Using Ammonia as Fuel*. (MSC.1/Circ.1687). Available online: <https://futurefuels.imo.org/safety-guidelines/>, accessed 1 July 2026
- [3] Wärtsilä, 2025. *LCHS 5000 TechSim Methanol Bunkering Simulator (IGF) – Trainee Manual (Version 1.0)*. Wärtsilä Corporation
- [4] Wärtsilä, 2021. *e-Tutor 5000 User Manual (Version 1.7)*. Wärtsilä Corporation
- [5] Wärtsilä, 2023. *TechSim 9 Instructor Manual (Version 9)*. Wärtsilä Corporation

Comprehensive Identification and Analysis of Key Challenges in the Blue Economy Sectors

Ana Gundić^{1,*}, Astrid Zekić¹, Mateo Ivanac², Jasna Pletikosić³

¹ University of Zadar, Maritime Department, Zadar, Croatia
E-mail: agundic@unizd.hr azekic22@unizd.hr

² Innovamare
E-mail: mateo@innovamare.org

³ Croatian Chamber of Economy, Zagreb, Croatia
E-mail: jpletikosic@hgk.hr

Abstract

The Blue Economy definition used by the European Commission includes all economic activities regarding oceans, seas, and coasts, as well as a wide range of interrelated, established, and new, growing sectors [1]. The concept itself presumes cross-sector and cross-border coordination among various stakeholders [2]. Blue Economy activities provide jobs for 5.4 million people in the EU and account for a gross value added (GVA) of approximately 500 billion euros per year [3]. Therefore, Blue Economy is one of the essential development models of the 21st century. Consequently, it is important to understand how to optimally align growth, development, and sustainability in Blue Economy [4]. This paper presents the findings of a study on enhancing collaboration and fostering innovation across Blue Economy sectors. The research objective was to raise awareness of various pressures within the Blue Economy sectors. The aim was to identify key challenges in Blue Economy sectors that innovative marine technologies could resolve. Special emphasis has been placed on the diverse backgrounds of the stakeholders

* Corresponding/presenting author

participating in the research. Stakeholders from traditional sectors of the Blue Economy, as well as stakeholders from growing sectors, participated in the research. According to the results, stakeholders' contributions are essential for shaping future initiatives and technological solutions that promote sustainability and innovations within the Blue Economy sectors. However, they also indicate the need for establishing stronger collaboration among various sectors and the development of integrated approaches that could improve efficiency and resilience of Blue Economy in general.

Keywords: Blue economy; innovations; sustainability; resilience; competitiveness; challenges; Stakeholders

Acknowledgments: This research is a part of the Interreg Italy-Croatia 2021-2027 cross-border programme.

References

- [1] Mesut S. Blue Economy and Blue Ocean strategy. *Journal of Ecology & Natural Resources*. 2021;5:000263. <https://doi.org/10.23880/jenr-16000263>
- [2] European Commission. The 2018 Annual Economic Report on EU Blue Economy; European Union: Brussels, Belgium. 2018. Available at <https://op.europa.eu/en/publication-detail/-/publication/79299d10-8a35-11e8-ac6a-01aa75ed71a1>
- [3] European Commission. The EU's Strategy for Sustainable Marine and Maritime Growth: Blue Growth. 2012. https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en
- [4] Auad G, Fath BD. Towards a flourishing Blue Economy: Identifying obstacles and pathways for its sustainable development. *Current Research in Environmental Sustainability*. 2022;4:100193. <https://doi.org/10.1016/j.crsust.2022.100193>

Climate Risk in the Rhine–Danube–Sava Inland Waterway Corridor

Saša Petar¹, Božo Smoljan¹, Zoran Kobeščak^{2*}

¹ University North, Koprivnica, Croatia

E-mail: sasa.petar@unin.hr; bsmoljan@unin.hr

² Zagrebački holding d.o.o., Zagreb, Croatia

E-mail: zoran77k@gmail.com

Abstract

Inland waterway transport (IWT) is an important part of Europe's low-emission freight system, but it is highly exposed to climate-related hydrological change. Low-water episodes on the Rhine and Danube show how drought can reduce vessel loading capacity, raise freight rates and disrupt industrial supply chains [1]. This paper examines how such physical disruption leads to financial exposure for shippers, carriers, insurers and public authorities, with emphasis on the Rhine–Danube–Sava corridor.

The study uses a qualitative review and comparative analytical approach, combining transport-economics research on water levels, vessel loading and freight prices [2] with institutional assessments and market reporting on low-water disruption. A chronology of Rhine, Danube and Sava events from 2003 to 2026 is used to compare frequency, severity and navigation impacts, including the 2026 low-water episode on the Danube at Batina and Sava at Županja.

The findings indicate that low-water disruption can create substantial welfare, logistics and macroeconomic losses. In 2026, Rhine freight rates on the Rotterdam–

* Corresponding/presenting author

Karlsruhe route reportedly rose from about EUR45 per tonne in late June to EUR130-140 per tonne by late July [3]. Furthermore, flooding is a related hazard: reported Danube-basin flood damage reached about EUR3.6 billion in 2002 and EUR2.4 billion in 2013 [4]. Despite these impacts, climate-related financial risk remains weakly reflected in transport contracts, insurance products and adaptation-financing frameworks [5].

The paper concludes that inland waterway climate risk should be treated as both an operational and financial-planning issue requiring coordinated action by shippers, carriers, ports, insurers and public institutions. For the Sava-Danube corridor, early adaptation planning is essential because lower current freight volumes do not imply low future exposure.

Keywords: inland waterway transport, climate risk, low water, Rhine-Danube-Sava corridor, climate finance

References

- [1] Jonkeren, O., Rietveld, P. and Jourquin, B., 2011. Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the river Rhine area. *Transportation Research Part A: Policy and Practice*, 45(10), pp.1007-1019.
- [2] Popa, V.-I., Rusu, E., Chiroasca, A.-M. and Arseni, M., 2025. Danube River: Hydrological Features and Risk Assessment with a Focus on Navigation and Monitoring Frameworks. *Earth*, 6, 70. doi: 10.3390/earth6030070.
- [3] Reuters, 2026. Low Rhine water levels pose cost and logistics threat to German industry, analysts say. Reuters, 14 July.
- [4] PIANC, 2020. *Climate Change Adaptation Planning for Ports and Inland Waterways*. Brussels: PIANC, EnviCom Working Group 178.
- [5] Mooney, A., Savage, S., Fleming, S. and Bernard, S., 2026. The economics of Europe's drought. *Financial Times*, 24 August.

A Remote Sensing Framework for Environmental Monitoring of Sustainable Coastal and Submarine Infrastructure Systems: A Pilot Study of a Cable-Landfall Coastal Area in Dubrovnik, Croatia

Augustine-Moses Gaavwase Gbagir^{1*}, Irena Jurdana²

¹ Department of Geographical and Historical Studies, University of Eastern Finland, Joensuu, Finland
E-mail: augustine.gbagir@uef.fi

² University of Rijeka, Faculty of Maritime Studies, Croatia
E-mail: irena.jurdana@pfri.uniri.hr

Abstract

The expansion of coastal and submarine communication infrastructure across the Adriatic and Mediterranean regions increases the need for scalable monitoring approaches that support both infrastructure resilience and marine ecosystem protection. Existing evidence indicates that ecological pressures from submarine cables are generally localized, most evident during installation, and particularly relevant in sensitive shallow-water habitats. At the same time, Scientific Monitoring and Reliable Telecommunications (SMART) subsea cable research shows that communication infrastructure can also contribute to environmental observation systems [1–3]. Dubrovnik is an established Croatian submarine-cable landing location associated with the Adria-1 system, operational since 1996, while the wider Adriatic region is becoming increasingly important within emerging digital-infrastructure corridors such as GreenMed [4–6]. In this study, we implemented a

* Corresponding/presenting author

Sentinel-2-based pilot monitoring framework for the Dubrovnik coastal area by combining impact-control spatial analysis, hydro-environmental interpretation, and non-parametric trend assessment for coastal and cable-landfall-style environments. The approach builds on established Sentinel-2 applications for monitoring turbidity, suspended sediments, chlorophyll-a, water clarity, and shoreline or coastal engineering responses in estuarine, coastal, and infrastructure-sensitive settings [7–13]. Monthly Sentinel-2 observations from the extended available surface-reflectance record were used to derive relative turbidity and optical water-quality indicators, including the relative turbidity proxy (TurbidityProxy), Normalized Difference Turbidity Index (NDTI), Normalized Difference Chlorophyll Index (NDCI), red/red-edge reflectance, suspended particulate matter proxy (SPMproxy), Normalized Difference Water Index (NDWI), and Modified Normalized Difference Water Index (MNDWI). The selected indicators are widely used for assessing chlorophyll-a and optically complex waters, with NDCI originally proposed for remote estimation of chlorophyll-a in productive and turbid waters and subsequently supported by red-edge-based chlorophyll retrieval approaches [14, 15]. Similar remote-sensing approaches have been demonstrated in Croatian and Adriatic environments, including Vrana Lake, Kaštela Bay, and Italian Adriatic coastal waters, confirming the regional relevance of Sentinel-2 for water-quality monitoring [16–20]. The analysis was divided into an early phase (2017–2019), middle phase (2020–2022), and recent phase (2023–2025/2026). The cable-landfall-style area was analysed as the impact zone, while a nearby coastal location with similar characteristics was used as the control zone. Results showed no significant monotonic trend in relative turbidity within the impact zone ($\tau = -0.0065$, $p = 0.9228$), control zone ($\tau = 0.0160$, $p = 0.8086$), or the impact-control difference ($\tau = -0.0044$, $p = 0.9485$). Sen's slope estimates were near zero for all series, indicating stable optical conditions throughout the monitoring period. Period-based Kruskal-Wallis and pairwise Wilcoxon tests also showed no significant differences among the early, middle, and recent monitoring phases. However, TurbidityProxy remained strongly correlated with sediment-sensitive Sentinel-2 indicators, including red reflectance, red-edge reflectance, SPMproxy, NDTI, and red/green ratios, supporting the internal consistency of the turbidity signal. The proposed framework demonstrates how satellite-based environmental monitoring can support baseline assessment, anomaly detection, and long-term monitoring of coastal infrastructure interfaces. The Dubrovnik pilot indicates stable coastal optical conditions and no persistent impact-zone turbidity elevation during the monitoring period. However, because no verified recent cable-installation timeline was available, the analysis should be interpreted as a coastal environmental monitoring pilot rather than a formal cable-impact assessment. Future applications should integrate Sentinel-2 monitoring with local validation, ACOLITE or C2RCC atmospheric workflows, and in situ turbidity and chlorophyll-a measurements to

improve interpretation of temporal water-quality dynamics in coastal infrastructure environments.

Keywords: Sentinel-2; turbidity; coastal monitoring; submarine cables; water quality; infrastructure resilience

References

- [1] Calhoun, E., Fletcher, R., McOwen, C., Ondo, I., Cannanure, V.K., Wrottesley, J., Clare, M., Bressie, K., Wopschall, R., 2025. Submarine cables and marine biodiversity. UNEP-WCMC and ICPC, Cambridge/Portsmouth. <https://doi.org/10.34892/V9NB-TR83>.
- [2] Clare, M.A., Lichtschlag, A., Paradis, S., Barlow, N.L.M., 2023. Assessing the impact of the global subsea telecommunications network on sedimentary organic carbon stocks. *Nature Communications* 14, 2080. <https://doi.org/10.1038/s41467-023-37854-6>.
- [3] Howe, B.M., Angove, M., Aucan, J.J., Barnes, C.R., Barros, J.S., Bayliff, N.B., Becker, N.C., Carrilho, F., Fouch, M.J., Fry, B., Jamelot, A., Janiszewski, H., Kong, L.S.L., Lentz, S., Luther, D.S., Marinaro, G., Matias, L.M., Rowe, C.A., Sakya, A.E., Salaree, A., Thiele, T., Tilmann, F.J., von Hillebrandt-Andrade, C., Wallace, L., Weinstein, S., Wilcock, W., 2022. SMART subsea cables for observing the Earth and ocean, mitigating environmental hazards, and supporting the blue economy. *Frontiers in Earth Science* 9, 775544. <https://doi.org/10.3389/feart.2021.775544>.
- [4] GeoCables, 2026. Adria-1 submarine cable system. Available online: <https://geocables.com/cable/adria-1> (accessed 22 June 2026).
- [5] Sparkle, 2023. Sparkle launches GreenMed submarine cable in the Adriatic to connect Italy with the Balkans and the Central-Eastern Mediterranean countries. Available online: <https://www.tisparkle.com/media/press-release/sparkle-launches-greenmed-submarine-cable-adriatic-connect-italy-balkans-and> (accessed 22 June 2026).
- [6] ASN, 2026. Sparkle, Alcatel Submarine Networks and Elettra to build GreenMed, the new subsea cable system in the Mediterranean. Alcatel Submarine Networks Press Release. Available online: <https://www.asn.com/press-release/sparkle-alcatel-submarine-networks-and-elettra-to-build-greenmed-the-new-subsea-cable-system-in-the-mediterranean/> (accessed 22 June 2026).
- [7] Altuntas, O.Y., Saygi, M., Colkesen, I., 2025. Long-term monitoring of coastal water quality using Sentinel-2 satellite images and Google Earth Engine: The case study Izmir and Erdek Bays. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVIII-M-6-2025*, 37–43. <https://doi.org/10.5194/isprs-archives-XLVIII-M-6-2025-37-2025>.
- [8] Cabezas-Rabadán, C., Pardo-Pascual, J.E., Palomar-Vázquez, J., Cooper, A., 2025. A remote monitoring approach for coastal engineering projects. *Scientific Reports* 15, 2955. <https://doi.org/10.1038/s41598-025-86485-y>.
- [9] Chowdhury, M., Vilas, C., van Bergeijk, S., Navarro, G., Laiz, I., Caballero, I., 2023. Monitoring turbidity in a highly variable estuary using Sentinel-2-A/B for ecosystem management applications. *Frontiers in Marine Science* 10, 1186441. <https://doi.org/10.3389/fmars.2023.1186441>.
- [10] Lock, M., Saintilan, N., van Duren, I., Skidmore, A., 2023. Monitoring coastal water body health with Sentinel-2 MSI imagery. *Remote Sensing* 15, 1734. <https://doi.org/10.3390/rs15071734>.
- [11] Pisanti, A., Magri, S., Ferrando, I., Federici, B., 2022. Sea water turbidity analysis from Sentinel-2 images: Atmospheric correction and bands correlation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVIII-4/W1-2022*, 371–378. <https://doi.org/10.5194/isprs-archives-XLVIII-4-W1-2022-371-2022>.

- [12] Sent, G., Biguino, B., Favareto, L., Cruz, J., Sá, C., Dogliotti, A.I., Palma, C., Brotas, V., Brito, A.C., 2021. Deriving water quality parameters using Sentinel-2 imagery: A case study in the Sado Estuary, Portugal. *Remote Sensing* 13, 1043. <https://doi.org/10.3390/rs13051043>.
- [13] Tsaimou, C.N., Kagkelis, D.G.N., Karantzalos, K., Sartampakos, P., Tsoukala, V.K., 2024. Remote sensing synergies for port infrastructure monitoring and condition assessment. *Journal of Engineering, Project and Production Management* 14, 0027. <https://doi.org/10.32738/JEPPM-2024-0027>.
- [14] Mishra, S., Mishra, D.R., 2012. Normalized difference chlorophyll index: A novel model for remote estimation of chlorophyll-a concentration in turbid productive waters. *Remote Sensing of Environment* 117, 394–406. <https://doi.org/10.1016/j.rse.2011.10.016>.
- [15] Gitelson, A.A., Dall'Olmo, G., Moses, W., Rundquist, D.C., Barrow, T., Fisher, T.R., Gurlin, D., Holz, J., 2008. A simple semi-analytical model for remote estimation of chlorophyll-a in turbid waters: *Remote Sensing of Environment* 112(9), 3582–3593. <https://doi.org/10.1016/j.rse.2008.04.015>.
- [16] Andričević, R., 2025. Upscaling in situ and airborne hyperspectral data for satellite-based chlorophyll retrieval in coastal waters. *Water* 17, 2356. <https://doi.org/10.3390/w17152356>.
- [17] Batina, A., Šerić, L., Krtalić, A., Šiljeg, A., 2026. Satellite-based machine learning for temporal assessment of water quality parameter prediction in a coastal shallow lake. *Journal of Marine Science and Engineering* 14, 566. <https://doi.org/10.3390/jmse14060566>.
- [18] Divić, M.G., Kvesić Ivanković, M., Divić, V., Kišević, M., Panić, M., Lugonja, P., Crnojević, V., Andričević, R., 2023. Estimation of water quality parameters in oligotrophic coastal waters using uncrewed-aerial-vehicle-obtained hyperspectral data. *Journal of Marine Science and Engineering* 11, 2026. <https://doi.org/10.3390/jmse11102026>.
- [19] Orlandi, M., Marzano, F.S., Cimini, D., 2018. Remote sensing of water quality indexes from Sentinel-2 imagery: Development and validation around Italian river estuaries. *Geophysical Research Abstracts* 20, EGU2018-19808-2.
- [20] Šiljeg, A., Cukrov, N., Batina, A., Marić, I., 2024. Spatial-temporal assessment of water quality dynamics using Sentinel-2 satellite data: Vrana Lake, Croatia. University of Zadar/Ruđer Bošković Institute conference paper.

Sustainable Coastal Management in Zadar County: Public Perceptions

Mia Šarić, Astrid Zekić*, Ana Gundić, Petra Radobuljac Alcedo

University of Zadar, Zadar, Croatia

E-mail: msaric124@unizd.hr; azekic22@unizd.hr; agundic@unizd.hr; psopic@unizd.hr

Abstract

Coastal areas represent some of the most important, but also the most sensitive natural and economic resources of the Republic of Croatia and worldwide. They support a wide range of social, economic and recreational activities that often conflict with the need to preserve natural resources and the environment [1, 2]. A substantial proportion of the global population lives in coastal zones, exposing these areas to considerable demographic pressure [3]. At the same time, tourism development, industrial activities, urbanisation and intensive exploitation of marine resources place additional pressure on coastal ecosystems, while climate change further increases their vulnerability and reinforces the need for sustainable management [4]. The aim of the study was to examine the attitudes of residents of Zadar County toward sustainable coastal management, with special emphasis on their perceptions of key problems, levels of awareness and involvement in management processes, and their support for sustainable development measures. Data were collected using a survey questionnaire.

The findings indicate that local residents make intensive use of the coastal area in everyday life, primarily for recreation, walking and swimming, confirming its important social and recreational functions. Respondents rated the condition of the

* Corresponding/presenting author

coastal area as unsatisfactory, with the main challenges being excessive urbanisation, coastal concretisation, tourist pressures, and pollution of the sea and beaches. The results indicate limited access to information and insufficient involvement of local population in the coastal area management processes, which indicates the need for greater transparency of institutions and strengthening participatory management. At the same time, respondents expressed a high level of support for environmental protection measures, responsible spatial planning, and sustainable coastal management. A particular contribution of this work lies in the empirical evidence on the attitudes of local residents as a key stakeholder group in coastal area governance. The findings may serve as a basis for developing more effective policies for sustainable coastal area management, based on a balance between economic development, environmental protection and the interests of the local community.

Keywords: coastal area; local residents; Zadar County; sustainable coastal management

References

- [1] Botero, C. M., Suman, D. O., Milanes, C. B., 2025. The Multiple Challenges Faced by Coastal and Marine Governance. *Water*, 17(15), 2322. <https://doi.org/10.3390/w17152322>
- [2] Bramati, M. C., Musella, F., Alleva, G., 2014. What drives environmental conflicts in coastal areas? An econometric approach. *Ocean & coastal management*, 101, 63-78. <http://dx.doi.org/10.1016/j.ocecoaman.2014.06.012>
- [3] Kovačić, M., Komadina, P., 2011. Upravljanje obalnim područjem i održivi razvoj. Sveučilište u Rijeci, Pomorski fakultet u Rijeci, Rijeka.
- [4] Štanfel, M., et al., 2016. Uloga geodezije u integriranom upravljanju razvojem u obalnom području i očuvanju obale. *Ekscentar*, 19, 92-96.

Pursuing Standardization: Identifying Operational Criteria for Effective Beach Safety Flag Management

Luka Vukić*, Gorana Jelić Mrčelić

University of Split, Faculty of Maritime Studies, Department for Maritime Management Technologies,
Split, Croatia

E-mail: lvukic@pfst.hr; gjelic@pfst.hr

Abstract

Drowning has been highlighted as one of the leading causes of unintentional injury-related death worldwide despite favourable trends in drowning mortality and continuous efforts to increase public awareness [1, 2]. Beach safety flags are an essential proactive means of communicating bathing conditions and protecting beach users from potential hazards [3]. Although the International Organization for Standardization (ISO) and the International Life Saving Federation (ILS) have established standardized beach safety flag systems, many inconsistencies remain in their interpretation, operational implementation, and use due to differences in national regulations [4, 5]. Also, the current body of literature provides limited guidance on the development of a relevant framework with identified and selected criteria for the proper deployment of beach safety flags under specific on-site conditions. To address this research gap, this study proposes an operational framework for effective beach safety flag management, based on the identification and analysis of the operational criteria to be considered in deploying general and coastal flags along beaches. The purpose of this study is to enhance the current

* Corresponding/presenting author

observational criteria of lifeguard services with a predefined set of parameters, reducing subjectivity in the decision-making process through a standardized approach. To achieve the research objectives, the study considers a systematic review of relevant scientific literature, the regulatory framework, and industry best practices [3–8]. The findings are integrated into an operational framework of individual criteria, based on current knowledge, operational safety principles, meteorological conditions, and expert judgement. The proposed framework establishes a set of objectively measurable, operationally relevant, and internationally recognized criteria for the deployment of general and coastal beach safety flags. The operational framework enables the deployment of safety flags according to predefined criteria while retaining sufficient flexibility to accommodate local environmental conditions. Additionally, the outputs of this research contribute to reducing the current subjectivity in beach safety flag deployment and support the standardization of operational decision-making. Development of a systematic and credible safety management framework based on objectively measurable criteria has the potential to improve beach safety flag management, enhance consistency in operational practice, and strengthen bathing safety through evidence-based decision-making.

Keywords: beach safety flags; drowning prevention; beach management; decision-making framework

References

- [1] United Nations, 2026. World Drowning Prevention Day. Available online: <https://www.un.org/en/observances/drowning-prevention-day>, accessed 15 May 2026.
- [2] Eurostat, 2025. Deaths by drowning in the EU down by 4% in 2022. Available online: <https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20250805-1>, accessed 17 June 2026.
- [3] Basterretxea-Iribar, I., Ruiz de Azua, S., Chica-Ruiz, J.A., de Santiago, I. and Dal Cin, A., 2022. Beach safety management: A systematic review. *Ocean & Coastal Management* 225, 106225. doi: 10.1016/j.ocecoaman.2022.106225.
- [4] International Organization for Standardization (ISO), 2007. Water safety signs and beach safety flags—Part 2: Specifications for beach safety flags—Colour, shape, meaning and performance (ISO 20712-2:2007). Geneva: International Organization for Standardization. Available online: <https://www.iso.org/standard/39683.html>, accessed 5 June 2026.
- [5] International Life Saving Federation, 2010. Lifesaving Position Statement LPS 14: Beach Safety and Information Flags. Available online: <https://www.ilsf.org/wp-content/uploads/2019/01/LPS-14-2010-Flags.pdf>, accessed 20 May 2026.
- [6] Roefs, F.D., Hoogslag, M. and Olivers, C.N.L., 2023. Familiarity with beach warning flags in the Netherlands. *Safety Science* 158, 105952. doi: 10.1016/j.ssci.2022.105952.
- [7] World Health Organization (WHO), 2024. World Drowning Prevention Day: A Guide to Taking Part. Available online: https://cdn.who.int/media/docs/default-source/documents/social-determinants-of-health/2024_wdpd_toolkit_web.pdf, accessed 26 June 2026.
- [8] Royal National Lifeboat Institution (RNLI), 2025. Safety. Available online: <https://rnli.org/safety>, accessed 17 June 2026.

Integrated Transport and Mobility Analysis to Improve Marina Planning: The Case of Sestri Levante (Italy)

Elide Alinovi^{1,*}, Martí Puig², Rosa Mari Darbra²

¹ Department of Political and International Sciences (DISPI), University of Genoa, Genoa, Italy
E-mail: elide.alinovi@edu.unige.it

² Sustainable Polymers and Ports (SP2), Department of Chemical Engineering, Universitat Politècnica de Catalunya · BarcelonaTech, Barcelona, Catalonia, Spain
E-mail: marti.puig@upc.edu; rm.darbra@upc.edu

Abstract

Recreational marinas are increasingly required to accommodate growing boating demand while ensuring the sustainable integration of transport infrastructure, coastal environments and local communities [1, 2]. This paper presents the case of the Port of Sestri Levante, where an integrated planning framework was developed to support the redevelopment of the port system and the surrounding Baia delle Favole. Two scenarios were considered. The first concerns the rationalisation and reorganisation of the existing harbour and the Baia, while the second involves the development of a more structured tourist marina. The methodology evaluates both scenarios through three complementary analytical dimensions: territorial and transport accessibility assessment, berth supply-demand analysis, and spatial analysis of recreational boating mobility, including satellite-based observations of anchorage dynamics. The results place Sestri Levante as a strategic destination within the Ligurian and Northern Italian recreational boating system. The analysis

* Corresponding/presenting author

highlights a strong demand pressure on the Ligurian marina system, which comprises around 25.000 berths (more than 15% of the national total) [3, 4]. At the same time, this area records 1 berth for every 437 inhabitants in its effective area, compared to the national average of 1 for every 362 inhabitants. Under the first scenario, the reorganisation would provide approximately 300 berths within the harbour, compared with around 150 currently available, together with 23 dedicated fishing moorings and a separate 40-buoy mooring field in the Baia delle Favole. This scenario is estimated to generate more than €5.4 million per year in port revenues and local economic benefits. Under the second scenario, the development of a tourist marina would provide 334 recreational berths and accommodate vessels of up to 32 metres. Its estimated annual economic impact would exceed €7.3 million and support the creation of approximately 21.5 jobs [5]. Beyond the Sestri Levante case study, the proposed approach provides an operational framework that may be adapted to other Mediterranean coastal destinations facing similar challenges related to marina capacity, seasonal boating pressure and sustainable waterfront redevelopment [6].

Keywords: sustainable marina planning; transport accessibility; nautical mobility; port infrastructure; spatial analysis

Acknowledgments: This research was carried out within the framework of the Italian National Nautical Observatory (Osservatorio Nautico Nazionale) in collaboration with Confindustria Nautica.

References

- [1] Benevolo, C., 2011. Problematiche di sostenibilità nell'ambito del turismo nautico in Italia. *Impresa Progetto – Electronic Journal of Management*, (2).
- [2] Martínez-Vázquez, R.M., de Pablo Valenciano, J., Caparrós Martínez, J.L., 2021. Marinas and sustainability: Directions for future research. *Marine Pollution Bulletin*, 164, 112035. Available online: <https://doi.org/10.1016/j.marpolbul.2021.112035>.
- [3] Pagine Azzurre, 2025. *Italian Marinas and Ports Database*. Available online: <https://www.pagineazzurre.com/>, accessed 28 June 2026
- [4] Assomarinas – Confindustria Nautica, 2025. *Italian Marina Development and Berth Supply Data*. Genoa, Italy.
- [5] Osservatorio Nautico Nazionale, Confindustria Nautica, 2026. *The Port of Sestri Levante – Opportunities for Nautical Tourism Development: Feasibility Analysis, Socio-Economic Impact and Legal Considerations*. Technical Report, Genoa, Italy.
- [6] Bowen, R.E., Riley, C., 2003. Socio-economic indicators and integrated coastal management. *Ocean & Coastal Management*, 46(3–4), 299–312.

Calculation of Correlation and CAGR in Nautical Tourism: A Case Study of the Republic of Croatia

Ana Perić Hadžić¹, Šime Vučetić^{2,*}, Ljiljana Peričin²

¹ University of Rijeka, Faculty of Maritime Studies, Croatia
E-mail: ana.peric@pfri.uniri.hr

² University of Zadar, Maritime department, Zadar, Croatia
E-mail: svucetic22@unizd.hr; lpericin22@unizd.hr

Abstract

Nautical tourism plays an important role in the Republic of Croatia and, as a distinct form of tourism, contributes significantly to the national economy [1]. The paper aims to investigate the level of correlation between the total number of nautical ports, the total number of employees in nautical tourism and the gross domestic product (GDP) per capita in the Republic of Croatia over the period 2005-2025 and determine whether the above variables have a continuous positive compound annual growth rate (CAGR). The application of the Spearman correlation coefficient calculation method in maritime affairs has previously been demonstrated by Poljičak et al. (2022) [2]. The research was conducted in two main stages. The first stage comprised desk research, including a review of the literature relevant to the research topic and the collection of numerical data required for the empirical analysis. Data on the total number of nautical tourism ports and the total number of employees in nautical tourism in the Republic of Croatia were obtained from the Croatian Bureau of Statistics [3], while data on GDP (per capita) in the Republic of Croatia were obtained from Croatian National Bank database [4]. In the second stage of the research, Spearman's rank correlation and CAGR values were successfully

* Corresponding/presenting author

calculated and the preliminary research results indicate that there is strong, significant and positive correlation among the variables examined and positive and continuous CAGR for all variables over the observed period.

Keywords: nautical tourism; nautical ports; employees; GDP; CAGR; Republic of Croatia

References

- [1] Kovačić, M., Luković, T., 2007. Prostorne značajke planiranja i izgradnje luka nautičkog turizma. *Geoadria*, 12 (2), 131-147. <https://doi.org/10.15291/geoadria.119>
- [2] Poljičak, A.M., Hinić, M., Kalac, A., 2022. Nautical Tourism – Case Study in the Republic of Croatia. *LOGI – Scientific Journal on Transport and Logistics*. 13. 73-83. doi: <https://doi.org/10.2478/logi-2022-0007>
- [3] Državni zavod za statistiku, <https://dzs.gov.hr/> (Accessed: 20/7/2026)
- [4] Hrvatska narodna banka, <https://www.hnb.hr/-/glavni-makroekonomski-indikatori> (Accessed: 20/7/2026)

Analysis of Trends in the Offer of Yacht Charter Agencies

Luka Grbić, Mate Barić*, Šime Vučetić

University of Zadar, Maritime Department, Zadar, Croatia

E-mail: lugrbic@unizd.hr; mbaric@unizd.hr; svucetic22@unizd.hr

Abstract

To develop nautical tourism, numerous factors influencing its growth—such as location, hydrographic resources, transport, infrastructure, and accessibility—must first be aligned, alongside the presence of cultural and social factors [1]. The nautical tourism industry encompasses not only marinas and cruise ships but also yacht and vessel chartering [2]. The significant and robust growth of the yacht charter sector plays a pivotal role in the tourism industry, particularly within nautical tourism as a distinct form of tourism activity [3]. Yacht and vessel chartering are a key element of tourism development for countries with indented coastlines that aim to significantly grow their nautical tourism sectors. By implementing various digital technologies nautical tourism can accomplish certain advantages and achieve overall financial benefits [4]. Driven by the strong impact of digitalization and emerging trends in nautical tourism, charter agencies have had to adapt and devise creative services to attract new clients while retaining existing ones. The aim of this paper is to analyse and present the latest and most interesting global trends in yacht and vessel charter services. The offer of charter agencies was researched through the Google search engine as well as relevant tourist agencies that provide yacht and vessel charter services. After

* Corresponding/presenting author

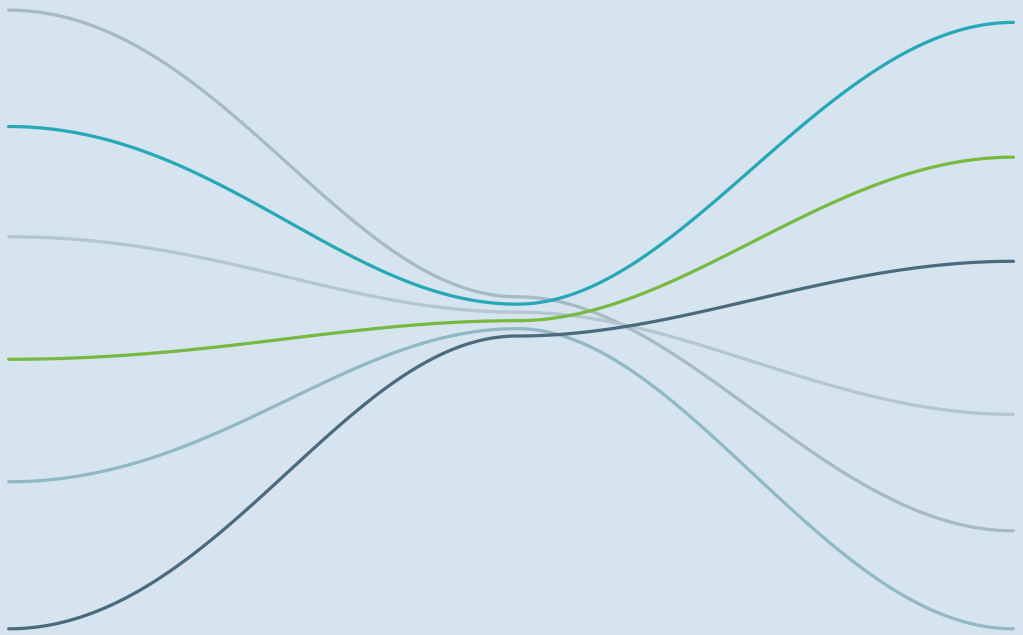
having analysed and summarised the results, ten most popular global services with charter service users in 2025/2026 are singled out.

Keywords: charter industry; charter service; charter agencies; trends; service quality

References

- [1] Vázquez, R., 2020. Nautical Tourism: A Bibliometric Analysis. *Journal of Tourism, Sustainability and Well-being*, CinTurs - Research Centre for Tourism, Sustainability and Well-being, University of Algarve, Vol. 8(4), pp. 320-330. Available at: URL: http://www.cieo.pt/journal/J_4_2020/article4.pdf (Accessed: 20.7.2026)
- [2] Luković, T., 2007. Nautički turizam – definicije i dileme. *Naše more*, 54(1-2)/2007. Available at: <https://hrcak.srce.hr/13164> (Accessed: 20.7.2026)
- [3] Jiménez-Jiménez, A., Sancha, P., Gessa, A., 2024. Beyond Chartering: Adapting the Offer to Customer Behavior for a Sustainable Yachting Industry. *Sustainability*, 16(24), 11179. <https://doi.org/10.3390/su162411179>
- [4] Dvornik, I.; Dvornik, J., 2025. Analysis of the Application of Digitalization in Nautical Tourism // 11th International Maritime Science Conference Book of Abstracts / Peronja, Ivan; Vukić, Luka; Mandić, Nikola et al. (ur.). Split: University of Split – Faculty of Maritime Science, 2025, 75, 9.

Paths That Meet



Global Supply Chain Disruptions and Import Resilience: Evidence from Croatia, 2015–2024

Miljenko Mustapić*, Davor Grgurević, Petra Tišler

University North, Department of Logistics and Sustainable Mobility, Croatia

E-mail: mmustapic@unin.hr; dgrgurevic@unin.hr; ptisler@unin.hr

Abstract

This paper examines the impact of global supply chain disruptions and logistics challenges on import dynamics in the Republic of Croatia during the period 2015–2024, with particular emphasis on system resilience in the context of global instability [1, 2]. Particular attention is given to the effects of the COVID-19 pandemic and geopolitical disruptions associated with the war in Ukraine, both of which substantially affected international transport and logistics flows [2, 3]. The empirical analysis draws on secondary data obtained from the Eurostat and UN Comtrade databases and employs descriptive statistics and multiple linear regression analysis. The results indicate that global trade activity plays a dominant role in determining Croatia's import levels, while the effects of individual crisis events are not statistically significant at the aggregate level. These findings suggest a relatively high level of resilience in import flows despite major disruptions in supply chains and logistics systems [1]. The study contributes by integrating economic and logistics perspectives and provides practical implications for supply chain management, including supplier diversification, enhanced flexibility of logistics systems, and policy design aimed at strengthening supply chain resilience in small open economies.

* Corresponding/presenting author

Keywords: supply chains; logistics; imports; global disruptions; resilience; transport systems

References

- [1] Christopher, M., 2016. Logistics & Supply Chain Management (5th ed.). Pearson.
- [2] Xu, Z., Elomri, A., Kerbache, L., & Omri, A., 2020. Impacts of COVID-19 on Global Supply Chains: Facts and Perspectives. *IEEE Engineering Management Review*, 48(3), 153–166.
- [3] Younis, H., Sundarakani, B., & Vel, P., 2023. The Impact of COVID-19 on Supply Chains: A Systematic Review. *Operations Management Research*, 16, 1–15.

Which Sectors Benefit Most from Logistics Improvements in Africa? Evidence from Firm-Level Data

Atila Cifter¹, N. Baris Vardar¹, Gul Esin Delipinar^{2*}

¹ Altınbaş University, Faculty of Economics, Administrative and Social Sciences, Economics, İstanbul, Türkiye

E-mail: atilla.cifter@altinbas.edu.tr; nevzatbaris.vardar@bau.edu.tr

² Altınbaş University, Faculty of Business, Logistics Management, İstanbul, Türkiye

E-mail: gul.delipinar@altinbas.edu.tr

Abstract

This study examines whether improvements in national logistics performance are associated with firm growth in African economies. Existing research on logistics performance and trade facilitation has largely focused on international trade outcomes [1, 2, 3, 4], while much less is known about whether improvements in logistics systems translate into firm-level expansion. However, evidence from developing economies shows that the broader business environment and infrastructure conditions can shape firm accumulation and growth [5, 6]. Evidence from Sub-Saharan Africa further suggests that transport-related capabilities are associated with higher firm growth [7]. Using 7,083 firm-year observations for 829 publicly listed non-financial, non-government firms in 12 African countries in the period from 2008 to 2023, we combine firm-level data with the World Bank Logistics Performance Index (LPI), annualized using Chow-Lin interpolation, and IMF real GDP growth. Firm growth is measured as the annual growth rate of total assets, while logistics improvement is captured by annual LPI growth. We estimate firm

* Corresponding/presenting author

and year fixed-effects models with firm-clustered robust standard errors, controlling for leverage, liquidity, firm size, and macroeconomic conditions. The results show a positive and statistically significant association between LPI growth and firm growth. In the baseline specification, a one-percentage-point increase in LPI growth is associated with approximately 0.64 percentage points higher firm asset growth. The relationship remains robust to alternative liquidity measures, fixed-effects structures, country-specific linear trends, excluding South Africa and Egypt, and restricting the sample to observed LPI survey years. However, the association is concentrated in 2016-2023 and is not statistically significant in the 2008-2015 subsample. Sectoral estimates show significant positive associations in manufacturing, mining, and retail trade, suggesting greater sensitivity among activities dependent on physical goods movement. Disaggregating the LPI shows that improvements in timeliness, international shipments, tracking and tracing, and logistics competence are associated with higher firm growth, whereas customs and infrastructure are not individually significant. The findings extend the logistics literature beyond trade outcomes by showing that improvements in national logistics systems are also associated with firm-level expansion in Africa, with substantial variation across sectors and logistics dimensions.

Keywords: firm growth; Logistics Performance Index; Africa; infrastructure; panel data analysis; firm-level analysis

References

- [1] Martí, L., R. Puertas, and L. García (2014), "The Importance of the Logistics Performance Index in International Trade," *Applied Economics*, 46(24), 2982-2992.
- [2] Gani, A. (2017), "The Logistics Performance Effect in International Trade," *The Asian Journal of Shipping and Logistics*, 33(4), 279-288.
- [3] Seck, A. (2016), "Trade Facilitation and Trade Participation: Are Sub-Saharan African Firms Different?," *Journal of African Trade*, 3(1-2), 23-39.
- [4] Dollar, D., M. Hallward-Driemeier, and T. Mengistae (2005), "Investment Climate and Firm Performance in Developing Economies," *Economic Development and Cultural Change*, 54(1), 1-31.
- [5] Aterido, R., M. Hallward-Driemeier, and C. Pagés (2011), "Big Constraints to Small Firms' Growth? Business Environment and Employment Growth across Firms," *Economic Development and Cultural Change*, 59(3), 609-647.
- [6] Goedhuys, M. and L. Sleuwaegen (2010), "High-Growth Entrepreneurial Firms in Africa: A Quantile Regression Approach," *Small Business Economics*, 34(1), 31-51.
- [7] Chu, Z. (2012), "Logistics and Economic Growth: A Panel Data Approach," *Annals of Regional Science*, 49, 87-102.

Intermodal Transportation and Green Logistics in Türkiye

Gul Esin Delipinar^{1,*}, Ibrahim Uzpeder²

¹ Altinbas University, Faculty of Business, Logistics Management, Istanbul, Türkiye
E-mail: gul.delipinar@altinbas.edu.tr

² Istanbul Bilgi University, Faculty of Applied Sciences, Logistics Management, Istanbul, Türkiye
E-mail: ibrahim.uzpeder@bilgi.edu.tr

Abstract

Environmental sustainability has become very important in freight transportation; governments, logistics service providers, and shippers aim to reduce greenhouse gas emissions to remain competitive. With this objective, policy frameworks such as the European Green Deal also highlight the transition toward cleaner, more efficient transport systems [4, 5]. Intermodal transportation is an effective mode to improve transportation efficiency by combining road, rail, and maritime transport and reducing environmental impacts [3]. This paper studies the strategic role of intermodal transportation in supporting the green transition in logistics with examples from Türkiye [6]. The study uses qualitative research on a systematic review of academic literature, international reports, and national policy documents, including Türkiye's 2053 Transport and Logistics Master Plan. The study combines current knowledge on the contribution of intermodal transportation with sustainable freight systems, given its superior socioeconomic and environmental performance [7, 8]. It also searches how transport infrastructure investments, logistics hubs, digitalization, and public policies influence the transition towards greener logistics. Türkiye's strategic geography, because of its logistics bridge among Asia, Europe, and the

* Corresponding/presenting author

Middle East, with national initiatives that promote rail freight, combined transport, and sustainable logistics corridors, [1] is essential for examining intermodal transportation. The paper provides a strategic framework for understanding the opportunities, challenges, and future priorities of expanding environmentally sustainable intermodal transportation in emerging economies [2, 9]. The results show that successful green logistics transitions need coordinated infrastructure investment, supportive public policies, digital transformation, and stronger integration between transport modes. The paper also presents results by outlining policy implications for logistics stakeholders and identifying promising directions for future research on sustainable freight transportation in emerging economies.

Keywords: sustainable freight transport; green logistics; transport policy; intermodal transportation; sustainability; Türkiye

References

- [1] Acar, A. Z., Bontyn, Z., & Kocaoglu, B. (2015). Turkey As a Regional Logistic Hub in Promotion of Reviving Ancient Silk Route Between Europe and Asia. *Journal of Management Marketing and Logistics*, 2(2), 94-109. <https://doi.org/10.17261/Pressacademia.2015211609>
- [2] Bottani, E. (2025). Trends in intermodal transport: A bibliometric analysis of recent literature (2020-2024). *Procedia Computer Science*, 274, 1055-1065. <https://doi.org/10.1016/j.procs.2025.12.103>
- [3] Demir, E., Hrušovský, M., Jammerneegg, W., & Van Woensel, T. (2019). Green intermodal freight transportation: Bi-objective modelling and analysis. *International Journal of Production Research*, 57(19), 6162-6180. <https://doi.org/10.1080/00207543.2019.1620363>
- [4] European Commission. (2020). The European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
- [5] European Environment Agency (2025, April 16). EEA greenhouse gases — data viewer. <https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>
- [6] Ministry of Transport and Infrastructure (2020). National Intelligent Transportation Systems Strategy Document and 2020 – 2023 Action Plan. Available online: <https://www.uab.gov.tr/media/14xfzlxz/ulusal-akilli-ulas-im-sistemleri-strateji-belgesi-ve-2020-2023-eylem-planı-eng.pdf>, accessed 18 June 2026
- [7] Ministry of Transport and Infrastructure (2023). Transport and Logistics Master Plan. Available online: <https://sgb.uab.gov.tr/uploads/pages/yayin-sunum-ve-tablolar/uab-2053-master-plan.pdf>, accessed 18 June 2026
- [8] Ministry of Trade (2021). Yeşil Mutabakat Eylem Planı [Green Deal Action Plan of Türkiye]. Available online: <https://ticaret.gov.tr/data/60f1200013b876eb28421b23/MUTABAKAT%20YE%C5%9E%C4%B0L.pdf>, accessed 18 June 2026
- [9] Temizceri, F.T., & Kara, S.S. (2024). Towards sustainable logistics in Turkey: A bi-objective approach to green intermodal freight transportation enhanced by machine learning, *Research in Transportation Business & Management*, 55, 101145. <https://doi.org/10.1016/j.rtbm.2024.101145>

From Paper to Interoperability: NSCP as a Model for Secure and Resilient Digitalization of Freight Transport

Dea Aksentijević^{1,*}, Mateo Crnković²

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: dea.aksentijevic@pfri.uniri.hr

² AKD d.o.o., Zagreb, Croatia
E-mail: mateo.crnkovic@akd.hr

Abstract

The digitization of freight transport documentation is a key prerequisite for a more efficient, secure and interconnected European transport area. Regulation (EU) 2020/1056 on electronic freight transport information (eFTI) establishes a common framework for the standardized electronic exchange of regulatory freight data between economic operators and competent authorities [1]. In Croatia, this framework is implemented through the National System for Electronic Storage and Exchange of Data in Road Transport (NSCP). This study examines NSCP as a national model for operationalizing the eFTI framework, with particular emphasis on its functional architecture, interoperability mechanisms, access control and institutional requirements. The system functions as a national digital gateway connecting certified commercial eFTI platforms, Croatian competent authorities and eFTI portals in other EU Member States [2]. It enables authenticated communication, authorization-based access and the real-time exchange of standardized freight information [3]. The analysis shows that NSCP is not structured as a centralised

* Corresponding/presenting author

database. Freight data remain on certified platforms and are retrieved only upon authorised request. This approach limits unnecessary data duplication and strengthens traceability, accountability and data governance. The findings also indicate that effective interoperability depends not only on technical standards but also on regulatory alignment, cybersecurity and coordination among public and private stakeholders. NSCP demonstrates how regulatory requirements can be translated into a secure national digital infrastructure connected to the wider European eFTI ecosystem. The system provides a relevant case for examining the transition from paper document-based administrative procedures towards interoperable, data-driven freight governance [4, 5].

Keywords: eFTI; digital interoperability; freight transport; data governance; NSCP

References

- [1] European Parliament and Council of the European Union, 2020. Regulation (EU) 2020/1056 of 15 July 2020 on Electronic Freight Transport Information. *Official Journal of the European Union* L 249, 33–48. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R1056>, accessed 10 July 2026
- [2] European Commission, 2024. Commission Implementing Regulation (EU) 2024/1942 of 5 July 2024 Laying Down Common Procedures and Detailed Rules for Accessing and Processing Electronic Freight Transport Information by Competent Authorities. *Official Journal of the European Union* L 2024/1942. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32024R1942>, accessed 10 July 2026
- [3] Pan, S., Trentesaux, D., McFarlane, D., Montreuil, B., Ballot, E., Huang, G.Q., 2021. Digital Interoperability in Logistics and Supply Chain Management: State-of-the-Art and Research Avenues towards Physical Internet. *Computers in Industry* 128, 103435. doi: 10.1016/j.compind.2021.103435
- [4] Wang, Y., Sarkis, J., 2021. Emerging Digitalisation Technologies in Freight Transport and Logistics: Current Trends and Future Directions. *Transportation Research Part E: Logistics and Transportation Review* 148, 102291. doi: 10.1016/j.tre.2021.102291
- [5] Dasaklis, T.K., Kopanaki, E., Chountalas, P.T., Rachaniotis, N.P., Voutsinas, T.G., Giannakis, K., Chondrokoukis, G., 2024. Exploring the Implementation Challenges of the Electronic Freight Transport Information (eFTI) Regulation: An Empirical Perspective from Greece. *Logistics* 8(1), 30. doi: <https://doi.org/10.3390/logistics8010030>

Connected Reefer Containers for Perishable Cargo Supervision: LSTM-Based Early Warning of Microclimate Conditions Associated with Accelerated Ripening

Marko Vukšić*, Jasmin Ćelić, Ivan Panić, Aleksandar Cuculić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: marko.vuksic@pfri.uniri.hr; jasmin.celic@pfri.uniri.hr; ivan.panic@pfri.uniri.hr; aleksandar.cuculic@pfri.uniri.hr

Abstract

Modern refrigerated containers can provide continuous operational and microclimate data during maritime and intermodal transport. In current practice, reefer supervision is mainly based on setpoint tracking, supply- and return-air temperature monitoring, and unit-level alarm thresholds. Such monitoring does not fully describe the time-dependent exposure of perishable cargo to combined thermal, hygro-metric, ventilation and atmospheric conditions that may accelerate ripening before a conventional alarm is generated. Previous work on virtual refrigerated containers has shown that temperature distribution and fruit-quality evolution inside a loaded container are spatially and temporally variable [1]. This paper proposes an LSTM-based early-warning approach for connected reefer containers carrying climacteric horticultural products. Sequential data from the refrigeration unit and cargo environment, including air temperatures, relative humidity, ventilation status, defrost events, compressor operation, carbon dioxide, oxygen and ethylene-related indicators, are used to identify microclimate patterns associated with increased

* Corresponding/presenting author

ripening risk. LSTM-based and related recurrent models have already been applied to temperature and environmental prediction in refrigerated and agricultural cold-chain applications [2, 3], while ethylene-related measurements and IoT-based monitoring support broader cargo-condition interpretation [4, 5]. The proposed approach is compared with conventional statistical and machine-learning methods, with emphasis on early detection capability, false-alarm behaviour and practical applicability in transport supervision. It positions the refrigerated container as a data-generating element of intelligent freight infrastructure and supports a transition from equipment-centred monitoring toward cargo-condition-oriented decision support in cold-chain logistics.

Keywords: connected reefer containers; cold-chain logistics; cargo microclimate; LSTM; accelerated ripening; intelligent transport systems

References

- [1] Defraeye, T., Verreydt, C., Gonthier, J., Lukasse, L., Cronjé, P., Berry, T., 2024. The virtual container: Physics-based simulation of refrigerated container map temperature and fruit quality evolution and variability in a shipment. *Postharvest Biology and Technology* 211, 112722. doi: 10.1016/j.postharvbio.2023.112722
- [2] Guo, J., Liu, D., Lin, S., Lin, J., Zhen, W., 2024. Temperature prediction of a temperature-controlled container with cold energy storage system based on long short-term memory neural network. *Applied Sciences* 14(2), 854. doi: 10.3390/app14020854
- [3] Jiang, J., Peng, C., Liu, W., Liu, S., Luo, Z., Chen, N., 2023. Environmental prediction in cold chain transportation of agricultural products based on K-Means++ and LSTM neural network. *Processes* 11(3), 776. doi: 10.3390/pr11030776
- [4] Lukasse, L., Staal, M., Schouten, R., Person, T., Pereira da Silva, F., 2025. Ethylene during controlled atmosphere transport of fruits and flowers: concentrations, causes and consequences. *European Journal of Horticultural Science* 90(1), 0015. doi: 10.1079/ejhs.2025.0015
- [5] Protopappas, L., Bechtsis, D., Tsotsolas, N., 2025. IoT services for monitoring food supply chains. *Applied Sciences* 15(13), 7602. doi: 10.3390/app15137602

Suspended Steel-Wheel String-Rail Complexes as a Second-Level Freight Transport Mode: A Comparative Techno-Economic and Environmental Assessment

Vice Milin¹, Marko Šundov^{2*}, Oleg Zaretskiy³

¹ Faculty of Maritime Studies, University of Split, Split, Croatia
E-mail: vmilin@pfst.hr

² University of Zadar, Maritime Department, Zadar, Croatia
E-mail: msundov@unizd.hr

³ uScovery DMCC, UAE
E-mail: ceo@uscovery.com

Abstract

Freight demand growth, congestion, land scarcity and decarbonisation targets are placing conventional road and rail networks under increasing pressure [1]. Elevated transport that exploits the vertical dimension has re-emerged as a means of relieving these pressures, so far mainly through aerial ropeways for passengers. This paper assesses a less studied variant intended for cargo: mounted and suspended steel-wheel rolling stock running on a prestressed string-rail overpass, in which the load-bearing element is a rail reinforced by a core bundle of pre-tensioned steel wires [2]. Using a structured desk-based comparative assessment, the reported technical parameters of three cargo configurations, namely containerised and piece cargo, bulk cargo, and general rolling stock, are compared with road, conventional rail and inland waterway freight across six criteria: throughput, speed, specific carbon dioxide

* Corresponding/presenting author

intensity, land take, capital and operating cost, and technological maturity. Emission intensities are estimated using the activity-based approach of ISO 14083 [3]. The results indicate that the electric string-rail concept is competitive with electrified rail in operational carbon dioxide intensity, while offering a markedly smaller ground footprint and the ability to overcome water and terrain barriers, at the cost of higher reported capital intensity for containerised lines and limited independent validation. The mode appears best positioned as a second-level feeder linking ports, terminals and industrial sites [4]. The principal limitations of the study are its reliance on manufacturer-reported data and the small number of demonstration installations.

Keywords: string-rail transport; elevated freight; second-level logistics; sustainable transport; techno-economic assessment; carbon dioxide emissions

References

- [1] European Environment Agency. 2022. "Specific CO2 emissions per tonne-km and per mode of transport in Europe," EEA, Copenhagen.
- [2] D. A. Escobar G., W. Sarache and E. Jiménez-Riaño, 2022. "The impact of a new aerial cable-car project on accessibility and CO2 emissions considering socioeconomic stratum: a case study in Colombia," *Journal of Cleaner Production*, vol. 340, art. 130802.
- [3] International Organization for Standardization, ISO 14083:2023 Greenhouse gases: quantification and reporting of greenhouse gas emissions arising from transport chain operations. Geneva: ISO, 2023.
- [4] T. Notteboom and J.-P. Rodrigue, 2005. "Port regionalization: towards a new phase in port development," *Maritime Policy & Management*, vol. 32, no. 3, pp. 297–313.

Reconstruction of the Rijeka Railway Junction as a Prerequisite for the Development of the Port of Rijeka

Siniša Vilke^{1*}, Josip Knežević², Bariša Rašić²

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: sinisa.vilke@pfri.uniri.hr

² HŽ Infrastruktura Ltd., Croatia
E-mail: josip.knezevic3@hzinfra.hr; barisa.rasic@hzinfra.hr

Abstract

This paper analyses the role of the reconstruction and functional reconfiguration of the Rijeka railway junction in the development of the Port of Rijeka and strengthening the Rijeka–Zagreb–Central Europe intermodal transport route [1–5]. The emphasis is placed on the spatial and functional separation of passenger and freight rail traffic, with freight capacities being relocated to peripheral locations in the wider Rijeka area, while passenger traffic is integrated into the urban fabric of the City of Rijeka. With the commissioning of the Rijeka Gateway container terminal and the growth of container traffic, the existing railway infrastructure does not provide sufficient capacity or the required levels of reliability and speed. Therefore, the construction of a new double-track lowland railway line between Rijeka and Zagreb is emerging as a key infrastructure project of national and international importance. The paper presents the transport and logistics characteristics of the Port of Rijeka, analyses the current condition of the Rijeka railway junction, and considers the planned railway infrastructure modernisation and reconstruction

* Corresponding/presenting author

projects. Particular attention is given to the technical and operational characteristics of the new lowland railway line and its effects on the efficiency of container dispatch and receipt by rail. The findings indicate that the functional reconfiguration of the Rijeka railway junction and the construction of the new line are fundamental prerequisites for the sustainable development of the Port of Rijeka and for strengthening its competitiveness within the North Adriatic port system.

Keywords: Rijeka railway junction; Port of Rijeka, Rijeka–Zagreb lowland railway line; intermodal transport; railway transport system

References

- [1] Dundović, Č., Vilke, S., Šantić, L., 2010. Značenje željezničke pruge visoke učinkovitosti Zagreb-Rijeka za razvoj riječke luke. *Pomorstvo - Scientific Journal of Maritime Research*, 24(2).
- [2] HŽ Infrastruktura d.o.o., n.d. Modernizacija i izgradnja željezničke pruge državna granica - Botovo - Zagreb - Rijeka - Studija opravdanosti. Zagreb.
- [3] Port of Rijeka Authority, 2024. Rijeka Gateway Container Terminal - Project Overview. Rijeka. Available online: <https://www.portauthority.hr/rgp-kontejnerski-terminal-jadranska-vrata/>, accessed 10 May 2026.
- [4] Vilke, S., 2020. Rekonstrukcija željezničkog prometnog sustava u funkciji razvoja riječke luke - izgradnja nove nizinske pruge Rijeka-Zagreb. *Željeznice* 21, 19(3), 7-15.
- [5] Vilke, S., Šantić, L., Glad, M., 2011. Redefining of the Rijeka Railway Junction. *Promet - Traffic & Transportation*, 23(6), 443-451.

Cargo Consolidation Strategies and Documentation Flow in LCL Logistics

Tanja Poletan Jugović^{1,*}, Dražen Žgaljić¹, Anastazija Jakovac^{1,2}

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: tanja.poletan@pfri.uniri.hr; drazen.zgaljic@pfri.uniri.hr

² Boxline UCL d.o.o., Sežana, Slovenia

E-mail: a.mihelcic@hotmail.com

Abstract

This paper examines the formation and consolidation characteristics of Less-than-Container Load (LCL) cargo flows, where smaller consignments from multiple shippers are consolidated into a single container. LCL transport is an important element of maritime logistics chains, enabling the consolidation of small consignments and their subsequent deconsolidation at the destination [1]. Shipment consolidation can generate economies of scale and reduce transport costs [2], while appropriate cargo preparation and container-loading planning can support more efficient utilisation of available container capacity [3]. Building upon a structured theoretical framework that defines the key concepts, components and operational specificities of LCL containerised cargo flows, the research is conducted through a case study methodology focused on consolidator's operations and information flows. The empirical analysis encompasses workflow organisation, operational procedures, and documentation processes, with particular attention to the interaction between physical and documentation flows throughout the transport process, from booking and cargo receipt at the container freight station (CFS) to consolidation, ocean transport, deconsolidation and final delivery, as well as the

* Corresponding/presenting author

identification of critical challenges in cargo consolidation and information flows. The aim of the paper is to analyse the organisation of LCL cargo flows and the integration of physical and documentation processes within maritime transport. The scientific contribution of this research lies in the systematic evaluation of the transport logistics and documentation framework as a key factor in optimising operational efficiency, transport, logistics and documentation processes for LCL transport in international maritime supply chains.

Keywords: container cargo flows; cargo consolidation; LCL logistics; documentation flows

References

- [1] Bešković, B., Stojaković, M., 2019. Establishing an efficient outbound overseas logistics chain of small consignments: The perspective of Eastern Adriatic region. *Transport Problems* 14(4), 113–125. doi: 10.20858/tp.2019.14.4.10.
- [2] Ülkü, M.A., 2009. Analysis of Shipment Consolidation in the Logistics Supply Chain. PhD dissertation, University of Waterloo, Department of Management Sciences, Waterloo, Ontario, Canada. Available online: <https://uwspace.uwaterloo.ca/items/01ccfdbd-2896-4134-b2cb-df5f19491684>, accessed 10 June 2026.
- [3] Jugović, A., 2020. The Economic Impact of Container-loading Problem. *Transactions on Maritime Science* 9(2), 271–278. doi: 10.7225/toms.v09.n02.010.

Optimization of Delivery Vehicle Allocation and Routing Using Free Open-Source Tools: A Case Study of Express Parcel Delivery in Rijeka, Croatia

Svjetlana Hess*, Mirano Hess, Teo Tomulić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: svjetlana.hess@pfri.uniri.hr; mirano.hess@pfri.uniri.hr; teo.tomulic@gmail.com

Abstract

This paper presents a mathematical modelling framework for optimizing delivery vehicle allocation and routing in parcel logistics, addressing the Vehicle Routing Problem (VRP) [1, 8] through free, open-source software tools. Two complementary models were developed and implemented in Python using the Google OR-Tools library [2]: a vehicle allocation model minimizing the number of active vehicles [7], and a routing model based on the Pickup and Delivery Problem with Time Windows (PDPTW) [4, 6]. Queueing theory models (M/M/1, M/M/S and M/G/1) [3, 9] were additionally applied to validate fleet-sizing decisions from a service-level perspective. The methodology was tested on a case study of NovaExpress parcel delivery in the city of Rijeka, comparing an urban delivery area (85 customers) and a suburban delivery area (42 customers) against experience-based dispatcher solutions. The mathematical model reduced the required fleet by 33.3% in the urban area and 50.0% in the suburban area, cut total operational time by 14.6% and 13.4% respectively, and eliminated all time-window violations present in the dispatcher solutions. Queueing analysis confirmed the VRP-derived fleet sizes as an efficient

* Corresponding/presenting author

trade-off between vehicle utilization and customer waiting time. The results demonstrate that free, open-source optimization tools can deliver measurable operational and economic improvements for small and medium-sized logistics operators without software licensing costs [5].

Keywords: vehicle routing problem; fleet allocation; queueing theory; Google OR-Tools; parcel delivery logistics; open-source optimization

References

- [1] Dantzig, G.B., Ramser, J.H., 1959. The Truck Dispatching Problem. *Management Science* 6(1), 80-91. doi: doi.org/10.1287/mnsc.6.1.80
- [2] Google OR-Tools Documentation, 2024. Vehicle Routing. Available online: <https://developers.google.com/optimization/routing>, accessed 05 July 2025
- [3] metricgate.com M/G/1 Queue: Pollaczek-Khinchine Formula. Available online: <https://metricgate.com/docs/queue-mg1-pollaczek-khinchine/>, accessed 20 June 2026
- [4] Wassan, N.A., Nagy, G., 2014. Vehicle Routing Problem with Deliveries and Pickups: Modelling Issues and Meta-Heuristics Solution Approaches. *Int. J. Transp.* 2(1), 95-110. doi: dx.doi.org/10.14257/ijt.2014.2.1.06
- [5] de Mello Bandeira, R.A. et al., 2019. Electric Vehicles in the Last Mile of Urban Freight Transportation: A Sustainability Assessment of Postal Deliveries in Rio de Janeiro-Brazil. *Transp. Res. Part D Transp. Environ.* 67 (4), 491-502. doi: doi.org/10.1016/j.trd.2018.12.017
- [6] Solomon, M.M., 1987. Algorithms for the Vehicle Routing and Scheduling Problems with Time Window Constraints. *Operations Research* 35(2), 254-265. doi: doi.org/10.1287/opre.35.2.254
- [7] Švehla, A.; Božić, D.; Stanković, R., 2016, Allocating Delivery Vehicles Within the Transport Network by Applying a Mathematical Model. In *Proceedings of the ZIRP International Scientific Conference "Perspectives on the Croatian 3PL Industry in Acquiring International Cargo Flows"*; Ščukanec, A., Babić, D., Eds.; Faculty of Transport and Traffic Sciences, University of Zagreb: Zagreb, Croatia, 231-240. Available online: <https://drive.google.com/file/d/1H-DiYgyjk5WhRXsChUbYb0H2gJBm0gFc/view>, accessed 20 June 2026
- [8] Toth, P., Vigo, D. (eds.), 2014. Vehicle Routing: Problems, Methods, and Applications, Second Edition. MOS-SIAM Series on Optimization. Philadelphia, PA, USA. doi: doi.org/10.1137/1.9781611973594, accessed 15 June 2026
- [9] Zenzerović, Z., 2003. *Teorija redova čekanja (Queueing Theory)*. Pomorski fakultet u Rijeci, Rijeka.

Comparative Analysis of Energy Efficiency in Metaheuristic Algorithms for the Container Relocation Problem

Marko Gulić^{1*}, Neven Grubišić¹, Srđan Žuškin¹, Tonči Biočić²

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: marko.gulic@pfri.uniri.hr; neven.grubisic@pfri.uniri.hr; srdan.zuskin@pfri.uniri.hr

² University of Dubrovnik, Faculty of Maritime Studies, Dubrovnik, Croatia

E-mail: tonci.biocic@unidu.hr

Abstract

Metaheuristic algorithms have proven effective for solving NP-hard combinatorial problems, including the Container Relocation Problem [1-4]. Although these algorithms are typically evaluated in the literature based on solution quality and convergence speed, their energy consumption during execution is rarely considered, despite the growing importance of energy efficiency in computational systems [5]. This study analyses the electrical energy consumption of the Genetic Algorithm and African Buffalo Optimization when solving instances of the Container Relocation Problem, with energy measurements obtained experimentally using a Wattmeter EMOS P5801 device, while simultaneously considering the quality of the solutions obtained. The experimental evaluation was conducted across multiple configurations of each algorithm, considering key parameters that influence the search process and the utilisation of computational resources. The results show that the choice of algorithm configuration significantly affects both solution quality and energy consumption, with configurations yielding better solutions not necessarily being

* Corresponding/presenting author

the most energy-efficient, offering broader insight into the relationship between optimisation quality and energy use, and providing guidance for algorithm selection in applications where energy efficiency is as important a criterion as solution quality.

Keywords: metaheuristic algorithms; energy efficiency; Container Relocation Problem; Genetic Algorithm; African Buffalo Optimization

Acknowledgments: Funded by the European Union - NextGenerationEU - E-MOTION - PU-239 uniri-iz-25-156. The views and opinions expressed are solely those of the authors and do not necessarily reflect the official stance of the European Union or the European Commission. Neither the European Union nor the European Commission can be held accountable for them.

References

- [1] M. Gulić and M. Žuškin, "Enhancing Metaheuristic Optimization: A Novel Nature-Inspired Hybrid Approach Incorporating Selected Pseudorandom Number Generators," *Algorithms*, vol. 16, no. 9, p. 413, Aug. 2023, doi: 10.3390/a16090413.
- [2] M. Gulić, L. Maglić, T. Krljan, and L. Maglić, "Solving the Container Relocation Problem by Using a Metaheuristic Genetic Algorithm," *Applied Sciences (Switzerland)*, vol. 12, no. 15, 2022, doi: 10.3390/app12157397.
- [3] L. Maglić, M. Gulić, and L. Maglić, "Optimization of container relocation operations in port container terminals," *Transport*, vol. 35, no. 1, 2020, doi: 10.3846/transport.2019.11628.
- [4] M. Gulić, L. Maglić, and S. Valčić, "Nature inspired metaheuristics for optimizing problems at a container terminal," *Pomorstvo*, vol. 32, no. 1, 2018, doi: 10.31217/p.32.1.16.
- [5] M. Gulić, P. Turkalj, M. Valčić, and N. Grubišić, "Experimental Analysis of Pseudorandom Number Generators Considering Sequence Quality and Energy Consumption," in 2026 49th MIPRO ICT and Electronics Convention (MIPRO), IEEE, May 2026, pp. 298–303. doi: 10.1109/MIPRO70003.2026.11591948.

Evidence-Based Urban Mobility Planning Using Multi-Source Transport Data: A Case Study of Opatija, Croatia

Nives Domjan Kačarević*, Ante Klečina, Ivan Cvitković

University North, Department of Logistics and Sustainable Mobility, Croatia

E-mail: nidomjan@unin.hr; anklecina@unin.hr; icvitkovic@unin.hr

Abstract

Public transport planning in tourist cities requires decision-making based on reliable and comprehensive transport data. While travel behaviour surveys provide valuable insights into users' mobility patterns and travel preferences, traffic counts quantify actual transport demand, and infrastructure assessments identify physical constraints affecting accessibility and network performance. However, relying on a single source of information may lead to incomplete planning decisions. Integrating multiple transport data sources offers a more comprehensive understanding of urban mobility and supports evidence-based public transport planning [1, 2]. This paper examines the contribution of integrating travel behaviour surveys, traffic counts, infrastructure assessment, and public transport system analysis to the planning of a public transport network in the City of Opatija, Croatia. The research is based on a comprehensive transport study comprising household travel survey results, automatic and manual traffic counts, road infrastructure assessment, and public transport service analysis. Rather than evaluating the proposed public transport network itself, the study investigates how different transport data sources complement one another during the planning process and contribute to informed

* Corresponding/presenting author

decision-making [3]. The findings indicate that each data source provides unique information that cannot independently support effective public transport planning. Travel behaviour surveys explain users' mobility needs and travel preferences, traffic counts quantify transport demand, while infrastructure assessment identifies operational constraints influencing service accessibility and network organisation. Their integration enables a more comprehensive evaluation of transport conditions and provides a robust basis for developing evidence-based public transport solutions in tourist-oriented urban environments. The proposed approach may serve as a transferable methodology for supporting sustainable public transport planning in cities facing similar mobility challenges [4].

Keywords: public transport planning; sustainable mobility; travel behaviour survey; traffic counts; evidence-based planning; tourist cities

References

- [1] Vuchic, V., 2005. *Urban Transit: Operations, Planning and Economics*. John Wiley & Sons, Hoboken, New Jersey. ISBN: 978-0-471-63265-8.
- [2] Walker, J., 2012. *Human Transit: How Clearer Thinking About Public Transit Can Enrich Our Communities and Our Lives*. Island Press, Washington, DC.
- [3] City of Opatija, Promocija Plus d.o.o., 2025. *Travel Behaviour and Mobility of the Citizens of Opatija*. Opatija, Croatia. Internal survey report.
- [4] Cvitković, I., Klečina, A., Krpan, Lj., Domjan Kačarević, N., Biškup, N., 2025. *Transport Study for the Collection and Analysis of Traffic Data in the City of Opatija*. University North, Varaždin, Croatia. Technical report prepared for the City of Opatija.

Expert and User Perceptions of Multimodal Public Transport Attributes: A Comparative Analysis for Stated Preference Design

Nikola Kožul*, Luka Novačko, Borna Abramović, Tomislav Fratrović

University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia

E-mail: nikola.kozul@fpz.unizg.hr; luka.novacko@fpz.unizg.hr; borna.abramovic@fpz.unizg.hr; tomislav.fratrović@fpz.unizg.hr

Abstract

Stated Preference (SP) experiments are a cornerstone of discrete choice modelling in transport research [1, 2], yet the selection of attributes to include is a critical methodological decision that is often insufficiently addressed. In practice, attribute lists are commonly derived from literature and expert judgment [3], implicitly assuming that transport professionals' priorities align with those of the users whose behaviour is being modelled. The MOBIUS project aims to develop a behavioural mode choice model for multimodal public transport (PT) in Zagreb, Croatia. As part of the underlying methodological work, the present study empirically tests the alignment between expert and user assessments of 33 PT attributes and derives an evidence-based tier framework for SP design. Two parallel surveys were conducted. An expert panel ($n = 32$; 19 respondents from the region and 13 international specialists) and a Zagreb PT user sample ($n = 67$) rated the importance of 33 attributes on a 1–10 scale and identified the seven attributes they considered most critical. The 33 attributes were classified into five thematic groups (Operational, Multimodality, Service Quality, Contextual, Psychological) reflecting established PT quality frame-

* Corresponding/presenting author

works [4, 5]. In the between-sample comparison Mann–Whitney tests per attribute with, Spearman rank correlation and Jaccard indices for top seven lists were used. All analyses were performed in SAS Studio. Overall alignment between expert and user rankings was strong on overall ranking of attributes, but there was disagreement between the two groups in the attributes they actively prioritised. Users consistently valued travel-experience attributes (crowding, perceived safety, waiting time, trust in digital services) more highly than experts, while experts more strongly prioritised network-level attributes (integrated ticketing, number of transfers, total travel cost). Bringing these findings together, an integrated tier framework classifies the 33 attributes into six categories: five core attributes with high cross-sample agreement (Total travel time, Travel time reliability, Service frequency, Waiting time, Ease of transfer), two critical disagreement attributes with substantial user-driven gaps (Crowding level, Spatial accessibility), four user-driven and five expert-driven attributes reflecting the systemic-versus-experiential divide, and two attributes recommended for exclusion from SP variation. This framework directly supports evidence-based SP design decisions for the MOBIUS project and is applicable to comparable multimodal mode choice studies elsewhere. Ongoing analyses extend these findings to user heterogeneity through cluster analysis of preference structure.

Keywords: stated preference; public transport; mode choice modelling; attribute selection

Acknowledgments: This work is funded by the European Union – NextGenerationEU as part of the institutional research project of the University of Zagreb, Faculty of Transport and Traffic Sciences (Project: Integrating Behavioural and Contextual Factors in Multimodal Mode Choice Modelling - MOBIUS).

References

- [1] J. J. Louviere, D. A. Hensher, J. D. Swait, and W. Adamowicz, 2000. *Stated Choice Methods*. Cambridge University Press. doi: 10.1017/cbo9780511753831.
- [2] N. Kožul, L. Novačko, K. Babojelić, and P. Brlek, "Stated Preference Approach in Shaping Urban Sustainable Multimodal Transport—A Literature Review," *Systems*, vol. 13, no. 10, p. 853, Sep. 2025. doi: 10.3390/systems13100853.
- [3] J. de D. Ortúzar and L. G. Willumsen, *Modelling Transport*. Wiley, 2011. doi: 10.1002/9781119993308.
- [4] L. Redman, M. Friman, T. Gärling, and T. Hartig, "Quality attributes of public transport that attract car users: A research review," *Transp. Policy (Oxf)*, vol. 25, pp. 119–127, Jan. 2013. doi: 10.1016/j.tranpol.2012.11.005.
- [5] L. Dell'Olio, A. Ibeas, and P. Cecin, "The quality of service desired by public transport users," *Transp. Policy (Oxf)*, vol. 18, no. 1, pp. 217–227, Jan. 2011. doi: 10.1016/j.tranpol.2010.08.005.

A Survey-Driven Digital Framework for Planning Demand Responsive Transport in Rural Areas: A Tour-Based Simulation Approach

Neven Grubišić^{1,*}, David Brčić¹, Tomislav Krljan²

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: neven.grubisic@uniri.hr; david.brcic@pfri.uniri.hr

² PTV Group, Vienna, Austria
E-mail: tomislav.krljan@ptvgroup.com

Abstract

Demand Responsive Transport (DRT) has emerged as a promising solution for providing public transport services in rural and sparsely populated regions where conventional fixed-route services are economically unsustainable [1, 2]. However, the successful planning of DRT systems requires realistic estimation of travel demand and its temporal distribution, which remains one of the major challenges in transport planning. Existing studies have predominantly focused on dynamic dispatching strategies, ride-sharing optimisation and agent-based simulation of DRT operations [3–5], while recent research has further extended DRT applications towards integrated passenger-freight transport and advanced operational strategies [6–8]. Comparatively less attention has been devoted to generating realistic transport requests from observed travel behaviour prior to service implementation.

This paper presents a digital modelling framework for planning and evaluating DRT services based on behavioural survey data describing travel habits, socio-demographic characteristics, travel purposes and users' service preferences. Individual transport requests are generated stochastically within predefined outbound and return time

* Corresponding/presenting author

windows, producing realistic demand patterns that reflect users' mobility behaviour. The proposed methodology is implemented within the PTV Visum transport modelling environment, where the generated requests are integrated with a routing-enabled transport network. A tour planning procedure dynamically links travel demand with transport supply by assigning passenger requests to an available vehicle fleet while considering pick-up and drop-off locations and operational constraints. The resulting vehicle tours are evaluated through dynamic DRT simulation, enabling the assessment of fleet utilisation, ride-sharing efficiency, passenger service quality and overall operational performance under different service configurations.

The methodology is demonstrated through a case study conducted on the Croatian island of Cres, a typical low-demand island environment characterised by dispersed settlements, and limited viability of conventional public transport services. The results demonstrate that the proposed framework provides an effective decision-support tool for designing and assessing DRT services while offering a transferable methodology applicable to other rural and island regions.

Keywords: Demand Responsive Transport (DRT); tour-based simulation; transport planning; dynamic ride-sharing; rural mobility

References

- [1] Berrada, J., & Poulhès, A. (2021). Economic and socioeconomic assessment of replacing conventional public transit with demand responsive transit services in low-to-medium density areas. *Transportation Research Part A: Policy and Practice*, 150, 317–334. <https://doi.org/10.1016/j.tra.2021.06.008>
- [2] Bruzzone, F., Scorrano, M., & Nocera, S. (2021). The combination of e-bike-sharing and demand-responsive transport systems in rural areas: A case study of Velenje. *Research in Transportation Business & Management*, 40, Article 100570. <https://doi.org/10.1016/j.rtbm.2020.100570>
- [3] Ronald, N., Thompson, R. G., & Winter, S. (2015). Simulating demand-responsive transportation: A review of agent-based approaches. *Transport Reviews*, 35(4), 404–421. <https://doi.org/10.1080/01441647.2015.1017749>
- [4] Yao, R., & Bekhor, S. (2024). A ridesharing simulation model that considers dynamic supply-demand interactions. *Journal of Intelligent Transportation Systems*, 28(1), 31–53. <https://doi.org/10.1080/15472450.2022.2098730>
- [5] Huang, J., Cui, Y., Zhang, L., Tong, W., Shi, Y., & Liu, Z. (2022). An overview of agent-based models for transport simulation and analysis. *Journal of Advanced Transportation*, 2022, Article 1252534. <https://doi.org/10.1155/2022/1252534>
- [6] Calabrò, G., Inturri, G., & Pira, M. L. (2026). Integrating passenger and freight transport in demand-responsive systems: A novel agent-based modelling approach. *Transportation Research Procedia*. <https://doi.org/10.1016/j.trpro.2026.02.095>
- [7] Cho, S.-W., Lim, Y.-H., Ju, S.-H., & Seo, K.-M. (2025). Analyzing new operation strategy of demand-responsive transport using a discrete-event simulation framework. *Systems*, 13(4), 303. <https://doi.org/10.3390/systems13040303>
- [8] Fehn, F., Engelhardt, R., Dandl, F., Bogenberger, K., & Busch, F. (2023). Integrating parcel deliveries into a ride-pooling service—An agent-based simulation study. *Transportation Research Part A: Policy and Practice*, 169, Article 103580. <https://doi.org/10.1016/j.tra.2022.103580>

Assessing the Impact of Real-Time Passenger Information Systems on Perceived Bus Transport Service Quality: A Systematic Literature Review

Nikola Biškup^{1*}, Ante Klečina², Nives Domjan Kačarević²,
Ivan Cvitković²

¹ Academica d.o.o., Bjelovar, Croatia
E-mail: nikola.biskup@academica.hr

² University North, Department for logistics and sustainable mobility, Varaždin, Croatia
E-mail: anklecina@unin.hr; nidomjan@unin.hr; icvitkovic@unin.hr

Abstract

Real-Time Passenger Information (RTPI) systems are increasingly implemented in public transport with the aim of improving service quality, reducing passenger uncertainty, and increasing the attractiveness of bus transport. This study analyses the effects of RTPI systems on passenger perception through a systematic literature review of scientific research. The review was conducted using a qualitative synthesis approach based on the principles of Synthesis Without Meta-analysis (SWiM) [1]. Ten scientific studies investigating different RTPI solutions, including passenger information displays [2], mobile applications [3, 4], web platforms [3], SMS services, and combined information systems [5–8], were analysed. The identified effects were classified into three main categories: reduction of perceived waiting time, increase in passenger satisfaction, and improvement of reliability perception and user trust. The results indicate that RTPI systems have the strongest and most consistent

* Corresponding/presenting author

positive impact on reducing uncertainty during waiting periods. Six studies analysed the perceived waiting time; five of them reporting positive effects, including reductions of approximately 1.5–2 minutes and improvements in perceived waiting experience. All studies examining passenger satisfaction identified positive effects, mainly related to reduced frustration, better travel planning, and improved overall travel experience. Furthermore, seven studies investigated reliability perception and user trust, with six reporting positive outcomes related to increased predictability and passenger control. However, the analysed studies also show that the effectiveness of RTPI systems strongly depends on the accuracy and reliability of provided information. Inaccurate arrival predictions may negatively affect user trust and reduce the perceived value of the system. The findings confirm that RTPI systems represent an important measure for improving the perceived quality of bus transport services, primarily by reducing uncertainty and enabling better travel planning. Nevertheless, their benefits depend on the quality of underlying operational data and the overall performance of the public transport service.

Keywords: real-time passenger information; public transport; bus services; passenger satisfaction; waiting time

References

- [1] Campbell, M., et al., 2020. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. *BMJ* 368. doi: 10.1136/bmj.l6890
- [2] Brakewood, C., Watkins, K., 2018. A Literature Review of the Passenger Benefits of Real-Time Transit Information. *Transport Reviews* 39(3), 327–356. doi: 10.1080/01441647.2018.1472147
- [3] Brakewood, C., Macfarlane, G.S., Watkins, K., 2015. The impact of real-time information on bus ridership in New York City. *Transportation Research Part C: Emerging Technologies* 53, 59–75. doi: 10.1016/j.trc.2015.01.021
- [4] Henríquez-Jara, B., et al., 2025. Evidence of the Impact of Real-Time Information on Passenger Satisfaction Across Varying Public Transport Quality in 13 Chilean Cities. Available online: <https://ssrn.com/abstract=5179220>, accessed 23 March 2026
- [5] Marcedo, E., et al., 2021. Real-time information systems for public transport: user perspective. *Transportation Research Procedia* 52, 732–739. doi: 10.1016/j.trpro.2021.01.087
- [6] Cullen, M., Ahuja, V., 2017. Real-Time Transit Information Systems: Effect on Passenger Waiting Time Perception and Mode Choice. Available online: <https://ssrn.com/abstract=6726458>, accessed 8 February 2026
- [7] Lu, H., et al., 2018. The impact of real-time information on passengers' value of bus waiting time. *Transportation Research Procedia* 31, 18–34. doi: 10.1016/j.trpro.2018.09.043
- [8] Brakewood, C., Barbeau, S., Watkins, K., 2014. An experiment evaluating the impacts of real-time transit information on bus riders in Tampa, Florida. *Transportation Research Part A: Policy and Practice* 69, 409–422. doi: 10.1016/j.tra.2014.09.003

From Service Standards to Infrastructure Needs: A Transferable Model for Suburban and Regional Railway Network Planning

Ante Klečina^{1*}, Tanja Poletan Jugović², Dražen Žgaljić²,
Nives Domjan Kačarević¹

¹ University North, Croatia

E-mail: ante.klecina@unin.hr; nidomjan@unin.hr

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: tanja.poletan@pfri.uniri.hr; drazen.zgaljic@pfri.uniri.hr

Abstract

This paper proposes a service-standard-led method for planning local, suburban, and regional passenger railway networks. Instead of deriving future services primarily from the constraints of existing railway infrastructure, the proposed method first defines the desired level of service in terms of frequency, connectivity and accessibility. These objectives are then translated into a hierarchical operational passenger transport network with clearly defined service standards, from which the corresponding infrastructure requirements are derived [1, 2]. Central Croatia is used here as a case study. The existing railway service is analyzed using selected indicators related to passenger service frequency, direct connections, opportunities for coordinated transfers, and timetable structure [3, 4]. It is then compared with a proposed hierarchical network of regional, suburban, and local passenger services based on the integrated clock-face timetable concept [3–6]. A schematic network diagram is used as both a technical [3–6] and graphical representation [7] of the proposed line

* Corresponding/presenting author

hierarchy, stopping patterns, service structure, and coordinated transfer opportunities. The main scientific contribution is the development of a planning framework that links desired public transport outcomes and citizens' mobility needs with operational service design and long-term railway infrastructure requirements. Under this approach, infrastructure development is guided by a carefully designed passenger service network intended to meet the mobility needs of most of the population, rather than by existing infrastructure constraints alone. The proposed method should be transferable to other metropolitan and polycentric regions with comparable geographical structures and passenger mobility needs.

Keywords: integrated clock-face timetable; passenger railway service; public transport; service standards; passenger offer; transport planning

References

- [1] Klečina, A., Krpan, Lj., Žgaljić, D., Tišler, P., Cvitković, I., 2025. *The proposal of the development of suburban passenger railway transport in the metropolitan region of the city of Rijeka as a tool for sustainable connectivity and sustainable economic and spatial development*. Zbornik radova Riječki identitet: gospodarski, povijesni, jezični i kulturni odjeci povodom 150. obljetnice izgradnje željezničkih pruga Rijeka - Pivka i Rijeka - Karlovac, Rijeka, available online: <https://izdavastvo.ffri.hr/wp-content/uploads/2025/11/Rijecki-identiteti-mali-format-2.11.2025.pdf>, accessed 6 July 2026
- [2] Cvitković, I., Klečina, A., Domjan Kačarević, N., Ivanišević, A., 2025. *Integrated Clock-Face Timetable as a Tool for Optimizing the Municipal Public Transport System in the City of Ludbreg and Surrounding Municipalities*, Sustainability 2025, vol. 17, no. 7943, 2025. doi: <https://doi.org/10.3390/su17177943>
- [3] Vuchic, V., 2005. *Urban Transit Operations, planning and economics*, Hoboken, New Jersey: Wiley & Sons, ISBN: 978-0-471-63265-8
- [4] Vuchic, V., 2007. *Urban Transit Systems and Technology, 1st ed.*, Hoboken, New Jersey: Wiley & Sons. doi: <https://doi.org/10.1002/9780470168066>
- [5] Walker, J., 2012. *Human Transit - How Clearer Thinking About Public Transit Can Enrich Our Communities and Our Lives*, Washington: Island Press. doi: <https://doi.org/10.5198/jtlu.v5i3.370>
- [6] Tzieropoulos, P., Emery, D., Tron, D., 2010. *How regular is a regular-interval timetable?*, WIT Transactions on The Built Environment, vol. 114, pp. 283-294. doi: 10.2495/CR100271
- [7] Allard, J., 2009. *The Design of Public Transport Maps, Graphic elements and design operations in the representation of urban navigation systems, doctoral thesis*, Milan: Politecnico di Milano, Dipartimento INDACO, available online: <https://brt.cl/wp-content/uploads/2012/01/Tesis-Jose-Allard-light.pdf>, accessed 6 July 2026

Analysis of Cycling Infrastructure and Road Accidents Involving Cyclists in the European Union

Predrag Brlek^{1,*}, Luka Novačko¹, Karlo Babojelić¹, Zlatko Sovreski²

¹ University of Zagreb, Faculty of Transport and Traffic Sciences, ZUK Borongaj, Zagreb, Croatia
E-mail: pbrlek@fpz.unizg.hr; lnovacko@fpz.unizg.hr; kbabojelic@fpz.unizg.hr

² University St. Kliment Ohridski in Bitola, Faculty of Technical Sciences, Bitola, North Macedonia
E-mail: zlatkosovre@yahoo.com

Abstract

Cyclists remain among the most vulnerable road users. Unlike occupants of cars, vans and lorries, cyclists have little physical protection. As a result, collisions involving cyclists are more likely to lead to serious injury or death [1]. In the EU, cyclists represent 10% of all road user deaths. In 2024, 1,926 cyclists were killed on EU roads, and a further 22,153 cyclists were killed between 2014 and 2024 [1]. The increasing use of electric bicycles is influencing casualty trends. In countries that distinguish between bicycle types, deaths among electric bicycle users have increased while deaths among conventional bicycle users have generally decreased. The growing popularity of electric bicycles, particularly among older riders, may partly explain this trend [1]. A survey by Eurocities, which represents over 200 large cities including Paris, Berlin and Rome, found that a large majority of those that adopted a 30 km/h limit were seeing positive results in terms of reduced injury and death on the roads [2]. Although there is no official source that provides information about the cycling infrastructure, European Union research has identified more than 900,000 km of

* Corresponding/presenting author

cycle paths and lanes at EU level. Of that, a little over 300,000 km belongs to the dedicated cycle network (cycle tracks + cycle lanes), and the rest is cycle-friendly mixed traffic roads. The results highlight strong national differences in coverage, quality, classification systems, definitions, and completeness. Based on EU-wide surveys 23.6% of EU residents cycle at least once per week (male residents: 27.6%, female residents: 20.0%) and cycling represents on average 7.8% of all trips under 300 km [3]. Using cycling infrastructure tracker ECF quantify the different types of cycling infrastructure across the European countries and compare the lengths of relevant public road networks to estimate the level of completeness of the cycle network [4]. According to previous research, the countries with the most cyclists (the Netherlands, Denmark, Belgium and Germany) record the highest absolute number of accidents, but this is a consequence of high exposure and the number of kilometres travelled. When looking at the risk per kilometre travelled, these countries are among the safest in Europe [5]. On the other hand, on global size, despite having lower infrastructure density and traffic calming metrics than the Global Top 30, Asian cities maintain a better safety rate (0.23 fatalities vs. the 0.29 global average), proving that sheer volume and cultural integration can create “safety in numbers [6].

Using the aforementioned data, this paper will compare the development of cycling infrastructure with the number of traffic accidents, especially in countries with a pronounced separate cycling infrastructure.

Keywords: cycling; cycling infrastructure; cyclist accidents

References

- [1] ETSC, 2026. Improving the safety of cycling in Europe. https://etsc.eu/wp-content/uploads/PINFLASH_50_FINAL.pdf, accessed 5 june 2026
- [2] <https://www.euractiv.com/news/too-many-cyclists-still-dying-on-eu-roads-safety-advocates-warn/>, accessed 5 june 2026
- [3] European Commission, 2026. THE DEVELOPMENT OF CROSS-BORDER CYCLING LANE INFRASTRUCTURE: Study on current state and possible development of European Union cycling infrastructure – Final Report
- [4] <https://www.ecf.com/en/resources/ecfs-cycling-infrastructure-tracker/>, accessed 5 june 2026
- [5] https://road-safety.transport.ec.europa.eu/european-road-safety-observatory/statistics-and-analysis-archive/roads/cyclists_en, accessed 5 june 2026
- [6] The Copenhagenize Index 2025 - EIT Urban Mobility Edition The Global Ranking of Bicycle Friendly Cities, EIT Urban Mobility, Copenhagenize, 2025

Mobile Eye Tracking as a Tool for Behaviour Analysis of Vulnerable Road Users

Paula Čaklec^{1,*}, Miljenko Mustapić¹, Nikola Biškup²

¹ University North, Koprivnica, Croatia

E-mail: pacaklec@unin.hr; mmustapic@unin.hr

² Academica d.o.o., Zagreb, Croatia

E-mail: nikola.biskup@academica.hr

Abstract

Mobile eye-tracking glasses enable researchers to examine where road users direct their visual attention and how they respond to different traffic situations [1]. This technology is particularly valuable for studying vulnerable road users, including pedestrians, cyclists, and e-scooter users, whose behaviour is strongly influenced by the surrounding traffic environment [2–4]. This paper presents a structured literature review of mobile eye-tracking applications to the study of vulnerable road users. The focus is on pedestrian crossing behaviour, cyclist visual attention, interactions with transport infrastructure, and the emerging use of eye tracking in micromobility research [4]. The review shows that mobile eye tracking provides valuable insights into visual attention, hazard perception, and decision-making in urban traffic environments. However, existing research is still unevenly distributed. Pedestrians and cyclists have received considerably more research attention, while e-scooter users and other micromobility users remain comparatively underexplored [4]. The paper identifies key research gaps, including the need for more real-world studies, greater consistency in the use of eye-tracking metrics, and more comparative research across different vulnerable road user groups. The findings suggest that

* Corresponding/presenting author

mobile eye tracking can support safer infrastructure design, more effective road safety measures, and the development of more sustainable urban mobility systems.

Keywords: eye-tracking glasses; vulnerable road users; visual attention; sustainable urban mobility

References

- [1] Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures*. Oxford University Press.
- [2] Lévêque, L., Ranchet, M., Deniel, J., Bornard, J.-C., & Bellet, T. (2020). Where do pedestrians look when crossing? A state of the art of the eye-tracking studies. *IEEE Access*, 8, 164833–164843. doi: 10.1109/ACCESS.2020.3021208
- [3] Ma, S., Zhang, W., Noland, R. B., & Andrews, C. J. (2024). Eye tracking measures of bicyclists' behavior and perception: A systematic review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 107, 52–68. doi: 10.1016/j.trf.2024.08.026
- [4] Pashkevich, A., Burghardt, T. E., Puławska-Obiedowska, S., & Šucha, M. (2022). Visual attention and speeds of pedestrians, cyclists, and electric scooter riders when using shared road: A field eye tracker experiment. *Case Studies on Transport Policy*, 10(1), 549–558. doi: 10.1016/j.cstp.2022.01.015

Video-Based Assessment of Spatial Driver Behaviour in a Speed Enforcement Zone: A Case Study from Northern Croatia

Nives Domjan Kačarević*, Ante Klečina, Ivan Cvitković,
Paula Čaklec

University North, Department of Logistics and Sustainable Mobility, Croatia

E-mail: nidomjan@unin.hr; anklecina@unin.hr; icvitkovic@unin.hr; pacaklec@unin.hr

Abstract

Driver behaviour is widely recognised as one of the most important determinants of road safety, while inappropriate speed remains a major contributing factor to both the occurrence and severity of traffic crashes. Although fixed speed enforcement systems have been extensively implemented to improve road safety, their effectiveness is predominantly evaluated using aggregated indicators such as average speed, traffic violations, or crash frequency. Recent advances in unmanned aerial vehicle (UAV) technology and video analytics enable detailed observation of vehicle trajectories, providing new opportunities for the objective evaluation of road safety measures [1, 2]. This study presents a video-based assessment of driver behaviour in a speed enforcement zone located on the D2 state road in Northern Croatia. Traffic data were collected using an unmanned aerial vehicle (UAV), while the recorded videos were processed using the DataFromSky platform to automatically detect vehicles and extract vehicle trajectories, speed, and acceleration data. The analysis included 153 passenger vehicles travelling under uninterrupted traffic flow conditions, and descriptive statistical analysis was applied to compare driving behaviour

* Corresponding/presenting author

before, within, and after the monitored section [3]. The results indicate progressive behavioural adaptation throughout the monitored road section. Vehicle speeds decreased when approaching the speed enforcement zone, whereas the greatest acceleration variability was observed within the monitored section, indicating active speed adjustment. After passing the monitored section, vehicle movement became more stable, suggesting a transition towards a less dynamic driving pattern. The findings demonstrate that trajectory-based video analytics provide an objective and effective approach for assessing driver behaviour and evaluating road safety measures, supporting evidence-based traffic engineering and sustainable transport planning [4].

Keywords: driver behaviour; video analytics; vehicle trajectories; road safety; speed enforcement, UAV

References

- [1] Morris, B.T., Trivedi, M.M., 2008. Learning, Modeling, and Classification of Vehicle Track Patterns from Live Video. *IEEE Transactions on Intelligent Transportation Systems* 9(3), 425-437. Available online: <https://doi.org/10.1109/TITS.2008.922881>, accessed 6 July 2026.
- [2] Razi, A., Wang, W., Rashidi, T.H., Nguyen, H., 2023. Deep Learning Serves Traffic Safety Analysis: A Forward-Looking Review. *IET Intelligent Transport Systems* 17(9), 2448-2470. Available online: <https://doi.org/10.1049/itr2.12257>, accessed 6 July 2026.
- [3] Wen, X., Li, X., Li, Z., Tian, Z., 2021. Driver Behavior Classification at Stop-Controlled Intersections Using Vision-Based Trajectory Data. *Sustainability* 13(3), 1404. Available online: <https://doi.org/10.3390/su13031404>, accessed 6 July 2026.
- [4] Abdel-Aty, M., Mahmoud, N., Elhenawy, M., 2023. Advances and Applications of Computer Vision Techniques in Vehicle Trajectory Generation and Surrogate Traffic Safety Indicators. *arXiv*. Available online: <https://arxiv.org/abs/2303.15231>, accessed 6 July 2026.

Simulation-Based Generation of Traffic State Datasets for Machine Learning-Based Decision Support in Centralized Traffic Management

Tomislav Krljan^{1*}, Neven Grubisic², Luka Novačko³, Marko Gulić²

¹ PTV Group, Vienna, Austria

E-mail: tomislav.krljan@ptvgroup.com

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: neven.grubisic@uniri.hr; marko.gulic@pfri.uniri.hr

³ University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia

E-mail: Inovacko@fpz.unizg.hr

Abstract

Operational Intelligent Transport Systems (ITS) and centralized traffic management increasingly require reliable data-driven methods for understanding and managing dynamic traffic conditions in relation to predefined performance indicators [1–3]. However, the development of data-based decision-support models is often limited by the lack of representative datasets, especially for congested, imbalanced, or unusual traffic states, often unachievable in a real-world environment [4, 5]. Therefore, this research proposes a simulation-based approach for generating structured traffic state datasets for data-based decision support in centralized traffic management. The proposed methodology uses microscopic traffic simulation to generate different assignment scenarios, demand levels, saturation conditions, and route distributions [6, 7]. Simulation outputs are transformed into machine learning ready datasets using selected network state variables, including vehicle counts, average speed, delay, queue length, stopped time, and route impedance.

* Corresponding/presenting author

The generated datasets are then used as a basis for regression-based traffic state estimation, following the broader role of travel-time and traffic-state prediction in transport decision-support systems [8, 9]. Several machine learning algorithms are subsequently trained using the generated datasets, and their evaluation, based on relevant performance metrics, demonstrates satisfactory predictive accuracy in estimating network conditions and identifying traffic states relevant to management interventions. The results indicate that microsimulation provides a controllable and reproducible environment for generating representative traffic states that are difficult to systematically observe in real-world conditions. These findings contribute to the integration of traffic simulation, machine learning, and decision-support methods within operational ITS and centralized traffic management.

Keywords: decision-support system; network performance; microsimulation; machine learning; centralized traffic management

References

- [1] Almukhalafi, H.; Noor, A.; Noor, T. H. Traffic Management Approaches Using Machine Learning and Deep Learning Techniques: A Survey. *Engineering Applications of Artificial Intelligence* 2024, 133, 108147. doi: 10.1016/j.engappai.2024.108147
- [2] Houbraken, M.; Logghe, S.; Audenaert, P.; Colle, D.; Pickavet, M. Examining the Potential of Floating Car Data for Dynamic Traffic Management. *IET Intelligent Transport Systems* 2018, 12, 335–344. doi: 10.1049/iet-its.2016.0230
- [3] Kotsi, A.; Politis, I.; Mitsakis, E. The Impacts of Centralized Control on Mixed Traffic Network Performance: A Strategic Games Analysis. *Sustainability* 2024, 16, 6343. doi: 10.3390/su16156343
- [4] Shafiei, S.; Mihăiță, A.-S.; Nguyen, H.; Cai, C. Integrating Data-Driven and Simulation Models to Predict Traffic State Affected by Road Incidents. *Transportation Letters* 2022, 14, 629–639. doi: 10.1080/19427867.2021.1916284
- [5] Kim, Y.; Tak, H.-Y.; Kim, S.; Yeo, H. A Hybrid Approach of Traffic Simulation and Machine Learning Techniques for Enhancing Real-Time Traffic Prediction. *Transportation Research Part C: Emerging Technologies* 2024, 160, 104490. doi: 10.1016/j.trc.2024.104490
- [6] Liu, B.; Mehrara Molan, A.; Pande, A.; Howard, J.; Alexander, S.; Luo, Z. Microscopic Traffic Simulation as a Decision Support System for Road Diet and Tactical Urbanism Strategies. *Sustainability* 2021, 13, 8076. doi: 10.3390/su13148076
- [7] Bamdad Mehrabani, B.; Erdmann, J.; Sgambi, L.; Snelder, M. Proposing a Simulation-Based Dynamic System Optimal Traffic Assignment Algorithm for SUMO: An Approximation of Marginal Travel Time. *SUMO Conference Proceedings* 2022, 3, 121–143. doi: 10.52825/scp.v3i.119
- [8] Bai, M.; Lin, Y.; Ma, M.; Wang, P. Travel-Time Prediction Methods: A Review. In *Smart Computing and Communication*; Qiu, M., Ed.; Springer International Publishing: Cham, Switzerland, 2018; pp. 67–77. doi: 10.1007/978-3-030-05755-8_7
- [9] Akhtar, M.; Moridpour, S. A Review of Traffic Congestion Prediction Using Artificial Intelligence. *Journal of Advanced Transportation* 2021, 2021, 8878011. doi: 10.1155/2021/8878011

Generative Infrastructure: Redefining Sustainable Mobility through AI Urbanism

Katarina Stojanović^{1,2,*}, Andrea Ivanišević³, Slađana Milovanović³,
Ksenija Orlandić Osmajić⁴, Robert Maršanić⁵

¹ Faculty of Contemporary Arts, Belgrade, University Business Academy in Novi Sad, Serbia
E-mail: katarina.stojanovic@fsu.edu.rs

² Faculty of Economics and Engineering Management, University Business Academy in Novi Sad, Serbia
E-mail: katarina.stojanovic@fimek.edu.rs

³ Faculty of Technical Sciences Novi Sad, University of Novi Sad, Novi Sad, Serbia
E-mail: adrea.ivanisevic@gmail.com; sladjana.milovanovic@gmail.com

⁴ Faculty of Law for Commerce and Judiciary in Novi Sad, University Business Academy in Novi Sad, Serbia
E-mail: ksenija.o@pravni-fakultet.info

⁵ University North, Koprivnica, Croatia
E-mail: rmarsanic@unin.hr

Abstract

The transition from smart cities to the era of “AI urbanism” is fundamentally redefining spatial planning methodologies and urban mobility management in the 21st century [1]. This paper critically examines the paradigm of “post-smart urbanism”, focusing on the transformation brought about by large urban models [2], software agents [4], and city-scale digital twins in the context of sustainable transport [2]. From the perspective of architecture and urban morphology, the research highlights a shift from static data collection toward generative spatial configuration and dynamic geometric optimization of traffic flows [2, 5]. Particular attention is given to advanced urban simulations and 3D geometric modelling of complex urban

* Corresponding/presenting author

surfaces [5], defining them as key tools for the three-dimensional visualisation, projection, and reorganization of intermodal transport hubs. Through a comparative analysis of traditional smart mobility concepts and emerging forms of algorithmic governance [3], the author points out potential methodological and spatial pitfalls of the “autonomous city”, including the possible erosion of human creativity in spatial design and the complexities of regulating public space [1]. The paper offers an innovative conceptual framework and a new vocabulary that bridge architectural theory, advanced spatial geometric modelling, and artificial intelligence systems, providing guidelines for human-centred and morphologically sustainable planning of future urban mobility.

Keywords: AI urbanism; sustainable mobility; spatial-geometric modelling; city-scale digital twins; urban morphology

References

- [1] Cugurullo, F., Caprotti, F., Cook, M., Karvonen, A., McGuirk, P., Marvin, S., 2024. The rise of AI urbanism in post-smart cities: A critical commentary on urban artificial intelligence. *Urban Studies*, 61(6), 1168-1182
- [2] Huang, J., Elias Bibri, S., Keel, P., 2025. Generative spatial artificial intelligence for sustainable smart cities: A pioneering large flow model for urban digital twin. *Environmental Science and Ecotechnology*, Volume 24, 100526
- [3] Lartey, D., Law, K., 2025. Artificial intelligence adoption in urban planning governance: A systematic review of advancements in decision-making, and policy making. *Landscape and Urban Planning*. 258. 10.1016/j.landurbplan.2025.105337
- [4] Tiwari, A., 2025. Beyond Automation: The Emergence of Agentic Urban AI. *Automation*, 6(3), 29. <https://doi.org/10.3390/automation6030029>
- [5] Milovanović, S., Cvitković, I., Stojanović, K., Mustapić, M., 2026. Artificial Intelligence and Spatial Optimization: Evaluation of the Economic and Social Value of UGS in Vračar (Belgrade). *Sustainability*, 18(2), 745. <https://doi.org/10.3390/su18020745>

Operational and Environmental Inefficiency in Air Transport: A By-Production Approach with Tourism Dependence

Aythami Santana-Padrón^{1,*}, Lorenzo Masiero²,
Matias Manuel González Hernández¹, Javier de León¹

¹ Research Institute for Tourism and Economic Sustainable Development (TIDES), University of Las Palmas de Gran Canaria, Las Palmas, Spain

E-mail: aythami.santana@ulpgc.es; matiasmanuel.gonzalez@ulpgc.es; javier.leon@ulpgc.es

² Department of Economics, University of Bologna, Rimini, Italy

E-mail: lorenzo.masiero@unibo.it

Abstract

Aviation occupies a paradoxical position in decarbonisation policy: absolute emissions continue to grow despite sustained operational efficiency gains. Existing regulatory instruments — the EU ETS, ICAO's Carbon Intensity Indicator, and national benchmarking frameworks — implicitly assume that improvements in operational efficiency are aligned with improvements in environmental performance. This paper provides the first direct empirical test of that assumption at the national system level and finds that the assumption does not hold. We estimate a by-production stochastic frontier model [1] for 32 European countries over the period 2015–2022, recovering separately identified operational and environmental efficiency scores. Unlike deterministic approaches, the stochastic frontier decomposition separates genuine structural underperformance from random noise, a precondition for valid policy inference. A copula function links the joint distribution of the two

* Corresponding/presenting author

inefficiency terms [2], allowing the direction and strength of their co-movement to be estimated from the data rather than fixed by assumption. Three main findings emerge. First, the two dimensions are in persistent structural tension: aviation systems performing closer to the operational efficiency frontier tend to perform less favourably relative to the environmental frontier. Second, this trade-off is significantly attenuated in tourism-dependent economies, implying that uniform carbon pricing generates structurally heterogeneous outcomes. Third, COVID-19 reveals an asymmetric adjustment dynamic: environmental inefficiency expanded further and recovered more slowly than operational, reflecting longer capital commitment horizons in fleet and network decisions. These results imply that effective aviation decarbonisation requires instruments that separately target each efficiency dimension, calibrated to their structural relationship rather than assuming it away.

Keywords: aviation efficiency; environmental efficiency; by-production; EU ETS; tourism dependence; decarbonisation policy

References

- [1] Murty, S., Robert Russell, R. and Levkoff, S.B., 2012. 'On modeling pollution-generating technologies', *Journal of Environmental Economics and Management*, 64(1), pp. 117–135. doi:10.1016/j.jeem.2012.02.005.
- [2] Skevas, I., 2025. 'Technical and environmental inefficiency measurement in agriculture using a flexible by-production stochastic frontier model', *Journal of Agricultural Economics*, 76(1), pp. 164–181. doi:10.1111/1477-9552.12619.

Beyond Frontiers: A Symmetric Dual-Method Framework for Technical and Environmental Efficiency in European Aviation

Carmelo J. León¹, Aythami Santana-Padrón^{1,2,*}, Javier de León¹

¹ University Institute for Tourism and Sustainable Economic Development (TiDES), University of Las Palmas de Gran Canaria, Las Palmas, Spain

E-mail: carmelo.leon@ulpgc.es; javier.leon@ulpgc.es

² ECOMAR Group, PORMAR Chair, University of Las Palmas de Gran Canaria, Campus de Tafira, Las Palmas de Gran Canaria, Spain

E-mail: aythami.santana@ulpgc.es

Abstract

Aviation was the only EU ETS sector to significantly exceed its 2022 emissions target, with emissions increasing by 11% while other regulated industries achieved substantial reductions [1]. However, the EU ETS applies a uniform carbon price that does not distinguish between structurally constrained airlines – ageing fleets, legacy networks – and genuinely underperforming operators, a distinction that is critical for instrument design. Research indicates that the EU ETS only works when the premium mechanism accounts for airline heterogeneity [2], and that structurally constrained operators require alignment with fleet renewal incentives and ReFuelEU Aviation SAF mandates (European Commission, 2023) rather than price signals alone. Existing eco-efficiency approaches based on DEA or single-equation SFA cannot jointly characterise productive and environmental performance or formally test their co-movement. To address this limitation, we propose a Symmetric Dual-Method Efficiency Framework (SDEF) which estimates four scores for each airline:

* Corresponding/presenting author

Technical Efficiency using SFA and XGBoost quantile regression ($\tau = 0.95$) on the productive frontier, and Environmental Efficiency using both methods on the emissions frontier. The SFA model follows a by-production specification with Correlated Random Effects, while XGBoost incorporates SHAP decomposition for interpretability. The four scores are integrated through a copula system using Sklar's theorem [3], enabling three targeted dependence tests: structural co-inefficiency (SFA–SFA), potential co-inefficiency (XGBoost–XGBoost), and parametric-vs-machine-learning gaps within each dimension. The empirical application covers European airlines over 2013 to 2023, combining EU ETS verified CO₂ data with ICAO output and fleet-level inputs. The resulting taxonomy distinguishing structurally constrained operators – requiring fleet renewal and SAF incentives – from operationally underperforming ones amenable to slot and route management, as well as doubly underperforming airlines requiring a combination of interventions.

Keywords: stochastic frontier analysis; XGBoost; copula; environmental efficiency; EU ETS; aviation decarbonisation

References

- [1] Transport & Environment. 2024. *Above the clouds: European aviation emissions in 2023*. Transport & Environment Briefing, April 2024. <https://www.transportenvironment.org>
- [2] Cui, Q., Li, Y., Wei, Y.-M., & Li, R. 2023. The EU emissions trading system and airline low-carbon transition: A game-theoretic approach. *Journal of Air Transport Management*, 109, 102393. <https://doi.org/10.1016/j.jairtraman.2023.102393>
- [3] European Union. 2023. Regulation (EU) 2023/2405 of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation). *Official Journal of the European Union*, L 2023/2405.

ESG Reporting as a Driver of Green Logistics: A Systematic Literature Review

Ivana Martinčević*, Ana Globočnik Žunac, Ivona Huđek Kanižaj

University North, Croatia

E-mail: ivana.martincevic@unin.hr; ana.globocnik.zunac@unin.hr; ihudek@unin.hr

Abstract

The growing emphasis on sustainable business practices has positioned green logistics as a strategic priority for organisations seeking to reduce their environmental impact while maintaining operational efficiency. Sustainability reporting practices in the logistics sector are still evolving, while academic literature remains relatively limited, particularly regarding social sustainability indicators and global perspectives [1]. Despite growing interest in environmental, social, and governance (ESG) reporting, research gaps remain concerning the motivations, practices, and consequences of ESG disclosures from a supply chain management perspective [2]. At the same time, green logistics has attracted increasing research attention due to the need to reduce the environmental impacts of transportation activities and improve supply chain efficiency [3]. Previous studies indicate that green logistics performance is positively associated with sustainability reporting [4]. This paper examines the relationship between ESG and sustainability reporting and green logistics through a systematic literature review. The study investigates how sustainability reporting can support green logistics initiatives and sustainable supply chains. Furthermore, it discusses the role of ESG reporting in enhancing stakeholder transparency, regulatory compliance, and strategic decision-making. The findings

* Corresponding/presenting author

highlight ESG reporting as more than a disclosure mechanism, positioning it as a potential driver of green logistics practices and sustainable business transformation. The study identifies research gaps and proposes directions for future research on the integration of ESG and sustainability reporting into logistics management.

Keywords: ESG reporting; green logistics; sustainable supply chains; sustainability reporting

References

- [1] Lambrechts, W., Son-Turan, S., Reis, L., Semeijn, J., 2019. Lean, Green and Clean? Sustainability Reporting in the Logistics Sector. *Logistics*, 3(1), 3.
- [2] Yan, F., Chen, L., & Jia, J. (2024). Environmental, social, and governance disclosure in supply chains: a systematic literature review. *Production Planning and Control*. Advance online publication. <https://doi.org/10.1080/09537287.2024.2434147>
- [3] Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., Chen, Z., 2020. A Systematic Literature Review of Green and Sustainable Logistics: Bibliometric Analysis, Research Trend and Knowledge Taxonomy. *International Journal of Environmental Research and Public Health*, 17(1), 261. <https://doi.org/10.3390/ijerph17010261>
- [4] Karaman, A. S., Kilic, M., Uyar, A., 2020. Green logistics performance and sustainability reporting practices of the logistics sector: The moderating effect of corporate governance. *Journal of Cleaner Production*, 258, 120718. <https://doi.org/10.1016/j.jclepro.2020.120718>

Gender and Age Differences in Citizens' Perceptions of Sustainable Urban Logistics and Quality of Life

Karlo Knežević, Vesna Sesar*

University North, Croatia

E- mail: kaknezevic@unin.hr; vesna.sesar@unin.hr

Abstract

The development of sustainable urban logistics represents one of the key challenges faced by modern cities due to the need to reduce the negative impacts of delivery traffic on citizens' quality of life. Recent research highlights the importance of sustainable last-mile delivery solutions, including parcel lockers, cargo bikes, and other environmentally friendly delivery concepts, in improving urban sustainability while maintaining consumer satisfaction [2–4]. The aim of this paper is to examine citizens' perceptions of the impact of sustainable logistics solutions on quality of life and to determine whether there are differences in attitudes according to respondents' gender and age. The study was conducted using an online survey among residents of the Koprivnica city. The paper analyses responses related to the perceived impact of parcel lockers, urban logistics hubs, electric delivery vehicles, and other sustainable delivery solutions on reducing traffic congestion, noise levels, improving road safety, and enhancing overall quality of life. In addition, the study examines citizens' level of support for the implementation of sustainable urban logistics measures, including their willingness to accept changes in parcel collection methods. Previous studies have shown that consumer attitudes and behavioural

* Corresponding/presenting author

intentions, particularly regarding parcel lockers and alternative delivery options, play an important role in the successful implementation of sustainable last-mile logistics solutions [1, 3]. The collected data will be analysed using descriptive statistical methods, while differences in perceptions between male and female respondents and among different age groups will be examined using appropriate non-parametric statistical tests. The results are expected to indicate a high level of public support for sustainable logistics solutions, as well as differences in perceptions according to respondents' gender and age. The findings may contribute to a better understanding of citizens' attitudes towards sustainable urban logistics and provide a basis for planning and implementing measures aimed at reducing the negative impacts of delivery traffic and improving the quality of life in local communities.

Keywords: sustainable urban logistics; quality of life; citizens' perceptions; sustainable delivery; gender; age

References

- [1] Simović, S., Ivanišević, T., & Trifunović, A., 2026. Analysis of User Attitudes and Behavior in the Context of Traditional Delivery and the Use of Parcel Lockers. *Logistics*, 10(4), 90.
- [2] Huang, H., Zhang, X., Corrente, S., Siraj, S., & Kiba-Janiak, M., 2024. Facilitating sustainable logistics policy development using multicriteria satisfaction analysis: a case of preference mapping for cargo bike last-mile delivery. In *Strengthening European mobility policy: Governance recommendations from innovative interdisciplinary collaborations* (pp. 129-144). Cham: Springer Nature Switzerland.
- [3] Rose, W. J., Confente, I., Peinkofer, S. T., & Russo, I., 2025. Activating the Consumer: Toward More Sustainable Last-Mile Delivery. *Journal of Business Logistics*, 46(4), e70041.
- [4] Gatta, V., Marcucci, E., Nigro, M., & Serafini, S., 2019. Sustainable urban freight transport adopting public transport-based crowdshipping for B2C deliveries. *European Transport Research Review*, 11(1), 1-14.







Analysis of Pedestrian Behaviour in Relation to Traffic Infrastructure around University North in Varaždin: A Case Study of Vinka Međerala Street

Sara Kučiš*, Nives Domjan Kačarević

University North, Department of Logistics and Sustainable Mobility, Croatia
E-mail: sakucis@unin.hr; nidomjan@unin.hr

Abstract

Pedestrian safety is a fundamental component of sustainable urban mobility, particularly in areas characterised by intensive interactions between pedestrians and motor vehicle traffic [1]. University campuses represent complex urban environments in which pedestrian movement does not always correspond to planned infrastructure, often resulting in informal crossing behaviour and increased conflict risk [2]. This paper analyses pedestrian behaviour in relation to the existing traffic infrastructure surrounding University North in Varaždin, Croatia, with particular focus on Vinka Međerala Street. The research aims to explore the relationship between pedestrian movement patterns and the current transport infrastructure, identify infrastructure-related safety deficiencies, and propose measures to support safer and more sustainable mobility within the university area. The study is based on field research comprising an assessment of the existing traffic infrastructure, five days of traffic counts conducted during morning and afternoon peak periods, systematic observation of pedestrian movement, and a questionnaire survey involving students and other users of the study area. The findings reveal that

* Corresponding/presenting author

pedestrian movement is strongly influenced by the spatial distribution of university buildings, commercial facilities, and public amenities located near the campus. Consequently, many pedestrians choose the shortest walking routes, which do not always coincide with designated pedestrian facilities, thereby creating potential conflict points between pedestrians and motor vehicles. The field investigation also identified deficiencies in pedestrian connectivity, the positioning of pedestrian crossings, and the overall organisation of traffic, indicating the need for infrastructure improvements that better reflect actual user behaviour. The results highlight the importance of incorporating observed pedestrian movement patterns into transport planning and infrastructure design. The proposed measures provide practical guidance for improving pedestrian safety and accessibility in university environments and may also serve as a basis for developing sustainable mobility solutions in other urban areas with similar spatial and traffic characteristics [3, 4].

Keywords: pedestrian behaviour; pedestrian safety; traffic infrastructure; university area; sustainable mobility; traffic survey

References

- [1] Makarova, I., Gubacheva, L., Gabsalikhova, L., Mavrin, V., Boyko, A., 2025. Developing Intelligent Integrated Solutions to Improve Pedestrian Safety for Sustainable Urban Mobility. *Sustainability* 17(19), 8847. Available online: <https://doi.org/10.3390/su17198847>, accessed 1 July 2026.
- [2] Pollack, K.M., Gielen, A.C., Ismail, M.N.M., Mitzner, M., Wu, M., Links, J.M., 2014. Investigating and Improving Pedestrian Safety in an Urban Environment. *Injury Epidemiology* 1(11). Available online: <https://injepijournal.biomedcentral.com/articles/10.1186/2197-1714-1-11>, accessed 1 July 2026.
- [3] Budzynski, M., Gobis, A., Guminska, L., Jelinski, Ł., Kiec, M., Tomczuk, P., 2021. Assessment of the Influence of Road Infrastructure Parameters on the Behaviour of Drivers and Pedestrians in Pedestrian Crossing Areas. *Energies* 14(12), 3559. Available online: <https://doi.org/10.3390/en14123559>, accessed 1 July 2026.
- [4] Sharma, S.N., Dehalwar, K., 2025. A Systematic Literature Review of Pedestrian Safety in Urban Transport Systems. *Journal of Road Safety* 36(4), 55-78. Available online: <https://doi.org/10.33492/JRS-D-25-4-2707507>, accessed 1 July 2026.

Analysis of Pedestrian Desire Lines in Relation to Traffic Infrastructure in the University North Campus Area: A Case Study of Peteranska Road, Koprivnica

Mihaela Niković*, Petra Bedeković, Marina Premužak,
Nives Domjan Kačarević

University North, Department of Logistics and Sustainable Mobility, Croatia

E-mail: minikovic@unin.hr; pebedekovic@unin.hr; mapremuzak@unin.hr; nidomjan@unin.hr

Abstract

Pedestrians do not always use designated crossing facilities when these deviate from their preferred walking routes. Instead, they often select the shortest and most direct paths, commonly referred to as *desire lines*, despite the associated safety risks [1]. Previous studies have shown that pedestrian route choice is influenced by surrounding land use, the location of trip generators and the design of the transport environment [2]. This study investigates pedestrian desire lines in the University North campus area in Koprivnica, Croatia, focusing on Peteranska Road. The objective was to examine whether the existing pedestrian crossing corresponds to actual pedestrian movement patterns and to assess the implications of the observed behaviour for traffic safety. Previous research has highlighted the value of combining field observations with user surveys to provide evidence for improving pedestrian infrastructure and supporting safer mobility [3, 4].

* Corresponding/presenting author

The research combined an assessment of the existing traffic infrastructure, five-day traffic counts, systematic observations of pedestrian crossing behaviour, and a questionnaire survey among students and other users of the study area. The results indicate that many pedestrians avoid the designated pedestrian crossing and instead follow informal routes that provide more direct access to key trip generators located opposite the university campus. This mismatch between the existing infrastructure and actual pedestrian movement patterns creates unnecessary conflict points between pedestrians and motor vehicles and reduces the effectiveness of the current crossing arrangement. The study also identified opportunities to improve pedestrian accessibility by adapting crossing facilities to actual movement patterns. The findings highlight the importance of integrating pedestrian desire lines into the planning and design of traffic infrastructure. Aligning pedestrian crossings with observed movement patterns can improve pedestrian safety, encourage the use of designated crossing facilities and contribute to more sustainable mobility planning in university environments and other urban areas with similar characteristics.

Keywords: pedestrian desire lines; pedestrian safety; traffic infrastructure; sustainable mobility

References

- [1] Irannezhad, E., Yazdani, M., Rashidi, H.T., Furnell, A., 2023. How Our Decision-Making Process Impacts Our Street Crossing Habits: Exploring the Factors Behind Use of Desire Lines. Australasian Transport Research Forum (ATRF) 2023 Proceedings. Available online: https://australasiantransportresearchforum.org.au/wpcontent/uploads/2022/05/ATRF_2023_Paper_89.pdf, accessed 1 July 2026.
- [2] Yazdani, M., Irannezhad, E., Rashidi, H.T., 2023. Desire Lines User Behaviour Research: Initial Scoping and Feasibility. Project No. 3-027, iMOVE Cooperative Research Centre, Melbourne, Australia. Available online: <https://imoveaustralia.com/wp-content/uploads/2025/10/Desire-Lines-User-Behaviour-Research-Initial-Scoping-and-Feasibility.pdf>, accessed 1 July 2026.
- [3] Makarova, I., Gubacheva, L., Gabsalikhova, L., Mavrin, V., Boyko, A., 2025. Developing Intelligent Integrated Solutions to Improve Pedestrian Safety for Sustainable Urban Mobility. Sustainability 17(19), 8847. Available online: <https://doi.org/10.3390/su17198847>, accessed 1 July 2026.
- [4] Budzynski, M., Gobis, A., Guminska, L., Jelinski, Ł., Kiec, M., Tomczuk, P., 2021. Assessment of the Influence of Road Infrastructure Parameters on the Behaviour of Drivers and Pedestrians in Pedestrian Crossing Areas. Energies 14(12), 3559. Available online: <https://doi.org/10.3390/en14123559>, accessed 1 July 2026.

Sustainable Mobility in the Railway Sector

Helena Luketić^{1,*}, Luka Novačko², Borna Abramović²

¹ HŽ Passenger Transport Ltd, Croatia
E-mail: helena.luketic@hzpp.hr

² University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia
E-mail: luka.novacko@fpz.unizg.hr; borna.abramovic@fpz.unizg.hr

Abstract

This research compares several studies on the environmental impact of the railway sector, with particular emphasis on night-train operations. It examines the economic challenges associated with their operation, including high fixed and operating costs and competition from more carbon-intensive transport modes such as aviation and road travel. Although night trains offer clear environmental advantages, their long-term viability remains constrained in the absence of stronger policy support, structural reforms, and public investment. Transport is a carbon-intensive sector and a major contributor to global greenhouse gas (GHG) emissions. Air travel alone accounts for approximately 3.5% of the anthropogenic impact on the global climate [1], while the transport sector as a whole is responsible for approximately 25–30% of energy-related GHG emissions and represents a major source of noise and air pollution in urban areas [2]. Road transport is a particularly significant contributor to global climate change and local air-quality deterioration, accounting for more than 70% of transport-related GHG emissions in the EU [3]. Recent attention has been given to the potential for shifting travel demand to trains, either through high-speed or night trains, to reduce the carbon footprint of long-distance travel [4]. The European Commission designated 2021 as the European Year of Rail, with the aim of

* Corresponding/presenting author

promoting rail transport across Europe, and supporting, among other developments, a revival of night-train services [5]. By choosing international train services instead of short-haul flights, travellers can reduce their carbon footprint by more than tenfold, with trains emitting an average of 25 g of CO₂ equivalent per passenger-kilometre compared to 263 g for air travel [6]. Rail can produce green energy, considering that European rail is already largely “green” with approximately 81% of train-kilometres in the EU powered by electricity [7], and many national operators (such as those in Sweden, Austria, and the Netherlands) use 100% renewable energy or emission-free hydropower to operate their fleets [8, 9]. Night trains may also contribute to the development of sustainable tourism, an economically important sector in many national economies [10]. Overall, night trains represent a viable and sustainable mode of transport, once the economic challenges are addressed.

Keywords: environment; railway; sustainability; emission reduction; night trains

Acknowledgements: Project PhDs EU-Rail (Grant number: 101175856). Funded by the European Union, Europe’s Rail Joint Undertaking. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Europe’s Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.

References

- [1] Ran M., Baohua M., Qi X, Tong Z., Min W., 2018. Analysis of Demand for Sunset-departure and Sunrise-arrival Trains on High-speed Rails Based on Generalized Cost. 3rd IEEE International Conference on Intelligent Transportation Engineering (ICITE), Singapore, 2018, pp. 85-90, doi: 10.1109/ICITE.2018.8492557
- [2] EEA. 2026. Transport and mobility. European Environment Agency. Retrieved from <https://www.eea.europa.eu/en/topics/in-depth/transport-and-mobility>
- [3] Erçetin M.A. 2026. Influence of highway transportation on environment: A state of art. Environmental Research & Technology vol. 9 (2). Retrieved from <https://orcid.org/0000-0001-7583-0832>
- [4] EEA. 2021. Transport and Environment Report 2020: Train or Plane? European Environment Agency, Copenhagen. Retrieved from <https://www.eea.europa.eu/en/analysis/publications/transport-and-environment-report-2020>
- [5] European Commission. 2021. Action Plan to boost passenger rail - Mobility and Transport. Retrieved from eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=COM:2021:810:FIN&from=EN
- [6] Gerosa T., Cellina F. 2024. Who uses night trains and why? A mixed-method study profiling night train. Travel Behaviour and Society vol. 37, 100854. doi:10.1016/j.tbs.2024.100854
- [7] European Commission. 2021. Action Plan to boost passenger rail - Mobility and Transport. Retrieved from eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=COM:2021:810:FIN&from=EN

- [8] Kortekas K. 2024. An Overview of Sustainability-Related Strengths and Weaknesses of Night Trains in Europe. *Global Journal of Tourism, Leisure and Hospitality Management* vol. 1 (1). doi:10.19080/GJTLH.2023.01.555555
- [9] European Commission. 2021a. New transport proposals target greater efficiency and more sustainable travel. Retrieved from https://transport.ec.europa.eu/news/efficient-and-green-mobility-2021-12-14_en
- [10] Curtale R., Larsson J., Nassen J. 2023. Understanding preferences for night trains and their potential to replace flights in Europe. The case of Sweden. *Tourism Management Perspectives* vol. 47, 101115. Retrieved from www.elsevier.com/locate/tmp

Last-Mile Delivery Solutions for Sustainable Urban Logistics

Šimun Šabijan*, Saša Petar

University North, Department of Logistics and Sustainable Mobility, Croatia
E-mail: sisabijan@unin.hr; spetar@unin.hr

Abstract

The rapid growth of e-commerce, rising customer expectations, and increasing pressure to decarbonise urban freight transport have made last-mile delivery one of the most challenging segments of logistics systems. Traditional delivery models, largely based on dispersed home deliveries and conventional vehicle fleets, contribute to traffic congestion, greenhouse gas emissions, failed delivery attempts, and inefficient use of urban space. In response, last-mile delivery solutions have emerged as an important pathway towards more sustainable urban logistics [1]. Last-mile delivery solutions improve the environmental and operational performance of urban logistics systems. Particular attention is given to parcel lockers, urban micro-hubs, cargo bikes, electric delivery vehicles, and digital route optimisation tools [1, 2]. The last-mile solutions can significantly improve urban freight operations by reducing vehicle kilometres travelled, delivery-related emissions, and the number of failed deliveries, while also increasing flexibility and spatial efficiency. Parcel lockers and micro-hubs appear particularly relevant for dense urban environments, where delivery consolidation and alternative delivery modes can reduce pressure on city-centre transport systems. At the same time, cargo bikes, electric vehicles, and data-driven routing solutions contribute to lower emission and more adaptive delivery networks. However, their effectiveness depends on urban context,

* Corresponding/presenting author

infrastructure availability, regulatory support, and consumer acceptance [3]. The paper contributes to the growing discussion on sustainable urban logistics by providing a synthesised overview of last-mile delivery models and their relevance for the transition towards more resilient, low-emission, and service-oriented urban freight systems [4].

Keywords: last-mile delivery; urban logistics; sustainable freight transport; parcel lockers; micro-hubs; cargo bikes; route optimisation

References

- [1] Grant, D.B., Trautrim, A., Wong, C.Y., 2017. *Sustainable Logistics and Supply Chain Management: Principles and Practices for Sustainable Operations and Management*. 2nd ed. London: Kogan Page. Available online: https://moodle.srce.hr/20252026/pluginfile.php/12554899/mod_resource/content/1/Sustainable-Logistics-and-Supply-Chain-Management_-Principles-and-Practices-for-Sustainable-Operations-and-Management.pdf, accessed 18 July 2026.
- [2] Taniguchi, E., Thompson, R.G., 2014. *City Logistics: Mapping the Future*. CRC Press, Boca Raton, Available online: https://api.pageplace.de/preview/DT0400.9781482208924_A24097439/preview-9781482208924_A24097439.pdf?utm, accessed 18 July 2026.
- [3] Silva, V., Amaral, A., & Fontes, T., 2023. *Sustainable urban last-mile logistics: A systematic literature review*. *Sustainability*. Available online: <https://doi.org/10.3390/su15032285>, accessed 19 July 2026.
- [4] Bertolini, M., De Matteis, G., Nava, A., 2024. *Sustainable last-mile logistics in economics studies: A systematic literature review*. Available online: <https://doi.org/10.3390/su16031205>, accessed 20 July 2026.

Simulation-Based Evaluation of Urban Freight Delivery Flows: A Case Study of Rijeka, Croatia

Luka Liker*, Mladen Jardas, Ana Perić Hadžić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: luka.likier@pfri.uniri.hr; mladen.jardas@pfri.uniri.hr; ana.peric@pfri.uniri.hr

Abstract

Urban freight transport significantly influences traffic conditions, environmental sustainability, and the overall quality of life in city centres. Growing demand for goods distribution in urban areas has intensified the need for efficient delivery management and evidence-based planning tools. Microsimulation has emerged as a valuable methodology for analysing complex traffic systems because it enables the detailed representation of vehicle interactions and the evaluation of alternative logistics scenarios under realistic operating conditions [1]. This study investigates the application of traffic microsimulation to the assessment and optimisation of urban freight delivery flows [2] within the city centre of Rijeka, Croatia. The research was conducted using the PTV VISSIM microsimulation platform. Input data were obtained from traffic counts provided by Rijeka Promet d.d. and from surveys completed by freight carriers and business operators. Key parameters included delivery locations, delivery frequency, vehicle types, travel times, the duration of loading and unloading activities and the share of freight vehicles within total traffic flows [3]. The developed model was calibrated and validated using the Geoffrey E. Havers (GEH) statistical method, with GEH values remaining below the recommended threshold for more than 90% of observed traffic flows [4]. Four delivery scenarios were analysed: [1] the existing delivery system (status quo), [2] goods

* Corresponding/presenting author

delivery from a single urban consolidation centre located at the D404 entrance to the city centre, [3] delivery from two urban consolidation centres positioned on the eastern and western approaches to the city centre, and [4] a liveability scenario in which the Riva corridor was converted into a pedestrian-oriented zone with restricted vehicle access. Each scenario was simulated using twenty replications over an eleven-hour operating period to ensure the statistical reliability of the results. The findings confirm that traffic microsimulation is an effective decision-support tool for evaluating urban freight transport policies and infrastructure measures. Furthermore, the results suggest that establishing a strategically located urban consolidation centre could improve freight distribution efficiency in Rijeka while reducing adverse environmental and traffic-related impacts. Future research should incorporate low-emission delivery vehicles, dynamic routing strategies, and real-time traffic management measures to further enhance the sustainability of urban logistics systems.

Keywords: city logistics; microsimulation; traffic optimization; urban freight transport; urban consolidation centre

References

- [1] N. Anand, H. Quak, R. van Duin, and L. Tavasszy, "City Logistics Modeling Efforts: Trends and Gaps – A Review," *Procedia - Soc. Behav. Sci.*, vol. 39, no. December, pp. 101–115, 2012, doi: 10.1016/j.sbspro.2012.03.094.
- [2] F. Figari, A. Paulus, and H. Sutherland, "Microsimulation and Policy Analysis," *Handb. Income Distrib.*, vol. 2, pp. 2141–2221, 2015, doi: 10.1016/B978-0-444-59429-7.00025-X.
- [3] Jaspers, "The Use of Transport Models in Transport Planning and Project Appraisal The Use of Transport Models in Project Appraisal", *JASPERS Apprais. Guid.*, no. August, 2014.
- [4] M. Šraml and G. Jovanović, "Mikrosimulacije u prometu (radni udžbenik s primjenom VISSIM-a)", 2014. Accessed: Sep. 22, 2020. [Online]. Available: http://www.ptv-vision.com/cgi-bin/traffic/traf_vissim.pl.

Port-City Relationships in the Context of Sustainable Development

Bor Petrovčič*, Elen Twrdy

University of Ljubljana, Faculty of Maritime Studies and Transport, Ljubljana, Slovenia
E-mail: bor.petrovcic@fpp.uni-lj.si; elen.twrdy@fpp.uni-lj.si

Abstract

Historically, ports and cities evolved as closely connected systems, but industrialization and containerization led to their growing spatial and functional separation. More recently, this relationship has shifted toward reintegration through digitalization, sustainable development, and collaborative governance, transforming ports from predominantly logistical facilities into multifunctional urban hubs that must balance economic growth, environmental sustainability, and community well-being [1–3]. This study conducts a literature review of port-city relationships based on the PRISMA 2020 framework [4], focusing on scientific papers published between 2020 and 2025. After screening for relevance and accessibility, 29 papers were selected. VOSviewer was used to identify key research themes, and the literature was classified into five categories: physical-spatial, infrastructure-support, economic, management-social, and environmental. The findings indicate increasing methodological diversification in port-city research, combining traditional quantitative approaches with qualitative and mixed-methods analyses that explore governance, stakeholder relations, and community values. Research is predominantly concentrated in Europe and China, while emerging studies increasingly address the distinct challenges of developing countries. The literature is dominated by management-social themes, followed by infrastructure-support and economic issues, whereas

* Corresponding/presenting author

environmental and physical-spatial dimensions are increasingly incorporated through concepts such as the port cityscape and green port development. At the same time, the literature reveals a persistent tension between global demands for efficiency and throughput, and local demands for environmental quality and urban liveability. This study demonstrates a fundamental shift in the understanding of port-city relationships, from viewing ports as isolated logistics facilities to recognizing them as integral components of a broader port cityscape shaped by economic, social, and environmental interactions. A key finding is the growing importance of governance, stakeholder engagement, and the “social license to operate”, with community trust, procedural fairness, and quality of life increasingly regarded as prerequisites for sustainable port development. The review also identifies a lack of a comprehensive assessment framework for evaluating sustainability in port-city systems. Existing studies tend to research economic, environmental, and social dimensions independently, limiting comparability and hindering a holistic understanding of sustainable port-city development. Addressing this gap represents an important direction for future research and decision support in sustainable port planning. Ultimately, modern port cities are evolving toward a more balanced and inclusive model in which long-term success depends not only on cargo volumes but also on their capacity to reconcile economic growth with environmental and social objectives.

Keywords: port-city relationship; sustainable port development; green port; port integration

References

- [1] C. Hein, 'Port City Porosity: Boundaries, Flows, and Territories', *Urban Plan.*, vol. 6, no. 3, pp. 1–9, Jul. 2021, doi: 10.17645/up.v6i3.4663.
- [2] F. Russo and G. Musolino, 'Port-city interactions: models and case studies', in *Transportation Research Procedia*, 2023. doi: 10.1016/j.trpro.2023.02.225.
- [3] J. Wang, H. Wang, and F. Tan, 'Coordinated Port–Industry–City Development from a Green Port Perspective: An Empirical Study of Shanghai Port', *Sustainability*, vol. 17, no. 17, p. 7747, Jan. 2025, doi: 10.3390/su17177747.
- [4] M. J. Page et al., 'The PRISMA 2020 statement: an updated guideline for reporting systematic reviews', *BMJ*, p. n71, Mar. 2021, doi: 10.1136/bmj.n71.

Legal and Economic Comparison of Charterparty Agreements and Contracts for the Carriage of Individual Consignments with Particular Reference to Seaports

Eva Mlinar Mikuličić¹*, Alen Jugović², Siniša Rajačić³, Juraj Bukša⁴

¹ Institute of Agriculture and Tourism, Croatia
E-mail: eva@iptpo.hr

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: alen.jugovic@pfri.uniri.hr

³ Primorsko-Goranska County, Rijeka, Croatia
E-mail: Sinisa.Rajacic@pgz.hr

⁴ ACI d.d., Croatia
E-mail: j_buksa@yahoo.com

Abstract

Maritime shipping constitutes a global industry and remains the most economically efficient mode of transporting the majority of goods in international trade [1]. The movement of cargo by sea is primarily conducted through contracts of carriage, which enable the performance of international sales contracts by ensuring that sellers fulfil their obligation to deliver goods to buyers [2]. The effective functioning of this system depends on a coherent legal framework that regulates the rights and obligations arising from maritime transport while supporting legal certainty, commercial predictability, and operational efficiency [3]. This paper examines charterparty agreements and contracts for the carriage of individual consignments, representing the two principal contractual arrangements governing the maritime

* Corresponding/presenting author

transport of goods [4]. Through an integrated legal and economic approach, the paper investigates the distinguishing characteristics of these contractual models and evaluates their contribution to the development of maritime law and the efficiency of maritime transport systems [5]. Particular emphasis is placed on their implications for seaport organization and development, port operational efficiency, logistics management, and the ability of port infrastructure to respond to the evolving requirements of global supply chains and intermodal transport [6]. Rather than treating these contracts exclusively as legal instruments, the paper examines them as complex legal and economic mechanisms that influence the operational performance and strategic development of the port sector [7]. Their legal structure directly affects cargo flow organization, utilization of port facilities, and the competitiveness of seaports within international maritime markets [8]. By developing a comparative analytical framework for evaluating the legal and functional characteristics of these contractual models, the research contributes to a deeper understanding of their practical application in relation to different cargo categories, transport organization methods, and the requirements of contemporary logistics networks. The findings highlight the importance of integrating legal, economic, and operational perspectives in strengthening the efficiency, resilience, and sustainability of maritime transport systems and supporting the long-term development strategies of seaports.

Keywords: maritime transport; charterparty agreements; contracts of carriage; seaports; port logistics; sustainable transport

References

- [1] Jugović, A., Komadina, N., Perić Hadžić, A., "Factors Influencing the Formation of Freight Rates on Maritime Shipping Markets", *Multidisciplinary Scientific Journal of Maritime Research*, Vol. 29, 2015, p. 23.
- [2] Pavić, D., *Pomorsko imovinsko pravo*, Književni krug Split, Split, 2006.
- [3] *Pomorski zakonik*, NN 181/04, 76/06, 146/08, 61/11, 56/13, 26/15, 17/19
- [4] Plomaritou, E., "A Review of Shipowner's & Charterer's Obligations in Various Types of Charter", *Journal of Shipping and Ocean Engineering*, Vol. 4, 2014.
- [5] Grabovac, I., *Teretnica i prijevoz robe morem*, Rijeka, 2015.
- [6] Notteboom, T., Rodrigue, J.-P., "The Future of Containerization: Perspectives from Maritime and Inland Freight Distribution", *GeoJournal*, Vol. 74, No. 1, 2009, pp. 7–22.
- [7] Stopford, M., *Maritime Economics*, 4th ed., London: Routledge, 2009.
- [8] Notteboom, T., Pallis, A. A., Rodrigue, J.-P., *Port Economics, Management and Policy*, 2nd ed., New York: Routledge, 2022.

Nuclear Propulsion for Maritime Decarbonization: Challenges and Prospects

Marko Kopic*, Radoslav Radonja

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: marko.kopic@uniri.hr; radoslav.radonja@uniri.hr

Abstract

The maritime sector faces increasing pressure to reduce greenhouse gas emissions while maintaining the operational requirements of long-distance shipping. In this context, nuclear propulsion has a potential as a long-term solution for achieving near-zero operational emissions in merchant shipping [1]. This study reviews the potential application of nuclear propulsion in commercial maritime transport, with emphasis on currently available conventional reactor technologies, such as Pressurized Water Reactors (PWRs), and selected advanced Generation IV concepts [2]. The review suggests that advanced reactor concepts offer significant advantages for long-range maritime transport through high energy density, extended refuelling intervals, and low operational emissions [3]. However, widespread implementation remains dependent on regulatory harmonization, economic viability, and public acceptance. Nuclear propulsion should therefore be regarded as a promising long-term option within the broader transition toward sustainable maritime transport rather than as a near-term replacement for conventional marine fuels [4, 5].

Keywords: maritime decarbonization; nuclear propulsion: merchant ships: Generation IV reactors; sustainable shipping

* Corresponding/presenting author

References

- [1] "IMO's work to cut GHG emissions from ships." Accessed Nov. 04, 2025. [Online]. Available: <https://www.imo.org/en/mediacentre/hottopics/pages/cutting-ghg-emissions.aspx>
- [2] J. Emblemsvåg, C. H. Ordóñez, C. Garrido Tamm, T. Strand, J. S. Ortigosa, and Y. M. Colilles, "Selecting Nuclear Reactor for Merchant Shipping," *Nucl. Technol.*, pp. 1–22, Dec. 2025, doi: 10.1080/00295450.2025.2575544.
- [3] K. E. Holbert, "A Review of Maritime Nuclear Reactor Systems," *J. Nucl. Eng.*, vol. 6, no. 1, 2025, doi: 10.3390/jne6010005.
- [4] M. Drosińska-Komor *et al.*, "Integrating fourth-generation reactors into maritime transport," *Ocean Eng.*, vol. 342, p. 122891, Dec. 2025, doi: 10.1016/j.oceaneng.2025.122891.
- [5] A. Peakman, H. Owen, and T. Abram, "The core design of a Small Modular Pressurised Water Reactor for commercial marine propulsion," *Prog. Nucl. Energy*, vol. 113, pp. 175–185, May 2019, doi: 10.1016/j.pnucene.2018.12.019.

From Regulatory Requirements to Operational Practice: The Environmental Officer's Role in Sustainable Cruise Ship Operation

Mišo Kucelj*

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: miso.kucelj@uniri.hr

Abstract

This paper explores the practical role of the environmental officer in translating regulatory requirements into effective shipboard environmental compliance [7, 10]. In the cruise industry, environmental performance is shaped not only by formal compliance frameworks such as MARPOL and ISO 14001 [10], but also by the daily realities of shipboard operations [1, 7, 13]. This requires significant effort in coordination with port authorities, vendors, and multiple onboard departments [2, 13]. Recent literature on cruise sustainability emphasizes that performance depends on operational coordination, stakeholder alignment, and the implementation of sustainability practices in complex maritime settings [3, 7, 12, 13]. Drawing on professional experience in cruise ship environmental management, the paper examines how environmental standards are implemented under challenging operational constraints [4, 5]. It focuses on tasks such as waste segregation, record verification, audit readiness, incident follow up, and data management [6, 8, 10, 15]. These responsibilities require continuous attention despite limitations in time, space, and infrastructure [5, 13, 14]. Studies of cruise environmental governance further highlight that effective control depends on traceability, practical checks, and

* Corresponding/presenting author

the capacity to manage environmental impacts consistently across different operational contexts [9, 13]. The paper argues that the environmental officer serves as a key intermediary between regulatory expectations and shipboard execution [4, 7]. Rather than functioning solely as a compliance checker, the role encompasses coordination, training, and verification of environmental management systems across departments [11]. This perspective aligns with broader research on sustainable maritime operations, which indicates that sustainability improves when operational knowledge is captured and translated into workable routines [1]. By focusing on the operational function, the paper also contributes to current discussions on sustainable cruise ship operations [4, 13].

Keywords: environmental compliance; sustainable cruise ship operation; environmental management system; port; environmental officer

References

- [1] Ahn, J., 2019. Corporate social responsibility signaling, evaluation, identification, and revisit intention among cruise customers. *Journal of Sustainable Tourism* 27, 1634–1647. doi: 10.1080/09669582.2019.1650055
- [2] Andrade, M. J., et al., 2021. Challenges for European tourist-city-ports: Strategies for a sustainable coexistence in the cruise post-COVID context. *Land* 10(11), 1269. doi: 10.3390/land10111269
- [3] Bonilla-Priego, M.J., et al., 2014. Corporate sustainability reporting index and baseline data for the cruise industry. *Tourism Management* 44, 149–160. doi: 10.1016/j.tourman.2014.03.004
- [4] Bruzzi, S., Benevolo, C., 2022. Cruisers' intention of returning to European destinations: A regression analysis. *International Journal of Tourism Research* 24(2), 311–322. doi: 10.1002/jtr.2503
- [5] Chen, J. M., et al., 2019. A meta-analysis of the direct economic impacts of cruise tourism on port communities. *Tourism Management Perspectives* 31, 209–218. doi: 10.1016/j.tmp.2019.05.005
- [6] De Grosbois, D., 2016. Corporate social responsibility reporting in the cruise tourism industry: A performance evaluation using a new institutional theory based model. *Journal of Sustainable Tourism* 24, 245–269. doi: 10.1080/09669582.2015.1076827
- [7] Hoarau-Heemstra, H., et al., 2023. Cruise tourism destinations: Practices, consequences and the road to sustainability. *Journal of Destination Marketing & Management* 30, 100820. doi: 10.1016/j.jdmm.2023.100820
- [8] James, L., et al., 2020. Sustainability and cruise tourism in the Arctic: Stakeholder perspectives from Ísafjörður, Iceland and Qaqortoq, Greenland. *Journal of Sustainable Tourism* 28(9), 1425–1441. doi: 10.1080/09669582.2020.1745213
- [9] Klein, R. A., 2011. Responsible Cruise Tourism: Issues of Cruise Tourism and Sustainability. *Journal of Hospitality and Tourism Management* 18(1), 107–116. doi: 10.1375/jhtm.18.1.107
- [10] Kulkov, I., et al., 2023. Sustainable Cruise Tourism: Systematic Literature Review and Future Research Areas. *Sustainability* 15(10), 8335. doi: 10.3390/su15108335
- [11] Paiano, A., et al., 2020. Managing sustainable practices in cruise tourism: The assessment of carbon footprint and waste of water and beverage packaging. *Tourism Management* 77, 104016. doi: 10.1016/j.tourman.2019.104016

- [12] Papathanassis, A., 2017. Cruise tourism management: State of the art. *Tourism Review* 72(1), 104–119. doi: 10.1108/TR-01-2017-0003
- [13] Ramoa, C.E.A., et al., 2018. The convergence of environmental sustainability and ocean cruises in two moments: in the academic research and corporate communication. *Revista Brasileira de Pesquisa em Turismo (RBTUR)* 12(2), 152-178. doi: 10.7784/rbtur.v12i2.1432
- [14] Stefanidaki, E., Lekakou, M., 2014. Cruise carrying capacity: A conceptual approach. *Transportation Business and Management* 13, 43–52. doi: 10.1016/j.rtbm.2014.11.005
- [15] Strazza, C., et al., 2015. Life Cycle Assessment from food to food: A case study of circular economy from cruise ships to aquaculture. *Sustainable Production and Consumption* 2, 40–51. doi: 10.1016/j.spc.2015.06.004

Environmental Pressure Associated with Blackwater at Nautical Anchorages: A Case Study of Zadar County

Tomislav Mavra^{1,*}, Antonija Mišura², Astrid Zekić¹, Ana Gundić¹

¹ University of Zadar, Maritime Department, Zadar, Croatia
E-mail: tmavra@unizd.hr; azekic22@unizd.hr; agundic@unizd.hr

² University of Split, Faculty of Maritime Studies, Split, Croatia
E-mail: amisura@pfst.hr

Abstract

Maintaining marine environmental quality and balancing tourism, maritime, and environmental interests are essential for the sustainable development of nautical tourism, a significant segment of the tourism industry [1, 2]. The growing number of vessels involved in nautical activities places increasing pressure on the marine environment, particularly in coastal areas, where the risk of pollution from sanitary blackwater is rising [3]. The extent of environmental pressure is closely related to vessel traffic intensity and the volume of blackwater generated [4]. The aim of this study was to analyse the environmental pressure of nautical anchorages, with particular emphasis on blackwater stored in vessel holding tanks. The analysis considers the availability of blackwater reception facilities at anchorages, the holding tank capacity of 14.6 m vessels, which was used to estimate the environmental pressure and corresponds to the design capacities of the analysed anchorages, as well as spatial indicators of anchorage use intensity. The study was conducted in Zadar County using a quantitative descriptive approach and spatial

* Corresponding/presenting author

analysis. Data were obtained from concession agreements, technical documentation, and waste management plans. Based on the collected data, an analytical approach was developed to link holding tank capacities with environmental pressure at anchorages. The results show that none of the analysed anchorages is equipped with a blackwater reception system. The limited holding tank capacity of smaller vessels increases the likelihood that tanks will reach full capacity during the vessel's stay at an anchorage, thereby increasing the risk of blackwater discharge into the sea. Spatial analysis also revealed uneven vessel density and varying levels of environmental pressure among anchorages, indicating an increased risk of pollution. In conclusion, the establishment of a blackwater reception system is a key prerequisite for the sustainable management of nautical anchorages. The proposed analytical approach enables the identification of locations exposed to greater environmental pressure and can support the planning of marine environmental protection measures and improvements in anchorage management.

Keywords: nautical anchorages; blackwater; environmental pressure; spatial analysis; sustainable management; marine environment

References

- [1] Luković, T., 2013. Nautical Tourism. CABI, Wallingford.
- [2] Borčić, L., Slišković, M., Jelić Mrčelić, G., 2013. Ecological Aspects of Nautical Tourism. Proceedings of the 5th International Maritime Science Conference (IMSC 2013), pp. 109–112.
- [3] Koboević, Ž., 2015. Model onečišćenja mora crnim otpadnim vodama s plovila. PhD thesis, Faculty of Maritime Studies, University of Rijeka, Rijeka.
- [4] Perić, T., 2016. Model vrednovanja onečišćenja Jadranskog mora sanitarnim otpadnim vodama s brodova za kružna putovanja. PhD thesis, Faculty of Maritime Studies, University of Rijeka, Rijeka.

Review of Emerging Sensor Fusion Technologies Integrating Electro-Optical and Advanced Radar Systems in the Maintenance of National Security

Roko Brečić^{1,*}, Tomislav Sunko^{2,**}, Toni Mišković³, Vilim Đura¹

¹ Rectory, Dr. Franjo Tuđman Defense and Security University, Zagreb, Croatia
E-mail: vilim.dura@sois-ft.hr; roko.brecic@sois-ft.hr

² Ministry of Defence of the Republic of Croatia, Croatian Defense Academy "Dr Franjo Tuđman",
Zagreb, Croatia
E-mail: tsunko@morh.hr

³ Transmitters and Communications Ltd., Zagreb, Croatia
E-mail: toni.miskovic@oiv.hr

Abstract

This paper analyzes the contemporary development and application of sensor fusion technologies that integrate electro-optical and advanced radar systems in the maintenance of national security and the support of civil institutions. In conditions characterized by evolving and increasingly complex security threats, as well as the growing need for comprehensive monitoring of maritime, terrestrial, and aerial domains, the integration of advanced technologies has become essential for the development of effective situational awareness [1]. Particular emphasis is placed on the use of electro-optical sensors in combination with advanced radar sensing technologies to enhance the precision and speed of threat detection, especially under challenging operational conditions and in environments with reduced

* Presenting author

** Corresponding author

visibility. The objective of this study is to provide an overview of the operational principles of newly developed systems and to analyze their effectiveness in improving surveillance and security infrastructures [2]. Examples of such systems include architectures based on the Internet of Things (IoT) and 5G/6G connectivity, which enable the networking of all available assets and sensors within a given operational area such as vehicles, infrastructure, unmanned aerial systems (UAS), maritime platforms, and other monitoring devices into a unified operational picture accessible to multiple services and agencies in the field [3]. These systems frequently operate on the principle of thermal signature detection, enabling efficient identification and tracking of vehicles, vessels, aircraft, and individuals for example in search and rescue (SAR) operations or border surveillance, as well as the detection of fires, smoke, and other anomalous events [4]. The study will conduct a comparative analysis of existing technological solutions and examine practical case studies related to their implementation. Furthermore, the paper will conceptually assess the potential trajectories of their future technological advancement. In conclusion, advanced sensor fusion systems represent a significant advancement in the development of integrated situational awareness and in enhancing the efficiency of responses to security threats and incidents. They also provide opportunities for strengthening the resilience of national security systems through their integration into a comprehensive information awareness and decision-support framework.

Keywords: sensor fusion; national security; integrated systems; search and rescue

References

- [1] B. Bal Şahin, Ç. B. Erdaş, and E. Sümer, 'Multi-sensor data fusion in maritime surveillance: a review on methods and applications', *PeerJ Computer Science*, vol. 12, p. e3765, Apr. 2026, doi: 10.7717/peerj-cs.3765
- [2] V. Đura, 'Detection of Low-Flying, Slow, and Small Targets in Contemporary Electromagnetic Warfare', M. S. thesis, Sveučilište obrane i sigurnosti "Dr. Franjo Tuđman", Split, 2026
- [3] C. Herglotz, I. Jabłoński, R. Karnapke, K. Shahin, and M. Reichenbach, 'Designing Intelligent Sensor Networks: A Comprehensive Survey of Sensing, Edge AI, and 5G+/6G Connectivity', *IEEE Access*, vol. 13, pp. 172306–172325, 2025, doi: 10.1109/ACCESS.2025.3615205
- [4] Transmitters and Communications Ltd, 'OIV Fire Detect AI'. Available online: <https://oiv.hr/en/services-and-platforms/oiv-fire-detect-ai/>, accessed 2 July 2026

Feasibility Assessment of UAV Delivery Logistics in the UTM/U-space Environment

Pia Biondić*, Neven Grubišić

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: piabiondic1@gmail.com; neven.grubisic@uniri.hr

Abstract

The increasing use of UAVs in delivery logistics creates the need for a structured assessment of mission feasibility in digitally managed low-altitude airspace. Large-scale low-altitude UAV operations require traffic-management support because they may involve deliveries, BVLOS missions and operations in airspace affected by static and dynamic constraints [1]. The European U-space framework defines mandatory services for UAS operations in U-space airspace, including network identification, geo-awareness, UAS flight authorisation and traffic information. It also allows weather information and conformance monitoring to become mandatory where required by the airspace risk assessment [2]. For UAV delivery missions, feasibility is affected by payload constraints, available energy autonomy and wind-dependent energy consumption [3]. Communication requirements are also part of the operational assessment because 3GPP support for UAS includes C2 communication, remote identification, route-data exchange, route modification and latency requirements [4]. This paper develops a technical-operational framework for assessing the feasibility of UAV delivery missions in the UTM/U-space environment. The framework connects aircraft range, payload requirements, energy reserve, communication reliability and U-space constraints into a structured assessment of delivery scenarios. The proposed approach distinguishes missions

* Corresponding/presenting author

that are technically feasible, operationally acceptable and logistically justified from missions limited by energy consumption, communication performance, traffic-management requirements or infrastructure constraints. The paper provides a planning-oriented basis for future evaluation of UAV delivery in rural and island areas.

Keywords: UAV delivery; UTM; U-space; delivery logistics; C2 communication; mission feasibility

References

- [1] P. Kopardekar, et al., "Unmanned Aircraft System Traffic Management Concept of Operations to Safely Enable Low Altitude Flight Operations," 16th AIAA Aviation Technology, Integration, and Operations Conference, Jun. 2016, pp. 1–2, doi: 10.2514/6.2016-3292.
- [2] European Commission, "Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space," Official Journal of the European Union, Apr. 22, 2021. , [Online]. Available: https://eur-lex.europa.eu/eli/reg_impl/2021/664/oj/eng.
- [3] F. B. Sorbelli, et al., "Energy-Constrained Delivery of Goods with Drones under Varying Wind Conditions," IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 9, pp. 1-2, Sep. 2021, doi: 10.1109/TITS.2020.3044420.
- [4] European Telecommunications Standards Institute, "5G; Uncrewed Aerial System (UAS) Support in 3GPP," ETSI TS 122 125 V17.7.0, May 2024. [Online]. Available: https://www.etsi.org/deliver/etsi_ts/122100_122199/122125/17.07.00_60/ts_122125v170700p.pdf.

With the Wind at our Backs: Implications of Wind-Assisted Propulsion Systems for Maritime Training and Navigational Safety

Domagoj Stojanović*, Igor Rudan, Davor Šakan

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: domagoj.stojanovic@student.uniri.hr; igor.rudan@pfri.uniri.hr; davor.sakan@pfri.uniri.hr

Abstract

Wind-Assisted Propulsion Systems (WAPS) are considered promising technologies for improving energy efficiency and reducing greenhouse gas emissions in line with the International Maritime Organization (IMO) decarbonisation and energy-efficiency initiatives, including the Energy Efficiency Design Index (EEDI) and the Energy Efficiency Existing Ship Index (EEXI) [1–3]. Technologies such as wing sails, rotor sails, suction sails and kite sails are emerging as commercially viable solutions [2, 3]. However, the implementation of such systems presents operational, technical and navigational challenges that are not yet specifically addressed within the existing International Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW) framework [4, 5]. This paper presents a qualitative review of relevant IMO regulations and conventions, including EEDI, EEXI, SEEMP, STCW and COLREGs [1, 4, 6], to analyse the implications of WAPS deployment for maritime training and navigational safety. It also discusses the principal WAPS technologies and their influence on ship operation and manoeuvrability [2, 10, 11] and reviews the ECDIS training scheme as a possible model for the development of future WAPS-related competencies [7, 8]. The analysis identifies essential competency

* Corresponding/presenting author

requirements for deck, engineering and electro-technical officers, including knowledge of aerodynamic principles, automated control systems, maintenance procedures and emergency response [5, 9]. Furthermore, forces generated by WAPS may affect leeway, manoeuvrability, stopping distances and collision-avoidance decisions, highlighting the need for further research on the practical application of COLREG provisions in certain operational scenarios [10, 11]. The paper proposes a role-based approach to WAPS training and supports the ongoing discussion on the safe integration of wind-assisted propulsion technologies into maritime operations, education and regulations.

Keywords: Wind-Assisted Propulsion Systems (WAPS); maritime education and training; STCW; COLREGs; ship handling

References

- [1] International Maritime Organization (IMO), 2021. 2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the Attained EEDI and EEXI (MEPC.1/Circ.896). Available online: <https://bit.ly/45elksu>, accessed 16 June 2026.
- [2] Kolodziejewski, M., Sosnowski, M., 2025. Review of Wind-Assisted Propulsion Systems in Maritime Transport. *Energies* 18(4), 897. doi: <https://doi.org/10.3390/en18040897>
- [3] Gaul, K., Rutkowski, G., 2025. Harnessing the Wind: The Rise of Wind-Assisted Ship Propulsion (WAPS) in the Transformation of Maritime Transport. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation* 19(1). doi: <https://doi.org/10.12716/1001.19.01.25>
- [4] International Maritime Organization (IMO), 2017. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), including the 2010 Manila Amendments. London: IMO.
- [5] Lamvik, G., Berg, T.E., Sylwestrzak, A., Rialland, A., 2025. Onboard Competence for Optimal Application of WAPS Systems. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation* 19(2). doi: <https://doi.org/10.12716/1001.19.02.39>
- [6] International Maritime Organization (IMO), 1972. Convention on the International Regulations for Preventing Collisions at Sea (COLREGs). London: IMO.
- [7] Brčić, D., Žuškin, S., Barić, M., 2017. Observations on ECDIS Education and Training. In: Weintrit, A. (Ed.), *Marine Navigation*. CRC Press, London, pp. 29-36. doi: <https://doi.org/10.1201/9781315099132-2>
- [8] Žuškin, S., Brčić, D., Šabalja, D.Đ., 2013. A Contribution to Improving the Standards of ECDIS Training. *Scientific Journal of Maritime Research* 27(1), 131-148. <https://hrcak.srce.hr/104192>
- [9] Rieffel, J., Corlay, L., Selosse, M., Merino-Laso, P., Ahmad, H., Sacher, M., 2025. Identifying Key Requirements for Maritime Bridge Simulators in Wind-Assisted Ship Propulsion Training. In: *OCEANS 2025 Brest*, Brest, France, pp. 1-5. doi: <https://doi.org/10.1109/OCEANS58557.2025.11104548>
- [10] Feldtmann, O.N., 2025. Challenges in Operating Wind-Assisted Propulsion Vessels. Master's Thesis, Høgskulen på Vestlandet, Norway. Available online: <https://hdl.handle.net/11250/3204951>
- [11] Werner, S., Trodden, D., Alterskjær, A., Eggers, R., Kim, Y., Gao, Y., Zhang, X. and Kume, K. (2024) 'Report of the Wind Powered and Wind Assisted Ships Committee', 30th International Towing Tank Conference (ITTC). doi: <https://www.ittc.info/media/12074/13-wind-powered-and-wind-assisted-ships.pdf>







Co-funded by
the European Union

Digital Education for Maritime Communication

Zorica Đurović

University of Montenegro, Faculty of Maritime Studies, Kotor, Montenegro
E-mail: zoricag@ucg.ac.me

Summary

The main objective of the DigiMar project is to enhance the safety of navigation, as measured by statistically significant improvements in maritime communication skills before and after the implementation of the digital pilot study among shore service operators and higher education students. The project's objectives include the development of open-access instructional videos and speech-recognition chatbots to support continuous and self-directed learning. In addition to the studies conducted and the results generated throughout the project, the development, deployment, and evaluation of these open-access digital education tools are expected to strengthen the capacity and readiness of the participating institutions to effectively manage the transition towards digital education and, ultimately, improve the safety of navigation. Based on the project results achieved through the implementation of five comprehensive work packages, specific recommendations will be submitted to the competent authorities to support potential improvements to the standard protocols for routine maritime communication.

Project partners: University of Ljubljana, The Faculty of Maritime Studies and Transport, Slovenia; University of Rijeka, Faculty of Maritime Studies, Croatia; Yrkeshögskolan vid Åbo Akademi, Finland; University of Montenegro, Faculty of

Name of the Programme: Erasmus+

Programme priority: HE: Stimulating innovative learning and teaching practices

Programme specific objectives/mission: KA220-HED aims to strengthen the quality, relevance and innovation of higher education through transnational cooperation.

Call: 2023 Round 1 KA2

Project ID and acronym: KA220-HED-D888B3CE, DigiMar

Maritime Studies Kotor, Montenegro; Chalmers Tekniska Högskola AB, Sweden; Administration for Maritime Safety and Port Management, Montenegro; Swedish Maritime Administration; Norwegian Coastal Administration; Ministry of Infrastructure, Slovenian Maritime Administration; Fintraffic Vessel Traffic Services, Finland

Project links: <https://digimar.si/>

Acknowledgement: Co-funded by the European Union



Funded by
the European Union
NextGenerationEU

Multimedia Interactive Simulation Systems in the Maritime Sector

Ana Perić Hadžić*, Dario Ogrizović, Irena Jurdana, Renato Ivče, Jasmin Ćelić, Marko Vukić, Antonio Blažina, Luka Liker

University of Rijeka, Faculty of Maritime studies, Rijeka, Croatia

E-mail: ana.peric@pfri.uniri.hr; dario@pfri.uniri.hr; irena.jurdana@pfri.uniri.hr; renato.ivce@pfri.uniri.hr; jasmin.celic@pfri.uniri.hr; marko.vukic@pfri.uniri.hr; antonio.blazina@pfri.uniri.hr; luka.likier@pfri.uniri.hr

Summary

Multimedia interactive simulation systems (MISS) in the maritime sector are a key component in the development of safe, efficient and sustainable maritime operations in maintaining ship systems and improving operations to transport cargo and passengers safely and efficiently. By applying virtual (VR), augmented (AR), mixed (MR) and extended (XR) reality, they enable the creation of an interactive fully immersive computer-generated digital environment in which various types of interactions with virtual and real objects, both in the virtual and physical world are possible.

The proposed project contributes to scientific excellence and cooperation with the maritime industry, and establishes a unique interdisciplinary research laboratory.

* Corresponding/presenting author

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects of the University of Rijeka financed from Source 581 – Recovery and Resilience Facility

Project ID and acronym: uniri-mzi-25-47, MISS

Furthermore, the innovativeness of the project is reflected in the development of two pilots:

3D VR/MR/XR model of the system for monitoring the location and condition of refrigerated container parameters with M2M communication enabled to improve maintenance processes and procedures as well as additional training of technical staff. Remote support for ship system maintenance using mixed reality and large language models (LLM) allows technicians to be guided through specific tasks, increasing their speed and efficiency, improving system response time and extending the lifecycle of equipment. The use of artificial intelligence (AI) and 3D modelling (VR), ensures even better condition-based or predictive maintenance.

3D VR/AR model of a computer-generated ship ballast system that provides the ability to examine the performance of the system as a whole and individual system segments by monitoring the state of parameters with constant monitoring and preventive and corrective maintenance. VR provides the opportunity to compare and analyse the application of conventional and modern methods of measuring tank liquid levels under controlled conditions, which allows for better evaluation and improvement of the measurement process itself

Project links: <https://portal.uniri.hr/ProjektiPU2025/Details/0305?up=true>

Acknowledgement: Funded by the European Union – NextGenerationEU – MISS - uniri-mzi-25-47



Funded by
the European Union

NextGenerationEU

Research on Dynamic Impacts and the Proposal of Modular Solutions for the Complex Electronic Navigation Environment

David Brčić^{1*}, Jasmin Čelić¹, Sanjin Valčić¹, Serđo Kos¹,
Mario Bakota², Nermin Hasanspahić³, Maro Car³

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: david.brcic@pfri.uniri.hr; jasmin.celic@pfri.uniri.hr; sanjin.valcic@pfri.uniri.hr;
serdjo.kos@pfri.uniri.hr

² University of Split, Faculty of Maritime Studies, Split, Croatia
E-mail: mbakota@pfst.hr

³ University of Dubrovnik, Faculty of Maritime Studies, Dubrovnik, Croatia
E-mail: nermin.hasanspahic@unidu.hr, mcarl@unidu.hr

Summary

Maritime navigation on vessels subject to the International Convention for the Safety of Life at Sea (SOLAS) increasingly relies on the Electronic Chart Display and Information System (ECDIS) as a primary navigational tool, and on Global Navigation Satellite Systems (GNSS) as the main shipborne positioning source. In such an environment, safe navigation depends on the reliability, continuity, and correct operational interpretation of position information. The project investigates dynamic

* Corresponding/presenting author

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects of the University of Rijeka financed from Source 581 – Recovery and Resilience Facility

Project ID and acronym: uniri-iz-25-143, DYNAMO_SCENE

influences affecting GNSS performance, with particular attention to position reliability and degraded positioning conditions. The research considers the GNSS operational environment, the way in which the physical maritime environment is represented on electronic navigational charts, and GNSS-dependent maritime information services (e.g. Automatic Identification System (AIS) derived vessel position data). It examines satellite geometry, signal propagation, local environmental effects, interference, traffic-related spatial patterns, and other sources of positioning degradation and uncertainty. The main objective is to establish a scientifically grounded basis for identifying, categorising, and visualising navigational risk zones as additional, modular risk-information layers. These layers would support the interpretation of positioning reliability in relation to the surrounding navigational and traffic context and assist Officers of the Navigational Watch (OOW) in making more informed decisions. The project contributes to GNSS performance analysis in maritime conditions and supports improved situational awareness, timely route and navigation adjustments, as well as safer and more efficient maritime navigation through advanced navigational information systems.

Project partners: University of Rijeka, Faculty of Maritime Studies; University of Split, Faculty of Maritime Studies; University of Dubrovnik, Faculty of Maritime Studies, Croatia

Project link: <https://portal.uniri.hr/ProjektiPU2025/Details/0221>

Acknowledgement: Funded by the European Union – NextGenerationEU – DYNAMO_SCENE - uniri-iz-25-143



Improving Localization
Accuracy and Resilience of
Global Navigation Satellite
Systems Positioning



Funded by
the European Union
NextGenerationEU

Improving Localization Accuracy and Resilience of Global Navigation Satellite Systems Positioning

Mario Muštra^{1*}, Edouard Ivanjko¹, Tomislav Radišić¹, Niko Jelušić¹,
Jasna Leder Horina¹, Marijana Greblički¹, Luka Kramarić¹,
David Brčić², Franc Dimc³, Danijel Šugar⁴

¹ University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia
E-mail: mmustra@fpz.unizg.hr

² University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

³ University of Ljubljana, Faculty of Maritime Studies and Transport, Ljubljana, Slovenia

⁴ University of Zagreb, Faculty of Geodesy, Zagreb, Croatia

Summary

The ARES-GNSS project aims to develop a high-accuracy augmentation positioning system for Unmanned Aerial Vehicles (UAVs) by fusing Global Navigation Satellite Systems (GNSS) with Ultra-wideband (UWB) localization technology. Because GNSS signals are frequently degraded or blocked in indoor and occluded environments, this research focuses on enhancing UAV navigation efficiency in signal-constrained areas and achieving the precision required for tight-formation swarm flights. This will be accomplished through the (non)linear data fusion of absolute GNSS coordinates

* Corresponding/presenting author

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects financed from Source 581 – Recovery and Resilience Facility

Project acronym: ARES-GNSS

and relative UWB transceiver positioning, with validation planned for both indoor and outdoor laboratory tests.

Additionally, the project addresses the critical issue of GNSS resilience against jamming and spoofing, which threatens positioning and timing accuracy across multiple industries. Utilizing Software-Defined Radio (SDR) receivers, the research will analyse the impact of malicious signal interference on commercial, amateur, and professional receivers. The ultimate goal is to design and implement effective mitigation strategies that prevent inaccurate localization solutions from commercial, amateur, and professional receivers.

Project partners: University of Rijeka, Faculty of Maritime Studies; University of Zagreb, Faculty of Geodesy, Croatia; University of Ljubljana, Faculty of Maritime Studies and Transport, Slovenia

Project link: <https://www.fpz.unizg.hr/assets/media/projects/ares-gnss.html>

Acknowledgement: Funded by the European Union through the Source 581 – Recovery and Resilience Facility



Sea State Estimation from Wave-Induced Ship Response Using Advanced Deep Learning Methods

Nikola Lopac

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: nikola.lopac@pfri.uniri.hr

Summary

Reliable knowledge of sea conditions is fundamental to safe and efficient maritime operations. It supports safer navigation, lower fuel consumption, improved route planning, and the continued development of autonomous ship systems. However, conventional wave measurement technologies, including satellite and radar systems and wave buoys, remain constrained by high costs, complex infrastructure, and limited spatial and temporal resolution. These limitations have encouraged growing interest in ship-based sea state estimation, in which wave conditions are inferred from vessel motions already recorded during routine operation. Such an approach enables local and continuous assessment without requiring additional specialized measurement equipment. This project focuses on the development of a deep learning-based method for estimating sea state and individual wave parameters from ship responses to wave excitation. The research will combine simulated data generated through numerical models with real-world data obtained during operational navigation. The data will be processed and integrated into a representative dataset intended for the development and evaluation of the proposed model.

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects of the University of Rijeka financed from Source 581 – Recovery and Resilience Facility

Project ID and acronym: uniri-mz-25-49, SEALEARN

State-of-the-art neural network architectures and advanced data pre-processing techniques will be applied to investigate two complementary tasks: sea state classification and estimation of individual wave parameters. Special attention will be given to transfer learning across different vessel types and operational conditions, with the aim of improving the robustness and generalization capability of the developed model. By combining ocean engineering, signal processing, and artificial intelligence, the project seeks to establish a reliable and accurate computational approach to sea state estimation. Its results are expected to provide a basis for future maritime industry applications and for further scientific development in maritime and intelligent systems. In the longer term, the project may contribute to safer navigation and more efficient vessel operation in response to the increasing digitalization and autonomy of maritime transport.

Project partners: University of Rijeka, Faculty of Maritime Studies, Croatia

Project link: <https://portal.uniri.hr/ProjectsPU2025/details/0308?up=true>

Acknowledgement: Funded by the European Union – NextGeneration EU – SEALEARN – uniri-mz-25-49.



Funded by
the European Union

NextGenerationEU

Transformation of Maritime Transport: Digital Technologies and Alternative Fuels (TRANSMAR)

Edvard Tijan^{1*}, Saša Aksentijević¹, Gea Mišćević¹, Marija Jović²

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia

E-mail: edvard.tijan@pfri.uniri.hr, sasa.aksentijevic@pfri.uniri.hr, gea.miscevic@pfri.uniri.hr

² Institute of Shipping Economics and Logistics, Germany

E-mail: marija.jovic@isl.org

Summary

The project is focused on enhancing maritime transport through the implementation of innovative digital technologies, smart energy management systems and the use of alternative fuels. In this context, the research of digital technologies in port process management and shipping will enable the development of new business models in the maritime sector, with their application encompassing a wide range of innovations. Key components include the use of artificial intelligence, blockchain, the Internet of Things (IoT), advanced analytics, and autonomous systems for container traffic management, as well as the development of platforms for route optimization. This will result in faster and more efficient cargo handling, reduced congestion in ports, and significant improvements in energy efficiency. Particular emphasis is placed on the exploration of sustainable fuels such as hydrogen,

* Corresponding/presenting author

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects of the University of Rijeka financed from Source 581 – Recovery and Resilience Facility

Project ID and acronym: uniri-iz-25-13 TRANSMAR

ammonia, and LNG, in line with European decarbonization and environmental protection goals.

The project contributes to raising the scientific excellence of the Faculty through research and the implementation of digital and green technologies in the maritime sector, thereby increasing its international recognition and academic reputation. At the same time, it strengthens cooperation with industry by developing innovative solutions for optimizing logistics operations, attracting investments, and improving the competitiveness of Croatian and European ports. Students will have the opportunity to learn about the latest technologies and trends, while the project results will serve as examples of best practices for port concessionaires in the region and beyond, encouraging the broader adoption of green technologies and strategies for reducing the ecological footprint.

Project partners: University of Rijeka, Faculty of Maritime Studies, Croatia; Institute of Shipping Economics and Logistics, Germany

Project link: <https://portal.uniri.hr/ProjektiPU2025/Details/020>

Acknowledgement: Funded by the European Union – NextGenerationEU – TRANSMAR - uniri-iz-25-13



Funded by
the European Union
NextGenerationEU

Application of Energy-Efficient Metaheuristics to Optimisation Problems in Maritime Container Transport

Marko Gulić^{1*}, Neven Grubišić¹, Srđan Žuškin², Marko Valčić²,
Tonći Biočić³

¹ University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: marko.gulic@pfri.uniri.hr, neven.grubisic@pfri.uniri.hr, srdan.zuskin@pfri.uniri.hr

² University of Zadar, Department of Mechatronics and Robotics, Zadar, Croatia
E-mail: mvalcic@unizd.hr

³ University of Dubrovnik, Faculty of Maritime Studies, Dubrovnik, Croatia
E-mail: tonci.biocic@unidu.hr

Summary

Maritime container transport is crucial for global trade, but it faces a number of optimization challenges. In this context, digital transformation and advanced optimization techniques have become essential for overcoming these challenges. This project focuses on increasing the energy efficiency of metaheuristic algorithms that will be used to optimize logistics problems in container transport, with particular emphasis on the role of pseudo-random number generators in these algorithms. The pseudo-random number generator is crucial for the successful application of

* Corresponding/presenting author

Name of the Programme: Croatian National Recovery and Resilience Plan 2021–2026, funded by the European Union – NextGenerationEU through the Recovery and Resilience Facility (RRF)

Programme priority: Component C3.2 – Boosting Research and Innovation Capacity

Programme specific objectives/mission: To improve the system of institutional funding for universities and research institutes, increase the quality and relevance of research results, strengthen scientific productivity and research capacity, and enhance knowledge transfer and the impact of research on the economy and society.

Call: Call for Funding Institutional Research Projects of the University of Rijeka financed from Source 581 – Recovery and Resilience Facility

Project ID and acronym: uniri-iz-25-156, E-MOTION

metaheuristic algorithms as it significantly impacts the behaviour, efficiency, and quality of solutions. Although its role is often overlooked, selecting the right generator can significantly reduce energy consumption while improving optimization performance. Within this project, energy-efficient metaheuristics will be developed and applied, which not only enable the finding of high-quality solutions for specific logistics problems but also reduce energy consumption during the optimization process without compromising solution quality. These energy-efficient algorithms will be applied to specific logistics challenges in the maritime sector, such as berth allocation, quay crane assignment, container placement at terminals and on ships, and determining the optimal ship size for transport on a given route. With the goal of optimizing all stages of container transport, these algorithms improve efficiency, reduce costs and resource consumption, ultimately contributing to sustainability. The project will evaluate the proposed solutions with an emphasis on analysing the energy efficiency of metaheuristics and their success in solving specific logistics problems. A significant advantage of this research is its broader applicability. These algorithms can be used for various optimization problems in the real world across different industries, enabling more energy-efficient and sustainable solutions beyond the maritime sector.

Project partners: University of Rijeka, Faculty of Maritime Studies; University of Zadar, Maritime Department; University of Dubrovnik, Faculty of Maritime Studies, Croatia

Project links: <https://portal.uniri.hr/ProjektiPU2025/Details/0239>

Acknowledgement: Funded by the European Union – NextGenerationEU – E-MOTION - uniri-iz-25-156



**Funded by
the European Union**
NextGenerationEU

Optimization of Urban Delivery Models through Simulation Analysis

Mladen Jardas

University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: mladen.jardas@pfri.uniri.hr

Summary

Modern urban delivery systems face numerous challenges, including growing demand for timely deliveries, traffic congestion, increased harmful emissions, and stricter environmental standards. This project aims to explore and develop innovative solutions for optimizing delivery activities in urban areas using simulation tools. The goal is to understand the dynamics of existing delivery flows, identify key issues, and propose sustainable models that meet the needs of all stakeholders – from transporters and businesses to urban planners and residents. Through simulations in specialized software tools, the project will analyse different delivery scenarios, including the use of consolidation centres, electric vehicles, and the reorganization of delivery routes.

The focus will be on reducing negative environmental impacts and increasing the efficiency of logistics processes. The project also includes collaboration with stakeholders to ensure the application of multi-criteria decision-making methods that consider economic, ecological, and social aspects.

Name of the Programme: Recovery and Resilience Facility (RRF), NextGenerationEU

Programme priority: Research and innovation capacity under RRF

Programme specific objectives/mission: The main objective of the project is to develop simulation models for the analysis and optimization of delivery activities in urban areas, with the aim of improving the efficiency of logistics processes and reducing their negative environmental impacts.

Call: University of Rijeka Institutional Research Projects 2025–2029/RRF

Project ID and acronym: uniri-mz-25-58, OPUS

The research results are expected to provide concrete guidelines for improving urban logistics through the integration of modern technologies and sustainable practices. This will not only improve the quality of life in urban areas but also lay the foundation for further development of scientific methods in the field of simulation and optimization of logistics systems.

Project links: <https://portal.uniri.hr/ProjektiPU2025/Details/0357?up=true>

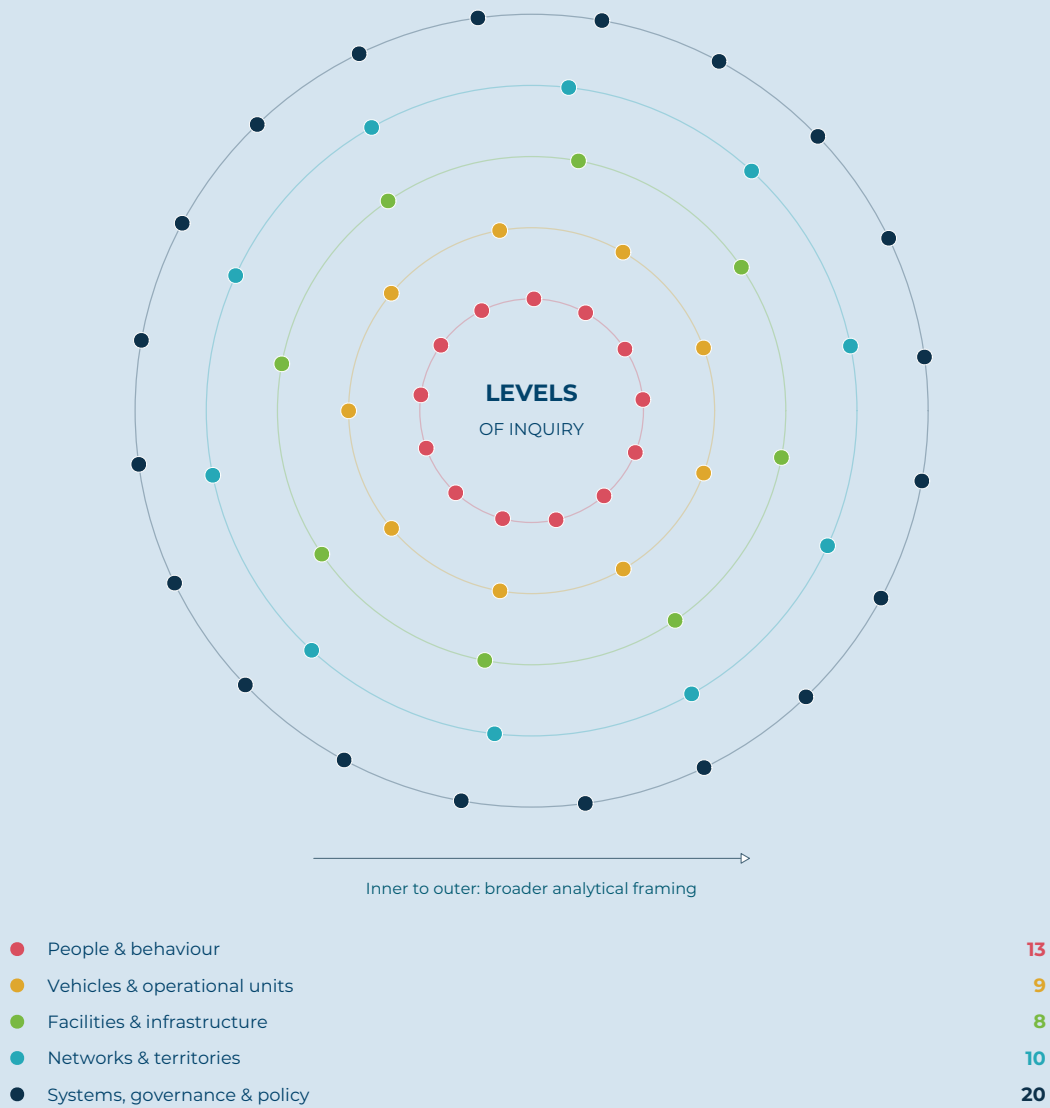
Acknowledgement: Funded by the European Union – NextGenerationEU – OPUS - uniri-mz-25-58



The Scale of Inquiry

From people and operational units to networks, systems and policy

SuTra 2026 contributions operate at markedly different analytical levels. Some focus on individual behaviour or specific vessels and operational units, while others examine infrastructure, territorial networks, transport systems and governance. Each dot represents one conference contribution.



Editorial classification: one primary analytical level is assigned to each contribution. The categories indicate the dominant level of inquiry rather than every level addressed.

The Intellectual Landscape

Challenges, research approaches and intended impact

The connections that emerge across the conference's core thematic domains reveal an interconnected field of shared challenges, research approaches and intended impacts. Recurring concerns, including safety, resilience, decarbonisation, digital transformation and human factors, cut across transport modes and research areas and are addressed through different analytical, technological and conceptual approaches. Their convergence towards broader outcomes highlights both the interdisciplinary character of the conference and the connections that extend beyond individual thematic sections. The mapping represents an editorial synthesis of the 60 conference contributions, with each contribution assigned a primary pathway while recognising that many span several domains, approaches and intended impacts.

HOW TO READ

Numbers indicate contributions per category. Each block accounts for all 60 contributions.

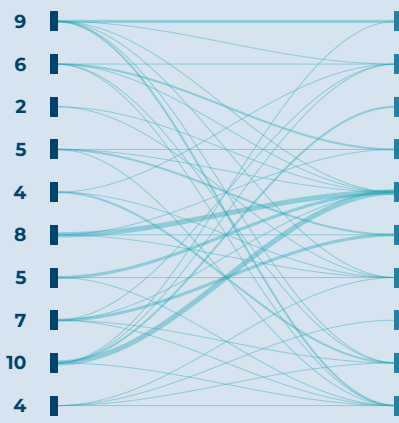
Thicker links indicate a larger number of shared contributions.

Approaches are repeated to connect the two blocks.

01 CHALLENGES

What is being addressed?

Digital transformation
Safety & risk
Resilience & critical infrastructure
Human factors & competence
Decarbonisation & energy transition
Environmental pressures
Infrastructure & capacity
Mobility & accessibility
Logistics & supply-chain complexity
Governance, standards & regulation



APPROACHES

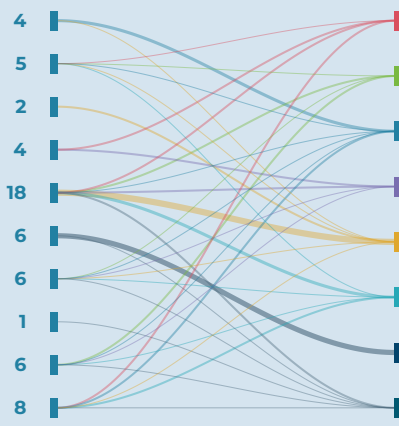
How is it investigated?

AI & machine learning
Modelling & simulation
Optimisation
Measurement & sensing
Data analytics & case studies
Surveys & behavioural research
Framework & method development
Policy & regulatory analysis
Literature & conceptual synthesis
Conceptual & professional analysis

02 APPROACHES

Same categories as above

AI & machine learning
Modelling & simulation
Optimisation
Measurement & sensing
Data analytics & case studies
Surveys & behavioural research
Framework & method development
Policy & regulatory analysis
Literature & conceptual synthesis
Conceptual & professional analysis



INTENDED IMPACT

Link colour identifies the impact

Safer
Cleaner
Smarter
More resilient
More efficient
Better connected
More human-centred
Better governed

CROSS-CUTTING CONCEPTS

DATA	39	SYSTEMS	25	TRANSITION	24	HUMAN	16
SAFETY	11	AI	8	ENERGY	6	RESILIENCE	6

Top 8 | multiple concepts per contribution

Editorial classification: one primary category is assigned at each stage.

Intended impacts represent analytical orientation, not measured outcomes.

Scope: source IDs 1-60. Invited lectures, panels and project summaries are excluded.



<https://sutra-conference.com/>