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Safety and Security in the Marine and Harbor Environment

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Abstract

This paper shows an innovative virtual laboratory which is pivotal for the experimental derivation of strategic and operational plans pertinent to the energy transition and adjustments in maritime and port contexts, utilizing Modeling & Simulation and Artificial Intelligence. The primary aim of this project is to provide robust decision-making support by emphasizing themes of environmental, economic, and sustainability. Additionally, the project ensures the development of resilience by employing simulation techniques to address present and future challenges—especially in light of the evolving geopolitical landscape and the ever-pressing issue of climate change. One of the most significant advancements of this paper is the creation of a Digital Twin for ports and marine infrastructures. This is instrumental in evaluating and analyzing environmental impacts, operational efficiency, vulnerabilities, and risks. Building upon their predecessor Simulators developed by Simulation Team, this Simulator, called ALACER2, broadens its scope by integrating Intelligent System Models. These models are tailored to address strategic developments linked to renewed energy resources and infrastructures such as LNG, Offshore Wind Farms, Undersea Pipelines, and Port Terminals.

Keywords: Modeling and Simulation, Training

1. Introduction

In the contemporary era, where climate change, energy demand, and geopolitical intricacies are shaping global paradigms, the maritime sector finds itself at the crossroads of sustainability, resilience, and energy efficiency (Benamara et al., 2019). Ports and marine infrastructures serve as primary conduits for global trade, energy resources, and intermodal transportation, and their role is especially significant in regions marked by intense transnational interactions (Verschuur et al., 2022). The maritime zone spanning between Italy (IT) and France (FR) is one such pivotal nexus.

However, these critical maritime infrastructures are often challenged by fluctuating energy demands, the need for sustainable operations, and the ever-growing imperative for resilience against both natural and man-made disruptions. As countries worldwide delineate their pathways for recovery and resilience, particularly in the post-pandemic landscape, the enhancement of port infrastructures, especially in terms of energy resilience and sustainability becomes non-negotiable (Sadiq et al., 2021).

This is where the need for a simulator, like ALACER2, becomes not just beneficial, but essential. This innovative solution not only provides decision-making support but also offers a platform for rigorous testing and optimization of energy initiatives within port environments. Such a simulator forecast, analyze, and recommend actionable strategies to ensure the uninterrupted flow of maritime traffic, seamless intermodal transitions, and crucially, the import of critical energy resources. Furthermore, in the intertwined maritime region of IT and FR, ensuring this unbroken chain of energy supply and maritime operation can significantly bolster both countries' Energy Recovery and Resilience Plans.

The ALACER2 Intelligent System, therefore, is not just a technological marvel; it is an embodiment of the answer to some of the most pressing challenges in the maritime energy sector. Through its state-of-the-art capabilities, ALACER2 promises to uphold the twin pillars of resilience and sustainability, which are indispensable for the future we collectively aspire to create.

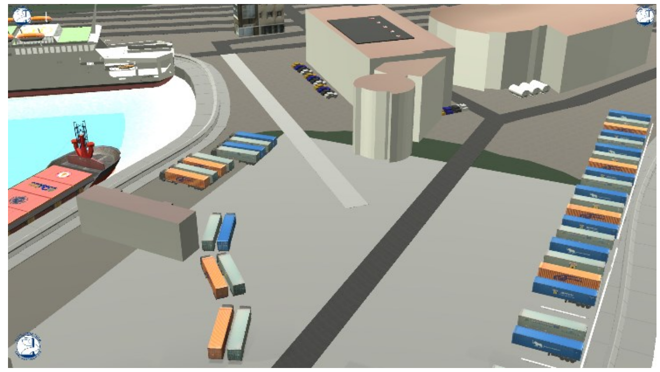
2. State of the art

In our rapidly changing world, energy plays a crucial role in shaping the economy, geopolitics, and environmental sustainability. Ports and marine infrastructures lie at the nexus of these evolving dynamics. Their function as vital hubs of energy transit and trade has grown increasingly complex. The maritime sector plays a foundational role in global trade, with over 80% of global merchandise transported by sea (Unctad, 2020). This demands decision-making tools that prioritize resilience and sustainability.

Marine pollution, primarily from ballast waters, oil spills, and greenhouse gas emissions, has placed the maritime sector under global scrutiny (Smith et al., 2016)

Ports and seas are becoming increasingly intertwined with energy provision, and their criticality cannot be understated. This interconnectedness between ports and cities necessitates evolving solutions to mitigate mutual impacts. Especially in the Italy-France maritime area, there is an exigency for energy resources from the Mediterranean, Africa, and the East. As these resources present significant growth opportunities, decision-makers and operators require a clear vision and the ability to quantitatively assess advantages, disadvantages, and risks.

Maritime traffic, particularly in local and regional contexts, is inherently tied to sustainability and resilience. Current efforts in the Trans-European Transport Network (TEN-T) and in the transborder maritime region between Italy and France are commendable (Casaca et al., 2007). These initiatives range from Cold Ironing, alternative fuels usage, to renewable energy strategies. Yet, despite these underway or emerging efforts, the maritime infrastructure still finds itself in nascent stages. This is particularly true considering international choices, the evolution of shipping, and technological advancements such as LNG and LNG Bunkering. Ship design innovations and alternative fuels, such as Liquid Natural Gas (LNG), biofuels, and hydrogen, present



opportunities to mitigate environmental impacts (Lindstad et al., 2015). Recent conflicts and crises have underscored the vulnerabilities in European, Italian, and French energy policies, revealing an urgent need for well-strategized plans. These strategies should not only ensure energy supply but must evolve sustainably, weighing economic, environmental, social, and risk factors.

Marine infrastructures represent Complex systems, which, by their very nature, are intricate to manage (Bruzzone et al., 2021a). In crises, this complexity amplifies, making these systems even more challenging to control. The situation necessitates tools and models that can support key players in managing these complexities efficiently and effectively (Singh et al., 2019). in maritime domains, simulation-based solutions have emerged to address unique challenges like port traffic control. Such models have proven instrumental in predicting and managing maritime traffic, enhancing port operational efficiency, and mitigating potential crises (Bruzzone et al., 2008; 2012).

One of the distinct advantages of simulation-based solutions is their capability to incorporate real-time data. By assimilating data directly from sensors and other relevant sources, the simulations can replicate an environment that is remarkably realistic. For instance, models can integrate data concerning hazardous materials or potentially dangerous goods (Dewan et al., 2023). Additionally, information about security systems and areas adjacent to ports can be woven into these simulations, offering an enriched, realistic perspective of potential challenges and solutions (Bruzzone et al., 2011a; 2011b).

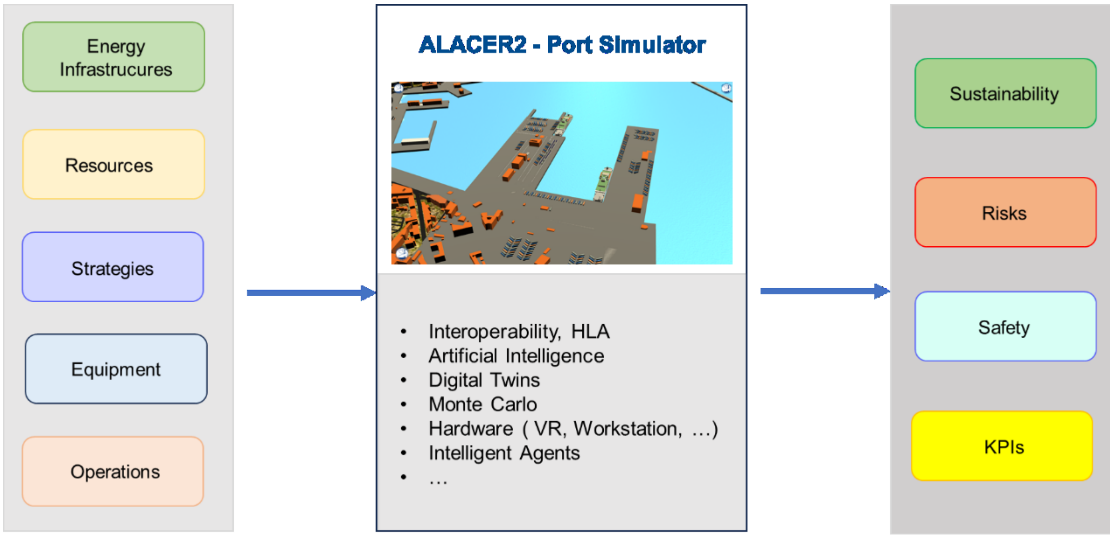


Figure 2. ALACER2 Workflow

ALACER2 is arising from the expertise of Simulation team in develop simulators for decision making in maritime sector and its objective is to provide a shared vision to all decision-makers and involved actors through virtual experimentation (Bruzzone et al., 2021b). This integrated use of simulation and AI is essential for a comprehensive assessment of risks and opportunities, particularly in the maritime areas spanning Italy and France. The development in these regions plays a pivotal role in the growth of the Blue Economy, ensuring sustainability and resilience with a backdrop of effectiveness and efficiency

3. Simulation

The maritime sector confronts challenges from various fronts: environmental, operational, and geopolitical. Addressing these effectively demands sophisticated tools that not only capture the intricacies of port operations but also the broader context in which they operate. The ALACER2 project, leveraging HLA-based interoperable simulation, seeks to assist ports in resource optimization and environmental impact mitigation. The project employs a Discrete Event stochastic simulator underpinned by the MS2G Paradigm (modeling Simulation and Serious Games), allowing the integration of different elements seamlessly using High-Level Architecture (HLA). This ensures that various components, from energy consumption to vessel movements, work cohesively.

In fact, each entity may represent its own characteristics, risks and advantages, which may result in unexpected outcomes when the entity is part of a broader Complex System, eg. when interacts with other entities. Resources like fuels may be useful considering refill of vehicles, however certain fuels may catch fire and possibly cause explosions when dangerous material is nearby. Each entity/model has to be represented in all its layer of details, thus considering interactions with others entities. In order to cope this problem, interoperable models are required. Authors will use experience gained from ALACRES2 project in order to develop new models while integrating previously developed models for safety and security aspects. Artificial Intelligence will be integrated in the models, in particular to create Intelligent Agents needed for constructive simulation and autonomous decisions.

The ALACER2, in its innovative approach, facilitates easy access to the Digital Twin of the Port. This digital representation assists in evaluating current and future strategies, optimizing outcomes, sharing alternative evaluations in the decision-making process, and diminishing risks. Key to its success is the inclusive approach - involving operators, service providers, and terminal operators. They play a pivotal role in setting priorities and needs, shaping dedicated scenarios for specific maritime zones like Mar Ligure, alto Tirreno, Porto Cagliari, and Porto di Bastia. These scenarios are formulated based on case studies co-developed with domain experts and users. ALACER2 specifically zeroes in on actions aimed at curtailing environmental impacts while ensuring efficiency, resilience, and sustainability. Noteworthy among these are strategies focusing on OPS (Onshore power supply), CI (Cold Ironing), AFIR (Alternative Fuel Infrastructure), RES (Renewable Energy Sources), PMS (Power Management Systems), EESU (Electric Energy Storage Units), SMG (Seaport Microgrid), and DG (Distributed Generation).

4. Conclusions

Ports and maritime infrastructures are increasingly becoming critical elements for energy supply, with potential vulnerabilities and risks escalating during crisis periods. As ports and cities continue to grow, they become more intricately intertwined. This closeness mandates a need for evolving solutions to minimize mutual impacts in the pursuit of sustainability. These considerations become paramount within the Maritime Area of Italy and France, especially in light of the necessity to procure energy resources from the south, leveraging the vast resources available in the Mediterranean, Africa, and the East. These resources are poised to offer significant growth opportunities.

In order to guide decision-makers and operators through these intricate landscapes, it's imperative to provide them with a clear vision and the capability to evaluate the advantages, disadvantages, and associated risks quantitatively. This paper introduces an innovative solution centered around a Digital Twin of the Port and Marine Infrastructure. The primary aim of this Digital Twin is to holistically evaluate aspects of efficiency, savings, safety, and risks, especially when faced with challenges and opportunities brought about by the ecological transition.

Envisioned as the central component of the Virtual Laboratory, this Digital Twin, when paired with simulation models and Artificial Intelligence systems, will facilitate the exploration of cutting-edge solutions on energy-related topics. Additionally, it paves the way to craft recommendations and optimizations that take into account a myriad of factors and their intricate interplay. This not only addresses savings or operational aspects but also delves deep into the risks, threats, and impacts emanating from various alternative choices.

In conclusion, this approach will not just serve as a decision-support tool for planning but will emerge as a cornerstone for fostering a new capability—Resilience. In a world riddled with complexities and crises, this resilience will empower stakeholders to respond effectively, ensuring seamless operations and fostering sustainable growth.

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