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Transforming Sri Lanka's Maritime Future with UDA Framework

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Sri Lanka, an island nation with a massive civilisational legacy, has an advantageous geostrategic location in the Indian Ocean. The geopolitical power play pushed Sri Lanka into a hotbed of strategic manoeuvres. The tropical waters of the Indian Ocean Region (IOR) have massive potential for economic growth and prosperity. However, the absence of home-grown technology made the region dependent on the west-driven technology and know-how, which underperformed there as they were developed to work in temperate and polar waters. The governance mechanism has to be strong to retain strategic autonomy by building its internal capabilities. Digital transformation is the de facto tool for governance like the Marine Spatial Planning (MSP), promoted as the tool for enhanced ocean governance by the United Nations. This paper discusses the digital transformation with a special focus on Sri Lanka as a case study to prioritise Underwater Domain Awareness (UDA) for safe, secure, and sustainable growth for the tropical waters of the IOR.

[**Keywords**: Indian Ocean Region (IOR), Marine Spatial Planning (MSP), Ocean governance, Tropical waters, Underwater Domain Awareness (UDA)]

Introduction

The Maritime Domain Awareness (MDA) effectively understands anything associated with the maritime domain that could impact the security, safety, economy or environment. The resource limitation resulted in the conventional MDA remaining on the surface with minimal understanding of the underwater domain, though over 90 % of the threats and resources exist below the surface. Hence, the UDA needs to be considered appropriately and prioritised, including specialised acoustic capacity and capability building to penetrate the depths of the water surface[1].

Massive UDA efforts were undertaken by the American-led North Atlantic Treaty Organization (NATO) and Russia. They invested heavily in UDA, supported by massive-scale field experimental validation to develop reliable & effective sonars. However, post-cold war, the theatre of naval interactions shifted away from the Greenland, Iceland, and UK gap (GIUK gap), and the massive allocation of resources in the name of strategic security became non-viable leading to no further developments in the sonars developed for the temperate and polar waters[2].

In recent times, the security landscape in the IOR region has encountered new challenges, necessitating an evolved approach to Maritime Domain Awareness incorporating heightened safety measures, anti-piracy operations, and counter-terrorism efforts. The economic implications of the maritime domain, which have an impact on trade, resource extraction, and the blue economy, highlight the need for a comprehensive MDA framework that integrates economic stakeholders who can provide valuable insights into maritime-related activities[3]. However, the significant constraints in budget allocation, technology, and expertise resulted in insufficient focus on underwater monitoring and analysis. This gap leaves a substantial under-monitoring of various risks, such as illegal fishing, human trafficking, and environmental degradation[4]. Given the significant threats and resources located beneath the surface, the prioritisation of UDA is essential. Empowering institutions with the necessary tools and expertise for underwater surveillance is crucial for advancing an integrated approach to maritime and UDA. Investment in research and development related to underwater acoustics, sensor technologies, and data analytics is to be prioritised to enhance UDA capabilities[5,6].

The nations in the tropical waters of the IOR have an opportunity to embrace digital transformation by encouraging the pooling of resources and synergising the efforts to drive digital transformation in a nuanced manner. Together, the policy and technology interventions, along with acoustic capacity &

capability building, are also to be taken up for truly managing the tropical challenges and opportunities of the developing nations with minimal resources and understanding[7].

The tropical waters are rich in biodiversity. The conducive climatic conditions ensure diversity in species, genetics and ecosystems. Tropical coral reefs, despite covering less than 0.2 % of the ocean floor, are astonishingly rich in biodiversity, hosting one-quarter to one-third of all marine species. However, the coral species that construct reefs are now at risk of extinction. Between 2009 and 2018, there was a progressive loss of about 14 % of the coral from the world's coral reefs. Additionally, tropical waters are home to approximately 50 % of all marine mammals like dolphins, whales, and dugongs.

The sonars sourced from the west mostly remained underperforming, distorting the acoustic propagation in the tropical waters. The degradation of sonar performance in tropical waters is of the order of 60 %, compared to the temperate or polar waters for which they were originally designed and developed. The sound axis (line joining minimum sound speed) is the determining factor for sonar performance. The acoustic signal propagates around this sound axis due to total internal reflection within the water column. The depth of sound axis in the tropical waters is approximately 1500 m, whereas in the polar waters, it is approximately 100 m. Thus, acoustically, the signal suffers significant interactions with the surface and the bottom in the tropical waters while propagating through the underwater channel, impacting the propagation[8].

The UDA in the tropical waters is determined by two factors. The ambient noise in the receiver location and the underwater channel distortions during the acoustic propagation from the source to the receiver. The ambient noise impacts the Signal to Noise Ratio (SNR), and it is determined largely by three factors: distant shipping noise (below 1500 Hz), wind noise (2.5 to 15 kHz) and the biological noise produced by the marine species in the location. Since the underwater channel behaviour is determined by the depth of the sound axis, tropical waters face significant distortions during acoustic propagation[9].

Sri Lanka is strategically located in the IOR, close to the major Sea Lanes of Communication (SLOC) and encompasses an EEZ that is seven times larger than its land area. Thus the potential of blue economy and strategic planning to harness the massive resources available on the seabed is important for the development of Sri Lanka. The rapid growth in tourism across various segments such as adventure, relaxation, and luxury hospitality can degrade the environment massively, if not regulated appropriately.

The rise of super luxury tourism generates substantial solid waste, whose disposal through traditional landfill-based disposal is unsustainable for an island nation like Sri Lanka due to limited space and the risk of environmental contamination. To mitigate these issues, Sri Lanka must adopt Integrated Solid Waste Management (ISWM) strategies that emphasise waste separation at the source, recycling, and the use of advanced technologies for waste treatment[10].

Massive energy requirements for the development of the island nation have to be planned with a mix of renewable and non-renewable sources. Blue energy sources like wind, tide, thermal, biomass and others need to be exploited to the maximum capacity. The connectivity through the water bodies needs to be exploited to its full potential.

Managing safety from natural disasters must be a top priority, requiring the integration of advanced prediction and early warning systems into a cohesive national response framework. The recent naval accidents, such as the MT New Diamond and MV X-Press Pearl, underscore the urgent need for such preparedness to protect the coastal environment and population.

Security planning must also account for the complex threat landscape of the Indian Ocean Region (IOR), where political volatility often enables non-state actors to operate with relative ease. These actors pose significant challenges to maritime security, using disruptive tactics that conventional measures struggle to counter. A nuanced understanding of these threats is critical to avoid over-reliance on western military solutions and to develop a calibrated, context-specific response strategy[11].

The risks posed by climate change are immediate and pressing concerns. Sri Lanka's experiences with environmental disasters linked to maritime activities highlight the need for a proactive response. This response should not only incorporate modern technology but also integrate local traditional knowledge and practices. By combining these elements, Sri Lanka can build a more resilient and sustainable framework for managing its coastal and maritime environments, ensuring long-term security and prosperity.

The growth potential is vast, but a strong governance mechanism that will balance the people, economy and nature without alienating the native communities is essential for the development process. A structured, comprehensive and inclusive framework is desired[12]. The structured approach will minimise the fragmentation among the stakeholders, regional players, national authorities and native communities. The seamless interactions among these entities will allow an effective and efficient way forward. The multiple entities will have divergent interests and priorities; thus, converging them into one single and focused governance mechanism will be a challenge. The comprehensive governance mechanism must be holistic and inclusive, addressing all stakeholder needs without omission.

UDA is particularly significant for Sri Lanka due to its extensive maritime territory and reliance on marine resources. UDA enhances the understanding and management of underwater environments, which is essential for effective governance. By integrating UDA into the governance framework, Sri Lanka can better address environmental and socio-economic challenges, ensuring that all communities, including those in coastal and riverine areas, are included and their needs are met within a cohesive national and regional strategy[13].

Materials and Methods

Literature review was conducted to establish a foundational understanding of Underwater Domain Awareness (UDA) and its implications for maritime security, economic sustainability, and environmental management, particularly in the Indian Ocean Region (IOR). The analysis focused on the historical evolution of Maritime Domain Awareness (MDA) and the necessity of UDA, the technical and environmental challenges associated with deploying conventional sonar in tropical waters, and the socio-economic and ecological significance of the maritime domain for Sri Lanka. Furthermore, the review explored the role of Marine Spatial Planning (MSP) as a governance tool for integrated maritime management and examined existing frameworks and policy recommendations related to blue economy development, security, and climate resilience.

To evaluate the feasibility and impact of UDA on maritime governance, a comprehensive quantitative analysis was conducted using data from multiple sources. Environmental data, including oceanographic datasets on ambient noise levels, water temperature, salinity, and depth profiles, were analysed to assess sonar performance degradation in tropical waters. Economic indicators, such as trade statistics, fisheries revenue, and blue economy contributions, were examined to understand the economic reliance on maritime resources. Additionally, security metrics were assessed by analysing incidents of illegal fishing, piracy, and human trafficking in the IOR to highlight gaps in conventional MDA approaches. Furthermore, computational modelling techniques were employed to predict ambient noise propagation and optimise sonar system performance under varying underwater conditions.

Given the multifaceted nature of maritime governance, extensive stakeholder engagement was undertaken to ensure inclusivity and collaboration. This process included workshops and webinars with representatives from government agencies, naval forces, environmental organisations, and coastal community groups to gather insights and align priorities. Field visits to strategic locations such as Veraval and Ratnagiri provided firsthand insights into the operational challenges faced by maritime industries and local communities. To enhance capacity-building efforts, e-learning modules and skilling programs were developed to train stakeholders on UDA principles, sonar deployment, data interpretation, and policy implementation. Digital transformation strategies were explored through the integration of tools such as Geographic Information Systems (GIS), remote sensing, and simulation models to enhance data accessibility and decision-making. By adopting this comprehensive approach, the study aimed to bridge gaps in knowledge, technology, and governance frameworks to advance an effective and sustainable UDA strategy for Sri Lanka and the broader IOR region.

Results

The review highlighted the limitations of existing MDA frameworks, particularly in tropical waters, where high ambient noise levels and fluctuating oceanographic conditions reduce sonar effectiveness. Case studies from NATO and Russia demonstrated the benefits of integrating digital tools with acoustic capacity-building for improved maritime security and environmental monitoring. The review emphasised the need to embed UDA into Sri Lanka's maritime governance to address security, economic, and environmental challenges, advocating for a coordinated Marine Spatial Planning (MSP) approach that aligns

with international standards while being tailored to local socio-economic conditions. The review further reinforced these concerns, revealing that the sonar detection range in tropical waters is reduced by up to 40 % compared to temperate regions[9]. Security assessments highlighted illegal fishing and piracy incidents in the IOR occur within Sri Lanka's EEZ, leading to annual economic losses. Computational modelling suggested that integrating predictive noise mapping with adaptive sonar systems could enhance detection accuracy, improving situational awareness.

Stakeholder engagement efforts identified governance gaps, particularly the lack of coordination among fisheries, environmental and social empowerment ministries, which hinders effective MSP implementation. Community engagement underscored the need for localised skilling programs to boost awareness and participation in UDA initiatives. Policy dialogues led to the development of a proposed Environmental, Social, and Governance (ESG) framework for MSP to enhance transparency and accountability in maritime decision-making. Additionally, digital tools such as GIS and remote sensing were successfully integrated into training programs, improving real-time monitoring capabilities. This study contributes to the advancement of UDA-driven MSP by combining scientific modelling, stakeholder insights, and digital transformation to enhance maritime security, economic sustainability, and environmental resilience in Sri Lanka and the broader IOR.

The United Nations Educational Scientific & Cultural Organizations (UNESCO) Inter-government Oceanographic Commission (IOC) developed MSP, which is useful as a key governance tool for coastal and ocean management. MSP represents the digital transformation of marine areas and dialogue and consensus among the key stakeholders of the coast and ocean before undertaking developmental activities. MSP also involves accurate mapping and simulation of various scenarios to understand the effects of planned interventions on the marine environment.

A comprehensive MSP offers substantial benefits for Sri Lanka and the Indian Ocean Region. The digital MSP supports strategic decision-making by predicting both historical and future trends. This data-driven approach enables in-depth analysis across socio-economic, socio-political, and socio-cultural dimensions, which is crucial for effective policy formulation. For those who are investing in the region, MSP offers a clear roadmap to assess return on investment, making it easier to allocate resources. Financial institutions, often hesitant to invest in uncertain sectors, can rely on MSP for better future predictions, thus enhancing support for local communities. This, in turn, fosters equality and prosperity, reduces migration, and encourages local engagement in political and economic matters, significantly improving sustainability and climate change management[14].

Fragmentation among stakeholders is a significant issue in advancing Marine Spatial Planning (MSP). Currently, the fisheries ministry oversees MSP for fisheries and aquaculture, while the environment ministry addresses sustainability and climate change impacts, and the social empowerment ministry handles related social issues independently. A UDA-driven MSP can unify these diverse stakeholders and optimise resource deployment. By pooling resources and coordinating efforts, this approach fosters greater cohesion among stakeholders and policymakers. Implementing an MSP-based Environmental, Social, and Governance (ESG) framework ensures objective governance enhancing transparency, which builds trust and encourages better participation from all stakeholders[14].

Discussion

Key recommendations include establishing an inter-ministerial coordination body for MSP, investing in adaptive sonar technologies, and expanding digital literacy programs for coastal communities. Future research should refine predictive models, broaden data collection, and develop policy frameworks aligned with emerging global UDA and blue economy governance standards.

The tropical waters of Sri Lanka demand a deeper appreciation of the unique local site-specific characteristics. The nuanced way forward will require digital transformation to bring enhanced governance mechanisms. The combination of UDA-MSP appears to be the best way forward to address the developmental issues of Sri Lankan coasts and their management. Systematic outreach through workshops, seminars, conferences, and interactions across the cross-section of stakeholders and decision-makers will help promote the ideas of UDA-MSP philosophy and modalities. Multidisciplinary research focused on local site-specific understanding, knowledge of traditional practices, and the development of technology are to be recognised and supported.

Conflict of Interest

The authors declare that they have no known conflicts of interest that could have influenced the research, analysis, or findings presented in this work. The views expressed in this document are solely those of the author and do not necessarily reflect the opinions of any affiliated institutions or organizations.

Ethical Statement

This is to certify that the reported work in the paper entitled "Transforming Sri Lanka's maritime future: Driven by the Underwater Domain Awareness (UDA) framework" submitted for publication is an original one and has not been submitted for publication elsewhere. I further certify that proper citations to the previously reported work have been given and no data/table/figure has been quoted verbatim from other publications without giving due acknowledgement and without the permission of the author.

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