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INTEGRATION OF ARTIFICIAL INTELLIGENCE AND SUSTAINABLE MARITIME TRANSPORTATION IN OPTIMIZING INDONESIA'S BLUE ECONOMY: A DPSIR FRAMEWORK ANALYSIS BASED ON BPS SDLP 2023 OFFICIAL DATA

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ABSTRACT

This paper examines how artificial intelligence (AI) could be integrated with sustainable maritime transportation and fisheries governance to support Indonesia's blue economy. It develops a conceptual extension of the Drivers–Pressures–State–Impact–Response (DPSIR) framework using secondary statistics in Indonesia's official Statistics of Marine and Coastal Resources 2023 (BPS SDLP 2023) and traceable maritime, environmental and policy literature. Reported fishery gross domestic product at current prices grew from IDR 385.9 trillion in 2018 to IDR 505.1 trillion in 2022, while 2022 fishery exports reached 1,224,060 tonnes and US$6.242 billion [1]. The 2022 marine capture fleet comprised 893,258 craft, of which 100,109 were non-powered and 429,113 were outboard-motor boats [1]. An AI-enabled architecture is proposed for vessel monitoring, satellite-image analysis, route decision support and conservation surveillance. These functions are mapped to DPSIR response mechanisms, but have not been experimentally implemented or validated in this study. The findings therefore concern documented sector conditions and a research-informed integration framework, not demonstrated AI-derived fuel savings or environmental impacts.

Keywords: Artificial Intelligence; Blue Economy; BPS SDLP 2023; DPSIR Framework; Marine Conservation; Maritime Transportation; Vessel Monitoring.

1. Introduction

1.1 Autonomous Navigation and Colregs Assurance

Indonesia's dispersed island geography creates sustained demand for sea connectivity, fisheries and coastal resource management. The blue economy aims to support productive ocean-based activities while maintaining ecological systems and coastal livelihoods [2]. Indonesia's Ocean Policy under Presidential Regulation No. 16 of 2017 provides a policy foundation for coordinated maritime development [9]. These priorities overlap with efforts to reduce emissions from shipping, including the International Maritime Organization's 2023 greenhouse-gas strategy [4].

The scale and economic significance of Indonesia's marine and fisheries sector provide an important basis for examining these challenges. According to Statistics of Marine and Coastal Resources 2023 (SDLP 2023), fishery gross domestic product (GDP) at current prices increased from IDR 385.9 trillion in 2018 to IDR 505.1 trillion in 2022, while fishery exports reached approximately US$6.242 billion in 2022 [1]. The same publication reports 893,258 marine fishing craft in 2022, consisting of non-powered, outboard-motor, and inboard-motor vessels [1]. These statistics indicate the scale of economic activity and the diversity of maritime assets that require effective monitoring and governance. However, the statistics themselves do not establish the effects of artificial intelligence (AI) on economic performance, fuel consumption, emissions, or environmental conditions.

The increasing availability of vessel-tracking and satellite-observation technologies provides opportunities to strengthen maritime monitoring. Kroodsma et al. [5] demonstrated the value of vessel-tracking data for mapping global fishing activity, while Paolo et al. [6] combined satellite imagery, vessel-tracking information, and deep-learning techniques to identify industrial activity that may not be captured through conventional public tracking systems. These studies demonstrate the potential of

data-driven and AI-supported approaches for improving the visibility of maritime activities. Nevertheless, evidence from global or non-Indonesian applications cannot by itself demonstrate the performance of a new AI system in Indonesia. The transferability of such approaches therefore requires consideration of local data availability, operational conditions, governance arrangements, and validation requirements.

A relevant analytical structure for organizing these environmental and socioeconomic dimensions is the Drivers–Pressures–State–Impact–Response (DPSIR) framework. The European Environment Agency describes DPSIR as an analytical framework that connects socioeconomic drivers with environmental pressures, environmental states, impacts, and responses [3]. Importantly, the BPS SDLP 2023 publication already applies the DPSIR approach in presenting Indonesia's marine and coastal resource conditions [1]. Therefore, the contribution of the present study is not the creation of a new DPSIR framework or the introduction of DPSIR to Indonesian marine-resource analysis. Instead, this study explores how feasible AI-related maritime functions can be conceptually mapped onto the existing DPSIR structure to organize potential information flows and policy responses.

This distinction is important because the present study is based on secondary data and conceptual analysis rather than experimental AI implementation. The study uses official BPS statistics and traceable scientific and institutional literature to describe documented conditions in Indonesia's fisheries and marine-resource sectors. AI functions such as vessel monitoring, satellite-image analysis, anomaly detection, and route decision support are considered as proposed components within an integration framework rather than as experimentally validated technologies. Consequently, the study does not claim specific fuel savings, emission reductions, improved fishing compliance, or environmental benefits resulting from AI implementation. Such outcomes would require empirical testing using appropriate operational data, baseline conditions, model validation, and measurable performance indicators.

The research gap therefore concerns the integration of documented Indonesian marine-sector conditions with a research-informed conceptual architecture linking AI functions to the established DPSIR structure. Existing studies demonstrate the usefulness of vessel tracking, satellite imagery, and deep learning for maritime observation [5,6], while the BPS SDLP 2023 provides an established DPSIR-based description of Indonesia's marine and coastal resources [1]. However, these elements are not directly integrated in the cited sources into a single conceptual structure that identifies potential AI-supported functions and the evidence required for their future verification. This study addresses that gap by connecting the available Indonesian secondary statistics with established maritime-monitoring research within a DPSIR-oriented conceptual framework.

Accordingly, this study aims to: (1) summarize verifiable developments in Indonesia's fisheries economy, fishery exports, fishing-fleet structure, and marine conservation conditions based on BPS SDLP 2023; (2) organize these documented conditions through the existing DPSIR framework; and (3) propose a conceptual AI–maritime integration architecture that can be subjected to empirical testing in future research. The study thus contributes a traceable secondary-data synthesis and a research-informed conceptual framework rather than an experimentally validated AI system.

2. Literature Review

2.1 Blue Economy and Sustainable Maritime Transportation

The World Bank and UN DESA conceptualize the blue economy as ocean-based economic and social development aligned with environmental sustainability [2]. For Indonesia, sustainable maritime operations involve transport connectivity, fuel and resource efficiency, and marine-ecosystem protection. The 2023 IMO GHG Strategy establishes an international framework for shipping decarbonization, although a national fishing fleet should not be presumed subject to identical regulatory or operational conditions without further vessel-level assessment [4].

2.2 Artificial Intelligence Applications in the Maritime Domain

AIS and VMS vessel-position records can inform navigation analysis and support the identification of potentially unusual activity, but data coverage and model reliability must be evaluated. Global fishing-effort mapping has demonstrated the value of tracking information [5], while the use of satellite imagery and deep-learning classifications shows the potential to detect vessels that public tracking misses [6]. Remote-sensing research also demonstrates how satellite time series may measure coastline changes [8]. Taken together, these studies support the feasibility of a multimodal monitoring research agenda; they do not substantiate the untested 15–25% or 18–22% fuel-saving percentages that appeared in the source manuscript.

2.3 The DPSIR Framework for Environmental Governance

The European Environment Agency's DPSIR framework relates socioeconomic drivers to environmental pressures, states, impacts and policy responses [3]. BPS explicitly uses DPSIR in SDLP 2023 [1]. In the present adaptation, fishery output and demand represent drivers; fishing activity, emissions and pollution represent pressures; stock condition and ecosystem status represent states; livelihood and environmental outcomes represent impacts; and targeted surveillance, fleet planning and conservation measures represent responses. This is an analytical classification, rather than a tested causal statistical model.

3. Materials and Methodology

This work employs descriptive secondary-data analysis combined with conceptual systems design. Its primary Indonesian statistical source is BPS SDLP 2023, released on 30 November 2023 (Publication 04300.2303), which compiles BPS and ministry data [1]. External references are restricted to traceable institutional reports, official legislation and peer-reviewed publications [2–12]. The analysis reports the original observation years, rather than presenting historical 2022 results as measurements made in 2026.

3.1 Data Extraction and Consistency Checks

Data were obtained from Statistics of Marine and Coastal Resources 2023 (BPS SDLP 2023) to ensure source traceability. Fishery GDP for 2018–2022 was taken from Figure 2.1, fishery exports for 2022 from Appendix Table 2.13, fishing-vessel data from Appendix Table 3.7, and marine conservation areas from Chapter 3 [1]. The figures were organized according to their original units and observation periods. Descriptive calculations included real GDP growth, vessel-category shares, export-value shares, and conservation-area totals.

The extracted figures were cross-checked against the corresponding BPS tables and figures, with additional checks on calculated percentages and totals. The reported 21,839,932.79 ha of marine conservation areas was derived by summing the three administrative categories reported by BPS [1]. Likewise, the 56,333 metric tonnes per year of plastic entering the ocean is presented as a model-based estimate reported by BPS and attributed to Meijer et al. [7], rather than as a direct national measurement. These figures are used solely to describe documented sector conditions and are not interpreted as evidence of AI-related environmental or operational effects.

3.2 DPSIR–AI Operational Mapping

An operational matrix maps each DPSIR stage to data inputs, potential analytical tasks, policy responses and measurable future evaluation indicators. Proposed technical elements are AIS/VMS feeds, onboard instrumentation, metocean data, satellite imagery, anomaly classifiers, route recommendation models and geographic dashboards [5, 6, 8]. Proposed field validation would require ethics and access permissions, a clearly defined baseline, training–test separation, out-of-sample validation, vessel and route comparability, and measured fuel/emissions outcomes. No AI model was trained within the present desk study.

4. Results and Discussion

4.1 Fishery GDP and Export Trends

The original BPS publication documents both nominal and constant-price fishery GDP growth over 2018–2022 [1]. Nominal GDP rose from IDR 385.9 trillion to IDR 505.1 trillion (30.88%), while real GDP increased from IDR 238.6 trillion to IDR 275.5 trillion (15.44% in the BPS report). These figures measure sector economic activity, not changes caused by the proposed AI architecture.

Table 1. Development of Indonesian fishery GDP, 2018–2022

Year	GDP Current Prices (IDR Trillion)	GDP Constant Prices (IDR Trillion)	Real Growth From Prior Year
2018	385.9	238.6	—
2019	419.6	252.3	5.74%
2020	431.5	254.1	0.71%
2021	469.6	268.0	5.47%
2022	505.1	275.5	2.80%

Source: BPS SDLP 2023, Figure 2.1 [1]. Year-on-year rates calculated from rounded constant-price figures; 2021 and 2022 are provisional in the BPS figure.

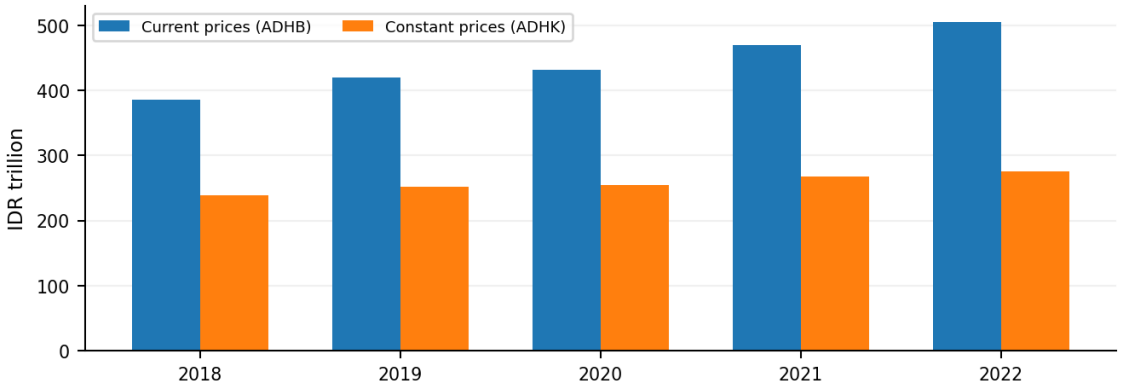


Figure 1. Fishery GDP at current and constant prices, 2018–2022. Source: BPS SDLP 2023, Figure 2.1 [1].

Fishery exports in 2022 reached 1,224,060 tonnes with a reported value of US$6,242,085 thousand. Shrimp, tuna/skipjack/mackerel, seaweed and crab products contributed substantial shares of export value [1]. This export composition identifies sectors that might benefit from traceability, but it does not provide a quantitative estimate of AI-enabled savings.

Table 2. Fishery exports by major commodity in 2022

Commodity	Volume (Tonnes)	Value (US$ Thousand)	Share of Value
Shrimp	241,201	2,157,134	34.56%
Tuna, skipjack, mackerel	194,724	960,266	15.38%
Seaweed	253,680	600,356	9.62%
Crab and swimming crab	29,178	484,228	7.76%
Pearls	13	54,658	0.88%
Lobster	1,470	25,701	0.41%
Other commodities	503,795	1,959,741	31.39%
TOTAL	1,224,060	6,242,085	100.00%

Source: BPS SDLP 2023, Appendix Table 2.13 [1]. Percentage shares are rounded; individual value components differ from the published total by US$1 thousand due to reporting/rounding.

4.2 Fishing Fleet Structure

BPS SDLP 2023 reports 893,258 fishing craft in 2022, compared with 1,004,060 in 2021 [1]. Of the 2022 total, 100,109 were non-powered, 429,113 were outboard-motor boats and 364,036 were inboard-motor vessels. The first two categories together account for 59.25% of the count. Vessel-category shares alone do not establish age, emissions, AI readiness or fuel inefficiency; those would require vessel-level evidence.

Table 3. Indonesian marine fishing craft by propulsion category

Type of Vessel	2021 (Units)	2022 (Units)	Change	2022 Share
Non-powered	136,848	100,109	−26.85%	11.21%
Outboard motor	476,484	429,113	−9.94%	48.04%
Inboard motor	390,728	364,036	−6.83%	40.75%
TOTAL	1,004,060	893,258	−11.04%	100.00%

Source: BPS SDLP 2023, Appendix Table 3.7 [1]. Shares and percentage changes calculated from source counts.

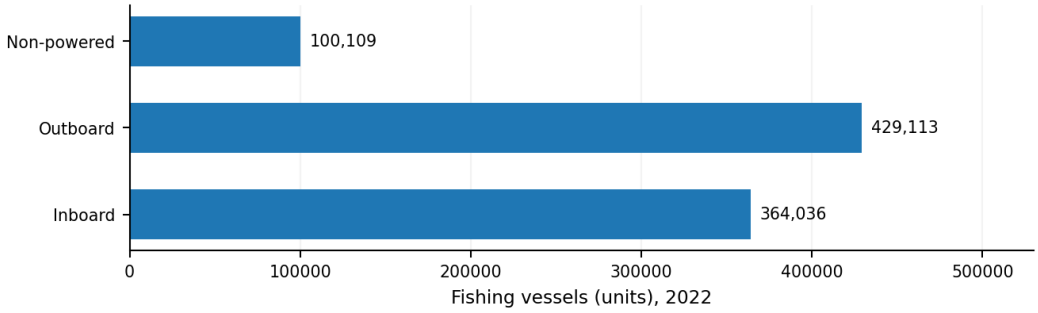


Figure 2. Composition of Indonesia's marine fishing craft, 2022. Source: BPS SDLP 2023, Appendix Table 3.7 [1].

4.3 Proposed AI Platform Architecture and DPSIR Linkage

Figure 3 replaces the untestable performance claims in the draft with a proposed information flow. Tracking data, onboard sensors and remote observations could feed anomaly screening, route decision support and ecosystem-change detection. These outputs can inform public responses under the DPSIR approach, provided data quality, model performance, safe operating boundaries and governance conditions are verified [3, 5, 6, 8].

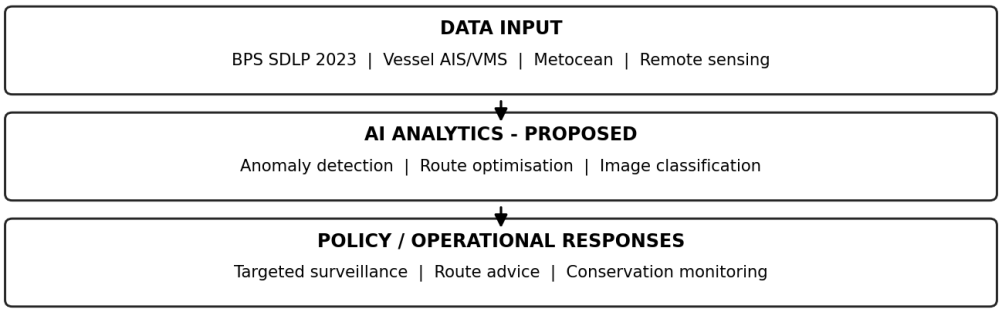


Figure 3. Proposed AI–maritime integration architecture (conceptual only; not an implemented prototype).

Table 4. Conceptual DPSIR interpretation and future verification

DPSIR Stage	Observed or Proposed Domain	Evidence/Verification Needed
Drivers	Fishery GDP, export demand and inter-island connectivity	BPS sector data [1]
Pressures	Fishing effort, vessel activity, pollution	Track records and emissions measurements; literature [5, 7]
State	Marine habitats, coastline condition, fish stocks	Validated geospatial/stock datasets [8, 12]
Impact	Livelihood exposure and ecological degradation	Local impact surveys and time-series evaluation
Responses	AI-assisted monitoring, fleet planning and protection	Prospective testing: model recall, fuel logs, response times

Source: Authors' conceptual synthesis using EEA DPSIR [3], BPS SDLP [1], and published monitoring research [5, 6, 8]; proposed components are not measured outcomes.

4.4 Marine Conservation and Outermost Islands

BPS SDLP 2023 reports 116 marine conservation areas in 2022, comprising 11 nationally administered areas covering 5,374,532.70 ha, 87 provincially administered areas covering 11,144,079.09 ha, and 18 areas administered by the Ministry of Environment and Forestry covering 5,321,321.00 ha [1]. The three categories total 21,839,932.79 ha, with provincially administered areas accounting for the largest share (51.03%), followed by nationally administered areas (24.61%) and areas under the Ministry of Environment and Forestry (24.36%).

Table 5. Reported marine conservation area by administering authority (2022)

Authority	Areas	Area (ha)	Share

Authority	Areas	Area (ha)	Share
National marine/fisheries ministry (KKPN)	11	5,374,532.70	24.61%
Provincial administration (KKPD)	87	11,144,079.09	51.03%
Environment and forestry ministry	18	5,321,321.00	24.36%
TOTAL	116	21,839,932.79	100.00%

Source: BPS SDLP 2023, Chapter 3, pp. 41–44 [1]. Totals and percentages calculated from cited categories.

The distribution indicates that marine conservation management is institutionally dispersed, with provincial authorities administering the largest share of the reported area. Within the DPSIR framework, these conservation areas represent part of the State and Response dimensions because their extent reflects the documented condition and institutional management of marine resources [1,3]. However, the reported area is an administrative measure and does not demonstrate improved ecological conditions or any effect of AI implementation.

Indonesia also has 111 Outermost Small Islands (PPKT) designated under Presidential Decree No. 6 of 2017 [10]. Their geographical distribution creates a potential application area for satellite-based observation and other remote-sensing technologies. Existing coastal-monitoring research demonstrates the feasibility of remote sensing for spatial observation, but such evidence does not establish that AI-based monitoring would prevent erosion or other environmental changes [8]. Similarly, the 56,333 metric tonnes per year of plastic entering Indonesian waters reported in BPS SDLP 2023 is a model-based estimate attributed to Meijer et al. [7], rather than a direct national waste-flow measurement.

From an AI–DPSIR perspective, these findings identify marine conservation areas, PPKT, and documented pollution estimates as potential monitoring targets, while satellite imagery, vessel monitoring, and anomaly detection can be considered candidate technological responses. Their effectiveness, however, requires future empirical validation using spatial-temporal monitoring data and measurable environmental or operational indicators.

5. Conclusion

Official BPS SDLP 2023 statistics show growth in Indonesia's fisheries economy from 2018 to 2022, US$6.242 billion in fishery exports in 2022, and a 2022 marine fishing fleet of 893,258 craft [1]. The same official report already uses the DPSIR framework, which this study extends conceptually by mapping vessel monitoring, remote sensing and route decision support to possible governance responses [1, 3]. The verified outputs of this article are a traceable secondary-data synthesis and a proposed integration framework; no AI performance gains, reduction in illegal fishing or measured fuel savings have been demonstrated.

Policy Recommendations

Priorities for future work are a representative pilot with port and vessel partners, documented access to AIS/VMS and fuel-consumption records, baseline/control conditions, out-of-sample model validation and before–after fuel and emissions assessments. Policy alignment should include Indonesian ocean governance [9], outermost-island protections [10], measured fishing arrangements [11], and scientific stock-management rules [12]. Any subsequent claims of operational savings or ecological impact should be reported only after these verification procedures are completed.

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