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IoT-ENABLED SMART MARITIME TRANSPORTATION ARCHITECTURE FOR INDONESIA'S BLUE ECONOMY: A CAUSAL DPSIR FRAMEWORK ANALYSIS UTILIZING BPS SDLP 2023 AND OFFICIAL MARITIME DATA

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ABSTRACT

Indonesia's archipelagic transport and fisheries networks need interoperable monitoring and decision-support tools. This study develops a conceptual Internet of Things (IoT) architecture linked to the Drivers–Pressures–State–Impact–Response (DPSIR) framework and reviews official indicators from BPS Statistics of Marine and Coastal Resources 2023 and Indonesia's Ministry of Marine Affairs and Fisheries (KKP). BPS reports that fisheries gross domestic product at current prices rose from IDR 385.9 trillion in 2018 to IDR 505.1 trillion in 2022; fisheries exports reached approximately USD 6.24 billion in 2022. The proposed four-layer architecture joins onboard sensors and AIS/VMS, edge processing, secure network transmission, and cloud-based fleet and environmental dashboards. A DPSIR matrix connects economic drivers, environmental pressures, observed conditions, associated impacts, and policy or technology responses. Official KKP reporting puts the national marine conservation area at about 28.91 million hectares at end-2022, a broader figure than the 21.84 million hectares reproduced in the submitted manuscript. The framework is a design proposal supported by secondary statistical description: no IoT prototype, vessel-fuel trial, predictive-maintenance experiment, or quantified emissions benefit was independently validated in this study.

Keywords: Internet of Things; Blue Economy; BPS SDLP 2023; DPSIR; Edge Computing; Maritime Transportation; Vessel Monitoring System.

1. Introduction

Indonesia's geography makes maritime access central to local livelihoods, commodity distribution, fisheries and coastal governance. Statistics Indonesia (BPS) documents the spatial and economic dimensions of these resources in its Statistics of Marine and Coastal Resources 2023 publication (catalogue 3312002, publication 04300.2303) [1]. The World Bank identifies sustainable fisheries, marine ecosystems and pollution management as priorities for a blue-economy transition [2]. Maritime digitalization can contribute operational information, but its effectiveness depends on suitable infrastructure, data ownership and institutional capacity [4], [5].

According to BPS [1], fisheries GDP at current prices increased from IDR 385.9 trillion in 2018 to IDR 505.1 trillion in 2022, while fisheries exports reached about USD 6.24 billion in 2022. These figures describe the scale of the sector; they do not, by themselves, demonstrate an IoT-driven improvement. Secondary ports and small fishing craft may face different connectivity, affordability and monitoring constraints from commercial deep-sea fleets. A dedicated archipelagic architecture should therefore distinguish available statistics, observed pressures and proposed technology responses.

The contribution of this paper is (i) a traceable descriptive synthesis of selected official marine-economic indicators; (ii) a four-layer vessel-to-shore IoT design; and (iii) a DPSIR matrix linking candidate monitoring variables to decisions. The analysis is conceptual and secondary-data-based rather than an experimental evaluation of fuel savings or automation performance.

2. Literature Review

2.1 Maritime Digitalization, IoT and Smart Ports

Sanchez-Gonzalez et al. [4] review digital technologies in maritime transport including IoT, cloud/edge computing, AI and digital security. Paraskevas et al. [5] provide a systematic review of smart-port concepts, identifying interoperability, performance assessment and governance as recurring implementation issues. These works support a modular design in which vessel sensors, port platforms and institutional databases can exchange governed information; they do not establish the accuracy or cost savings of the present proposed architecture.

2.2 Engine Condition Monitoring and Weather Routing

Cheliotis et al. [6] analyze machine-learning fault detection for ship systems, and Park and Oh [7] demonstrate a maintenance-oriented algorithm using ship generator-engine data and simulations. Zis et al. [8] review weather-routing and speed-optimization approaches and emphasize the need for comparable performance benchmarks. The literature justifies studying these functions as candidate application modules. Savings of 18–22% in fuel use and 35% in downtime claimed in the initial draft are excluded here because no author-supplied trial protocol, baseline, sample, or calculation supports applying such percentages to Indonesian vessels.

2.3 DPSIR and Marine Sustainability

The European Environment Agency defines the DPSIR typology as the connection between driving forces, pressures, states, impacts and societal responses [3]. World Bank evidence [2] reinforces the need to distinguish economic activity from ecological condition. Meijer et al. [9] demonstrate the complexity of riverine plastic emissions globally; the paper should not be cited as direct experimental evidence of Indonesian vessel-generated plastic or as proof that a precise local emission total comes from ship operations.

3. Materials and Methodology

3.1 Source Documents, Screening and Analysis

This is a descriptive document analysis and conceptual systems-engineering study. The primary government evidence base consists of BPS SDLP 2023 [1], KKP's 2022 performance report [10], Keppres No. 6/2017 on outermost small islands [11], and Government Regulation No. 11/2023 concerning measured fishing [12]. Peer-reviewed research [4]–[9] informs the proposed technical functions. Figures are reproduced only where a corresponding official publication or verifiable publisher record could be identified; statistics that have conflicting definitions are discussed rather than silently combined.

Extraction variables comprise annual fisheries GDP (current and constant prices), broad fishery export measures, vessel classes, designated marine conservation areas, and the legal basis for monitoring. Descriptive comparisons use direct differences and percentage change: growth (%) = (value in later year / value in earlier year − 1) × 100. No vessel-level telemetry, AI training data, sensor tests, or field intervention results were provided for independent replication.

3.2 DPSIR Coding and Proposed Technical Workflow

First, an economic or ecological indicator is placed into its DPSIR category. Second, a feasible measurement mechanism (e.g., engine fuel-flow telemetry, GNSS/AIS position, geofencing, temperature or salinity) is identified. Third, intended users and outputs are assigned to the proposed system. This mapping is an analytical proposal, not proof of causal effect. Candidate IoT performance indicators for future validation are data completeness, alert delay, classification precision, energy per voyage and maintenance downtime.

4. Results and Discussion

4.1 Fisheries Economic Indicators

Table 1. Indonesian fisheries GDP, 2018–2022 (IDR trillion; BPS SDLP 2023 [1]).

Year	Current Price (ADHB)	Constant 2010 Price (ADHK)	Real Growth (%)
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

Year	Current Price (ADHB)	Constant 2010 Price (ADHK)	Real Growth (%)
2022	505.1	275.5	2.80

The nominal increase from IDR 385.9 trillion to IDR 505.1 trillion equals approximately 30.9%, while constant-price GDP rose from IDR 238.6 trillion to IDR 275.5 trillion (about 15.5%), based on published BPS figures [1]. The figures establish sector context only and should not be interpreted as an effect of digital technology adoption.

Table 2. Selected 2022 fishery export indicators (BPS SDLP 2023 [1]; categories as identified in the submitted manuscript).

Category	Volume (Tonnes)	Value (USD Thousand)
Shrimp	241,201	2,157,134
Tuna/skipjack and related fish	194,724	960,266
Seaweed	253,680	600,356
Crab and swimming crab	29,178	484,228
National total (all fishery products)	≈1.22 million	≈6,240,000

BPS explicitly reports a total 2022 fishery export volume of approximately 1.22 million tonnes and value of USD 6.24 billion [1]. The selected species-group figures above reproduce categories in the submitted source; their aggregation is not a substitute for the original detailed annex, and the source grouping should be confirmed before a submission-grade commodity-level econometric analysis.

4.2 Fishing Fleet and Implications for Monitoring

Table 3. Fishing craft classified by propulsion, 2021–2022 (KKP statistics compiled in BPS SDLP [1]).

Category	2021 (Units)	2022 (Units)	Share In 2022 (%)
Non-powered boats	136,848	100,109	11.21
Outboard motorboats	476,484	429,113	48.04
Inboard motor vessels	390,728	364,036	40.75
Total	1,004,060	893,258	100.00

Non-powered and outboard-motor boats together account for approximately 59.25% of the 2022 fleet count in the reported administrative series [1]. This share cannot be used to conclude that 59.25% of craft are 'un-digitized': technology ownership is a separate variable that is not measured by propulsion class. A phased IoT strategy could prioritize lower-cost, low-power devices, with satellite support considered only where local coverage and operating budgets justify it.

4.3 Conceptual Four-Layer IoT Architecture

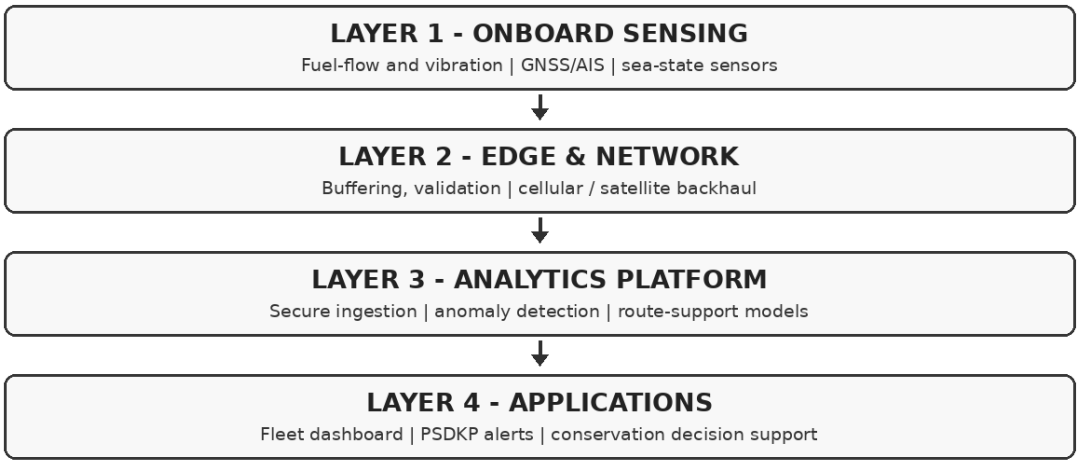


Figure 1. Proposed vessel-to-shore IoT architecture (authors' conceptual design; not a deployed system).

Layer 1 collects GNSS/AIS and engine/environmental measurements where equipment and permissions allow. Layer 2 buffers data and selects available coastal or satellite backhaul. Layer 3 enables time-series analytics, route-support and anomaly alerts subject to labelled datasets and model validation. Layer 4 provides role-specific dashboards for ship operators, port managers and competent fisheries authorities. Encryption, consent, cybersecurity and secure governance are design requirements, not verified properties of an operating deployment [4], [5].

4.4 DPSIR Linkage: Problems, Evidence and Intervention Options

Table 4. Analytical DPSIR matrix for maritime IoT applications (synthesis based on [1]–[5], [10]–[12]).

Component	Documented Context / Indicator	Proposed Monitoring or Response
Drivers	Fisheries GDP and export demand; transport connectivity	Freight visibility, cold-chain telemetry and digital scheduling
Pressures	Fuel use and vessel activity; IUU fishing concerns; plastic pollution	Fuel metering, AIS/VMS geofencing, environmental observations
State	Marine ecological conditions and designated protected areas	Buoy sensors, satellite observations and verified ecosystem indicators
Impact	Livelihood and ecosystem risks; operational costs	Risk alerts, incident reports and decision-support scenarios
Response	Measured-fishing regulation; conservation and maritime governance	Authorized enforcement dashboards, audit logs and staged pilots

In this matrix, the arrows from indicators to IoT functions constitute proposed interventions, not measured causal effects. Policy effectiveness, vessel compliance and ecological improvement require longitudinal observations, suitable controls, legal authorizations and external evaluation.

4.5 Marine Conservation Indicators: Reconciling the Denominator

Table 5. Official and original-manuscript conservation area figures, with scope cautions.

Indicator	Area	Evidence/status
KKP national conservation total, 2021	28.40 million ha	KKP official 2022 performance report [10]
KKP national conservation total, 2022	28.91 million ha	KKP official 2022 performance report [10]
Original draft figure described as 2022 total	21.84 million ha	Different/unclear subtotal; not national total
KKP policy target for 2030	32.5 million ha	KKP official statement [13]

The KKP performance report [10] records 28.91 million hectares of conservation areas in 2022, compared with 28.40 million hectares in 2021. The submitted manuscript's 21.84-million-hectare table has a narrower or inconsistent compilation and is not labelled as the national total here. The distinction

affects all conclusions about the proportion of sea area monitored. Keppres No. 6/2017 legally identifies 111 outermost small islands [11]; the draft's inhabited/uninhabited split is not used as a verified classification without its original annex.

5. Conclusion

This study organizes verifiable Indonesian maritime and fisheries statistics into a conceptual IoT architecture and DPSIR decision-support framework. BPS records fisheries GDP of IDR 505.1 trillion and approximately USD 6.24 billion in fishery exports in 2022 [1]. The national marine-conservation measure should follow KKP's 28.91-million-hectare end-2022 figure [10] rather than the narrower figure used without clarification in the initial manuscript. Four logical tiers—sensing, edge communication, analytics and applications—offer a practical agenda for testing data collection and risk-monitoring functions in selected maritime settings.

Policy Recommendations

Priorities include a pilot with documented baseline vessel fuel use, connectivity coverage, data completeness and user permissions; integration of AIS/VMS records only under applicable regulations; and clear separation of administrative monitoring, environmental monitoring and causal impact evaluation. Precise benefits (fuel savings, emission cuts, downtime reduction or enforcement uplift) should only be published after reproducible controlled tests. This study does not report such experimental performance.

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