



Optimizing Maritime Domain Awareness through Artificial Intelligence Integration and Personnel Digital Competence: A Qualitative NVivo and SWOT Analysis of Satsurvei Pushidrosal

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ABSTRACT

Maritime Domain Awareness (MDA) demands rapid, accurate, integrated maritime information, yet expanding hydro-oceanographic data challenge conventional processing. This qualitative case study examines Artificial Intelligence (AI) use and personnel digital competence at the Survey Unit (Satsurvei) of Indonesia's Navy Hydro-Oceanographic Center (Pushidrosal), formulating an MDA optimization strategy. Data from five key informants, field observation, and document analysis were coded in NVivo 12 Plus. Internal and external factors were assessed using IFAS-EFAS and SWOT, guided by Digital Transformation Theory. Findings reveal AI adoption remains early, limited to rule-based automation and constrained by infrastructure, interoperability, and data governance. Personnel digital competence is uneven, weakest in AI understanding and interpreting AI output. SWOT places Satsurvei in Quadrant I (IFAS +0.007; EFAS +0.005), supporting an aggressive SO strategy. The integrated strategy combines survey data, personnel experience, and organizational support through a digital transformation roadmap, dedicated budgeting, integrated digital infrastructure, AI analysis modules, systematic AI training, and interagency data sharing. Phased implementation and evaluation are recommended

INTRODUCTION

The maritime strategic environment is becoming more complex as traditional and non-traditional threats grow in number and variety. These include territorial disputes, violations of sovereignty, transnational crime, smuggling, illegal, unreported, and unregulated (IUU) fishing, maritime terrorism, and threats arising from information technology and cyberspace (Bueger, 2015; Bueger & Edmunds, 2017). In this setting the Indonesian Navy (TNI Angkatan Laut) needs maritime information that is fast, accurate, integrated, and continuous, as the basis for both strategic and operational decisions. A central concept for meeting this need is Maritime Domain Awareness (MDA), the capability to build a comprehensive understanding of activities in the maritime domain through the collection, integration, analysis, and dissemination of information from many sources (Department of Homeland Security, 2005; Truver, 2006). As the main guardian of maritime security, the Navy needs effective MDA instruments to gather information and act on it (Budiman et al., 2026).

The Navy Hydro-Oceanographic Center (Pusat Hidro-Oseanografi TNI Angkatan Laut, Pushidrosal) holds a strategic position in this capability. As the developer of the hydro-oceanographic function, it provides the data, information, and products that support military operations, navigation safety, and national maritime development. Its Survey Unit (Satuan Survei, Satsurvei) carries out hydro-oceanographic surveys, sea mapping, and the collection of marine environmental data, so the data it produces form part of the foundation of MDA. Advances in sensors, satellites, unmanned systems, and geospatial information systems keep increasing the volume, variety, and velocity of maritime data. Without optimal management, this growth can reduce the timeliness and quality of the information available to decision makers.

Artificial Intelligence (AI) offers a way to address this problem. AI can process large datasets, recognize patterns, perform predictive analysis, and detect anomalies in maritime activity (Russell & Norvig, 2021). Research on maritime surveillance shows, for instance, that neural-network approaches can learn normal vessel trajectories from Automatic Identification System (AIS) data and flag abnormal behavior (Nguyen et al., 2022). However, technology alone does not guarantee results. From the standpoint of Digital Transformation Theory, transformation is an organizational change process that involves technology, organization, and people together (Vial, 2019). The digital competence of personnel, meaning the ability to manage digital data, operate AI-based systems, and adapt to new technology, is therefore a condition for effective AI use.

Earlier studies have examined MDA from national, regional, and strategic perspectives. Agastia and Perwita (2018) identified weak sustained operational capacity, poor interagency coordination, and sense-making problems in Indonesia's MDA. Prakoso et al. (2026) and Rudiyanto et al. (2026) found that data fragmentation between agencies, limited real-time surveillance, cyber threats, and limited AI use still hinder MDA, while Syawal et al. (2026) linked sectoral ego and limited cybersecurity architecture to weak data integration at

the Sunda Strait choke point. Few studies, however, examine how AI use and personnel digital competence jointly shape MDA inside a hydro-oceanographic survey organization. At Satsurvei Pushidrosal, three problems are visible: AI is not yet used optimally to process survey data, maritime data sources are only partly integrated, and personnel digital competence is uneven.

This study addresses these gaps with three objectives: (1) to analyze the current use of AI in supporting MDA at Satsurvei Pushidrosal; (2) to analyze the digital competence of its personnel for implementing AI; and (3) to formulate a strategy to optimize MDA through AI integration and the improvement of personnel digital competence. The study treats technology, human resources, and organization as three linked dimensions (Figure 1) and combines NVivo-assisted qualitative coding with IFAS-EFAS SWOT analysis to move from field evidence to a prioritized strategy.

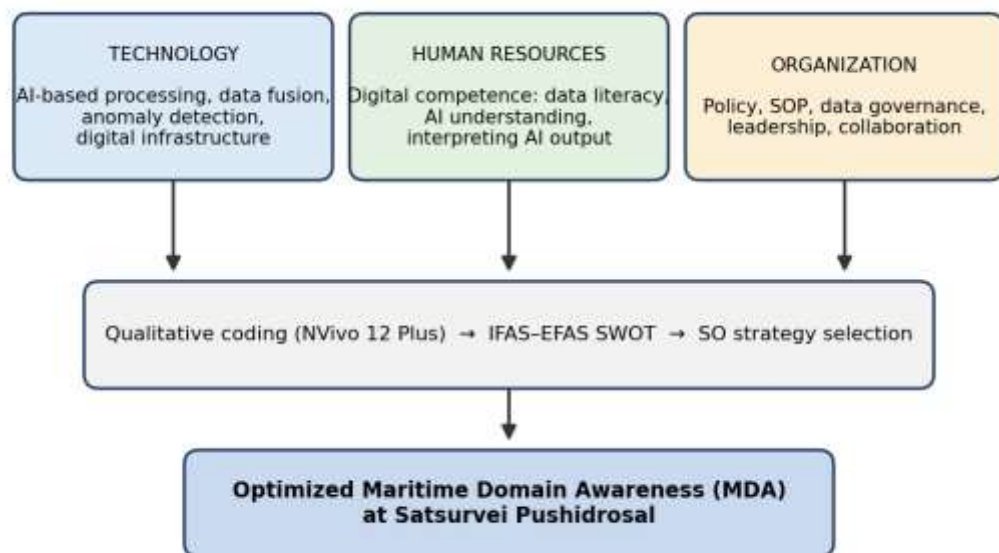


Figure 1. Conceptual Framework of the Study.

Source: Authors' analysis, based on Digital Transformation Theory (Vial, 2019).

LITERATURE REVIEW

Maritime Security and the Concept of Maritime Domain Awareness

Maritime security is a broad and contested concept. Bueger (2015) argues that it is best understood through its relationships with other concepts, namely marine safety, the blue economy, human security, and national security, rather than through a single definition. Bueger and Edmunds (2017) extend this view by calling for a research agenda that takes the sea itself seriously as a security space, moving beyond what they describe as seablindness. Both works support the premise of this study that threats at sea are diverse, from territorial disputes and transnational crime to illegal fishing, terrorism, and cyber threats, and that they cannot be addressed without reliable information.

MDA is the capability that supplies this information. The U.S. Department of Homeland Security (2005) defined MDA as an effective understanding of anything in the maritime domain that could affect security, safety, the economy,

or the environment, and stressed information sharing and integration across agencies as its core requirements. Truver (2006) likewise presents MDA as a key to maritime security. Taken together, these sources define MDA not as a single sensor or system but as a process of collecting, integrating, analyzing, and disseminating information, a view that places data producers such as hydro-oceanographic survey units at the foundation of the capability.

Maritime Domain Awareness in Indonesia

Studies of Indonesian MDA have examined it from national, regional, and strategic perspectives. Agastia and Perwita (2018) analyze MDA as an essential element of the Global Maritime Fulcrum and identify weak sustained operational capacity, poor interagency coordination, and sense-making problems as principal challenges. Budiman et al. (2026) discuss the role of the Indonesian Navy in strengthening MDA, reflecting the Navy's position as the main guardian of maritime security. More recent work links MDA to technology and data integration. Prakoso et al. (2026) and Rudiyanto et al. (2026) find that data fragmentation between agencies, limited real-time surveillance, cyber threats, and limited use of AI still hinder MDA, and Syawal et al. (2026) connect sectoral ego and a limited cybersecurity architecture to weak data integration at the Sunda Strait choke point. These studies share a macro-level focus on agencies, regions, and strategy. The organizational level at which maritime data are actually produced, and the capabilities of the personnel who produce them, receive far less attention.

Artificial Intelligence for Maritime Data Analysis

AI is commonly understood as the design of systems that perceive, learn, and act to achieve goals, with machine learning as a central approach to recognizing patterns in large datasets (Russell & Norvig, 2021). For maritime applications, this capability is relevant to the growing volume, variety, and velocity of data from sensors, satellites, unmanned systems, and geospatial information systems. Nguyen et al. (2022) offer a concrete example in GeoTrackNet, a probabilistic neural-network approach that learns normal vessel trajectories from Automatic Identification System (AIS) data and detects abnormal tracks. Such studies show that anomaly detection, pattern analysis, and predictive analysis are technically feasible for maritime surveillance. They also imply a dependence on clean, structured, and integrated data, which makes data governance and interoperability preconditions of AI use rather than afterthoughts.

Digital Transformation and Personnel Digital Competence

Technology alone does not determine the outcome of AI adoption. Vial (2019) reviews the digital transformation literature and describes it as a process in which digital technologies create disruptions that trigger strategic responses, which in turn require structural change and must overcome organizational barriers. This perspective treats technology, organization, and people as interdependent and provides the conceptual basis of the framework used in this study. The human dimension can be operationalized through digital competence

frameworks. DigComp 2.2 (European Commission, 2022) organizes digital competence into five areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving, and it includes examples relating to AI. Applied to defense personnel, such a framework helps to identify where gaps lie, for example in understanding AI systems and interpreting their output.

METHODS

This research used a descriptive qualitative method with a case study approach. A qualitative design was chosen because the aim was to understand actual conditions, problems, supporting and inhibiting factors, and possible strategies, rather than to measure statistical relationships between variables (Sugiyono, 2017; Creswell & Creswell, 2023). The case is Satsurvei Pushidrosal, an organization that produces the hydro-oceanographic data needed for MDA. Three aspects were examined: technology (the use of AI to process, integrate, analyze, and present maritime data), human resources (the digital competence of personnel), and organization (governance, policy, work mechanisms, and organizational support).

Primary data were collected through semi-structured in-depth interviews using a prepared interview guide (Kallio et al., 2016). Five key informants were selected purposively to represent different roles: the Commander of Satsurvei (I1), the Commander of the survey ship KRI Canopus-936 (I2), a Survey Unit Commander (I3), the Personnel Administration Staff Officer of Satsurvei (I4), and a Satsurvei member (I5). Field observation covered survey activities, data processing, the use of information systems, and personnel work patterns; because the researcher had previously served at the location for a long period, extended observation was not required. Secondary data came from document analysis (Bowen, 2009) of organizational and Navy policy documents, survey and data management documents, and relevant literature. The three techniques were compared to triangulate the findings (Denzin & Lincoln, 2018).

Interview transcripts and documents were managed and coded in NVivo 12 Plus (Bazeley & Jackson, 2019). The procedure followed data management, exploratory reading (skimming), and the building of nodes and mind maps that link the research questions, interview guide, and themes. Coding proceeded in three stages: open coding to identify units of meaning, axial coding to relate categories, and selective coding to determine the core category. Data reduction, display, and conclusion drawing followed Miles et al. (2014). The coded categories were then classified as internal (strengths and weaknesses) or external (opportunities and threats) factors and evaluated with Internal and External Factor Analysis Summary (IFAS and EFAS) tables (David & David, 2020).

Each factor was weighted and rated through expert assessment. Weights were obtained from the importance judgments recorded for each factor (significant = 4, not significant = 2) and normalized across all factors of the same table. Ratings used a four-point scale (1 = very poor to 4 = very good) and were normalized in the same way. The weighted score of a factor is its weight multiplied by its normalized rating. The position on the SWOT quadrant is given

by $X = \Sigma S - \Sigma W$ and $Y = \Sigma O - \Sigma T$. Sixteen SO, WO, ST, and WT combinations were then formed, and the SO strategies were ranked by the product of the weights of the paired strength and opportunity.

RESULTS AND DISCUSSION

The findings are organized around the three research questions: the current use of AI, the digital competence of personnel, and the strategy to optimize MDA. Informants are cited by the codes I1 to I5 given in the Research Methods section, and interview statements are paraphrased from the Indonesian originals.

Current Use of AI in Supporting MDA at Satsurvei Pushidrosal

Interviews, observation, and documents show that AI use at Satsurvei is at an early development stage. The survey workflow is already digital: planning is still conventional but computerized, data are acquired with single-beam and multibeam echosounders and satellite navigation equipment, and raw data are processed with dedicated hydrographic software. I5 named acquisition software such as Hypack and QINSy, bathymetric processing with CARIS HIPS and SIPS, geospatial analysis with ArcGIS and QGIS, and office applications for presenting information. Automation, however, is rule-based. I3 explained that it covers basic steps such as tidal correction, sound velocity correction, and sensor calibration, and that no adaptive AI system yet detects anomalous data automatically, even though such a capability would speed up quality control. Validation and presentation still depend largely on technically skilled personnel (I1, I2). In short, AI has not yet reached predictive analysis, anomaly detection, or complex data fusion.

NVivo coding of the first research question produced ten aspects (Table 1). Three groups of constraints stand out. First, integration and interoperability: I1 described the integration of data from different systems as the greatest challenge, and I3 confirmed that survey data are still stored in various formats and systems, which makes it difficult to connect AI with the MDA system. This echoes the integration problem that the Department of Homeland Security (2005) identified for MDA, and the data fragmentation reported by Prakoso et al. (2026). Second, infrastructure: I2 stressed that AI software alone is insufficient without connectivity, processing devices, storage, and applications suited to survey data, while I3 reported that limited bandwidth at some survey locations hinders real-time data sharing and that not every unit has hardware compatible with AI applications. Third, governance and security: data standards, SOPs for collecting, processing, validating, and exchanging data, and protection against leakage and cyberattack remain to be strengthened, particularly because AI needs clean, structured, and integrated data.

Despite these limits, readiness is evident. I1 and I2 considered AI very helpful when applied appropriately, especially as data volumes grow, and the mission of Pushidrosal to modernize survey facilities and make the organization the national hydrospatial information center gives the effort a clear organizational mandate. Seen through Digital Transformation Theory (Vial, 2019), the technology dimension is the main driver of change, but its success depends on the readiness of supporting infrastructure and information systems.

Table 1. Aspects Identified through NVivo Coding by Research Question.

Research question	Aspects identified
RQ1: Current use of AI to support MDA (10 aspects)	AI capability in data processing; data fusion; anomaly detection; pattern analysis; survey data processing; multi-source data integration; decision support; infrastructure and information systems; system interoperability; data security
RQ2: Personnel digital competence (10 aspects)	Ability to use digital systems; data processing and analysis; AI understanding; interpreting AI output; digital literacy; training and education; personnel experience; adaptability to new technology; cyber/data security; need for competence improvement
RQ3: Optimizing MDA (13 aspects)	AI-MDA system integration; data sharing; interoperability; decision support; data governance; SOP; organizational policy; leadership; digital infrastructure; training and education; collaboration; information security; continuous evaluation and development

Source: Authors' NVivo 12 Plus analysis (2026).

Results of the Processed Research Questions shown in figure 2. Figure 2 shows the NVivo output for the processed research questions as a link map that connects each coded node to the interview transcripts from which it was derived. The circular nodes represent the themes produced through open, axial, and selective coding, such as AI understanding, digital literacy, data sharing, interoperability, and data governance, while the document icons on the right represent the transcripts of the informants. The dense network of connecting lines suggests that most themes are not grounded in a single respondent but are referenced across several transcripts, which supports the source triangulation that the study aimed to achieve (Denzin & Lincoln, 2018). The map also shows that nodes concerning technology, personnel competence, and organizational governance converge on the same set of sources. In other words, informants discussed the conditions of AI use, digital competence, and organizational readiness as interdependent matters rather than separate topics, which is consistent with the integrated framework in Figure 1 and with the view of digital transformation as simultaneous change in technology, people, and organization (Vial, 2019). Because the node labels were generated from Indonesian-language transcripts, they appear in the original language.

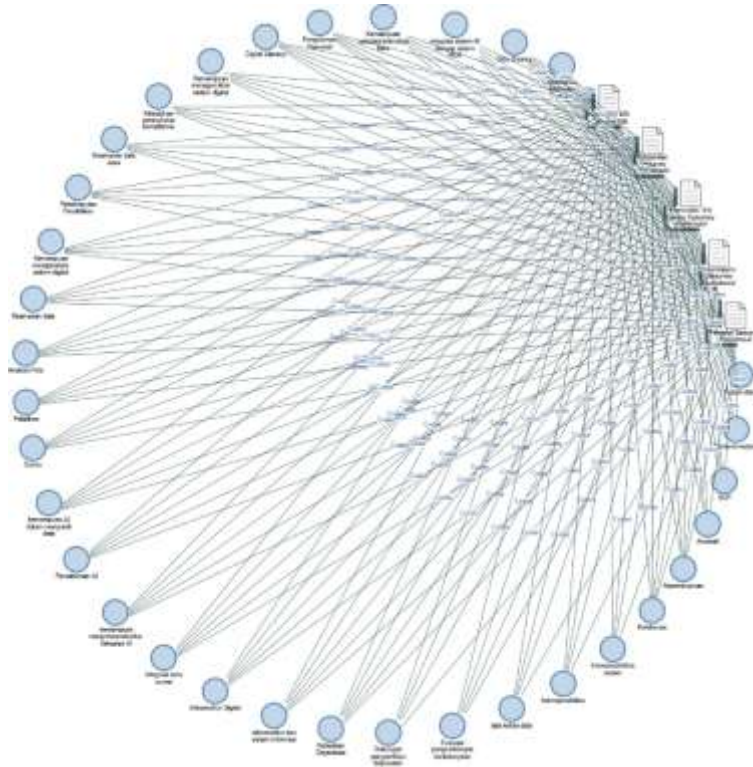


Figure 2. Results of the Processed Research Questions
Source: Authors' NVivo 12 Plus analysis (2026).



Figure 3. Word query results for all research questions
Source: Authors' NVivo 12 Plus analysis (2026).

Figure 3 presents the word query, a word-frequency visualization in which a larger font indicates a higher frequency across the interview transcripts for all research questions. The words are in Indonesian because the interviews were conducted and transcribed in that language. The most prominent content words are *personel* (personnel), *kemampuan* (capability), *digital*, *kompetensi* (competence), *sistem* (system), *teknologi* (technology), *informasi* (information), and *survei* (survey), followed by terms such as *pendidikan* (education),

keamanan (security), organisasi (organization), and analisis (analysis). This distribution indicates that informants framed the issue mainly around people and their capabilities, and only secondarily around hardware or software, in line with the finding that competence development is a prerequisite for AI adoption. The frequent appearance of the negations *belum* (not yet) and *tidak* (not), together with *harus* (must) and *kebutuhan* (needs), reflects the early-stage condition of AI use and the prescriptive tone of informants when describing what the organization still requires. Since word frequency is only descriptive and does not by itself establish significance, these patterns are treated as supporting evidence that complements, rather than replaces, the thematic coding reported in Table 1.

Digital Competence of Satsurvei Personnel

The second research question also yielded ten aspects (Table 1). Informants agreed that personnel can use the digital systems needed for survey tasks. I3 and I5 described competence in operating standard acquisition and processing software, applying basic corrections, and producing simple bathymetric maps and GIS products. Competence was nevertheless described as uneven, shaped by educational background, experience, assignments, and access to training (I1, I4). I4 noted that personnel with an information technology background are few, and that digital qualifications for personnel have not been standardized.

The gap is widest where AI begins. Understanding of AI was described as low and uneven by I3, I4, and I5, and I1 and I2 listed AI understanding and the interpretation of AI output among the competences that must be raised; I5 said that his own understanding was minimal and that his analytical ability was limited to structured data, so the ability to interpret AI output had not yet formed. Digital literacy was largely limited to using applications, available training does not yet respond systematically to AI-related needs, hands-on experience with AI is scarce, adaptability to new technology varies because of both knowledge limits and work culture, and cyber and data security was named as a gap by I1 and I2. Read against the five areas of DigComp 2.2 (European Commission, 2022), the weakest areas are information and data literacy and technology-based problem solving, with digital safety also needing attention. Without interpretive competence, AI output risks being misread or underused, which is why competence development is a prerequisite for, not a by-product of, AI adoption.

SWOT Position of Satsurvei Pushidrosal

The factors that emerged from coding were mapped into four strengths, four weaknesses, four opportunities, and four threats, and then weighted and rated (Table 2). Among the strengths, the technical experience and competence of personnel (S2) carries the highest weight, followed by the availability of survey data and maritime information (S1), the use of existing digital technology (S3), and organizational support for MDA (S4). Among the weaknesses, limited infrastructure and technological support (W3) carries the highest weight of any factor, ahead of limited AI and data-analysis competence (W1), weak data and

system integration (W2), and limited SOPs and governance for AI use (W4). Externally, the development of AI for maritime data analysis (O1) and the opportunity for data and system integration and collaboration (O4) have the highest opportunity weights, while cyber threats (T1) and technology that evolves faster than the organization can adapt (T2) lead the threats.

Table 2. IFAS–EFAS Results for Satsurvei Pushidrosal.

Code	Factor	Weight	Rating	Weight × Rating
Internal factors: Strengths				
S1	Availability of survey data and maritime information	0.116	0.133	0.0155
S2	Technical experience and competence of personnel	0.132	0.133	0.0176
S3	Use of digital technology already available	0.116	0.137	0.0160
S4	Organizational support for MDA	0.124	0.137	0.0170
Internal factors: Weaknesses				
W1	Limited AI and data-analysis competence	0.124	0.118	0.0146
W2	Data and systems not yet optimally integrated	0.124	0.106	0.0131
W3	Limited infrastructure and technological support	0.140	0.122	0.0170
W4	Limited SOPs and governance for AI use	0.124	0.114	0.0141
External factors: Opportunities				
O1	Development of AI for maritime data analysis	0.133	0.137	0.0183
O2	Growing demand for data- and technology-based MDA	0.119	0.129	0.0153
O3	Opportunity to develop personnel digital competence	0.119	0.125	0.0149
O4	Opportunity for data/system integration and collaboration	0.126	0.129	0.0163
External factors: Threats				
T1	Cybersecurity threats to systems and data	0.133	0.125	0.0167
T2	Technology advancing faster than the organization can adapt	0.133	0.118	0.0157
T3	Risk of dependence on external technology and systems	0.119	0.118	0.0139
T4	Threats to the quality, reliability, and security of AI data	0.119	0.118	0.0139
IFAS: $X = \Sigma S - \Sigma W = 0.0661 - 0.0588 = +0.0073$				
EFAS: $Y = \Sigma O - \Sigma T = 0.0648 - 0.0603 = +0.0045$				

Source: Authors' calculation from expert assessment (2026). Values are computed from unrounded raw scores; $\Sigma S = 0.0661$, $\Sigma W = 0.0588$, $\Sigma O = 0.0648$, $\Sigma T = 0.0603$.

The totals are $\Sigma S = 0.0661$ and $\Sigma W = 0.0588$, giving $X = +0.007$, and $\Sigma O = 0.0648$ and $\Sigma T = 0.0603$, giving $Y = +0.005$. Both coordinates are positive, which places Satsurvei Pushidrosal in Quadrant I (Figure 2). Internal strengths outweigh weaknesses and external opportunities outweigh threats, so the appropriate posture is aggressive: use internal strengths to capture external opportunities. The margins are small, though, and should be read as a favorable but not comfortable position, in which the weakest factor, infrastructure, can erode the advantage if left unaddressed.

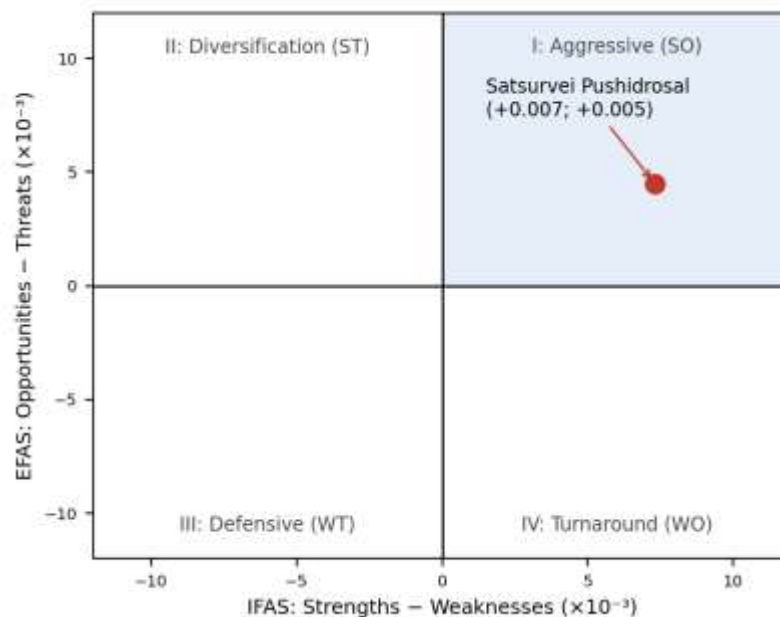


Figure 2. SWOT Quadrant Position of Satsurvei Pushidrosal.
Source: Authors' calculation (2026).

Strategy Formulation and Integrated Strategy

In Quadrant I the SO strategies are the primary choice. Pairing the four strengths with the four opportunities produced sixteen SO strategies, which were ranked by the product of the paired weights. S2O1 scored highest (0.0176), followed by S2O4 (0.0166) and S4O1 (0.0165). S1O1 (0.0155) was also retained, because the survey data holdings of Satsurvei are the precondition for any AI analysis module. Table 3 lists the four priority strategies.

Table 3. Priority SO Strategies.

Code	Strategy	Score
S2O1	Use the technical experience and competence of personnel to adopt AI in maritime data analysis, so that operational experience is combined with AI-based analytics.	0.0176
S2O4	Use the technical experience and competence of personnel to build data and system integration and collaboration with other agencies, including interoperability and data sharing.	0.0166
S4O1	Use organizational support for MDA to adopt AI in maritime data analysis through policy, budget, and infrastructure development.	0.0165

Code	Strategy	Score
S1O1	Use the availability of survey data and maritime information to develop AI in maritime data analysis (machine learning, deep learning, computer vision, predictive analytics) and improve the quality of hydro-oceanographic analysis.	0.0155

Source: Authors' analysis (2026).

The four strategies were combined into one integrated strategy: optimizing an AI-based maritime data analysis system by using survey data, personnel experience, and organizational support together to strengthen MDA. It is implemented through the following lines of effort, each grounded in what informants said was missing.

Policy, budget, and infrastructure (S4O1). A comprehensive digital transformation policy and roadmap should set technology direction, data standards, information security, human resource development, and the use of AI analysis results (I1). It should rest on three pillars: digital infrastructure and AI-MDA integration, sustained and structured training, and data governance and information security, with measurable targets, schedules, and performance indicators. A dedicated budget should fund high-specification servers, storage, AI analytics software, and applications suited to survey needs, built in stages (I3). The integrated digital infrastructure should include a data center or cloud computing capability, secure and stable communication networks, and an analytics platform accessible to all units, in line with I2's call for connectivity, processing devices, and storage suited to survey data.

AI analysis modules and data foundation (S1O1 and S2O1). Modules for anomaly detection, data classification, pattern analysis, and predictive analysis should be built on a centralized data platform that replaces the present scatter of formats, together with updated SOPs for collecting, storing, and exchanging data (I3). I2 advised starting from the operational needs that AI can actually solve and only then selecting technology. Because experienced personnel understand the data and its quality problems, they should be paired with AI tools from the start, so that operational experience trains and validates the models.

Competence development (S2O1 and S2O4). A systematic and sustained AI curriculum should cover AI understanding, data analysis, geospatial information systems, cyber and data security, and the ability to interpret AI output, with both theory and practice (I5). Competence mapping should identify gaps, and mentoring and collaborative teams should pair experienced senior personnel with younger personnel who adapt faster to digital tools. I4 proposed making digital capability a standard criterion in education, assignment, and career development.

Collaboration and interoperability (S2O4). Satsurvei should build a collaboration ecosystem with Bakamla RI, the Ministry of Marine Affairs and Fisheries, the Ministry of Transportation, universities, research institutions, and technology industry, using interoperability standards that adopt International Hydrographic Organization (IHO) practice. A digital collaboration platform in the form of an Integrated Maritime Data Fusion Center could combine hydro-oceanographic survey data, AIS, satellite imagery, and other sensor data, and

allow joint analysis with analysts from other agencies. Such a platform should apply human-in-the-loop principles so that AI output is validated by competent personnel before it is used for strategic or operational decisions. Continuous evaluation through competence tests, performance appraisal, and feedback should keep the strategy aligned with technological change.

Theoretical and Practical Implications

The results support the view that digital transformation in a defense organization is not the procurement of technology but a coordinated change in technology, people, and organization (Vial, 2019). At Satsurvei the three dimensions are uneven: the technology dimension has working digital tools but little adaptive AI, the human dimension has operational skill but little AI understanding, and the organizational dimension has supportive leadership but incomplete SOPs and data governance. As I1 put it, AI development must not be technology-oriented while personnel are unprepared, and competence building must in turn be supported by adequate systems and infrastructure. This reciprocal dependence is the main reason the strategy is formulated as one integrated package instead of separate technology and training programs.

Practically, the findings give Navy leadership and Pushidrosal a sequence: set policy and funding first, build the data foundation and infrastructure, train personnel in parallel, and expand through interagency integration. Several limitations should be noted. The study is a single case with five informants, so the findings are analytically rather than statistically generalizable; the SWOT weights and ratings rely on expert judgment, and the narrow margins of the quadrant position call for cautious interpretation; and the study addresses AI as a supporting technology for processing, analysis, integration, and presentation, not the technical development of algorithms. Future research could develop a digital competence model for defense personnel that integrates DigComp 2.2 with minimum viable competency and adaptive competence frameworks, a maritime data governance framework for interagency integration, and pilot tests of the proposed AI modules.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes, first, that the use of AI to support MDA at Satsurvei Pushidrosal is still at an early stage. AI is limited to rule-based automation and has not reached predictive analysis, anomaly detection, or complex data fusion, mainly because of limited infrastructure and information systems, weak interoperability, limited personnel digital competence, and incomplete data governance, although stakeholders are aware of and ready for AI integration. Second, the digital competence of personnel is uneven. The most prominent gaps are low understanding of AI, the inability to interpret AI output, and digital literacy that stops at using applications, while training is not yet systematic and cyber and data security receives little attention.

Third, MDA can be optimized through an integrated approach. The SWOT analysis places Satsurvei in Quadrant I (IFAS +0.007; EFAS +0.005), so an aggressive SO strategy is appropriate. The resulting strategy optimizes an AI-

based maritime data analysis system through the combined use of survey data, personnel experience, and organizational support, realized through a digital transformation roadmap, dedicated budgeting, integrated digital infrastructure, AI analysis modules, AI training and certification, mentoring teams, interoperability standards, and a digital collaboration platform with human-in-the-loop validation. Future work should test the strategy in a pilot implementation and build a competence model suited to defense hydro-oceanography.

FURTHER STUDY

This study is a single case with five informants, and its SWOT weights and ratings rely on expert judgment. Future research can therefore extend it in several directions.

First, the proposed integrated strategy should be tested through a phased pilot implementation at Satsurvei Pushidrosal, for example by deploying an anomaly-detection or data-classification module on a limited set of survey data and comparing processing time, data quality, and decision support before and after implementation. Second, a digital competence model for defense hydro-oceanographic personnel should be developed and validated. Such a model could integrate DigComp 2.2 with minimum viable competency and adaptive competence frameworks and include measurable indicators for AI understanding, interpretation of AI output, and cyber and data security.

Third, a maritime data governance framework for interagency integration is needed. It should specify data standards, interoperability rules aligned with International Hydrographic Organization practice, data-sharing mechanisms with Bakamla RI, the Ministry of Marine Affairs and Fisheries, and the Ministry of Transportation, and security safeguards for shared data. Fourth, the Integrated Maritime Data Fusion Center proposed in this study could be examined through design-oriented or experimental research, including the technical architecture for combining survey data, AIS, and satellite imagery, and the effectiveness of human-in-the-loop validation.

Fifth, because the quadrant position is only narrowly favorable, subsequent studies could use a larger and more varied set of informants, including other Pushidrosal units and users of hydrographic products, and apply sensitivity analysis to the weights and ratings or complementary methods such as the Analytic Hierarchy Process or the Quantitative Strategic Planning Matrix to test the stability of the strategy ranking. Finally, comparative studies across other Navy units and defense organizations, as well as longitudinal evaluation of competence development and AI adoption, would show how far the findings transfer and how the three dimensions of technology, people, and organization change over time.

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