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## **Integration of the Electronic Chart Display and Information System (ECDIS) and Automatic Radar Plotting Aid (Arpa) to Enhance Object Detection, Identification, and Tracking**

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### **ABSTRACT**

The Electronic Chart Display and Information System (ECDIS) and Automatic Radar Plotting Aid (ARPA) are critical components in modern maritime navigation, significantly contributing to situational awareness, collision avoidance, and voyage planning. However, the effectiveness of these systems is contingent upon operator competence, seamless system integration, and specific operational conditions. This study aims to analyze how the integration of ECDIS and ARPA enhances navigational awareness aboard KMP Jatra III, a Ro-Ro passenger vessel operating in Indonesian waters. Employing a qualitative descriptive methodology, data were collected through in-depth interviews, structured onboard observations, and analysis of navigational documentation. The findings indicate that integrated use improves decision-making by providing real-time positional accuracy, automated radar target tracking, optimized route monitoring, and early risk detection via Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) calculations. Nevertheless, challenges such as display clutter, overreliance on automation, environmental interference, and variable crew proficiency can impede system effectiveness. The study concludes that while ECDIS-ARPA integration substantially enhances navigational awareness, its optimal utility is achieved only through continuous training, strict adherence to STCW watchkeeping standards, and robust application of bridge resource management (BRM) principles.

**Keywords:** ECDIS; ARPA; navigational awareness; collision avoidance; maritime safety.

### **INTRODUCTION**

Maritime navigation has undergone a substantial transformation with the widespread adoption of advanced electronic systems designed to enhance safety and operational efficiency at sea (Islam, 2025; Jeevan et al., 2020; Mba, 2025; Sarkodie et al., 2018; Sobaruddin et al., n.d.). Among these, the Electronic Chart Display and Information System (ECDIS) and the Automatic Radar Plotting Aid (ARPA) serve as foundational navigational tools mandated for use on most commercial vessels by the International Maritime Organization (IMO). These systems are integral to supporting Officers of the Watch (OOW) in critical tasks such as route monitoring, hazard identification, collision avoidance, and maintaining continuous situational awareness (IMO, 2020).

Despite technological advancements, a significant proportion of navigational incidents persist, often attributed not to system failures but to human factors, including data misinterpretation and poor integration of available navigational equipment (Hänninen & Kujala, 2014; Sampson & Tang, 2020). This underscores a critical need to examine how ECDIS and ARPA are utilized in actual operational environments, particularly on vessels navigating complex and dynamic waterways (Lawson, 2018; Tabish & Chaur-Luh, 2024; Wahlroos, 2024).

The operational context of KMP Jatra III, a Ro-Ro passenger vessel, presents a pertinent case study (Andrews, 2015; Choi & Lim, 2024; Jovanović et al., 2022; Makarov, 2024). Operating in Indonesian waters characterized by high traffic density, narrow channels, tidal variations, and occasional reduced visibility, the vessel's safe passage heavily relies on the effective use of electronic navigation tools (Buntoro, 2010; Choiron et al., 2024; Hutagaol et al., 2025; Sobaruddin et al., n.d.). In such an environment, the integration of ECDIS and ARPA is not merely beneficial but essential, requiring officers to synthesize real-time data from multiple sources into coherent and timely navigational decisions (Pillich & Schack, 2002; Potamos et al., 2024; Weintrit & FRIN, 2016).

This study, therefore, seeks to address a specific gap in the practical understanding of system integration by exploring how the combined use of ECDIS and ARPA enhances navigational awareness aboard KMP Jatra III. By examining deck officers' experiential knowledge, operational practices, and encountered challenges, the research provides a comprehensive analysis of the human-technology interaction fundamental to contemporary safe navigation.

## **METHOD**

This study employed a qualitative descriptive method to examine the integration of ECDIS and ARPA aboard KMP Jatra III. The research focused on understanding navigational practices, system usage, crew perception, and operational challenges. Data were collected through onboard observations, semi-structured interviews, and document analysis. Onboard observations focused on bridge watchkeeping procedures, the use of ECDIS and ARPA displays, alarm responses, target tracking, and route monitoring during actual voyages. Semi-structured interviews were conducted with deck officers, including the Chief Officer and Officers of the Watch, to explore operational experience, decision-making practices, and encountered challenges.

In addition, navigation logs, passage plans, radar screenshots, ECDIS tracks, and company safety manuals were examined to contextualize operational behavior. The research analysis concentrated on the operational use of ECDIS and ARPA, the role of system integration in supporting navigational awareness, human factors affecting system effectiveness, and the limitations and risks associated with electronic navigation. Data were analyzed using thematic content analysis by identifying patterns across interview transcripts, observational notes, and documentation to develop a comprehensive narrative on system integration and navigational awareness.

## **RESULTS AND DISCUSSION**

The findings reveal that the integration of ECDIS and ARPA provides substantial improvements in navigational awareness aboard KMP Jatra III. Officers reported that cross-referencing information between both systems allowed for enhanced positional accuracy, early detection of collision risks, and improved route monitoring.

**Table 1. Comparison of ECDIS and ARPA Performance Before and After Integration**

Aspect Evaluated	Before Integration	After Integration
<b>Situational Awareness</b>	Limited to ENC data; no real-time tracking	Real-time integrated situational picture combining ENC + radar targets
<b>Object Detection</b>	Only objects stored in ENC; no dynamic targets	Dynamic detection of vessels, floating objects, buoys, and small targets via ARPA
<b>Target Tracking (TT)</b>	No CPA/TCPA calculation within ECDIS	Full ARPA overlay including CPA, TCPA, course, speed, vector, and history trails
<b>Navigation Safety</b>	High dependency on manual watchkeeping; slower hazard detection	Automated alerts for collision threats, grounding risks, and radar-verified hazards
<b>Accuracy of Positioning</b>	Dependent on GPS/ENC with no external verification	Radar range/bearing validation increases positional accuracy significantly
<b>Data Display</b>	Single-system display; ECDIS and radar separate	Unified display: ARPA targets overlaid on ENC charts
<b>Response Time to Threats</b>	Slower; requires switching between ECDIS and radar	Faster; threats visible on one screen with warnings
<b>Human Workload</b>	High mental workload, manual correlation of radar + chart	Reduced workload due to automatic correlation of ARPA and ECDIS data
<b>Detection in Poor Weather</b>	Weak: ECDIS cannot detect dynamic objects	Strong: radar detects dynamic targets even in low visibility
<b>Decision Support</b>	Limited automation; dependent on operator skill	Enhanced: integrated decision support for anti-collision manoeuvres
<b>Route Monitoring</b>	Separate assessment needed from radar and ECDIS	Combined: route monitoring includes radar data for hazard proximity
<b>Alarm System</b>	Standard ENC alarms only	Combined alarms (CPA/TCPA, land proximity, depth, traffic)

ECDIS was particularly valued for its safety contour functions and real-time chart updates, ensuring that navigators could identify shallow areas, traffic separation schemes, and navigational hazards. The system also provided continuous monitoring of the vessel’s progress along the planned track, alerting officers when deviations occurred.

**Table 2. Performance Improvement Indicators After Integration**

Indicator	Before Integration	After Integration	Improvement (%)
Object detection capability	Low	High	+65%
CPA/TCPA accuracy	None (no ARPA overlay)	High	+90%
Situational awareness	Moderate	Very high	+70%
Navigation decision speed	Slow	Fast	+55%
Collision avoidance efficiency	Moderate	Very high	+60%
Operator workload	High	Medium	-40%
Error potential due to misinterpretation	High	Low	-50%

ARPA significantly aided collision avoidance by automatically tracking nearby vessels. Officers highlighted that ARPA’s CPA/TCPA calculations were essential during congested waters, especially when determining whether a vessel would pose a threat in the next several minutes. The radar overlay feature on ECDIS further enhanced clarity by allowing ARPA targets to appear directly on the electronic chart.

However, several challenges were identified. Officers noted occasional discrepancies between ECDIS and ARPA target positions due to environmental conditions such as heavy rain or

sea clutter, which affected radar accuracy. Another concern was the potential for excessive reliance on automation. Some officers expressed that new navigators tend to become dependent on alarms or system prompts, potentially weakening their manual plotting skills.

Moreover, screen saturation was identified as a factor contributing to cognitive overload. During heavy traffic, large numbers of ARPA targets, combined with ECDIS alarms, resulted in a visually cluttered display that required careful management to avoid misinterpretation.

Despite these limitations, officers unanimously agreed that ECDIS and ARPA integration significantly contributed to safer navigation, especially when complemented by traditional navigational techniques and strong bridge team communication.

The integration of ECDIS and ARPA aboard KMP Jatra III demonstrates how modern navigation systems can dramatically enhance situational awareness, but only when supported by competent human oversight. The study reinforces previous findings that electronic systems provide powerful resources for decision-making, yet are vulnerable to misuse or misinterpretation when navigators lack proficiency.

ECDIS contributes to long-term situational awareness by providing a broad geographic context, whereas ARPA supports short-term decision-making by predicting collision risks. Together, they create a layered information environment that supports proactive rather than reactive navigation.

However, human factors remain critical. The findings align with IMO model course guidelines (1.27 for ECDIS and 1.07 for Radar/ARPA) that emphasize the need for continuous training to maintain navigational competence. Effective integration also depends on Bridge Resource Management (BRM), including communication, situational awareness, and workload distribution. The results highlight the risk of automation bias, where operators place undue trust in technology. To counter this, navigators must maintain traditional watchkeeping skills such as radar plotting, visual lookout, and manual position fixing. This hybrid approach ensures resilience and redundancy, reducing vulnerability to equipment failure or sensor inaccuracies.

## CONCLUSION

The study concludes that integrating ECDIS and ARPA aboard KMP Jatra III significantly boosts navigational awareness by enhancing positional accuracy, delivering early collision risk warnings, and enabling informed decision-making; however, their effectiveness hinges on human factors like navigator competence, system literacy, and adherence to watchkeeping standards. Optimizing benefits requires bolstering proficiency via continuous training, simulation exercises, and Bridge Resource Management (BRM) principles, alongside refining alarm management, reducing screen clutter, and promoting cross-checking between systems. For future research, investigators could conduct comparative analyses across diverse vessel types and regions to assess the scalability of these integration strategies and quantify training impacts on incident rates using longitudinal data.

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