



Operational Management of Ship Pilotage Services: A Case Study of Pilot Competency and Integrated Digital Service Systems

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ABSTRACT

Purpose – This study examines operational management of ship pilotage services at PT Pelindo Banjarmasin by examining how pilot competency and digital and environmental information are translated into operational decision-making, adaptive responses, and service effectiveness in the Barito River. **Methodology/approach** – A qualitative case study was conducted using semi-structured interviews, field observations, and document analysis from January to May 2026. **Findings** – Pilot competency, reflected in navigation knowledge, operational experience, and information interpretation capability, supports pilots in responding to changing river conditions. Integrated digital systems, including Phinnisi, Inaportnet, Integrated Planning and Control (IPC), and navigation and communication technologies, support information exchange, monitoring, navigation, and coordination. Their operational use is affected by network reliability, ship and - readiness, traffic density, water depth, tides, sedimentation, and weather conditions. These factors are considered in operational decision-making and coordination, enabling adaptive responses during pilotage operations. **Novelty/value** – This study identifies an adaptive operational management mechanism that connects pilot competency and digital and environmental information with operational decision-making, coordination, adaptive responses, and service effectiveness.

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1. INTRODUCTION

Pilotage services are a strategic part of port operational management because they are related to navigational safety, smooth ship traffic and tugboat-barge combinations (tugboats that pull barges), punctuality of service, and efficiency of port processes. The effectiveness of pilotage services is determined not only by the ability of individual pilots or the availability of technology, but also by the organization's ability to integrate human resources, information systems, operational facilities, and environmental conditions in the decision-making process.

PT Pelindo Banjarmasin provides pilotage services for ships and tugboat-barge combinations in the Barito River channel, which has operational characteristics that differ from those of other port waters. Pilotage activities are influenced by channel conditions, tides, sedimentation, depth, ship traffic density, movements of tugboat-barge combinations, ship readiness, as well as weather and

communication conditions. At the same time, increased ship activity requires the organization to provide a service system capable of supporting more integrated planning, coordination, monitoring, and control.

Operational data from PT Pelindo Banjarmasin show that ship and tugboat-barge combination movements increased during the 2023–2025 period, as presented in Table 1.

Table 1. Number of ship and tugboat-barge combination Movements at Banjarmasin Port (2023–2025)

Year	Numbers of Ship and Tugboat-Barge combinations
2023	31,339
2024	35,560
2025	64,683

Based on Table 1, ship movements and tugboat-barge combination movements increased during the 2023–2025 period. This increase indicates a growing intensity of ship service activities and tugboat-barge operations that the company needs to manage.

In its operational transformation, Pelindo Banjarmasin utilizes Phinnisi as its ship service management system and Inaportnet as its port service system managed by the Harbor Master. Both systems support planning, monitoring, information exchange, and coordination of ship services through monitoring and control mechanisms. However, research shows that the use of digital systems has not always been optimal due to network disruptions, downtime, and inter-platform dependencies.

Previous research has demonstrated the importance of pilot competency, pilot adequacy, pilotage operational systems, the digitalization of the Inaportnet and Phinnisi systems, and the condition of the Barito River channel. However, these studies tend to address human, technological, and environmental aspects separately. Thus, there is still relatively limited explanation of how pilot competency and digital systems interact to generate operational decisions and adaptive responses in the dynamic Barito River pilotage environment.

This gap becomes even more critical in the context of the Barito River. Digital information such as ship position and movement via AIS, bathymetry data, tidal information, selective communications via DSC, and navigation information via NAVTEX must be translated by pilots into the basis for operational decision-making. Similarly, Phinnisi and Inaportnet need to maintain service processes when network or application disruptions occur.

Thus, the novelty of this research does not lie in the integration of pilot competency and digitalization alone, but in the explanation of the operational management mechanisms that connect pilot competency and digital information and the environment with decision-making, coordination, adaptive response, and service effectiveness.

2. LITERATURE REVIEW

2.1 Human Capital Theory

Human Capital Theory views knowledge, skills, experience, education, and competency development as assets that can support organizational performance. Pilot competency encompasses navigational knowledge and skills, operational experience, and the ability to interpret information about ships, routes, the environment, and traffic.

This competency is crucial because digital information does not automatically generate decisions; it must be understood and interpreted by pilots before being used in operational actions.

This competency is crucial because digital information does not automatically generate decisions; it must be understood and translated by users into operational actions. Pilot competency development is not only directed at conventional navigation skills, but also at the ability to use and interpret digital information in a dynamic operational environment.

2.2 Systems Theory

This research uses Systems Theory proposed by Bertalanffy (1968). Systems Theory is used to understand organizations as systems consisting of various interconnected subsystems. In pilotage services, pilot competency, digital systems, operational facilities, and the aquatic environment cannot be viewed as standalone components.

In this study, Pilot Competency is positioned as a human subsystem, while the Phinnisi, Inaportnet, IPC, PPU, AIS, DSC, and NAVTEX systems are part of the technology and information support. Tidal conditions, sedimentation, depth, traffic, weather, ship readiness, tugboat-barge combinations, and connectivity are operational environments that influence interactions between subsystems. Thus, service effectiveness is understood as part of the system's ability to integrate human resources, information, technology, and operational conditions.

2.3 Conceptual and Analytical Framework

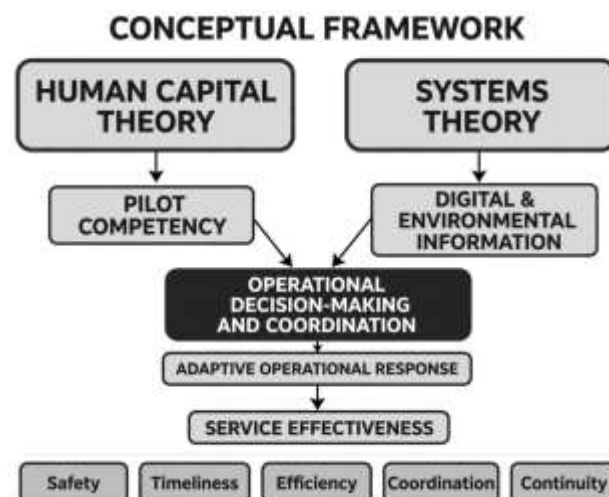


Figure 1. Conceptual and Analytical Framework of the Research

Figure 1 shows the conceptual and analytical framework of the study, integrating Human Capital Theory and Systems Theory, to explain the operational management of pilotage services. Human Capital Theory defines Pilot Competency as a human capability encompassing navigational knowledge, technical skills, operational experience, decision-making, and the use of digital systems. Systems Theory, on the other hand, defines digital service systems as part of a system that supports information integration, coordination, monitoring, and service control.

These two aspects generate digital and environmental information, which is then used for operational decision-making and coordination, including route planning, ship position control, maneuvering, and coordination with ships, tugboat-barge combinations, vessel traffic service (VTS) Banjarmasin, and other relevant units. This process leads to adaptive operational responses to changes in weather, channel conditions, system disruptions, and operational needs. These mechanisms are directed toward achieving service effectiveness, reflected in safety, timeliness, efficiency, coordination, and continuity of service.

This framework also considers contextual and operational factors such as tides, sedimentation and channel depth, traffic density, the availability of tugboat-barge combinations, ship readiness, and system disruptions as factors influencing decision-making and coordination. Thus, the research

framework emphasizes that the effectiveness of pilotage services on the Barito River is determined not only by pilot competency or technology in isolation, but also by the interaction among human capabilities, digital and environmental information, decision-making, coordination, and adaptive responses within a dynamic operational system.

2.4 Pilot Competency

Minister of Transportation Regulation Number 57 of 2015 concerning Ship Pilotage and Towing serves as the normative basis for the provision of pilotage services for ships and tugboat-barge combinations. Pilotage competency includes knowledge, technical skills, experience, communication, understanding of channel characteristics, risk evaluation, and decision-making (Lolo Tandung et al., 2020). Ship pilotage is also related to safety and accident risk reduction (Pantjadjatmika, 2024), while the adequacy of pilotage supports ship services (Pasha et al., 2025). Pilotage professionalism, pilotage services, and navigational safety are related to the smooth flow of ship traffic (Nasution et al., 2025). In river and lake transportation, safety is also related to human resource competency, infrastructure, and the environment (Santoso et al., 2023).

Pilot competencies in this study include navigation knowledge and skills, operational experience, and the ability to interpret information related to ships, routes, the environment, and traffic.

2.5 Integrated Ship Service Operation Digital System

A digital ship service operations system is a technological ecosystem that supports the management, planning, monitoring, control, information exchange, and coordination of ship services. In port operations, Business Process Management Systems (BPMS) support the integration and coordination of business processes (Martín-Navarro et al., 2020).

The implementation of Inaportnet supports the integration of electronic ship services, but still faces technical-operational and institutional challenges (Malisan & Tresnawati, 2019). Disruptions to the information technology system can also cause delays in the ship document processing process (Lolo Tandung et al., 2022). Inaportnet implementation is related to service quality and employee performance (Kwartama et al., 2024), while its implementation still faces technical challenges, operator competence, and inter-agency coordination (Ahyana et al., 2025). The Phinnisi system is also used in ship pilotage and towing services to support ship service processes (Finoawa et al., 2025; Palangiran et al., 2025). The digital system for ship service operations includes Phinnisi, Inaportnet, IPC, PPU, AIS, DSC, and NAVTEX as systems and devices that support service management, navigation information, and operational communications.

2.6 Efektivitas Pelayanan Pemanduan Kapal

The effectiveness of pilotage services is related to the service's ability to support the safety, smoothness, punctuality, and quality of ship operations. Purnomo and Ario (2009) place pilotage service performance as a crucial part of achieving optimal ship service. Amir et al. (2024) discuss the effectiveness of pilotage services in relation to the implementation of ship services at ports. Austin et al. (2024) highlight the operational management of pilotage services in supporting smooth service.

Safety is a crucial part of pilotage services. Pantjadjatmika (2024) examines the role of pilotage in reducing the risk of ship accidents, while Ramadhannur et al. (2024) discuss preventing navigational hazards when ships enter the narrow Barito River channel. Previous research discussed the effectiveness of pilotage services from the aspects of safety, timeliness, efficiency, coordination, and smoothness of service.

2.7 Synthesis of Previous Research, Findings, and Research Gaps

Table 2. Synthesis of Previous Research, Findings, and Research Gaps

Group	Researchers	Research Focus	Key Findings	Research Gaps
Pilot				



Competency and Navigation Safety	Pantjadjatmika (2024)	The role of pilotage in reducing the risk of accidents in Mandatory Pilotage Waters.	Ship pilotage supports safety and reduces the risk of accidents.	Has not explained the integration of competencies, digital information, and the environment in adaptive decisions.
	Pasha et al. (2025)	Technical competence of guides	Technical competence, navigation, experience and critical decisions in service. pilotage.	It has not yet explained how these competencies are supported by digital information in the navigation process. Not yet integrating pilot competency with digital systems and dynamic operational conditions.
	Amir et al. (2024)	Adequacy and development of pilot competency	Adequate pilot competency supports smooth service.	It has not specifically explained the competencies of guides in a digitalized service environment.
	Austin et al. (2024)	Human resource competency management	Human resource competency management is related to efficiency and quality of service.	Has not explained the use of scout competencies in environmental condition-based decisions.
	Nasution et al. (2025)	Professionalism of guides, service, safety, and smooth traffic flow.	The professionalism of the pilot, service and safety affect the smooth flow of ship traffic.	Not yet integrated pilot competency, bathymetric information, digital technology, and operational coordination.
	Ramadhannur et al. (2024)	Navigation on the Barito River	The narrow course of the Barito River requires attention to water conditions and navigation.	Focus on operator safety, has not examined pilot competency, digitalization, and adaptive response.
	Santoso et al. (2023)	Shipping safety and understanding the safety of river and lake ship operators.	Transportation safety is influenced by human resource competency, facilities and infrastructure, and the environment.	
Digitalization and Integrated Ship Services	Ahyana et al. (2025)	Implementation of Inaportnet in ship clearance services	naportnet faces technical constraints, operator competency,	Not yet connecting digitalization, pilot competency, environmental information, and

			emergency SOPs, and coordination.	operational decisions.
Lukijanto & Priyatmono (2019)	Digitalization of pilot services	Digitalization supports the integration of services and information exchange.	It has not yet explained how digital information is used by guides in navigation decision making.	
Malisan & Tresnawati (2019)	Implementation of the Inaportnet system	Inaportnet supports ship services, but is affected by system integration and stability.	Not yet linking system reliability with pilot competency and operational response in the field.	
Finoawa et al. (2025)	Phinnisi in the service of guidance and towing	The Phinnisi system supports the digitalization of service processes and coordination of ship services.	It has not explained the relationship between the use of the Phinnisi system and the pilot's competence and operational environmental conditions.	
Kwartama et al. (2024)	Ship service procedures using the Phinnisi system	Ship service is related to employee performance and port processes.	Has not explained the integration of digital and environmental information in adaptive decision guidance.	
Palangiran & Hidayat (2025)	Reliability of the Inaportnet system and coordination between agencies	The Phinnisi system supports digital ship coordination and service processes.	Not yet integrating human aspects, digital systems, and environmental conditions into one operational framework.	
Dewi (2023)	Inaportnet system disruption	The effectiveness of digital system implementation is influenced by system reliability and coordination between agencies.	Has not explained the role of the pilot competency when the digital system is disrupted.	
		BPMS supports automation, integration, and coordination of port processes.		
Martín-Navarro et al. (2020)	Business Process Management Systems in port processes		Has not yet examined digital integration, scout competency, and the environment in adaptive decisions.	



Operational Conditions, Coordination, and Adaptive Management	Novico et al. (2017)	Morphodynamics and shallowing of the Barito channel	Morphodynamic conditions and shallowing influence the condition of shipping lanes.	It has not yet explained how information on channel conditions is used together with pilot competency and digital systems in decision-making.
	Ahmadi (2016)	Management of the Barito River flow	The condition of the channel and environment affects the smoothness and safety of shipping. Structured operational management and work procedures support service optimization.	Not yet integrating environmental conditions with pilot competency and digital information systems. Not yet discussing operational management of pilotage in a digital environment and dynamic operational conditions.
	Purnomo & Ario (2009)	Operational management of pilot services	Coordination between units is an important element in supporting the smooth running of ship services.	Has not explained the integration of coordination with pilot competency, digital systems, and environmental conditions.
	Hikam (2026)	Ship service coordination		

Based on this synthesis, previous research has explained the importance of pilot competency, the benefits of digital systems, and the influence of environmental conditions and coordination on ship services. However, relatively limited studies have explained how these three aspects interact in the decision-making process and adaptive response in pilotage services on dynamic river channels. This research fills this gap through an integrated and adaptive operational management framework that connects pilot competency, digital and environmental information, decision-making and coordination, adaptive response, and service effectiveness.

3. METHODOLOGY

3.1 Research Design and Study Context

This study uses a qualitative case study design to examine how pilot competency and the integrated ship service digital system support operational decision-making and service effectiveness in ship pilotage activities. The qualitative case study approach was chosen because this study focuses on understanding actual operational practices, including ship pilotage operations, communication, coordination, pilotage transfer processes, decision-making, and the use of digital systems in pilotage services.

The research was conducted at PT Pelindo Banjarmasin and the Barito River Class I Pilotage Waters, specifically in the operational area extending from the Barito River estuary to the Barito Bridge. The research was conducted from January to May 2026. The operational context of the

research area is characterized by relatively narrow shipping lanes, fluctuations in water levels, sedimentation, ship traffic density, tugboat-barge movements, and reliance on pilot competency and digital information to support navigation decision-making and ship service coordination.

3.2 Unit of Analysis

The unit of analysis in this study is the operational process of ship pilotage services at PT Pelindo Banjarmasin, specifically in the Barito River Class I Mandatory Pilotage Waters. The analysis focuses on how the pilotage service process is planned, coordinated, implemented, monitored, and controlled under actual operational conditions.

The operational processes analyzed include several interrelated activities, namely: Pilot competency and operational decision-making, pilot transfer and communication, Navigation and environmental information, integrated digital service systems, operational coordination, service effectiveness.

Thus, individual informants are not the research unit of analysis. Their experiences, explanations, and operational knowledge are used as sources of evidence to understand the pilotage service process. The analysis focuses on the interrelationships between pilotage competency, navigational and environmental information, communication and coordination, integrated digital systems, and operational decision-making in the implementation of pilotage services.

3.3 Informants and Purposive Sampling

This study involved 11 informants who were purposively selected based on their involvement, experience, and knowledge of the operational processes of ship pilotage services. The informant characteristics, interview dates, duration, interview methods, and interview focus are presented in Table 3.

Table 3. Informants, Operational Roles, and Interview Characteristics

Code	Informant / Position	Operational Role	Date	Duration	Interview Method	Main Interview Focus
P1	Marine Pilot	Ship pilotage and operational navigation decision-making	10 February 2026	30 minutes	In-person interview	Pilot Competency in interpreting Digital and Environmental Information for operational decision-making
P2	Marine Pilot	Ship pilotage operations and adaptive navigation	14 February 2026	35 minutes	In-person interview	Competency and experience in adaptive decision-making under changing Digital and environmental information
KS1	Banjarmasin Harbourmaster Officer	Ship-service administration and system Inaportnet processes	1 March 2026	20 minutes	In-person interview	System Inaportnet use and information flow in ship-service administration
AG1	Shipping Agent / PT Timur Mila Utama (Staff)	Ship-service administration and coordination	15 March 2026	20 minutes	Voice-recorded interview	Digital information reliability and coordination in supporting pilot readiness and service timeliness



Code	Informant / Position	Operational Role	Date	Duration	Interview Method	Main Interview Focus
AG2	Shipping Agent / PT Dharma Lautan Utama (Staff)	Ship-service administration and coordination	20 April 2026	15 minutes	Voice-recorded interview	Sistem information, readiness, and operational conditions in ship-service coordination
AG3	Shipping Agent / PT Gayatri Samudera Mandiri Banjarmasin (Staff)	Ship-service administration and system Inaportnet processes	21 April 2026	15 minutes	Voice-recorded interview	Operational responses to digital-system disruptions and their effects on pilotage coordination
AB1	PT Ambapers Staff	Barito River channel management	5 May 2026	30 minutes	In-person interview	Channel conditions, dredging, bathymetry, and navigational safety
NM1	Master, MV Dharma Rucitra 1	Ship navigation and interaction with pilotage services	10 May 2026	30 minutes	In-person interview	Pilotage, communication, ship manoeuvring, and operational coordination
NM2	Master, MV Barito Equator	Dredging operations in critical areas of Zone 2	15 May 2026	35 minutes	In-person interview	Dredging activities and channel depth in critical areas
NM3	Master, MV Haida	Barito River navigation and ship traffic	15 May 2026	20 minutes	In-person interview	River-channel conditions and ship traffic affecting navigation
O1	IPC Operator, PT Pelindo Banjarmasin	Ship planning, monitoring, and operational control	31 May 2026	30 minutes	In-person interview	System Phinnisi, Inaportnet, and IPC integration, information quality, and operational coordination

3.4 Data Collection

Data were collected from January to May 2026 using three complementary techniques: semi-structured interviews, direct observation, and documentary evidence. These three techniques were used to assess the operational processes of ship pilotage services, including pilot competency, navigation decision-making, communication and coordination, environmental and channel conditions, and the integrated digital service system.

3.4.1 Semi-Structured Interviews

Semi-structured interviews were conducted with informants purposively selected based on their direct involvement in pilotage and ship service activities at PT Pelindo Banjarmasin. The interview guide was developed based on the research objectives and conceptual framework. Questions covered pilotage competency, navigation decision-making, ship approaches, VHF and DSC communications, environmental and channel conditions, digital systems, operational coordination, and service effectiveness.

The same main theme was used throughout all interviews, while follow-up questions were tailored to each informant's position and operational experience. This approach allowed researchers to maintain consistency in the interviews while exploring the specific operational situations experienced by each informant. The main themes and questions are presented in Table 4.

Table 4. Semi-Structured Interview Guide

Interview Topics	Main Questions	In-depth / Follow-up Questions
Pilot Competency	How are your competencies and experience as a pilot applied when facing various operational conditions during ship pilotage services on the Barito River?	What competencies are required in narrow, shallow, or high-traffic areas? How does experience help you interpret operational information?
Operational Navigation Decision Making	How do you make operational navigation decisions during ship pilotage services?	How do you simultaneously consider the ship's draft, channel depth, tides, currents, wind, weather, traffic, and digital information? How do these considerations translate into decisions about speed, position, and route?
Planned Guidance Route / Corridor	How do you determine or adjust the route or corridor used by the ship during pilotage on the Barito River?	How do channel depth, bathymetry, ship draft, wind, current, traffic, and passing arrangements affect route selection?
VHF Communications and Operations	How is VHF communication used to support navigation decisions and operational coordination during pilotage?	How do you handle overlapping or unclear VHF communications? When is DSC used? What information is exchanged with ships, VTS Banjarmasin, tugboat-barge combinations, or dredgers?
Environmental Conditions	How do changing environmental conditions affect your navigation decisions during pilotage?	How do wind, current, tide, weather, fog, smoke, rain, and visibility affect speed, route, execution time, and other operational decisions?
Channel Conditions and Bathymetric Information	How is channel condition and bathymetry information used in making navigation decisions?	How do you identify shallow or critical areas? How do you verify updated bathymetric information? How do sedimentation, dredging activities, or changes in channel depth affect decisions?
Integration of Digital Navigation and Information	How do you integrate PPU, AIS, electronic charts, radar, and bathymetric information in making navigation decisions?	How are position, heading, speed, close point of approach (CPA), time to closest point of approach (TCPA), and course information interpreted? How do you verify digital information with actual conditions? What do you do when digital information differs from ground conditions?
Integrated Digital System	How are the Phinnisi, Inaportnet, and IPC systems used in ship services?	How does the system support service planning, pilot assignment, monitoring, coordination, and operational control? How does the information from the system support pilotage decisions and coordination between operational parties?
Adaptive Navigation	How do you adjust navigation decisions	Under what conditions do you slow down or maintain speed, change route or position,



Interview Topics	Main Questions	In-depth / Follow-up Questions
Integrated Coordination Ship Services	actual conditions change from the initial plan?	delay movement, or change settings when passing? How do you respond to sudden changes in traffic, weather, water conditions, or information?
	How are navigation decisions during pilotage of coordinated with those dock readiness, availability, ship readiness, supporting the ship's movement and agent information coordinated? How are until it arrives at port?	How is ETA information communicated through the operational system? How are dock readiness, availability, ship readiness, and agent information coordinated? How are operational issues handled?
	How do pilot competency, digital information integration, environmental conditions, communication, and coordination affect the effectiveness of ship pilotage services?	How do these factors affect the safety, timeliness, consistency, and continuity of service? What operational conditions most frequently affect service effectiveness?
Operational Improvements	What improvements are needed to strengthen the adaptive capacity and effectiveness of ship pilotage services on the Barito River?	What improvements are needed in pilot competency, digital navigation support, bathymetric information, communications, coordination, or integrated ship service operations digital systems?

3.4.2 Interview Recording and Transcription

Interviews were recorded with the informants' permission to ensure data accuracy. Voice-recorded interviews were transcribed for analysis, while non-recorded interviews were documented through notes based on the same interview guide. Each informant was assigned a code to facilitate data organization and maintain confidentiality.

3.4.3 Observation and Documentary Evidence

Direct observations were conducted during ship pilotage activities, pilot transfers, ship approaches, communication procedures, and the use of digital systems in operational activities. Observations focused on actual operational practices and their relationship to environmental and navigational conditions. Documentary evidence included operational records, information from digital systems, navigation and bathymetry information, service records, relevant regulations, and other documents related to ship pilotage operations. Observation data and documentation were used to supplement and cross-check the interview results.

3.5 Data Analysis

Data dianalisis menggunakan model interaktif Miles dan Huberman (2014), yang dioperasikan melalui tahapan analisis data, coding, kategorisasi, dan analisis tematik. Analisis dilakukan secara sistematis untuk mengidentifikasi pola, hubungan, dan tema yang berkaitan dengan kompetensi pandu, pengambilan keputusan navigasi, kondisi lingkungan dan alur, informasi digital terintegrasi, koordinasi operasional, dan efektivitas pelayanan.

3.5.1 Data Preparation

Interview, observation, and documentation data were organized based on research sources and focus, then compared across informants and sources to identify relevant congruencies, differences, and patterns as a basis for the coding process.

3.5.2 Coding

Data from interviews, observations, and documentation were first reduced and coded based on information relevant to the research focus. Related codes were then grouped into categories, such as

pilot competency, operational decision-making, environmental conditions, digital systems, communication, coordination, and service effectiveness.

3.5.3 Categories

Codes with similar meanings and relevance to the research focus were grouped into categories. This grouping was done to identify broader patterns in the data and serve as a basis for developing research themes.

Table 5. Coding, Categories, and Themes

Data Source	Initial Codes	Categories	Themes
P1, NM1	P2, navigation experience; route knowledge; risk assessment	Pilot Competency	Pilot Competency as Information-Interpretation Capability
P1, NM1	P2, PPU ENC, AIS; bathymetry; tide; ship draft; radar	Integrated navigational information	Digital and Environmental Information
P1, NM1	P2, route selection; speed adjustment; CPA/TCPA; passing point; draft depth assessment	Operational navigation decision-making	Translation of Integrated Information into Navigation Decisions
P1, NM1	P2, changing channel; weather; traffic; adaptive response	Adaptive operational decision-making	Adaptive Navigation under Changing Operational Conditions
NM1, P2	P1, VHF communication; overlapping communication; DSC; traffic information	Operational communication	Operational Communication and Coordination
AB1, NM3	NM2, channel depth; sedimentation; dredging; traffic	Environmental channel conditions	and Environmental and Channel Conditions
KS1, AG2, O1	AG1, Sistem Phinnisi; Inaportnet; flow; assignment; monitoring	IPC; Integrated pilot service system	digital Integrated Digital Service Systems and Operational Coordination
P1, NM1, O1	P2, safety; timeliness; efficiency; coordination; continuity	Service effectiveness	Service Effectiveness and Operational Improvement

3.5.4 Thematic Analysis

The resulting categories were then compared across informants and data sources to identify patterns, relationships, similarities, and differences. These categories were then developed into main themes that describe the operational processes of the pilotage service. The resulting themes were then interpreted based on the research's conceptual framework and used as the basis for compiling the findings.

3.5.5 Findings and Theoretical Interpretation

Empirical findings are organized based on key themes derived from coding and thematic analysis. Human Capital Theory and Systems Theory are used as theoretical lenses in interpreting the findings to explain how pilot competency, digital information, decision-making, coordination, and environmental conditions interact to produce effective pilotage services.

3.6 Trustworthiness and Data Verification

3.6.1 Triangulation

Triangulation was conducted by comparing information from various informant groups and data sources. Information obtained from pilots was compared with information from operational personnel, port stakeholders, and service users, and cross-checked through field observations and operational

documents. Table 5 summarizes the concordance of evidence from various informants regarding pilot competency, digital systems, environmental information, operational decision-making, adaptive response, and service effectiveness.

3.6.2 Thematic Saturation

Theme saturation was assessed gradually by comparing codes, categories, and themes generated by 11 informants. Initial interviews generated codes that formed key analytical categories, particularly those related to guide competency, digital service systems, digital information and the environment, operational decision-making and coordination, adaptive operational response, and service effectiveness. Subsequent interviews provided additional and varied information, but this information could be placed within established categories and did not generate new substantive themes.

As summarized in Table 5, information from informants in the final stage primarily confirmed, strengthened, or varied the themes formed in the previous stage. No additional interviews yielded new substantive categories or themes that required changes to the established thematic structure. Thus, theme saturation was achieved for 11 informants.

3.6.3 Researcher Bias Control

Researcher bias was controlled by comparing interpretations across informant groups and various data sources, ensuring that findings were not based solely on the perspective of a single informant. Researchers maintained a traceability between empirical evidence, codes, categories, themes, and reported findings. Discrepant or inconsistent information was retained for further examination and comparison with other interview results, observations, and operational documents. This procedure was used to reduce the possibility that findings were determined solely by the researcher's initial assumptions or the perspectives of a particular informant group.

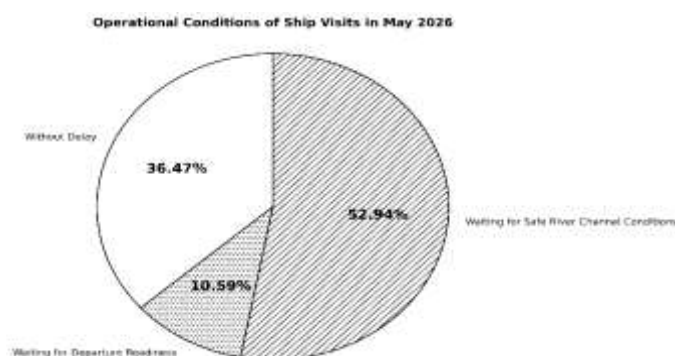
3.6.4 Informed Consent

Prior to each interview, informants were provided with an explanation of the research objectives, scope of the interview, the voluntary nature of participation, and the use of information for academic purposes. Informant consent was obtained before each interview. Interviews were recorded only after obtaining consent. Informant identities are presented in the article using codes to maintain the confidentiality of the information provided.

4. RESULT

4.1 Operational Context: Digital monitoring and service conditions

Operational data obtained from the IPC integrated with the Phinnisi system shows that 85 ship visits were recorded during May 2026. The operational documentation indicates that 45 visits (52.94%) experienced waiting times due to unsafe shipping lane conditions, 9 visits (10.59%) were



related to departure readiness, and 31 visits (36.47%) proceeded without delay. Observations of the service process were used to supplement this information by examining operational conditions and implementing service monitoring.

Figure 2. Operational Conditions of Ship Visits in May 2026

Pilotage services take into account channel conditions and operational readiness. Wait times are primarily related to unsafe channel conditions and departure readiness. The Phinnisi system supports integrated monitoring as the basis for managing and coordinating ship services.

4.2 Pilot Competency

Pilot competency on the Barito River include knowledge of channel characteristics, experience in dealing with operational conditions, and the ability to interpret navigational information related to ships, channels, the environment, and traffic. Knowledge of channel characteristics is an important part of piloting because navigational space conditions differ in each sector. Based on the Decree of the Minister of Transportation of the Republic of Indonesia Number KP 720 of 2017, the shipping lane entering Banjarmasin Port consists of several sectors, with Sector II (Barito Threshold) having a depth of 5 mLWS, a width of 100 meters, and a length of 15,000 meters or 8.1 NM, while Sector III (Trisakti Port) has a depth of 6 mLWS, a width of 200 meters, and a length of 27,025 meters or 14.48 NM. The decree also stipulates the route system in the Banjarmasin Port shipping lane as a two-way route.

4.2.1 Navigation Knowledge and Skills

Pilots understand the characteristics of the channel from the Barito River estuary to Banjarmasin Port, including the differences in conditions in Sectors II and III. This understanding encompasses depth, width, length, route configuration, shallow channel conditions, and available navigation space. The narrower characteristics of Sector II, with a depth of approximately 5 mLWS, are part of the navigational knowledge pilots use to identify conditions in the navigational space. Meanwhile, Sector III is 200 meters wide and has a depth of approximately 6 mLWS. The characteristics of these two sectors contribute to the pilots' knowledge of the channel conditions they navigate during their pilotage services.

Field observations demonstrate the pilots' understanding of the channel's characteristics through observations of ship positions and movements of tugboat-barge combinations during the voyage. Traffic documentation and parallel-track configurations demonstrate the navigational space used during pilotage.

In Sector II, pilotage navigation knowledge also includes parallel track configuration, namely the division of routes consisting of the main route in the middle which is equipped with five routes on the east side, namely routes 1 to route 5, and five routes on the west side, namely routes 1 to route 5. The distance between routes is approximately 0.01 NM or 18.52 meters, with the ship's position adjusted to the available channel space. Pilots understand the channel section that has depth limitations and the characteristics of the space available for ships moving between tugboat-barge combinations. This understanding is also related to the characteristics of ship movement based on draft, tidal conditions, wind direction, and the presence of other ships in the channel.



Figure 3: Ships and tugboat-barge combinations in shipping traffic on the Barito River

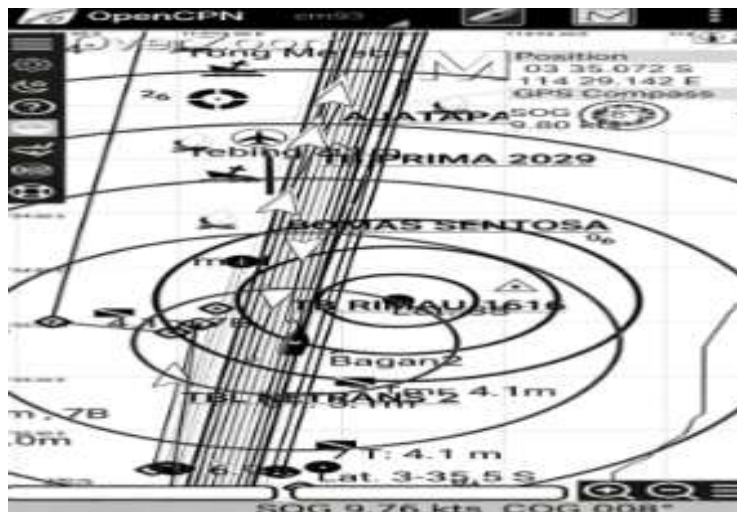


Figure 4. Parallel track system in Banjarmasin waters

Knowledge of channel conditions is essential for navigational competence. Pilots recognize depth changes and critical areas based on bathymetric information and actual conditions, including dredging activities by the MV Barito Equator.

Pilotage navigational knowledge also encompasses the relationship between a ship's draft and channel depth. Pilots understand that ships with different drafts require different amounts of under-keel space when navigating channels with limited depth. Tidal conditions are also understood as part of the channel's characteristics, which are related to changes in effective depth during navigation.

In addition to channel characteristics, pilots understand environmental factors related to ship movement, including wind direction and strength, tides, currents, waves, and visibility. This knowledge also encompasses the movement characteristics of tugboat-barge combinations. Pilots recognize differences between coal-laden and empty barges, including the tendency of loaded barges to move at low tide and the effect of wind on empty barges.

Pilots also understand encounter patterns with other ships and traffic conditions in sections of the channel with limited navigational space. The density of tugboat-barge combinations in Sector II is part of their knowledge of traffic characteristics. The presence of grounded ships is also recognized as a condition that can reduce available navigational space.

“The pilot must understand the characteristics of the channel from the estuary to Banjarmasin Port, including the differences in conditions in Sector II and Sector III, the depth and width of the channel, the position of the parallel track, bathymetric conditions, and the relationship between the ship's draft and the tides in determining the depth required by the ship.” (P1). “The pilot needs to understand the

effects of wind, tides, currents, waves, and visibility on ship movement, as well as the characteristics of tugboat-barge combinations, including the differences in the movement of loaded and empty barges when facing convoys, passing ships, and heavy traffic in sections of the channel with limited navigation space.” (P2). “The pilot understands the condition of the channel and the characteristics of the ship being guided by paying attention to the position of the ship, the channel space, and the movements of other ships before giving directions to the captain, especially in conditions of heavy traffic or limited navigation space.” (NM1).

Navigation Knowledge and Skills includes the pilot's understanding of the characteristics of the channel, depth and route, ship conditions, environmental factors, and traffic movements during the pilotage.

4.2.2 Operational Experience

Pilotage operational experience is built through direct involvement in a variety of pilotage conditions on the Barito River. This experience includes dealing with the different characteristics of coal-laden and empty barges, convoy movements, passing ships, changing wind and tidal conditions, and limited navigation space.

When handling tugboat-barge combinations, pilot experience includes recognizing the characteristics of loaded barges, which can shift or drift under certain conditions, especially at low tide. Empty barges are more easily influenced by wind direction. Experience in dealing with these characteristics becomes part of the operational knowledge developed through pilotage practice.

Operational experience includes dealing with traffic density in Sector II, movements of tugboat-barge combinations, passing in confined spaces, as well as changes in wind, tides, waves, visibility, and channel conditions.

“Piloting experience helps pilots navigate differences in ship characteristics and channel conditions. For coal-laden tugboat-barge combinations, pilots need to understand the tendency of loaded barges to drift, especially during low tide, while empty barges are more susceptible to wind direction. Experience in handling tugboat-barge combinations and passing ships also helps pilots understand ship movement characteristics and available navigational space.” (P2). “Changes in wind direction, tides, traffic density, and the presence of ships coming from the opposite direction can be recognized more quickly through experience in similar conditions, including when navigational space is limited and pilotage adjustments are required.” (NM1).

Operational experience includes pilot experience in dealing with the characteristics of ship movements, convoys and passing, changes in wind and tides, and conditions of navigation space during pilotage.

4.2.3 Information Interpretation Capability

Piloting competency also includes the ability to interpret information related to the condition of the ship, the channel, the environment, and traffic. Information regarding depth, draft, tides, bathymetry, the ship's position, and the movements of other ships are understood as part of the navigational conditions encountered during pilotage.

Interpretive skills are evident in the pilot's understanding of the relationship between ship characteristics and channel conditions. Information regarding the ship's draft is understood in conjunction with channel depth and tidal conditions, while bathymetric information is used to identify depth variations and areas of the channel that require attention. Information regarding the position and movement of other ships is also understood in relation to the navigational space and traffic conditions. In addition to information available through the navigation system, the pilot also pays attention to conditions directly observed during the voyage.

“The pilot uses available navigation information and channel conditions to understand the ship's position, navigation space, and the movements of other ships, then compares them with the actual conditions encountered during the pilotage.” (P1). “Information regarding the ship's position, channel conditions, and the movements of other ships is used to understand the navigation situation before giving directions to the captain.” (NM1).

In addition to understanding navigation conditions, pilots also demonstrated the ability to recognize information limitations when digital systems could not be optimally updated. “Network instability in the estuary area could disrupt the implementation of several service activity stages on

Phinnisi, such as Departure, On Board, Command On, Command Off, and Pilot Off." (P1). In such conditions, pilots coordinated with the IPC via VHF Channel 12 to convey activity status and ensure operational information continued to be communicated.

Information Interpretation Capability includes the pilot's ability to relate ship, channel, environmental and traffic information to navigation conditions, and adjust communications when digital information is not optimally available.

4.3 Digital Service System

Digital systems in ship services at the Port of Banjarmasin are used to support the flow of service information, pilot assignments, work implementation, monitoring, and control of operational activities. The systems used include the Inaportnet system as a port service platform, the Phinnisi system as a ship operational management system for PT Pelindo Banjarmasin, and the IPC as a monitoring and control system for activities in both systems. In addition to the operational service system, the pilotage process is also supported by digital navigation information through the PPU with the Pilotpro system.

4.3.1 Digital Service System and Information Integration

The integration of the Inaportnet, Phinnisi, and IPC systems creates a flow of information from the ship service process to the implementation and monitoring of pilotage work. Information on ship service requests available through the Inaportnet system is linked to the operational service process in the Phinnisi system. This information becomes part of the service planning and pilotage assignment process.

After the piloting Work Order is issued, the job is in Assigned status in the Phinnisi system, meaning a pilot has been assigned to the job. The job is then sent through the Deployed process, making the job information available on the Phinnisi system device in the piloting PPU. Once the job begins to be implemented, the status changes to Live. Piloting activity realization is recorded through the stages of Departure, On Board, Command On, Command Off, and Pilot Off.

Once all activities are completed, the job status changes to Completed. The IPC is used to monitor job progress based on the status recorded in the system. This monitoring includes information regarding pilot assignments, job status, and the progress of piloting activities. The availability and update of information on the Phinnisi system is affected by communication network conditions. From the Barito River estuary, sector II to Tanjung Telan, sector III, internet and cellular network connectivity are not always stable. This condition can hinder the implementation of piloting work on the Phinnisi system through the Departure, On Board, Command On, Command Off, and Pilot Off stages, so job status updates are not always smooth.

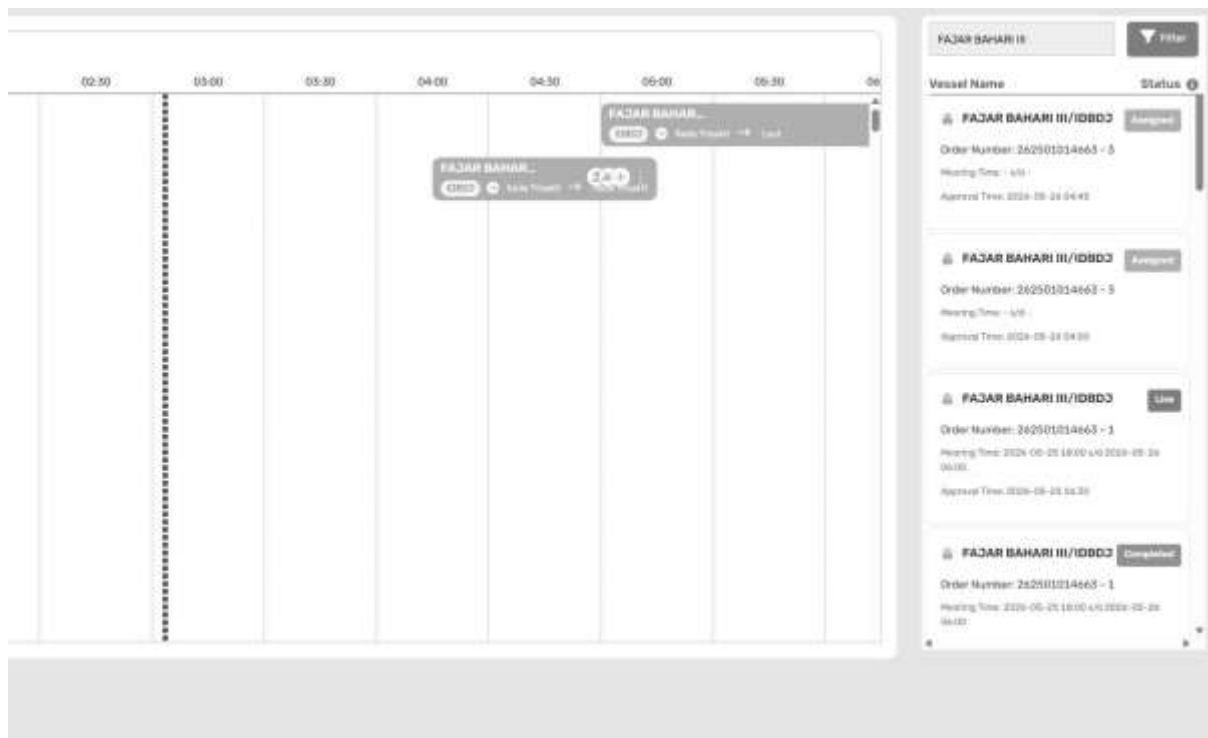


Figure 5 : Monitoring the movement and operational status of the ship.

“The Phinnisi and Inaportnet systems provide ship service information, while the IPC is used to monitor and control operational processes, including service status, pilot assignments, and ship movement progress.” (O1). “The Inaportnet system is used to convey and process ship service information digitally as part of the administration and coordination process.” (KS1). “Digital information from the Phinnisi system helps determine the status and development of services and coordinates the readiness of ships and pilots according to ship movement needs.” (AG1, AG2), “When the system experiences disruptions, the flow of service information becomes abnormal so that coordination, assignments, and service readiness become more difficult.” (AG3), “The instability of the internet and cellular networks from the estuary to Tanjung Telan in Sector III sometimes causes delays in sending or updating the realization of pilotage activities on the Phinnisi system.” (P1).

The integration of the Inaportnet, Phinnisi, and IPC systems encompasses the flow of service information, pilot assignments, job implementation, monitoring, and completion through the Assigned, Deployed, Live, and Completed stages. Information updates at each stage are influenced by the condition of the communication network along the shipping route..

4.3.2 Digital Navigation Information

Pilotage services on the Barito River are supported by various digital navigation information sources used to monitor ship conditions, channels, the environment, and traffic. This information is obtained through the PPU with the Pilotpro system, which displays NCS, AIS, and tidal information. Depth information is obtained through an echo sounder, while radar is used as an additional source of information regarding conditions and objects around the ship. Operational communications are supported by VHF and DSC, while weather and navigation information are also obtained through NAVTEX.



Figure 6. Digital Navigation Information Display on PPU: ENC



Figure 7. Digital Navigation Information Display on the PPU: Tides.

especially when ships pass each other” (NM3), “Explains that pilots consider ship draft, channel depth, tides, currents, wind, and weather simultaneously to see the actual navigation conditions” (P1), “Explains that when actual conditions change, pilots reassess the channel, weather, traffic, and ship conditions” (P2).

Digital and Environmental Information includes the integration of navigation and environmental information, including depth, sedimentation, draft, tides, weather, traffic, and channel conditions, which are read together with actual conditions during pilotage.

4.5 Operational Decision-Making and Coordination

Operational decisions in pilotage services are made through the interpretation of information regarding the ship, the route, the environment, and operational conditions. Information obtained from digital systems and actual conditions is used as assessment material before the pilot determines a course of action and communicates this to those involved in the service.

4.5.1 Information Interpretation

Operational decision-making begins with the use of available service and navigation information to assess the condition of the ship, the channel, and the environment. Service and planning information is obtained through the Phinnisi, Inaportnet, and IPC systems, while navigation information is obtained through the PPU with the Pilotpro system, NCS, AIS, echo sounder, and tidal information. This information is used, along with actual conditions during pilotage, as a consideration before determining operational actions.

"Information from navigation systems and equipment is used to assess the condition of the ship and the channel. Data on depth, tides, weather conditions, and ship information must be considered together before determining action," (P1). "The information received cannot be used immediately. The condition of the channel and the condition of the ship must be understood and then compared with existing information so that decisions are made in accordance with conditions on the ground," (P2).

In the operational decision-making process, service information, navigation, and actual conditions are used as considerations before action is determined.

4.5.2 Operational Communication and Coordination

Operational decisions are communicated and coordinated with the parties involved in ship service delivery. Communication with the ship is conducted using VHF radio, while coordination involves the ship, tugboat-barge combinations, VTS Banjarmasin, Harbor Master, IPC, and related units as needed.

"Decisions made must be communicated to the ship and related parties. Coordination with the VTS Banjarmasin and tugboat-barge combinations is necessary to ensure ship movements are carried out according to operational conditions," (P1). "Coordination takes place during service, not just before the ship moves. Operational conditions and requirements need to be communicated to all involved," (P2).

Communication and coordination are carried out by conveying information to ships, tugboat-barge combinations, VTS Banjarmasin, Harbor Masters, IPC, and related units during service implementation.

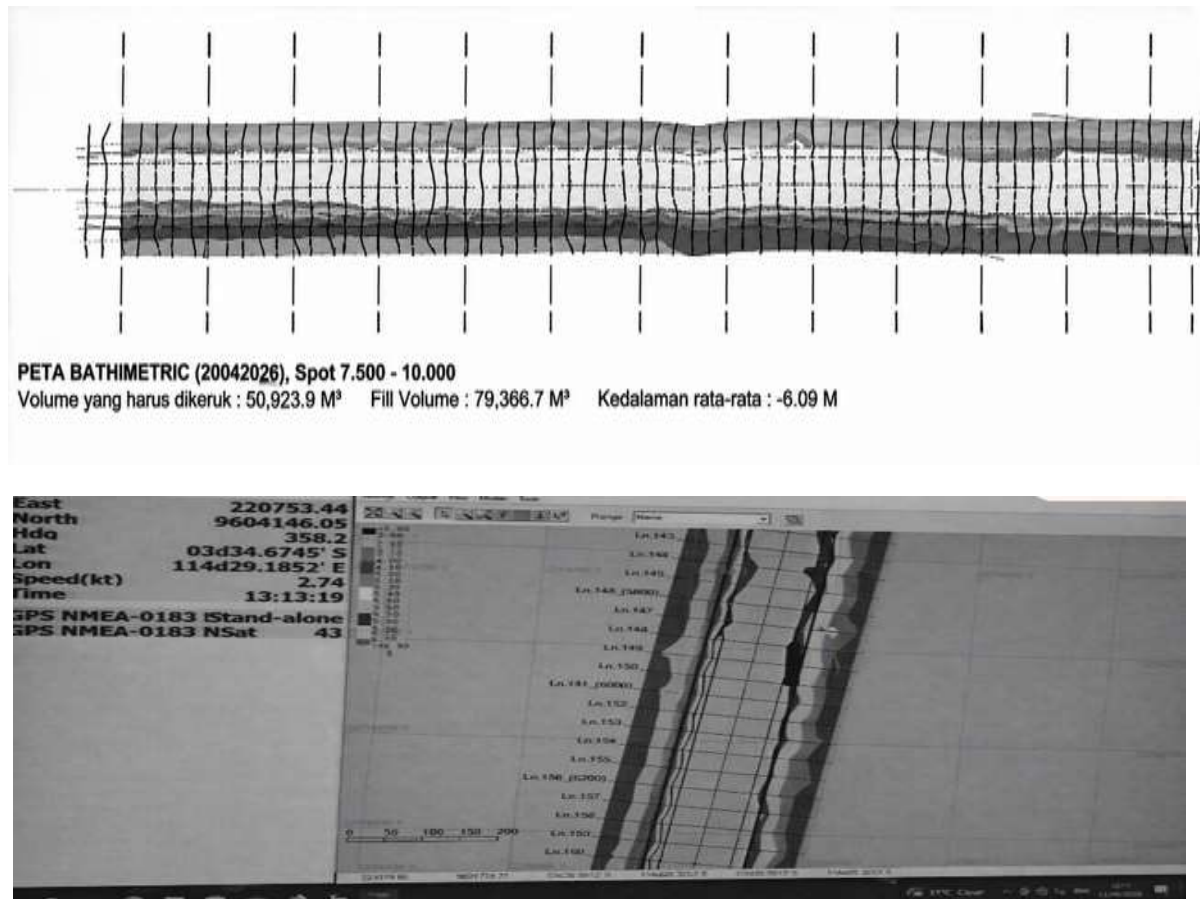
4.5.3 Decision Based on Operational Conditions

The pilot's operational decisions relate to the actual conditions of the ship and the route, particularly in determining speed, selecting or adjusting routes, positioning, and maneuvering time, as well as considering the ship's depth and draft. The pilot correlates the information available in the system with the actual conditions encountered during service.

The characteristics of the Barito River channel, including depth changes, the presence of shallower sections, tidal conditions, and ship draft characteristics, are taken into consideration when determining operational actions. Bathymetric information and channel conditions are used in conjunction with ship and environmental information to assess ship movement conditions.

Bathymetric map documentation in Sector II shows variations in depth in the channel sections which are of concern in the implementation of pilotage. The bathymetric map was created by PT Ambapers based on survey results following dredging activities by the MV Barito Equator. The information on the map serves as a reference during dredging activities to identify sections of the channel requiring treatment. It also provides depth information that pilots can use as a guide for ship navigation.

Figure 9: Bathymetry results after dredging the MV Barito Equator





Changes in operational conditions during pilotage operations are followed by adjustments to the conditions encountered. Adaptive responses include navigation adjustments to weather and flow conditions, communications adjustments, and handling disruptions to digital systems and networks.

4.6.1 Weather, Channel and Navigation Adjustments

Weather and channel conditions are important considerations during pilotage. Changes in wind, waves, visibility, tides, depth, sedimentation, and channel conditions are followed by adjustments to the ship's movements.

"Channel and weather conditions are continuously monitored while the ship is moving. When there are changes in depth, wind, waves, or channel conditions, the ship's speed and movement are adjusted to the conditions encountered." (P1). "Changes in actual conditions are taken into consideration in adjusting the ship's speed, position, and movement during pilotage." (P2).

Adjustments are also made taking into account the ship's draft and the channel's characteristics. For ships with a draft approaching the channel's depth limit, movement is adjusted to tidal conditions and available depth. In shallow areas, speed is reduced to adapt the ship's movement to the channel's conditions.

Navigational responses are made by adjusting the speed, position, route and movement of the ship to changes in weather, depth, tides and channel conditions.

4.6.2 Adaptive Communication

Communication adjustments are made when communication conditions change during service. Operational communications between pilots, ships, tugboat-barge combinations use VHF. In certain situations, such as overlapping or dubbing communication channels, the method of information delivery is adjusted to suit the communication conditions encountered.

"Explains that "when communication via VHF experiences overlap or dubbing, especially in bad weather conditions, night time, heavy rain, or strong winds, communication can be adjusted through the use of DSC to contact the ship in a more targeted manner." (P1).

Communication adjustments are also made through coordination with ships, tugboat- barge combinations, and VTS Banjarmasin according to communication conditions and ship movement requirements during service. Communication responses are made through media adjustments and coordination when communication conditions do not support normal information delivery.

4.6.3 Digital System Disruption Response

Disruptions to digital systems and networks can impact access and updates to operational information during service. The integrated Phinnisi and Inaportnet systems require network availability to update job information and service status. On the service route from Muara to Tanjung Telan in Sector III, internet and cellular network connectivity are unstable, resulting in delays in job status updates on the Phinnisi system.

In the event of a disruption, operational information is coordinated with relevant parties to obtain or convey the necessary information during service.

"When a system or network experiences disruption, service information needs to be coordinated through the relevant parties so that operational processes can continue." (P1,AG1).

Response to system disruptions is carried out through coordination with relevant parties to maintain the availability of operational information during service.

4.7 Service Effectiveness

The effectiveness of pilotage services relates to safety, punctuality, efficiency, coordination, and continuity of service. These five aspects are reflected in service implementation, the readiness of the parties involved, operational conditions, and the ability to maintain service when channel, weather, communication, and system conditions change.

4.7.1 Safety

Safety of service relates to navigational and environmental conditions during the ship's movement. Depth, channel, weather, movement of other ships, and communications are among the conditions considered during service. Adjustments to navigational measures are made when conditions change during pilotage.

"Channel conditions can change during service. If there are changes in depth, wind conditions, waves, or different channel conditions, actions such as ship speed and movement must be adjusted to the circumstances. If communications are disrupted, communication facilities must be adjusted accordingly." (P1, P2)

Safety of service is related to adjusting the implementation of pilotage to the conditions of the channel, depth, weather, movement of other ships, and communication during the movement of the ship.

4.7.2 Timeliness

Timeliness of service is related to the readiness of the pilot, ship, and service facilities, as well as channel and weather conditions. Operational data indicates that there are waiting times for service, including waiting for unsafe channel conditions, ship readiness to depart, and other operational conditions. Pilot readiness is essential for service delivery because pilot availability is required when a ship requires pilotage services.

"The pilot must be ready at the estuary when the ship arrives. Once the pilot is ready, services can be immediately provided according to the ship's needs." (AG1).

Timeliness of service is related to the readiness of the pilot, ship, and service facilities as well as the condition of the route and weather which affect waiting time.

4.7.3 Efficiency

The service implementation utilizes digital systems, navigation information, and environmental information according to operational needs. The Phinnisi and Inaportnet systems are used in the service process and information exchange, while navigation and environmental information are used during pilotage. This information utilization includes depth data, ship position and movement, channel conditions, and navigation information available during the service.

"Information from navigation systems and conditions is used as needed. Depth data, AIS, radar, and other information help assess ship and channel conditions before taking action." (P1, P2).

The use of digital systems, navigation information, and environmental information is part of the implementation of services according to operational needs.

4.7.4 Coordination

Pilotage services involve coordination between pilots, ship, tugboat-barge combinations, VTS Banjarmasin, and related units. Information regarding ship conditions, routes, movements, and service requirements is communicated through operational communications throughout the service. Coordination is carried out according to the conditions and needs of ship movements, including when there are changes in operational conditions.

"Coordination is carried out with ships and tugboat-barge combinations according to ship movement conditions. If there are changes in conditions or specific needs, information is conveyed and coordinated with the relevant parties." (P1, P2).

Service coordination involves pilots, ships and tugboat-barge combinations, VTS Banjarmasin, and other relevant operational units, depending on operational conditions and needs.

4.7.5 Continuity

Service continuity is related to operational readiness, traffic and weather conditions, communications availability, and digital system availability. Changes in service conditions are followed by adjustments to implementation and coordination as needed.

Disruptions in digital systems or networks can impact the availability of service information. In such situations, coordination with relevant parties is necessary to obtain or deliver necessary operational information.

"If the system experiences disruption, the information in the system cannot be used as usual. Coordination with relevant parties is carried out to ensure operational information remains available. If traffic or weather conditions change, services are adjusted accordingly." (AG1, P1).

Continuity of service relates to operational readiness and the continuity of information delivery and coordination when there are changes in flow conditions, weather, communications or digital systems.

5. DISCUSSION



5.1 Findings and theoretical interpretation

The research results show that pilotage services on the Barito River are an operational process that connects pilot competency, digital and environmental information, decision-making, and response to changing operational conditions. Operational data indicates that waiting times are primarily related to unsafe channel conditions and departure readiness. These findings suggest that service effectiveness is influenced not only by administrative readiness but also by the ability to manage changing operational conditions.

5.1.1 Human Capital Theory

Findings indicate that pilot competency consists of navigational knowledge, operational experience, and the ability to interpret information. Knowledge of channel characteristics, draft, tides, traffic, and environmental conditions is combined with experience in various pilotage situations. From a Human Capital Theory perspective, knowledge and experience are resources that support job performance. Research findings show that the value of a pilot competency lies not only in mastering knowledge, but also in the ability to use that knowledge and experience to understand actual conditions before determining operational actions.

5.1.2 Systems Theory

The findings also indicate that pilotage services are a system that connects the Inaportnet, Phinnisi, IPC systems, navigation equipment, communications, pilotage, ships, and environmental conditions. This integration allows for the use of service information, assignments, work implementation, monitoring, and navigation information in operational processes. However, network disruptions demonstrate that system effectiveness depends on the continuity of connections between components. When digital information is not updated regularly, coordination with relevant parties becomes part of the service process. Thus, Systems Theory helps explain that service effectiveness is the result of the interaction between people, technology, information, communication, and operational conditions.

5.2 Pilot Competency as Operational Capability

The findings indicate that pilot competency functions as an operational capability because it connects information to action. Previous research has generally positioned pilot competency in the context of technical knowledge, experience, safety, and risk reduction. This study extends this perspective by showing that pilot competency also involves the ability to interpret various operational information when determining appropriate actions. Pilots do not use information on depth, ship draft, tides, weather, and traffic separately; rather, they interpret these factors in the context of ship and channel conditions. Thus, pilot competency functions as a mechanism that translates information into operational decisions. Navigational knowledge, experience, and interpretive ability shape the pilot's capacity to assess conditions and determine appropriate actions.

5.3 Digital integration and Operational Decision-Making

Digital integration provides information to support operational decision-making, but the available information needs to be interpreted based on actual operational conditions before it can be translated into action. Previous research has generally emphasized digitalization and channel management in terms of information availability and operational support. Consistent with this perspective, this study shows that the integration of Inaportnet, Phinnisi, IPC, and navigation information supports the planning, monitoring, and coordination of pilotage services. However, this study extends previous research, including Ahmadi et al. (2016) on Barito River channel management, by directly linking channel, digital, and environmental information to operational decision-making in pilotage services. This relationship can be formulated as: Digital and Environmental Information → Information Interpretation → Operational Decision-Making → Operational Action. Thus, pilot interpretation functions as the connecting mechanism between available information and operational action, indicating that the value of digital integration depends not only on information availability but also on how the information is interpreted and applied in operational decision-making.

5.4 Adaptive Operational Decision-Making

Operational decisions in this study are adaptive because channel conditions, weather, traffic, communication, and system conditions may change during service delivery. Previous research on ship pilotage has generally emphasized safety, risk reduction, and navigational competence in supporting service delivery. This study extends this perspective by showing that pilot competency and available operational information are used not only to determine initial decisions but also to reassess conditions and adjust actions when changes occur during service delivery. Such changes are followed by adjustments in ship speed, position, route, communication, and coordination. Adaptive response is not a separate process from decision-making but a continuation of the interpretation of actual conditions. When conditions change, pilots reassess the situation and adjust their actions accordingly. This mechanism can be formulated as: Pilot Competency → Digital and Environmental Information → Operational Decision-Making and Coordination → Adaptive Operational Response → Service Effectiveness. Findings related to safety, timeliness, efficiency, coordination, and continuity indicate that adaptive response is an integral part of service delivery when operational conditions change. Thus, the contribution of this study lies in identifying adaptive operational capability as a mechanism that explains how pilot competency and operational information are continuously translated into adjusted actions to maintain service effectiveness.

5.5 Theoretical contribution

This research connects Human Capital Theory and Systems Theory through the operational decision-making process. Pilot competency provides the ability to interpret information, while digital systems provide and stream the information needed in the service process.

Based on this synthesis, this study conceptualizes Operational Adaptive Capability, namely the operational capability to integrate pilot competencies, digital and environmental information, decision-making, coordination, and adaptive responses in the face of changing service conditions.

This concept positions competence and digitalization not as stand-alone factors, but as part of an operational mechanism that connects information, decisions, adaptive actions, and service effectiveness.

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