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Beyond Perceived Compliance: A Mixed-Methods Evaluation of Safety and Security in Ferry Operations on the Merak-Bakauheni Crossing, Indonesia

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ABSTRACT

This study evaluates maritime safety and security on the Merak-Bakauheni ferry crossing in terms of the implementation of safety standards and facilities, the compliance and awareness of service users, and the effectiveness of oversight by the port authority. A convergent parallel mixed-methods design was employed, combining a 43-item questionnaire administered to 166 respondents with field observation and in-depth interviews. Quantitative findings indicate that the availability of safety facilities falls within the very good category with a mean of 4.21, that passenger compliance and awareness achieved the highest mean of 4.25, and that the effectiveness of oversight recorded the lowest mean of 4.08. The qualitative strand, however, exposed operational risks that these perceptions failed to capture, namely main-engine failure during manoeuvring within the port basin, recurrent outages of aids to navigation, and limitations in crew competence in maritime English and emergency medical response. Triangulation revealed a pattern of divergence between favourable perceptions and technical integrity, convergence on weaknesses in regulatory oversight, and complementarity between strong passenger compliance and gaps in niche competence. The study concludes that the locus of the safety problem has shifted from individual behaviour towards system integrity and hardware reliability

INTRODUCTION

The ports of Merak in Banten Province and Bakauheni in Lampung Province constitute the principal node of ferry transport in Indonesia, connecting the islands of Java and Sumatra. The crossing plays a vital role in supporting the mobility of people and goods as well as national logistics distribution, and it is widely recognised as the busiest ferry route in the country, particularly during the Eid homecoming period, the year-end holiday season, and extended public holidays. The intensity of these movements, however, frequently generates operational problems that affect service quality, including passenger and vehicle congestion, departure delays, and heightened exposure to safety and security risks.

Incidents recorded on the crossing, ranging from delayed evacuation procedures and inadequate safety equipment to overcapacity practices and weak supervision of standard operating procedures, indicate that gaps persist within the maritime safety management system. These concerns are not confined to the Indonesian context. Formal safety assessments of roll-on/roll-off passenger (RoPax) operations have repeatedly demonstrated that the residual risk for this vessel category remains within the upper region of what is considered tolerable, even in mature regulatory environments (Endrina et al., 2018; Montewka et al., 2014). Because RoPax vessels carry large numbers of people in a single hull, the consequences of a single failure are disproportionately severe, and the evacuation process itself constitutes a safety-critical task involving thousands of persons in motion under conditions of considerable uncertainty (Ventikos et al., 2023).

The Merak-Bakauheni crossing is further distinguished by its navigational setting. The route traverses the Sunda Strait, a strategic choke point connecting the Indian Ocean with the Java Sea, in which the International Maritime Organization approved a Traffic Separation Scheme (TSS) effective 1 July 2020 in order to enhance navigational safety and prevent marine pollution (Nursyamsu et al., 2025). Quantitative evaluations of the scheme indicate that, although the TSS has contributed to a more orderly traffic pattern, the projected frequency of ship collisions in the strait is expected to rise appreciably as traffic density grows (Wuryaningrum et al., 2024). A formal safety assessment of routeing measures in the same waters concluded that, notwithstanding a substantial reduction in collision frequency attributable to the preferred risk control option, the residual collision frequency remains intolerable and requires additional mitigation strategies (Nugroho et al., 2024). Ferry operations on this crossing therefore take place within a corridor whose baseline navigational risk is already elevated.

Existing scholarship on ferry safety in Indonesia has tended to rely on single-strand designs, most commonly perception surveys of passengers or documentary reviews of regulatory compliance. Such designs are vulnerable to a well-known limitation: passengers can only evaluate what is visible to them, and their assessments therefore reflect formal compliance rather than system integrity. The distinction matters because the most consequential hazards in ferry operations, including machinery failure during manoeuvring and the unreliability of shore-based navigational infrastructure, are largely invisible to

the travelling public. Where a study reports high satisfaction scores without interrogating the technical substrate that underpins them, it risks producing a reassuring but misleading account of the safety situation.

Against this background, the present study evaluates safety and security on the Merak-Bakauheni crossing through a convergent parallel mixed-methods design in which a large-scale perception survey is deliberately triangulated against field observation and in-depth interviews with serving deck officers and regulators. Three research questions guide the enquiry: first, to what extent are safety and security standards implemented on the crossing; second, what factors account for shortfalls in compliance among vessel operators and service users; and third, how effective are supervision and regulatory enforcement by the port authority. The contribution of the study lies less in the individual findings of either strand than in the systematic comparison between them, which permits the identification of divergence, convergence, and complementarity across data sources and thereby yields a more candid account of the safety situation than either strand could produce alone. This differs from prior Indonesian ferry-safety studies that rely on passenger perception alone or on corridor-level navigational modelling (e.g., Jung, 2021; Fauzi et al., 2025), in that the divergence, convergence, and complementarity observed here are treated as the primary analytical evidence rather than as a validity check on a single data source, allowing the study to distinguish formal compliance from underlying system integrity in a way that single-strand designs cannot.

LITERATURE REVIEW

Risk in Roll-On/Roll-Off Passenger Operations

RoPax vessels occupy a distinctive position within the maritime risk landscape. Montewka et al. (2014) developed a proactive framework for estimating risk in maritime transportation systems with a RoPax as the struck vessel, using Bayesian belief networks to model the sequence of events following a collision in open water, and found good agreement between modelled outcomes and historical records. Endrina et al. (2018) applied the first two steps of the IMO Formal Safety Assessment methodology to RoPax operations in the Strait of Gibraltar, a corridor in which approximately one third of some 110,000 annual ship movements involve this vessel type, and constructed a risk matrix from historical accident data and expert judgement. Both studies converge on the observation that the frequency of RoPax incidents is non-trivial and that their consequences, measured in both financial and human terms, are severe.

The evacuation phase has attracted particular attention. Ventikos et al. (2023) developed an enhanced risk model covering the entire event sequence in emergency cases on board large passenger vessels through to the survival-at-sea phase, combining event tree analysis with Bayesian networks. Wang et al. (2023) proposed a risk assessment model for human evacuation from passenger ships structured around human, ship, environment, and organisation factors, and reported that evacuation decision-making and the operation of life-saving appliances constitute the principal risks, whereas passenger behaviour carries a comparatively lower risk priority. Wang et al. (2024) subsequently applied a

fuzzy DEMATEL-ISM-Bayesian network approach to dissect the interdependencies among risk-influencing factors in the same process. Taken together, this body of work suggests that the decisive determinants of evacuation outcomes lie with organisational decision-making and equipment functionality rather than with passenger conduct, a proposition of direct relevance to the interpretation of the present findings.

Regulatory Oversight and Enforcement

The effectiveness of maritime safety regimes depends substantially on the consistency of inspection and enforcement. Li and Zheng (2008) examined ship total loss data alongside port state control records and concluded that the enforcement of port state control demonstrably improves the safety level of maritime transport. Chen et al. (2019) identified the key determinants of ship detention using a grey relational analysis model with improved entropy weighting, while Chuah et al. (2022) analysed six years of inspection data to establish how individual risk factors influence detention outcomes. Karahalios (2025) analysed 43 port state control appeal cases within the Tokyo Memorandum of Understanding and found that in 84% of successful appeals inspectors had applied overly strict interpretations or detained vessels without conducting sufficient additional tests, illustrating that inconsistency in enforcement operates in both directions.

A recent review of the field by Sheriff et al. (2025) synthesised scholarship published between 2017 and 2024 and identified nine critical issues, among them disparities in regional enforcement practices, inconsistencies in inspector training and legal frameworks, and persistent enforcement gaps as perceived by stakeholders. The salience of stakeholder perception is important for the present study, since the perceived consistency of oversight is itself a determinant of compliance behaviour. Where users of a transport service believe that enforcement is episodic rather than routine, the deterrent effect of regulation is correspondingly attenuated.

Navigational Risk in the Sunda Strait

The Sunda Strait presents a particular concentration of navigational hazard arising from high traffic volume, complex geography, and limited navigational facilities. Nursyamsu et al. (2025) reviewed the implementation of the Traffic Separation Scheme in the strait and concluded that, while the scheme has contributed meaningfully to reducing collision risk and improving traffic order, persistent challenges remain in the form of limited Vessel Traffic Service coverage, uneven compliance by foreign vessels, and inter-agency coordination. Wuryaningrum et al. (2024) applied the IALA Waterway Risk Assessment Program to the same waters and calculated a collision frequency of 1.55 x 10-3 accidents per year, projected to rise to 1.44 x 10-3 accidents per year within the TSS area alone by 2035 under forecast traffic growth.

Nugroho et al. (2024) conducted a formal safety assessment of routeing measures connecting the Sunda Strait and the Java Sea and demonstrated that a traffic separation scheme is more effective in reducing collision frequency than a two-way route, with the preferred risk control option achieving a 54% reduction

relative to existing conditions; nevertheless, the residual collision frequency was judged unacceptable. Comparable design studies in other Indonesian waters reach similar conclusions regarding the necessity of structured traffic management in strategic waterways (Fauzi et al., 2025). Beyond the Indonesian context, Liu et al. (2025) proposed a rasterised, data-driven framework for identifying regional collision risk within traffic separation schemes, and Xin et al. (2023) developed a traffic clustering approach for proactively detecting high-risk multi-ship encounter scenarios in complex waters. These methodological advances indicate that the monitoring of dense corridors is increasingly feasible, which in turn raises expectations of the shore-based infrastructure that supports such monitoring.

Human Factors and Safety Culture

Human and organisational factors remain the dominant contributory category in maritime casualties. Chauvin et al. (2013) analysed collisions reported to investigative authorities in the United Kingdom and Canada using an adapted Human Factors Analysis and Classification System and found that most collisions arise from decision errors, with preconditions including loss of situational awareness, deficits in inter-ship communication, and weaknesses in bridge resource management. Shi et al. (2024) identified manoeuvring, course maintenance, decision-making, cognitive capacity, situational awareness, and communication as the seafarer competencies most critical to accident prevention. Fan et al. (2023) advanced a conceptual framework for incorporating seafarer psychological factors into maritime safety assessment, while Veltsin et al. (2025) demonstrated through a DEMATEL analysis that decision-making skills mediate the synergistic effects of training, leadership, and communication upon safety culture.

Safety culture itself has been shown to exert a measurable influence on behaviour at the operator level. Xi et al. (2025) reported empirical evidence from the shipping industry that safety culture shapes the safety behaviour of deck officers, and Jung (2021) documented perceptual differences in maritime safety climate across seafarer groups, indicating that safety climate is neither uniform nor uniformly perceived within a single fleet. Fatigue represents a persistent and unresolved contributor to casualties despite long-standing regulation of rest hours (Rajapakse & Emad, 2023). Studies of ferry services in comparable archipelagic settings similarly emphasise the interaction between operator practice, regulatory supervision, and passenger expectation in determining safety outcomes (Gohari et al., 2025).

Research Gap

Two gaps emerge from this review. First, the literature on RoPax and evacuation risk is dominated by modelling approaches that draw upon historical casualty statistics or expert judgement, and comparatively few studies collect primary perception data alongside operator testimony within a single design. Second, the literature on the Sunda Strait TSS is concerned principally with the corridor as a navigational system, and rarely descends to the level of the

individual ferry service that operates within it. The present study addresses both gaps by examining a single high-density ferry crossing through parallel quantitative and qualitative strands, and by treating the discrepancy between the two as an analytical resource rather than as measurement error. Jung (2021), for instance, evaluated maritime safety climate exclusively through seafarers' self-reported perceptions, without independent verification against observed operational conditions, while Fauzi et al. (2025) examined the Sunda Strait traffic separation scheme at the level of the corridor as a whole, without descending to the operational practice of an individual ferry service. Neither gap has, to the authors' knowledge, been addressed through a design that triangulates perception data against direct observation and operator testimony at the level of a single high-density crossing.

The contribution of this study relative to the literature reviewed above is accordingly twofold. First, it extends modelling-based evaluations of RoPax and evacuation risk (e.g., Montewka et al., 2014; Ventikos et al., 2023) by grounding the assessment in primary perception data collected alongside operator testimony, rather than in historical casualty statistics or expert judgement alone. Second, it brings the analysis of the Sunda Strait traffic corridor down to the level of a single ferry service, complementing corridor-wide navigational studies (e.g., Nugroho et al., 2024; Fauzi et al., 2025) with an operational account of how standards are implemented, complied with, and enforced on one specific crossing.

METHODOLOGY

Research Design

This study adopted a convergent parallel mixed-methods design in which quantitative and qualitative data were collected concurrently, analysed independently, and subsequently merged during interpretation. The rationale for this design lies in the complementary epistemic strengths of the two strands: the quantitative strand furnishes measurable and generalisable evidence concerning perceptions of safety across a large body of service users, while the qualitative strand supplies depth and operational context that survey instruments cannot access. The overall design and the logic of integration are represented in Figure 1.

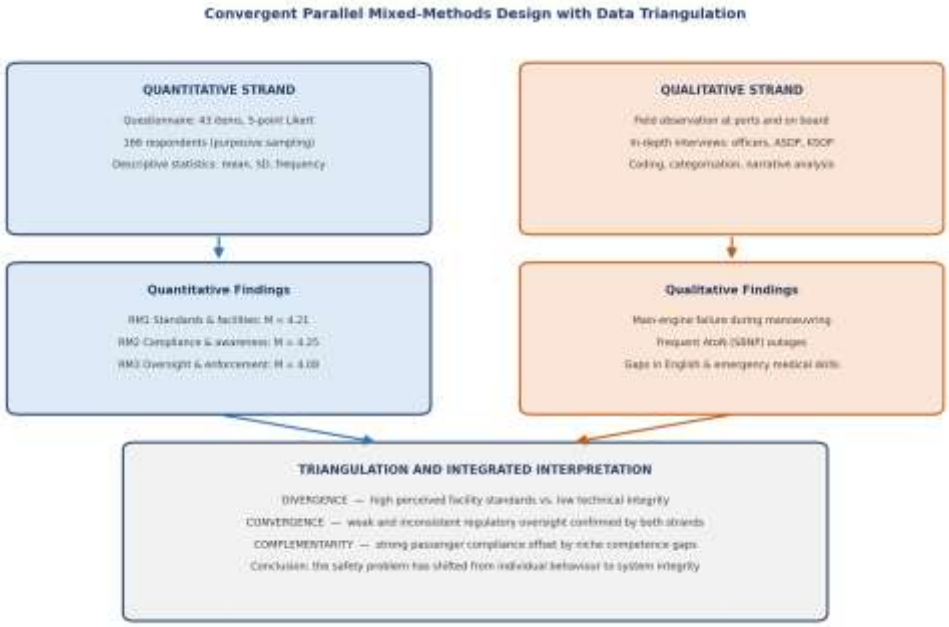


Figure 1. Convergent Parallel Mixed-Methods Design with Data Triangulation.

Setting and Timeframe

Fieldwork was conducted at the Port of Merak in Cilegon, Banten Province, and at the Port of Bakauheni in South Lampung Regency, Lampung Province. These sites were selected because the Merak-Bakauheni crossing is the busiest ferry link in Indonesia and therefore constitutes a critical case for the evaluation of ferry safety systems. Data collection extended over three months, from September to November 2025. This window was chosen deliberately to fall outside the peak homecoming season, so that the resulting account would reflect routine operating conditions rather than the exceptional arrangements mobilised during periods of surge demand.

Population and Sampling

The study population comprised four groups directly involved in the delivery of ferry services on the crossing: port personnel responsible for regulating passenger and vehicle flow; ships' crew responsible for vessel operation and passenger safety; passengers as users of the service; and harbourmaster personnel exercising supervisory and enforcement functions. Purposive sampling was applied on the ground that not all members of the population possess information relevant to the research focus. A total of 166 respondents completed the questionnaire, drawn proportionally from each group. For the qualitative strand, in-depth interviews were conducted with the Chief Officer and Second Officer of a ferry operating on the route, together with representatives of the operator and the harbourmaster and port authority office.

Inclusion and Exclusion Criteria

Respondents were eligible for inclusion where they held current, direct involvement in the delivery or use of ferry services on the Merak-Bakauheni crossing during the fieldwork period of September-November 2025, and were

able to provide first-hand testimony or judgement relevant to at least one of the three research questions. Individuals without current operational responsibility on the crossing, and questionnaire returns that were incomplete or internally inconsistent, were excluded from analysis.

Instruments and Data Collection

Three complementary techniques were employed. Field observation was conducted both within the port precincts and on board ferries, and was directed at the availability and condition of safety facilities including life jackets, life rafts, fire-fighting equipment, evacuation routes, and safety signage, as well as at the operational procedures followed during the embarkation and disembarkation of passengers and vehicles. In-depth interviews were conducted with parties holding substantive responsibility for the delivery of the service in order to elicit detailed accounts of constraints, the effectiveness of supervision, and the perceptions of different actors regarding the implementation of safety standards. The questionnaire comprised 43 items measured on a five-point Likert scale, organised into three dimensions corresponding to the research questions: implementation of standards and facilities, compliance and awareness, and effectiveness of oversight and enforcement.

Instrument Validity and Reliability

Content validity of the questionnaire was established through expert judgement: the item pool was reviewed against the three research questions and refined prior to fieldwork so that each item corresponded unambiguously to one of the three dimensions of implementation, compliance, and oversight. The qualitative instruments (the observation checklist and interview guide) were reviewed on the same basis for coverage of the three research questions before use in the field. [Author to report here the reliability statistic actually computed for the questionnaire, e.g., Cronbach's alpha for each dimension together with the sample on which it was calculated, before submission.]

Data Analysis

Quantitative data were analysed using descriptive statistics, including frequency, percentage, mean, and standard deviation, in order to characterise the distribution of responses across the three dimensions and to identify individual items registering unusually high or low agreement. Qualitative data derived from interviews and observation were analysed through coding, categorisation, and narrative interpretation, with the aim of identifying patterns, themes, and relationships among the factors influencing safety and security. Integration was performed at the interpretive stage through systematic comparison of the two datasets, classified according to whether the strands diverged, converged, or complemented one another. This classification structures the presentation of results and forms the analytical core of the study.

Ethical Considerations

Participation in the study was voluntary; respondents and interviewees were informed of the purpose of the research and the intended use of their responses before providing consent, and individual identities have been withheld in the reporting of qualitative findings. [Author/institution to insert the reference number of the ethical clearance or institutional review, if applicable, before submission.]

RESEARCH RESULT

Overall Perception of Safety and Security

Descriptive analysis of the 43 questionnaire items completed by 166 respondents indicates that perceptions of safety and security on the Merak-Bakauheni crossing fall within the very good category, with an overall mean of 4.18. Seventy-eight per cent of responses were concentrated in the strongly agree and agree categories, suggesting that respondents were in general satisfied with and felt secure in the service provided. Variation across the three dimensions nonetheless identifies specific areas warranting closer attention, as summarised in Table 1.

Table 1. Comparison of mean scores by research question dimension.

Research question	Focus variable	Mean	Interpretation
RQ 1	Implementation of standards and facilities	4.21	Very good
RQ 2	Compliance and awareness factors	4.25	Very good
RQ 3	Effectiveness of oversight and regulation	4.08	Good
Overall	All 43 items	4.18	Very good

Implementation of Standards and Availability of Facilities

This dimension, comprising 23 items concerning the physical condition of vessels, equipment, and formal procedures, achieved a mean of 4.21. The magnitude of this score reflects the success of operators in satisfying minimum standards and in addressing those aspects readily observable by passengers. Key items within the dimension are presented in Table 2.

Table 2. Key Items within the Implementation of Standards Dimension.

Questionnaire item	Mean	Remark
Q1: Safety facilities (life jackets, life rafts) are adequate	4.38	Highest score within this dimension
Q5: Fire-fighting systems function properly	4.35	Indicates confidence in emergency readiness

Questionnaire item	Mean	Remark
Q9: Vessels never operate in overcapacity conditions	4.09	Relatively low; indicates respondent doubt

The results indicate that, in administrative terms, the completeness of safety assets has been verified favourably by respondents, with the item concerning the adequacy of life jackets and life rafts attracting the highest score within the dimension at 4.38. The comparatively lower score of 4.09 recorded by the item asserting that vessels never operate in overcapacity conditions constitutes an early indication of an operational gap inconsistent with formal standards. This decline signals public unease regarding the integrity of loading limits, notwithstanding a favourable assessment of equipment provision.

Compliance and Awareness

The dimension covering the behaviour, awareness, and compliance of passengers and crew achieved the highest mean of the study at 4.25. Key items are presented in Table 3.

Table 3. Key Items Within the Compliance and Awareness Dimension.

Questionnaire item	Mean	Remark
Q34: Passengers comply with the prohibition on remaining on the vehicle deck	4.55	Highest score across all 43 statements
Q31: Passengers know and understand safety procedures	4.45	Very high level of passenger awareness
Q33: Crew respond promptly in providing instruction or assistance	4.30	Indicates professionalism of ship personnel

The mean of 4.55 recorded by the item concerning passenger compliance with the prohibition on remaining on the vehicle deck represents the highest score across all 43 statements. This finding is significant because it indicates that educational and enforcement efforts have succeeded in establishing a robust culture of discipline among service users. The favourable perception is reinforced by the score of 4.45 for passenger knowledge and understanding of safety procedures, which suggests that the human factor as it pertains to passengers is no longer the principal source of risk but has instead become a strength within the safety ecosystem of the crossing.

Effectiveness of Oversight and Enforcement

The oversight dimension, encompassing the role of the port authority and the enforcement of regulation, recorded the lowest mean at 4.08. Although this figure remains within the positive range, it signals dissatisfaction or doubt among respondents. Critical items are presented in Table 4.

Table 4. Critical Items Within the Oversight and Enforcement Dimension.

Questionnaire item	Mean	Remark
Q42: Supervision is conducted routinely, not only during peak season	3.91	Lowest score across all 43 statements
Q25: Supervision of vehicle overcapacity is firmly enforced	4.01	Second lowest; indicates lack of firmness
Q27: Coordination among supervisory agencies is effective	4.15	Comparatively higher, yet still questioned

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The lowest scores in the study were recorded by the item concerning the routine conduct of supervision outside peak season, at 3.91, and the item concerning firm supervision of vehicle overcapacity, at 4.01. Respondents evidently doubt the consistency of supervision and consider that the supervisory authority tends to concentrate its attention upon particular periods, namely the homecoming and holiday seasons, while neglecting daily operations. This doubt is reinforced by the score for overcapacity enforcement, which reflects a public view that regulatory enforcement in this area remains weak or susceptible to compromise. Given that overcapacity constitutes one of the most consequential safety risks in ferry operations, doubt on this item represents a serious signal for the authority.

Qualitative Findings

Interviews with the Chief Officer and Second Officer of a ferry operating on the route provided substantive context regarding operational vulnerabilities not disclosed by the favourable survey responses. Three findings are of particular consequence. First, officers reported that the main engine had failed suddenly during manoeuvring within the port basin. Manoeuvring in confined port waters demands precision and full control, and engine failure at this juncture may result in the vessel striking a berth or another vessel, or grounding, with substantial potential for loss of life and property. Second, officers reported that aids to navigation in the approaches to the Port of Merak frequently cease to function. Inoperative aids to navigation disrupt navigational guidance, particularly at night or in poor visibility, in a corridor already characterised by dense traffic within the Sunda Strait Traffic Separation Scheme.

Third, interviews identified specific competence limitations constituting security gaps. Crew acknowledged insufficient detailed knowledge in managing emergency medical situations, particularly childbirth, in the absence of medical personnel on board. They further acknowledged limited proficiency in maritime English communication, a significant constraint given the proximity of the crossing to Indonesian Archipelagic Sea Lane I, along which foreign merchant vessels transit. Communication failure in a congested area may precipitate collision between vessels of different flags.

DISCUSSION

Divergence: Perceived Compliance versus Technical Integrity

The most consequential finding of this study is the marked disparity between favourable respondent perception and the operational reality disclosed by operators in the field. The quantitative strand places the implementation of standards and the availability of facilities in the very good category at 4.21, with items concerning the provision of life jackets, life rafts, and fire-fighting equipment exceeding 4.30. The qualitative strand, by contrast, exposes a fundamental threat to system reliability in the form of sudden main-engine failure during manoeuvring, a finding that stands in direct contradiction to the survey mean.

The implication of this divergence is that the favourable perception recorded by respondents reflects the satisfaction of formal compliance requirements, whereas the testimony of crew reveals a failure of technical integrity. The risk of engine failure while manoeuvring within a port basin, an environment demanding high precision, is exponentially more hazardous than a shortfall in the number of life jackets. This finding indicates either that the vessel maintenance regime is not functioning optimally or that vessels in service have exceeded the limits of their operational reliability. It constitutes a serious warning that safety on the Merak-Bakauheni crossing rests upon a fragile technical foundation. Respondents, being predominantly passengers, have no access by which to assess the technical condition of machinery, and their assessment is therefore necessarily confined to what is visible.

This pattern accords with the emphasis in the evacuation risk literature upon organisational and equipment factors rather than passenger conduct. Wang et al. (2023) found that evacuation decision-making and the operation of life-saving appliances constitute the principal risks in human evacuation from passenger ships, whereas passenger behaviour carries a lower risk priority. The present findings extend this observation to the pre-emergency phase: the reliability of propulsion machinery, which determines whether an emergency arises at all, lies entirely outside the perceptual field of the travelling public and is correspondingly absent from perception-based evaluations of safety.

Convergence: Weaknesses in Regulatory Oversight

In the oversight dimension the two strands converge, albeit from different vantage points, upon the same conclusion. The lowest score across all 43 items was recorded by the statement that supervision is conducted routinely rather than only during peak season, at 3.91, situating it at the lower threshold of the good category and rendering it the weakest indicator in public perception. This weakness is reinforced by the qualitative finding that aids to navigation in the approaches to the Port of Merak frequently cease to function.

The interpretive link between these two findings is instructive. Aids to navigation fall within the responsibility of the navigational authority, and their frequent failure is plausibly attributable to a reduction in routine supervision and maintenance outside the peak season, precisely the deficiency identified by respondents. Where the authority concentrates upon vessel readiness while neglecting vital shore-based navigational infrastructure, the risk of casualty

increases, particularly during hours of darkness. Respondents doubted consistency, and conditions in the field indicate that their doubt is well founded. Effective supervision must encompass the system in its entirety, extending from the vessel to the supporting infrastructure.

This interpretation is consistent with the broader port state control literature. Li and Zheng (2008) established that enforcement improves safety outcomes, while Sheriff et al. (2025) identified enforcement gaps and stakeholder perceptions as critical issues within contemporary oversight practice. Karahalios (2025) demonstrated that inconsistency in inspection practice is itself a source of dispute and inefficiency. The present findings suggest that inconsistency in the temporal distribution of supervisory effort constitutes an analogous problem: episodic enforcement produces episodic compliance, and the intervals between periods of intensive scrutiny become the intervals in which infrastructure reliability degrades.

A parallel convergence is evident in relation to overcapacity. The item concerning firm enforcement against vehicle overcapacity recorded a mean of 4.01, indicating that the public perceives tolerance or compromise in the enforcement of loading limits. This score functions as a counterweight to the very high score of 4.55 for passenger compliance with vehicle deck restrictions. In other words, although passengers are highly disciplined in observing prohibitions imposed upon them, they nevertheless doubt the resolve of the authority in ensuring that vessel capacity is not exceeded. The locus of the problem has accordingly shifted from passenger behaviour to the integrity of enforcement within the port.

Complementarity: Strong Compliance and Niche Competence Gaps

The qualitative strand adds a dimension to the discussion of human factors that complements the high quantitative score of 4.25 for compliance and awareness. Elevated compliance scores demonstrate the success of general safety socialisation, but the interviews disclose deficiencies in niche competence. The acknowledgement by crew of insufficient detailed knowledge in managing emergency childbirth reveals a gap in the standard safety training curriculum. Although crew hold basic first-aid certification, complex and sensitive medical scenarios exceed the scope of that preparation. On the short Merak-Bakauheni passage the time available for evacuation to shore-based medical facilities is critical, and failure of on-board management may prove fatal.

The acknowledgement of limited maritime English proficiency is similarly consequential in view of the proximity of the crossing to the Sunda Strait Traffic Separation Scheme and Indonesian Archipelagic Sea Lane I. Ineffective communication with foreign merchant vessels, particularly in close-quarters situations, may precipitate an international casualty. This finding aligns closely with Chauvin et al. (2013), who identified deficits in inter-ship communication among the preconditions for collision, and with Shi et al. (2024), who ranked communication among the seafarer competencies most critical to accident prevention. Although this competence was not measured directly by the

questionnaire, it constitutes a warning signal that must be integrated into the assessment of both compliance and oversight.

Implications for the Navigational Corridor

The findings acquire additional weight when situated within the documented risk profile of the Sunda Strait. Wuryaningrum et al. (2024) projected that collision frequency within the TSS area will rise substantially by 2035 under forecast traffic growth, and Nugroho et al. (2024) concluded that residual collision frequency in the corridor remains intolerable even under the preferred risk control option. Nursyamsu et al. (2025) identified limited Vessel Traffic Service coverage and inter-agency coordination as persistent challenges to the effective operation of the scheme. Against this baseline, the unreliability of aids to navigation reported by crew is not a peripheral maintenance issue but a direct erosion of the mitigation measures upon which the corridor's risk assessment depends. Methodological advances in traffic monitoring, including the rasterised risk identification framework of Liu et al. (2025) and the traffic clustering approach of Xin et al. (2023), presuppose a functioning shore-based infrastructure; their potential contribution to safety in the Sunda Strait is therefore contingent upon the reliability deficits identified here being addressed.

Limitations

Several limitations qualify the interpretation of these findings. First, the qualitative strand rests upon interviews with a small number of officers serving on a single vessel, and the technical failures reported may not be representative of the wider fleet operating on the crossing. Second, the quantitative strand measures perception rather than objective safety performance, and no attempt was made to corroborate respondent assessments against inspection records, casualty statistics, or maintenance documentation. Third, purposive sampling, while appropriate to the research objectives, limits the statistical generalisability of the survey results. Fourth, data collection outside the peak season, although deliberate, means that the findings do not capture conditions during periods of surge demand, when both risk exposure and supervisory intensity differ materially from the routine state documented.

CONCLUSIONS AND RECOMMENDATIONS

This study evaluated safety and security on the Merak-Bakauheni ferry crossing through a convergent parallel mixed-methods design. The implementation of standards and the availability of safety facilities were assessed by respondents as very good, with a mean of 4.21, supported by a high level of passenger compliance. The integrity of maritime safety and security is nevertheless not fully assured, owing to a very high operational risk arising from the potential failure of ship machinery during manoeuvring. The human factor as it pertains to service users proved highly satisfactory, with compliance and awareness attaining the highest mean of 4.25; current threats derive instead from environmental factors, notably traffic density within the Sunda Strait Traffic Separation Scheme, and from limitations in specific crew competencies including maritime English and emergency medical response. Oversight by the port

authority fell within the good category with a mean of 4.08, but public doubt persists regarding the consistency of routine supervision and the firmness of enforcement against overcapacity, reinforced by qualitative evidence of unreliable aids to navigation.

Four practical recommendations follow. First, vessel operators should institute in-depth and unscheduled technical stress testing of propulsion machinery in order to detect incipient operational failure, with priority accorded to vessels serving high-density crossings. Second, operators should mandate refresher training in maritime English communication and specialised training in emergency medical scenarios in order to close the identified competence gaps. Third, the port and navigational authorities should act immediately to restore and guarantee the reliability of aids to navigation in the approaches to Merak and Bakauheni, and should enforce overcapacity regulation through sanctions that are not open to negotiation. Fourth, the pattern of supervision should be reformed from a reactive posture concentrated upon peak season to a routine and randomised regime, in direct response to the weakest indicator identified by respondents.

ADVANCED RESEARCH

Four avenues for further enquiry are indicated. First, subsequent research should employ safety culture analysis to explain the divergence between respondent perception and operational reality documented here, drawing upon instruments developed for the maritime sector (Jung, 2021; Xi et al., 2025). Second, studies should examine the integration of smart port technologies for managing traffic density within the Sunda Strait Traffic Separation Scheme in order to mitigate collision risk with vessels transiting the archipelagic sea lane, building upon the monitoring frameworks proposed by Liu et al. (2025) and Xin et al. (2023). Third, the perception measures employed here should be triangulated against objective indicators including port state control detention records, machinery defect reports, and aids to navigation availability statistics, so that the gap between perceived and actual safety can be quantified rather than merely demonstrated. Fourth, a longitudinal design spanning both peak and routine periods would permit assessment of whether the inconsistency in supervision perceived by respondents is reflected in measurable variation in safety performance

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