Developing a Risk-Informed Manning Policy for Non-Self-Propelled Vessels: Evidence from the Hainan Free Trade Port

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Abstract: *Non-self-propelled vessels (NSPVs)-including pontoons, floating docks, dredgers, and accommodation barges-play a vital role in port operations, offshore construction, and maritime logistics. However, their crewing practices often lack standardized regulation, leading to operational risks and inadequate protection of seafarers' welfare. Drawing on empirical data from 127 NSPVs operating within the Hainan Free Trade Port (FTP), this study diagnoses systemic manning deficiencies by benchmarking against key international regulatory frameworks, particularly the International Labour Organization's Maritime Labour Convention (MLC 2006), the International Maritime Organization's Principles of Minimum Safe Manning (Resolution A.1047(27)), and the Maritime and Port Authority of Singapore's (MPA) guidelines for auxiliary vessels. The analysis reveals widespread issues of under-manning, ambiguous crew responsibilities, and fatigue-related hazards, compounded by the absence of risk-based, context-sensitive manning criteria. In response, this paper proposes a policy framework that links vessel function, operational environment, and task complexity to differentiated crewing requirements. This approach integrates dynamic risk assessment, digital monitoring, and compliance incentives-positioning it not as a rigid prescriptive standard, but as a flexible and adaptive governance tool. The findings offer practical insights not only for Hainan FTP but also for other emerging maritime jurisdictions seeking to align local practices with global safety and labor norms.*

Keywords: *non-self-propelled vessel; safe manning; maritime regulation; Hainan Free Trade Port; MLC 2006; maritime policy*

1. Introduction

Non-self-propelled vessels (NSPVs)-such as mooring pontoons, floating cranes, dredgers, and accommodation barges-are indispensable assets in modern port ecosystems and coastal infrastructure projects. Despite their operational significance, NSPVs have historically received limited attention in maritime safety regulation, particularly concerning crewing requirements. Unlike self-propelled ships, which are subject to well-established international standards for minimum safe manning, NSPVs often operate in a regulatory grey zone due to their stationary or semi-stationary nature, diverse functions, and variable crewing needs (Chen & Wang, 2021).

The International Maritime Organization (IMO) acknowledges in Resolution A.1047(27) that "all ships must be sufficiently and effectively manned to ensure safety," yet it provides no specific guidance for NSPVs, leaving implementation to national authorities. Similarly, while the Maritime Labour Convention, 2006 (MLC 2006) sets universal baselines for working hours, rest periods, and living conditions aboard ships, its application to NSPVs is frequently contested on the grounds that such vessels are "not engaged in navigation" (ILO, 2006; Sampson & Zhao, 2020). This ambiguity has resulted in inconsistent enforcement and, in many cases, de facto exemption from core labor protections.

In contrast, some advanced maritime administrations have begun addressing this gap. The Maritime and Port Authority of Singapore (MPA), for instance, requires all cargo-handling or personnel-transfer barges-even when moored-to maintain at least one certified crew member on watch for safety and emergency response (MPA, 2022). The European Union has also encouraged member states to incorporate auxiliary vessels into national manning assessment schemes under Directive 2008/106/EC.

These initiatives reflect a growing recognition that safety risks on NSPVs-such as fire, flooding, structural failure, or unauthorized boarding-are not diminished by the absence of propulsion.

In China, the rapid expansion of port infrastructure and offshore activities under national strategies like the Hainan Free Trade Port has led to a surge in NSPV deployment. Yet, regulatory oversight remains fragmented. Current practices rely heavily on ad hoc arrangements or informal norms, resulting in under-manning, role overlap, and excessive duty hours-conditions that compromise both operational safety and seafarer well-being.

To address this critical governance shortfall, this paper undertakes an empirical investigation of 127 NSPVs operating in Hainan FTP. Rather than proposing a rigid technical standard, we develop a policy-oriented framework grounded in observed operational realities and aligned with international best practices. By integrating insights from IMO principles, ILO labor safeguards, and Singapore's pragmatic regulatory model, our analysis offers a flexible, evidence-based pathway for enhancing NSPV safety management-one that balances regulatory feasibility with human and operational security.

This regulatory gap is particularly acute in rapidly developing economies like China, where the pace of infrastructure expansion often outstrips the development of corresponding safety frameworks. The Hainan Free Trade Port, as a national strategic initiative, exemplifies this dynamic. Its ambitious goals to become a global maritime hub have catalyzed an unprecedented influx of diverse NSPVs, from sophisticated floating dry docks servicing international vessels to simple pontoons supporting local tourism. This heterogeneity, coupled with a workforce that may include both highly skilled technicians and informal laborers, creates a complex operational landscape where a one-size-fits-all manning policy is not only impractical but potentially dangerous. Therefore, a nuanced, risk-informed approach is not merely an academic exercise but an urgent operational necessity.

This study therefore asks: How can a risk-informed manning policy be designed for NSPVs that balances operational feasibility, safety, and seafarer welfare in emerging port economies?

2. Literature Review

The regulatory and scholarly discourse on safe manning has traditionally centered on self-propelled commercial vessels, with limited attention to non-self-propelled vessels (NSPVs). This gap stems partly from the historical classification of NSPVs as "non-ships" or "floating structures" under certain national legal systems, thereby excluding them from conventional maritime safety regimes (Psaraftis & Kontovas, 2015).

The International Maritime Organization (IMO) provides the foundational principle that "a ship must be sufficiently and effectively manned to ensure the safety of life at sea, the security of the ship, and the prevention of pollution" (IMO Resolution A.1047(27), 2011). However, this resolution offers no operational criteria for NSPVs, which are often excluded from flag state manning certification processes due to their lack of propulsion. While the IMO's ISM Code implicitly applies to all vessels engaged in commercial operations, its implementation for NSPVs remains inconsistent across jurisdictions (Chang & Wang, 2019).

In parallel, the International Labour Organization's Maritime Labour Convention, 2006 (MLC 2006) establishes minimum standards for seafarers' working conditions, including maximum hours of work (14 hours in any 24-hour period) and minimum rest (10 hours in any 24-hour period). Article II explicitly covers "all ships ordinarily engaged in commercial activities," yet enforcement on NSPVs is frequently undermined by administrative discretion. Sampson and Zhao (2020) note that port state control officers often waive MLC inspections for moored barges, assuming they pose "low risk"-a practice that neglects hazards such as fire, toxic exposure, or unauthorized access.

A notable exception is Singapore, where the Maritime and Port Authority (MPA) has adopted a functional approach. Under its Code of Practice for Barges Engaged in Cargo Transfer Operations (MPA, 2022), any barge used for cargo or personnel transfer-regardless of propulsion-must carry at least one certified deck officer and one engine rating when operating within port limits. This reflects a shift from "navigation-centric" to "operation-centric" safety logic, recognizing that risk arises not from movement alone but from task complexity and environmental exposure (MPA, 2022).

Academic research on NSPV crewing remains sparse. Most studies focus on offshore support vessels or floating production units (e.g., Vanem et al., 2018), with little empirical work on inland or coastal auxiliary craft. Chen and Liu (2021) analyzed accident reports in Chinese ports and found that

37% of NSPV-related incidents involved human factors linked to fatigue or inadequate manning, yet none triggered regulatory review due to the absence of binding crewing rules. Similarly, a recent ILO technical report (2023) identified NSPVs as a “blind spot” in global seafarer protection, urging member states to clarify coverage under MLC 2006.

Beyond Singapore and the EU, other jurisdictions offer instructive, albeit less formalized, approaches. For instance, the United States Coast Guard (USCG) regulates certain non-self-propelled units, such as offshore oil rigs and floating production storage and offloading (FPSO) vessels, under its Outer Continental Shelf (OCS) regulations, which mandate specific manning levels based on the facility's function and potential hazards. However, smaller, coastal NSPVs often fall outside this scope, regulated instead by state or local authorities with varying standards. Similarly, in many Southeast Asian nations, the regulation of auxiliary craft remains largely reactive, triggered only after incidents occur, rather than being proactive and preventative.

This ambiguity is further illustrated in Japan, where the Ship Safety Act classifies floating docks and accommodation barges as “marine facilities” rather than “vessels,” thereby exempting them from mandatory manning certificates. Yet these same units are subject to fire safety inspections under the Fire Service Act-a dual-track system that creates regulatory silos and accountability gaps. Such jurisdictional fragmentation highlights how even advanced maritime states struggle to integrate NSPVs into a coherent safety governance framework.

This global patchwork of regulatory responses underscores a fundamental challenge: the lack of a universally accepted taxonomy for NSPVs that links their physical characteristics directly to quantifiable risk metrics. Without such a common language, cross-jurisdictional learning and the development of harmonized international guidelines remain elusive. Our study aims to contribute to this nascent effort by proposing a functional classification system grounded in observable operational parameters.

Collectively, the literature reveals a critical disjuncture: while international instruments provide normative foundations, their application to NSPVs is fragmented, discretionary, and often absent. This study responds by bridging empirical observation with regulatory innovation, offering a context-sensitive policy framework grounded in real-world operations.

3. Methodology

This study employs a mixed-methods design combining quantitative survey data with qualitative operational analysis, following a sequential explanatory strategy (Creswell & Plano Clark, 2017).The sample represents approximately 90% of all active NSPVs registered in the Hainan Free Trade Port as of Q2 2024. We conducted a census-style survey of all registered NSPVs operating within the Hainan Free Trade Port between January and June 2024. Out of 142 vessels on record, 127 (89.4%) provided complete operational logs and crew rosters; 15 were excluded due to decommissioning or data unavailability. The sample includes:

(1) 58 pontoons (45.7%)

(2) 32 dredgers (25.2%)

(3) 21 floating docks (16.5%)

(4) 16 accommodation/living barges (12.6%)

For each vessel, we collected: (1) type, gross tonnage, and operational status; (2) actual crew composition (roles, certifications, duty hours); (3) incident records over the past 24 months; and (4) operator interviews (n=34) on perceived manning adequacy.

Analytical Approach:

Quantitative data were analyzed using descriptive statistics and cross-tabulation to identify patterns in crew size relative to vessel function and tonnage. Qualitative inputs from operator interviews were coded thematically using NVivo 14, focusing on three dimensions: (a) perceived safety risks, (b) regulatory awareness, and (c) operational constraints. Findings were triangulated against international benchmarks-specifically IMO manning principles, MLC 2006 rest requirements, and Singapore MPA’s barge guidelines-to assess compliance gaps and contextual divergence.

Ethical approval was obtained from the Hainan Maritime Safety Administration Research Ethics

Committee, and all participants provided informed consent.

4. Results and Discussion

Source: Authors' field survey, Hainan FTP, 2024.

Table 1. Manning Practices in Hainan FTP vs. International Benchmarks

Indicator	Hainan FTP (This Study)	Singapore MPA (2022)	IMO/ILO Expectation
Avg. crew per NSPV (>1,000 GT)	2.1	≥2 (certified)	Task-appropriate, sufficient for safety
Crew with formal certification	29%	100% (for operational barges)	Required under MLC Art. II
Avg. daily duty hours	12.6	≤12 (with rest logs)	≤14 (MLC 2006, Reg. 2.3)
Regulatory basis	Informal/local discretion	Functional operation-based rules	Principles-based (IMO A.1047)

(1) Systematic Under-Manning: 78% of surveyed NSPVs operated with fewer than three crew members, regardless of size or function. Notably, 63% of dredgers (>1,000 GT) had only two crew, contradicting industry norms for machinery-intensive operations.

(2) Fatigue and Role Overload: The average reported duty hours were 12.6 per day, with a significant 41% of crews exceeding the MLC 2006 maximum of 14 hours during peak operational seasons. Crew commonly performed dual roles (e.g., deckhand + cook + watchkeeper), increasing cognitive load.

(3) Certification Gaps: Only 29% of crew held nationally recognized maritime certificates; many were hired as "general laborers" to circumvent formal manning rules.

(4) Incident Correlation: Vessels with <3 crew reported 2.3× more minor incidents (e.g., equipment failure, near-misses) than those with ≥3, though no major casualties occurred during the study period.

The qualitative data from our operator interviews provide crucial context for these quantitative findings. Many operators expressed a genuine desire to comply with safety norms but cited significant economic pressures as a primary barrier. 'With thin profit margins,' one dredger operator explained, 'hiring an extra certified crew member can be the difference between breaking even and a loss on a short-term contract.' This highlights a critical tension between safety imperatives and commercial viability, especially for small and medium-sized enterprises (SMEs) that dominate the NSPV sector in Hainan. Furthermore, the perception of risk among operators was often misaligned with actual hazards. Several pontoon operators, for example, viewed their vessels as 'just floating platforms' with minimal risk, overlooking vulnerabilities such as fire from electrical systems, structural failure during typhoons, or security breaches. This cognitive gap suggests that regulatory reform must be accompanied by targeted awareness campaigns and capacity-building programs to shift the prevailing safety culture. The current 'regulatory vacuum' is thus not only a legal deficiency but also a cultural and economic one.

These findings contrast sharply with Singapore's MPA model, where even small cargo barges require at least two certified personnel. In Hainan, regulatory ambiguity allows operators to classify NSPVs as "non-vessels," thereby avoiding crew certification and rest-time enforcement-a loophole not permitted under MPA's functional definition.

Moreover, while IMO's manning principles emphasize "task-based assessment," Hainan's current practice relies on static, tonnage-only thresholds inherited from self-propelled ship regulations. This mismatch fails to account for high-risk NSPV tasks such as night-time cargo transfer or dredging in congested waterways.

Interestingly, our data align with ILO's (2023) warning that informal employment on auxiliary vessels erodes MLC 2006 protections. Yet unlike EU ports-where labor inspectors routinely audit barge crews-Hainan lacks inter-agency coordination between maritime and labor authorities.

The results thus confirm a "regulatory vacuum" specific to NSPVs: neither maritime safety nor labor frameworks fully apply, creating systemic vulnerabilities masked by low fatality rates.

5. Policy Implications

Rather than imposing prescriptive rules, the following framework seeks to enable adaptive governance through evidence-based guidance.

The paper proposes a tiered, risk-informed policy framework comprising three pillars:

Pillar 1: Functional Classification System

Classify NSPVs not by tonnage alone, but by operational risk profile, defined along two axes:

Task Complexity (e.g., cargo handling vs. static mooring)

Environmental Exposure (e.g., open anchorage vs. sheltered dock)

This mirrors Singapore MPA's approach but adapts it to Hainan's diverse coastal geography.

Pillar 2: Dynamic Manning Guidance

Develop non-binding but evidence-based minimum crew guidance tables for each NSPV category, specifying:

Core roles required (e.g., safety watchkeeper, machinery operator)

Minimum certification levels

Maximum continuous duty duration (aligned with MLC 2006)

Crucially, these would be issued as administrative guidance, not mandatory regulation, allowing flexibility for small operators while enabling port state control to use them as inspection benchmarks.

Pillar 3: Digital Compliance Incentives

Leverage Hainan FTP's "smart port" infrastructure to implement cloud-based crew logging, automatically flagging violations of rest-hour rules or unqualified personnel. Operators who voluntarily adopt and consistently comply with the system could be incentivized through benefits such as expedited berthing or reduced inspection frequency-thereby employing a 'carrot' approach to complement, rather than replace, traditional enforcement ('stick') mechanisms.

Note: Certification aligned with China MSA Class III or equivalent; rest hours per MLC 2006.

Figure 1. Proposed Functional Classification Matrix for NSPVs in Hainan FTP

Operational Risk Level	**Low Environmental Exposure (e.g., sheltered dock)**	**High Environmental Exposure (e.g., open anchorage, night ops)**
Low Task Complexity (e.g., static mooring pontoon)	Tier 1: 1 certified watchkeeper Max 12-hr shift	Tier 2: 1 certified watchkeeper + 1 assistant Max 10-hr shift
High Task Complexity (e.g., dredging, cargo transfer)	Tier 3: 1 deck officer + 1 engineer Rest ≥10 hrs/24h	Tier 4: 2 deck + 1 engineer (min) Real-time monitoring required

This framework does not seek to replicate IMO's certification model for ocean-going ships but instead offers a proportionate, scalable governance tool for auxiliary vessels in emerging maritime economies. It acknowledges resource constraints while anchoring local practice in global norms on safety and labor rights.

Implementing this framework will require a multi-stakeholder governance model. The Hainan Maritime Safety Administration (MSA) would serve as the lead regulator, responsible for issuing and updating the dynamic manning guidance tables. However, effective enforcement and cultural change necessitate collaboration with other entities. Labor bureaus must be integrated into the inspection regime to ensure MLC 2006 rest-hour provisions are upheld, closing the current inter-agency coordination gap. Industry associations can play a pivotal role in disseminating best practices, providing training for certification, and acting as a feedback channel for operators to report practical challenges with the new guidelines.

A phased implementation strategy is recommended to manage the transition. Phase 1 could focus on high-risk Tier 3 and Tier 4 vessels (e.g., dredgers, cargo transfer barges), where the safety case is

strongest and the potential for serious incidents is highest. This would allow regulators and operators to test the system, refine the guidance, and build confidence. Phase 2 would then extend the framework to lower-risk tiers. To support SMEs, the government could establish a subsidy or low-interest loan program to offset the initial costs of hiring additional certified personnel or implementing digital logging systems. Such a supportive ecosystem is essential to prevent the policy from becoming a mere paper exercise and to ensure it achieves its core objectives of enhancing both safety and seafarer welfare.

6. Conclusion

This study addresses a critical yet overlooked dimension of maritime safety: the crewing of non-self-propelled vessels (NSPVs) in emerging port economies. Through empirical analysis of 127 NSPVs in the Hainan Free Trade Port, we identify systemic gaps in current practices-namely chronic under-manning, role ambiguity, excessive working hours, and weak regulatory oversight-that collectively undermine both operational safety and seafarer welfare. While international instruments such as IMO Resolution A.1047(27) and MLC 2006 provide normative foundations, their application to NSPVs remains inconsistent due to definitional ambiguities and enforcement discretion.

By benchmarking against Singapore's functional regulatory model and recent ILO guidance, this paper proposes a context-sensitive policy framework that shifts focus from vessel propulsion to operational risk. The three-pillar approach-functional classification, dynamic manning guidance, and digital compliance incentives-offers a pragmatic pathway for jurisdictions like Hainan to align local governance with global standards without imposing disproportionate burdens on small operators.

Several limitations warrant acknowledgment. First, the study is confined to one Chinese free trade port; cross-jurisdictional validation is needed. Second, long-term safety outcomes could not be assessed due to data constraints. Future research should explore the cost-benefit dynamics of proposed measures and test the framework in other developing port contexts.

Nonetheless, by demonstrating how evidence-based, adaptive regulation can enhance safety on auxiliary vessels-vessels that, though lacking engines, are far from marginal to the maritime ecosystem-this work makes a tangible contribution to filling a notable gap in maritime policy literature..

Conflict of Interest Statement: The authors declare no conflict of interest.

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