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Safety at Sea Is Not Gender-Neutral: A Study on Human-Factors, Protective-Equipment-Anthropometry, Occupational-Safety and Well-Being Gaps for Women Seafarers

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Abstract

Personal protective equipment, workspaces and safety systems are engineered around assumptions about the bodies and behaviour of their users. In the maritime workforce those assumptions have historically been male: women make up fewer than two per cent of the world's 1.9 million seafarers, and the shipboard environment they work in, including its protective equipment, machinery, accommodation and emergency systems, was overwhelmingly designed for a male population. This paper treats the resulting disadvantages as an applied human-factors and occupational-safety problem, asking how a male-default design baseline translates into measurable safety, health and equipment gaps, and how engineering methods can close them. Following the PRISMA 2020 guideline, we searched Scopus, Web of Science and PubMed, screened 516 records, and synthesised 50 sources. Five engineering-relevant clusters emerged: (i) protective equipment sized to male anthropometry; (ii) workspace and accommodation design that embeds gendered reach, force and privacy penalties; (iii) a high and persistent burden of harassment, bullying and sexual misconduct, with reported prevalence exceeding 50 per cent among women; (iv) under-addressed occupational and reproductive-health exposures; and (v) weak, non-anonymous reporting and redress systems. Across clusters the evidence is dominated by qualitative and survey research with heterogeneous, non-standardised definitions and almost no engineering-grade quantification of risk. We argue that several of these gaps are tractable design problems, namely anthropometry-driven protective-equipment specification, inclusive ergonomic standards in equipment and safety-system design, and tamper-evident digital reporting tools, and we set out a structured, engineering-oriented research agenda. Framed as an applied human-factors and safety-engineering question rather than solely a policy concern, accommodating the full user population emerges as a precondition for a safe, inclusive and resilient workforce.

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1. Introduction

Shipping moves roughly four-fifths of world merchandise trade, and it does so on the labour of approximately 1.9 million seafarers crewing more than 74,000 merchant vessels [1,2]. That workforce remains one of the most gender-imbalanced in the modern economy. The most recent global enumeration, the BIMCO/ICS Seafarer Workforce Report, estimated 24,059 women among certified seafarers, or about 1.2 to 1.3 per cent of the total. Although this represented a 45.8 per cent increase over the previous five-year period, women were concentrated in the cruise and passenger sectors and remained scarce on cargo ships [1–3]. Recruiting and retaining women is therefore not only a question of equity; against a projected officer shortfall it is increasingly framed as a question of workforce sustainability [2,4].

The case for gender balance at sea is well rehearsed in policy. The International Maritime Organization launched its Strategy on the Integration of Women in the Maritime Sector as early as 1988 and has since institutionalised the agenda through the annual International Day for Women in Maritime and the Busan Declaration [5,6]. The Maritime Labour Convention obliges flag States to secure decent working and living conditions for all seafarers, and the broader 2030 Agenda makes gender equality an explicit Sustainable Development Goal [7,8]. Yet a recurring observation across three decades of scholarship is that the maritime workplace itself, both the physical ship and the social order aboard it, was configured for men, and that women have largely been expected to adapt to it rather than the reverse [9–11].

This configuration has a tangible safety dimension that is easily obscured when gender is treated purely as a human-resources or cultural matter. Protective equipment issued aboard is frequently sized to male anthropometry; emergency and deck equipment assumes male reach and grip; accommodation and sanitary arrangements presume a male crew; and the informal social environment exposes women to harassment and assault at rates far above those reported by their male colleagues [12–15]. Each of these is, at root, a mismatch between a system and a portion of its users, precisely the class of problem that safety and human-factors engineering exists to address. Despite this, the literature on women at sea is overwhelmingly qualitative and policy-facing, and engineering journals have engaged with it only sparingly.

This last point motivates the contribution of the present paper. A considerable body of scholarship now documents the experience of women at sea, and several recent syntheses address their participation, advancement and well-being from policy and social-science perspectives [4,9,11]. What is comparatively scarce is a synthesis that reads this evidence through a safety-engineering lens, asking not only whether women are disadvantaged, but where those disadvantages originate in measurable mismatches between technical systems and their users, and which of them are therefore tractable by design rather than by exhortation alone. By organising heterogeneous academic and grey-literature evidence around five engineering-relevant gap clusters, appraising the measurement quality of each, and mapping the gaps onto concrete intervention and research pathways, this paper aims to give an engineering readership a structured entry point into a problem that has so far been articulated largely in other vocabularies.

This paper was undertaken within the POMORKINJE 4.0 project (“Women Seafarers 4.0: equality, technology and the sea”), whose work programme couples gender-sensitive analysis of shipboard equipment and working conditions with the development of digital tools for reporting unsafe situations on board. Consistent with that orientation, our aim is deliberately framed for a maritime science and engineering readership: to consolidate what is known about the safety, equipment and well-being gaps that specifically affect women seafarers; to characterise the quality and limits of the underlying evidence; and to identify where engineering methods, including anthropometric design, ergonomic

standardisation, risk modelling and secure digital systems, can make a measurable difference. Three research questions, as seen in Table 1 below, structure the work:

Table 1. The research questions guiding the study.

RQ Number	Question
RQ1	What safety, protective-equipment, occupational-health and well-being gaps specific to women seafarers are documented in the academic and sector literature?
RQ2	What is the methodological character and quality of that evidence base, and where are its principal gaps?
RQ3	Which of the identified gaps are amenable to maritime-engineering and socio-technical intervention, and what research is required to enable them?

1.1. The Business and Safety Case

It is worth stating plainly why this is a maritime-engineering problem and not only a matter of fairness. The industry confronts a structural shortage of certified officers; the 2021 workforce report identified a shortfall of more than 26,000 officers and projected a need for tens of thousands more by mid-decade, and the pressure has if anything intensified since [1,2]. Women are the largest under-tapped pool of maritime talent, and every credible analysis of attraction and retention identifies the physical and social conditions documented in this study, such as ill-fitting equipment, unsafe interpersonal environments and inadequate facilities, as primary causes of attrition [12,16]. A vessel that physically and socially accommodates only part of its potential workforce is, in effect, operating with an artificially constrained labour supply. The safety case is equally direct: protective equipment that does not fit, and emergency tasks calibrated to a body type the wearer does not have, degrade the protective margins on which the entire safety-management system depends. Equity, retention and safety are, in this domain, the same problem viewed from three angles.

1.2. The Regulatory Landscape

A dense lattice of international instruments bears on the position of women at sea, and recent amendments have begun to address the equipment question specifically. Table 2 summarises the principal instruments and their relevance to the gaps examined here. Notably, amendments to the Maritime Labour Convention have strengthened requirements that protective equipment be of appropriate size and fit, a regulatory acknowledgement of precisely the anthropometric mismatch documented in Section 3.3, while the ILO's Violence and Harassment Convention provides an external benchmark for the interpersonal-safety failures documented in Section 3.5 [8,17].

Table 2. The principal international instruments relevant to the safety, equipment and well-being of women seafarers.

Instrument	Body/Year	Relevance to This Study
Strategy on Integration of Women in the Maritime Sector	IMO, 1988	First sustained policy commitment; underpins Women in Maritime programme [5,6]
SOLAS & LSA Code	IMO, 1974 onward	Life-saving-appliance performance presumes correct fit of lifejackets/immersion suits [18]

Maritime Labour Convention (as amended)	ILO, 2006/2024	Decent work; strengthened PPE size- and-fit and onboard welfare require- ments [8]
Violence and Harassment Convention (No. 190)	ILO, 2019	Benchmark for preventing and reme- dying harassment and violence at work [17]
SDG 5 (2030 Agenda)	UN, 2015	Gender equality as a measurable de- velopment target [7]
STCW Convention	IMO, as amended	Competence and certification frame- work within which barriers arise [11,19]

The salient feature of this landscape is the distance between aspiration and verification. The instruments establish that protective equipment should fit, that the workplace should be free of violence and harassment, and that gender equality is a development target; what they largely lack is a mechanism that measures whether a given ship, fleet or flag actually meets these expectations for its female crew. The strengthened size-and-fit language of the Maritime Labour Convention, for instance, is a necessary advance, but in the absence of an agreed accommodation metric (Section 4.1) compliance remains a matter of assertion rather than demonstration. This gap between a well-intentioned rule and a verifiable outcome is itself an engineering opening: standards become enforceable when the quantity they govern can be measured, and several of the research items proposed in Section 4.4 are, in effect, the measurement infrastructure these instruments presuppose but do not yet possess [8,18,20].

The remainder of the paper is organised as follows. Section 2 sets out the paper protocol. Section 3 reports the search outcome, a brief bibliometric profile of the corpus, and a thematic synthesis organised around five gap clusters, including an illustrative anthropometric analysis of protective-equipment mismatch. Section 4 discusses the cross-cutting limitations of the evidence and the engineering opportunities they imply, and presents a structured research agenda. Section 5 concludes.

2. Materials and Methods

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [21]. Because the relevant knowledge is distributed across peer-reviewed science, maritime-policy scholarship and a substantial body of sector grey literature (classification societies, welfare charities, industry alliances and regulators), the protocol was designed as a mixed academic–grey systematic review with an explicitly engineering-facing synthesis rather than a meta-analysis. A meta-analytic pooling of prevalence figures was considered but rejected, for reasons made explicit in Section 4.1: the primary studies use incompatible populations, definitions and reference periods.

The choice of PRISMA as the reporting framework reflects its now-established role in maritime research. Structured systematic reviews and bibliometric analyses following PRISMA have been applied across a wide range of maritime domains in recent years, including machine-learning-assisted port State control inspections [22], maritime traffic complexity [23], the safety and security of maritime communication systems [24], navigational hazards from offshore wind farms [25], port-related shipping emissions [26], ship manoeuvring in shallow and narrow waters [27], the education and training of seafarers for autonomous shipping [28], and maritime signalling communication technologies [29]. This body of work shows that the framework transfers well to the heterogeneous, partly grey-literature evidence base typical of maritime studies, and it motivates its use here for the specific question of safety, equipment and well-being gaps affecting women seafarers.

2.1. Eligibility Criteria

Sources were eligible if they (i) addressed seafarers or the seagoing maritime workforce; (ii) reported gender-disaggregated information or focused specifically on women; and (iii) reported at least one outcome relating to occupational safety, protective equipment, ship or accommodation design, occupational or reproductive health, interpersonal harm (harassment, bullying, discrimination, sexual misconduct), or reporting and redress mechanisms. Both empirical studies and authoritative sector reports were admitted; purely biographical, fictional or opinion pieces without data were excluded, as were studies confined to shore-based maritime employment. English-language sources published between January 2003 and May 2026 were included, the start point marking the first comprehensive ILO treatment of women seafarers. Detailed criteria can be found in Table 3 below.

Table 3. Inclusion and exclusion criteria.

Criterion	Included	Excluded
Population	Seagoing seafarers (all ranks, departments and ship types)	Exclusively shore-based maritime staff; non-maritime workforces
Focus	Women-specific or gender-disaggregated	No gender dimension reported
Outcome	Safety, PPE, design, health, interpersonal harm, reporting	No relevant outcome
Source type	Peer-reviewed studies; authoritative sector/regulator reports	Opinion, fiction, biography without data
Language/period	English; 2003–May 2026	Other languages without translation; pre-2003

2.2. Information Sources and Search Strategy

Three bibliographic databases were searched, namely Scopus, Web of Science Core Collection and PubMed, complemented by structured grey-literature searching of IMO, ILO, BIMCO/ICS, the Global Maritime Forum/All Aboard Alliance, classification societies and maritime welfare organisations, and by backward and forward citation tracking of included studies. The core query combined a population facet with an outcome facet, adapted to each database's syntax. The canonical Scopus string is given in Appendix A.

All database searches were executed on the full record (title, abstract and keywords) and were run in May 2026; the counts reported in Section 3.1 and in Figure 1 therefore represent that dated search snapshot rather than provisional figures to be regenerated later. The full search string used for each database is reproduced in Appendix A.

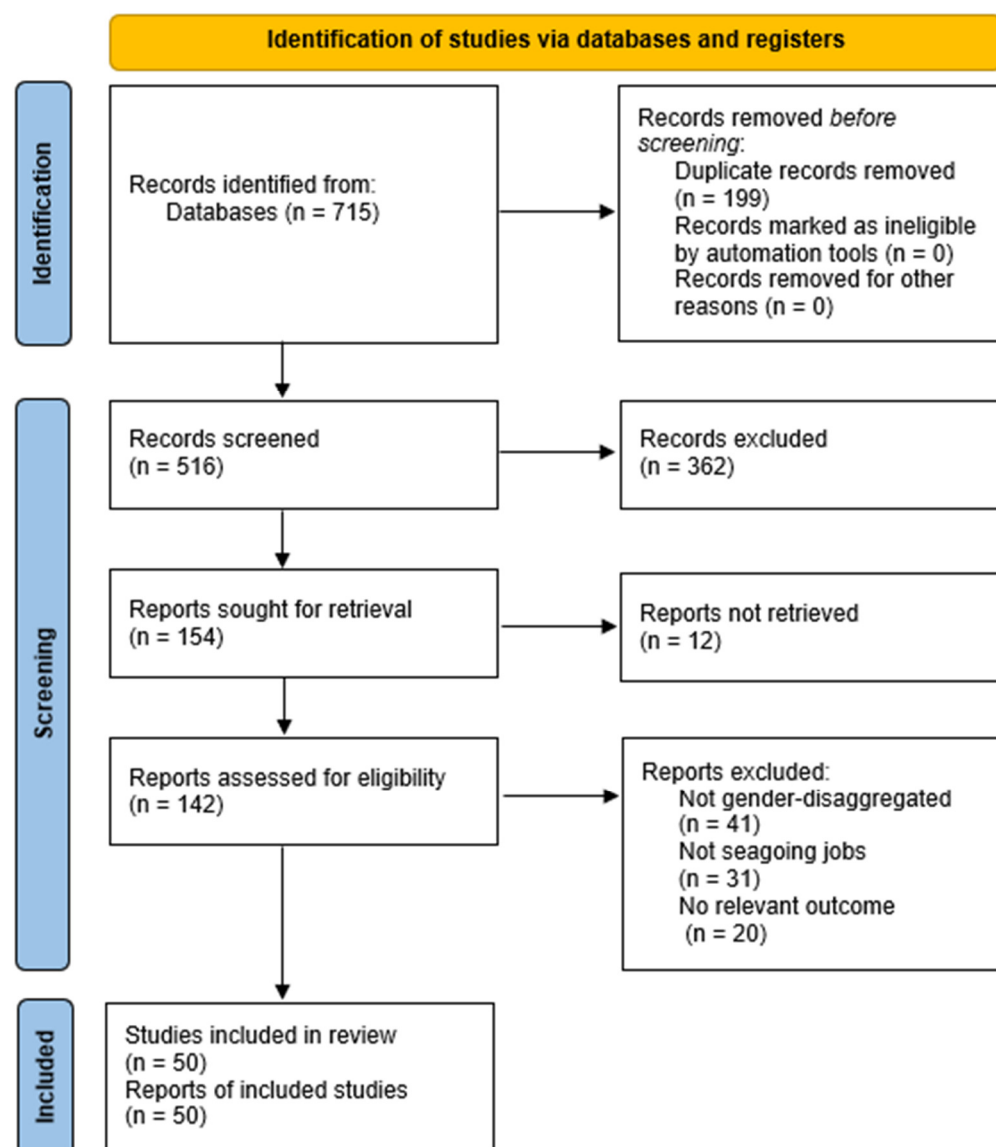


Figure 1. A PRISMA 2020 flow diagram of the identification, screening and inclusion of sources.

2.3. Selection, Extraction and Appraisal

Records were de-duplicated and screened on title and abstract, after which full texts were assessed against the eligibility criteria. From each included source we extracted bibliographic metadata, study type and method, population and setting, the safety/equipment/health/interpersonal outcome reported, any quantitative figures, and the stated implications. Methodological quality was appraised at a level appropriate to source type: empirical studies were appraised with the Mixed Methods Appraisal Tool (MMAT), covering the appropriateness of design, sampling, measurement and analysis, while grey-literature and sector reports were appraised with the AACODS checklist (Authority, Accuracy, Coverage, Objectivity, Date, Significance). On the basis of this appraisal each source was assigned to one of three confidence tiers (higher, moderate or indicative), and that tier governed the interpretive weight it was given, so that indicative grey-literature figures inform direction and order of magnitude rather than being treated as precise estimates. The appraisal criteria and tier definitions are summarised in Appendix B. Because the corpus is methodologically heterogeneous, findings are synthesised narratively and

thematically, with quantitative figures tabulated and displayed but not statistically pooled.

3. Results

3.1. Search Results

The combined search of bibliographic databases and grey-literature sources returned 715 records (Scopus 331, Web of Science 286, PubMed 98). After removal of 199 duplicates, 516 records were screened on title and abstract, of which 362 were excluded as off-topic. Of 154 reports sought for retrieval, 12 could not be obtained, and the remaining 142 were assessed in full. Of these, 92 were excluded, most commonly because they were not gender-disaggregated (41), did not concern the seagoing workforce (31), or reported no relevant safety, equipment or health outcome (20). Fifty sources were retained for synthesis. The selection process is summarised in Figure 1.

3.2. Profile of the Evidence Base

The corpus is recent and accelerating: a clear majority of included sources were published from 2017 onwards, and roughly a third appeared in 2023–2026, reflecting intensified industry attention following high-profile diversity initiatives. Geographically, the empirical literature is dominated by Europe and Asia, with notably sparse coverage of Latin America, Africa and the Middle East; the 2025 Colombian study of women officers and the Eastern and Southern Africa career study are partial exceptions that themselves emphasise this imbalance [30,31]. A further asymmetry compounds the geographic one: the major seafarer-supply nations, notably the Philippines, India, Indonesia, China, Russia and Ukraine, which together crew a large share of the world fleet, are markedly under-represented as study settings, so the populations most exposed to the gaps documented here are among the least studied. The review found no source that systematically compared these supply-nation cohorts, and we therefore treat their absence as a distinct evidence gap carried into the research agenda (Section 4.4). Methodologically, qualitative and survey designs predominate, including interviews, focus groups and cross-sectional questionnaires, alongside a large share of sector reports. Experimental, observational-ergonomic and quantitative risk-modelling studies are almost entirely absent. This profile is itself a central finding: the field is rich in lived experience and poor in engineering-grade measurement (RQ2).

The disciplinary distribution reinforces the point. The included sources cluster in maritime-policy, occupational-health, welfare and social-science outlets, with engineering and human-factors venues represented only thinly and largely through the protective-equipment and anthropometry literature drawn on in Section 3.3. Grey literature, including classification-society guidance, charity and welfare-network reports and industry-alliance surveys, accounts for a substantial share of the most current evidence, which is both a strength, in that it captures practice ahead of the academic cycle, and a limitation, in that its sampling frames and data provenance are not always fully documented. We therefore treat the grey-literature findings as directionally informative rather than as precise estimates, and we foreground provenance in the appraisal that follows. Taken together, the temporal, geographic, methodological and disciplinary profile of the corpus defines the opportunity this paper seeks to frame: a maturing but still pre-quantitative field awaiting the engineering measurement that would let it move from description to design.

Thematic coding of the 50 sources produced five clusters, summarised in Table 4 and elaborated in Sections 3.3–3.8. The clusters are not mutually exclusive, since ill-fitting equipment, for instance, both degrades protection and signals exclusion, but they organise the evidence in a way that maps onto distinct intervention pathways.

Table 4. The thematic clusters identified in the synthesis (clusters are non-mutually exclusive: a source addressing several themes is counted under each, so the column counts sum to 58 rather than to the 50 unique included sources, indicating breadth of thematic coverage rather than a partition of the corpus or the relative strength of evidence).

Theme	Sources (n)	Representative Findings
PPE & protective equipment	13	Equipment sized to male anthropometry; >80% of women report gender-related PPE problems; improvisation creates secondary hazards [14,15,32–38]
Ship & accommodation design	9	Gendered reach/force demands; privacy, sanitary and medical-provisioning gaps [15,19,30,39]
Interpersonal safety	17	Harassment/bullying/sexual misconduct; reported prevalence >50% among women; severe under-reporting [12,13,16,40–44]
Occupational & reproductive health	8	Exposure, fatigue and mental-health burden; maternity and medical-fit-out gaps [15,30,39]
Reporting & redress	11	Weak, non-anonymous channels; fear of retaliation; nascent digital tools [41,44,45]

3.3. Protective Equipment Sized to Male Anthropometry

The most consistently documented engineering gap concerns personal protective equipment (PPE). The premise is uncontroversial in ergonomics: standard PPE has historically been designed and sized around the dimensions of male reference populations, and women cannot be safely accommodated simply by issuing smaller men's sizes, because female anthropometry differs not only in scale but in proportion [20,37,38]. In the maritime setting this manifests directly. A 2019 CHIRP investigation reported that women were routinely issued men's PPE and described specific consequences: oversized boiler suits and high-visibility jackets whose excess material can snag on machinery; gloves too large to maintain grip; and safety footwear available only in sizes far larger than required, in one case a smallest fire-safety boot of size 10 issued to a size-4 wearer [14,36]. A 2020 Solent University survey found that more than 80 per cent of female participants had experienced PPE problems related to their gender [32], and sector and academic sources independently document women resorting to safety pins, or purchasing their own equipment ashore, to obtain a workable fit [15,33,46]. The safety logic is twofold. First, protection is degraded directly: respirators and eye protection sized to broader male faces do not seal correctly; harnesses positioned for male torsos compromise fall protection; immersion suits and lifejackets sized to a male median fit poorly at the extremes of the size distribution, which matters acutely for life-saving appliances whose performance under SOLAS and the LSA Code is predicated on correct fit [18,20,38]. Second, ill-fitting equipment is itself a hazard through snagging, tripping and impaired dexterity, and, when uncomfortable or impractical, it is less likely to be worn at all, so that nominal compliance overstates real protection [14,33]. Figure 2 below shows the reported personal-protective-equipment fit problems in the maritime sector.

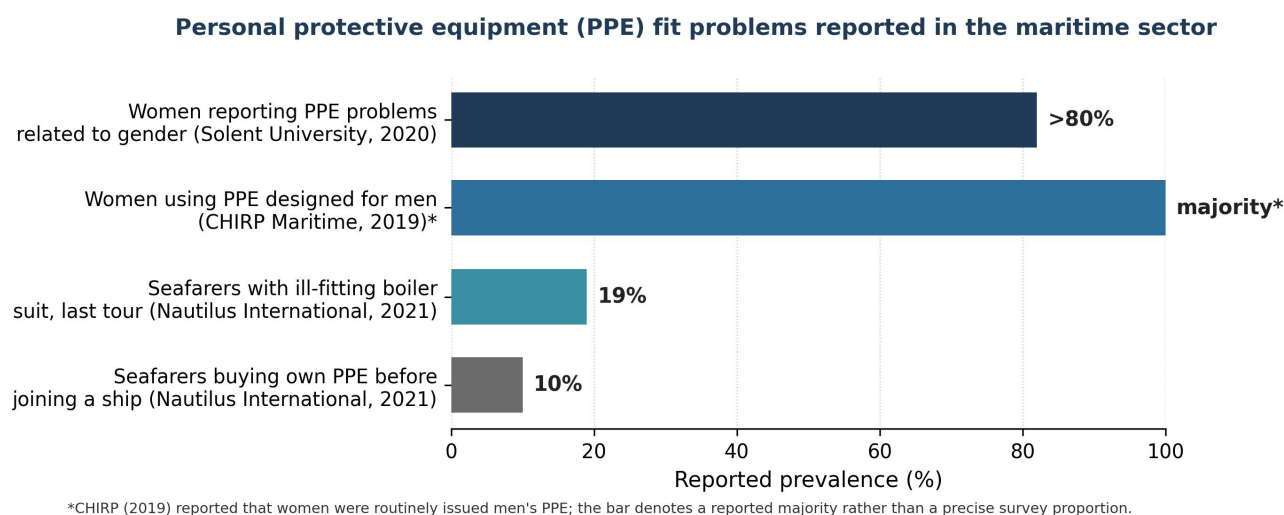


Figure 2. Reported personal-protective-equipment fit problems in the maritime sector. The CHIRP (2019) value denotes a reported majority experience rather than a precise survey proportion; the remaining values are survey-reported percentages drawn from heterogeneous samples [14,32,33].

An Illustrative Anthropometric Mismatch

To make the mechanism concrete in engineering terms, consider sizing systems anchored to a male reference population. PPE size ranges are commonly specified to accommodate a central band of the intended users, conventionally from the 5th to the 95th percentile, so that those near the distribution's tails are “disaccommodated”. When the reference population is male, the female user is displaced toward, and frequently beyond, the lower tail. Stature offers the simplest illustration: a 5th-percentile man and a 5th-percentile woman differ by on the order of 10–12 cm, and the median woman sits close to the lower bound of a male-anchored range. For dimensions governing safety-critical fit, such as facial breadth and depth for respiratory and eye protection, hand breadth and length for gloves, foot breadth for footwear, and chest and torso geometry for harnesses and flotation, the female distribution is displaced further still, and the proportional differences (for example, narrower feet at a given length, smaller hand breadth at a given hand length) mean that a length-correct men's item is routinely width-incorrect [28,37,38]. The practical corollary is that a single male-anchored size range cannot, even in principle, accommodate the female safety-critical percentiles; achieving equivalent protection requires female-specific size curves derived from female anthropometric data, not a rescaling of male curves. We present this as an illustrative argument rather than a validated quantification: the maritime literature does not yet contain a study that measures a representative female seafaring population and computes accommodation rates for each PPE class against the relevant standards. That absence is, in our reading, one of the single most actionable research gaps this paper identifies, and we return to it in Section 4.3.

Table 5 makes the displacement concrete using widely reported civilian percentile values for a small number of safety-critical body dimensions. The figures are indicative, drawn from general adult anthropometric reference ranges rather than from a seafaring sample, and are intended to show the structure of the problem rather than to specify a sizing system. The pattern is nonetheless unambiguous: across every safety-critical dimension the female distribution lies materially below the male distribution on which conventional sizing is anchored, and for proportional dimensions such as foot breadth relative to length, hand breadth relative to length and facial seal geometry, a length-matched men's item remains width- or seal-incorrect.

Table 5. Indicative anthropometric displacement for safety-critical dimensions (general adult reference ranges; values approximate and illustrative only, after ISO 7250 conventions [20]). The table demonstrates the structure of the mismatch and motivates a seafaring-specific accommodation study (Section 4.3).

Body Dimension (Relevance)	Male 5th–95th	Female 5th–95th	Median Gap	Safety Consequence of Male-Anchored Fit
Stature (general scaling)	1630–1870 mm	1510–1730 mm	~120 mm	Reach/clearance assumptions misaligned
Foot length (footwear)	240–285 mm	215–255 mm	~25 mm	Oversized boots; slips, trips, reduced control
Foot breadth (footwear)	90–105 mm	80–95 mm	~10 mm	Width-incorrect even when length matched
Hand length (gloves)	170–205 mm	155–190 mm	~15 mm	Loss of dexterity and grip
Hand breadth (gloves)	78–95 mm	68–84 mm	~11 mm	Glove rotates; reduced tactile control
Face breadth (respirator/eyewear)	130–155 mm	120–143 mm	~12 mm	Seal failure; ingress of contaminants
Chest depth/torso (harness/flotation)	Male-centred	Smaller, different geometry	Not applicable	Harness mis-positioning; poor immersion-suit fit

3.4. Ship and Accommodation Design

Beyond worn equipment, the fixed environment of the ship encodes gendered assumptions. Deck and engine-room tasks frequently presuppose male reach envelopes and grip strength in the placement of valves, controls and manual-handling tasks, so that the same task imposes a higher relative physiological load on many women, a classic ergonomic mismatch with implications for both injury risk and fatigue [19,39,47]. Accommodation and sanitary arrangements, designed for an assumed male crew, often lack privacy provisions; medical lockers and telemedicine protocols are not always provisioned for female or reproductive-health needs; and the welfare literature documents the cumulative toll of these omissions on isolation and well-being during long tours [15,30]. The recently validated questionnaire instrument of Çalışkan and colleagues is notable precisely because it attempts to operationalise such gender-based occupational and ergonomic challenges for systematic measurement, signalling a nascent move from narrative to instrument [39].

Several specific design features recur across the welfare and survey literature. Sanitary and changing facilities are frequently shared or insufficiently private, a problem compounded on older vessels and on ships with very small numbers of women aboard, where a single woman may have no practical privacy for extended tours [12,15]. Cabin and corridor security, covering lockable doors, sightlines and lighting in accommodation and access routes, acquires a different salience when the interpersonal-safety burden of Section 3.5 is taken into account, yet it is rarely treated as a security-design parameter [12,32]. Manual-handling tasks, stores-loading and the operation of heavy doors, valves and hatches presuppose a force envelope drawn from a male population, so that the same task represents a higher proportion of maximum voluntary capacity for many women, with consequences for both acute injury and cumulative musculoskeletal load [19,39]. None of these features is individually remarkable; what is notable is that they are documented overwhelmingly as lived experience rather than measured as design deficits, which is precisely the narrative-to-instrument transition the field now needs.

3.5. Interpersonal Safety: Harassment, Bullying and Sexual Misconduct

The largest thematic cluster concerns interpersonal harm, and here the evidence, though methodologically uneven, is consistent in direction and disturbing in magnitude. A Nautilus International survey found that roughly 42 per cent of maritime workers had encountered bullying, harassment or discrimination, while Safer Waves reported that 58 per cent had experienced sexual misconduct at sea [40,41]. Synthesis work informing the Global Maritime Forum’s Sustainable Crewing Guidelines estimated that 8–25 per cent of all seafarers experience harassment and bullying, with the figure exceeding 50 per cent for women specifically [13,16]. The 2024 Diversity Study Group survey, its first to poll serving crew, found that half of responding women reported at least one incident of psychological harassment and one in four reported sexual harassment [42]. The International Seafarers’ Welfare and Assistance Network recorded a sharp rise in harassment cases in early 2023, and a 2025 framework initiative reported that 80 per cent of surveyed seafarers had experienced or witnessed a sexual offence at sea within the preceding five years [43,44]. The All Aboard Alliance’s foundational interviews distilled fifteen “pain points” for women, spanning professional progression, social relations, employment conditions and physical conditions on board [12]. Figure 3 displays these figures as separate, annotated points to convey order of magnitude without implying comparability.

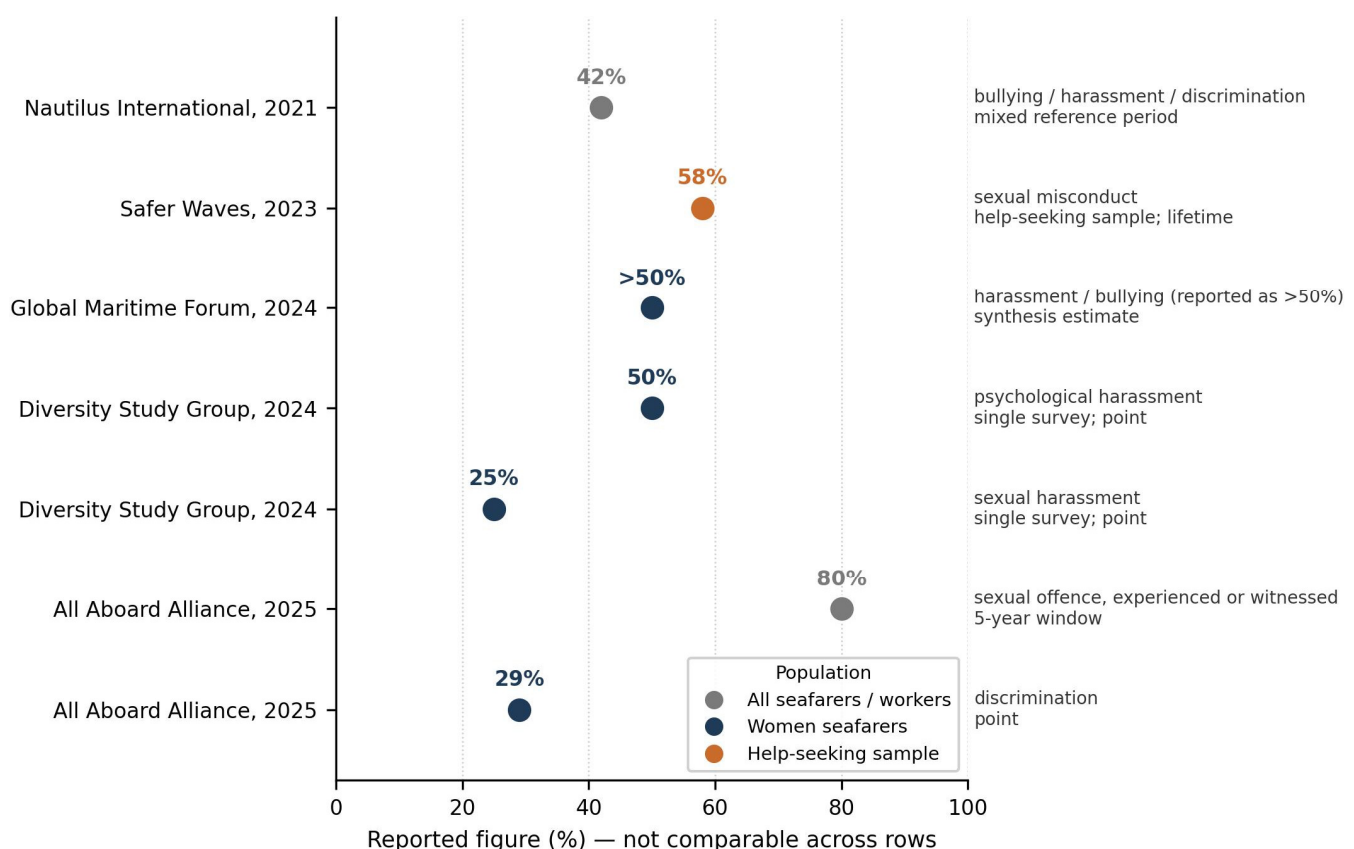


Figure 3. The reported figures for interpersonal harm at sea, shown as a dot plot grouped by study population. Each point is a separate estimate carrying its own construct and reference period (annotated on the right); because the values derive from heterogeneous samples, definitions and reference periods, they are not directly comparable and are shown only to convey order of magnitude. The ISWAN figure (a 45% rise in helpline contacts) is a change metric rather than a prevalence and is omitted from the plot [12,13,16,40–44].

Two features of this evidence deserve emphasis for an engineering audience. First, the figures are not commensurable: they mix “all seafarers” with “women only”,

“experienced” with “experienced or witnessed”, lifetime with five-year and point prevalence, and definitions of “harassment” that range from bullying to specific sexual offences. Table 6 lays out these parameters side by side and makes the incommensurability explicit. The apparent spread from 25 to 80 per cent is therefore as much an artefact of measurement as a substantive finding, a point we develop in Section 4.1. Second, every source that examines reporting concludes that incidents are heavily under-reported, owing to fear of retaliation, career consequences and the absence of confidential channels in an environment where the alleged perpetrator may be a direct superior in a small, isolated crew [12,41,44]. Under-reporting is the hinge that connects this theme to the engineering agenda, because it is precisely the failure mode that well-designed digital reporting systems are meant to mitigate [45].

Table 6. The reported prevalence of interpersonal harm across recent sources, showing why the figures cannot be statistically pooled.

Source (Year)	Population	Construct Measured	Reported Figure	Why It Is Not Directly Comparable
Nautilus Intl. [33]	All maritime workers	Bullying/harassment/discrimination	~42%	Mixed construct; not gender-specific; mixed reference period
Safer Waves [41]	All seafarers (help-seeking)	Sexual misconduct	58%	Service-user sample; self-selection toward affected
GMF/Diversity@Sea	Women seafarers	Harassment/bullying	>50%	Synthesis estimate; definition spans several behaviours
Diversity Study Group (2024) [42]	Women seafarers	Psychological harassment	50%	Single-survey; small women sub-sample
Diversity Study Group (2024) [42]	Women seafarers	Sexual harassment	25%	Different construct, same survey
ISWAN (2023) [43]	Helpline contacts	Reported harassment cases	+45% (rise)	Change metric, not prevalence
Unspoken (2025) [44]	All seafarers	Sexual offence experienced/witnessed, 5-yr	80%	Includes witnessing; 5-year window inflates vs point prevalence
All Aboard Alliance (2024) [44]	Women in maritime	Discrimination	29%	Construct narrower than harassment

3.6. Occupational and Reproductive Health

Health outcomes specific to women receive comparatively little dedicated study, but the available evidence points to a compounded burden. The general seafaring health literature documents fatigue, noise, chemical exposure and mental-health strain; for women these interact with the design and social gaps above and with reproductive-health considerations that the standard medical fit-out and repatriation arrangements were not built to address [15,30]. A Colombian mixed-methods study of women officers found restricted technical duties, harassment and limited institutional support, but also strong adaptive coping, a reminder that resilience is not the same as a safe system, and that placing the adaptive burden on women is not a substitute for design change [30]. Maternity provision, sea-shore rotation and family-planning support recur across the welfare literature as structural gaps that shape both health and retention [12,16].

Three exposure pathways recur and warrant dedicated measurement. The first is the interaction of standard occupational exposures, namely noise, vibration, heat, chemicals and shift-induced fatigue, with ill-fitting protective equipment, since a respirator that does not seal or hearing protection that does not fit converts a controlled exposure into an uncontrolled one specifically for the disaccommodated user [14,38]. The second is mental health: the welfare literature links isolation, the absence of confidential support and the

interpersonal-safety climate of Section 3.5 to elevated psychological strain, and the small number of women aboard a typical vessel can intensify rather than relieve that isolation [15,16,42]. The third is reproductive and menstrual health, where the standard medical fit-out, telemedicine protocols, provisioning and repatriation arrangements were not designed with female physiology in mind, leaving gaps that range from the routine to the potentially serious during long deep-sea voyages [12,30]. As with the other themes, the dominant pattern is that these exposures are described qualitatively far more often than they are measured, so that their contribution to attrition and to fitness-for-duty remains largely unquantified.

3.7. Reporting and Redress Mechanisms

The final cluster concerns the systems through which unsafe situations are reported and resolved. The picture is one of weak, fragmented and often non-anonymous mechanisms. Recognising this, the IMO launched in 2024 an interactive global map of reporting channels and support systems organised by flag State, intended to help seafarers locate help wherever they are [45]; and industry alliances have begun developing standardised frameworks for identifying, grading and responding to sexual misconduct, including initiatives to gather first-person accounts at scale [44]. These are early-stage, largely informational responses. The literature does not yet contain a rigorously evaluated, anonymous, tamper-evident shipboard reporting tool of the kind that the under-reporting evidence implies is needed, a gap that sits squarely within maritime information-systems engineering and directly motivates the digital-tool work programme of projects such as POMORKINJE 4.0.

From an information-systems standpoint the requirements such a tool must satisfy are specifiable. It must guarantee reporter anonymity strongly enough to overcome the retaliation fear that the evidence identifies as the dominant barrier, while remaining resistant to tampering or suppression by an implicated superior, a combination that points toward append-only, cryptographically verifiable records and an escalation path that does not depend solely on the shipboard chain of command [41,44,45]. It must function within the intermittent, low-bandwidth connectivity typical of vessels at sea, degrade gracefully when offline, and integrate with the flag-State and shore-side channels catalogued by the IMO map rather than adding yet another isolated silo [45]. And, critically for an engineering contribution, it must be evaluated against the outcome that matters, namely whether incidents that would otherwise go unreported are surfaced and resolved, rather than against mere availability or download counts. The absence of any rigorously evaluated tool meeting these requirements is, alongside the anthropometric accommodation study, one of the two most actionable build-and-test gaps identified by this study. Table 7 makes these requirements concrete, setting out a reference architecture for such a tool together with the quantifiable indicators against which any field deployment should be evaluated.

Table 7. Reference architecture and quantifiable field-evaluation indicators for a secure, anonymous shipboard reporting tool. The specification is offered as a design proposal for future build-and-test work, not as a deployed system.

Layer/Component	Design Specification	Quantifiable Evaluation Indicator
Capture (client)	Offline-capable mobile and web client; multilingual; no device-identifying metadata retained	Offline submission success rate (target more than 99%); median completion time; language coverage vs. crew-nationality mix
Anonymity	Credential-free or pseudonymous submission; k-anonymity (k of at least 5) on any released aggregate; no IP or device logging	Achieved k-anonymity level; share of reports submitted anonymously; re-identification risk in testing

Integrity	Append-only, hash-chained (tamper-evident) log; each entry cryptographically signed	Tamper-detection rate under adversarial testing (target 100%); log-verification pass rate
Escalation and routing	Rule-based routing to a recipient independent of the shipboard chain of command (company data-protection officer, flag State, external ombudsman)	Share of cases routed to an independent recipient; median time-to-acknowledgement
Connectivity	Store-and-forward synchronisation tolerant of intermittent, low-bandwidth links; integration with the 2024 IMO reporting map [45]	Synchronisation latency at sea; service uptime; coverage of flag-State channels integrated
Case management	Status tracking; two-way anonymous follow-up; defined resolution workflow	Case-resolution rate; median time-to-resolution; reporter follow-up rate
Field-evaluation outcome	Pre- and post-deployment comparison against the under-reporting baseline	Reporting-rate uplift vs baseline; corroborated-to-total ratio; false-report rate

3.8. The Under-Representation Pipeline and Retention

A final, cross-cutting theme concerns the pipeline into and out of the profession, because the safety and equipment gaps above do not operate in isolation, since they interact with structural barriers to entry and advancement. The literature consistently describes a “leaky pipeline” in which women are lost at successive career stages, shaped by gender stereotypes about physical capacity and leadership, gender-based placement into junior or support roles, and slow policy implementation [11,31,48–50]. A documented gender pay gap, certification barriers that fall harder on women from developing States, and limited maternity and rotation provision compound the effect [12,51]. Identity-management research shows women adopting “sameness” strategies, that is, minimising visible femininity to gain acceptance in a masculine occupational culture, a coping response that is itself evidence of an unaccommodating system [9,10,49]. For the present study the significance is that retention is the outcome variable through which equipment, design and interpersonal-safety failures ultimately register at the fleet level: a woman who leaves because her PPE never fit, or because reporting an assault ended her career rather than the perpetrator’s, becomes a statistic of “attrition” that obscures its engineering and organisational causes [16,30].

4. Discussion

The synthesis answers RQ1 by consolidating five robustly attested gap clusters, and RQ2 by characterising an evidence base that is experientially rich but methodologically thin from an engineering standpoint. This section draws out the cross-cutting implications and, in answer to RQ3, maps the gaps onto tractable interventions and a research agenda.

4.1. The Measurement Problem

The most important cross-cutting limitation is the absence of standardised, gender-disaggregated measurement. The harassment figures in Figure 3 cannot be pooled because their denominators, definitions and reference periods differ; the PPE evidence rests largely on the proportion of women reporting a problem rather than on measured accommodation rates against standards; and ship-design concerns are described qualitatively rather than quantified as load, reach or exposure differentials. This is why we did not attempt a meta-analysis: pooling incommensurable proportions would manufacture false precision. The constructive implication is that a shared measurement framework, comprising agreed definitions, common instruments such as the validated questionnaire of Çalışkan and colleagues [39], and routine gender-disaggregated reporting, is a

precondition for cumulative science in this area. Standardisation is itself an engineering contribution, and arguably the highest-leverage one.

Concretely, a usable measurement framework would have several components. For interpersonal harm it would fix the construct boundaries that the sources of Table 6 currently blur, separating bullying, discrimination, sexual harassment and sexual assault, and would standardise the reference period and the population denominator so that figures become additive rather than merely juxtaposed. For protective equipment it would replace “proportion reporting a problem” with measured accommodation rates: the percentage of a representative female population that a given size range fits to standard, computed per PPE class against the relevant EN/ISO and LSA-Code requirements. For ship and accommodation design it would express the qualitative complaints of Section 3.4 as load, reach, clearance and exposure differentials amenable to ergonomic assessment. And across all themes it would require routine gender-disaggregated reporting, without which even a perfect instrument yields no fleet-level signal. None of these is methodologically novel in isolation; the contribution would lie in assembling them into an agreed, repeatable set that turns a decade of narrative evidence into a cumulative measurement programme.

4.2. Gender as a Safety-Engineering Variable

The unifying argument of this study is that the gaps women experience at sea are, to a substantial degree, instances of system–user mismatch, and therefore belong to the domain of safety and human-factors engineering rather than to policy alone. Figure 4 sets out the logic: each evidence theme operates through a common mechanism, the increase in residual risk via degraded protection, usability and well-being, and each is addressable by a corresponding socio-technical intervention. Framing the problem this way reclassifies “women’s issues” as design requirements, which is both more actionable and less liable to be deprioritised than an equity framing alone.

This reframing also clarifies why the male-anchored design baseline persisted for so long without being recognised as a defect. In safety engineering, a system optimised for a reference user appears to perform well precisely as long as the actual user population resembles that reference; the mismatch becomes visible only when the population diversifies, at which point what was latent becomes a measurable loss of protective margin. The historical near-absence of women at sea thus concealed a design assumption that is now, with a slowly diversifying workforce, being exposed as a constraint. Read this way, the gaps catalogued in Section 3 are not a series of isolated oversights but the predictable, system-level consequence of designing to a single body and a single set of social expectations. The corrective is correspondingly systemic: not a succession of accommodations granted case by case, but the inclusion of the full user population in the reference data, standards and assurance processes from which ships and their equipment are specified. This is the same move that human-factors engineering has made in other safety-critical domains, from automotive occupant protection to cockpit design, once their user populations broadened [20,37,38].

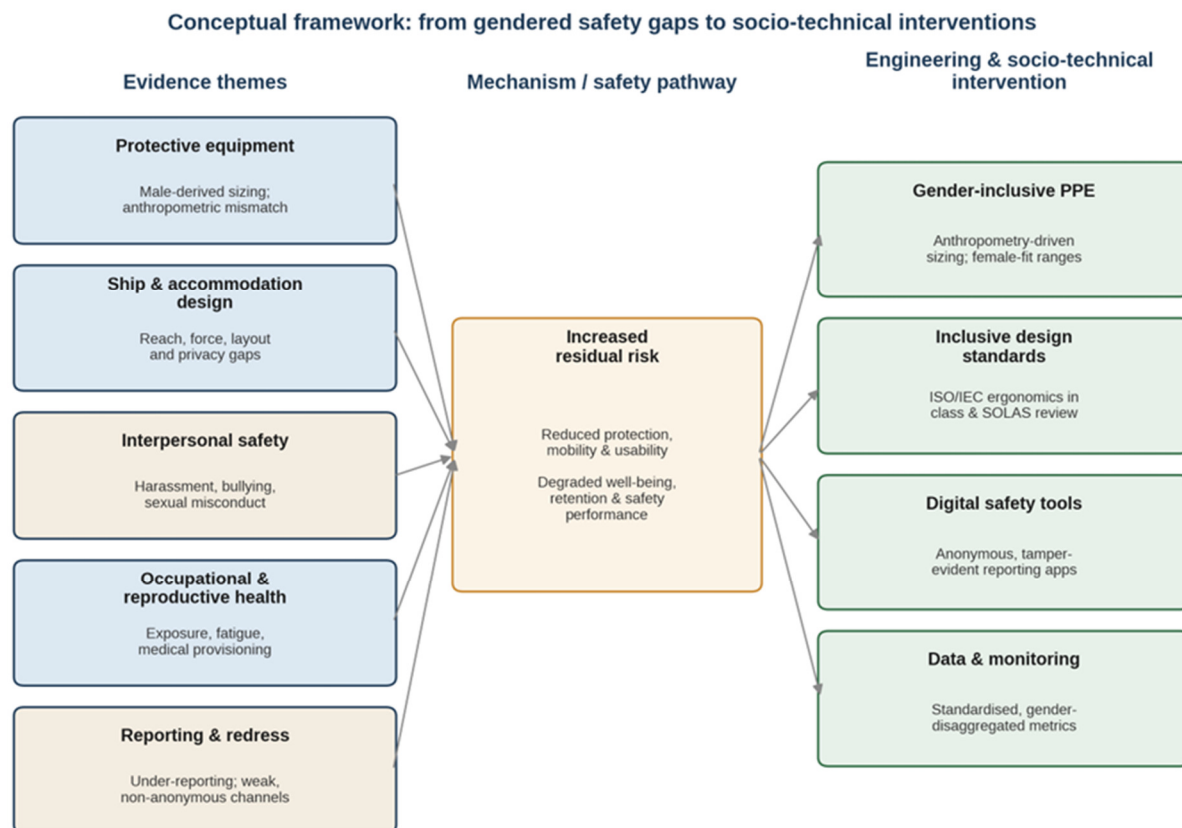


Figure 4. A conceptual framework linking the five evidence themes, through a shared residual-risk mechanism, to maritime-engineering and socio-technical interventions.

4.3. Engineering Opportunities

Three opportunities follow directly. The first is anthropometry-driven protective equipment: deriving female-specific size curves from representative anthropometric data for each safety-critical PPE class, computing accommodation rates against the relevant EN/ISO and LSA-Code requirements, and validating fit empirically. This is a self-contained, high-value study that the field currently lacks [18,20,37,38]. The second is inclusive design standardisation: embedding gender-inclusive ergonomic criteria into classification-society requirements, accommodation and equipment standards, and the periodic review of SOLAS life-saving-appliance provisions, so that inclusivity is specified rather than retrofitted [18,20]. The third is secure digital reporting: designing, deploying and rigorously evaluating an anonymous, tamper-evident shipboard reporting and support tool, integrated with flag-State channels [45], and assessed against the under-reporting failure mode rather than mere availability. The progressive adoption of highly digitalised operations and Maritime Autonomous Surface Ships has been argued to lower some physical barriers to women’s participation; this transition is an opportunity to design inclusivity in from the outset rather than to inherit the legacy ship’s assumptions [52].

Two further considerations make these opportunities tractable rather than aspirational. The first is that each can be expressed in the quantitative language that engineering decision-making already uses: an accommodation rate against a percentile target, a measured reach or force differential, and a reporting-tool adoption and resolution rate. Reframing equity goals as verifiable performance specifications allows them to enter the same trade-off and assurance processes as any other safety requirement, which is both more durable and less easily deprioritised than a narrative commitment. The second is that the marginal cost of inclusion falls sharply when it is specified early. Retrofitting privacy

provisions, re-sizing issued equipment fleet-wide, or bolting a reporting process onto an established culture is expensive and partial; writing the same requirements into a new-building specification, a procurement standard or a digitalised operating concept from the outset is comparatively cheap. The ongoing transition toward highly digitalised and partially autonomous operations is therefore a time-limited design window: the assumptions encoded now will shape vessels and systems for decades, and an inclusive baseline established at this stage avoids a further generation of retrofits [19,45].

4.4. A Research Agenda

Priority in the agenda that follows is not assigned impressionistically. Each candidate item was rated on three explicit axes: (i) safety impact, the directness with which the gap affects protection or injury risk; (ii) evidence-gap severity, how completely the current literature fails to quantify it; and (iii) intervention feasibility, whether a self-contained study of established method could close it at reasonable cost and without depending on regulatory processes outside the researchers' control. Items rated high on all three axes are labelled High priority; those constrained on feasibility, or contingent on standard-setting and regulatory adoption, are labelled Medium. Table 8 consolidates these into a prioritised, engineering-oriented agenda, indicating for each item the gap addressed, an indicative method, and the project work-package theme to which it corresponds.

Table 8. An engineering-oriented research agenda mapping identified gaps to methods and priority (RQ3). Priority (High/Medium) reflects a combined rating on three axes defined in the text: safety impact, evidence-gap severity and intervention feasibility.

Research Item	Gap Addressed	Indicative Method	Priority
Female anthropometric accommodation study for PPE	Male-anchored sizing; no measured fit data	Anthropometric survey + percentile/accommodation modelling vs EN/ISO/LSA	High
Quantified ergonomic load differentials for deck/engine tasks	Reach/force assumptions undocumented	Task analysis, biomechanical and exposure measurement	High
Standardised gender-disaggregated safety metric set	Incommensurable definitions; no pooling possible	Delphi consensus + instrument validation [39]	High
Anonymous, tamper-evident reporting tool	Under-reporting; weak channels	Design-science build + field evaluation; integration with IMO map [45]	High
Inclusive criteria in class/SOLAS review	Inclusivity retrofitted, not specified	Standards gap analysis; regulatory proposal [18,20]	Medium
Under-represented-region evidence	Europe/Asia bias	Multi-site mixed-methods replication [30,31]	Medium
Reproductive-health & medical-fit-out provisioning	Medical/maternity gaps	Provisioning audit; telemedicine protocol design	Medium

4.5. Implications for Maritime Stakeholders

Because the gaps documented here are distributed across the maritime system, closing them requires coordinated action by several distinct actors, each holding a different lever. For shipowners and operators, the most immediate implication is that protective equipment must be procured in a genuine range of sizes and fits rather than nominally “unisex” stock, and that this is a measurable procurement specification rather than a goodwill gesture; the welfare evidence indicates that fit, privacy and medical provisioning are retention factors, so the business case noted in Section 1.1 applies directly at the operator

level [12,14,16,32]. For classification societies and standard-setting bodies, the implication is that gender-inclusive ergonomic and anthropometric criteria belong in the rule sets that govern accommodation, equipment and life-saving appliances, so that inclusivity is verified at survey rather than left to discretion [18,20]. For equipment manufacturers, the female-specific size curves and accommodation analyses called for in Section 4.3 represent both an unmet safety need and a commercial opportunity, as the emergence of tailor-made marine PPE offerings already suggests [33,37].

For maritime education and training (MET) institutions, the pipeline evidence implies that recruitment, cadet-berth allocation and onboard mentoring all shape whether women complete the sea-time required for certification, and that curricula addressing bystander intervention and reporting can reduce the interpersonal-safety burden documented in Section 3.5 [11,31,49]. For flag and port States and the IMO, the priority is the standardised, gender-disaggregated reporting and redress infrastructure whose absence underlies the measurement problem of Section 4.1, building on the 2024 global reporting map toward verified, anonymous and tamper-evident channels [45]. For research-and-development projects such as POMORKINJE 4.0, finally, the implication is that the work packages map cleanly onto the three engineering opportunities of Section 4.3: equipment and working-condition analysis (WP1), digital reporting and onboard-safety tools (WP2), and the dissemination and association-building activity (WP3–WP4) that can carry standardised metrics into practice. The common thread is that no single actor can close the gaps alone, but each can specify, measure and verify its own contribution, which is precisely what treating gender as a safety-engineering variable makes possible. Table 9 sets out these actor-specific levers as a phased roadmap.

Table 9. A phased roadmap for embedding inclusive design and reporting into maritime practice, mapping each actor to a lever, an enabling mechanism, a verification indicator and an indicative time horizon.

Actor	Lever	Mechanism	Indicator	Horizon
Shipowners and operators	Procurement	Protective equipment specified in a genuine female size range; privacy and medical provisioning written into new-building specifications	Share of female crew with fitted PPE; retention differential	Near-term
Classification societies	Rules and survey	Gender-inclusive ergonomic and anthropometric criteria in accommodation and equipment rule sets	Criteria adopted; share of surveys that verify fit	Near to mid-term
Equipment manufacturers	Product design	Female-specific size curves and accommodation analyses for each safety-critical PPE class	Accommodation rate against percentile target	Near to mid-term
Flag and port States, IMO	Reporting infrastructure	Standardised, gender-disaggregated, tamper-evident reporting built on the 2024 IMO map	Reporting-rate uplift; case-resolution rate	Mid-term
Standards bodies (ISO, EN)	Standardisation	Anthropometric annex and inclusive-design provisions; structured input to SOLAS and LSA-Code review	Standard or annex published	Mid to long-term
MET institutions	Training	Bystander-intervention and reporting curricula; equitable cadet-berth allocation	Sea-time completion parity	Near to mid-term
R&D projects (e.g., POMORKINJE 4.0)	Evidence and metrics	Delivery of the Section 4.4 studies; dissemination of standardised metrics through industry associations	Studies completed; uptake of the metric set	Ongoing

4.6. Limitations of This Study

This paper has limitations of its own. Restriction to English-language sources will have excluded the relevant national literatures, for example in Chinese, Japanese, Korean, Spanish and Scandinavian maritime outlets, an acknowledged concern given the geographic bias already noted; because several of the largest seafarer-supply nations publish substantially in languages other than English, multilingual screening is a clear methodological priority for future updates of this review and would likely surface evidence from precisely the under-represented regions identified in Section 3.2. The reliance on sector grey literature, while necessary to capture current practice, introduces sources whose data provenance is not always fully transparent; we have therefore foregrounded provenance in appraisal and avoided pooling. The boundary counts in the PRISMA diagram reflect the corpus assembled by the dated database searches described in Section 2.2. Finally, as a synthesis of existing work, this paper inherits the field's qualitative skew; the anthropometric analysis in Section "An Illustrative Anthropometric Mismatch" is illustrative and is offered as a motivation for primary measurement, not as a substitute for it.

5. Conclusions

Women remain a small minority of the world's seafarers, and the ship they work on, with its equipment, its layout and its social order, still largely reflects a workforce they were not assumed to be part of. This paper has shown that the resulting gaps are not diffuse cultural grievances but, in large part, specific and measurable system–user mismatches: protective equipment sized to male bodies, environments built around male reach and privacy assumptions, an interpersonal-safety burden that falls disproportionately on women, under-addressed health exposures, and reporting systems too weak to surface the problem reliably. The evidence establishing these gaps is consistent in direction but, judged by engineering standards, immature in measurement, being dominated by qualitative and survey work, geographically skewed, and lacking the anthropometric, ergonomic and risk-modelling studies that would let the sector design rather than merely describe.

The central recommendation is therefore to treat gender as a safety-engineering variable. Doing so converts a set of well-documented problems into a tractable design and measurement programme: female-specific protective-equipment sizing validated against standards; inclusive ergonomic criteria written into classification and SOLAS review; standardised, gender-disaggregated safety metrics that make cumulative science possible; and secure, anonymous digital reporting tools evaluated against the under-reporting failure mode they exist to address. These are achievable engineering objectives, aligned with the Maritime Labour Convention and Sustainable Development Goal 5, and they are the objectives toward which projects such as POMORKINJE 4.0 are oriented. A maritime industry facing a structural shortage of skilled crew cannot afford a ship designed for only half of its potential workforce; making the vessel fit the seafarer, rather than the reverse, emerges from the evidence reviewed here as both an equity imperative and a plausible safety gain, a proposition this review advances as a hypothesis for the primary studies it calls for rather than one it can itself demonstrate.

Beyond its immediate findings, the article points to a way of working. The evidence base on women at sea will not become an engineering evidence base on its own; it requires a deliberate shift from documenting experience to measuring it, from cataloguing complaints to specifying requirements, and from urging good intentions to verifying outcomes. The agenda set out in Section 4.4, comprising a female anthropometric accommodation study, quantified ergonomic load differentials, a standardised gender-disaggregated metric set, and a rigorously evaluated secure reporting tool, is offered in that spirit: as a small set of concrete, fundable studies whose results would let classification societies,

regulators, operators and equipment manufacturers act on measurement rather than assertion. Pursued together, they would convert a well-attested but pre-quantitative field into one in which the safety of women at sea can be designed for, audited and improved like any other engineered property of the ship.

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Abbreviations

The following abbreviations are used in this manuscript:

BIMCO	Baltic and International Maritime Council
CHIRP	Confidential Hazardous Incident Reporting Programme
DSG	Diversity Study Group
EN	European Norm
GMF	Global Maritime Forum
ICS	International Chamber of Shipping
ILO	International Labour Organization
IMO	International Maritime Organization
ISO	International Organization for Standardization
ISWAN	International Seafarers’ Welfare and Assistance Network
LSA	Life-Saving Appliance
MASS	Maritime Autonomous Surface Ships
MET	Maritime Education and Training
MLC	Maritime Labour Convention
PPE	Personal Protective Equipment
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RQ	Research Question
SDG	Sustainable Development Goal
SOLAS	International Convention for the Safety of Life at Sea
STCW	Standards of Training, Certification and Watchkeeping for Seafarers

Appendix A. Database Search Strings

The following strings were used for each database, adapted to its native syntax and executed on the title, abstract and keyword fields in May 2026. Authors should confirm the exact execution date for each database at the point of resubmission.

Database	Search String (Fields: Title, Abstract, Keywords)
Scopus	("women seafarer*" OR "female seafarer*" OR "women at sea" OR "gender") AND (seafarer* OR crew OR "merchant navy" OR shipboard OR "on board") AND (safety OR "protective equipment" OR PPE OR ergonomic* OR anthropometr* OR harassment OR "sexual misconduct" OR bullying OR "well-being" OR health OR "ship design" OR accommodation)
Web of Science Core Collection	TS = (("women seafarer*" OR "female seafarer*" OR "women at sea" OR gender) AND (seafarer* OR crew OR "merchant navy" OR shipboard OR "on board")) AND (safety OR "protective equipment" OR PPE OR ergonomic* OR anthropometr* OR harassment OR "sexual misconduct" OR bullying OR "well-being" OR health OR "ship design" OR accommodation))
PubMed	("women seafarer*[tiab] OR "female seafarer*[tiab] OR "women at sea"[tiab] OR gender[tiab]) AND (seafarer*[tiab] OR crew[tiab] OR "merchant navy"[tiab] OR shipboard[tiab] OR "on board"[tiab]) AND (safety[tiab] OR "protective equipment"[tiab] OR PPE[tiab] OR ergonomic*[tiab] OR anthropometr*[tiab] OR harassment[tiab] OR "sexual misconduct"[tiab] OR bullying[tiab] OR "well-being"[tiab] OR health[tiab] OR "ship design"[tiab] OR accommodation[tiab])

Appendix B. Critical-Appraisal Criteria and Confidence Tiers

Empirical studies were appraised with the Mixed Methods Appraisal Tool (MMAT) and grey-literature and sector reports with the AACODS checklist. Each source was then assigned to a confidence tier that governed the interpretive weight placed on it.

Instrument/Criterion	What Was Assessed
MMAT (empirical studies)	Clarity of the research question; appropriateness of design; sampling and representativeness; validity of measurement; completeness and appropriateness of analysis
AACODS: Authority	Standing and accountability of the producer (e.g., IMO, ILO, a classification society or an established industry alliance)
AACODS: Accuracy	Whether methods, data sources and referencing are stated, and whether the account is internally consistent
AACODS: Coverage	Whether the population, scope and limits of what is claimed are made explicit
AACODS: Objectivity	Balance versus advocacy, and disclosure of standpoint or interest
AACODS: Date	Recency and the presence of a datable point of reference
AACODS: Significance	Relevance and contribution to the review question

Tier definitions. Higher confidence: peer-reviewed empirical studies meeting most MMAT criteria. Moderate confidence: institutional grey literature with transparent methods meeting at least four of the six AACODS criteria. Indicative: sector or advocacy reports with limited methodological transparency, used only to establish direction and order of magnitude. Prevalence figures from indicative sources (for example those in Table 6 and Figure 3) were never statistically pooled and are reported as ranges with their definitional caveats.

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