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Smart & Resilient Logistics Corridors Future Gateway to the Green Trade

HUMAN-CENTERED DESIGN AT SEA: SEAFARERS' COMFORT PRIORITIES AS A FOUNDATION FOR DEVELOPING THE MARITIME COMFORT INDEX (MCI)

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Keywords: Seafarers' comfort; human factors; ship interior design; well-being at sea; Maritime Comfort Index (MCI); pilot study; maritime ergonomics.

ABSTRACT

Working and living at sea is a demanding experience that challenges both the physical and psychological probability of living for seafarers. While technological innovation, emissions reduction, and infrastructure development have advanced maritime efficiency, the comfort and well-being of those onboard remain underexplored dimensions of maritime design and sustainability. This study adopts a human-centred design perspective to evaluate seafarers' perceptions of key onboard comfort factors that influence performance, satisfaction, and quality of life at sea. Six environmental and psychological comfort dimensions—lighting, noise, whole-body vibration, air conditioning quality and ventilation, space arrangement, and psychological comfort—were examined across four functional zones on board: workspaces, accommodation, leisure areas, and corridors.

The study introduces a methodological framework that integrates empirical perception data with measurable comfort indicators, forming the basis for a proposed Maritime Comfort Index (MCI). The MCI aims to quantify comfort levels and guide evidence-based improvements in ship interior design and operation. By embedding human comfort into maritime design and regulatory practice, this research contributes to the broader pursuit of sustainable, efficient, and resilient maritime logistics systems that prioritise both safety and well-being.

1. INTRODUCTION

Comfort is a crucial component of the human experience and a major factor in determining performance, happiness, and general well-being in any environment. It demonstrates the complex interaction of environmental, psychological, and physical elements that affect how people see and react to their world. Comfort becomes even more important because ships serve as both living and workplace. Due to the fact that ships function as both workplace and living space comfort becomes even more critical.

In maritime life, end-users spend long periods in confined environments where professional duties, rest, and recreation occur within the same limited setting. This dual function makes comfort not merely a desirable feature, but an essential condition for maintaining health, alertness, and operational efficiency.

In maritime operations, human factors play a critical role (Maternová et al. 2023; Ma, Liu, and Yang 2023), influencing not only safety but also the productivity and overall well-being of end-users. Ship designers are increasingly expected to account for the physical, mental, and emotional needs of those living and working at sea. Environmental elements such as lighting, noise, whole-body vibration, air conditioning quality and ventilation, space arrangement, and psychological factors can significantly affect the end-user's ability to perform duties effectively, reduce fatigue, and maintain general well-being.

Despite the recognized importance of these factors, maritime regulations - such as those established by the International Maritime Organization (IMO) and the International Labor Organization (ILO) - have traditionally prioritized occupational health and safety over broader comfort and human-centered design consideration (Costa 2018). As a result, vessel design and evaluation frameworks continue to fail to adequately address the psychological, ergonomic, and aesthetic needs of seafarers. The human experience within ships has frequently been neglected in favor of fuel efficiency, emissions reduction, and operational reliability in recent decades due to advancements in ship technology, automation, and environmental regulation.

In the context of this gap, the current study utilizes a human-centered design approach to investigate the environmental and psychological comfort elements that influence seafarers' experiences onboard. The study intends to lay the foundation for the Maritime Comfort Index (MCI), a systematic, user-centered framework designed to measure comfort levels in ship interior design, by identifying and ranking these aspects. In order to improve comfort, safety, and performance at sea, the MCI aims to assist designers, ship owners, and policymakers in making effective choices.

Enhancing comfort is fundamentally a concern for human wellbeing and a strategic element of sustainable and resilient maritime operations.

The research's originality is rooted in its end-user approach, highlighting seafarers' real-life experiences and comfort needs instead than just concentrating on technical or regulatory criteria. This research establishes the marine Comfort Index (MCI) based on the impressions of individuals residing and working onboard, so presenting a human-centered framework that positions comfort as a crucial component of sustainable and resilient marine operations.

This paper is structured as follows: Section 2 presents the background and literature review on comfort factors in maritime environments. Section 3 describes the methodology used in the pilot study. Section 4 presents the results on seafarers' comfort perceptions. Section 5 discussion and finally section 6 present the conclusion and recommended future work.

2. BACKGROUND

The concept of comfort aboard ships is complex and includes mental as well as physical wellness (Tsioutsia 2024). Although functionality, safety, and technical performance have been the main focus of parent maritime legislation, there is growing realization that long-term efficiency and safety are equally connected to the environmental and emotional quality of life that seafarers experience at sea (Grech 2024).

2.1 Comfort in Maritime Context

Seafarers live and work within the same confined environment for extended periods (Abeysiriwardhane 2017). Their physical stressors, which include extended exposure to noise, vibration, poor lighting, low ventilation, and cramped quarters, can cause exhaustion, disturbed sleep, cognitive strain (Fan et al. 2023). Beyond the physical,

psychological comfort plays a vital role in morale, motivation, and mental health, particularly during long voyages or isolation at sea. The availability of private spaces, access to recreation, and pleasing visual and acoustic conditions can mitigate stress and enhance emotional stability (De Looze, Kuijt-Evers, and Van Dieen 2003; Vink et al. 2017). Nevertheless, such aspects are often overlooked in the design and construction phases of ships (Rumawas 2016), particularly in training or working vessels that are not built to passenger-ship standards.

2.2 The Role of Human Factors and Ergonomics

Human factors engineering emphasizes designing systems that accommodate users' needs, capabilities, and limitations. In maritime operations, applying human-centered design (HCD) principles improves safety, reduces errors, and enhances crew satisfaction (Grech 2024). However, while industries such as aviation and healthcare have widely integrated HCD into performance and safety models, maritime applications remain limited (Brown et al. 2022). The absence of formal comfort assessment tools has hindered ship designers from systematically evaluating how environmental and interior features affect human performance.

2.3 Regulatory Gaps

International conventions such as the International Maritime Organization (IMO)'s (IMO 2024) Maritime Safety Convention SOLAS (Guevara and Dalaklis 2021), and the International Labor Organization (ILO)'s (ILO 2023) Maritime Labor Convention MLC, 2006 (Chang and Khan 2023) establish minimum standards for safety, accommodation, and welfare (ISM 2018). However, these frameworks primarily emphasize functional and occupational health requirements, offering little guidance on comfort, habitability, or aesthetic quality. The ISO 21010 and DNV Comfort Class (Rutkowski and Korzeb 2024) provide some technical references for vibration, noise, and thermal conditions, yet they are neither comprehensive nor universally applied across all ship types, especially training and working vessels (Karkori 2024).

A design gap has resulted from this regulatory contradiction, whereby long-term comfort, motivation, and mental well-being are not sufficiently addressed while physical safety is guaranteed. Both end-user empirical data and standardized methods that may convert subjective comfort judgments into measurable design criteria are needed to close this gap.

2.4 Need for a Maritime Comfort Index (MCI)

Responding to these challenges, this study presents the concept of a Maritime Comfort Index (MCI) - a framework designed to quantify comfort levels and integrate them into the design and evaluation of ship interiors. By measuring the importance and satisfaction levels of key environmental and psychological factors such as lighting, noise, whole-body vibration, air conditioning quality and ventilation, space arrangement, and psychological comfort - across four main functional zones onboard ship (workspaces, accommodation, corridors and passageways, and leisure and entertainment areas), the MCI aims to provide scientific criteria that support human-centered innovation, regulatory evolution, and sustainable maritime development.

Ultimately, enhancing comfort is not an isolated concern but a strategic driver of workforce resilience, retention, and performance (Ajayi and Udeh 2024). Addressing it systematically contributes to safer, healthier, and more sustainable operations across global maritime logistics corridors (Lau et al. 2024).

3. METHODOLOGY

3.1 Questionnaire Survey

In order to measure end users' views on the importance of six essential comfort factors onboard a ship —lighting, noise, whole-body vibration, air conditioning quality and ventilation, space arrangement, and psychological comfort—a quantitative research approach was used with an online structured questionnaire. This was done primarily across six functional zones: 1. Workspaces; 2. Accommodation areas; 3. Corridors and passageways; and 4. Leisure and entertainment areas. This approach provided a comprehensive understanding of how environmental and psychological dimensions contribute to the overall comfort experience at sea.

3.2 Data Analysis

For assessing the relative importance of each comfort element and its sub-factors, descriptive statistics (means and standard deviations) were used to examine the data. Excel software was used for the analysis, and the findings were evaluated to determine the fundamental weighting of the factors used to create the Maritime Comfort Index (MCI). Comfort factors were prioritized in later design and modeling stages based on higher mean values, which suggested respondents gave them more priority.

3.3 Questionnaire Design

In order to ensure inclusivity and clarity, the survey was bilingual in Arabic and English. It consisted of four main parts:

- Part A: Respondent profile (rank, age, nationality, vessel type, years of experience).
- Part B: Respondents were rank the relative the overall importance of each of the six main comfort factors (lighting, noise, vibration, air conditioning quality & ventilation, space arrangement, psychological comfort) across four onboard zones—working, accommodation, corridors & passageways, and leisure & entertainment areas, using a five-point Likert scale (1 = Not Important at All to 5 = Very Important). This gave each zone a general hierarchy with regards to importance.
- Part C: Ratings of sub-factors linked to each comfort factor (e.g., brightness level, air freshness, privacy) in each zone. To maintain participant engagement and reduce response fatigue, Part C was divided into three different survey sections, each including two comfort factors only:
  Section 1: Lighting and Noise;
  Section 2: Whole-body Vibration and Air Quality & Ventilation;
  Section 3: Space Arrangement and Psychological Comfort.
  Each sub-factor was assessed for its perceived importance across the four functional areas listed above.
- Part D: Participants were invited to provide qualitative feedback and suggestions for improving onboard comfort and interior design. These responses offered valuable insights that complemented the quantitative findings.

3.4 Target Group

A wide range of seafarers and trainees, covering a variety of experience levels and vessel types, were the target of the survey, including cadets, crew members, nautical officers, and engineering officers. This combination made it possible to document differences in perception according to exposure to various maritime circumstances, operational role, and rank. In order to promote candid feedback, participation was anonymous and entirely voluntary. 19 valid responses in all were obtained and incorporated into the study, but still waiting for other respondents will be analysed to the final MCI studies.

3.5 Study Scope and Limitations

This study constitutes a preliminary investigation designed to examine the comfort priorities of seafarers on commercial and training vessels. Warships and private yachts were excluded due to their unique operational, security, and comfort standards, which substantially differ from those of merchant vessels. Although the sample size is limited, the study offers valuable preliminary insights that will guide the future development and validation of the Maritime Comfort Index (MCI). The respondents operated on various types of commercial vessels under diverse operational conditions, aligning with the exploratory objectives of the study.

4. RESULTS AND DISCUSSION

The findings from the study of respondents' assessments of the importance of different ship comfort elements and their associated sub-factors throughout the four main ship zones—working, accommodation, passageways and corridors, and leisure and entertainment areas—are shown in this section. In the upcoming research phase, information about psychological comfort and space arrangement will be incorporated into the full Maritime Comfort Index (MCI) because there are currently no responses to their questionnaires.

4.1 Mean Importance Ratings

The mean and standard deviation (SD) for each comfort factor across the four ship zones were determined using descriptive statistical analysis, as indicated in Table 1. The findings show that respondents strongly believed that lighting and air conditioning quality and ventilation had an impact on onboard comfort, as seen by the highest mean significance ratings they received (4.14 and 4.15, respectively). With intermediate mean values (3.44 and 3.64), noise and whole-body vibration came next, indicating that although these components are important, their effects may differ based on the ship's location and operational circumstances.

Table 1. Mean Importance and S.D of Comfort Factors Across Ship Zones

Factor	working	Accommodation	corridors and passageways	leisure and entertainment area	Overall Mean	SD
Lighting	4.26	4.31	3.84	4.15	4.14	0.21
Noise	3.36	3.84	3.05	3.52	3.44	0.33
WBV	3.10	3.94	3.73	3.78	3.64	0.37
Air conditioning quality and ventilation	4.21	4.31	3.73	4.36	4.15	0.29
Space arrangement	3.63	4.05	3.63	3.73	3.76	0.20
Psychological factor	4.00	3.78	3.47	4.10	3.84	0.28

The accommodation space continuously displayed the highest mean ratings across the majority of criteria in terms of spatial distribution, underscoring its crucial importance in crew comfort. In contrast to other ship zones, corridors and passageways were rated significantly lower, indicating a shorter exposure time and a lower focus for comfort design.

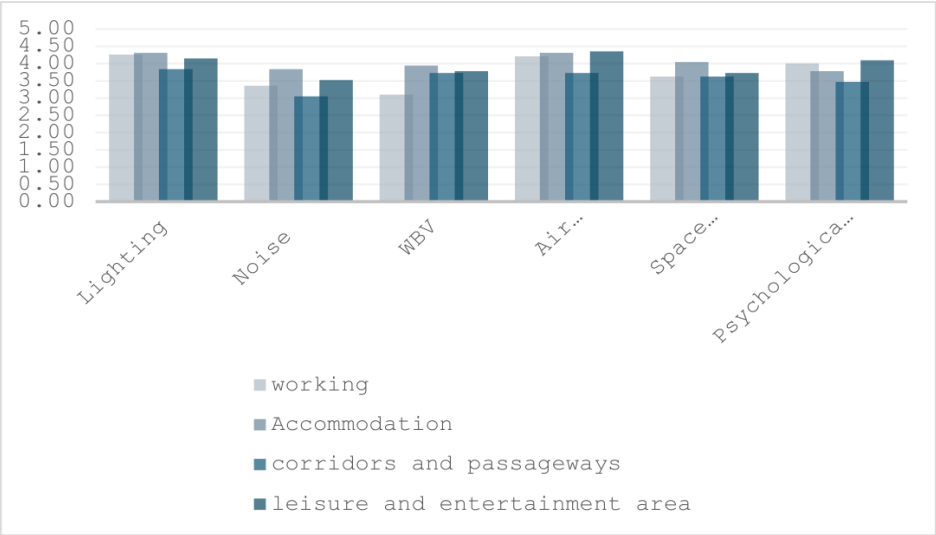

Figure 1. Mean Importance of Comfort Factors

4.2 Sub-Factors Importance

Table 2 provides a summary of the specific mean and SD values for each comfort factor's sub-factors. Light hue and brightness were found to be the most significant sub-factors linked to lighting, whilst uniformity and reflection levels received somewhat lower evaluations. The quality of the insulation and noise from nearby cabins and machines were cited as the most important factors for the noise category. All of the sub-factors in the Whole-Body Vibration example received moderate relevance ratings (mean values between 2.0 and 2.2), suggesting a persistent worry about the sources of vibration from machinery and engines. Additionally, the sub-factors of ventilation and air conditioning quality, in particular air dispersion and temperature stability, were rated reasonably highly (overall mean ≈2.4), indicating their critical role in thermal and psychological comfort. The lack of replies in the corresponding survey sections for Space Arrangement and Psychological Factor was consistent with the lack of sub-factor data for these variables.

Table 2. Mean Importance and Standard Deviation of Sub-Factors Across Comfort Dimensions

Sub-factor	working	Accommodation	corridors and passageways	leisure and entertainment area	Over all Mean	SD
Brightness (Illuminance level)	1.89	1.74	1.84	1.58	1.76	0.14
Lighting distribution	1.84	1.68	1.74	1.68	1.74	0.07
Glare and reflections control	1.84	1.68	1.68	1.63	1.71	0.09
Visual task adequacy	1.84	1.63	1.74	1.68	1.72	0.09
Lighting uniformity / stability	1.95	1.89	1.84	1.58	1.82	0.16
Color temperature	1.74	1.63	_	1.42	1.60	0.16
Access to daylight	1.89	1.74	1.53	1.53	1.67	0.18
Control of lighting	1.95	1.68	1.68	1.42	1.68	0.21
Aesthetic or ambience quality	1.42	1.89	1.63	1.68	1.66	0.19
Acceptable overall noise level	1.42	1.68	1.63	1.47	1.55	0.13

Sub-factor	working	Accommodation	corridors and passageways	leisure and entertainment area	Over all Mean	SD
Communicate with others without interference	1.58	1.84	1.37	1.84	1.66	0.23
Sufficient quietness to support work and rest	1.58	1.89	1.74	1.89	1.78	0.15
Sound insulation	1.42	1.79	2.00	1.63	1.71	0.24
Disturbance or annoyance from continuous noise	1.63	1.79	2.00	1.74	1.79	0.15
Vibration intensity and frequency	2.21	2.05	2.37	2.16	2.20	0.13
Direction and transmission of vibration	2.26	2.16	2.11	2.37	2.22	0.12
Vibration exposure duration	2.16	2.21	2.21	2.32	2.22	0.07
Structural-borne vibration noise	2.05	2.05	2.05	1.95	2.03	0.05
Equipment-induced vibration	2.05	2.00	2.11	2.16	2.08	0.07
Floor vibration perception	1.84	1.89	1.95	1.89	1.89	0.04
Vibration variability across zones	2.05	2.05	2.37	2.26	2.18	0.16
Thermal comfort (temperature stability)	2.74	2.21	2.47	2.21	2.41	0.25
Airflow direction and velocity	2.47	2.26	2.58	2.32	2.41	0.14
Humidity level	2.63	2.16	2.47	2.53	2.45	0.20
Fresh air supply/ventilation rate	2.79	2.37	2.53	2.53	2.55	0.17
Air quality perception (odors, stuffiness)	2.63	2.37	2.53	2.21	2.43	0.18
Noise and draft from HVAC systems	2.37	2.11	2.47	2.16	2.28	0.17

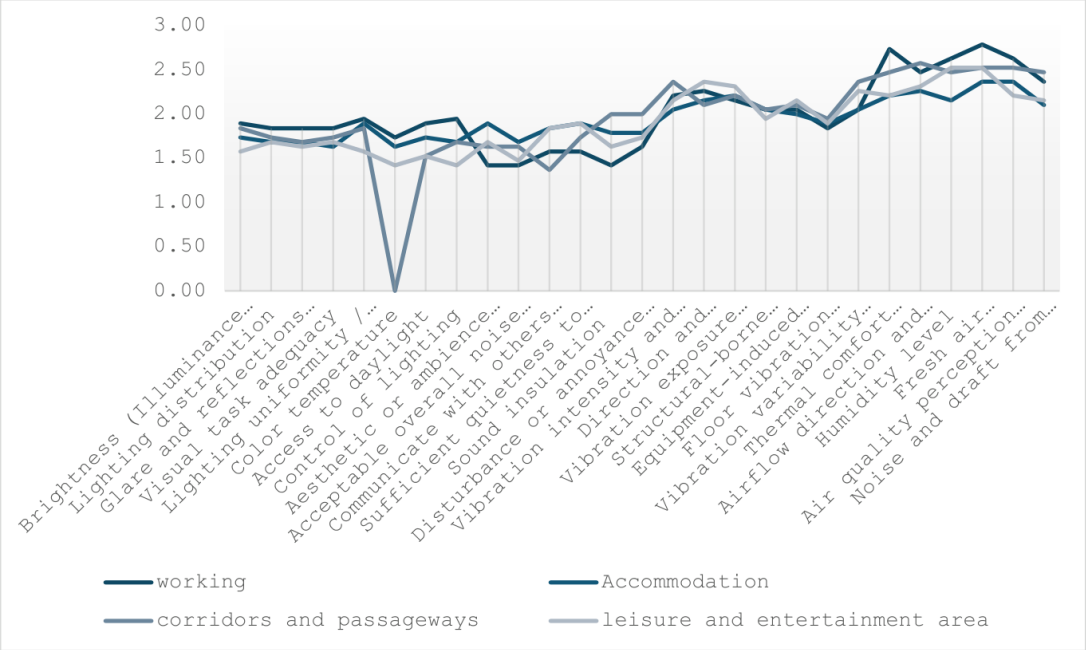

Figure 2. Comfort sub-factor' importance across shipboard zones.

4.3 Qualitative Insights from Open-Ended Responses

The open-ended questions provided significant qualitative data about how comfortable seafarers felt aboard. According to the majority of respondents, the ship's rooms and accommodations spaces need the most comfort improvements, especially with regard to lighting, noise levels, and air conditioning. The majority of comments highlighted how psychological comfort is greatly impacted by lighting color and brightness in cabins, indicating the need for warmer or adaptable lighting to promote relaxation. Regarding noise, respondents often brought up the lack of proper soundproofing, which contributes to stress, fatigue and disturbs sleep, particularly when offshore operations are occurring.

The significance of cabin-level environmental control is further supported by feedback on whole-body vibration and airflow conditions, which showed that vibration and excessive air movement in cabins had a negative impact on psychological comfort.

Responses related to space arrangement and psychological factors were minimal ("zero"), indicating either a lack of knowledge or difficulty describing the emotional and spatial components of comfort. However, participants' worries regarding noise control, privacy, furniture arrangement, and consistency of upkeep were evident in the last two questions, which asked about overall design and suggestions for improvement.

Common recommendations included:

- Remodeling and expanding sleeping and sleeping areas,
- Enhancing sound insulation,
- Improving air ventilation, especially in corridors and stair zones,
- Providing recreation and fitness spaces, and
- Upgrading interior finishes, furniture ergonomics, and lighting systems.

Overall, respondents noted that relaxation, recovery, and psychological health depend on comfortable accommodations, and that future ship interior modifications should give priority to accommodations and mess-room facilities.

4.4 Implications for Ship Design

The results unequivocally show that comfort is an essential need rather than a secondary pleasure. Enhancements in lighting balance, temperature stability, and air quality improve focus and fatigue resistance, all of which have a direct impact on efficiency and safety. By using human-centered design concepts, the Maritime Comfort Index (MCI) can be optimized, providing designers and policymakers with measurable information to enhance vessel habitability.

5. DISCUSSION

The study's conclusions emphasize how crucial it is to use a human-centered approach when designing ship interiors in order to improve the overall comfort and wellbeing of seafarers. Several important conclusions about which comfort aspects have the greatest impact on seafarers' perceptions and how these priorities differ among ship zones were drawn from the analysis of both quantitative and qualitative responses.

5.1 Dominance of Environmental Comfort Factors

The findings show that the two most highly regarded comfort elements were Lighting and Air Conditioning Quality and Ventilation both of which had mean importance values above 4.10. This illustrates how seafarers' everyday experiences on board are greatly influenced by their thermal and visual comfort. In addition to improving visual performance, appropriate lighting, color, and brightness have an impact on mood, attentiveness, and post-work psychological recovery. Similar to this, keeping the temperature and ventilation in tight ship environments at a suitable level is essential to reducing fatigue and thermal stress, especially in the accommodations and recreation areas where seafarers spend the majority of their time off duty.

These results are in line with earlier studies in the fields of building design and aviation, which demonstrate that thermal comfort and lighting are important factors that affect how well people function and how satisfied they are in enclosed spaces (Hu et al. 2023). Due to extended travel times, exposure to severe weather, and the lack of alternate rehabilitation areas, these environmental issues are particularly significant in the maritime context.

5.2 Influence of Noise and Whole-Body Vibration

Although noise (mean = 3.44) and whole-body vibration (mean = 3.64) are acknowledged sources of discomfort, their effects could vary depending on the operational environment and spatial arrangement of the ship, according to their moderate ratings. Respondents specifically underlined how noise from machinery and poor sound insulation in cabins negatively impact concentration and sleep quality, which is in line with well-established research on seafarer tiredness.

In a similar vein, vibration exposure was considered a chronic stressor, particularly in accommodations close to engine rooms. These findings highlight the need for acoustic and vibration mitigation techniques, including better insulation, separating equipment areas, and installing ergonomic vibration isolation devices in living areas.

5.3 Significance of Accommodation Spaces

The accommodation area was consistently rated as the most important aspect across all comfort criteria. This strengthens the knowledge that accommodations are the main onboard healing environment, having a direct impact on operational effectiveness, mental and physical health, and well-being. The open-ended comments from respondents also

emphasized the need for improved privacy, ventilation, soundproofing, and room layouts, showing that poor design in this area directly contributes to stress and lower sleep quality.

This result is consistent with human-centered design principles, which emphasize that crew quarters should be viewed as restorative places that are essential for preserving psychological equilibrium and operational preparedness rather than just functional areas.

5.4 Absence of Data on Spatial and Psychological Factors

The fact that neither Space Arrangement nor Psychological Factor received any responses indicates that seafarers could have trouble expressing or accurately assessing the emotional and spatial aspects of comfort. This might be because these variables are more abstract than tangible environmental factors like temperature or lighting. Their absence, however, does not suggest that they are irrelevant; rather, it emphasizes the necessity for future research to use qualitative or through visuals methods of inquiry (such as design walkthroughs or surveys based on photographs) in order to capture these less quantifiable but no less significant elements of interior comfort.

5.5 Towards the Maritime Comfort Index (MCI)

The integration of quantitative and qualitative findings offers the foundation for constructing a Maritime Comfort Index (MCI) — a framework that quantifies the relative importance of each comfort aspect on total seafarer well-being. The MCI can be a useful design tool for ship operators, naval architects, and interior designers by weighing environmental, physical, and psychological aspects based on their perceived relevance.

By allowing a uniform evaluation of comfort performance across various ship types and zones, such an index would support evidence-based enhancements and benchmarking in the maritime sector. The study's conclusions, especially its focus on thermal management, illumination, and comfort in the accommodations, offer a crucial empirical foundation for determining the initial MCI parameters.

6. CONCLUSION AND FUTURE WORK

This study examined the significance of comfort for seafarers in various ship zones using a human-centered design approach. An analysis of quantitative assessments and qualitative comments indicates that environmental comfort characteristics, such as lighting, ventilation, and air conditioning quality, are the most significant factors affecting onboard comfort and psychological well-being. These findings indicate that the most crucial area for improving crew morale, living circumstances, and sleep quality is the ship's cabins.

Moderate whole-body vibration and noise ratings indicate persistent issues with vibration and acoustic control that must be addressed in the design.

However, the lack of responses for psychological comfort and spatial arrangements suggests that, despite being less evident to mariners, these factors should not be ignored when evaluating interior design. They should be further examined utilizing qualitative and visual research methods in order to gain deeper experiential insights.

By combining the findings of quantitative and qualitative assessments, this study establishes the foundation for developing a Maritime Comfort Index (MCI), a recommended assessment tool to evaluate and quantify comfort elements aboard ships. The MCI will help designers, operators, and lawmakers systematically assess comfort conditions across different ship types and operational settings in order to align interior design with the real needs and experiences of seafarers.

6.1 Future Work

- Increase the sample size and response variety to cover a range of ship types, crew nationalities, and trip lengths.
- Use assessment instruments based on virtual reality or visuals to incorporate psychological and spatial design elements.
- Validate and refine the proposed Maritime Comfort Index (MCI) by testing its application across case studies and ship classes.
- Explore correlations between comfort importance, satisfaction, and performance, to establish a more comprehensive understanding of how interior design contributes to safety, health, and productivity at sea.

Through these future developments, the maritime sector can move toward evidence-based interior design standards that reflect seafarers' lived experiences — promoting comfort, health, and sustainable performance in shipboard environments.

7. DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

The author employed ChatGPT (OpenAI) to facilitate linguistic refinement while preparing this work. Following the use of this tool, the author took full responsibility for the publication's content and reviewed and edited it as needed.

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