

Content Analysis of International Standards for Human Factors in Ship Design and Operation

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Human-related factors account for more than 80% of accidents at sea, based on studies. According to Global Claims Review 2017 released by Allianz Global Corporate & Specialty, an estimated 75-96% of shipping accidents have a high probability of involving human error (AGCS, 2017). Designs that do not meet human factors' needs play a significant role in contributing to human error. Documents in terms of design standards and guidelines, rules, and laws are analyzed. As a result, several documents related to human factors have been identified. These documents are based on whether to implement it, even if some are prescriptive, and others are mandatory, being published at different enforcement levels. In ensuring the consistent implementation of human factors, regulators and authorities need to take stricter measures in all the processes involved in designing and building such ships.

KEY WORDS

- ~ Human Factor, Ship Design
- ~ American Bureau of Shipping (ABS)
- ~ Lloyd's Register (LR)
- ~ Det Norske Veritas (DNV)
- ~ International Organisation for Standardization (ISO)
- ~ International Maritime Organization (IMO)
- ~ American Society for Testing and Materials (ASTM)

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1. INTRODUCTION

This journal describes how ship design covers aspects of human factors. Generally, 75-96% of shipping accidents have a high probability of human error (AGCS, 2017; McAfferty & Baker, 2006). This study aims to enhance appreciation of the cause of maritime accidents in terms of the role of human factors.

Results from poor management, maintenance of faults, incorrect installation, imperfect design, and the system's weaknesses are factors that tend to make the user a victim (Muschara, 2017). Therefore, user-centred design is vital in integrating non-engineering design disciplines into marine engineering during building of ships (Ahola, Murto & Mallam, 2018).

Human factor elements are on the bottom of interest in Corporate social responsibility (CSR) for the top 15 shipping companies, which control 80% global container shipping market, even though it is an exciting issue (Tang & Gekara, 2020). Imposing disciplinary action on any accidents at work, giving speeches and encouragement to work more safely, adding manuals or written procedures, or providing additional training will not overcome human errors caused by weaknesses in workplace design (Dekker, 2017; Ross, 2017). To find out the design is human friendly and good, three methods can be used:

Accepting the design, the rules and regulations set by such an organization must comply with ship design. Ross also identified the rules and standards appropriate to ship design, such as hull shape, structure, engine, machine interface with human and general arrangement (Papanikolaou et al., 2019).

Relevant human factors literature was studied, and the ship design model was discovered using reference analysis. In addition, relevant codes, regulations, laws, and guidelines were

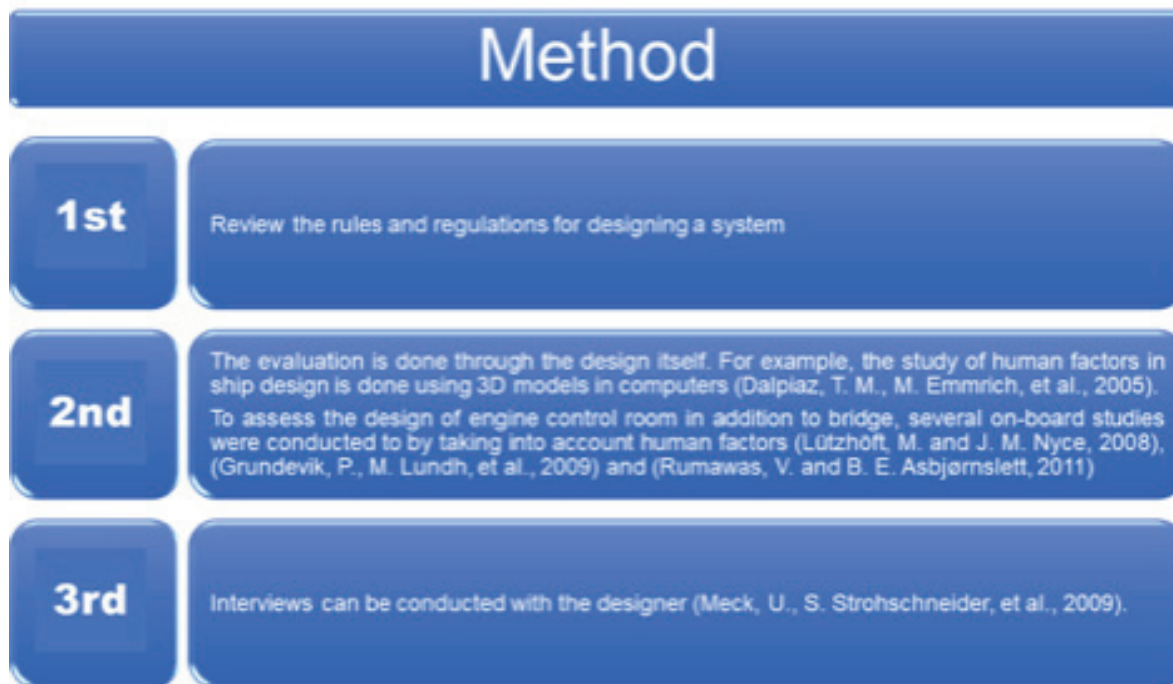


Figure 1.
Method to Measure Human Factors on Board Ships.

reviewed. The aim is to examine how human factors guidelines are provided and what things to discuss. The findings can be helpful for those engaged in ship construction and attentive in incorporating human-factors-related concepts in their design.

2. BACKGROUND AND RELATED WORKS

In this literature review, the human factor principle in ship design are established. It begins with the definition of the human factor from the investigated shipping community. Then, the ship planning stage is addressed. Finally, in the construction of ships, the application of the human element must be taken into consideration.

The word 'human element' for human factors is used and described by the International Maritime Organization (IMO, 2004) as "All aspects of human activities carried out by lawmakers, ship crews, shipyards, recognized organizations, regulatory bodies, land management, and other related parties involved in the human factor."

Human Factors and Ergonomics Society (HFES) defines human factor as "Applications related to what we understand about humans, the work they do, the environment in which they work, the characteristics and limitations of the equipment design they use and their capabilities are emphasized in the Human factor" (2020).

The human factor is also defined by The International Ergonomics Association (IEA, 2020) as "Emphasis on understanding the relationship between humans and other systems through scientific discipline that applies methods to design, data, principles, and theories, with the purpose of overall the system performance itself and optimize human wellbeing."

2.1. Ship Design Process

Ship designing is a lengthy and interrelated process, separated into several phases or stages. The design process involves developing needs, performing analysis, developing sketches and plans, building electronic models, and developing written specifications.



Figure 2.
Three major ships design process.

Current developments influence the method of dividing and naming the three major ship development processes (Trincas et al., 2018). It has later distinguished the two stages of ship design depicted in Figure 3 (Andrews, 2018):

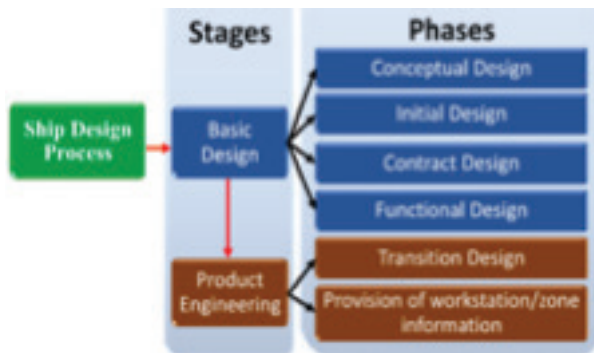


Figure 3. Two stages of ship design.

The ship design process is divided into four phases in the book "Ship Design and Construction Textbook", as shown in Figure 4 (Papanikolaou, 2019).

The first step in this process is the mission statement, such as the area it will operate in and the type of ship to be built based on its operational nature. The longer this process, the more detailed the problems identified, e.g. HVAC diagram as well as an equipment list, installation diagram, electrical equipment, accommodation arrangement, pipe, machinery room, and machinery control room design, bridge design, ship layout, the type of machine to be installed, the type of hull to be used and the dimensions of the ship.

Any of the subjects discussed above are typical marine-based concerns, and not all issues are relevant to human factors, but may still affect their work efficiency, effectiveness, and safety.



Figure 4. Four-phase ship design process.

2.2. Human Factors in Ship Design

From acquisition until disposal, people are interested in a ship's life cycle. This process involves founders, architects-designers, registration boards, regulatory agencies, shipbuilders, manufacturers, managers/ operators of ships, sailors/unions, and insurers (Tang & Gekara, 2020). They all have distinct yet critical impacts on protection, productivity, and effectiveness. In addition, all regulatory authorities play a significant function and can have an extensive safety effect.

The maritime administration's role, serving as the national controller of the ship's flag, is to ensure conformity with the regulations (Xaζιζα, 2019). The classification authority shall set criteria and technical rules. However, they still must guarantee that the building and specifications are up to par. The designation authority has been traditional to conduct regulator roles as the flag state. Much of this information is stipulated in the specifications and recommendations that prioritize human factors to reduce design costs.

According to Rawson and Tupper, the human aspect in architecture is protected by a team with vast knowledge and experience, such as psychologists, physiologists, mechanics, and physicists who make up the squad. This human-factors team will inform engineers about how to build structures or facilities. As a result, individuals can execute activities more reliably, increase machine quality, improve human output, and have an eventual degree of environmental parameters (Trincas et al., 2018).

In a ship design and construction book published by the SNAME (Society of Naval Architects and Marine Engineers), human factor is considered as a descriptive concept encompassing all facets of the system's biomedical and psychological considerations that occur to humans. Human factors are often listed, including life support and human engineering, worker's selection, facilities for training and preparation, job equipment, as well as achievement assessment and appraisal. Human factor engineering is separately specified in ship construction. Human factor engineering incorporates strategies to assess the role of humans in dynamic environments, simulation, and modelling of human resources reduction, crew workloads, assessment of workloads for operator/maintenance, decision-making tools to minimize human error and injuries, to increase human efficiency and protection and advanced human-machine interfaces, as well as approaches and data for ship design (Charlton & O'Brien, 2019).

Lloyd's Register (LR) identifies human variables as relevant to the activities they undertake and the context in which they operate (Lloyd's register, 2008). The word human factor signifies, as used for the construction, the function of a ship and its structures, taking human ability, expertise, weaknesses, needs into account and human usage as part of the system. The human factor describes the work environment's analysis and design

for the value of protection, performance, productivity, health, and comfort. Shipyards, equipment control rooms, galleys, and elements relevant to work processes and procedures provide work conditions. For any ship to run safely and efficiently, it must be built to serve the persons on board without risking their wellbeing, protection, and efficiency.

In ship design, nine human factors describe motion, vision, sound, climate, safety and health, human-machine interface (Charlton and O'Brien, 2019). Concerning human factors, LR consistently identifies many different concept qualities. This concept involves the following (Lloyd's register, 2008):

Habitability - is the availability of sufficient and convenient living space, including furniture and laundry services, galleys, and room for leisure. In terms of scale, form, gender, and different environmental pressures, such as noise, heat, and vibration, this provision must consider multiple marine differences.

Maintenance - arranging the production of maintenance activities to be fast, secure, and practical, enabling systems and equipment to reach a defined standard of achievement. It involves entry concerns, removing paths, instruments, skills, disposal, and lifetime help.

Workability - customers, activities, facilities (including some software), material, processes, and the physical and social setting.

Controllability - planning the layout of ship control centres, machinery control spaces, freight control rooms, considering the integration of personnel and facilities, devices and interfaces, such as contact equipment, monitors, screens, computer stations, video monitoring units, and alarms.

Manoeuvrability - has suitable manoeuvrability for the ship's position and operating ability, including the propulsion systems, steering arrangements, including the output of shaft arrangements.

Survivability - is the fire protection facilities, damage management, and life-saving provision.

3. METHODOLOGY

Systematic literature review methods such as reference analysis are needed to determine how human factors are accepted in ship design, such as regulations, rules, specifications, and recommendations.

3.1. Content Analysis

Content analysis is a study tool to draw inferences that can be copied and checked in the sense of its usage from available models or data (Cohen et al., 2017). Neuendorf, Leedy & Oron characterize content analysis as a comprehensive, systematic, thorough evaluation and explanation of relevant literature to

find trends, meanings, prejudices, and themes (Kyngäs, 2020). In a quantitative study, the content analysis may be implemented deductively, resulting in groups' frequency of previously chosen values or values relevant to particular variables (Heidi, 2008). In order to respond to the problems in this report, this approach is considered essential. Thus, the study of material can be seen as an observation of organized and quantitative literature to see how human factors are considered in constructing ship designs and systems.

To date, there is no systematic taxonomy available in the maritime domain about human factors. LR gives the three structures the best rational and detailed framework, thus used as the fundamental framework (Lloyd's register, 2009). Measurements for coding purposes are defined and named as eight construction characteristics, as depicted in Figure 4.

Several components and facets are defined under each dimension. It realized that the system does not always follow the concept of mutually exclusive and complete code sheet development; overlap exists, and certain elements are contradictory in classifying components or aspects. Table 1, which generates the original code sheet along with the method of coding, is presented.

A code sheet was developed based on the formation of the human factor principle of ship construction. Its formation is very fluid and multi-dimensional, as depicted in Table 1.

LR Construction Characteristics
Habitability (HAB)
Maintainability (MAIN)
Workability (WORK)
Controllability (CONT)
Manoeuvrability (MANV)
Survival (SURV)
Occupational Health and Safety (OHS)
System Safety (SS)

Figure 5. The LR eight construction characteristics.

3.2. Sample and Limitation

To illustrate the coverage of human factors in ship construction, several papers can be discussed. First, a textbook and a ship construction guidebook, as seen above in section II. A (Human Factors in Ship Design) is a credible source. Next, a significant knowledge source would be published newspapers, meeting articles, studies, bulletins, and magazines. Furthermore, the recommended protocols, criteria, laws, instructions, and

procedures issued by the classification agencies are the last listed, but most important. Since they are liable for classifying ships, the classification agencies' publications may authentically portray the industry's reality.

This study focuses on construction using an international standard system. Research population identified as records, rules, regulations, or guidance provided by the related classification agencies and foreign agencies regulating certain aspects of ship design may influence human efficiency, health, or safety on board. In the study, three prominent classification organizations as samples: Det Norske Veritas (DNV), Lloyd's Register (LR), and the American Bureau of Shipping (ABS) and China Classification Society (CCS). In addition, the following organizations also have been sampled, which is ASTM, IMO, and ISO.

According to the level of research facility, only two data discovery stages were conducted. First, a detailed survey brings the list of publications in each source in the first instance. At this point, the document's title is determined. Next, a thorough reference review is conducted on each chosen document by applying a predefined code sheet covering keywords relevant to human factors.

3.3. Society for Classification

The three primary classification societies, DNV, LR, and ABS, constitute a large part of the ship classification sector and are significantly involved in the human factors considered in maritime architecture. This analysis also will include CCS due to its importance in shipping classification and acceptance by 55 major global shipping countries.



Figure 6. Classification Societies.

Table 1. Code sheet.

Dimension	Component	Aspect / object
Habitability (HAB)	Accommodation	Galleys, Mess Recreational Space Cabin
	Crew Variant	Size Shape Gender
	Environment Pressure	Surrounding Condition Indoor Climate Comfort, Noise, Sound Heat, Temperature Air Speed, Ventilation Air quality, smell Ship Motion Vibration Lighting
Maintainability (MAIN)	Maintenance Task	Layouts, Entrance, Exit Equipments Specialist Disposal Lifelong Support

Workability (WORK)	Users Assignment Equipment and Software Material & procedure Physical and Social Environment	Accessibility Arrangement Space
Controllability (CONT)	Control Center	Bridge Engine Control Room Combat Information Center
	System-Crew Integration Man-machine Interface	Communication Equipment Switch and Control Display, video display unit Alarm Automation Computer Station
Manoeuvrability (MANV)	Propulsion System Steering System Thrust	
Survivability (SURV)	Fire Fighting Damage Control Life Saving Equipments	
Occupational Health and Safety (OHS)	Impact on Work Working Environment Accommodation Condition	
System safety (SS)	Risk Assessment	

A few recommendations are presented by ABS covering problems relevant to human factors and include supplementary notes such as HAB and COMF. DNV gives extra COMF notation. In addition to the laws and regulations, LR includes CEPAC notation and allows much effort.

The four global major classification bodies are the Det Norske Veritas (DNV), Lloyd's Register (LR), American Bureau of Shipping (ABS), and China Classification Society (CCS). They display a particular interest in the human factors in naval architecture. The ABS guides resolving human factor challenges and includes supplementary notations such as Comfort (COMF) and Habitability (HAB). The DNV gives extra COMF notation. In addition to regulations and guidelines, The LR includes the Crew and Embarked Personnel Accommodation Comfort (CEPAC) notation.

3.3.1. Det Norske Veritas (2020)

DNV defines the regulations and guidelines from Ship Classification Laws, High-Speed Classification Rules, Regulatory

Definition, Service Requirements, Offshore Operation Criteria, Offshore Standards, and Practices Suggested. The publications released by the DNV in Table 2 can accommodate human factors in commercial and naval vessel construction.

Not all the publications referred to in Table 2 were built on the foundation of the facets of human factors. For example, the Definition of Vibration in Part 6, Chapter 15 was rendered by considering that vibration can influence the operation of some vital equipment and machinery and cause harm to any significant arrangements. SILENT Class Notation in Chapter 24 implements the correct operation of the machinery utilized by the ship.

DNV defines the regulations and guidelines from Ship Classification Laws, High-Speed Classification Rules and Navy Ships, Regulatory Interpretation, Service Requirements, Offshore Operation Specifications, Offshore Standards, and Practices Suggested.

The publications released by the DNV in Table 3 are known to accommodate human factors in commercial and naval vessel construction.

Table 2.

The DNV Human factors related to rules for classification of ships and vessels.

Rules for Ship Classification		
Part 3	Hull and equipment – Main Class	
	Ch 3	Ship Hull and Safety Equipment
Part 4	System and Machinery – Main Class	
	Ch 9	Control and Monitoring System
	Ch 10	Fire Fighting
	Ch 14	Steering Gear
Part 5	Special Type and Class– Additional Class	
	Ch 12	Comfort Class
Part 6	Special Equipment and System Class – Additional Class	
	Ch 2	Redundancy Propulsion System
	Ch 3	Machinery Room Without Periodic Supervision
	Ch 4	Additional Fire Protection System
	Ch 8	Nautical Safety
	Ch 9	Computer Systems for Longitudinal Stability and Strength
	Ch 15	Vibration Class
	Ch 24	Notation Class SILENT

Table 3.

The remaining DNV documents taking human factors into account in the design stage.

Recommended Action	
A203	New Technology Qualifications
C205	Environmental Conditions and Environment
D102	Analysis of Failure and Impact Methods of Overlapping Systems
D201	Dependence on Integrated Software Systems

3.3.2. Lloyd's Register (2020)

The regulations and laws are divided into two classifications by the LR: energy and maritime. There are 130 documents in the

maritime division, and 25 documents in the resources category. Table 4 provides the documents from the LR applicable to ship construction, focusing on human factors.

Table 4.

The LR documents related to human factors.

Rules and Regulations for Ship Classification		
Part 3	Ships Structure (General)	
	Ch 3	Ships Control System
Part 5	Main and auxiliary machinery	
	Ch 18	Integrated Propulsion System
	Ch 19	Steering Gear Control
	Ch 21	Requirements for System Condition Monitoring
	Ch 22	Redundancy Propulsion and Steering Control
	Ch 23	Safely Return to the Port
Part 6	Control, Electricity, Cooling and Fire	
	Ch 1	Engineering Control System
	Ch 2	Electrical Engineering
	Ch 4	Fire Protection, Detection and Control Requirements
Part 7	Other Ship Systems and Types	
	Ch 9	Integrated Navigation and Bridge Systems
	Ch 11	Arrangements and Equipment for Environmental Protection
	Ch 12	Integrated Fire Protection System (IFP)
	Ch 13	Comfort of Passenger and Crew Accommodation
	Ch 15	Requirements for Engineering Machines and Systems for Unconventional Design
Guide Notes	Vibration and Noise Guide Notes on Ships	

3.3.3. The American Bureau of Shipping (2020)

According to the ABS, 138 maritime business regulations and rules cover ships, offshore installations, floating structures, underwater vessels, machinery, parts, and products. Therefore, a total of seventeen articles in this study can be classified as targeted papers (see Table 5).

3.3.4. China Classification Society (CCS) (2021)

The CCS offers specific guidelines for vehicles, offshore facilities, vessels, and associated manufacturing goods and develops certification, classification and professional advisory support in an unbiased, objective, and truthful way. There are 22 papers from the CCS applicable to ship construction standards, focusing on the human factor (see Table 6).

Table 5.

The ABS human factors in ship design rules and regulations.

Pub#	Title
86	Application of Ergonomics to Marine Systems
94	Bridge Design and Navigational Equipment/Systems
97	Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries
102	Crew Habitability on Ships
103	Passenger Comfort on Ships
116	Review and Approval of Novel Concepts
117	Risk Evaluations for the Classification of Marine Related Facilities
119	Ergonomic Design of Navigation Bridges
112	Alternative Design and Arrangements for Fire Safety
141	Fire-Fighting Systems
145	Vessel Manoeuvrability
147	Ship Vibration
151	Vessels Operating in Low Temperature Environments
154	Means of Access to Tanks and Holds for Inspection
163	Crew Habitability on Workboats
170	Rapid Response Damage Assessment
185	Integrated Software Quality Management (ISQM)

Table 6.

The CCS documents on the human factor.

Rules and Notations for Ship Classification			
Part 2	Chapter 2	Section 18	Helicopter Facilities
Part 3	Chapter 8		Z-propulsion
	Chapter 8		Thruster
	Chapter 8		Controllable Pitch Propeller
	Chapter 8		Waterjet Unit
Part 4	Chapter 2	Section 15	Electrical Propulsion System
Part 5	Chapter 2		Automation of Machinery Space
	Chapter 3		Machinery Centralized Control
	Chapter 4		Bridge Remote Control
Part 7	Chapter 2	Section 2	Life Saving Appliance
	Chapter 2	Section 3	Communication Equipment
	Chapter 2	Section 4	Navigation Equipment
	Chapter 2	Section 5	Signalling Equipment

	Chapter 3		Crew Accommodation Equipment
	Chapter 3		Comfort (Noise)
	Chapter 3		Comfort (Vibration)
	Chapter 4	Section 3	Clean Naval Ship
	Chapter 7		Manoeuvrability of naval ships at sea
Part 8	Chapter 4		Open man Bridge Operation
	Chapter 8	Section 3	Refrigeration System
	Chapter 11		Dynamic Positioning System

3.4. International and Industry Standards

Three other related bodies in legislation and standardization were assessed in addition to the classification body, as presented in Figure 7.



Figure 7. International and Industry Standards.

3.4.1. The American Society for Testing and Materials (ASTM, 2020)

The organization by the ASTM was created referring to international principles with the consensus volunteers. In 1978, the ASTM founded a committee named F25 to create Ships and Maritime Technology Standards. Two unique norms suit the purpose of this study:

F1166-07	Maritime Structures, Machinery, and Services Standard Practices for Human Engineering Architecture
F1337-10	Best Procedures for Ships and Structures, Machinery, and Services Specifications for the Human Engineering Program

Figure 8. The ASTM unique norm covers human factor.

3.4.2. International Maritime Organization (IMO, 2020)

The IMO is responsible for ensuring that legislation is continuously modified to ensure that as many countries as possible ratify those regulations and fully adopt all treaties and agreements by the countries that adopt them. Human factors in ship activities link to a vast number of the IMO publications. In numerous formats, the IMO documents issues: agreements, circulars, guidelines, conventions, guides, manuals, model classes, practices, suggestions, laws, rules, and resolutions. Conventions and codes promulgated by the IMO are depicted in Figures 8 and 9.

The STCW covers the acoustic impedance on board, and applies to code and resolution as to code and convention. These codes and conventions suggest that in the IMO publication specific issues are discussed more than once.

Conventions	
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
SOLAS	International Convention for the Safety of Life at Sea
Load Lines 1966	International Convention on Load Lines
COLREGS	International Regulations for Preventing Collisions at Sea

Figure 9. The essential Conventions referring to human factor.

Codes
• STCW Code - International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
• Noise Levels - International Convention for the Safety of Life at Sea
• LSA Code - International Convention on Load Lines
• FSS Code - International Regulations for Preventing Collisions at Sea
• Code on Alerts and Indicators, 2009

Figure 10. The human-factors-related IMO Codes.

Examples of other IMO publications related to human factors in ship construction include:

Table 7.
The IMO publications concerning human factors in the construction of ships.

IMO Circulars, MSC Circulars	
587	Life Saving Appliances
601	Fire Protection in Machinery Spaces
616	Evaluation of Free-Fall Lifeboat Launch Performance
645	Guidelines for Vessels with Dynamic Positioning Systems
834	Guidelines for Engine-Room Layout, Design and Arrangement
846	Guidelines on Human Element Considerations for the Design and Management of Emergency Escape Arrangements on Passenger Ships
849	Guidelines for the performance, location, use and care of emergency escape breathing devices (EEBD's)
982	Guidelines on Ergonomic Criteria for Bridge Equipment and Layout
1002	Guidelines on Alternative Design and Arrangements for Fire Safety
Assembly Resolutions (RES)	
A.342(IX)	Recommendation on Performance Standards for Automatic Pilots
A.468(XII)	Code on Noise Levels on Board Ships
A.601(15)	Provision and Display of Manoeuvring Information on Board Ships
A.708(17)	Navigation Bridge Visibility and Functions
A.817(19)	Performance Standards for Electronic Chart Display and Information Systems (ECDIS)
A.861(20)	Performance Standards for Shipborne Voyage Data Recorders (VDRs)
A.947(23)	Human Element Vision, Principles and Goals for the Organization
A.1021 (26)	Code on Alerts and Indicators
Maritime Safety Committee (MSC) Resolution	
128(75)	Performance Standards for a Bridge Navigational Watch Alarm System (BNWAS)
137(76)	Standards for Ship Manoeuvrability
190(79)	Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigational Displays

3.4.3. The International Organization for Standardization (ISO, 2020)

The ISO creates universal principles and publishes them. The Technical Committee (TC)/Sub Committee (SC) in the International Classification for Standards (ICS), which is accountable for supplying those standards, may be used to access

the ISO norm. For example, the ICS number 47 encompasses shipbuilding and marine structures standards, while TC 8 encompasses shipbuilding and marine technologies standards. In TC 159, ergonomics rules are described differently.

Documents under TC 159 exclusively include human factors represented in Figure 11.

Table 8.

Human factors related to the ISO documents.

ISO	Document Title
2412:1982	Shipbuilding - Colours of indicator lights
8468:2007	Ships and marine technology - Ship's bridge layout and associated equipment - Requirements and guidelines
27991:2008	Ships and marine technology - Marine evacuation systems -- Means of communication
24409-1:2010	Ships and marine technology - Design, location and use of shipboard safety signs, safety-related signs, safety notices and safety markings - Part 1: Design principles
20283-4	Mechanical vibration - Measurement of vibration on ships - Part 4: Measurement and evaluation of vibration of the ship propulsion machinery
20283-2:2008	Mechanical vibration - Measurement of vibration on ships - Part 2: Measurement of structural vibration
17894:2005	Ships and marine technology - Computer applications - General principles for the development and use of programmable electronic systems in marine applications
17631:2002	Ships and marine technology - Shipboard plans for fire protection, life-saving appliances and means of escape
6954:2000	Mechanical vibration - Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships
5489:2008	Ships and marine technology - Embarkation ladders
5488:1979	Shipbuilding - Accommodation ladders
3797:1976	Shipbuilding - Vertical steel ladders
2923:1996	Acoustics - Measurement of noise on board vessels
2631-1:1997	Mechanical vibration and shock - Evaluation of human exposure to wholebody vibration - Part 1: General requirements

ISO/TR 16982:2002	Human device interaction ergonomics - Techniques of usability that promote human-centered architecture
ISO 11064-3:1999	Control centre ergonomic architecture - Section 3: Configuration of the control space
ISO 9241-210:2010	Human system interface ergonomics; Part 210: Dynamic machine human-centered architecture
(VDTs)	Section 1: General introduction
ISO 9241-1:1997	Ergonomic specifications for visual interface terminals for office jobs
ISO 26800:2011	Ergonomics General strategy, values and definitions
ISO 6385:2004	In the construction of job processes, ergonomic concepts

Figure 11.

The ISO documents under TC159 that exclusively include human factors.

ICS 47.040 and 47.020, TC8/SC 8, TC 8/SC 6, and TC 8/SC 1 represent the scope of this study. Table 8 illustrates the descriptions of ISO documentation relevant to human elements in ship design.

4. ANALYSIS AND RESULTS

With multiple processing units, two phases of data analysis were conducted, followed by all related document reviews from the seven institutions. The paper's title as the unit of study was the measurements of human factors (Table 1) as the basis for coding. Secondly, it chooses and then analyses in depth some of the most significant and most applicable articles, in which a part of human factors in terms of the elements and facets are presented as a coding sheet.

4.1. Publication Analysis

Some documents are relatively thin, just two pages, and some of them reach hundreds of pages. A full text is described by specific names, while others reflect chapters from a collected document, as represented in Table 9.

117 paper titles already focus on the human element. Detailed findings are provided in the Appendix to Table A1, while the description is presented in Table 9. Table 9 indicates that usable records span all aspects of human variables: regulation,

rule, legislation, and instructions. Clearly, "System Safety" is the most frequently stated in the paper since security has always

been a big concern, whereas "Maintainability" is the most unchecked.

Table 9.

Overview of paper outcomes in ship construction, covering human factors.

Publication Body	No of Document	Human Factor / Ergonomic	Habitability	Maintainability	Workability	Controllability	Maneuverability	Survivability	Occupational Health and Safety	System Safety
ABS	17	2	6	1	7	4	1	3	3	9
DNV	18	0	1	1	6	7	3	3	0	11
LR	16	0	2	1	2	6	3	6	1	7
CCS	22	3	2	2	7	10	7	1	3	7
IMO	29	2	2	1	6	8	3	11	4	14
ISO (TC8)	13	0	7	0	3	2	0	4	0	2
ASTM	2	2	1	1	2	1	0	1	1	2
Total	117	9	21	7	33	38	17	29	12	52

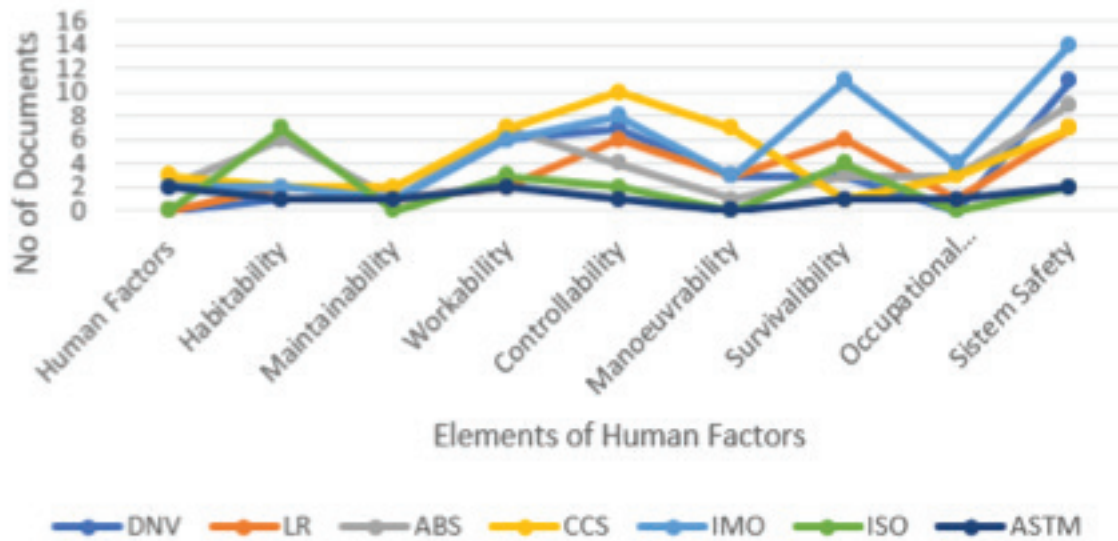


Figure 12.

Documents in ship construction, covering human factors.

These results support Andersson's and Lützhöft's (IMO, 2004) critiques of engine control rooms' lousy nature. Meanwhile, "Survivability," "Controllability," and "Workability" include a large number of papers. "Habitability" is reasonably covered; however, as the emphasis of this review is on the "OHS" portion, not too many records cover "design".

4.2. Study On Material

As described, a comprehensive evaluation conduct, utilize the materials and facets of each human factors field. More elements and aspects are uncovered as the coding process continues and eventually integrated into the system, becoming a very lengthy list. As the system is created, the coding phase performs repeatedly. In the Appendix to Table A2, the final results can be seen. Any records addressing very particular subjects, such as life-saving and steering devices, fire protection software, and risk control, are not included. In ship design, the nature of human influences occupies all of these aspects. The "Workability" and "System safety" are below "Habitability."

The most widely addressed subjects of "Controllability" are sensors, control centres, workstations, buttons, and switches. These documents have clarified the fundamental problems of human factors on board. However, more complex issues emerge as simple problems are addressed. Noise, for example, is known as an onboard concern. A total of 15 records have the overall parameters of the noise level on board in this study. Among all 15 articles, the overwhelming majority does not discuss concrete concerns. The only paper describing "tonal sound" and "impulsive noise" is the ISO 2923, but it does not explain how to cope with them. The CCS also covers noise in the comfort notation in Part 7, Chapter 3, Section 7, noting the enclosure regulated at the stated sound level.

Vibration is another simple HF problem that is adequately discussed. According to this report, it has been bound by 14 records. Generally, vibration cannot be treated as an intimidating issue any more. The CCS covers vibration in the comfort notation in Part 7, Chapter 3, Section 7, noting the enclosure regulated at the stated vibration level. However, it tends to be challenging, created from certain primary forms of "vibration" (Trincas et al., 2018): ship slamming and rotation. From the aspect of human factors, one paper addresses ship motion: ISO 2631-1. This paper is the first text that separates sensations between two systems: low frequencies (for motion sickness: <0.5 Hz) and high frequencies (for wellbeing, relaxation, and perception: >0.5 Hz). The Motion Sickness Dosage Value (MSDV) accepted onboard by the ISO 2631 is applied by ABS 103 and 147. The ABS 86 deals with slamming, from all the documents surveyed in this report. A common trend often appears in "alarms" protected by 14 survey records. Thus, the underlying dilemma of alarms is resolved. However, more complex alarms have been uncovered like an

irrelevant number of alarms that irritate operators. Fortunately, the IMO A.1021(26) pointed out the following problems indicate how to include specific info and decrease alarms.

5. DISCUSSION

While different manuals have adequately discussed the problems of human factors, they are not mandatory. The standard bodies' laws and regulations are voluntary or optional, while the remainder are recommendations. The actual enforcement of human factors values relies mainly on the shipowner's devotion. Shipyards certainly play an essential function. The freight owner or the buyers and the personnel might have some feedback to make things work. However, the classification societies and the regulators should go further. Without exception, such intrinsic human conditions as noise, sound, motion, and indoor environment should be obligatory. Prospective naval architects and shipbuilders need to add some of these subjects, such as ship-human related requirements.

Three publications addressing the issue of human factors are considered to be comprehensive: the ASTM F1166, DNV Nautical Protection, and ABS 86, which have become the preferred manuals for coping with human factors in the construction of ships regardless of the flag, anywhere the ships are recorded and listed. Several problems were found in the coding sheet production stage, but have not been enclosed in any text, such as the disparities in ethnicity, disabilities, and religious differences of seafarers.

The analysis does not provide any reliability index because of inadequate resources. The reliability over time is, however, verified. Compared to the results reported earlier, this research shows that human factor involvement in ship design is increasingly evolving, represented by a growing number of published papers. Relatively stable is the trend of all the facets of human factors considered, such as disturbance, vibration, and alarms.

Concerning the least addressed problems on board, such as ship motion, i.e. slamming, smell, gender issues, and high-pitch erratic noise, they are described in (Trincas et al., 2018), choosing the feature of human factors to recognize in design process through a more intelligent approach. A fast comparison with the HF reference reveals that some of the records analysed in this sample do not cover human reliability, decision-making, and social considerations.

6. CONCLUSIONS

Using a reference analysis approach, a literature review of other documentation has been performed. The research was conducted to discuss whether human aspects are ignored in the design and construction of ships. At least 117 publications describe

it as essential to resolving human factors in the construction of ships, and the numbers continue to rise exponentially. It can be inferred from the analysis that human factors are not ignored in ship design specifications. 30 articles discuss it in depth. Human factors turn out to be an extensive aspect comprising several ship materials and dimensions, but their degree of coverage differs throughout the dimensions. The two dimensions often covered are protection and survivability, indicated by the overall number of papers published on the subjects. The broadest coverage is that of habitability and controllability. A more assertive intervention proposes to promote the values of human factors incorporated into ship design. The research on human factor implementation on board can be conducted using the available documents that set up the standards internationally. Performing research by questioning shipbuilders, shipyards, marine mechanics and naval architects is recommended.

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APPENDIX
Document Content Analysis

No	Source	ID**	HF	HAB	MAN	WORK	CONF	MANY	SUR	OHS	SS
1	DNV	Pt 3 Ch 3	0	0	0	0	0	1	0	0	0
2	DNV	Pt 4 Ch 9	0	0	0	1	1	0	0	0	1
3	DNV	Pt 4 Ch 10	0	0	0	0	0	0	1	0	1
4	DNV	Pt 4 Ch 14	0	0	0	0	1	0	0	0	0
5	DNV	Pt 5 Ch 12	0	1	0	0	0	0	0	0	0
6	DNV	Pt 6 Ch 2	0	0	0	0	0	0	0	0	1
7	DNV	Pt 6 Ch 3	0	0	1	0	0	0	0	0	1
8	DNV	Pt 6 Ch 4	0	0	0	0	0	0	1	0	1
9	DNV	Pt 6 Ch 6	0	0	0	0	1	0	0	0	0
10	DNV	Pt 6 Ch 7	0	0	0	0	1	0	0	0	0
11	DNV	Pt 6 Ch 8	0	0	0	1	1	1	0	0	1
12	DNV	Pt 6 Ch 9	0	0	0	0	0	0	0	0	1
13	DNV	Pt 6 Ch 20	0	0	0	1	1	1	1	0	1
14	DNV	Pt 6 Ch 26	0	0	0	1	1	0	0	0	0
15	DNV	A203	0	0	0	1	0	0	0	0	1
16	DNV	C205	0	0	0	0	0	0	0	0	0
17	DNV	D102	0	0	0	0	0	0	0	0	1
18	DNV	D201	0	0	0	1	0	0	0	0	1
DNV			0	1	1	6	7	3	3	0	11
19	LR	Pt 3 Ch13	0	0	0	0	0	0	0	0	0
20	LR	Pt 5 CH 18	0	0	0	0	1	1	0	0	0
21	LR	Pt 5 CH 19	0	0	0	0	0	0	0	0	0
22	LR	Pt 5 CH 21	0	0	1	0	0	0	0	0	0
23	LR	Pt 5 CH 22	0	0	0	0	1	1	1	0	1
24	LR	Pt 5 CH 23	0	0	0	0	0	0	1	0	1
25	LR	Pt 6 Ch 1	0	0	0	0	1	0	1	0	1
26	LR	Pt 6 Ch 2	0	0	0	0	1	1	1	0	1
27	LR	Pt 6 Ch 4	0	0	0	0	0	0	1	0	1
28	LR	Pt 6 Ch 1	0	0	0	0	0	0	0	0	0
29	LR	Pt 7 Ch 4	0	0	0	1	1	0	0	0	0
30	LR	Pt 7 Ch 9	0	0	0	1	1	0	0	0	0
31	LR	Pt 7 Ch 12	0	0	0	0	0	0	1	1	1
32	LR	Pt 7 Ch 13	0	1	0	0	0	0	0	0	0
33	LR	Pt 7 Ch 15	0	0	0	0	0	0	0	0	1
34	LR	GN	0	1	0	0	0	0	0	0	0
LR			0	2	1	2	6	3	6	1	7
35	ABS	86	1	1	1	1	1	0	0	1	1
36	ABS	94	0	0	0	1	1	0	0	0	0
37	ABS	97	0	0	0	0	0	0	0	0	1
38	ABS	102	0	1	0	0	0	0	0	0	0
39	ABS	103	0	1	0	0	0	0	0	0	0
40	ABS	116	0	0	0	0	0	0	0	0	1
41	ABS	117	0	0	0	0	0	0	0	0	1
42	ABS	119	1	0	0	1	1	0	0	0	0
43	ABS	122	0	0	0	0	0	0	1	0	1
44	ABS	141	0	0	0	0	0	0	1	0	0
45	ABS	145	0	0	0	0	0	1	0	0	0
46	ABS	147	0	1	0	1	0	0	0	0	0
47	ABS	151	0	1	0	1	0	0	0	1	1
48	ABS	154	0	0	0	1	0	0	0	1	1
49	ABS	163	0	1	0	0	0	0	0	0	0
50	ABS	170	0	0	0	0	0	0	1	0	1
51	ABS	185	0	0	0	1	1	0	0	0	1
ABS			2	6	1	7	4	1	3	3	9

No	Source	ID**	HF	HAB	MAN	WORK	CONF	MANV	SUR	OHS	SS
52	CCS	Pt 2 Ch 2	0	0	0	1	0	0	0	0	1
53	CCS	Pt 3 Ch 8	0	0	0	0	1	1	0	0	0
54	CCS	Pt 3 Ch 8	0	0	0	0	1	0	0	0	0
55	CCS	Pt 3 Ch 8	0	0	0	0	1	1	0	0	0
56	CCS	Pt 3 Ch 8	0	0	1	0	0	0	0	0	0
57	CCS	Pt 4 Ch 2	0	1	1	1	1	1	0	0	1
58	CCS	Pt 5 Ch 2	0	0	0	1	1	0	0	0	1
59	CCS	Pt 5 Ch 3	1	0	0	1	1	0	0	0	1
60	CCS	Pt 5 Ch 4	1	0	0	1	1	1	0	0	1
61	CCS	Pt 7 Ch 2	0	0	0	1	0	0	1	1	0
62	CCS	Pt 7 Ch 2	0	0	0	0	0	0	0	0	0
63	CCS	Pt 7 Ch 2	0	0	0	0	1	1	0	0	0
64	CCS	Pt 7 Ch 2	0	0	0	0	1	0	0	0	0
65	CCS	Pt 7 Ch 2	0	0	0	0	0	0	0	0	0
66	CCS	Pt 7 Ch 3	1	1	0	0	0	0	0	1	0
67	CCS	Pt 7 Ch 3	0	0	0	0	0	0	0	0	0
68	CCS	Pt 7 Ch 3	0	0	0	0	0	0	0	0	0
69	CCS	Pt 7 Ch 4	0	0	0	0	0	0	0	1	0
70	CCS	Pt 7 Ch 7	0	0	0	0	0	1	0	0	0
71	CCS	Pt 8 Ch 4	0	0	0	1	0	1	0	0	0
72	CCS	Pt 8 Ch 8	0	0	0	0	0	0	0	0	1
73	CCS	Pt 8 Ch 11	0	1	0	0	1	0	0	0	1
CCS			3	2	2	7	10	7	1	3	7
74	IMO	COLREGS	0	0	0	0	1	0	0	0	1
75	IMO	LL	0	0	0	0	0	0	0	0	1
76	IMO	SOLAS	0	0	0	0	0	0	0	0	1
77	IMO	STCW	0	0	0	1	0	0	0	0	0
78	IMO	ALI	0	0	0	0	0	0	1	0	1
79	IMO	CAI	0	0	0	0	0	0	1	0	1
80	IMO	FSS	0	0	0	0	0	0	1	0	1
81	IMO	LSA	0	0	0	0	0	0	1	0	1
82	IMO	NOISE	0	1	0	0	0	0	0	0	0
83	IMO	A 342 (IX)	0	0	0	0	1	0	0	0	1
84	IMO	A 468 (XII)	0	1	0	0	0	0	0	0	0
85	IMO	A 601 (15)	0	0	0	0	0	1	0	0	0
86	IMO	A 708 (17)	0	0	0	0	1	0	0	0	0
87	IMO	A 817 (19)	0	0	0	1	1	1	0	0	0
88	IMO	A 830 (19)	0	0	0	0	0	0	0	0	0
89	IMO	A 861 (20)	0	0	0	0	0	0	0	0	1
90	IMO	A 947 (23)	1	0	0	0	0	0	0	0	0
91	IMO	Res 128 (75)	0	0	0	0	0	0	1	1	1
92	IMO	Res 137 (76)	0	0	0	0	0	1	0	0	0
93	IMO	Res 190 (79)	0	0	0	1	1	0	0	0	0
94	IMO	Circ 587	0	0	0	0	0	0	0	0	0
95	IMO	Circ 601	0	0	0	0	0	0	1	0	1
96	IMO	Circ 616	0	0	0	0	0	0	1	0	1
97	IMO	Circ 645	0	0	0	1	1	0	0	0	0
98	IMO	Circ 834	0	0	1	1	1	0	1	1	1
99	IMO	Circ 846	0	0	0	0	0	0	1	0	0
100	IMO	Circ 849	0	0	0	0	0	0	1	1	0
101	IMO	Circ 982	1	0	0	1	1	0	0	0	0
102	IMO	Circ 1002	0	0	0	0	0	0	1	0	1

IMO			2	2	1	6	8	3	11	3	14
101	ISO	2631-1:1997	0	1	0	0	0	0	0	0	0
102	ISO	2923:1996	0	1	0	0	0	0	0	0	0
103	ISO	3797:1976	0	0	0	1	0	0	0	0	0
104	ISO	5488:1979	0	1	0	0	0	0	0	0	0
105	ISO	5489:2008	0	1	0	0	0	0	1	0	0
106	ISO	6954:2000	0	1	0	0	0	0	0	0	0
107	ISO	17631:2002	0	0	0	0	0	0	1	0	1
108	ISO	20283-2:2008	0	1	0	0	0	0	0	0	0
109	ISO	20283-4	0	1	0	1	1	0	0	0	0
110	ISO	24409-1:2010	0	0	0	0	0	0	1	0	1
111	ISO	27991:2008	0	0	0	0	0	0	1	0	0
112	ISO	8468:2007	0	0	0	1	0	0	0	0	0
113	ISO	2412:1982	0	0	0	0	1	0	0	0	0
ISO			0	7	0	3	2	0	4	0	2
114	ASTM	F1166-07	1	1	1	1	1	0	1	1	1
115	ASTM	F1337-10	1	0	0	1	0	0	0	0	1
ASTM			2	1	1	2	1	0	1	1	2