# Design for the human factor
# The move to goal-based rules

J V Earthy, BSc(Hons), PhD  B M Sherwood Jones, BSc(Hons), MSc, FErgS
*Lloyd's Register*

**SYNOPSIS**

The human element is addressed, explicitly and implicitly, in a large number of rules and regulations. There is also a body of guidance on ergonomic and operational design. There is the view that the value of the human element aspects of current requirements is not being fully realised, in part due to a lack of awareness and in part due to a lack of integration from the seafarer viewpoint. An analysis of a classification society rules has shown that the implicit nature of many requirements imposes expertise demands, and that coverage is variable.

According to the IMO Human Element Principles, rules and regulations addressing the seafarers directly should be simple, clear and comprehensive. However, it is not clear that much progress has been made in this regard.

The move to goal-based regulation provides both a challenge and an opportunity to the human element community (seafarers and specialists). The challenge is to find an appropriate structure for the consideration of the human element within the new framework for rules and regulations. The opportunity is to place better requirements as follows:

- coverage of human element issues and the many factors that influence them
- requirements that are usable by appropriate stakeholders and particularly by seafarers
- requirements that 'honour the seafarer' by seeking and respecting the opinions of those that do the work at sea
- requirements that address human variability and adaptability
- criteria that are based on sound data and that reflect the context of use.

This paper discusses a number of possible structures for the inclusion of the human element and approaches to the development of appropriate material.

## INTRODUCTION

The human element has long been recognised as important to marine safety. Human error in the operation of ships has traditionally been seen as the individual responsibility of the officers and crew of the ship. However, there is a growing awareness in the marine sector that this view is too simple and that the human element needs to be considered in the design and maintenance of ship systems, equipment and procedures if the mariner is to operate a ship and its systems safely and effectively and if non-shipboard staff are to do their jobs in a similar manner.

From a classification point of view, rules are written with the assumption of competent operation by the officers and crew. During design and construction, the necessary knowledge of how a ship is likely to be operated has traditionally been supplied from the experience of the designer, superintendent or surveyor. Nowadays, however, jobs, operations, manning and systems are all more complex and variable. As a result, experience quickly becomes out of date. Something therefore needs to be done to replace this experience in appraisal and survey.

In 1997, IMO adopted Resolution A.850 (revised in 2004 as Resolution A.947[1]) on '*the human element vision, principles and goals*' for the Organization. This acknowledges the need for an increased focus on human-related activities in the safe operation of ships, and the need to achieve and maintain high standards of safety and environmental protection for the purpose of significantly reducing maritime casualties. It recognises that the whole range of stakeholders needs to cooperate to address human element issues effectively.

---

**Authors' biographies**

Dr Jonathan Earthy is Principal Human Factors Specialist for Lloyd's Register. He joined Lloyd's Register in 1992 after working for British Petroleum and Imperial Chemical Industries. He is responsible for research and development with respect to the Human Element and Systems Engineering. He coordinates all technical aspects of Lloyd's Register's treatment of the Human Element and its involvement with IMO, IEC and ISO on these topics. He is editor of ISO 17894, ISO PAS 18152, ISO TR 19529. ISO/IEC TR 24774.

Hon Prof Brian Sherwood Jones is a Human Factors consultant to Lloyd's Register, assisting with implementation of its Human Element strategy. After ten years in the aircraft industry he worked for YARD Ltd. for fifteen years before setting up Process Contracting Limited. He has had extensive experience of working on Naval platform projects. He is an Honorary Professor at the Digital Design Studio, Glasgow School of Art, where he is assisting with virtual shipbuilding.

A simple flowchart, the Human Element Analysing Process[2] (HEAP) was developed to assist IMO in its own consideration of the human element. However, limited feedback and anecdotal evidence suggests that the response from IMO Working Parties and Committees has been patchy with some good work, but little improvement overall. To improve the consideration of the human element, the MSC/MEPC Human Element Working Group has proposed to support its strategy[3] with:

- a checklist for use by IMO bodies,
- activity to strengthen the human element input to the work of IMO, and
- a framework for IMO consideration of ergonomics and the work environment.

It is too soon to assess the success of these recent activities.

Consideration of the human element is made more complex because the situation is dynamic. The operational context is changing. The seafarer population is changing, with a marked drop in the European/US element and a changing culture and skill set. Ship and equipment design is changing, with the probability of increased adoption of computer-intensive technology. It is not obvious that these independent developments are compatible with safe and effective operation. The present arrangements did not anticipate such a dynamic situation, e.g. the arrangements for definition of STCW and Safe Manning Certificates, and their links to equipment type approval include long time delays. These developments also make it harder for stakeholders to assess the effectiveness of control measures on the basis of experience. ISO TC159 Ergonomics, SC4 Human System Interaction has developed standards for Human Centred Design (HCD)[4, 5]; the analytic approach used here to replace subjective judgment is 'context of use' analysis (Fig 1). Such analysis can be conducted at the level of shipping as a system[6] down to the level of specific equipment[7]. Lloyd's Register (LR) has supported the development of these standards on the basis that the cost-effective approach for the Marine sector is to tailor existing best practice rather than re-invent it.

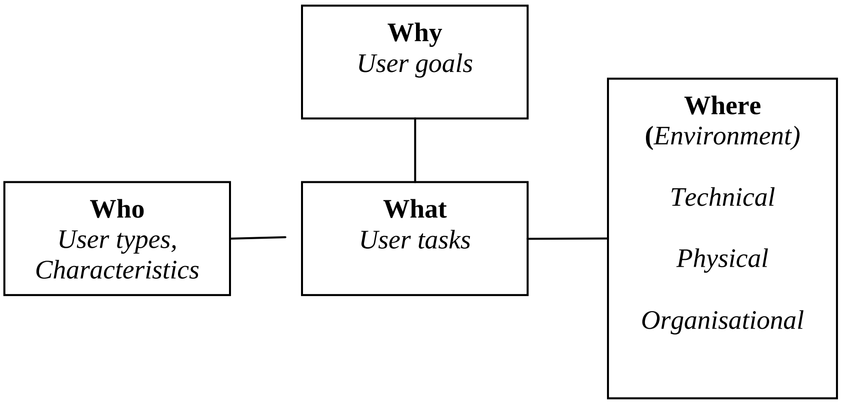



**Fig 1** Context of Use

The introduction of goal-based regulation has the potential to change consideration of the human element dramatically – potentially for the better. In particular, it ought to provide flexibility to address the changing context of use. However, the change to a goal-based approach is not without risk, and requires some consideration of the current situation and the changes required in regulatory and operational practice for the new approach to succeed. This paper examines these topics.

## COVERAGE OF THE HUMAN ELEMENT

Human science knowledge is commonly divided into the following six domains, which define the potential coverage of the human element. The first three domains are aspects of Human Resources and the second three are aspects of Human Factors:

- Manpower - the number of personnel required and potentially available to operate, maintain, sustain and provide training for the ship. The following factors influence the choice and number of qualified people required to operate a ship.
- Personnel - the cognitive and physical capabilities required to be able to train for, operate, maintain and sustain the ship and provide optimum quality and quantity of the crews to man a modern ship.
- Training - the instruction or the education, and on-the-job or part-task or full-mission training required to provide personnel with their essential job skills, knowledge, values and attitudes.
- Human Engineering - the comprehensive integration of human characteristics into the definition, design development, and evaluation of the ship to optimise human/machine performance under specified conditions.

- Safety - the identification, assessment and amelioration of short- or long-term hazards to health occurring as a result of normal operation of the ship.
- Health and Safety - the risks occurring when the ship and its systems are functioning in a normal or abnormal manner.

The desired outcome can be stated as 'Quality In Use'[1]. The capability required to deliver systems with Quality In Use is known[4]. The principles to be followed in design, development and operation are known. The means to deliver a process and principles based solution that can take account of context of use exist. However, these developments in Human Centred Design have largely taken place outside the marine sector, which has yet to adopt them.

The need to raise informed awareness of the human element was recognised by Lloyd's Register and the Nautical Institute, leading to the publication of the *Alert!* bulletin and its associated website[9].

## Current Situation

In the particular area of design for reduced human error, notable work includes the Nautical Institute's publication "Improving Ship Operational Design"[10] and the America Bureau of Shipping's (ABS) explicit statements of Human Factors requirements in its guide on ship ergonomics[11].

Against this background, Lloyd's Register's Research and Development Department analysed its Rules[12] with regards to the human element[13], and found that the treatment of the human element in the Rules was patchy, inconsistent and probably incomplete. The human element is treated differently in different chapters and even deliberately omitted in some. Explicit requirements were found in notations for bridge design, integrated navigation and bridge systems and habitability, and the Rules related to control systems, which call for the application of ergonomic principles to machinery control, but in the many other cases human element requirements were more or less implied. If the human element is to be addressed in a controlled and harmonised fashion by class, both implicit and explicit requirements need to be made consistent and addressed in a uniform fashion by suitably trained surveyors. Because human element requirements are not stated explicitly or clearly, their correct interpretation requires expertise. At this time it is not clear whether this expertise is available to surveyors. The project proposed the following actions arising from its work:
- train or otherwise equip surveyors with sufficient knowledge about the human element
- set up a group to supervise human element issues in the Rules
- investigate the new or changed operational risks arising from new or changed means of construction.

There have been similar developments in the last few years as regards manning and ship operation, including International Safety Management (ISM)[14], Standards for Certification and Training of Watchkeepers (STCW), Principles of Safe Manning and the Safe Manning Certificate.

## Integration of the human element

It is generally the case that the human resources issues are addressed separately from the technical human factors issues, rather than adopting a socio-technical approach. IMO regulations place requirements on the safety, management and environmental impact of the shipping industry (including operational safety and security) and International Labour Organisation (ILO) conventions place requirements on employment (including occupational health and safety). Ship design issues are typically addressed by classification rules, while ship operational issues are typically addressed by the requirements of International Safety Management (ISM). Design for ease of use can fall between these regimes, particularly in a dynamic situation (Fig 2).

---

[1] Defined in ISO 9126-1[8] as 'the capability of a system to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in specified contexts of use".

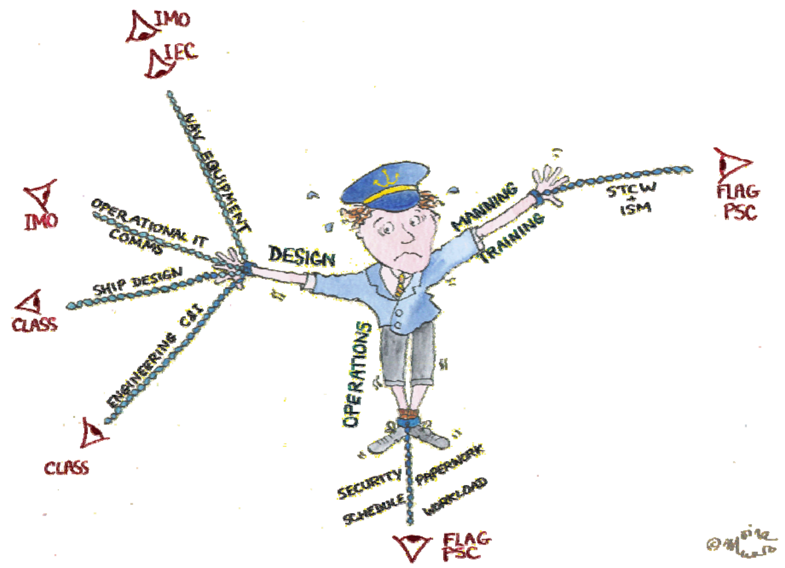


**Fig 2** Fragmentation of regulation and the user

The NTSB Report on the grounding of the ROYAL MAJESTY[15] stated

> *"Thus, while human engineering is a known concept in the marine industry, there have not been any unifying efforts to integrate this concept into the marine engineering and manufacturing sector. Additionally, human engineering in the broader context of Human System Integration has been given little or no consideration. Consequently, the potential for error causing behaviour related to these [automated] systems has not been adequately addressed by the marine industry".*

The response to this was SOLAS Chapter V Regulation 15[16], which is perhaps a first attempt to produce an integrated approach. The Regulation aims to address some of the most fundamental human element concerns relating to the ship's bridge and to define the aims that the navigation equipment and bridge procedures should meet. The impact of a regulation that addresses both design and operation is still unfolding.

Guidance to support the link between operation and design has also been produced by IMO, notably MSC/Circ. 1091[17].

## Lifecycle coverage

Coverage of the human element over the lifecycle is also fragmented. The rules and regulations relating to classification and type approval are the main means of mitigating human error in the design and construction of ships and their components. The human error issues in design and construction addressed by class rules include incorrect programming, inspection for the wrong defects, assumptions about procedures, etc. The adoption of new technologies (e.g. digital displays, keycard locks) by manufacturers is also an issue. Some of the rule requirements inherited from regulation relate to crew health and safety (for example width of spaces, size of manholes).

Although a surveyor's knowledge and experience allow a consistent interpretation on engineering topics, additional training is required in the relevant aspects of human perception and ergonomics in order to ensure that words related to the ship-crew interface are interpreted with equal competence. In addition, surveyor's judgement could be supplemented by following the ISO 13407[4] requirement to include users (crew) in testing of alarms and equipment. Training of surveyors should also include greater awareness of the human element components of maintenance (increasingly being referred to as 'maintainability') and how adaptations made by the crew may obscure or impede usability and access of controls and equipment. If trained in this way, surveyors with ISM Code[14] approvals would be able to test procedures and equipment in combination. This would give system-level effectiveness tests. Interpreting the topics of the human element and surveying more broadly raises the issue the human element of surveying itself. There is potential for training surveyors with respect to the performance factors affecting their capability (illumination, fatigue, safety) and likelihood of error and cultural issues related to the areas where the Rules require the surveyor to exercise judgement (wording such as 'suitable' and 'sufficient').

Shipyard and office health and safety issues are traditionally addressed by the relevant national agencies in the countries concerned. Stevedore health and safety are addressed by national agencies and ILO conventions. This has led to gaps in the coverage of ship design for stevedore safety[18].

Geiger[19] has pointed out the benefits of a whole life approach as regards slips, trips and falls. It is hoped to take this approach as part of the IMO human element strategy[3].

## HONOUR THE SEAFARER

There are two ways that the general obligation to honour the seafarer might be met: input during the design and development process (of ships, equipment, procedures etc.), and feedback in-service.

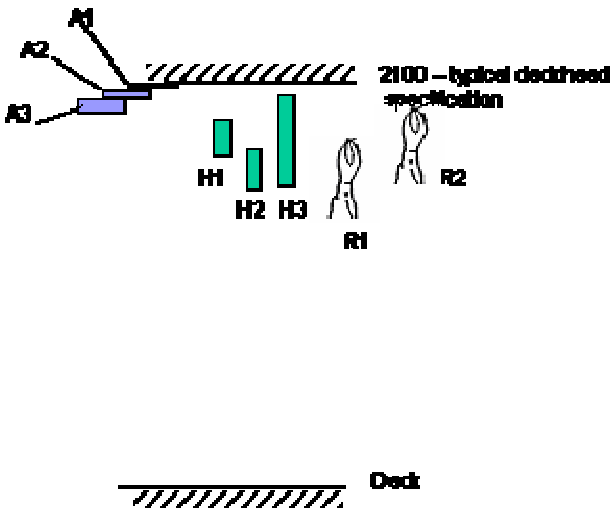
The custom of crews standing by is an example of the first. However, there is scope for much more input of this nature; the changing context of use makes this more important than it has been.

Feedback channels are limited to near-miss databases such as MARS[20] and CHIRP[21], the Nautical Institute conferences[22, 23] and some online fora[24]. Formal links between these channels, incident reports and the design or regulation of ships and equipment are less widespread than their equivalents in other sectors. The use of a risk-driven approach is more or less a corollary of a goal-based approach, and explicit use of operational risk data will need to become more widely adopted.

## THE AVAILABILITY OF SOUND DATA

One of the objectives of the *Alert!* project[9] is to make sound data more readily available to the marine professional. There is data on the seafarer population from SIRC Cardiff[25]. However, there is a lack of valid ergonomic data applicable to the maritime sector. The Maritime Ergonomics Special Interest Group of the Ergonomics Society (MarESIG)[26] and the Maritime Human Factors Research Group[27] are endeavouring to start to fill this gap.

Some of the lack of data is caused by the global nature of the industry. For example, there are no sound data on the height of seafarers. An attempt to define ranges for design purposes is shown below (Fig 3).




This figure shows a typical headroom clearance and some related design factors. A1, A2, A3 are allowances that may need to be made. A1 - 25 mm for normal footwear; A2 - 50 mm for the dynamic characteristics of walking and starting; A3 - 75 mm for a hard hat. Adding a safety clearance factor is a matter of assumption and judgment. H1, H2, H3 are the variations in height (stature) for three different populations (5th percentile to 95th percentile). H1 - N European males, compatible with the deck height (design for the maximum); H2 - male Philipinos; H3 represents a range from a small female to a large male for a population up to 2015. This is (just) compatible with the deck height but with no hard hat or safety factor allowances. R1 (South Indian), R2 (UK) are 5th percentile vertical functional reach heights for the two different populations. For Europeans, controls over walkways are not quite possible, while for a wider population they are definitely out of reach.

**Fig 3** Headroom considerations

MarESIG has been asked to improve data on passenger weight for small craft. Both the International Standardisation Organisation and IMO currently require the use of 75 kg as the standard weight of a person for load and stability calculations, including ISO 14946[28]. However, incidents in the UK[29] and Canada[30] have highlighted concerns over this value. The topic is still under investigation and correspondence on the topic is web-based[31].

Human variability and adaptability make detailed prescription particularly difficult for areas affected by the human element. For situations where there is any significant change in the manning, technology or type of operation, there are major difficulties with producing detailed prescriptive design specifications. Any solution of manning, documentation and procedures, user interface design and platform design can only be judged as correct against a context of use. The specification of fitness for purpose for the human element cannot be generic. Pomeroy[32] states:

> *"Interestingly, because of the flexibility of human action and the complexity of software behaviour (two critical components of the new human-machine interface) it was not feasible to develop Rules in the traditional way. It was found that as prescriptive Rules could not reasonably be expected to cover all eventualities it was necessary to take an innovative approach - a set of high-level principles for both product and life cycle assessment."*

## THE MOVE TO GOAL-BASED REGULATION

There are two general approaches to regulation that can be adopted; a goal-setting approach and a prescriptive approach. The distinction between the two has been summarised as the difference between methods that stand an adequate chance of producing a good result and methods that stand a good chance of assuring an adequate result. The goal-based approach offers great potential benefits (mostly in terms of flexibility) but is not without risk.

Shipping, like other sectors, is in transition between an approach to specification and regulation based on detailed prescriptive statements and an 'open-textured' approach based on goal-setting. The increasing adoption of system engineering approaches in a number of other sectors is in response to a similar trend. . However, these trends have not until now been widely recognised in the marine sector. For example, Lloyd's Register was the only marine organisation involved in the development of the international standard for system engineering[34] and led the development of the international standard for dependable maritime programmable electronic systems[33], These standards will underpin any goal based approach.

The structure for goal-based new ship construction standards does not have explicit consideration of the human element. However, there has been some recognition of the need for it[35].

> *"...in order to ensure the safety of ships in a holistic manner, operation and maintenance standards should also be considered in the process of developing goal-based construction standards."*

Standards for operation and maintenance would need to be developed in combination with standards for design and construction.

Parallel goal-based regimes have been proposed[36] to include the human element. These would address other areas such as the standards of training and watch-keeping for seafarers, structural and watertight integrity, stability, electrical systems, machinery, lifesaving appliances etc. High-level goals have also been proposed[37] to set out the aims to be achieved by merchant shipping. Goals would address topics such as the watertight integrity of the vessel, the dependability of machinery and equipment, safety, escape and survival measures and adequacy of crewing.

### Practical issues with Goal-Based Regulation

An example of issues arising from the different approaches to specification is presented at Appendix 1, using alarm design. In this section, three examples of goal-based requirements for bridge design are discussed. Two examples come from incidents where what appears to be an adequate goal-based requirement was not implemented. They are taken as being representative of the current situation.

The first example is based on the grounding of *Katia*[38], a high-speed craft on trials. Shortcomings in the operating compartment were noted, including the use of a paper chart rather than ECDIS or ENC. The following IMO requirements[39] could be considered pertinent:

> *15.2 General*
> *The design and layout of the compartment from which the crew operate the craft shall be such as to permit operating crew members to perform their duties in a correct manner without unreasonable difficulty, fatigue or concentration, and to minimize the likelihood of injury to operating crew members in both normal and emergency conditions.*
>
> *15.4.4 The arrangement of equipment and means for navigation, manoeuvring, control, communication and other essential instruments shall be located sufficiently close together to enable both the officer in charge and any assisting officer to receive all necessary information and to use the*

*equipment and controls, as required, while they are seated. If necessary, the equipment and means serving these functions shall be duplicated.*

*15.4.7 The design and layout of the compartment from which the crew operate the craft and the relative positions of the primary controls shall be assessed against the essential operational manning level. Where minimum manning levels are proposed, the design and layout of the primary and communication controls shall form an integrated operational and emergency control centre from which the craft can be controlled under all operational and emergency events by the operating crew without the necessity for any crew member to vacate the compartment.*

Current design/build and approval processes do not generate early assurance of usability. Essentially the information flow and operational validation could be considered too little too late. For designers and regulators to apply goal-based requirements – even at this relatively low level – there must be explicit activity to meet goals throughout design/build/test and approval.

The second example is a Canadian incident submitted to MarESIG[40]. Here, communication and teamworking difficulties arose in part because of the separation of the OOW and the pilot; 22 ft (6.7m) between workstations (radars) (a not-uncommon feature in traditional bridge design). There is a long-standing requirement in ISO 8468[41]:

*6.1.6 From a monitoring workstation, it shall be possible to see and hear the person at the navigation, manoeuvring and steering workstations.*

This requirement may not have been sufficiently strong to meet the needs of the case, and there is some ambiguity perhaps as to whether seeing and hearing is in the context of bridge resource management, or just the ability to see and hear a person (in general). More recent requirements, such as SOLAS Chapter V Regulation 15[16] are more abstract but more onerous. The ease with which such requirements can be applied correctly with current procedures and skill levels is unclear; certainly greater awareness would seem likely to be necessary.

The third example comes from standards for bridge equipment, typically IMO performance standards and IEC technical standards. As a generalisation, these standards include general requirements about human performance that might best be described as aspirational, detailed prescriptive design requirements (where ease of use is an assertion), and other requirements of varying provenance. There is a general assumption that there is no need to analyse the context of use or to conduct testing with users. Fortunately, this situation may be starting to improve. The revised *Performance Standards for Radar Equipment*[42] includes the requirement "7.6.1 The design should ensure that the radar system is simple to operate by trained users." IEC TC80 WG1 is giving serious consideration to the treatment of the requirement in the development of IEC 62388[43]. Full use of human-centred design standards from ISO TC159/SC4 (user system interface) would be an effective way to demonstrate compliance with this requirement. However, this would be a major change in the way of working. In the shorter term, considerable progress can be made by requiring a manufacturer to submit documentary evidence of a user performance test demonstrating that the radar system can be used by representative users working in a representative context of evaluation to maintain safety of navigation with sufficient effectiveness, efficiency and satisfaction to meet the requirements of the current version of the STCW code. ISO 9241 Part 11[44] specifies the means of doing this.

## CONCLUSIONS AND RECOMMENDATIONS

The move to a goal-based approach has the potential to provide flexibility to accommodate human variability and adaptability, and also the dynamics of the marine system (changing technology, operations and manning). Standards exist to enable the human element to be addressed effectively. However, the change in approach required will require changes in practice, training and culture by many stakeholders in the industry working in concert.

There have been proposals for including the human element in the framework of goal-based rules, so that the goals extend beyond structural design. These proposals need to be developed to provide a structure for incorporating the human element in the new regulatory structure. The new structure needs to be expressed clearly so that it is understood by stakeholders and supported with simple tools.

Design and operation need to become more user-centred. The sector needs to make greater use of mechanisms for gathering data on the characteristics of seafarers and for achieving user input; the beginnings of such mechanisms exist at the Seafarers International Research Centre and the Nautical Institute. There are a range of topics where research is required to better inform regulation; the Ergonomics Society is endeavouring to make this connection.

The feed of requirements from IMO needs to be more complete and consistent across all domains of the human element, i.e. to cover the whole system and not just people. The new IMO strategy for the human element[3] attempts to redress the early emphasis on training and manning by placing increased emphasis on ergonomics.

Train or otherwise equip surveyors with sufficient knowledge about the human element, particularly for plan approval. Find ways of treating risks arising from new or changed means of construction.

There are regulatory and competitive reasons for class in general and individual societies in particular to 'better' address the human element. Certainly, Class is committed to improving the industry's treatment of this important issue[9]. The analysis of Lloyd's Register Rules[13] suggests that being in class will not, by itself, guarantee that all human element issues are addressed for the ship and its operation. This is not least because class is only obliged to consider the human element insofar as it affects class issues. Beyond that, the issue could be addressed by delegation. This boundary is a fundamental issue that needs to be resolved.

## DISCLAIMER

Except as permitted under current legislation no part of this work may be photocopied, stored in a retrieval system, published, performed in public, adapted, transmitted, recorded or reproduced in any form or by any means, without the prior permission of Lloyd's Register, the copyright holder. Enquiries should be addressed to Lloyd's Register, 71 Fenchurch Street, London EC3M 4BS.

Lloyd's Register, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'Lloyd's Register Group'. The Lloyd's Register Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract. Copyright of Figure 2 remains with Moira Munro.

## REFERENCES


1. IMO Assembly, A23/Res.947, Resolution 947, Human Element Vision, Principles and Goals for the Organisation, IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (2004)
2. IMO Maritime Safety Committee, MSC/Circ. 878/MEPC/Circ. 346 Human Element Analysing Process (HEAP), IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (1998)
3. IMO Maritime Environmental Protection Committee, MEPC53/WP12 'Future Role of Formal Safety Assessment and Human Element Issues. Report of the Working Group'. IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (2005)
4. ISO 13407:1999, Human-centred design processes for interactive systems, British Standards Institution, Chiswick, London, W4 4AL, www.bsi-global.org, (1999)
5. ISO PAS 18152:2003, A specification for the process assessment of human-system issues, British Standards Institution, Chiswick, London, W4 4AL, www.bsi-global.org, (2003)
6. J V Earthy, How to define Quality – Methods and Intentions, results of a workshop to identify the available elements for added value shipping, part of WP 2.2 ADVANCES seminar, EU Added Value Network Concerning European Shipping (ADVANCES) WP2.2 (2003) (available from Lloyd's Register, 71 Fenchurch Street, London, EC3M 4BS, UK, www.lr.org)
7. M May, Specification of Context of Use, EU ATOMOS IV project ref A402.10.01.051.002, www.atomos.org (2001)
8. International Standards Organisation, ISO/IEC 9126-1:2001 'Software engineering -- Product quality -- Part 1: Quality model' British Standards Institution, Chiswick, London, W4 4AL, www.bsi-global.org, (2001)
9. Nautical Institute, Alert! newsletter and website, The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, www.he-alert.org, (1998)
10. Nautical Institute 'Improving Ship Operational Design Through Teamwork', The Nautical Institute, ISBN 1 870077 47 4. The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, www.nautinst.org, (1998)
11. American Bureau of Shipping, Guidance notes for the Application of Ergonomics to Marine Systems, American Bureau of Shipping, ABS Plaza 16855 Northchase Drive Houston, TX 77060 USA, www.eagle.com, (2003)
12. Lloyd's Register, Rules and Regulations for the Classification of Ships, Lloyd's Register, 71 Fenchurch Street, London, EC3M 4BS, UK, www.lr.org, (2003)
13. L Antonio**,** J V Earthy, 'The Human Element in Class Rules', RINA Conference 'Human Factors in Ship Design and Operation', London (2005)

14. IMO, International Safety Management Code, IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (2002)
15. National Transportation Safety Board, Marine Accident Report 'Grounding of the Panamanian Passenger Ship ROYAL MAJESTY on Rose and Crown Shoal near Nantucket, Massachusetts, June 10, 1995. NTSB PB97-916401, NTSB/MAR-97/01. (1997)
16. IMO International Convention for the Safety of Life at Sea (SOLAS) Chapter V Regulation 15 ‘Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures’ (2000)
17. IMO Maritime Safety Committee, MSC/Circ. 1091 ‘Issues to be considered when introducing new technology on board ship’ IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (2003)
18. Port Skills and Safety Ltd. ‘Vessel Design Considerations for Stevedore Safety’ Research and Information Series RIS6 http://www.saferports.org.uk (2004)
19. M B Geiger, 'Application of System Safety to Prevention of Falls from Height in Design of Facilities, Ships and Support Equipment for Weapons Systems' Proceedings of the 23rd International System Safety Conference (2004)
20. Nautical Institute, Marine Accident Reporting Scheme (MARS) The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, http://www.nautinst.org/MARS/index.htm,
21. CHIRP Charitable Trust, Confidential Hazardous Incident Reporting Programme ‘Maritime Feedback’ www.chirp.co.uk
22. Nautical Institute, ‘Integrated Bridge and Navigation Systems’ Conference Proceedings Ref: 0271 The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, (2002)
23. Nautical Institute, ‘Integrated Bridge Systems 2003’ Conference Proceedings Ref: 0279, The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, (2003)
24. Nautical Institute, Automatic Identification System (AIS) Forum, The Nautical Institute, 202 Lambeth Road, London SE1 7LQ, England, http://www.nautinst.org/ais/
25. Seafarers International Research Centre (SIRC), ‘Nationality Distribution of the World Fleet’. http://www.sirc.cf.ac.uk/index.html
26. Ergonomics Society Maritime Ergonomics Special Interest Group (MarESIG) http://www.maresig.org
27. Maritime Human Factors Research Group (MHFRG) http://www.maritimehumanfactors.org/
28. ISO 14946:2001 ‘small craft -- Maximum load capacity ISO 12217-1:2002 Small craft -- Stability and buoyancy assessment and categorization -- Part 1: Non-sailing boats of hull length greater than or equal to 6 m’ British Standards Institution, Chiswick, London, W4 4AL, www.bsi-global.org, (2001)
29. Marine Accident Investigation Branch, ‘Report on the investigation of the capsize of Breakaway 5 River Bure, Norfolk 19 July 2003’ MAIB Report No 2/2004 (2004).
30. Transportation Safety Board of Canada, ‘Fire and sinking small fishing vessel Silent Provider of Petit-de-Grat, Nova Scotia.’ Marine Investigation Report M03M0077, (2003)
31. Ergonomics Society Maritime Ergonomics Special Interest Group (MarESIG) http://www.maresig.org/twiki/view/Anthropometry/PassengerWeight
32. R.V Pomeroy, C.M Tomlinson, 'A Systems Approach to Integrating the Human Element into Marine Engineering Systems' in RINA Conference 'Human Factors in Ship Design and Operation', London, (2000)
33. ISO 17894:2005 – ‘Ships and marine technology — Computer applications — General principles for the development and use of programmable electronic systems in marine applications’ (2005)
34. ISO/IEC 15288:2002 ‘System engineering - system lifecycle processes’ (2002)
35. IMO Maritime Safety Committee, MSC/78/6/5 ‘Goal-based New Ship Construction Standards’ IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org (2003)
36. IMO Maritime Safety Committee, MSC 79/6/7, ‘Goal-Based New Ship Construction Standards – Role of the Human Element’, IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, 2004
37. IMO Maritime Safety Committee, IMO MSC/Circ. 79/6/24 ‘Goal-based new ship construction standards - Considerations in setting goals and functions’ IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org (2004)
38. Marine Accident Investigation Branch, ‘Report on the investigation of the grounding of HC Katia while undergoing sea trials in the Solent on 3 December 2003’ MAIB Report No 8/2004 (2004)
39. IMO ‘2000 HSC Code’ ‘Chapter 15 Operating compartment layout’ IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, (2001)
40. Ergonomics Society Maritime Ergonomics Special Interest Group (MarESIG) ‘Discussion of Canadian Incident ‘ http://www.maresig.org/twiki/view/MarESIG/IncidentAnalysis#CanadianIncident (2005)
41. ISO 8468:1994 ‘Ship's bridge layout and associated equipment - Requirements and guidelines’ (1994)
42. IMO Maritime Safety Committee, MSC 79/23/Add.2, Resolution MSA.192(79) ‘Adoption of the revised performance standards for radar equipment’, IMO, 4 Albert Embankment, London, SE1 7SR, www.imo.org, 2004

43. IEC 62388 Test Standard for the new Revised Performance Standards for Radar Equipment. (in press)
44. ISO 9241-11:1998 Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability (1998)

## APPENDIX 1 TYPES OF SPECIFICATION AND THEIR IMPLICATIONS

| Type of requirement | Example for alarms | Guidance to surveyor | Implications for assessment of compliance | Strengths, weaknesses |
|---|---|---|---|---|
| High level specification of Product | The presentation of alarms and indicators should be clear, unambiguous and consistent. | (partial) The alarm message clearly identifies the condition that has occurred. | Trip some items of equipment, read the alarm message and check that the message identifies the condition. | Very difficult to create conditions other than simple ones. To meet example requirement would involve extensive test programme.<br><br>Requires in-depth knowledge by the surveyor of the plant and of how the message would be interpreted by the crew in operational conditions. |
| Detailed specification of Product | Alarms shall provide specific information. | Each alarm entry in the alarm list should show: the alarm state marker (unaccepted, accepted, standing, clear, reset); the alarm priority marker; the alarm message; time and date. | Check alarm list on checklist. | Easy to do. Potentially many items to check. Probably low impact on safety. |
| High level specification of Performance | Timeliness. Sufficient warning. | Adequate time should be allowed for the operator to carry out his defined response. | Cause surprise failures under high workload (or high fatigue) conditions, time response, and check safety of ship, plant, personnel. | Very difficult to create representative conditions or adequate sample. |
| Detailed specification of Performance | No excess standing alarms.<br><br>No alarm cascades, grouping of alarms. | There shall be no more than 10 standing alarms (+ 30 shelved alarms) in the alarm list when running main engine(s) and auxiliaries alongside.<br><br>There shall be less than 20, and preferably less than 10 alarms in the 10 minutes following a major machinery disturbance. | Surveyor checks plant state, counts number of alarms in list. Records findings in checklist. Compatible with approach to mainstream surveys.<br><br>Surveyor trips a major piece of machinery (or arranges for it to be tripped) having checked that it is safe to do so, and then counts the number of alarms in the ECR and on the bridge in the next 10 minutes. | Easy to do, measures an accepted indicator, but ought to be tailored to design and manning of ship. |
| High level specification of process | The supplier shall follow a user-centred design methodology<br><br>The operator shall operate and maintain an alarm improvement strategy. | The supplier shall follow the principles of human-centred design and the design process specified in ISO 13407.<br><br>(principles and process descriptions supplied)<br><br>The operator shall appoint someone responsible for managing the alarm system.<br><br>There is senior management commitment.<br><br>Standards are set.<br><br>The system is reviewed. | Inspection of records concerning demonstration of usability; user involvement in design; development of design standards; analysis of context of use.<br><br>OR<br><br>Assessment of processes using ISO TR 18529.<br><br>Review of<br><br>process documentation;<br><br>management Terms of Reference;<br><br>evidence of review and change management. | Allows for new technology, addresses safety issues, but requires examination of design/development activity rather than the ship and its systems.<br><br>Generally compatible with an ISM audit in approach. Tackles important safety aspect.<br><br>Addresses a design topic from a management point of view. |