EXECUTIVE SUMMARY

AMSA hosted an e-Navigation Usability Workshop on 5 and 6 March, 2013 at Kingscliff, New South Wales, Australia. The aim was to assist in the development of the IMO’s e-navigation strategy implementation plan by developing guidelines for the usability of navigation equipment and systems. There were 44 delegates, representing 11 countries including two delegates who participated via Skype. Delegates represented four key stakeholder areas for e-navigation - maritime administrations, marine electronics industry and users (seafarers and shore organisations such as Vessel Traffic Services and pilots) and research/academia.

Scene setting presentations were provided by David Patraiko - Nautical Institute; Axel Hahn - University of Oldenburg; Yasuyuki Niwa - National Maritime Research Institute; Yasuhiro Urano - Japan Ship Technology Research Association; Antonio Di Lieto – Australian Maritime College; Peter Liley – Australasian Marine Pilots Institute; Michael Bergmann – Jeppesen; Margareta Lützhöft – Chalmers University of Technology, Jonathan Earthy – Lloyd's Register; Ben Brooks – Australian Maritime College and Michelle Grech – Australian Maritime Safety Authority.

Following the presentations delegates formed working groups to critically assess and further develop these draft guidelines. The working groups addressed three topics by providing feedback on:

(1) the draft Human Centred Design (HCD) guideline;
(2) regulatory and stakeholder input and roles; and
(3) identification of gaps within the draft HCD guideline.

This critical assessment demonstrated the need to continue to develop and mature the maritime domain’s approach to usability, while reasserting that the current HCD framework is a ‘good start’ to ensuring usability in e-navigation. Whilst views differed as to the extent of regulatory involvement, there was general agreement that regulators needed to understand the overall process and strive to achieve consistent international adoption and application, leaving the marine electronics industry to adopt, use and drive the process in a way that permits industry led development and innovation.

It was also agreed that further research and information gathering is needed. In particular, metrics (performance standards) for usability evaluation, in particular the associated methods to collect them will be crucial in identifying levels of usability, recognising that a range of stakeholder capabilities may be needed to reach the desired usability goals. Furthermore, the importance to understand that such usability evaluation within a HCD approach will also need to mature over time. With this, a number of benefits were identified with the adoption of usability guidelines, specifically safety improvements.

It was also established that different stakeholders would benefit in specific ways, in particular if a common view on usability is adopted. The workshop participants in general felt that the use of a HCD framework would provide significant opportunities to improve current levels of safety by making future e-navigation systems and equipment better fit the users’ abilities. The overall feedback obtained through the working group’s critical assessment discussions was used to amend and update the initial draft HCD guideline to take into account the key comments and suggestions provided.
Coordinator of the IMO Correspondence Group on e-navigation, John Erik Hagen (Norway) stressed the importance of addressing usability in the IMO’s e-navigation strategy implementation plan. In his closing remarks John Erik praised the workshop delegates for their efforts in helping to achieve guidance for the effective usability of future navigation support equipment and systems. The guidance will be understandable, succinct and adhere to the terms of reference that have been set by the IMO.
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1 INTRODUCTION

The e-Navigation Usability Workshop was held on 5 and 6 March, 2013 at Kingscliff, New South Wales, Australia. The event was hosted by the Australian Maritime Safety Authority to assist in the development of the IMO’s e-navigation strategy implementation plan by developing guidelines for the usability of navigation equipment and systems. The workshop aimed to further discuss and develop draft guidance on:

1. The usability of navigational equipment;
2. Quality assurance of software used in navigational systems (including updating regimes for software-driven applications);
3. Ensure human element issues associated with e-navigation are addressed.

The conference was attended by 44 delegates, representing 11 countries. A list of participants is provided in Attachment 1.

2 OPENING OF THE CONFERENCE

2.1 Welcome address by Mr Brad Groves – General Manager, Navigation Safety and International Division, Australian Maritime Safety Authority (AMSA)

The workshop was opened by Brad Groves, General Manager, Navigation Safety and International Division, Australian Maritime Safety Authority who welcomed attendees. A special welcome was extended to John Erik Hagen, Regional Director of the Norwegian Coastal Administration and those attendees who had made the effort to travel long distances to participate.

Brad noted the IMO has an ambitious plan to deliver an e-navigation strategy implementation plan next year and expressed his confidence in the group in achieving the goals of the workshop which was to provide the e-NAV correspondence group with some guidelines to achieve usability of e-navigation equipment and systems.

2.2 Update on progress at IMO on e-Navigation by Mr John Erik Hagen – Chairman, IMO Correspondence Group on e-Navigation

E-Navigation is defined as the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means. The goal is to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.

E-Navigation has been an evolutionary process, and in light of the latest prioritization of main solutions, e-navigation could be seen as a framework for the effective sharing of essential maritime information.

E-Navigation is user driven, not technology driven. If current technological advances continue without proper coordination there is a risk that the future development of marine navigation systems will be hampered through a lack of standardization on board and ashore, incompatibility between vessels and an increased and unnecessary level of complexity.

Seafarers may be expected to have the qualifications and competency to meet the advancement in technology. For IMO it is a challenge to ensure that new equipment for use onboard ships is designed with the needs, skills and capabilities of all users in mind. While e-navigation is intended to meet present and future needs through harmonization of marine navigation systems and supporting shore
services, the implementation of e-navigation will enhance management and usability of information on board and ashore to optimize decision making. The regulatory framework should keep up with the development of technology, and let us always remember that there is a link between technology, procedures and people.

The industry has an important role to play in this context. Close collaboration with the industry is essential to find technical solutions and innovations. We have to listen to the opinions of the industry to ensure we are on the right track and to assure that what we are thinking is achievable. New technical solutions and innovations could also create new business opportunities for the industry.

The effectiveness and success of e-navigation will also rely on the industry’s ability to ensure usability, data quality, system reliability, and the provision of information to support decision making. These areas will all be essential within an e-navigation Strategy Implementation Plan.

The IMO project has received broad international support, and today around 45 countries and 20 international organizations participate in the e-navigation Correspondence Group.

The introduction of the e-navigation Strategy Implementation Plan next year is not the end of the e-navigation process. It is not even the beginning of the end.

It is the start of a long-term process where authorities such as Flag States, Port States and Coastal States, international organizations, manufacturers, ship owners, training institutions, mariners, ports and all relevant shore based personnel accept and develop procedures, systems, equipment for harmonization, standardization and integration.

Several countries are already in the process of developing national e-navigation strategies.

We are moving quickly in a digital age. It is essential to ensure that we enable the benefits of these developments. The bottom line is that e-navigation is about human beings effectively sharing and using essential maritime information, making their professional lives easier, safer and more efficient. This is what e-navigation should do for us. When e-navigation solutions will be put into action, we must all pull together. We will rely on the positive attitudes, will and involvement of human beings for achieving e-navigation successfully on a global scale.

2.3 Outcomes of the January 2012 workshop on usability – Mr David Patraiko, The Nautical Institute, United Kingdom

David Patraiko reported to the group on the outcomes of the January 2012 Malmo workshop on usability, referencing the IMO paper NAV58/inf.6.

David also referenced Dr. Mark Nicholson’s paper, Computer Safety for Modern Bridge Systems which explores “the potential contributions of System System Safety Engineering including technical, operational management and crew capability contributions to CBS / IBS safety”.

Overall the key point of David’s presentation was the increasing volumes of information available which, without analysis (e.g. meteorological data), delivers little benefit.

The report of the January 2012 Malmo workshop is available at: https://apps.amsa.gov.au/enavapp

3 PRESENTATIONS

Six presentations were given by representatives from each of four key stakeholder groups represented at the workshop – maritime administrations (including classification society), the marine electronics industry, users (seafarers and shore based organisations such as vessel traffic services and pilots) and research/academia. The following section provides a brief abstract of each presentation. The full presentations are available at https://apps.amsa.gov.au/enavapp.

3.1 Safe Human Machine Interaction in Bridge Design

Presenter: Axel Hahn, University of Oldenburg, Germany
Authors: Axel Hahn, Andreas Lüdtke, Cilli Sobiech, University of Oldenburg, OFFIS, Germany

Abstract
The design of human machine interaction in modern ship bridges has a significant impact on the safety of seafaring. There is a direct impact on the capability of the nautical personnel to efficiently recognize the situation and to decide correctly. Consideration of efficiency and safety in early design phases of bridge equipment will improve the engineering processes in order to reduce design errors. Model (software) driven technology development is one option for efficient design of technical systems that proves to be a powerful tool which is becoming popular because of the reusability of the models in verification and code generation. This is also a very efficient process.

Based on former research on system engineering and human machine interaction risk assessments using cognitive simulation, this paper presents an integrated model based approach for analysis of human machine interactions. It combines technical, process and cognitive models for simulation based efficiency and risk assessment in bridge design.

3.2 Methodologies within the draft guidelines for usability evaluation of navigational equipment


Abstract
Modern navigation support systems such as ECDIS have many functions for supporting navigators and they may also have difficulties even in the procedures for fundamental tasks because of the lack
of simplicity and easiness to understand intuitively of the support systems. These difficulties may detrac
t from the useful support system’s functions and could reduce the safety of navigation. To
assess the difficulties and to ensure the simplicity of use of navigation support systems, we
developed the draft guidelines for usability evaluation of navigational equipment focusing on the
usability test (NAV 58/INF.13). Through the research on methodologies for usability assessment in
other sectors, we found that ISO 9241-11 would be useful for evaluating usability of navigational
equipment, and set it as a basis of methods in the guidelines. Consequently, the guidelines prescribe
that the results of the usability test should be evaluated by "effectiveness", "efficiency" and
"satisfaction". This paper further explains key methodologies in the draft guidelines. It is
recommended that the usability evaluation guidelines be included as a voluntary element in the e-
Navigation Strategy Implementation Plan currently under development by the IMO.

3.3 Usability evaluation of integrated navigation systems

Presenter: Antonio Di Lieto, Australian Maritime College, Australia

Abstract

Human-machine interfaces which maximize navigational safety and minimize risks constitute a core
objective of e-navigation, a strategic framework led by the International Maritime Organization
(IMO) to harmonise the uncontrolled proliferation of electronic navigation equipment. However,
IMO’s objective has not been yet translated into standardized and measurable usability goals. In
this context, what is the most suitable combination of methods to be adopted by navigational
equipment manufacturers (to engineer usability), by shipping companies (to procure usable
navigation equipment), and by Notified Bodies (to assess the compliance to a required level of
usability)? How should regulations incorporate such methods? This paper aims to explore the
applicability of usability evaluation methods to Integrated Navigation Systems (INS). The proposed
methodology results from the translation of Human Machine Interaction (HMI) concepts into a
workable combination of techniques applied to a commercial INS.

3.4 Pilotage consideration in the design of e-navigation

Presenter: Peter Liley, Australasian Marine Pilots Institute, Australia

Abstract

The development of e-Navigation and the focus that it has achieved provides us with a unique
opportunity to restore balance to the functionality and operation of ships. In many cases
regulations and rules have been set in place, the majority for very good reasons. Ships are usually
designed and built to comply with the regulatory minimum. The design and layout of the operations
spaces in many cases lack proper consideration for the needs of those who will operate the ship.

Pilots are in a unique position for several reasons.

1. Pilots are by necessity and definition not part of the crew.
2. In Australia, pilots regard themselves as part of the ship’s bridge management team.
3. Pilots then witness and participate in the operation of the ship whilst it is underway and in the
   most critical part of the voyage. In most cases, no one else attends the ship whilst underway.
4. Some sectors would also describe piloting as being the time when the ship is most likely to have
   an accident. (Which is a bit like saying “Stay away from hospital more people die there than any
where else.”) Pilotage is the time in a ship’s life when it comes on contact with the land. Pilots
   aim to ensure that contact is made as safely, efficiently and cost effectively as possible.
5. Statically, in the life of the ship pilotage is the shortest mode of operation. Steaming and cargo handling take up the greater proportion.

6. And more importantly, pilots sample a greater number of ships, bridge teams and wheelhouse designs than any other person and certainly more than any other marine professional. A pilot will likely sample as many port movements as any other with the exception perhaps of short haul ferry masters.

However there seems to be little input to the design and layout of modern ships that take into account the pilots’ task.

E-Navigation is being developed to enhance and support the decision making processes that take place in the operation of the ship. Therefore this requires the input of the pilot. In this paper I aim to give some practical insight to the development of systems to enhance and support the decision making processes that have taken place so far. And offer some suggestions for how future developments must engage all users.

### 3.5 Applying Human Centred Design (HCD) in support of data integration

**Presenter:** Michael Bergmann, Jeppesen, VP CIRM, Germany

**Abstract**

The development of e-navigation on different levels brings together static and dynamic data streams into a single e-Navigation display. In past years the static data collection found a basis in the IHO GI Register (often known as the S-100 Register) and the resulting Common Maritime Data Structure. With this development it will be essential that Human Centric Design (HCD) of the future e-Navigation systems will not only focus on the classic HCD, which looks mainly at the functionality, buttons, hardware design and interaction function. The composition, integration and situation centric rendering of dynamically selected and filtered data is a central part of the user experience and satisfaction as well as the effective and efficient usability of a new system.

This paper will explain opportunities and difficulties of merging these different data streams into a single display necessary to increase situational awareness and gain the expected positive results on safety of navigation and environmental protection. It will also highlight that while additional data will enrich the information portfolio of the navigator, the hydrographic data will be the basis of the data streams in foreseeable future - all of which will need to be optimized using HCD processes.

### 3.6 Human Centred Design – A case study

**Presenter:** Margareta Lutzhoft, Chalmers University, Sweden

**Abstract**

A case study was presented highlighting the application of a human centered design approach in the development of a navigation system. A description of the methods used for this approach was described within a research context. This presentation paved the way for the presentation of the draft human centred design (HCD) guideline which was further discussed during the workshop.
3.7 Introduction to an initial draft HCD framework to support the development of e-navigation usability guidelines

Presenters: Ben Brooks, Australian Maritime College and Michelle Grech, Australian Maritime Safety Authority

Abstract
E-Navigation systems exemplifying essential usability principles will enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment. One of the important principles of usability as described within ISO, other standards and research is that of Human Centred Design (HCD). The premise of HCD is that designable components of a system need to be fitted to the characteristics of the intended users (and maintainers), rather than selecting and/or adapting humans to fit the system, product or service. Addressing the needs of all users will support the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore. Most importantly the system should support the user in low and high stress environments (such as low and high traffic situations and during challenging navigation and environmental conditions), and particularly whenever system and operator breakdowns are most susceptible. This will improve user performance, decrease the time required for training, allow for error management and recovery, and the time and resources required for maintenance.

This framework provides HCD guidelines for the design and testing of e-navigation systems to achieve usability, system safety and integrity. This framework emphasizes the need to understand all users and their requirements and constraints. The objective is to ensure that HCD requirements and criteria, from all user perspectives (including maintainers), have been met. The achievement of usability within the development of e-navigation will be evolutionary and part of a continuous process as more understanding is gained of the whole system over time. This HCD framework was developed based on current usability standards, guidelines and research outcomes.

4 WORKING GROUPS

The workshop was provided with an initial draft version of a Human Centered Design (HCD) framework (see Attachment 3) which was based on several pieces of contemporary research and relevant current international standards. Based on this information, and using working groups over three separate sessions, workshop delegates critically evaluated and assessed the initial draft HCD framework.

Post the workshop the initial draft HCD framework was amended to take into account the key comments and suggestions provided by the working group’s critical assessments. The amended HCD framework is provided in Attachment 2 and is commended to the e-navigation correspondence group as suggested material to meet the correspondence group’s terms of reference.

The results of the working group’s critical assessments which support the latest version of the HCD framework (in Attachment 2) are detailed below.
4.1 **Theme 1: Draft HCD framework strengths and weaknesses**

4.1.1 **Working Group Coordinators**

Group 1: David Patraiko, The Nautical Institute, UK  
Group 2: Michael Bergmann, Jeppesen, Germany  
Group 3: Nick Ward, General Lighthouse Authorities, UK  
Group 4: David Blevins, Northrop Grumman Corporation, USA  
Group 5: Margareta Lützhöft, Chalmers University, Sweden

4.1.2 **Objective**

The aim of this assessment was to discuss and identify any issues with the initial draft HCD framework. Five vocationally mixed working groups addressed the following topics:

- Characteristics of e-navigation that may be missing from the initial draft HCD framework;
- Clarity and detail of the initial draft HCD framework; Other important information that should be included in the draft HCD framework;
- Extent of the HCD lifecycle (e.g. should decommissioning and disposal be included?)
- Benefits that can be achieved by ensuring adoption of the HCD framework.

4.1.3 **Characteristics of e-navigation that may be missing from the initial draft HCD framework**

It was agreed that the initial draft HCD framework was ‘a good start’ and provided a first step in ensuring usability in e-navigation. An important aspect highlighted was to ensure that the guidelines identify the scope and target audience and also identify how these fit within each part of the framework. Some other issues identified included the importance of ensuring that when considering usability the full scope of e-navigation and its interaction with the ‘full system’ (e.g. ship, bridge, cargo and engine room systems, operations, crew, ship to ship and ship to shore interaction, etc.) is accounted for. Furthermore, software integrity was not expressly covered in the initial guideline although usability is tightly linked to this (i.e. system quality and reliability) and hence it would be beneficial to include mention of software integrity.

4.1.4 **Clarity and detail of the initial draft HCD framework**

The working groups indicated that the initial draft HCD framework was fairly clear, but needed to be customised further to reflect its application within a maritime context. It was mentioned that the framework requires a starting point, and should incorporate an Early Human Element Analysis (EHEA) as a pre-activity phase which focuses on human element ‘lessons learnt’ from previous generation designs (both good and bad). In this regard Figure 1 in ISO 9421-210 (pg. 11) includes activity 5, ‘Plan the HCD process’. This defines the starting point and context of the HCD work, which is where the missing EHEA, market research and project resourcing would happen. Figure 1 in the ISO 9421-210 standard also has a clear stopping point that the ‘design solution meets user requirements’ (this could be a performance requirement, but requires a high level of maturity which is a first step in ensuring that the design solution addresses design principles (generic user requirements of any ergonomic system).

4.1.5 **Other important information that should be included in the draft HCD framework**

On this matter the working groups’ advice was in line with the comments made above. A
recommendation was put forward to include a number of case studies to give advice and examples of implementation.

4.1.6 Extent of the HCD lifecycle (e.g. should decommissioning and disposal be included?)

Discussion by working groups revolved around the issue of excluding the ‘operations’ phase of the lifecycle process within the HCD framework. In this regard most delegates agreed that this needs to be included to account for a number of aspects. Firstly, it provides an iterative approach including gathering data for the future versions (during operations) with feedback flowing back to equipment manufacturers. It would also make sure that redundant equipment is removed when it is replaced to help ensure usability, in particular when a change to context of use occurs.

4.1.7 Benefits that can be achieved by ensuring adoption of the HCD framework

A number of benefits were identified, in particular that the overall benefit would be safety improvements. It was also established that different stakeholders would benefit in specific ways, in particular if a common view on usability is adopted. The adoption of an iterative approach was identified as beneficial for manufacturers, shipbuilders and ship owners/operators, in particular as it encourages flexibility in design, ensuring future changes are accounted for. A usability guideline was also seen as a driver for standardization by adapting to generic user needs ensuring that user and functional requirements are adopted. An important aspect identified was that the draft HCD framework was developed by tapping into other industries already using a similar framework as best practice.

4.2 Theme 2: HCD stakeholder roles

4.2.1 Working Group Coordinators

Group 1: David Blevins, Northrop Grunman Corporation, USA
Group 2: Margareta Lützhöft, Chalmers University, Sweden
Group 3: Nick Ward, General Lighthouse Authorities, UK
Group 4: Michael Bergmann, Jeppesen, Germany
Group 5: David Patraiko, The Nautical Institute, UK

4.2.2 Objective

The aim of this assessment was to address stakeholders involved in e-navigation and their roles in facilitating a HCD framework and the need to ensure usability in e-navigation equipment or systems. Occupational working groups (based on ship and shore users, industry users, administration users, and research/academia) considered the following aspects of the initial draft HCD framework:

- Involvement of regulators and the roles of other stakeholders;
- Risks in adopting the HCD framework for e-navigation;
- Opportunities in adopting the HCD framework for e-navigation;

4.2.3 Involvement of regulators and the roles of other stakeholders

Whilst views differed as to the extent of regulatory involvement, there was general agreement that regulators needed to understand the overall process and work to achieve consistent international adoption and application, leaving the marine electronics industry to adopt, use and drive the
process in a way that permits industry led development and innovation.

It was agreed that regulators have a role to play in ensuring the development of relevant performance standards, but this should be from the perspective of the desired outcomes in terms of usability. It was identified that there could be several different contexts of regulatory involvement in achieving usability:

- products (e.g. equipment, systems and information);
- achieving operational safety;
- responsibility for the use of HCD;
- achievement of overall system or subsystem usability (e.g. single item of equipment, a combination of equipment forming a system, or a combination of systems forming larger systems)

Flag State regulators in particular could have the following roles and responsibilities:

- An overarching interest in and responsibility for ensuring HCD best practice is used, to the extent possible, for ships under their flag;
- Conduct audits of new build ships against the relevant parts of the HCD framework;
- E-navigation systems should be subject to periodic inspections to monitor servicing and updating activities

Recognised Organisations could assist Flag State regulators using existing delegation mechanisms.

The working groups identified that the HCD framework could serve as a guideline to help identify responsibilities and roles in achieving usability, but it should not also be a type approval process. A new mechanism to signify the satisfactory achievement of usability will need to be agreed. Some possible mechanisms were identified and it was acknowledged that further research in this area may be beneficial.

A key role for regulators will be to ensure a level of standardisation that supports safety of operations by limiting or negating the need for extensive familiarisation by users. This could be achieved using HCD-based performance standards for the design of systems and equipment. Such performance standards should be goal based. The degree of standardisation however will need to be carefully balanced with the generally accepted view that manufactures should be afforded flexibility to research, develop and innovate.

As the roles and responsibilities of regulators are further refined it will be useful to note two levels of regulatory activity: policy level, such as design approval bodies and international guidance setting (IMO); and implementation level, such as auditing and inspection (e.g. notified bodies such as classification societies, Flag States, Port State inspectors and Coastal State authorities).

4.2.4 Risks in adopting the HCD framework for e-navigation

There was general agreement that at the current stage of development the risks appeared to be few, whereas the benefits were likely to be many.

It was felt that interpretation of a usability guideline could vary, particularly during the early stages of adoption. This is linked to the risk that exists for e-navigation as a whole due to there being a wide range of levels of understanding about what e-navigation is. To counter this risk, care will be needed to use simple, concise, IMO language and to avoid as much as possible reliance on technical
or academic language. To mitigate this risk more efforts could be made to sell the benefits of
improving the ‘user experience’ through a more rigorous and systematic approach to achieving
usability than currently exists. In relation to this, it was felt that an uneven adoption of a HCD
framework to achieve usability may lead to differences between ships and between regional e-
navigation shore based services. This may involve Coastal States seeking or providing specific or
non-standard information. In addition, whilst not strictly a risk, it is important that the needs of
marine pilots be included in HCD. Marine pilots have a unique opportunity to visit and work on
many ships bridges and along with the outputs of accident investigations can provide valuable
contributions to the HCD process.

Some delegates felt that the use of a HCD framework to achieve improved levels of standardisation
may limit innovation. However, this view is held in tension with the risk that a lack of
standardisation can result in significant and ongoing training costs and lower levels of operational
safety.

Given that e-navigation is heavily dependent on the sharing of information there may be security
related risks due to the sharing of information in circumstances where the driver is HCD and
usability.

Other low level risks, some of which exist regardless of whether a HCD framework is used, included:

- academics and trainers not being included in the feedback loop for improving design;
- training not keeping pace with changes brought about by the use of HCD;
- inappropriate use of training simulators and computer-based training;
- existing training equipment not keeping pace with changes in equipment in operation;
- regulators being limited in their ability to establish and use goal based regulation;
- initial cost of equipment might be higher in some cases (although through life costs are expected
to be significantly less than many current equipment solutions);
- in some cases more users being involved might increase the risk of security breaches; and
- not adequately capturing and learning from users’ experience (an existing gap).

4.2.5 Opportunities in adopting the HCD framework for e-navigation

The workshop participants in general felt that the use of a HCD framework would provide significant
opportunities to improve current levels of safety by making future e-navigation systems and
equipment better fit the users’ abilities. It was agreed that using HCD will provide opportunities to
improve information sharing and also the performance of the operator.

Other opportunities, some of which depend on e-navigation in conjunction with the use of a HCD
framework, included:

- Provide a mechanism to ensures harmonisation between equipment manufacturers;
- Identify and consolidate best practice;
- Enhance the chances of e-navigation in general being user centred and focuses on the user;
- Allows user confidence in the final product/system;
- Gives a structured process to a new design;
- More effective/efficient voyages based upon better route management;
- Automated reporting – benefit to both ship and shore;
- Ability to transfer in port passage plan, prior to pilot boarding;
- More reliable systems due to planned maintenance;
Opportunities for increased and appropriate user engagement;
Better working environments – focus of work on the “real job”;
Training centres may be able to assist with usability evaluations and collect user feedback for manufacturers;
Data collection possibilities for researchers;
Research needed to support usability (e.g. context of use);
Changes, mainly efficiencies, for training (ship and shore users (e.g. VTS and MRCC));
Research opportunities (e.g. measurement of improvements and achievements due to use of a HCD framework)

4.3 Theme 3: HCD future activities and stakeholder capabilities

4.3.1 Working Group Coordinators

Group 1: David Patraiko, The Nautical Institute, UK
Group 2: Michael Bergmann, Jeppesen, Germany
Group 3: Nick Ward, General Lighthouse Authorities, UK
Group 4: David Blevins, Northrop Grunman Corporation, USA
Group 5: Margareta Lützhöft, Chalmers University, Sweden

4.3.2 Objective

This aim of this assessment was to discuss future activities (technical, training and others) that may be necessary to support the HCD framework for e-navigation. Five vocationally mixed working groups addressed the following topics:

- Gaps that may exist with respect to usability evaluation after finalising the HCD framework,
- Development of usability metrics (performance standards), and
- Capabilities and skills necessary to support HCD.

4.3.3 Gaps that may exist with respect to usability evaluation after finalising the HCD framework

The working groups generally agreed that:

- There is a cultural gap between what is being done now and the adoption of a HCD framework, and there will need to be a global educational process to bring about this paradigm shift;
- Research into how HCD is used (good and bad) from other industries (i.e. other transport modes and other high risk industries such as healthcare), and how this might translate to maritime should be done;
- Research should also be informed by clearly identifying and learning lessons from former maritime technological implementations;
- Accident and incident data could be analysed for usability issues to provide examples and learn how HCD might have been used;
- Consider the value of test beds (e.g. Singapore and North Sea) to support future developments in usability guidelines;
- Collect more data on actual user performance (i.e. systems ‘in-use’) and use as a base to analyse and to help improve the usability of the future iterations of systems, including issues within the system lifecycle;
• Training implications may follow improved usability – non-technical (e.g. in bridge resource management), technical (equipment generic and familiarization) and documentary (e.g. standard for readability of equipment manuals).

In summary, participants considered that it was important to understand that usability evaluation within a HCD approach must mature over time. A range of information and research will support this process. Such evaluations must include considering the system in use. A range of training implications may emerge from improved usability, but these may be benefits rather than increased costs.

4.3.4 Usability Metrics (performance standards)

Those stakeholders applying the framework will need more detailed guidelines on selection of appropriate metrics (performance standards) for Testing Evaluation and Assessment (TEA). These guideline might address gaps identified in the measurement of usability (as demonstrated by Japan ref: NAV 58/6/6; NAV 58/INF.12), confidence level of data (reliability and validity) and tolerance for incompatibility.

Real usability challenges include the following issues and these may require usability tests to be specially designed:

• Integration with existing systems (i.e. non-HCD, pre e-navigation)
• Inconsistent levels of e-navigation maturity (ashore and on board)

ISO & IEC test standards will need to be tailored for maritime application. The workshop saw presentations on usability evaluation methods from participants from Germany, Australia and Japan. The variation in these approaches demonstrates how wide the options are for evaluating usability. There was general agreement that providing access to these sorts of studies will assist stakeholders to better align themselves with the HCD framework.

4.3.5 Stakeholder Capabilities

ISO 9241 indicates that design and evaluation teams should be multi-disciplinary in nature. With this in mind, and given the unique aspects of the maritime domain, working groups were asked to critically reflect on the composition of such teams for e-navigation. The working groups generally agreed that, in order to support HCD in e-navigation the following should be considered:

• It is essential to have realistic end-user input, including from seafarers, pilots and relevant shore personnel;
• Pilots typically see many more ship’s bridges than most seafarers and therefore are uniquely placed to comment on bridge equipment usability issues;
• The disciplines should be adaptive to reflect the changing socio-technical environment
• There should be skills to translate user needs into user wants, and define implementation;
• Skills should also include system/software design, domain expert, engineers, human factors practitioners, social scientists, usability engineering, systems safety experts/engineers, project managers, and marketing experts.

This critical assessment demonstrated the need to continue to develop and mature the maritime domain’s approach to usability, while reasserting that the current HCD framework is a ‘good start’ to ensuring usability in e-navigation. Further research and information gathering is needed. Metrics
(performance standards) and the associated methods to collect them will be crucial in identifying levels of usability, recognising that a range of stakeholder capabilities may be needed to reach the desired usability goals.

5 DESIGN PRINCIPLES: RANKING EXERCISE

5.1 Overview

As part of the usability workshop delegates were requested to voluntarily participate in a study by scoring (using a 5-point rating scale) seven design principles against each of the six e-navigation proposed Solutions and eight Risk Control Measures (as identified by the Correspondence Group of e-navigation). As part of usability in any system design, we are aware that design trade-offs will be made. The aim of this study will be to assist in providing a better understanding, as a first step, on what are deemed to be the most important design principles that should be considered for e-navigation against the current information. Results of this study will be presented at NAV59 (IMO, safety of navigation sub-committee) as an information paper.

6 FINAL DISCUSSION AND WORKSHOP OUTCOMES

6.1 Conference conclusions

It was concluded that the draft HCD framework to support the development of usability guidelines presented at the workshop was an excellent baseline to work from, however should be updated to take into consideration the key comments, gaps and suggestions identified by the delegates at the workshop.

John Erik Hagen made a final address to the workshop stressing the importance of addressing usability in the IMO’s e-navigation strategy implementation plan. In closing remarks John Erik urged attendees to continue the good work which was started by a Japanese proposal, developed at a workshop in Sweden in 2012 and expanded at this workshop. The aim is to articulate guidance to achieve usability of future navigation equipment and systems. This guidance needs to be persistent, understandable, succinct and adhere to the terms of reference that have been set by the IMO.

The e-navigation correspondence group has requested submissions on test beds be provided to the group by 29 April 2013.

Attendees discussed the current e-navigation strategy in light of discussions at the workshop. Feedback was provided as follows:

- The strategy has a strong ship focus. The strategy should be further expanded to address shore side considerations (e.g. ports, administrations, etc.).
- The strategy should consider tools such as the ISM Code, the IMO does not have a similar code for risk management.
- Importance of quality management, usability and quality may be subject to degradation over time as new features or functionality is introduced.

6.2 Conference conclusions of relevance to the IMO process

A draft report was circulated for comments on the on 20 March 2013 to all delegates that participated in this workshop.
It was agreed the final report should reference previous workshops and proposals including the Japanese proposal which forms an integral part of the usability guidelines scope.

This final report was submitted to the Chairman of the Correspondence Group on e-Navigation on the 5 April 2013 with the objective being that the developed HCD framework would become part of the correspondence group’s efforts and provided to the IMO’s Safety of Navigation Sub-Committee as a crucial step in support of the achievement of usability in e-navigation equipment.

7 CLOSING OF THE CONFERENCE

Nick Lemon, Manager Nautical and Regulation, Australian Maritime Safety Authority thanked delegates for their attendance and positive participation and wished them well on their return journeys whether near or far.

Axel Hahn, on behalf of the delegates, thanked AMSA for convening and coordinating the workshop.

The chair extended additional thanks to John Erik Hagen for encouraging Australia to take the lead on this particular workshop, Ben Brooks from AMC and Michelle Grech from AMSA who both provided academic expertise, bringing a formality to the process of presentations and the formulation of the activities conducted at the workshop, Jonathan Earthy who gave up many hours sleep to participate and provide a significant contribution to the workshop over Skype, the AMSA team of Kerrie Abercrombie, Prasanthen Athipar, Iain Kerr and Tracy Whatman. Also thanks to the Australian maritime industry for supporting the event.

In conclusion the chair encouraged participants to maintain the connections established at the workshop to continue progression of the e-navigation concept and to ensure their respective administrations and industries are briefed on the event in preparation for IMO’s Safety of Navigation Sub-Committee (NAV 59) in September 2013.

8 SOCIAL EVENTS

8.1 Welcome Reception

On day 1, a welcome reception was held poolside at the workshop venue allowing delegates to enjoy the warmth of the Australian autumn, even if it was interrupted by a short rain shower. Nick Lemon from the Australian Maritime Safety Authority welcomed delegates and thanked them for travelling to Australia to participate in the workshop.

8.2 Workshop Dinner

On day 2, a workshop dinner was held offsite at a local restaurant, Fins Restaurant, where delegates had the opportunity to enjoy some fine Australian food and to continue discussions and debate about e-navigation and achieving improved levels of usability.

ATTACHMENTS

1. Participants list
2. Final version of draft HCD guideline
3. Initial version of draft HCD guideline
## ATTACHMENT 1 – Participants List

<table>
<thead>
<tr>
<th>Salutation</th>
<th>Surname</th>
<th>First Name</th>
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Achieving Usability in e-Navigation Systems

Draft Guideline on Human Centred Design for e-Navigation Systems

1. Definitions


Human Centred Design: An approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge [2].

Life-cycle: The stages and activities spanning the life of the system from the definition of its requirements to the termination of its use covering its conception, design, operation, maintenance support and disposal [3].

Stakeholder: An individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations [2] (Likely stakeholders for e-navigation include mariners, marine pilots, equipment manufacturers, Vessel Traffic Services (VTS), Rescue Coordination Centres, Recognised Organisations, coastal States, port States and flag States, hydrographic offices, ship builders, ship owners, ship operators, ship charterers and training organisations [4]).

Usability: The extent to which a product can be used by specified users to achieve specified goals with safety, effectiveness, efficiency and satisfaction in a specified context of use [2].

User: Any party interacting (input into and/or extract information) with the system including operators and maintainers.

System: Combination of interacting elements organized to achieve one or more stated purposes (A system can consist of products, equipment, services and people) [5].

2. Introduction

e-Navigation systems exemplifying essential usability principles will enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment. One of the important principals of usability as described within the International Standard Organization (ISO), other standards and research is that of Human-Centred Design (HCD). Human Centred Design (HCD) describes the methodology used to implement usability goals and to assess the result (It is interchangeably referred to as User Centred Design in some references). The premise of HCD is that designable components of a system need to be fitted to the characteristics of the intended user(s), rather than selecting and/or adapting humans to fit the system, product or service [p.5, [5].
Addressing the needs of all users on board and ashore will support the harmonized collection, integration, exchange, presentation and analysis of marine information. Most importantly the system should support the user in low and high stress environments (such as low and high traffic situations and during challenging navigation and environmental conditions), and particularly whenever system and user breakdowns are most susceptible. This will improve user performance, decrease the time required for training, allow for error management and recovery, and the time and resources required for maintenance [6].

This guideline outlines a HCD framework for ensuring usability in e-navigation systems. It is intended to be used by most stakeholders involved in e-navigation (as defined above), however the primary users of the HCD framework will be those who develop and evaluate e-navigation systems: equipment manufacturers, system integrators, state approval authorities, shipbuilders, ship owners, ship operators, VTS/RCC’s, IALA and the IMO, including the organisations and member states that participate in the IMO. As these guidelines are based on the system life-cycle process, various stakeholders would be involved at different stages of the life-cycle process. The requirements within this HCD framework are meant to be goal-based and are not intended to specify or discourage the use of any particular design solution relevant to the development, design and manufacture of e-navigation systems. As such detailed and prescriptive design requirements which specify design solutions are not included.

While systems integration is not covered within this guideline, it is important to note that the development of e-navigation systems must be undertaken within the broader context of systems integration (ship, other equipment, crew, shore, training, etc.) to ensure full consideration of usability issues.

3. HCD framework objectives

The guideline presents a HCD framework for the design and testing of e-navigation systems to achieve usability. It emphasises the need to understand all users and their requirements and constraints [7]. The objective is to ensure that HCD requirements and criteria, from all user perspectives, have been met. This includes all users of the system (including maintainers). The improvement of usability within the development of e-navigation will be evolutionary and part of a continuous process as more understanding is gained over time [8].

This HCD framework was developed based on current usability standards, guidelines and research outcomes [2, 9, 10]. Annex 1 provides a brief overview of relevant, current international standards.

An important aspect that must be considered as part of these guidelines is software quality assurance. This is important as highlighted by a paper presented to the sub-committee on safety of navigation in 2012 (NAV58/6/4) by the Republic of Korea [11]. This paper stressed the importance of ensuring that high-quality software that is both stable and complete will need to be installed to support e-navigation. The ISO/IES FCD 25010 standard provides further guidelines on systems and software product quality requirements and evaluation [12].

4. HCD framework process description

HCD framework requirements

The HCD framework process should as a minimum consist of these four activities:
1. Activity 1: Understand and specify the context of use (in which the system is/will be used);
2. Activity 2: Specify the user requirements;
3. Activity 3: Produce design solutions to meet user requirements;
4. Activity 4: Evaluate the designs against requirements

This framework will be required to be integrated into the ‘major’ phases of e-navigation system life-cycles (i.e. concept development, planning and analysis, design and testing, implementation and operation). Figure 1 outlines the activities to be undertaken when applying the HCD framework. It illustrates the interdependence of each activity within the HCD process. It does not imply a strict linear process, rather it illustrates that each step in each activity uses outputs from other activities. Embedded within each is the requirement to conduct Testing Evaluation and Assessment (TEA) [10]. As part of the HCD framework, Activity 5 was added to cover the operational phase of the life-cycle. This should ensure that when navigation systems are being modified or new systems fitted, the human element issues are addressed and supported during the integration process into the operational environment. This will need to be aligned with on-going crew training and maintenance support throughout the operational life, with the crew able to provide operational feedback that may lead to further refinements to the system and subsequently improved performance.

The processes within the HCD framework should ensure that the following requirements are included:

1. Establish a good understanding of any usability design shortfalls and strengths of previous generations of navigation systems (i.e. this may include conducting an early human element analysis (EHEA) to identify and document human element issues with current navigation systems). This is incorporated as a Pre-Activity phase within Figure 1 and is considered to be one of the starting points that feed into the HCD process activities. Results from this pre-activity can impact all future life cycle phases. As indicated, this EHEA is a continuous process with data collected during the operational phase providing feedback to the next generation of e-navigation systems.
2. Establish the context of use based upon an explicit and thorough understanding and assessment of users, tasks and environments (defined as Activity 1);
3. Ensure users are involved at each stage of activity during design and development;
4. Ensure the design addresses the whole user experience;
5. Ensure the design is driven and revised by user Testing, Evaluation and Assessment (TEA);
6. Ensure an iterative approach in the design process is adopted; and
7. Establish a design team that includes relevant multidisciplinary skills and perspectives.

**Usability design principles**

A central pillar within the current international standards is the ‘design usability principles’ referred to as ‘dialogues’ within the ISO standards [13]. These design principles consider some human limitations and provide a first step in establishing a core base for an understanding of good human centred design practice [10]. The design principles identified in the ISO standards complement previous work in this area by a number of ‘usability’ researchers who identified important design usability principles (so called “usability heuristics” in the research community) which should be considered as part of the design of systems [10-15]. As specified in the standards, these design principles are not strictly independent and they do overlap. It may be necessary to collaboratively interpret different principles in order to optimise usability for e-navigation.

The International Standard Organization (ISO 9421-110) identifies seven principles as being important for the design and evaluation of interactive systems. These can serve as a set of general subject areas for

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1 Please note that disposal of system has not been included at this stage. This is subject to further discussions.
the design and evaluation of e-navigation systems and could be incorporated as performance standards forming part of the usability evaluation activity. Table 1 in Annex 2 provides a definition and brief description of each of these seven design principles as highlighted in the ISO standards [13].

**Testing Evaluation and Assessment (TEA)**

In e-navigation the users play a crucial role and, hence the effectiveness of system usability evaluation is of particular importance. Therefore, the TEA is integrated within the HCD framework forming part of each phase of the system lifecycle and HCD activities. The TEA iterative process will ensure that human element issues are identified in the early stages of the design process and rectified accordingly. TEA covers a number of potential methods (i.e. heuristic evaluation, questionnaires, link analysis, walkthroughs and user tests) that could be used to evaluate system usability within each phase of the HCD process. As shown in Figure 1, the TEA circle becomes larger following each activity and each phase of the life-cycle process. This denotes the increasing intensity of the TEA process following each HCD activity [10]. There are a series of factors to be considered when selecting the appropriate TEA method within each activity. Often, in the early stages low-fidelity prototypes can be used to obtain feedback at a reduced cost. Annex 3 provides some examples of TEA methods that can be applied within each activity [2].

The TEA following activity 4 is conducted before a system is deployed operationally, ideally verifying and validating that usability requirements from all user perspectives have been met – this includes identified operational users as well as system maintainers. This TEA may involve the use of usability test beds with appropriate usability performance test methods and metrics\(^2\) to ensure a system meets performance criteria and operational needs. In 2012, Japan presented a paper to the IMO’s Safety of Navigation Subcommittee meeting (NAV58) proposing one suitable methodology for usability evaluation of navigational equipment which can be used within Activity 4 [20]. An important component of TEA is to ensure that appropriate usability performance standards are used during the design and development of e-navigation systems.

A brief description of each activity within the HCD framework is provided below.

**Pre-Activity – Conduct an early human element analysis (EHEA)**

This pre-activity involves identifying human element strengths and weaknesses in the design of navigation systems during the operational phase. Such an analysis is intended to capture human element issues at the earliest stages, and a degree of iteration is usually required to clarify and evaluate these issues as the project develops. Early recognition of broad risks, concerns, constraints, assumptions, requirements and opportunities can provide initial direction to the HCD effort, and result in substantial gains. This activity involves the following steps:

- early analysis to capture lessons learned from operating similar or precursor systems;
- extraction, assessment and prioritisation of human element issues and assumptions from all the information gathered, and their evaluation in terms of risk management;
- capture and compilation of the findings in a form that can be readily integrated into a Risk Register for future tracking and risk management before undertaking remaining activities.

**Activity 1 – Understand and specify the context of use**

This activity takes into account the overall environment in which the system will be used. It consists of

\(^2\) It is critical that appropriate usability metrics and test methodology are used at this stage of the TEA process to ensure usability.
the users’ characteristics, their goals, tasks, physical environment, social and management environment and other factors that may have an impact on safety and performance of the whole system.

This activity involves identification of the following [2]:
- the users and other stakeholder groups;
- the characteristics of the users or groups of users (characteristics pertinent to design such as physical and cultural);
- the goals and tasks of the users; and
- the environment(s) of the system (organisational (i.e. stakeholder perspectives, applicable standards, assessment measures, etc.), technical and physical environment (i.e. task environment such as space, lighting, etc.).

The identification of context of use [28] is a "living" activity that is added to, modified, and updated as system development progresses. It provides the foundation for Activity 2 in the HCD framework.

Activity 2: Identify user requirements

User requirements include user needs arising from human-system issues identified in the context of use related to the maritime environment. The objective is to develop a consistent set of user requirements (e.g. to achieving targets for performance, safety, maintenance, functionality, etc.) to reliably address human-system issues [9].

This activity involves the following [2]:
- clarification of system goals;
- analysis of stakeholders needs and expectations;
- analysis of user needs and expectations;
- resolving conflicts between different user requirements;
- assessment of health and safety risks;
- analysis of training needs;
- generation of operational concept, top-level system and mission requirements; and
- ensuring the quality of user requirements specifications.

Activity 3 - Produce and/or develop design solutions to meet user requirements

Activity 3 involves translating mission needs into top-level system functions which defines the operations and events that must be performed in order to meet the system requirements. Functions are then assigned between human and automation by comparing performance capabilities and limitations between humans and technology on a number of parameters (such as accuracy, speed, reliability, response flexibility, and strength). Cost factors and user cognitive and affective support needs are also considered.

This activity involves the following [2]:
- designing user tasks, user-system interaction and user interface to meet user and system requirements;
- applying design principles (see Table 1 in Annex 2);
- allocation of functions;
- production of a task model;
- development of design solutions (and altering design solutions based on human centred design evaluation and feedback);
specification of system and its use;
devlopment of prototypes;
development of user training; and
development of a maintenance regime and user support.

**Activity 4: Evaluate the design against criteria**

Activity 4 represents the TEA before a system is deployed operationally to ensure that the design meets the requirements of particular usability performance standards. This TEA activity should involve a process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets its usability performance specifications [8] as highlighted in Annex 3 and 4.

This activity involves the following [2]:
- specifying the context of evaluation
- evaluation to improve design;
- evaluation against system requirements;
- evaluation against required practice; and
- evaluation in use.

**Iterative process**

During Activity 5 which is the operational phase of the system the user is trained, and throughout its operational life the user should be able to provide operational feedback that may lead to further refinements to the system and subsequently improved performance.

Each activity is to be revisited iteratively throughout system development, with feedback between each of the activities used for refinement to meet user and organizational goals. For example, increased definition of the context of use may impact on user requirements or, after initial prototyping and evaluation of a design solution, deficient user-requirements may be identified and amended.
Figure 1: e-Navigation Human Centred Design Framework

**Operational**
- Activity 5: Introduce and operate system (train and maintain)

**Pre-Activity**
- Conduct Early Human Element Analysis (EHEA)

**Concept development**
- Activity 1: Understand and specify the context of use
- TEA

**Planning & Analysis**
- Activity 2: Specify the user requirements
- TEA

**Integration and testing**
- Activity 4: Evaluate the designs against requirements
- TEA

**Design**
- Activity 3: Produce design solutions to meet user requirements
- TEA

Designed solution meets user requirements

Feedback

Iterate, where appropriate

TEA – Testing, Evaluation and Assessment
5. Bibliography

28. There are tools available for describing context of use (e.g. www.usabilitynet.org/tools/context.htm).
Annex 1: Basis of Framework

This annex provides a brief overview of International Standards relevant to the design of e-navigation systems and consistent with the principles of the ergonomics of human-system interaction. The intent is to provide delegates with a summary of the key principles and concepts, as well as an outline of how the standards link together to provide guidance for the different components of human-centred design.

The e-navigation usability draft framework is developed based on the following standards:

- ISO 26800:2011(E)
- ISO 9241 Series
- ISO/TR18529
- ISO/TR 16982
- SAA HB59-1994
- MIL-STD-1472G
- ISO/IEC 25010:2011(E)

**ISO 26800:2011(E) Ergonomics – General approach, principals and concepts**

At the broadest level, ISO 26800:2011(E) identifies a general approach and broad principles and concepts relevant to the design and evaluation of interactive systems, “bringing together the basic principles and concepts of ergonomics in one document, and thus providing a high level view of the way in which ergonomics is applied”.

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The ISO 9241 series of standards are the central set of documents for human centred design. ISO 9241 is a multi-part standard addressing the ergonomics of human system interaction. The series moves from broad principles to more specific requirements for aspects of system design such as world-wide-web interfaces or physical input devices. The majority of the series have some relevance to the detailed design of e-navigation equipment, however most important are the usability concept, the dialogue principles, the characteristics of presented information and the human-centred process model.

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These handbooks will form the basis on which some of the e-navigation Human Centred Design (HCD) framework will be based. These handbooks described the human-centred lifecycle process model which has been developed in response to the need to improve the performance of the human-centred part of system development and support projects. The model is stand-alone, although is naturally linked to models such as ISO/IEC 12207 due to the interaction between hardware and software within the design of interactive systems. The model uses the format common to process assessment models, describing the processes that ought to occur in order to achieve defined technical goals. The human-centred process category therefore contains processes, and processes contain key practices. The processes generate and use work products.

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use and the characteristics and needs of the end-users. These more or less follows the design principals set out in the ISO, however are more suited for defence applications.

**ISO/IEC 25010:2011(E) - Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models**

This standard defines two sets of objectives required to achieve system and software quality as stated below:

a. A quality in use model composed of five characteristics (some of which are further subdivided into sub-characteristics) that relate to the outcome of interaction when a product is used in a particular context of use. This system model is applicable to the complete human-computer system, including both computer systems in use and software products in use.

b. A product quality model composed of eight characteristics (which are further subdivided into sub-characteristics) that relate to static properties of software and dynamic properties of the computer system. The model is applicable to both computer systems and software products.

The characteristics defined by both models are relevant to all software products and computer systems. The characteristics and sub-characteristics provide consistent terminology for specifying, measuring and evaluating system and software product quality. They also provide a set of quality characteristics against which stated quality requirements can be compared for completeness. The aspect of software quality is critical and needs to be linked to usability.
### Annex 2: Usability Design Principles

Table 1: This table provides a brief description of each of the nine design principles (based on ISO standards and research in this area) [13].

<table>
<thead>
<tr>
<th>Design Principal</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitability for the task</td>
<td>Supports the user in the completion of the task</td>
</tr>
<tr>
<td>Self-descriptiveness</td>
<td>At any time, it is obvious to the users which mode they are in, where they are within the mode, which actions can be taken and how they can be performed.</td>
</tr>
<tr>
<td>Conformity with user expectations</td>
<td>Conforms with user expectations if it corresponds to predictable contextual needs of the user and to commonly accepted conventions</td>
</tr>
<tr>
<td>Suitability for learning</td>
<td>Suitable for learning when it supports and guides the user in learning to use the system.</td>
</tr>
<tr>
<td>Controllability</td>
<td>System is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met.</td>
</tr>
<tr>
<td>Error Tolerance</td>
<td>A system is error-tolerant if, despite evident errors in input, the intended result may be achieved with either no, or minimal, corrective action by the user.</td>
</tr>
<tr>
<td>Suitability for individualisation</td>
<td>A dialogue is capable of individualization when users can modify interaction and presentation of information to suit their individual capabilities and needs.</td>
</tr>
</tbody>
</table>
Annex 3: Some examples of TEA methods

Table 2: Brief description of referenced methods than can be applied as part of TEA at various stages of the HCD framework.

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<th>HCD Stage</th>
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<td>Y</td>
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<td>Activity 4³</td>
</tr>
<tr>
<td>Performance-related measurements</td>
<td>Y</td>
<td>Collection of quantifiable performance measurements in order to understand the impacts of usability issues.</td>
<td>Activity 4</td>
</tr>
<tr>
<td>Critical incident analysis</td>
<td>Y</td>
<td>Systematic collection of specific events (positive or negative).</td>
<td>Activity 1</td>
</tr>
<tr>
<td>Questionnaires</td>
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<td>Indirect evaluation methods which gather users’ opinions about the user interface in predefined questionnaires.</td>
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</tr>
<tr>
<td>Thinking aloud</td>
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<td>Involves having users continuously verbalise their ideas, beliefs, expectations, doubts, discoveries etc. during their use of the system under test.</td>
<td>Activity 3 and 4</td>
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<tr>
<td>Collaborative design and evaluation</td>
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<td>Methods which allow different types of participants (users, product developers and human factors specialists, etc.) to collaborate in the evaluation or design of systems.</td>
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<td>Use of computer simulation modelling tools used for initial evaluations.</td>
<td>Activity 2 and 3</td>
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</table>

** The standard does not include expert users in this category but this could reasonably be considered another form of expert evaluation.

³ The usability evaluation methodology proposed by Japan fits into this activity area [16].
Annex 4: Some examples of usability assessment criteria

Table 3: Hornbaek Usability Performance Standards [27]

<table>
<thead>
<tr>
<th>Name</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>The number of errors users make completing tasks.</td>
</tr>
<tr>
<td>Recall</td>
<td>How much information can users recall after using the interface?</td>
</tr>
<tr>
<td>Completeness</td>
<td>The extent to which tasks are solved.</td>
</tr>
<tr>
<td>Quality of Outcome</td>
<td>Extensive measure of the outcome of tasks.</td>
</tr>
<tr>
<td>Measure of satisfaction</td>
<td>E.g. how satisfied were you with the use of the search engine?</td>
</tr>
<tr>
<td>Preference</td>
<td>Give users a choice of interfaces and see which they choose.</td>
</tr>
<tr>
<td>Content Dependent Questions</td>
<td>Users’ satisfaction with specific features.</td>
</tr>
<tr>
<td>Satisfaction before use</td>
<td>Do users think they will be able to use the system?</td>
</tr>
<tr>
<td>Satisfaction during use</td>
<td>Satisfaction obtained while tasks are solved. Can be measured with heart rate</td>
</tr>
<tr>
<td></td>
<td>variability, reflex responses and quantifications of negative comments.</td>
</tr>
<tr>
<td>Attitude towards content</td>
<td>How appealing was the subject matter?</td>
</tr>
<tr>
<td>Perceptions on outcome</td>
<td>Users’ sense of success.</td>
</tr>
<tr>
<td>Other measures of satisfaction</td>
<td>Easy to make mistakes, the display is cluttered, meaningfulness.</td>
</tr>
<tr>
<td>Measuring specific attitudes</td>
<td>Annoyance, anxiety, complexity control, engagement, flexibility, fun, intuitive,</td>
</tr>
<tr>
<td></td>
<td>learnability, liking, physical discomfort, want to use again.</td>
</tr>
</tbody>
</table>
ATTACHMENT 3 – Initial version of draft HCD guideline

Achieving Usability in e-navigation Systems

Draft Human Centred Design Framework

1. Definitions

**Design Principles:** Basic and fundamental concepts supporting good system design practices.

**E-Navigation:** the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment (MSC 85/26/Add.1 Annex 20).

**Human Centred Design:** An approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge (ISO 9241-210:2010(E)).

**Life-cycle:** The stages and activities spanning the life of the system from the definition of its requirements to the termination of its use covering its conception, operation, maintenance support and disposal (ISO/TR 18529).

**Stakeholder:** An individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations (ISO 9241-210:2010(E)).

**Usability:** The extent to which a product can be used by specified users to achieve specified goals with safety, effectiveness, efficiency and satisfaction in a specified context of use (ISO 9241-210:2010(E)). Usability is an outcome of Human Centred Design\(^4\) (HCD) (HCD is the methodology used to reach the outcome).

**User:** An individual interacting with the system (ISO/TR 18529), including system maintainers.

**System:** Refers to the users, the technology and the context in which it is used.

2. Introduction

E-navigation systems exemplifying essential usability principles will enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment. One of the important principals of usability as described within ISO, other standards and research is that of Human-Centred Design (HCD).

The premise of HCD is that designable components of a system need to be fitted to the characteristics of the intended users (and maintainers), rather than selecting and/or adapting humans to fit the system, product or service (p.5, ISO 26800:2011(E)).

Addressing the needs of all users will support the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore. Most importantly the system should support the user in low and high stress environments (such as low and high traffic situations and during challenging navigation and environmental conditions), and particularly whenever system and operator breakdowns are most susceptible. This will improve user performance, decrease the time required for training, allow for error management and recovery, and the time and resources required for maintenance [1].

\(^4\) Please note that the terminologies Human Centred Design and User Centred design are interchangeable and are similarly defined.
3. HCD framework objectives
This framework provides HCD guidelines for the design and testing of e-navigation systems to achieve usability, system safety and integrity. This framework emphasises the need to understand all users and their requirements and constraints. The objective is to ensure that HCD requirements and criteria, from all user perspectives, have been met. This includes all users of the system (including maintainers). The achievement of usability within the development of e-navigation will be evolutionary and part of a continuous process as more understanding is gained of the whole system over time [2].

This HCD framework was developed based on current usability standards, guidelines and research outcomes. Annex 1 provides a brief overview of relevant, current international standards.

4. HCD framework for e-navigation
This HCD framework outlines a process for ensuring usability in e-navigation systems. The requirements within this framework are meant to be goal-based and are not intended to specify or discourage the use of any particular design solution relevant to the development, design and manufacture of e-navigation systems. As such detailed and prescriptive design requirements which specify design solutions are not included.

Usability design principles
A central pillar within the current international standards is the ‘design usability principles’ referred to as ‘dialogues’ within the ISO standards. These design principles consider some human limitations and provide a first step in establishing a core base for an understanding of good human centred design practice [3]. The design principles identified in the ISO standards complement previous work in this area by a number of ‘usability’ researchers (i.e. [4-9]) who identified important design usability principles (so called “usability heuristics” in the research community) which should be considered as part of the design of systems. As specified in the standards, these design principles are not strictly independent and they do overlap. It may be necessary to achieve a “trade-off” between principles in order to optimise usability for e-navigation.

HCD framework requirements
Figure 1 outlines the activities to be undertaken when applying the HCD framework. This framework will be required to be integrated into the ‘major’ phases of e-navigation system life cycles (i.e. concept development, planning and analysis, design and testing, and implementation)5.

In general, the HCD framework should ensure that the following requirements are included:
8. Establish a good understanding of any usability design shortfalls of previous generations of navigation systems (i.e. this may preclude conducting an early human element analysis (EHSA) to identify and document human element issues with current navigation systems);
9. Establish the context of use based upon an explicit understanding of users, tasks and environments;
10. Ensure users are involved throughout design and development;
11. Ensure the design addresses the whole user experience;
12. Ensure the design is driven and revised by user Testing, Evaluation and Assessment (TEA);
13. The process is iterative;
14. The design team includes relevant multidisciplinary skills and perspectives.

In line with the above requirements and as shown in the Figure, the HCD framework process should as a minimum consist of these four activities:
6. Understand and specify context of use (in which the system is/will be used);
7. Identify user requirements;
8. Produce and/or develop design solutions to meet user requirements;
9. Evaluate the designs against defined criteria.

Figure 1 illustrates the interdependence of each activity within the HCD process. It does not imply a strict linear process, rather it illustrates that each step in each activity uses outputs from other activities. Embedded within each is the requirement to conduct TEA.

5 Please note that disposal of system has not been included at this stage. This is subject to further discussions.
**Testing Evaluation and Assessment (TEA)**

In e-navigation the users play a crucial role and, hence the effectiveness of system usability evaluation is of particular importance. Therefore, TEA is integrated within the HCD framework forming part of each phase of the system lifecycle and HCD activities. TEA covers a number of potential methods (i.e. heuristic evaluation, questionnaires, link analysis, walkthroughs and user tests) that could be used to test system usability within each phase of the HCD process. Annex B provides some examples of methods that can be applied within each activity of the HCD framework [10].

There are a series of factors to be considered when selecting the appropriate TEA method within each activity. The TEA iterative process will ensure that human element issues are identified in the early stages of the design process and rectified accordingly.

An important component of TEA is to ensure that appropriate usability assessment metrics are used during the design and development of e-navigation systems. Hornbaek ([11] 2006, p82) for example developed usability metrics that could be incorporated as part of the usability assessment activity. These are included in Annex 3. ISO9241-210 (2009) identifies three main components that are required to form part of the usability assessment metrics: Effectiveness (accuracy and completeness with which users achieve specified goals); Efficiency (resources expended in relation to the accuracy and completeness with which the users achieve goals); and Satisfaction (user’s perceived acceptability of the system). If these assessment criteria are adopted for e-navigation, another metric ‘safety’ should also be included.

A brief description of each activity within the HCD framework is provided below.

**Activity 1 – Understand and specify context of use**

This activity takes into account the overall environment in which the system will be used. It consists of the users’ characteristics, their goals, tasks, physical environment, social and management environment and other factors that may have an impact on safety and performance of the whole system.

This activity involves identification of the following (ISO/TR18529) [12]:

- user’s tasks;
- user attributes (characteristics pertinent to design such as physical and cultural);
- organisational environment (i.e. stakeholder perspectives, applicable standards, assessment measures, etc.);
- technical environment;
- physical environment (i.e. task environment such as space, lighting, etc.).

There are tools available for describing context of use (e.g. www.usabilitynet.org/tools/context.htm).

The identification of context of use is a "living" activity that is added to, modified, and updated as system development progresses. It provides the foundation for Activity 2 in the HCD framework.

**Activity 2: - Identify user requirements**

User requirements include user needs arising from human-system issues identified in the context of use related to the maritime environment. The objective is to develop a consistent set of user requirements (e.g. to achieving targets for performance, safety, maintenance, functionality, etc.) to reliably address human-system issues [13].

This activity involves the following: (ISO/TR18529) [12]:

- clarification of system goals;
- analysis of stakeholders;
- assessment of health and safety risks;
- system definition;
- generation of requirements;
- establishing “quality in use” objectives.
Activity 3 - Produce and/or develop design solutions to meet user requirements

Based on the first two activities, Activity 3 involves translating mission needs into top-level system functions which defines the operations and events that must be performed in order to meet the system requirements. Functions are then assigned between human and automation by comparing performance capabilities and limitations between humans and technology on a number of parameters (such as accuracy, speed, reliability, response flexibility, and strength). Cost factors and user cognitive and affective support needs are also considered.

This activity involves the following: (ISO/TR18529) [12]:

- allocation of functions;
- production of a task model;
- development of design solutions;
- specification of system and its use;
- development of prototypes;
- development of user training;
- development of in life servicing and user support.

Activity 4: Evaluate the design against criteria

Activity 4 represents the TEA prior to the system being deployed operationally to ensure that the design meets the requirements on particular usability metrics. This TEA activity would most probably involve a ‘process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets specific usability metrics [2] as highlighted in Annex 2 and 3.

This activity involves the following: (ISO/TR18529) [12]:

- specifying the context of evaluation
- evaluation to improve design;
- evaluation against system requirements;
- evaluation against required practice;
- evaluation in use.

Iterative process

Each activity is to be revisited iteratively throughout system development, with feedback between each of the activities used for refinement to meet user and organizational goals. For example, increased definition of the context of use may impact on user requirements or, after initial prototyping and evaluation of a design solution, deficient user-requirements may be identified and amended.
Figure 1: E-navigation Human Centred Design Framework (Draft)

- Introduce and operate system
- Concept development
  - Activity 1: Understand and specify context of use
  - TEA
- Activity 2: Identify user requirements
  - TEA
- Planning & Analysis
- Design
  - Activity 3: Produce and/or develop design solutions to meet user requirements
  - TEA
- Integration and testing
  - Activity 4: Evaluate the design against (assessment) criteria
  - TEA

TEA — Testing, Evaluation and Assessment
10. References


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<td>Collection of quantifiable performance measurements in order to understand the impacts of usability issues.</td>
<td>Any</td>
</tr>
<tr>
<td>Critical incident analysis</td>
<td>Y (gap analysis) 1</td>
<td>Systematic collection of specific events (positive or negative).</td>
<td>Activity 1</td>
</tr>
<tr>
<td>Questionnaires</td>
<td>Y(1)</td>
<td>Indirect evaluation methods which gather users’ opinions about the user interface in predefined questionnaires.</td>
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Annex 3: Some examples usability assessment criteria

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</tr>
<tr>
<td>Completeness</td>
<td>The extent to which tasks are solved.</td>
</tr>
<tr>
<td>Quality of Outcome</td>
<td>Extensive measure of the outcome of tasks.</td>
</tr>
<tr>
<td>Measure of satisfaction</td>
<td>E.g. how satisfied were you with the use of the search engine?</td>
</tr>
<tr>
<td>Preference</td>
<td>Give users a choice of interfaces and see which they choose.</td>
</tr>
<tr>
<td>Content Dependent Questions</td>
<td>Users’ satisfaction with specific features.</td>
</tr>
<tr>
<td>Satisfaction before use</td>
<td>Do users think they will be able to use the system?</td>
</tr>
<tr>
<td>Satisfaction during use</td>
<td>Satisfaction obtained while tasks are solved. Can be measured with heart rate variability,</td>
</tr>
<tr>
<td></td>
<td>reflex responses and quantifications of negative comments.</td>
</tr>
<tr>
<td>Attitude towards content</td>
<td>How appealing was the subject matter?</td>
</tr>
<tr>
<td>Perceptions on outcome</td>
<td>Users’ sense of success.</td>
</tr>
<tr>
<td>Other measures of satisfaction</td>
<td>Easy to make mistakes, the display is cluttered, meaningfulness.</td>
</tr>
<tr>
<td>Measuring specific attitudes</td>
<td>Annoyance, anxiety, complexity control, engagement, flexibility, fun, intuitive, learnability, liking, physical discomfort, want to use again</td>
</tr>
</tbody>
</table>