e-Navigation and the Human Element

D. Patraiko, FNI & P. Wake, FNI
The Nautical Institute, London, UK

A. Weintrit, FNI, FRIN
Gdynia Maritime University, Gdynia, Poland & Polish Branch of the Nautical Institute

ABSTRACT: e-Navigation is an IMO initiative defined as "the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard 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". IMO has dictated that e-Navigation should be 'User Need' led and take into account the Human Element. This paper will explore some of the Human Element issues within e-Navigation and stress that for enhancement of safety, security and environmental protection, the decision maker must be supported not only by the technology, but importantly with effective procedures and training.

1 BACKGROUND

The concept of e-Navigation was first introduced to the IMO in 2006 at the 81st session of the Maritime Safety Committee (MSC 81 – May 06) at which time the committee was requested to adopt this vast new project as a work programme based on a compelling need which remains as:

There is a clear and compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimized for good decision making in order to make maritime navigation and communications more reliable and user friendly. The overall goal is to improve safety of navigation and to reduce errors. However, 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.

At that time, the Secretary General of the IMO, Efthimios Mitropoulos who has become a champion of the e-Navigation concept warned that the role of the mariner must not be relegated to that of a 'monitor' and urged the Committee to take into account the Human Element and all it's frailty when developing the various aspects of e-Navigation.

To support this expectation, it was made clear from the beginning that e-Navigation should be 'user needs led' rather than led by technologists or regulators.

During the period of 2006-2008, the IMO e-Navigation Correspondence Group (CG) supported by organisations such as the IALA and The Nautical Institute carried out an international exercise to identify these needs. Potential users of e-Navigation both afloat and ashore were contacted and asked to identify what their needs were in terms of harmonised collection, harmonised integration, harmonised exchange, harmonised presentation and harmonised analysis of maritime information onboard and ashore by electronic means.

It is worth noting that this may have been the largest user needs analysis ever conducted in the maritime industry, and many lessons should be learned from this experience. In particular, most end users are not practiced in articulating their needs well, and tended to identify what they had and what they liked. This then required a good deal of analysis to distil the 'need' from the 'like'.

2 USER NEEDS

The 'User Needs Analysis' as conducted through the IMO e-Navigation CG examined hundreds of feedback forms from around the world and categorised these into needs of the generic SOLAS class ship users and the needs of generic shore authorities.

Much effort was put into analysing the needs from descriptions of what was already in use, and quite importantly, to take out any reference to existing technologies. For example there is a need to identify and track a target in order to prevent a colli-

sion, rather than there being a 'need' for a Radar with ARPA (although it is recognised from a practical point of view that in the short term Radar will certainly be a key tool within the e-Navigation concept).

From these two analyses of shipboard and shore-side needs, it was established that there were common 'high level' needs and these were consolidated, presented, and ultimately accepted by the IMO (MSC 85 – Dec 08) as the basis of an e-Navigation strategy.

These consolidated user needs are reproduced here with *italic* text used to emphasise some of the major Human Element issues defined within e-Navigation.

2.1 *Common Maritime Information/Data Structure*

Mariners require information pertaining to the planning and execution of voyages, the assessment of navigation risk and compliance with regulation. This information should be accessible from a single integrated system. Shore users require information pertaining to their maritime domain, including static and dynamic information on vessels and their voyages. This information should be provided in an internationally agreed common data structure. Such a data structure is essential for the sharing of information amongst shore authorities on a regional and international basis.

2.2 *Automated and Standardized Reporting Functions*

E-navigation should provide automated and standardized reporting functions for optimal communication of ship and voyage information. This includes safety-related information that is transmitted ashore, sent from shore to shipborne users and information pertaining to security and environmental protection to be communicated amongst all users. Reporting requirements should be automated or pre-prepared to the extent possible both in terms of content and communications technology. Information exchange should be harmonized and simplified to reduce reporting requirements. It is recognized that security, legal and commercial issues will have to be considered in addressing communications needs.

2.3 *Effective and Robust Communications*

A clear need was expressed for there to be an effective and robust means of communications for ship and shore users. Shore-based users require an effective means of communicating with vessels to facilitate safety, security and environmental protection and to provide operational information. *To be effective, communication with and between vessels*

should make best use of audio/visual aids and standard phrases to minimize linguistic challenges and distractions to operators.

2.4 *Human Centred Presentation Needs*

Navigation displays should be designed to *clearly indicate risk and to optimize support for decision making*. There is a need for an integrated "alert management system" as contained in the revised recommendation on performance standards for Integrated Navigation Systems (INS) (resolution MSC 252(83)). Consideration should be given to the use of decision support systems that *offer suggested responses to certain alerts*, and the integration of navigation alerts on board ships within a whole ship alert management system. Users require uniform and consistent presentations and operation functionality to *enhance the effectiveness of internationally standardized training*, certification and familiarization. The concept of S-Mode[1] has been widely supported as an application on board ship during the work of the Correspondence Group. Shore users require displays that are fully flexible supporting both a Common Operating Picture (COP) and a User Defined Operating Picture (UDOP) with layered and/or tabulated displays. *All displays should be designed to limit the possibility of confusion and misinterpretation when sharing safety-related information. E-navigation systems should be designed to engage and motivate the user while managing workload.*

2.5 *Human Machine Interface*

As electronic systems take on a greater role, facilities need to be developed for the capture and presentation of information from visual observations, as well as user knowledge and experience. The presentation of information for all users should be *designed to reduce "single person errors" and enhance team operations. There is a clear need for the application of ergonomic principles both in the physical layout of equipment and in the use of light, colours, symbology and language.*

2.6 *Data and System Integrity*

E-navigation systems should be resilient and take into account issues of data validity, plausibility and integrity for the systems to be robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems, should be considered.

---

[1]   S-Mode is the proposed functionality for shipborne navigation displays using a standard, default presentation, menu system and interface.
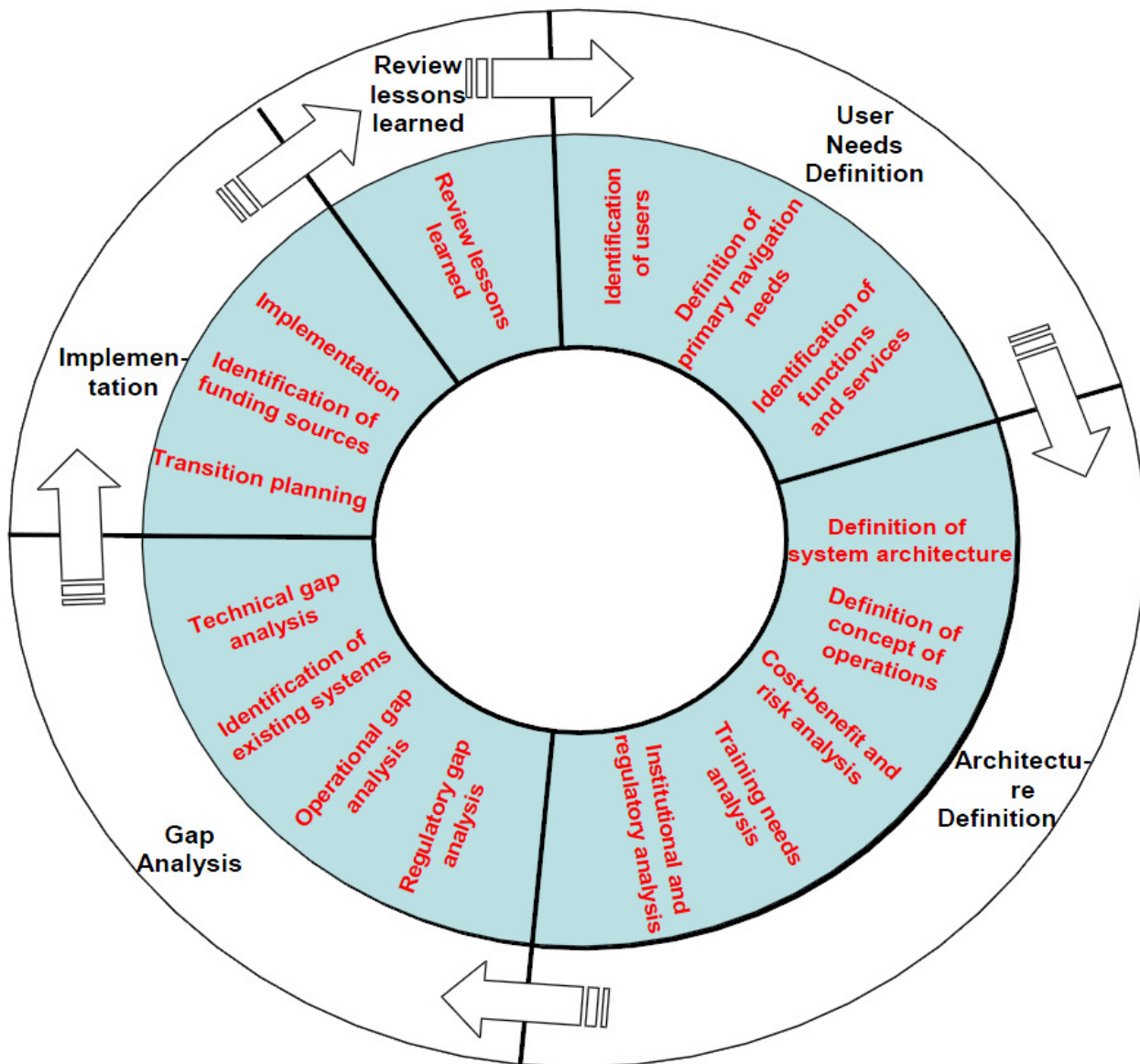
Figure 1. Potential components of an e-Navigation implementation plan [IMO NAV 54/WP.6 2008]

2.7 Analysis

E-navigation systems should *support good decision making, improve performance and prevent single person error*. To do so, shipboard systems should include analysis functions that support the user in complying with regulations, voyage planning, risk assessment, and avoiding collisions and groundings including the calculation of Under Keel Clearance (UKC) and air draughts. Shore-based systems should support environmental impact analysis, forward planning of vessel movements, hazard/risk assessment, reporting indicators and incident prevention.

Consideration should also be given to the use of analysis for incident response and recovery, risk assessment and response planning, environment protection measures, incident detection and prevention, risk mitigation, preparedness, resource (e.g., asset) management and communication.

2.8 Implementation Issues

Best practices, training and familiarization relating to aspects of e-navigation for all users should be effective and established in advance of technical implementation. The use of simulation to establish training needs and assess its effectiveness is endorsed. E-navigation should as far as practical be compatible forwards and backwards and support integration with equipment and systems made mandatory under international and national carriage requirements and performance standards. The highest level of interoperability between e-navigation and external systems should be sought where practicable.

It is clear from these 'user needs' that there is a major emphasis on supporting the decision making process, not only by better technology, but through the establishment of best practices for the use of such technology and the training needs that apply to both the technology and the procedures.

It should also be noted that needs such as *"E-navigation systems should be designed to engage and motivate the user while managing workload"* are easier said than done and will require a tremendous amount of research and testing to achieve.

3 S-MODE

In the description of 'Human Centred Presentation Needs' it is stated that "Users require uniform and consistent presentations and operation functionality to enhance the effectiveness of internationally standardized training, certification and familiarization."

The Nautical Institute through consultation with its members has proposed a concept called S-Mode to address this need for the shipboard users.

The concept calls for all navigation systems in the future to have a standard 'S-Mode' switch, that when activated defaults to a standard display (e.g. head-up display, relative vectors, etc.) that can then be fully manipulated through a standard menu system where functions (such as for changing range, aspect, or using EBL/VRM, parallel indexing, …) would all be standardised, and the input interface with the systems (perhaps track ball, joystick or keyboard) would be standard. The concept for S-Mode is to create standard features. S-Mode is not envisaged as a simplified or restricted display mode, but instead would offer a high degree of functionality. However, the use of these functions would all be standard and anyone trained in the use of S-Mode would therefore be competent and confident to make the best use of navigation systems on any ship so equipped.

S-Mode may also incorporate provisions for the use of personal settings that may be stored within the system or on a personal memory device that would allow a pilot or mariner to rapidly configure the system to their preferred settings, overlay custom display features or give access to specialist information.

S-Mode would not preclude the use of other navigation features that could be provided by a manufacturer. These may be designed to take advantage of cutting edge technology, advanced programming or innovative presentation options that would be operated outside of S-Mode.

It is the intention of The Nautical Institute to secure funding to implement a phased project approach to the development of S-Mode. The Nautical Institute considers it will be necessary for: the user needs of mariners to be defined; to work with industry to create mock-up variations; and then to test these variations using simulation and other techniques with representative bridge teams. After thorough testing and evaluation, the system and training requirements would be put forward to the International Maritime Organization for consideration. Further information about S-Mode is contained in (IMO NAV 54/13/1, 2008) which is a copy of the submission of the S-Mode proposal to the IMO Sub-Committee on Safety of Navigation July 08 (NAV 54).

4 PROFESSIONAL RELATIONSHIPS

One of the fundamental premises of e-Navigation is to create a 'wider area' navigation team that will facilitate better decision making by the sharing of information between ship's navigation team and all the shoreside support organisations. This is of course a valid objective, and if managed properly will create a more effective navigation team that minimises the risk of single person errors.

The maritime industry has of course spent a lot of effort during the past few decades learning how to implement effective teams and this has resulted in much discussion of effective Master/Pilot relationships; Bridge Team Management (BRM) training; and shipboard resource training. From this experience comes recognition that for teams to work effectively, it is absolutely essential that there be a common platform for communication (including language and terminology) and that there needs to be mutual professional respect between team members.

As e-Navigation develops and greater communication is established between mariners and shore authorities, will we have addressed these issues? At present, within a port that utilises VTS, it is usually the Pilot who acts as a communicator between the VTS staff and the shipboard staff. The Pilot has an established working relationship with the VTS staff, and while onboard, can make best use of interpersonal skills to establish a working relationship with the ship's crew (in an ideal situation). However how can we ensure that without this interpersonal interaction, the wide area navigation team will work well together?

Ongoing research by The Nautical Institute indicates that in order to communicate effectively and foster professional respect, clear procedures may have to be established possibly based on a far greater use of the IMO's Standard Maritime Communication Phrases (SMCP) and for training exercises to be conducted focusing on the various stakeholders within this evolving relationship. Even without the concept of e-Navigation, such issues will need to be addressed as the establishment of 'coastal surveillance' becomes more common and IALA develops the concept of Vessel Traffic Management (VTM) based on the management of traffic outside traditional VTS areas.

5 FURTHER RESEARCH

The success of e-Navigation will rely heavily upon the proper application of the Human Element throughout its development and implementation. The Nautical Institute believes that there are some major Human Element aspects that deserve further development and research to be done on an international basis to support the IMO's e-Navigation concept. These can be summarised as:

− Proper balance of information levels and workload on mariners and shore based operators.
− Effective display options to support good decision making (including the development of S-Mode).
− Tools and procedures for reducing 'rouge behaviour' or complacency and keeping the operator actively engaged in the process of safe navigation.
− Methods and procedures for reducing 'single person errors'.
− Optimum use of 'decision support systems' including the best use of alarms and alerts.
− Effective procedures for ship/shore communication and teamwork.
− Supporting decision making capabilities of individuals through self-esteem and confidence building.
− Ensuring that all technical developments within the concept of e-Navigation are supported by effective procedures and training.
− Developing effective tools for capturing and analysing user needs within the maritime industry.

It is recognised that much of this research and testing will best be done through using scenarios representing all appropriate stakeholders, and that the use of simulation may be a highly effective tool for testing, documenting and ultimately training for such aspects of e-Navigation.

6 CONCLUSION

e-Navigation is a broad concept that is aimed at enhancing navigation safety, security and the protection of the marine environment through the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means.

It is envisioned that e-Navigation will be a 'living' concept that will evolve and adapt over a long time scale to support this objective. During this time information will change, technologies will change, political and commercial objectives will change, and tasks will change. However it is unlikely that the need for safe and efficient seaborne transport will change significantly.

It is also certain that the safe and efficient transport will continue to rely on good decisions being made on an increasingly constant and reliable basis. Some decisions may be made with increased dependence on technology, but at some level we will always rely on good human decisions being made and therefore every effort needs to be made to apply an understanding of the Human Element at all stages, of design, development, implementation and operation of e-Navigation.

The Nautical Institute as the leading international body for maritime professionals will continue to use the resources of its members, branches, officers and staff to promote the effective application of the Human Element for e-Navigation and other industry developments, and invites all maritime professionals to join in this critical effort.

REFERENCES

Basker S. 2005. E-Navigation: The way ahead for the maritime sector. Trinity House, London, September.

Bibik L., Krolikowski A., Czaplewski K., Duda D. 2007. Vision of the Decision Support Model on Board of the Vessel with Use of the Shore Based IT Tools. *Advances in Marine Navigation and Safety of Sea Transportation*, *Chapter 10: E-Navigation*. TransNav'2007 Monograph edited by A. Weintrit. Gdynia Maritime University and the Nautical Institute, Gdynia.

EU MARINE STRATEGY. 2007. An Integrated Maritime Policy for the European Union. SEC(2007) 1278, COM(2007) 575, October.

Graff J. 2007. The Role of Operational Ocean Forecasting in e-Navigation. *Advances in Marine Navigation and Safety of Sea Transportation*, *Chapter 10: E-Navigation*. TransNav' 2007 Monograph edited by A. Weintrit. Gdynia Maritime University and the Nautical Institute, Gdynia.

IALA 2007a. The IALA Definition and Vision for E-Navigation. E-Nav 2-output 11, March.

IALA 2007b. E-Navigation, Frequently Asked Questions. IALA e-Nav OPS WG MTG WP1, July.

IMO MSC 81/23/10 2005. Work Programme. Development of an e-Navigation strategy. Submitted by Japan, Marshall Islands, the Netherlands, Norway, Singapore, the United Kingdom and the United States, International Maritime Organization, London, 19 December.

IMO NAV 52/17/4 2006. Any other business. An approach to E-Navigation, submitted by Japan. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 12 May.

IMO NAV 53/13 2007. Development of an E-Navigation Strategy. Report of the Correspondence Group on e-navigation, submitted by the United Kingdom. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 20 April.

IMO NAV 53/13/1 2007. Development of an E-Navigation Strategy. A method for identifying essential functions of shipboard system under the e-Navigation strategy, submitted by Japan. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 18 May.

IMO NAV 53/13/2 2007. Development of an E-Navigation Strategy. Position-Fixing for E-Navigation, submitted by the United Kingdom. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 18 May.

IMO NAV 53/13/3 2007. Development of an E-Navigation Strategy. IALA and e-navigation, submitted by the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA). Sub-Committee on Safety of Navigation, International Maritime Organization, London, 18 May.

IMO NAV 53/13/4 2007. Development of an E-Navigation Strategy. Display of Automatic Identification System (AIS) as an Aid to Navigation (AtoN), submitted by the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA). Sub-Committee on Safety of Navigation, International Maritime Organization, London, 18 May.

IMO NAV 54/13 2008. Development of an E-Navigation Strategy. Report of the Correspondence Group on e-navigation, submitted by the United Kingdom. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 28 March.

IMO NAV 54/13/1 2008. Development of an E-Navigation Strategy. The concept of S-Mode for onboard navigation displays, submitted by the International Federation Of Shipmasters' Associations (IFSMA). Sub-Committee on Safety of Navigation, International Maritime Organization, London, 24 April.

IMO NAV 54/13/3 2008. Development of an E-Navigation Strategy. IALA and e-Navigation, submitted by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Sub-Committee on Safety of Navigation, International Maritime Organization, London, 25 April.

IMO NAV 54/WP.6 2008. Development of an E-Navigation Strategy. Report of the Working Group. Sub-Committee on Safety of Navigation, International Maritime Organization, London, 2 July.

Korcz K. 2007. GMDSS as a Data Communication Network for e-Navigation. *Advances in Marine Navigation and Safety of Sea Transportation, Chapter 10: E-Navigation*. TransNav'2007 Monograph edited by A. Weintrit. Gdynia Maritime University and the Nautical Institute, Gdynia.

Mitropoulos E. 2007. E--navigation: a global resource. Seaways, The International Journal of the Nautical Institute, March.

Patraiko D. 2007a. Introducing the e-navigation revolution. *Seaways*, The International Journal of the Nautical Institute, March.

Patraiko D. 2007b. The Development of e-Navigation. *Advances in Marine Navigation and Safety of Sea Transportation, Chapter 10: E-Navigation.* TransNav'2007 Monograph edited by A. Weintrit. Gdynia Maritime University and the Nautical Institute, Gdynia.

Patraiko D. 2007c. The shipborne E-Navigation System – The Mariner's View and the need for S-Mode. *eNavigation 07 - Electronic Navigation and the Application of Information Technology to Short Sea Shipping and Waterborne Commerce*. November.

Patraiko D. 2008a. Implementing eNavigation: Defining User Needs within the context of an overall strategy for implementation. *eNavigation 08 - The role of e-Navigation in waterborne commerce and coastal zone management*. Seattle, November.

Patraiko D. 2008b. e-Navigation - A User Needs Led Strategy. *Human Element Conference*. Delhi, December.

Pillich, B. 2007. Developing e-Navigation, the early stages. U.S., Hydro Conference, 2007.

Weintrit A. 2006. Navitronics and Nautomatics. Advances in Transport Systems Telematics. Section III: Systems in Maritime Transport. Monograph edited by J. Mikulski, Faculty of Transport, Silesian University of Technology, Katowice.

Weintrit A., Wawruch R. 2006. Future of Maritime Navigation, E-Navigation Concept. *Proceedings of 10th International Conference "Computer Systems Aided Science, Industry and Transport" TransComp'2006*, Zakopane, Poland, December.

Weintrit A., Wawruch R., Specht C., Gucma L., Pietrzykowski Z. 2007a. Polish Approach to e-Navigation Concept. *Advances in Marine Navigation and Safety of Sea Transportation, Chapter 10: E-Navigation*. TransNav'2007 Monograph edited by A. Weintrit. Gdynia Maritime University and the Nautical Institute, Gdynia.