Effectiveness and Ergonomic of Integrated Navigation System

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Ergonomics increases the efficiency of people and device interaction. Nowadays, modern navigation bridges are designed in accordance with the requirements of navigators, designers and shipowners, production costs etc. The bridge design, various layouts, instrument arrangements and their capacities etc. have not been fully regulated by the SOLAS convention. The Convention regulates manufacturers' requirements which refer to accuracy, device sensitivity etc. However, factors that are important for ergonomics, and time required for familiarization and exploitation of the device are left to shipbuilders and charterers to decide. In this paper, authors are analyzing the ergonomics of the integrated navigation bridge - INS.

KEY WORDS

~ Integrated navigation system
~ Effectiveness, ergonomics
~ Navigation safety
~ Navigation bridge

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1. INTRODUCTION

Ergonomics is the engineering science whose aim is to study people and their behaviour. It determines the efficacy of interaction between machines and the people who use them. Ergonomics examines the ways of work quality improvement, increase in production, reduction of work related-injuries, professional diseases etc. Therefore, ergonomics increases the safety of object usage. It is related to the construction and technical projects as well as design (Bielic, 2004; Peric, 2004).

These days shipbuilding is focused on finding technical and technological solutions that would increase the cost-effectiveness of vessels, which is related to the profits they make.

Profits are possible by enlarging hold space, increasing the speed of cargo transport, reduction of crew, employment of cheap labour, reduction in maintenance costs, vessel registration under flags of convenience etc. The crew reduction has been a trend followed by current solutions for watch keeping, supervision, cargo handling, administration work etc.

Integrated Navigation System - INS implies the connection of navigation equipment and programme packages intended for adjustment of all required navigation parameters. It consists of various navigation components connected to the main computer network whose aim is adjustment and supervision of the system and provision of information relevant for navigation (Bowditch, 2002).

2. INS CONSTRUCTION

The bridge construction mostly depends on the shipowners' requirements i.e. the purpose of the vessel, as well as on modern trends in naval architecture. The construction and design should provide a good layout for the navigator. The navigating bridge must fulfil the requirements of the "International Convention for the Safety of Life at Sea"-SOLAS.

The SOLAS regulation for vessels over 45 m in length was defined by the 1998 rule III/3.12. The regulation governs the bridge construction and design requirements. The vessels constructed for special purpose with different design and construction of the navigating bridge must have a special approval for such exceptions by the Register (Rules, 2001).

The navigating bridge equipment on modern merchant vessels has to be approved in compliance with the standards and rules of SOLAS.

The watch officer on duty is often too busy with navigating his vessel. One of the reasons is that he receives relatively numerous data from the systems of vessel and her environment (Figure 1).

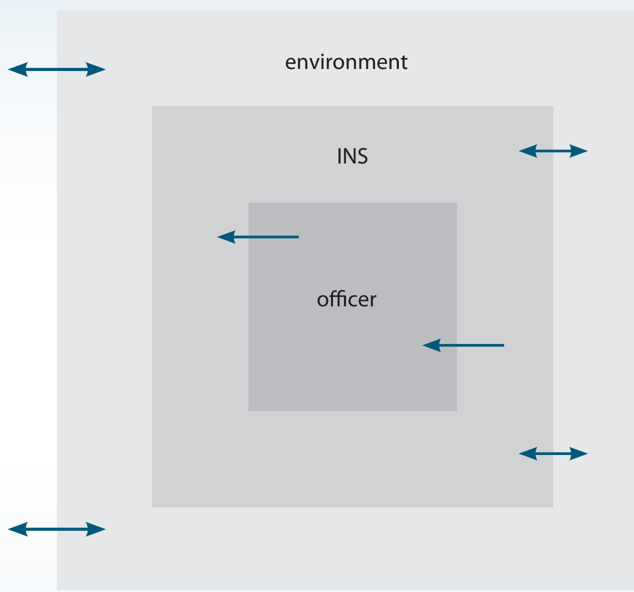

Figure 1.
Schematic display of data flow.
Source: authors.

The amount of data depends on the current state of the vessel (whether she is loaded or unloaded, preparing for survey etc.), and her environment such as administration, intensity of traffic, presence of dangers to navigation and the like. On modern bridge there are numerous electronic aids which provide a great amount of data in relatively short period of time. Therefore, it is to be expected that such large amount of data would require time to be processed into information which would assist the officer of the watch in making the right decision. Unnecessary data supply results in officer's distraction and fatigue. For that reason, the data need to be processed before reaching the operator.

Very sophisticated computer models with high capacity and speed are used for data processing. Their task is processing, display and printing of the data that need to be saved. In this way the time needed for data processing is reduced and information is supplied in less time. The time saved in data processing and their selections allow the officer to be more focused on decision making.

3. INS ROLE

The basic aim of the integrated navigation system (Figure 2) is to secure the added value to the functions and information required by the officer on navigation duty for planning, supervision and control of the vessel underway.

INS assists the safety of navigation. Its role is to evaluate the inlet data from various independent sensors, to fully supervise and to supply the information for safe navigation.

4. INS ERGONOMICS

The bridge E ergonomics can be expressed functionally as a dependant variable on navigation safety (S). The ergonomics will prove successful if all instruments are adjusted to the officer's needs in all possible situations. The use of ergonomically solved INS should significantly reduce the risk of human errors in ship handling (H):

$$f(S)=\frac{f(E)}{f(H)} \tag{1}$$

The INS equipment design should not disturb the vessel layout. Therefore, it is preferred that the counters with electronic aids are arranged so as to allow the access to all glass surfaces of the bridge. The size of the consoles should be adequate to improve significantly the access to all other bridge consoles, windows, wings etc.

Electronic navigation aids should be designed in compliance with the norms. It is suggested that the special norms be adopted by SOLAS. These norms would propose the construction of several types of bridges which would be ergonomically acceptable for various types of vessels. The equipment used on the bridge would be prescribed and unified (Figure 3). Special STCW training should be offered to enable navigators to attend specialized courses for a particular bridge type. Such specialization would be recognized by the issuance of certificates and it would certainly have effect on reduction of time needed for getting familiar with the bridge (Cockpit5You).

Also, there is a proposal for unification of the main navigation instrument menus. Their use should not be too demanding. Simplification of functional keys is especially useful for instrument tuning. These often contain settings which are not used in navigation. Many functional keys may cause distress

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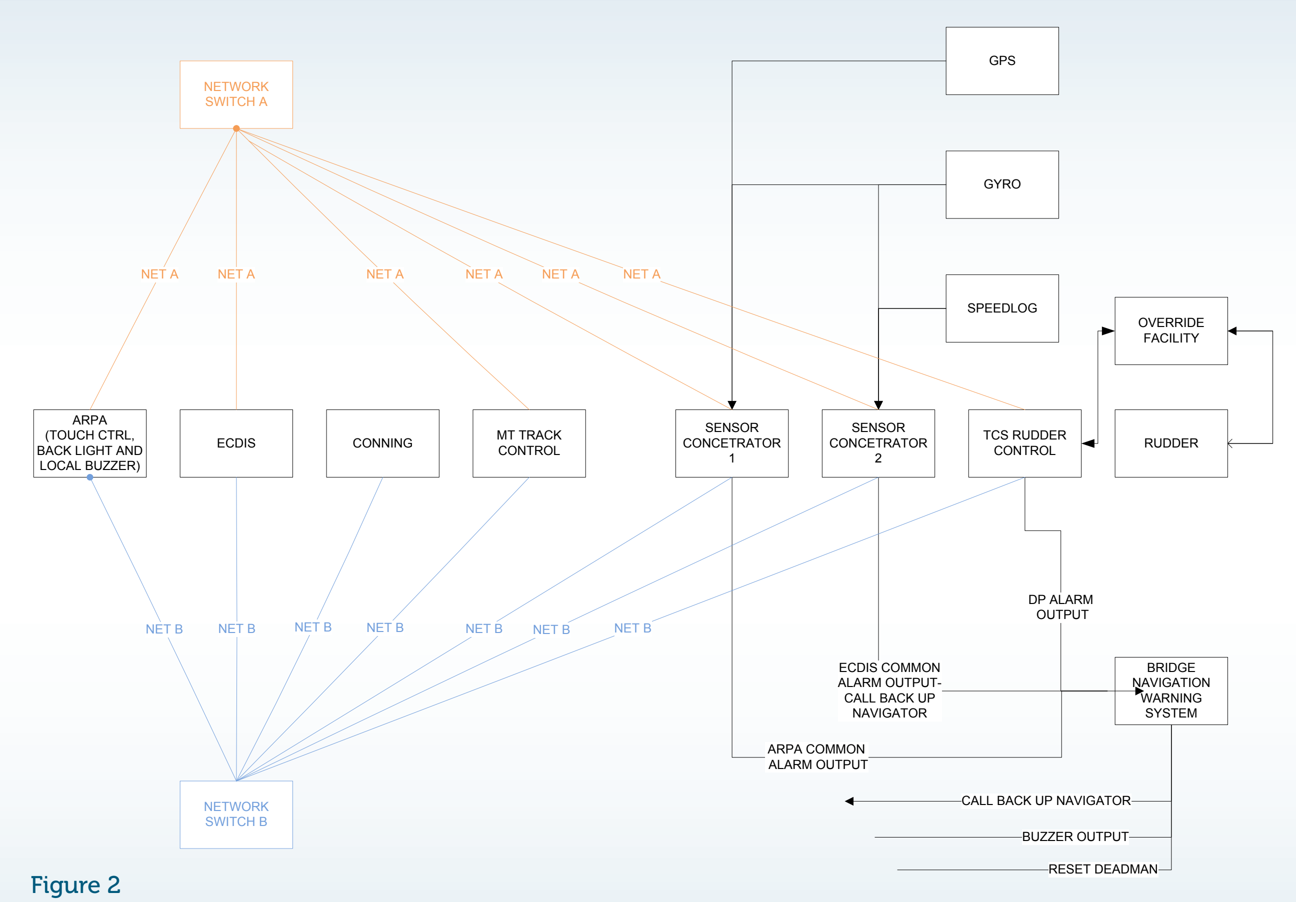

Figure 2

Schematic INS display.

Source: authors.

situations and navigator's error if improperly used. Therefore, the access to such options should be limited.

A proposal for instrument layout to be regulated by SOLAS is also considered. The quality as regards the period of exploitation could be subject to different prices, but the outlook and usage methods should be unified by all manufacturers. This would enable competition amongst producers with regard to the price, reliability and quality but the outlook would be unified as well as the instrument options that are mot used in navigation.

Warning alarms on the bridge should use various types of sound warnings. Having the alarm with voice message explaining the cause of alarm ought to be considered. Such demand becomes important if alarm is activated at the critical moment such as the manoeuvre, anchoring, sailing in bad weather, collision avoidance etc. In this way the time for alarm cancellation is reduced and the time saved is used for decision making which adds to the quality of the decision.

5. INS EFFECTIVENESS

The error in choosing the right information can lead to the wrong decision that can finally cause distress. Integrated navigation system has to be able to:

- Choose the relevant data;
- Process data and collect information;
- Give warning regarding the importance of information and system failure;
- Supply the navigator with quality information and more time for decision making.

The configuration of integrated navigation system depends on the needs and finances of the user. It can vary in simplicity and in quality. The reliability of the system can be expressed numerically by the probability of its operation without errors or failures. Therefore, the probability of the expected functioning of the system is the measure of its reliability. Such systems demand

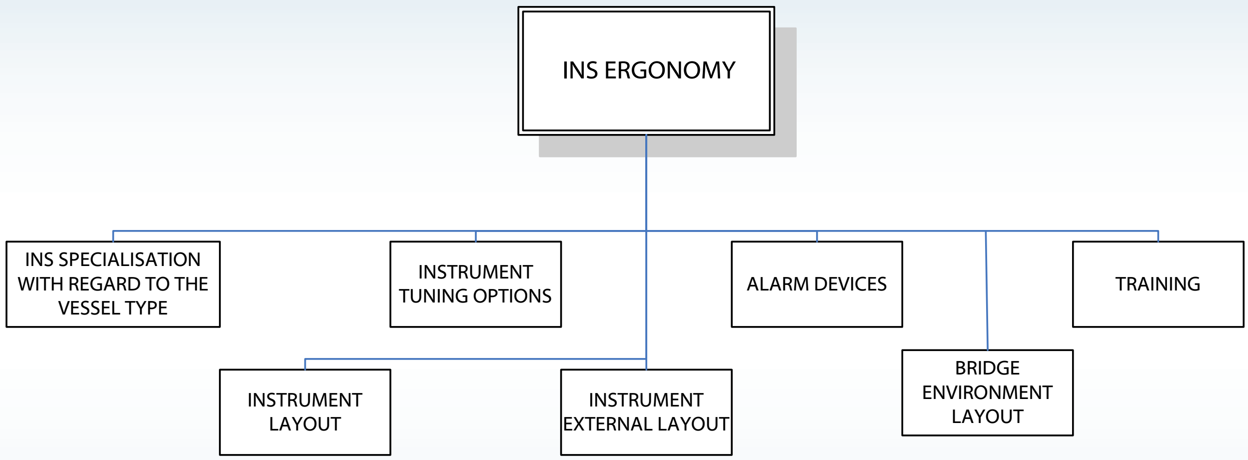

Figure 3.
Schematic display of INS ergonomics usage.
Source: authors.

high reliability which can be accomplished in two ways by:

- Choosing components (Ik)
- System execution (Is) (Balic, 2010).

Choosing components affects the reliability of the component itself, as well as the entire system. Reliability is the feature which depends on various factors such as: sensitivity, accuracy of data processing, number of possible errors, number of disturbances and other, as prescribed by the SOLAS Convention. The reliability of the system is guaranteed by the manufacturer. If approved by the SOLAS Convention, they can be used onboard.

Integrated INS component prices are sometimes three times higher than the conventional ones. Their reliability has been assessed to 100 times better than the one of conventional devices (Balic, 2010). It could be said that the choice of components depends on the price (PR), quality (C) and adaptability of the system (AS):

$$Ik\ I=f(PR,C,AS) \quad (2)$$

The price of components is conditioned by the market, i.e. the manufacturer. The same could be said about the quality. These two values are usually proportional to each other.

The system execution (Is) demands doubling and tripling of the number of devices in order to ensure satisfactory INS reliability. Thus it is important for Is to be larger so as to have better performances of INS. Actually, in order to increase the reliability of Is, individual components of Is system have parallel connections so that the failure of the first subsystem automatically activates the other subsystem.

As the navigation instruments are highly reliable, the regulations rarely require more than to duplicate components. The most important factor in the development of new solutions is the extended use of the latest IT solutions. The execution of the system should be such that it has as few failures as possible i.e. that the system is as reliable as it possibly could be. When the failure rate is closer to zero, then the reliability is closer to one. By the increase of the number of failures, reliability is closer to zero. Then the failure density function f (t) would be as in Figure 4.

Effectiveness of the system is limited by its usage. The main limitation regards the relation of effectiveness and efficiency of the system i.e. cost-effectiveness of the system.

In Table 1, there is a hypothetical display of the reliability coefficient value of individual devices in the integrated navigation system (A-F), as well as the reliability of the operator (O).

The error of the operator is an unknown and it is designated by „x". x varies depending on the factors which affect the operator such as: knowledge, training, fatigue, omission etc. The probability of error occurrence in the device from A to F is designated by P (x_A) do P (x_F).

a_1 = knowledge x_A error occurrence in device A,
a_2 = training x_B error occurrence in device B,
a_3 = fatigue x_C error occurrence in device C,
a_4 = omission x_D error occurrence in device D,
a_n = some other factor,
x_F = error occurrence in device F.

As it is matter of conditioned probability in several devices which interact with the operator, probability of error in device A,

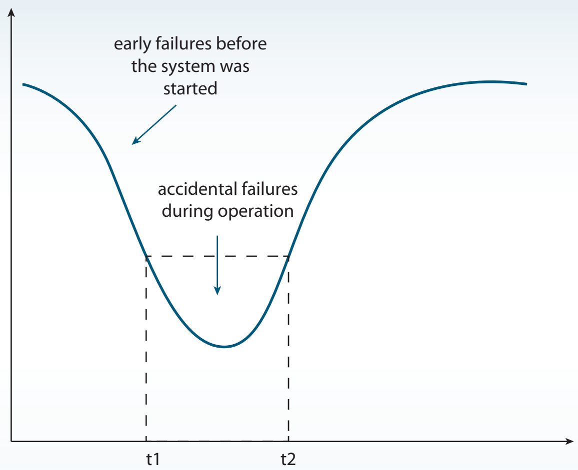

Figure 4.
Hypothetical f (t) INS display.
Source: authors.

or at least one error due to the factors which affect the operator, can be calculated by the following formulae:

$$P(x_A)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (2)$$

Probability of error in device B or at least one error due to the factors that affect the operator:

$$P(x_B)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (3)$$

Probability of error in device C or at least one error due to the factors that affect the operator:

$$P(x_C)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (4)$$

Probability of error in device D or at least one error due to the factors that affect the operator:

$$P(x_D)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (5)$$

Table 1.
Reliability of individual system devices and INS operator.

A = 2%	B = 1%	C = 1%
D = 2.5%	E = 1%	F = 1.7%
O = x		

Probability of error in the device E or at least one error due to the factors that affect the operator:

$$P(x_E)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (6)$$

Probability of error in device F or at least one error due to the factors that affect the operator:

$$P(x_F)=1-(1-P(a_1))(1-P(a_2)).....(1-P(a_n)) \quad (7)$$

Probability of at least one error has been shown by the following formulae (8):

$$P(x)=1-(1-P(x_A))(1-P(x_B)).....(1-P(x_n)) \quad (8)$$

6. CONCLUSIONS

Modern navigating bridge is the central place for the vessel control. Apart from the navigation aids, on the bridge, there are also devices for cargo space control, firefighting system, ballast control system, communication system etc. The concept of the navigating bridge is important and it is subservient to the officer. The navigating bridge should be user friendly in a way that it does not lose any of its quality and functionality. Therefore, it is important to apply the ergonomic principles by choosing the most appropriate components. The component design should be regulated by SOLAS. INS should fulfil the SOLAS requirements regarding its quality, longevity, functionality, reliability, sensitivity, precision etc. Finally, according to everything aforementioned, a special training should be prescribed for each type of INS.

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