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A potential of reducing the risk of ship casualties by 50%

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Abstract

From statistics we can read that about 50% of all ship casualties that occurred over a ten-year period were due to collision, grounding and heavy weather, not only when going by the number of ships or by tonnage, but also when referring to lives lost, oil spilled and claims paid. These plain statistics cannot be denied, and they do not leave much doubt that bridge operation is the area where we find the greatest potential for increasing safety and efficiency in waterborne transport at large.
By evaluation of the casualties, DNV has found it appropriate to differentiate between "Human Errors" and "Situation-caused Errors", where the "Human Errors" stands for approximately 80% of the accidents. If the bridge arrangement is based on functional requirements, very few casualties of the type "Human Errors" should occur, unless negligence or irresponsibility causes them.

Situation-caused errors arise from working conditions affecting the ability of the watch officer or a bridge team to carry out the bridge functions and tasks in an efficient and safe manner. Such conditions may make the bridge personnel lose control of operational situations and thereby become the initial cause of a nautical casualty. If the human operator errs, despite optimum operating conditions, this may be due to the lack of professional qualifications or "less than adequate" quality of personnel personality and attitude). Appropriate knowledge requirements may ensure that qualifications meet the needs, but operator quality is inevitably connected to the selection of personnel.

With the aim to reduce the probability of bridge system failure, DNV Rules for Nautical Safety regulate the following areas:

- **Design of workplace,** based on analyses of functions to be performed under various operating conditions and the technical aids to be installed
- **Bridge working environment,** based on factors affecting the performance of human operations
- **Range of instrumentation,** based on information needs and efficient performance of navigational tasks
- **Equipment performance and reliability,** based on IMO requirements and the suitability required for safety of navigation under various environmental conditions
- **Man/machine interface,** based on international standards and ergonomic principles
- **Qualifications,** based on competence required for mastering integrated and automatic systems installed on the bridge
- **Operating procedures,** based on the need to make the bridge system function under different operating conditions

1 The challenge is what you don't see!

1.1 Safety first

From a safety point of view, a bridge system requiring only one person for satisfactory operation is by far the best choice. Therefore, the bridge system shall be designed for one-man operation during all normal conditions. In addition it shall be arranged and equipped for efficient two-man operation to manage those operating conditions that require two navigators.

1.2 The overall view

The overall view from the inside of the bridge is imperative for safe navigation. The configuration of the bridge as well as the layout is affected by the view required from inside the bridge. This makes the view and the required field of vision the starting point when designing the bridge.

1.3 The workstation concept

Another main issue with regard to bridge design is the workstation concept. The workstation concept enables the single watch-keeper to collect all external and internal information and execute the decisions from one place. Workstations should be tailor-made for the functions to be performed. In order to achieve safe

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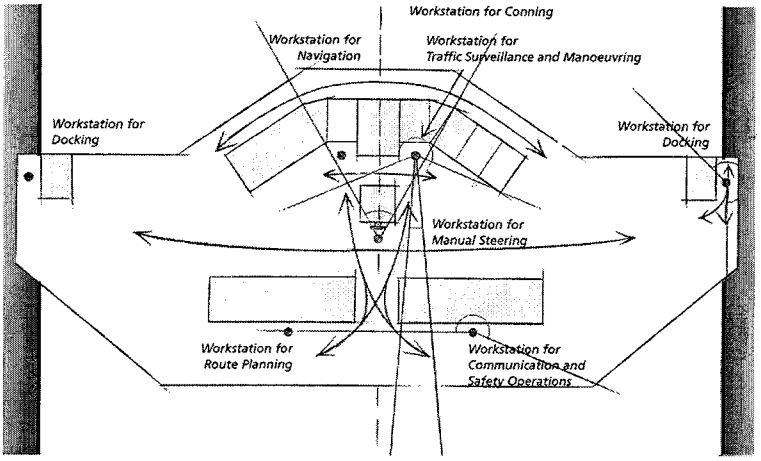
and rational bridge operations, workstations must be provided for the following functions:

- Navigation
- Traffic surveillance and manoeuvring (should include navigation functions if the bridge is to be arranged for one-person control in narrow waters)
- Route planning
- Safety operations (emergency, fire etc.)
- Manual steering
- Docking operations
- Conning (pilots)

In addition to these workstations there may be a need for separate workstations for optional bridge functions like extended communication and monitoring functions.



The sketch shows an example of a bridge design approved by DNV. The red angles are indicating the field of vision from the different workstations. The blue arrows are indicating the availability the navigator has to change between the different workstations. The location of the different workstations is designed to obtain complete control of situation from the different workstations.

1.4 Efficient workstations for the watch officer and bridge team management

The workstations for navigation and traffic surveillance and manoeuvring shall be located in close enough proximity to be operated by one person in ocean areas and along open coastlines under normal operating conditions. The watch

officer shall have easy access to all the information and controls required for carrying out his tasks within the area of these workstations. At the same time, the area must be logically equipped and spacious enough to allow two navigators to work in close co-operation in pilotage waters and when the workload exceeds the capacity of one person. These workstations must enable the navigator to:

- Determine and plot the ship's position, course, track and speed
- Analyse the traffic situation
- Decide on collision-avoidance manoeuvres
- Alter course
- Change speed
- Effect internal and external communications related to navigation and manoeuvring
- Monitor time, course, speed, track, propeller revolutions, pitch indicator and rudder order and angle.

1.4.1 "The command centre"

The workstation, which enables traffic surveillance and manoeuvring of the ship, is considered the command workstation. From this workstation it must be possible to monitor all navigation related alarm conditions on the bridge. To facilitate this, the alarm panels must be installed in a console facing the command workstation. This console shall be part of a safety workstation with access to contingency plans and drawings relevant to emergency situations and also internal and external communication facilities as well as safety monitoring systems if installed.

1.4.2 "The emergency command centre"

In an emergency, the Workstation for Communication and Safety Operations and the Workstation for Traffic Surveillance and Manoeuvring will form the emergency command centre. This centre shall enable one person to maintain full control of the navigation of the ship and the internal situation in the initial phase of an abnormal operating situation, and enable efficient co-operation between two persons each operating their workstation.

1.4.3 Conning position

In pilotage waters the separate navigation workstation, additional to a workstation for one-person operations, may be regarded as the conning position and dedicated to the pilot provided it is located close to the window at the ship's centre line. Alternatively, a separate conning position shall be located close to the front centre window with easy access to the required information concerning propulsion, speed, rudder angle and course as well as whistle control and VHF radio.

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1.5 Field of vision

The field of vision from the navigation and traffic surveillance and manoeuvring workstations shall be sufficient to enable the decision maker to comply with at least International Regulations for Preventing Collisions at Sea (COLREG). This implies that the officer of the watch, at all times, is able to maintain a proper lookout by sight and hearing, as well as by all available means appropriate in the prevailing circumstances and conditions, so as to make a full appraisal of the situation and of the risk of collision. From inside the bridge, it must be possible to observe all objects of interest for safe navigation, such as ships, lighthouses, buoys, etc. in any direction by moving no more than 7–8 metres to each side of the centre line. The view from workstations for navigation and traffic surveillance and manoeuvring, as well as from a conning position, should at least extend over an arc from dead ahead to 22.5 degrees abaft the beam on each side, and not be obscured by more than two ship lengths or 500 metres forward of the bow.

- **The workstation for manual steering** should preferably be located on the ship's centre line if the view is not obstructed by large masts, etc. The location of the workstation must not hinder the use of the workstations for navigation and traffic surveillance. The field of vision from the workstation for manual steering should at least extend over an arc from dead ahead to 60 degrees on each side.

- **The workstation for docking** must be equipped and located to enable full control of propulsion, steering and special means for manoeuvring and provide a view of the ship's side and a field of vision from at least 45 degrees on the opposite bow through dead ahead to dead astern.

- **The workstation for route planning** should be spacious enough to facilitate the use of two charts concurrently, sufficiently equipped for route planning.

In addition to the primary workstations listed above, there may also be a wish to include workstations for:

- Monitoring of the waters, traffic and bridge operations in general (this requires an additional radar display)
- Extended communication functions
- Extended monitoring and control of machinery and domestic systems
- Monitoring and control of ballasting and cargo operation
- Remote control of mooring winches, windlass, accommodation ladder, hatches and side ports.

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In such cases, we must analyse the bridge duties to ensure that the workload will be acceptable to the watch officer in various operational situations. Furthermore, we must ensure that nothing will prevent the watch officer abandoning a workstation for additional functions immediately, should it be considered necessary in situations where the primary functions demand full attention.

Bridge functionality and availability of correct information are imperative for system reliability.

An important conclusion obtained from investigation of nautical casualties and functional analysis of full-scale bridge operation is that the reliability of the total bridge system is not good enough when a single failure occurs in a subsystem. A simple malfunction very often has a fatal consequence for the performance of the total system. Equipment critical for the performance of the bridge system must be built with redundancy in technical design and physical separation.

There are basically six categories of information considered crucial within the bridge system:

- the chart
- the routeplan
- the present position
- the present course
- the present speed
- other vessels' relative course and speed.

The familiar term redundancy is used when the purpose is to replace a failed unit in order to keep a process going, e.g. stand-by generators, stand-by lubricating oil pumps etc. for machinery systems. Redundancy in bridge systems however, should be considered in a slightly different way.

1.6 The navigator is the most vital part

The navigator is the most vital part of the bridge system, performing a continuous integration of all available information in order to evaluate the correctness of the present course and speed.

It is essential that the information presented to the navigator is correct so that the right conclusions and decisions can be made. Therefore the redundancy in the bridge system should include the integrity of the information as well.
This suggests that the arrangement of two separate and independent gyrocompasses or other approved means having the capability to determine the ships heading in relation to geographic North, in addition to a magnetic compass, provides the necessary redundancy.

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The arrangement of one gyrocompass and one magnetic compass is only to be considered as redundancy in regard to information integrity. Furthermore, the magnetic compass cannot serve as a stand-by compass for a Grounding Avoidance System (GAS).

1.6.1 A correct picture of the traffic situation

Regarding the function "Traffic Surveillance and Collision Avoidance" the mutual behaviour of ships is distinctively regulated by The Convention of Regulations for Preventing Collisions at Sea (COLREG). The main tasks of the bridge system in this context is to obtain a correct picture of the traffic situation in the area, ascertain any collision danger and take correct action in accordance with COLREG.

1.6.2 ECDIS

ECDIS, an abbreviation for Electronic Chart Display and Information System, is in fact a complete navigation system. It is based on integrating information from other sensors, and displaying this in a more useful way, and combining this display with an up-to-date database. The database contains an up-to-date electronic chart, depth profiles, detailed information about lighthouses, and information about navigational hazards.

An electronic navigational chart (ENC) is the authorised, electronic chart database, which complies with the international standards. The ENC used by an approved ECDIS equipment with back-up arrangement may replace paper charts. Primary sensors include position fixing equipment such as GPS or differential GPS, the log and gyrocompass.
It is imperative that the ECDIS is interfaced to a radar enabling it to align the chart with the radar picture.

By using ECDIS, the navigator can focus his attention on one, "complete" navigation system. This will reduce the chances for miscalculations, whilst giving the navigator more time to keep a proper lookout.
It is estimated by DNV that ECDIS may reduce the number of groundings and collisions by about 40%, while statistics from Canada (on ships greater than 1500 grt) show that accidents have decreased by about 75% since the ships were equipped with DGPS and ECDIS.

1.6.3 Minimum two independent ARPA/radar systems

Since the behaviour of ships is strictly regulated in regard to types of ship and their mutual aspect (angle) to each other, it is important that the navigators involved obtain the same information regarding the situation they are taking part in. In good visibility the information obtained from the ARPA, can be verified

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by the visual lookout, and thereby be considered as redundancy. However, in restricted visibility the only information source, disregarding sound signals, is the picture presented by the ARPA/radar. Two independent ARPA/radar systems, as a minimum, are required to achieve redundancy.

1.6.4 Route planning in advance

Detailed planning of the intended route should take place before the start of the voyage. All the courses laid down and information attached to the plan should thereafter be checked prior to departure and whenever new information is available.
Route planning can be undertaken either on paper charts or using an electronic chart display and information system (ECDIS) displaying electronic navigational charts (ENC), subject to the approval of the flag state administration. ECDIS in raster chart display systems (RCDS) mode, displaying raster navigational charts (RNC) can be used for passage planning in conjunction with an appropriate folio of paper charts.

1.6.5 Redundancy in positioning fixing

In Ocean areas and Coastal waters, the requirement for redundancy in position fixing, with respect to
integrity is considered met when the GPS position and Loran-C position, or Dead Reckoning position, if outside their coverage areas, are simultaneously displayed allowing the navigator to monitor and compare the two positions in relation to each other and the route plan.
In coastal waters the radars provide the redundancy required with regard to both information integrity and the function itself. In narrow waters, both the accuracy and the frequency of position fixing are of great significance. The radar is a position-fixing system that fulfils the requirements for both accuracy and frequency when correctly used. The additional system should be a highly accurate Radio Navigation System such as the Differential GPS (DGPS). This will ensure the accuracy of the position fix; in narrow waters, however, it is only the relative position of the ship that is of interest for navigation, and accordingly the DGPS position should be displayed continuously in the actual sea chart, necessitating an Electronic Chart.

1.6.6 Maintaining a satisfactory level of reliability

The introduction of new modes in bridge operation due to integration and extended use of automation, together with reports stating that the reliability of bridge instruments appears to be deteriorating, stresses the importance of ensuring that instruments and systems maintain a satisfactory level of reliability.
The use of computers in bridge systems has also introduced the possibility of a new type of failure related to software quality.

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2 Grounding avoidance system - GAS

2.1 Must be planned in the engineering phase

The ultimate bridge system for enhancing safety and efficiency in bridge operations includes installation of a Grounding Avoidance System (GAS) and qualified personnel to operate it.
The grounding avoidance system shall facilitate functions that:

- enable planning of a safe route
- enable automatic steering of the ship along the pre-planned route
- detect danger of grounding related to time and distance
- enable safe automatic back-to-track functions after deviation from the route
- provide sufficient monitoring and safe second modes of operation to avoid system failures leading to critical situations.

The functions of the automatic grounding avoidance system shall:

a) ensure that the route is planned in navigable waters by:

   - enabling planning in an electronic chart system (ECDIS) or on paper charts with direct transfer to an approved electronic chart system if electronic nautical charts (ENC) are not available for the waters to be navigated.

b) ensure that the watch officer has full control of all the functions he/she is responsible for, in all types of waters by:

   - enabling continuous visual and automatic monitoring of own ship's position in relation to chart and radar information, planned route and other ships
   - displaying radar targets or full video on the electronic charts for continuous visual monitoring of the accuracy of the electronic chart
   - displaying electronic chart information on the radar display to be used for collision avoidance functions, enabling continuous visual monitoring of own ship's and other ships' position in relation to both the danger of collision and danger of grounding.

c) Ensure that the ship automatically follows the planned route in any type of waters by:

   providing automatic adjustment of the steering in relation to the planned route, both on straight courses and during the turns from one course leg to the other.

d) Ensure that the watch officer can easily monitor the reliability of the automatic grounding avoidance system and the performance of its functions by:

- displaying nautical information, operational status and ongoing and future changes on an individual monitor for providing situation awareness and safe conning of the ship
- enabling continuous visual monitoring of the sensor input data to the system and the response on the data received, the operational status regarding heading, speed, turns, cross track distance, remaining time and distance to next turn, the upcoming radius of turn, course and distance of the next leg and other relevant information

e) Ensure that all types of system failures have consistent fail-to-safe modes, thereby preventing critical situations from occurring by:

- safeguarding that the actual heading is maintained by the system in heading control mode, and that the present course change is completed
- enabling instant manual take-over of automatic steering functions or automatic changeover to components designed with redundancy.

f) Ensure that reliability of both the technical part and the human part of the bridge system are continuously monitored thereby avoiding sudden changes in the operating conditions causing a critical situation by:

- initiating alarms if there is danger of collision or grounding, or if equipment or systems fail or if the watch officer does not take instant action on an initiated alarm.
- transferring automatically any alarm that is not acknowledged in order to get another qualified navigator to the bridge instantly.

g) Ensure that the human part of the system, the watch officer, has the knowledge and skill required for safe and efficient operation of GAS by:

- requiring that the system supplier provides a training course comprising normal operation and failure modes of both the GAS and the individual equipment included in the integrated system
- requiring that the watch officer holds a certificate of competence issued by the system supplier or by a captain that has completed the training and obtained sufficient practical experience in using the system.

Ships satisfying the operational requirements will have the suffix Q added to the class notation and the following text entered in the "Appendix to the classification certificate":

- The suffix Q denotes that a qualification assurance system for safe navigation has been established, ensuring appropriate operational procedures and competent operation of the automatic grounding avoidance system.

The following main components shall be part of the integrated system for automatic grounding avoidance:

- two independent global positioning systems
- electronic chart system (ECDIS)
- radar
- track control system

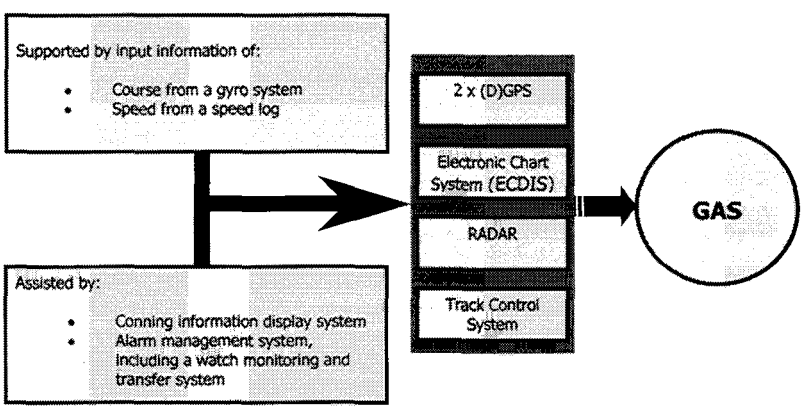
supported by input information of:

- heading from a gyro system
- speed from a speed log

assisted by:

- a conning information display system
- an alarm management system, including a system for watch monitoring and transfer of alarms.

Grounding Avoidance System –



DNV are offering two additional bridge class notations, NAUT-AW and NAUT-OC, with a potential **risk reducing of 50%** regarding ship casualties.