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Alarm Handling Onboard Vessels Operating in DP Mode

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ABSTRACT: This paper explores concerns regarding the design, implementation, and management of alarms in DP vessels that, while in operation, need an incredibly high level of accuracy along with high reliability and safe operations. The Human, Technological, and Organizational factors (HTO) method is primarily used as analysis tool to find weaknesses in alarm handling during DP operations. The research focuses on results collected from Dynamic Positioning Operators (DPO) and instructors. Findings from the survey are presented and compared to the results from past accidents and technical requirements from Petroleum Safety Agency Norway via YA 711. Three accidents from past are referred to picturize the findings from the survey results. Furthermore, the conclusion is given with recommendations reflecting the findings from the survey. The main findings are an urgency to establish a centralized marine accident investigation system which enforces learning and recommendation to make operations safer. In addition, the survey also suggests that prohibition of clients or limiting their access to the bridge is necessary. Manufacturers could focus on research and development of alarm prioritization, on structuring and presentation, and profiting by taking feedback from end-users to make DP operations safer.

1 INTRODUCTION

Compared to regular sea-going vessels, DP vessels have a high risk of getting into accidents due to their proximity of operations with the installations, even with a very reliable system. This reliability is achieved using a significant amount of electronic equipment due to increased complications in DP vessels. Humans are at the sharp end, and the chances of making errors are relatively large. Therefore, the maritime industry must reduce these risks to make the industry safer and more efficient.

This paper will review three accidents related to DP operations. Furthermore, a survey among experienced DP operators and instructors will be addressed. Issues regarding human performance, technological challenges, and organizational handling will be discussed and compared with the technical requirements published by Petroleum Safety Authority of Norway (YA-711) [8] as the codes on Alerts and Indicators 2009 by IMO only gives basic provides general design guidance [5].

A triangulated model is used to reflect on the issues in bridge operations and the alarm handling process. The three parameters for the triangulated model are survey results (α), technical requirements (β), and past (three) accidents (γ) as shown in Figure 1.

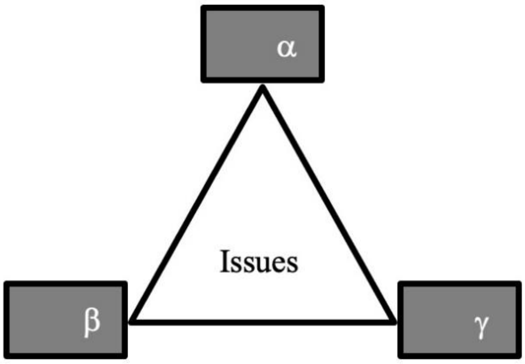

Figure 1 Triangulation of parameters.

The cause and effect of inefficiency and confusion on a bridge will be evaluated with the help of Human, Technology, and Organizational Analysis [9]. HTO factors comprise potential in system analysis, design, and improvement. This method reflects on the foundation of understanding, improvement, and development of a properly functioning system [10].

Finally, the results will be presented by discussing findings from the survey. HTO analysis will reveal the weaknesses of the current alarm system based on survey results. The revelation of practical issues occurs because the survey questionnaire focuses on practical issues during alarm handling while the vessel is in a DP mode. Hence, the accidents that have occurred on DP vessels under the operation in a DP mode will be used to validate the survey results.

2 METHOD

A qualitative approach based on literature review and survey is adopted as there are little quantitative data available. An investigative approach is taken in order to fulfill the purpose of the research [1].

HTO analysis is preferred to analyze the survey responses due to its simplicity in projection and understanding of the issues in three vital system categories. It is unpretentious to segregate any functioning structure to be implemented in the human, technology, and organizational division. Thus, implementing changes or mitigation measures would be straightforward and effective for impact on the safety, performance, and efficiency of DP Operations [10].

In HTO analysis, research is done using the term humans, pointing towards the operator operating the DP system, while the organization is the supplier of the equipment and the shipping company or an operator/charterer. Finally, the term technology is aimed to be used for the sensors, equipment, or instruments, both digital and analog, that aid in the safe and successful completion of DP operations.

An analysis is done by comparing existing guidelines (YA 711, [8]) for alarm systems with survey results. YA 711 has classified alarm design requirements into the following categories [8].

– General requirements
– Alarm generation
– Alarm structuring
– Alarm prioritization
– Alarm presentation
– Alarm handling

A list of 43 requirements in YA711 [8] for the six different categories mentioned above is divided into either human, technology, or organizational references, as shown in the appendix.

3 SCENARIOS

The main concern about alarm systems today is that offshore vessels are ineffective in resolving issues regarding alarm systems with advanced technological tools. It is essential to examine the fundamental issues hindering offshore vessels' resilience towards accidents caused by alarm systems.

Three past accidents are studied; the first is the collision of PSV Sjoborg with Statfjord A (2019) published by Equinor [4], the second the collision between Big Orange XVIII and Ekofisk 2/4-W (2009) investigated by [2], and the last the collision of Samundra Suraksha with Mumbai High North platform (2005) analyzed by [3]. These scenarios will be used for the validity of survey results.

A collision occurred between Statfjord A and PSV Sjoborg on 7th June 2019 while loading and discharging from the platform that was under a maintenance stop. Sjoborg was operating in load reduction mode with a preexisting technical issue, i.e., 10-15% reduction in thruster power. During operation, power to two of three bow thrusters was lost. The vessel drifted against the installation, resulting in severe material damages to the lifeboat station and monkey island but with no human or environmental fatalities [4].

It is seen from the accident investigation report by PSA that underlying causes resulted in insufficient thruster power [7]. This could be related to the failure of, or incorrectly installed components, or disruption from defective components, which led to network failure in the blackout safety system ("network storm"). Furthermore, loss of network frequency measurement on the main switchboard, activation of the load-reduction mode with restriction of all thrusters to 10-15 percent of maximum output, nonconformity between DP commands and automatic shutdown of thrusters 1 and 3 [4] occurred before the collision. Due to the overwhelming amount of error messages and alarms, Dynamic Positioning Operators (DPOs) could not take proper action to avoid a collision even with experienced DP operators.

On 8th June 2009, the well simulation vessel Big Orange XVIII (5000 tonnes) ran into Ekofisk 2/4W. The ship lost control after entering the 500-meter safety zone surrounding the Ekofisk complex [2]. The vessel with a speed of 9.7kn collided heads-on with approximately 71MJ collision energy with Ekofisk 2/4 X and 2/4 C [6]. Detailed analysis and calculation of impact loads is drawn in research performed by Shengming Zang in "The Mechanics of Ship Collisions" [12]. Due to severe damage to the jacket installation, ConocoPhillips decided to shut down the installation and permanently plug the wells. New ice class vessels that are built with new standards will complicate the situation. Design of these vessels can be seen in Guidelines for Finnish Swedish Ice class by TRAFICOM [11].

It is seen from the accident investigation report by ConocoPhillips (2009) that lack of cooperation between the bridge team and lack of situational awareness, together with shortcomings in the decision-making capacity of the bridge team, was the primary cause of the accident. However, the root cause of the accident was a distraction by an irrelevant bridge routine call to the captain within the 500 meters safety zone [2].

The third accident is Samundra Suraksha, a multipurpose vessel that collided with the Mumbai High North platform on 27th July 2005 to ensure the medical evacuation of ship personnel. The vessel collided with the riser leading to a leak of hydrocarbons, which eventually led to an explosion and total loss of both installation and ship (later, 1st August). On the day of the accident, the vessel had no preexisting issue in its instruments or its navigational system and was seaworthy. However, the vessel experienced challenging weather conditions (35kn wind, 5m swell and 3kn current) [3].

The collision risk management principles were insufficiently implemented in the third accident for in-field vessels' risk management as mentioned in the guidance on enforcement [14]. In the case of Samundra Suraksha, no procedures were established to manage risks of collision, which governs the overall approach to identify hazards, assess risk, and establish an appropriate procedure for the detection, control, and mitigation. This is reflected by the captain's misjudgment (observed that starboard azimuth thruster pitch was sluggish) while switching the vessel to manual maneuvering in tough weather conditions. These actions reflect on a poor organizational safety culture, where operating policies were not followed into operations by the DPO. The pre-entry checklist and procedures following the operation within the 500m safety zone were ignored.

4 RESULTS OF DATA COLLECTION

The safety culture has been shifting in time with the evolving concept of quality management (change management), the approach termed Kaizen (continuous improvements), emphasis on resilience organizations, and many other philosophies. However, the possibility of accidents occurrence depends on several minor details deep-rooted in the organizational structure. In order to understand issues regarding the alarm system present onboard offshore vessels, the study of relevant guidelines and technical requirements was done. At the same time, the results from the survey were evaluated under the umbrella of the YA 711 technical requirement published by Petroleum Safety Authority Norway (2001). While doing so, weaknesses in the current system are anticipated to be outlined.

A questionnaire for the target group was prepared to figure out the issues as per the technical requirements in YA 711, in six distinct categories. Each category has individual requirements for either human perspective, technological perspective, organizational perspective, or any combination of these three, as shown in Appendix.

Survey results were collected from two target groups, one being DP operators and the other being DP instructors. End-user input is expected from DPOs regarding training methods and information regarding the preparation of seafarers for DP operation.

Table 1. List of Participants in Target Group

Target Group	Questionnaire	Interview
DPO	40	1
Simulator Instructors	3	1
Total Participants	45	

HTO analysis is used for the categorization of answers and comparing them with relevant guidelines. Results from the survey are found to be as follows:

In general requirements of alarm development and function, the primary purpose of an alarm system is to act as a tool for operators to handle critical and atypical solutions with precision and effectiveness [8].

On the other hand, the survey reflects the importance of several factors, such as contributors, that reduce the attention and cognitive ability to handle alarm systems properly. One of the questions from the survey was the effect of a client's presence on the bridge while working on a DP operation. This event can be seen as distraction for DPO and hence, raises the risk of accidents during a DP operation. Nearly half of the participants agreed to this as shown in Figure 2.

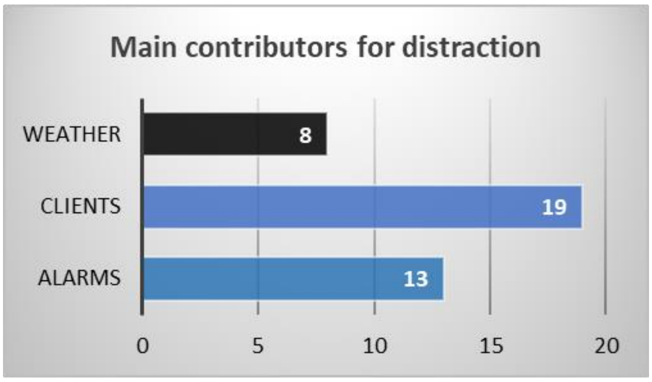

Figure 2 Main contributors for distraction in the bridge during operation.

The criticality of distraction on the bridge can also be seen from the collision between Big Orange XVIII and Ekofisk 2/4. The captain lost his focus while fulfilling responsibilities that had no connection with the vessel maneuvering. The captain enabled autopilot before taking a phone call. After his return, he could not figure out why the vessel was not responding to his input [2]. This fact supports that unwanted events affect the cognitive ability of DPO, especially when there is a need for full concentration in operation.

For alarm generation, there were a high number of technical requirements compared to human or organizational requirements [8]. The survey found that it was not allowed to change the alarm suppression system in many cases, and if allowed, the alarm suppression systems were used for the wrong reasons. An example during an interview was that the alarms were toned down, especially when the clients were onboard. In addition, it was revealed that there were several alarms for one variation or deviation from the preinstalled limit, and this one deviation affected several functions or positioning parameters. Alarms were triggered for all the connected systems / systems associated with the deviated parameter, which caused “alarm fatigue” to the DPOs.

The alarm generated and displayed on the bridge of Big Orange XVIII was not effective, as the captain could not notice the vessel was on autopilot that he initiated earlier. Thus, the captain did everything else but disengaging the autopilot before the collision.

In alarm structuring, the primary responsibility according to YA 711 lies in the technological sector to provide improved alarm structuring [8]. Provision for grouping, sorting, and selecting various alarms and features should be provided per operators’ needs. A simple overview of alarms that are suppressed, shelved, or inhibited should also be displayed. The alarm suppression system and its presentation method should be understood by the operator in the overview display. Simultaneously, the operator must understand the different alarm features, such as suppression of alarms and alarm filtration. PSA does not recommend the latter, according to YA 711.

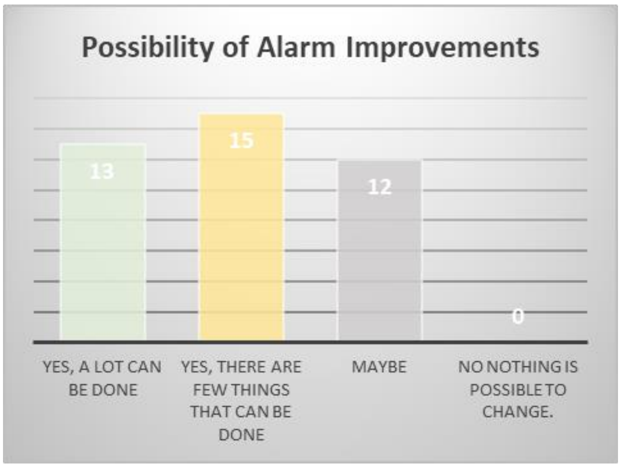

Figure 3 Areas where alarm performance could be improved.

According to the survey results shown in Figure 3, the DPOs suggested a necessity for improved technology for the end-user where alarms are manufactured according to human-centered design. These improvements will not just improve the end-users’ experience but will aid in reducing accidents.

In the collision between Sjoborg and Statfjord A, after the loss of 2 bow thrusters, the DPO onboard Sjoborg faced the challenge of keeping the vessel away from installation while sorting out the relevant alarms to avoid a collision. The DPOs were struggling because of overwhelming and numerous alarms in a short time [4]. This fact supports the finding from the survey where significant efforts are required to stage a structured alarm system that could increase the DP operator's effectiveness and reduce the limitation.

For alarm prioritization, all three parts of HTO play a role. Firstly, operators should prioritize the urgent alarms; thus, the operators should use this feature to be efficient and effective during abnormal situations. Given that manufacturers would provide a system that aids alarm prioritization, improving operators’ focus will severely impact operations.

From an organizational perspective, shipping companies should develop a strict policy to implement alarm routines and procedures. Standing orders from captains on the vessel should be clear and well-rehearsed in advance. These routines are constructive as it makes operators familiar and comfortable with the prioritization procedures that the system designers have developed.

Figure 4 shows that about 62% of the survey participants reflected the impracticality or lack of flexibility to prioritize alarms dedicated to critical operations. In contrast, 25% were sure that it was possible to prioritize alarms. Prioritization is critical as it eliminates human limitations by reducing the observation parameters to critical alarms only.

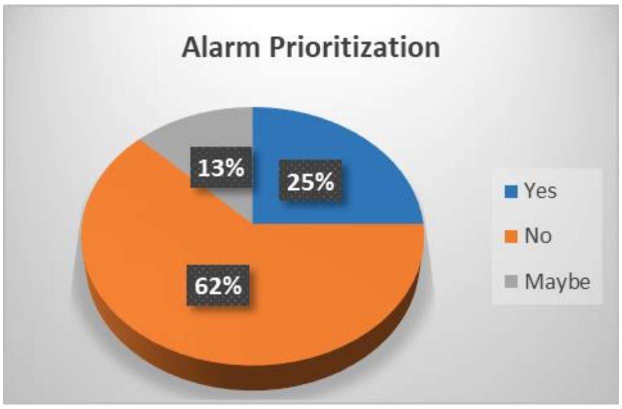

Figure 4 Possibility of improvement in Alarm Systems.

In case of the collision between Mumbai High North and Samundra Suraksha, the captain doubted the instrument message as “acting sluggish” in his opinion and switched to manual control once the medical evacuation was completed [3]. This might be because of a practical drift [13] in the organization or lack of procedures or in-field vessel risk management system. This incident reflects on the importance of alarms and their effects on the result of an operation. Ultimately, the DPO’s underestimation of the value of a working system led to the catastrophe.

For alarm presentation, it is asked from the manufacturers that the design of an integrated alarm system installed on a ship must have standard color codes, symbols, and alarm categorization methods, which help the operator be precise and effective. A ‘dark screen’ concept should be implemented because there should be no alarms on the main display when there are no genuine abnormalities on the ship or operation.

A necessity for flexibility is seen in Figure 5, when it came to reducing audio and flashing lights due to alarms. The majority of the participants said it was possible to reduce the overwhelming intensity of alarms both for visual alarms and audio alarms. Thus, alarm designs without a human-centric approach do not facilitate effective operator intervention.

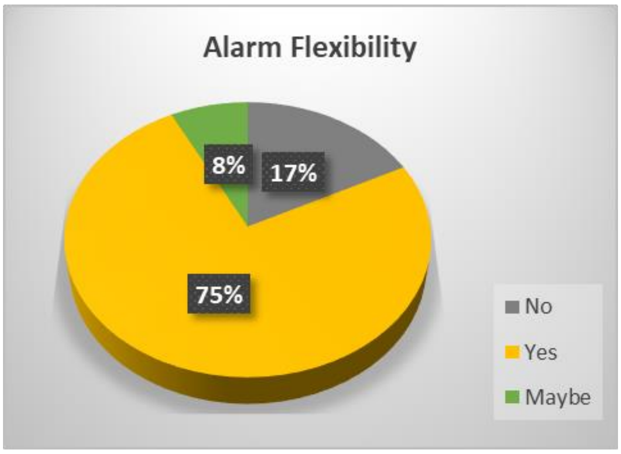

Figure 5. Alarm flexibility necessity according to DPO survey.

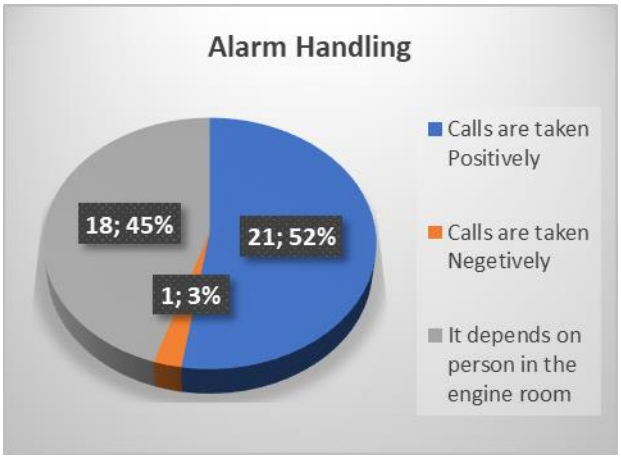

Figure 6. Crew Behavior for alarm handling.

Alarm logs from DP vessels are usually long and deterrent as they use many abbreviations and is like a maze to navigate through. Sjoborg, before colliding with Statfjord A, received numerous alarms, which never pointed to one specific problem but pointed at all the deviations caused by one problem. Hence, it was hard for the DPO to pinpoint issues and find a proper solution. Thus, the alarm presentation is critical as it helps to save valuable time to avoid accidents.

In the case of alarm handling, all three parts of HTO have significant roles. From a human perspective, operators should acknowledge all alarms that are triggered. Acknowledge, meaning the purpose of the alarm is first to be read, and then understood, and finally accepted. The alarm philosophy should describe whether an alarm should be accepted once the operator has read it or after they have completed an action.

From a technological perspective, a provision for alarm shelving should be provided so that the operator can remove standing or nuisance alarms. Shelving must be kept as a 'last resort' for handling irrelevant nuisance alarms that have not been successfully filtered or suppressed. A list of shelved alarms should always be available to the operator. Manufacturers ought to provide the solution that supports operators to make a quick and precise decision. Finally, procedures for the individual person responsible for monitoring and controlling operations, including emergencies, have to be readily available and familiarized.

Escalation of DP incidents has to be prevented by operator intervention. In several cases, the DPO alone cannot act independently to prevent an incident. Thus, it is vital that the onboard crew functions as a team. As seen in Figure 6, there is a demand for better cooperation between the bridge and the engine crew. At times, misunderstandings between bridge and engine crew might be the cause of the escalation of a DP incident. Nearly half of the survey participants said, "it depends on the person in the engine room," or calls from the bridge are perceived negatively. A culture of promoting safety culture, and reporting of near-miss situations is fundamental for future development of new technologies and maintaining a safe working environment.

The alarm system should increase efficiency by eliminating limitations of an operator; while doing so, alarm fatigue should also be acknowledged. Alarms received on the night of 7th June 2019 on Sjoborg were generated for the first time. The crew did not take the alarm seriously and were heading towards severe danger. This may be due to practical drift as nothing serious happened in the past or due to lack of operational procedures for alarm handling. Sjoborg was a DP class 2 vessel and had redundancies, which gave crew confirmation bias that everything would be all right. This was improper handling of alarms. A possibility to mute alarms irrelevant to the DP operation should be provided, and if not, there will be distractions leading to increased risk of incidents. There are lack of routines to come back for feedback from end users; this practice can be seen from the survey in Figure 7.

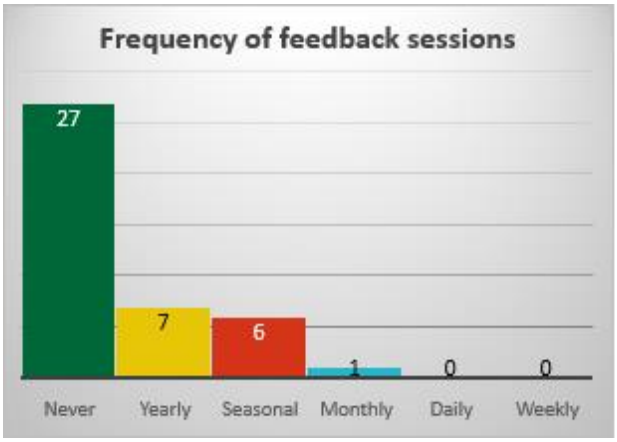

Figure 7. Feedback sessions held by makers with end-users

5 CONCLUSIONS AND SUGGESTIONS

The survey results and previous accidents show that several improvements can be made in the offshore industry, especially on DP vessels. Implications are broad and significant while the industry is expanding in the field of offshore wind and aquaculture together with oil and gas. The following conclusions may be drawn after the research:

Instead of making an individual shipping company or a maritime cluster resilient, IMO should take the initiative to centralize the accident investigation process or take part in accident investigations to enforce the learnings and recommendations to the ships under the IMO umbrella. This will eventually lead to strengthening the structures for improvement and to come back strongly after any setbacks. In addition, companies should work to figure out how to avoid practical drift so that there is relatedly tight situational coupling between the designed methods back to the engineered or applied logic action.

Also, instrument designers and producers should have a routine to get regular feedback from the end-users and utilize the technology to record the performance of their equipment onboard vessels. As a result, those data and information could be used to further research and develop alarm systems and upgrade the existing systems installed. In addition, manufacturers should focus on making the alarm systems user-friendly. All abbreviations should be understandable; if not all, the translation of error codes should be provided in the help menu and training manual.

Similarly, the presence of clients on the bridge has a negative influence, which is one of the major causes for poor performance of DP operators. In most cases, clients are provided with separate observatory and detailed operational information regarding offshore operations. Unnecessary visits and involvement in the DP operation should be criticized, prohibited, and in any case established before starting the operation.

Suggestions like the adaptation of the traffic light model of alarms are brought forward, similar to the lighting model of the Activity Specific Operating Guidelines (ASOG) but in an automatic form with no human involvement.

Manufacturers, shipping companies, operators, and charters should define and check the limits of alarm generations used for the operations and emphasis on those alarms that have safety implications; detailed descriptions should be presented by Fault Mode Effect Analysis (FMEA)/ ASOG for the responsible crew.

Proper training and familiarization of new crew members towards instruments and alarm panels should be prioritized. Extra courses regarding alarm systems and error messages should be part of the recruitment process as it helps the new crew integrate with the bridge and engine crew and educately familiarize them with the operational instruments.

The future recommendation for this research is to extend the survey to more DP operators and instructors worldwide to validate current findings or discover new findings.

The offshore industry is transitioning towards new fuel solutions in order to keep up with sustainable development goals. For future research on issues with alarm systems, it is recommended to perform a detailed study about the challenges created by implementing new hybrid fuel sources as hydrogen and batteries in DP vessels. As technology advances, there will be an increase in the number of alarms on a bridge. Thus, measures to avoid alarm fatigue must be explored to limit human errors and increase the efficiency of DP operators.

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