Safety and Reliability – Safe Societies in a Changing World – Haugen et al. (Eds)
© 2018 Taylor & Francis Group, London, ISBN 978-0-8153-8682-7

Towards an online risk model for dynamic positioning operations

Anna Yining Dong, Jan Erik Vinnem & Ingrid Bouwer Utne
Department of Marine Technology, NTNU, Norway

ABSTRACT: Automation and increasing complexity mean that operators have to handle data and alarms and emergent decisions under the pressure of unexpected and rapidly changing hazardous situations. Position loss during marine operations may lead to serious accidents, such as collision, loss of well integrity, etc. An online risk model aims at assisting operators in dynamic positioning operations to successfully recover the vessel's position in a good timing. The objective of this paper is to identify generic scenarios of position loss during operational phase and the information that is needed for successful recovery action. The results show that position loss normally involves of complex human machine interactions, generally in two patterns. Based on the findings, it has been recognized that risk model considering time aspect is of vital importance to develop an online risk model for DP operations.

1 INTRODUCTION

A dynamically positioned (DP) vessel is by the International Maritime Organization (IMO) defined as a vessel that maintains its position and heading (fixed location or pre-determined track) exclusively by means of active thrusters (1994). A DP system generally consists of three main subsystems, i.e., the power system, thruster system and DP control system. To further measure the designed equipment redundancy of the DP system, the IMO MSC Circ. 645 (1994) defines three classes, i.e., DP 1, DP 2 and DP 3. For DP class 1, position loss may occur given a single failure event of an active component. For DP class 2, position loss should not occur given a single failure, and for DP class 3, position loss should not occur given a single failure, including fire and flooding of watertight compartment or fire subdivision.

Based on more than two-decades of experience with safety management of DP marine operations, it has been shown that risk of position loss is intrinsic to all DP vessels (Chen and Nygård 2016). A position loss may happen on DP 1 vessels, as well as on DP 2 and DP 3 vessels. Meanwhile, offshore exploration and exploitation of hydrocarbons have opened up an era of DP vessels. There are wide applications of DP vessels in the offshore oil and gas industry, e.g., diving support vessels, pipe-layers, heavy lifting vessels, drilling rigs, subsea construction vessels, platform support vessels, shuttle tankers, etc. The focus of this paper is on offshore loading operations using DP shuttle tankers.

Nowadays, most liquid products (i.e., stabilised crude oil, condensate, liquefied petroleum gas, liquefied natural gas, etc.) from oil and gas fields in the North Sea are transported to refineries and terminals by DP shuttle tankers (ST). These large vessels with high thrust and power capacity may pose a significant collision risk to an adjacent offshore installation in case of position loss. Since 2000, there have been two collisions between shuttle tankers and facilities on the Norwegian Continental Shelf (NCS). In addition, there have been four near misses (collision events) and seven incidents related to loss of position, with varying degrees of severity.

There are two generic failure modes of position loss, i.e., drive-off and drift-off. The primary concern in this paper is on the drive-off scenario. The term *drive-off* is defined as a tanker moving away from its own target/desired position by its own power in off-loading operations. It might occur in different phases during offloading operations, i.e., approach, connection, loading and disconnection. Excessive relative motions between the FPSO (floating production storage and offloading) and tanker, categorized in surging and yawing modes, have been identified as the failure prone situations (drive-off) in tandem offloading (Chen 2003). Several recommendations have been given by (2003) regarding how to reduce the occurrence of excessive surging and yawing events. For instance, the coordination of mean heading control between the FPSO and tanker is important to minimize the probability of excessive yawing.

A recent review of DP accidents and incidents by the Petroleum Safety Authority in Norway (PSA) has shown that there is an increasing tendency in the number of DP drive-off accidents and incidents during offshore loading with shuttle tankers on the NCS in the past fifteen years (Kvitrud, Kleppestø et al. 2012). Vinnem et al. (2015) indicate the need for new risk reduction measure and outline an overall concept for online risk management. A research project has been initiated by the Department of Marine Technology in the Nowegian University of Science and Technology (NTNU). The main goal of the project is to develop an online risk monitoring and decision support system.

An analysis was performed on DP accidents and incidents with emphasis on root causes and barrier failures (Dong, Rokseth et al. 2017). One of the major conclusions was that the most recently drive-off accidents and incidents on NCS involve both technical and human/operational failures. The development of DP operator (DPO) decision support should focus on reducing the combination of causes. Five design principles for the online risk model, including complementarity, integration, early detection, early warning, and transparency were proposed by Hogenboom et al. (2017). Moreover, it is likely that an online risk management system may reduce the risk due to human machine interface (HMI) failures. Automation and increasing complexity mean that DPOs have to handle data and alarms and take safety-critical decisions under the pressure of unexpected and rapidly changing hazardous situations. A previous study shows that human error is the most complex and least understood factor in the failures of complex systems, accounting for as much as 60% to 80% of complex system failures (Sudano 1994). As an additional barrier function (Vinnem, Utne et al. 2015), the new decision support system should aim at supporting information to operators, reducing the potential for catastrophes induced or exacerbated by human errors. The complex HMI determines the importance of information support for operators' decision-making.

The objective of this paper is to identify the human action and types of technical failures in the initiating event of drive-off. The purpose is to find out the challenges and problems for early detection during DP operations, which online risk model and decision support system can provide the information to contribute to improve DPOs' situation awarness and decision making, and understanding of system performance as well.

The paper is structured as follows: the challenges of DPO decision-making are stated in Section 2, where classifications of decision and risk information are also introduced. In Section 3, human actions in the initiating event of drive-offs and classifications of failures are presented, following by the description of analysis and result in Section 4. Based on the analysis and result, discussions are given in Section 5. Lastly, conclusions are summarized in Section 6.

2 DP OPERATOR DECISION-MAKING, CHALLENEGES, TYPES OF DECISION AND RISK INFORMATION

An information-decision-execution model (Figure 1) for DPO reaction in a drive-off scenario was introduced by Chen (2003). One important factor and dimension that needs to be under control is the *time*. As illustrated in Figure 1, the model is presented with the time reference. It is worth noting that the three stages (Ta; Td; T1) do not happen in a purely linear, sequential manner. The estimation of the DPO action initiation time (T1) is, accordingly, based on an estimation of the following three characteristic time interval values, as shown in Figure 1:

- Information time: 0-Ta
- Decision time: Ta-Td
- Execution time: Td-T1

Chen (2003) states that the challenge of human intervention is that the DPO needs to make a decision within typically 45 seconds to avoid a collision in the case of drive-off, given that the typical distance between vessels is 75 m. Some previous studies show that DPOs when collisions occurred, used about 3 minutes before taking manual evasive action.

Loss of situation awareness has been recognized as the main reason for no early detection (Chen 2014). Situation awareness (SA) is defined as "the perception of the elements in the environment within volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley 1995). Moreover, Endsley (1995) developed a three-level model to describe the different levels involved in the formation of SA. Level 1, perception, refers to the perception of attributes and dynamics of elements in the environment. Level 2, comprehension, refers to the integration and understanding of the information, i.e. it involves the human operator's sense-making to establish what is happening in the situation. Level 3, projection, refers

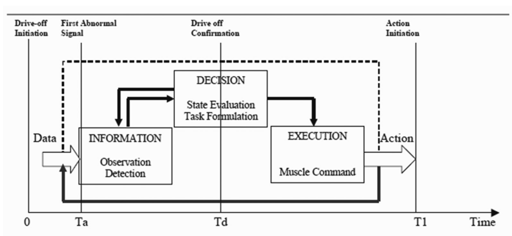

Figure 1. Information-Decision-Execution model for DP operator reaction in drive-off scenarios, adopted from (Chen 2003).

to the operator's estimation of future states of the system. The results of the assessment of the current situation can be utilized to determine future courses of action, thus supporting decision-making. However, Kjell et al. (2015) argued that the process of gaining SA does not follow sequentially from level 1 SA to level 2 SA, as set out by Endsley's model, but rather the build-up seemed to be adaptive and related to the work system's higher level goals, such as to avoid collision. He also found that in a majority of DP accidents and incidents, DPOs didn't expect the occurrence of an accident or incident. Some of the DPOs were not able to identify the relevant initiating events (lack of level 1 SA), or to understand the relevance of the initiating events (lack of level 2 SA) in DP accidents and incidents (Øvergård 2015). *Initiating event* is an identified event that upsets the normal operations of the system and may require a response to avoid undesirable outcomes (Rausand 2011). The initiating events that were used in the study include environmental impact, DP reference, human error, component failure, power management system, DP software failure (Kjell I. Øvergård 2015).

To avoid a collision and mitigate the consequence of position loss, successful human intervention has been considered as the main risk reduction measure, while efforts should be made on bridge ergonomics, HMI, alarm system, procedures and training. Meanwhile, it also needs to improve DPO's decision-making for gaining and maintaining situation awareness.

From a risk assessment perspective, decisions can be classified into planning decisions and execution decision. *Planning decision* is the decision made by blunt-end decision maker and middle level decision makers, such as operational managers. The time lag between decision and action is relative long. Enough time systematically identify and evaluate different alternatives. *Execution decision* is made by sharp-end personnel, who monitor or control ongoing operation and emergency response teams. The time lag between decision and action is much less. When DPO is in charge of making execution decision (illustrated in Figure 1), it can be further divided into *instantaneous decisions* and *emergency decisions*. Instantaneous decisions are taken spontaneously by sharp-end operators, e.g. to follow or deviate from procedures; ignore or react upon deviations in normal working conditions. The decision-making emphasizes situation assessment and pattern matching. This type of decision is normally taken quickly, although not necessarily. Emergency decisions are taken in emergencies to avoid or adapt to hazardous situations. Time dynamic is often so fast that pattern matching may not match the development of the situation. Decisions have to be made fast.

Furthermore, Yang and Haugen (2015) identify six different risk types to make the different operational decisions. To support execution (instantaneous and emergency) decisions, time-dependent action risk information is proposed. The time-dependent action risk can be estimated or predicted based on the margin between the performance of parameters in the current situation and operational limits.

In terms of early detection, focus should be on signals of deterioration of position to strengthen situation awareness during the monitoring (boredom) phases. Early warning including indicators derived from operating parameters against operating limits should faciliate early detection and reflect the operating limits and capabilities.

2.1 *Human actions in initiating event of drive-off*

To study the HMI in initiating event of drive-off, human action is used instead of human error. *Human error* is defined by Reason (1990) as all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some agency. Reason (1990) emphasizes that the notion of intention and error are inseparable. Human action can be categorized as intentional action and nonintentional action. Reasons argues that human error is only associated with the intentional action, and it has no psychological meaning in relation to nonintentional behaviour. This view is also accepted in paper, although nonintentional human behaviour may contribute to system failure from safety point of view.

The human actions and their interations with technical failure events have been categorized into initiating action, response action and latent action:

- *Initiating action* is an action that initiates a failure event in the system.
- *Response action* is an action that responds to the system demands, typically under technial failure events or special external situations. Chen (2003) points out that the response action may save or worsen the situation or cause a transition to another event.
- *Latent action* is an action that influences (but does not directly initiate) the technical failure, e.g. maintenance action, and/or the above two types of human actions.

2.2 *Types of failures*

With respect to the performance of an item, it is necessary to explain the difference between failure, fault and error, a relationship between failure, fault and error is given as follows (Rausand og Høyland 2004):

- A failure is an event that occurs at a specific point in time.
- A fault is the state of an item characterized by inability to perform a required function. While a failure is an event that occurs at a specific point in time, a fault is a state that will last for a shorter or longer period.
- The error is a discrepancy between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value of condition. An error is present when the performance of a function deviates from the target performance (i.e., the theoretically correct performance), but still satisfies the performance requirement. An error will often, but not always, develop into a failure.

An illustration showing the relationship can be found in Figure 2. A failure may originate from an error. When the failure occurs, the item enters a fault state. A failure mode is always related to a required function and the associated performance requirement. A failure mode is a description of a fault (i.e., a state) and not of a failure (i.e., an event). A correct term would, therefore, be a fault mode.

In addition, failures may be classified according to their causes, effects, detectability and several other criteria. It is worth to mention a special category of cause is common-cause failures (CCFs). According to the effect of the failure, IEC 61508 (2010) classifies failures as follows:

- *Safe failure:* failure which does not have the potential to put the safety-related system in a hazardous or fail-to function state.
- *Dangerous failure:* failures has the potential to put the safety-related system in a hazardous or fail-to function state.
- *Non-critical failure:* failures where the main functions of the item are not affected.

Safe and dangerous failures may be classified further as either detected (by diagnostics) or undetected (not detected by diagnostics).

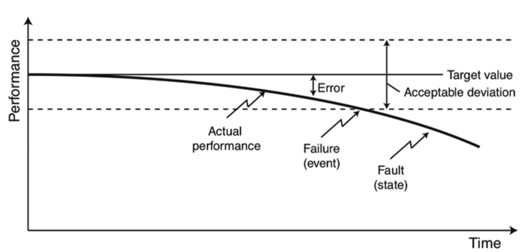

Figure 2. Difference between failure, fault and error (Rausand og Høyland 2004).

3 ANALYSIS AND RESULTS

The analysis is performed by reviewing the incident investigation reports of recently occurred DP accidents and incidents (a detailed overview can be found in (Dong, Rokseth et al. 2017)). According to the classifications of human action and failures that are stated above, the following keywords are used to analyse the accidents and incidents:

- Performance deviation
- Initiating event
- Failure (event), particularly technical failures
- Human initiating action
- Human response action

The result shows two identified situations regarding performance deviations.

Situation 1: Deviation is observed. Normal operational activity is required to perform.

Situation 2: Deviation is observed. Deviation represents the abnormal performance of the technical system.

For each situation, operator tasks, HMI, type of human action and typical technical failures are summarised in Table 1.

For the first situation (shown in Table 1), the operator needs to interact with the techncial system to perform operation activity when they observed deviations in normal working conditions. When performing the task, this situation mostly involved human initiating action. In addition, DP control logical failure has been identified as a typical technical failure that is initiated by the human action. For instance, the DPO might need to adjust ST heading to return backloading hose during disconnection. When giving the new setpoints, DPO initiated the software logic failure. However, it is challenging for the DPOs to identify the DP logic failure, since it is a type of undetected dangerous failure. Technical failures can be classified into (dangerous or safe) undetected and (dangerous or safe) detected failures. Dangerous Undetected (DU) failures are preventing activation on demand and are revealed only by testing or when a demand occurs. Sometimes, it is also called dormant failures (61508 2010).

The drive-off involving human initiating action also shows DPO lacks information for performing their task. A task analysis is conducted based on a case study of adjusting shuttle tanker position to return loading hose during disconnection. It is illustrated in Figure 3. The task analysis is made according to a six-step decision-making process (D. Husjord 2015) using in navigational training and practice. As shown in Figure 3, the main task is to adjust ST position to return loading hose

Table 1. Identification of situation that contributed to human action in DP accidents and incidents.

Situation	Description	Operator task	HMI	Type of human action	Identified technical failures	Type of technical failures
1	Deviation is observed. Normal operational activity is required to perform.	Interact with technical system to perform operation activity. i.e., adjust ST heading to return backloading hose during disconnection.	– Select an operation mode – Give new setpoints in user menu – Select DP reference orgin	Initiating action, i.e., DPO gives new setpoints.	– DP control logic failure. – Sensor failure.	Dangerous undetected
2	Deviations represent abnormal performance of technical system.	Interact with technical system to keep ST position.	Interaction depending on the type of technical failures (i.e., safe failures or dangerous failures) and causes of the technical failures.	Response action, i.e., DPO performs position drop-out to calibrate PRS	Inaccurate DP offset (s) for PRS (s) and/or gyros deviating from true north	Safe detected

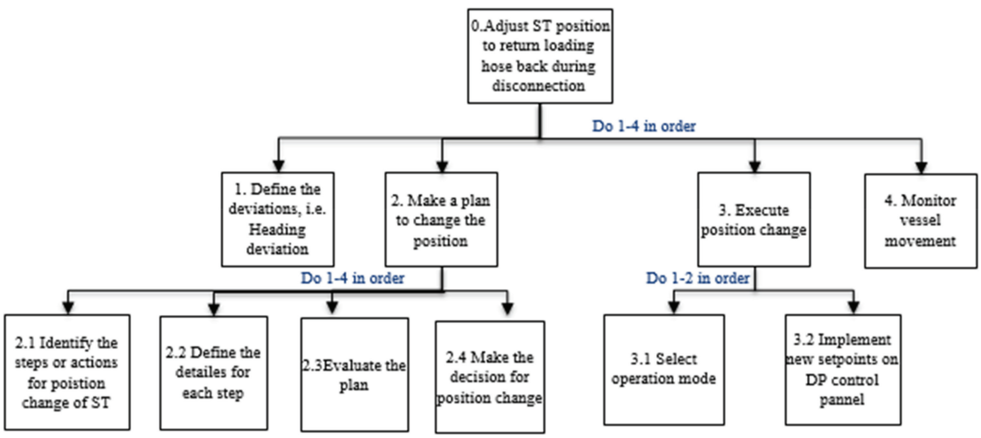

Figure 3. Task analysis of adjusting ST position to return backloading hose during disconnection.

during disconnection. To achieve it, there are a couple of steps, which are listed as follows:

Step 1: Define the heading deviations;
Step 2: Make a plan for changing the position;
Step 3: Execute the action for a position change;
Step 4: Monitor the movement of the vessel.

The operator should follow the Step 1-4 in order. However, this is not just a human task. It demands a human-machine collaboration to change the heading. While the operator decides whether the heading should be changed or not, execution of the position change needs thrust allocation, which is implemented by the DP control system. The problem is the DP control system might have limitations that are not stated in the user manual or hidden failures. Therefore, the operators need information about the real-time performance of the DP control system to avoid undesired outcome from the command they give to the control system. By referring to real-time, it means the weather conditions at the moment is also taken into account.

Regarding the second situation in Table 1, it is normally associated with technical failures. While technical failures appear, the DPO identifies the deviations. To ensure safe operation, the DPO further identifies the risk that can be caused by the technical failures so that they can take action to respond to the failure. Nevertheless, they might misunderstand the technical failures, which means they should be able to distinguish between dangerous and safe detected failures.

- Dangerous detected failures (DD): dangerous failures that are detected immediately when they occur, for instance by an automatic built-in self-test.
- Safe detected failures (SD): Dangerous failures that are detected (normally by automatic self-testing).

The detection of technical failures and identification of dangerous or safe failures have been mainly given as the task of the automation, which is performed by *diagnostic self-testing* (Rausand og Høyland 2004). Therefore, the increasing trust of the reliability of the automatic function (i.e., automatic self-testing) may result in loss of skill of human operators. The operator needs information support for being aware that the actual performance of DP system is within acceptable deviation even though a deviation is observed.

4 DISCUSSION

Based on the classifications of human actions, initiating action and response action are identified from the recently occurred DP accidents and incidents. First, it shows that the initiating event of drive-off does have to be a technical failure. It can be a human initiating action that triggers a failure in technical system with the purpose to perform a normal operational task. While lack of information support during performing the task is identified, it also represents the deficiency of proof testing to detect dangerous undetected failure (i.e., DP control logic failure). DPO needs information for evaluation before executing the decision when time is available. Lack of information may result in loss of situation awareness and *overconfidence* of the DP system performance. Sometimes, overconfidence is referred to as *complacency*, and can have severe negative consequence if the automation is less than fully reliable (Wickens, Gordon og Liu 1997). The cause of complacency is probably an inevitable consequence of the human tendency to let experience guide our expectancies. When DP systems are marketed as quite reliable, we should avoid that the DPOs perceive the device to be of "perfect reliability". Otherwise, it becomes a natural tendency for the operator to cease monitoring its operation or at least to monitor it far less vigilantly than is appropriate. One implication of automation for human intervention related to situational awareness is that people are better aware of the state of processes in which they are actively participating in than when they are passive monitors of someone (or something) else. If they are carrying out those processes to detect a failure in an automated system, they will be less likely to intervene correctly and appropriately if they are out of the loop and do not fully understand the system's momentary state. All of this information will be essential in order to develop the risk model, which the on-line monitoring will be based on.

In addition, a drive-off event can also be triggered by an observed technical failure with interaction of human response action. Indeed, it requires the DPO to be able to analyse if it is a safe or dangerous failure. The operator needs information support for being aware whether the actual performance of DP system is within acceptable deviation or not.

To avoid DPO overconfidence in the automation and imporve their understanding of actual system performance, it is necessary with an additional supervisory system to assist operators in detection, situational awareness and skill loss.

One of the purposes for such a system is to support the DPO in two situations described in Section 4 to avoid initiating action and response action during DP operations. The information support should help DPOs to have the reference for the following questions:

– Will the action initiate a dangerous undetected failure?
– Is it a dangeorus technical failure? Will the action worsen the situation?

For the first question, the system aims to support the operator in the situation that they face deviations in normal working condition and need to perform an operational action about the deviations. For instance, if the DPO needs to adjust ST position to return loading hose during disconnection if heading deviation has been observed. This information will be used in the forthcoming development of a risk model which will be the main basis of the online risk modeling tool.

Initiation of action is a decision-making process. Therefore, we can call the new system an online decision support system. It will support operator aiming to reduce initiating action and response action. Based upon the findings, the online decision support system should address two types of information support. An illustration is given in Figure 4 to demonstrate the online decision support system will support the two types of information.

1. Support information for DPO in the task planning in the situation that DPO encounters

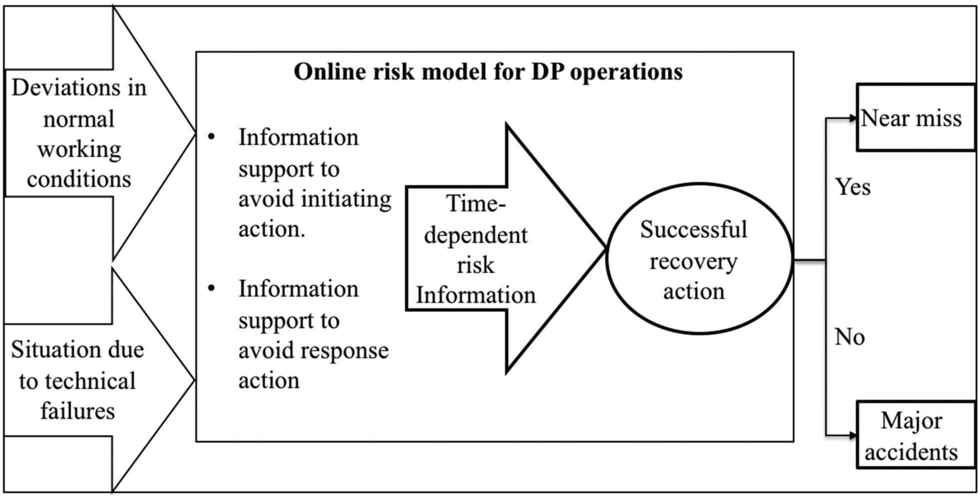

Figure 4. Two types of information support in an online decision support system.

deviations in normal working condition. The operator needs to be aware of whether their planned action will initiate a dangeorus undetected failure. This information support should avoid initiation of drive-off involving human initiating action.
2. Support information for DPO to analyse the actual system performance. The information is to help operator to be aware of whether their response action will make worse the situation leading to a drive-off.

Meanwhile, the importance of the time aspect should be emphasized, since responses may develop so fast in a drive-off situation that it might develop to a severe consequence, such as collision, within a very short time. Operator has to maintain awareness of the situation and catch the development of the situation.

5 CONCLUSIONS

Due to the nature of DP operations and human machine dynamics, loss of situation awareness has been recognized as the main reason for no early detection. One of the reasons is that the initiating event of position loss involves a complex HMI. Tanker drive-off potentially involves not only DP hardware and software, position reference systems, and vessel sensors and local thruster control system, but also the DP operator.

To improve DP operator's situational awareness and understanding of system performance, it is necessary to study the human machine interaction based on classification of human action and types of failures. It has been found that many DP accidents and incidents are involved human initiating action and response action.

Two situations are identified from the DP accidents and incidents involving initiating action and response action. First, DPO encounters the situation that is associated with deviations in normal working conditions (ST keeps its position within operating limits). Drive-off is initiated due to the interaction between human initiating action and dangerous undetected failures. Second, DPO faces a situation given by technical failures. The operator needs information support for being aware whether the actual performance of DP system is within acceptable deviation or not.

Based on the situations, some challenges are pointed out:

Challenge 1: In the first situation, the DPO should evaluate if their action will initiate a dangerous failure which has not been detected. It indicates the need for information support concerning the deficiency of proof testing, which should be supported operator' evaluation of planning a decision for the normal operational task.

Challenge 2: In the second situation, the DPO should analyze the detected failure if it is a safe failure or dangerous failure and if their response action will worsen the situation. Therefore, it is of vital importance for the operator to be aware of the actual system performance is acceptable deviations.

An online decision support system will be an advisory tool concerning the listed challenges to support the DPO to improve situation awarness and decision support. A benefit of introducing the system is to avoid DPO overconfidence in the DP system.

REFERENCES

61508, IEC. 2010. *IEC 61508*: *Functional Safety of E/E/PE Safety-related Systems*. International Eletrotechnical Commission.

Chen, Haibo. 2014. May 20. Accessed December 2017. https://www.ntnu.edu/documents/10392/881108733/4+Haibo+Chen.pdf/56fe1148-8a72-4466-8763-2c3384aa29f0.

—. 2003. *Probabilistic evaluation of FPSO-tanker collision in tandem offloading operation*. Trondheim: NTNU.

Chen, Haibo, and Bjørn Nygård. 2016. "Quantified Risk Analysis of DP Operations—Principles and Challenges." *SPE International Conference and Exhibition on Health, Safety, Security, Environmental and Social Responsibility.* Stavanger, Norway.

Chen, Haibo, Torgeir Moan, and Harry Verhoeven. 2008. "Safety of dynamic positioning operations on mobile offshore drilling units." *Reliability Engineering and System Safety* 1072–1090.

Dong, Yining, Børge Rokseth, Jan Erik Vinnem, and Ingrid Bouwer Utne. 2017. "Analysis of dynamic positioning system accidents and incidents with emphasis on root causes and barrier failures." *Risk, Reliability and Safety: Innovation Theory and Pratice.* Glasgow.

Eltervåg, Aina, Tommy B. Hansen, Elisabeth Lootz, Else Rasmussen, Eigil Sørensen, Bård Johnsen, Jon Erling Heggland, Øyvind Lauridsen, and Gerhard Ersdal. 2017. *Barrierenotat 2017: Prinsipper for barrierestyring i petroleumsvirksomheten.* Oslo: PSA.

Endsley, M.R. 1995. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors* 37(1): 32–64.

Hogenboom, Sandra, Jan Erik Vinnem, and Ingrid Bouwer Utne. 2017. "Towards an online risk model for DP operations: decison-making and risk information."

Husjord, D., and E. Pedersen. 2009. "Operational Aspects on Decision-making in STS Lightering." *Proceedings of the Nineteenth (2009) International Offshore and Polar Engineering Conference.* Psaka, Japan.

Husjord, Dagfinn. 2015. *Guidance and decison-support system for safe navigation of ships operating in close proximity*. Trondheim: NTNU.

IMO MSC Circ.645. 1994. "Guideline for vessels with dynamic positioning systems."

Kjell I. Øvergård, Linda J. Sorensen, Salman Nazir & Tone J. Martinsen. 2015. "Critical incidents during dynamic positioning: operators' situation awareness and decisionmaking." *Theoretical Issues in Ergonomics Science* 16(4): 366–387.

Kvitrud, Arne, Harald Kleppestø, and Odd Rune Skilbrei. 2012. "Position Incidents during Offshore Loading with Shuttle Tankers on the Norwegian Continental Shelf 2000–2011." *Proceedings of the twenty-second international offshore and polar engineering conference.* Rhodes, Greece.

Øvergård, Kjell I., Linda J. Sorensen, Salman Nazir, and Tone J. Martinsen. 2015. "Critical incidents during dynamic positioning: operators' situation awareness and decsion-making in maritime operations." *Theoretical Issues in Ergonomics Science* 366–387.

Pan, Yushan, Sathiya Kumar Renganayagalu, and Sashidharan Komarndur. n.d. "Tacticle cues for ship bridge operations." *Proceedings 27th European Conference on Modelling and Simulation.*

PSA. 2013. "Principles for barrier management in the petroleum industry."

Rausand, Marvin. 2011. *Risk Assessment Theory, Methods and Applications.* Hoboken, New Jersery: John Wiley & Sons.

Rausand, Marvin, and Arnljot Høyland. 2004. *System Relaibility Theory: Models, Statistical Methods, and Applications.* Hoboken, New Jersey: John Wiley.

Reason, J. 1990. *Human Error.* Cambridge University Press.

Sorensen, Linda J., Kjell I. Øvergåard, and Tone J.S. Maritinsen. n.d. "Understanding human decision making during critical incidents in dynamic positioning."

Sudano, J.J. 1994. "Minimizing human-machine interface failures in high risk systems." *Aerospace and Electronics Conference*. Dayton.

Vinnem, Jan Erik, Ingrid Bouwer Utne, and Ingrid Schjølberg. 2015. "On the need for online decision support in FPSO-shuttle tanker collision risk reduction." *Ocean Engineering* 101: 109–117.

Vinnem, Jan Erik, P. Hokstad, T. Dammen, H. Saele, H. Chen, and S. Haver. 2003. "Operational safety analysis of FPSO-ST collision risk reveals areas of improvement." *Proceedings of the OTC conference.* Houston, USA.

Wickens, Christopher D., Sallie E. Gordon, and Yiliu Liu. 1997. "Chapter 16 Automation." In *An Introduction to Human Factors Engineering*, 493–512. New York: Addison Wesley Longman.

Yang, Xue, and Stein Haugen. 2015. "Classification of risk to support decision-making in hazardous process." *Safety Science* 115–126.