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Use of Simulator Training to Mitigate Risks in Arctic Shipping Operations

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ABSTRACT: Over the recent years, ship traffic in the polar areas has increased. There is reason to believe that this traffic, and especially the cruise traffic, will increase further as the ice retracts towards the poles. There is also reason to believe that with the continued focus and exposure of the Polar Region, the cruise tourism to the region will grow.

The increased presence in the polar areas will create positive repercussions for several actors, both on sea and land. There will, however, also be challenges associated with the growing presence in the polar areas. Vessels will be operating at long distances to other vessels and land infrastructures. These vessels will also be operating in climate and conditions that will put extra pressure on both vessel and crew. These challenges need to be solved in order for the ship industry to operate safely in the Polar Region.

To ensure that companies operating in these areas identify and manage these challenges, the International Maritime Organization (IMO) developed the Polar Code (2017) with the intent of increasing the safety for vessels operating in polar waters, and to reduce the impact on humans and environment in this remote, vulnerable and harsh area. This code defines a number of requirements, with which the vessels should operate in accordance with.

In this paper, we reveal which challenges the vessel and its crew need to deal with when navigating in polar waters. The challenges will be analysed and assessed through the use of a preliminary qualitative risk analysis to determine the potential hazards the vessel is exposed to under operations in polar waters, and to find out what level of risk the different hazards represents for the vessel and its crew. The main objective of the paper is to find out how the risk levels can be reduced, with particular focus on the use of simulator training as a risk reducing measure. The final goal is to measure the risk towards acceptance criteria, which have been determined prior to conducting the analysis.

1 RISK ANALYSIS

Before conducting the preliminary hazard analysis, it was necessary to investigate the challenges related to navigation and operation in the Arctic. This was done through literature studies, interviews with experts on the field and review of statistical data. (Gudmestad et al. (1995), Koponen (2015), Kozuba and Bondaruk (2014), Rothblaum et al. (2002), Samuelsen et al. (2015), DNV (2010), DNV GL (2014), Rambøll (2011), Hjelmervik et al. (2018), Dalaklis and Baxevani (2018)).

The main findings in this research were as follows:

- The positioning systems and equipment, such as satellite systems, gyrocompass and magnetic compass are strongly affected by the high latitudes. Communication is also challenging due to long distances and lack of infrastructure.

- Another factor to consider are the conditions of the physical environmental. Both vessel and vital equipment can be severely affected by icing under given circumstances. Cold climate can also affect equipment in other ways, e.g. by reducing power source capacity.
- Challenges connected to human error were investigated in detail, as human error is the main source of maritime casualties. Studies of literature and statistical data showed that arctic operating conditions would increase the possibility of several kinds of human errors such as fatigue, complacency, poor judgement etc.
- As a final part of the work to identify the challenges of operation under arctic conditions, navigation in ice was discussed, as this is a vital part of operations in the Arctic.

Based on the findings related to operation and navigation in the Arctic, a preliminary hazard analysis was conducted. How to determine the risk connected to different kind of problems related to arctic operating conditions is, however, difficult due to lack of available statistical data. The conducted *qualitative risk assessment* was therefore strongly dependent on literature review and expert opinions.

The preliminary hazard analysis is shown below in Table 1. The results are summarized in the risk matrix in Table 2. The suggested accept criteria represent our best assessment. Note that a wide ALARP region (yellow color in Table 2) is suggested to ensure that cost benefit analysis can be incorporated. Table 3 shows the risk matrix with mitigating measures implemented. The effects of simulator training are highlighted.

Table 1. Preliminary Hazard Analysis

Hazard number	Problem	Cause	Possible consequences	Pre risk-reducing measures risk	Risk reducing measures	Post risk-reducing measures risk
Natural and environmental hazards						
1.1	Icing on hull	Icing due to sea spray and metrological factors	Reduced stability, reduced maneuverability, danger of equipment failure	P: 3 C: D	Heating of hull and equipment, manual removing of ice	P: 2 C: B
1.2	Difficulty to keep the vessel on course	Wave-, wind- or current-forces affecting the movement of the vessel through the water	Trouble following the intended route, possible grounding.	P: 4 C: D	Planning based on weather-information, adequate monitoring of the voyage, well trained personnel	P: 2 C: B
1.3	Reduced visibility	Icing on windows, reduced visibility due to fog, snow or rain.	Difficult to navigate by the use of optical techniques, difficult to detect other vessels or obstacles (ice), possible grounding or collision	P: 4 C: D	Deicing of windows, planning based on weather information, use of other equipment for navigational purposes, training of personnel	P: 2 C: B
Failure and inaccuracy of equipment						
2.1	Loss of GNSS-position	GNSS blackout	No position available, ECDIS failure, possible grounding	P: 2 C: C	Redundancy, training of personnel	P: 1 C: B
2.2	Inaccuracy for GNSS-position	Satellite-geometry, manipulation of satellite signal	Wrong position displayed to user, wrong position as ECDIS-input, possible grounding	P: 3 C: C	Use of more than one satellite system, training of personnel	P: 2 C: B
2.3	Freezing of GNSS-position	Icing on antenna, failure of receiver	Wrong position displayed to user, wrong position as ECDIS-input, possible grounding	P: 3 C: C	Deicing of antenna, redundancy, training of personnel	P: 1 C: B
2.4	Gyro Failure	Blackout, mechanical Failure	No heading-information provided to user, ECDIS-failure	P: 1 C: D	Redundancy, heading from magnetic compass, training of personnel	P: 1 C: B
2.5	Gyro Inaccuracy	High latitude, high speed, steering N-/S-course	Wrong heading-information provided to user, wrong heading as ECDIS and radar input	P: 5 C: C	Manual or automatic compensation for error, use of more advanced compasses, monitoring of voyage, training of personnel	P: 4 C: A
2.6	Magnetic compass failure	Frozen fluid, mechanical failure	No heading from magnetic compass provided for user	P: 1 C: A	No risk reducing measures needed	P: 1 C: A
2.7	Magnetic compass inaccuracy	Magnetic deviation, magnetic variation, un-calibrated compass	Wrong heading-information from magnetic compass provided for user	P: 5 C: A	Manual compensation for error, monitoring of voyage, training of personnel	P: 3 C: A
Human errors						
3.1	Fatigue	Lack of sleep, darkness, daylight	Reduced attention, increased response time, possible grounding/collision	P: 4 C: D	Reduced time on watch, extra lookout, training of personnel	P: 3 C: C
3.2	Complacency	Long watches with	Reduced attention,	P: 3	Reduced time on watch,	P: 2

		little action	increased response time, possible grounding/collision	C: D	extra crew, attitude forming, training of personnel	C: C
3.3	Inadequate technical knowledge	Special equipment only used under certain circumstances (Ice-radar, ice-charts)	Increased response time, wrong use of equipment, possible grounding/collision	P: 3 C: D	Checklists, follow-up on crew-competence, extra crew, training of personnel	P: 1 C: C
3.4	Poor equipment design	Loss of night-vision due to light pollution, equipment being inefficient placed	Navigational error, possible grounding/collision	P: 2 C: D	Testing of equipment, user feedback, personnel training	P: 1 C: D
3.5	Decisions based on inadequate information	Only use one method or aid, relay on limited information, complacency	Navigational error, possible grounding/collision	P: 3 C: D	Checklists, attitude forming, training of personnel	P: 2 C: D
3.6	Poor judgement	Lack of information, lack of experience, fatigue, complacency	Navigational error, possible grounding/collision	P: 4 C: D	Checklists, attitude forming, training of personnel	P: 3 C: D
3.7	Faulty standards, policies or practices	Lack of procedures, pressure to meet schedules, profit first thinking	Navigational error, possible grounding/collision	P: 3 C: D	Regulations and control by authorities, inspections, attitude forming	P: 2 C: D

Table 2 Risk Matrix prior to mitigating measures

Consequence→ Probability ↓	A Minimal	B Low	C Medium	D High	E Very High
5-Very high	(2.7)		(2.5)		
4-High				(1.2), (1.3 (3.1), (3.6)	
3-Medium			(2.2), (2.3)	(1.1), (3.2), (3.3), (3.5), (3.7)	
2-Low			(2.1)	(3.4)	
1-Very low	(2.6)			(2.4)	

Table 3. Risk matrix after implementation of mitigating measures. Those measures involving simulator training are marked in **bold.**

Consequence→ Probability ↓	A Minimal	B Low	C Medium	D High	E Very High
5-Very high					
4-High	**(2.5)**				
3-Medium	**(2.7)**		**(3.1)**	**(3.6)**	
2-Low		(1.1), **(1.2)**, **(1.3)**, **(2.2)**	**(3.2)**	**(3.5)**, (3.7)	
1-Very low	(2.6)	**(2.1)**, **(2.3)**, **(2.4)**	**(3.3)**	**(3.4)**	

During the development of the preliminary hazard analysis, we investigated how simulator training could be used as a risk-reducing measure for each problem/ unwanted event. For some problems, simulator training would have no impact on the risk level. For other problems, simulator training was found to have a significant risk-reducing effect. Different problems and scenarios were tested in the K-sim Navigation simulator (Kongsberg Maritime, 2018) at the Arctic University of Norway in Tromsø (UiT) to assess how the different kinds of problems could be simulated.

After implementation of the suggested mitigating measures, the risk associated with some of the problems should be reduced further, if possible. These are the problems where the risk falls in the ALARP zone.

2 EVALUATION BY EXPERIENCED PILOTS

To support the findings collected during the evaluation of problems associated with the ice-conditions, feedback regarding the simulation of ice-conditions were collected during a Polar Code certification-course at UiT in week 22, 2018. The participants at this course were Norwegian pilots who are piloting in the waters around Svalbard. The pilots participated in a standard simulator exercise during the certification courses for the Polar Code at UiT. The exercise (using the *K-sim platform*) included encounter with several different types of ice, including icebergs. After the simulation exercise, two of the pilots shared their thoughts regarding the simulation of operating in ice. Their opinions were:

- In general, the simulated environment is realistic and close to the real-life scenario.
- The visual factor is good, but in real life, it is easier to assess the thickness of the ice. In the simulator exercise, it was difficult to detect which ice was too thick to pass through.
- The quality of the simulated radar-image is satisfactory compared to a real-life radar. It could, nevertheless, not be compared to the quality of a real-life ice-radar.
- For training of personnel who are intended to operate in the waters around Svalbard, it will be very useful to participate in a simulator exercise with sludge ice and with elements of small icebergs and growlers; as such conditions represent normal operating conditions around Svalbard.
- The use of simulator exercises can absolutely reduce the risk in real life situations compared to having unexperienced personnel without training.

The above-mentioned factors are important to keep in mind when designing exercises for use as a risk-reducing measure. The eventual weaknesses of the simulated environment can to some degree be compensated for when designing the exercises.

The preliminary hazard analysis shows that simulator training can contribute in reducing the risk for most of the hazards that are found to be a threat in polar operating conditions. Especially when it comes to human error, which is the main source of error in the maritime industry, simulator training is found to be one of few effective ways in reducing risk. For more technical types of errors, such as equipment failure, simulator training is found to be useful, but then as an addition to conventional risk reducing measures such as duplication of equipment, regular maintenance etc.

It is unquestionable that operations of vessels in the polar area are connected with high risk due to increased probability for accidents to happen and increased consequences due to lack of infrastructure and harsh environmental conditions. A vessel operating in these areas without preparation and adjustments for such operations is not only breaking the law. It is also operating under a risk level that exposes the vessel and crew for immediate danger that can result in loss of lives and asset values. The preliminary risk analysis shows that the risk can be reduced to an acceptable level if mitigation measures are implemented.

3 SIMULATOR EXERCISES

Now, the next step would be to develop simulator exercises that can be used as a risk-reducing measure prior to operations in polar areas. These exercises would have to be assessed by experts in the field who has experience with operations under such conditions, in order to make the simulated environment as close to real life as possible. It may then be necessary to adjust the preliminary hazard analysis, as some of the simulated situations may not have the intended effect on the risk. The preliminary hazard analysis should, however, be a useful tool for development of the initial simulator exercises.

Regarding the technical part of the simulation, the main finding when trying out the different features regarding simulation of polar operating conditions is that the *K-sim platform* experiences some problems when it comes to simulation of radar-image in ice. It would therefore be interesting to investigate if it is possible to implement real-life radar images as a part of the simulator exercises. This is something that has to be considered when developing the simulator exercises.

Otherwise, the K-sim platform is found to be realistic when it comes to ice, especially the visual part. This is further strengthened by the feedback from the Norwegian pilots, who have experience from operations in polar waters. The level of realism is, however, something that have to be assessed through the initial simulator exercises before it is possible to determine how close to reality the simulator exercises can be. The level of risk-reduction through simulator exercises is strongly dependent on the realism in the exercises.

4 CONCLUSION AND FURTHER WORK

Simulator training can be used as a mitigating measure in reducing the risk when operating in polar conditions, especially to reduce the risk related to human errors. Simulator exercises could also contribute in reducing the risk related to technical errors, but then as a supplement to implementation of conventional risk reducing measures, such as duplication of equipment etc.

The main suggestions for further work are:

- Development of general simulator exercises to be used as risk reducing measures for operations in polar areas.
- Quality assurance of the exercises through feedback from experts in the field with experience from conditions being simulated.

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