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Human and operational factors in the risk assessment of ship-to-ship operations

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Abstract

This paper presents human and operational factors related to risk assessment during the operations of crude oil, petroleum products, and liquefied gas transfer between ships, called Ship to Ship (STS) operations. The lessons learned from accidents during STS when both ships are underway show that the most frequent accidents occur due to ship handling errors. Several influencing factors have already been identified, however there is still a need to investigate the human factor. Both human and operational factors are interrelated as the operational factors influence the human stress level. This paper identifies the stressors related to the external pressures imposed on the ship's staff, which can be limited to improve safety. The preliminary study of the influence of particular elements of human factors, e.g., personality traits and stress levels, on the probability of ship handling error is presented.

Introduction

The transfer of crude oil, petroleum products, and liquefied gas between two ships underway or one ship mooring alongside another at anchor is called STS (Ship to Ship) and requires the specific pre-planning of each phase of operation and implementation of appropriate safeguards to ensure that any identified risk is effectively managed. STS lightering is the operation of a smaller tanker (service ship) in ballast condition approaching alongside a loaded larger tanker (STBL – ship to be loaded). The reverse lightering starts with the approaching and berthing of a loaded service vessel alongside the STBL either partly loaded or in ballast condition. The passage plan of STS operation includes the details of all STS phases: approaching, mooring, unmooring, and emergency procedures.

STS Operations began to be legally regulated by IMO MEPC 186 (59) in 2010, which was a proactive initiative by the IMO (Glykas, 2017). The main guidelines related to the risk assessment of the crude oil, petroleum products, and liquefied gas between ships that are included in the OCMF/ICS/SIGTTO/CDI Ship to Ship Transfer Guide (Guide, 2013) and MARPOL Chapter 8 of Annex 1 consider structural factors, machinery equipment, outfitting, human and external factors, compatibility studies, and incident management.

The developments related to STS procedures and determination of the main factors that affect the operation are based on the lessons learned from accidents (Ventikosa & Stavroub, 2013). The approaching operation, followed by berthing, has been recognized as the operation most conducive to incidents. The large number of claims related to incidents that occur during STS berthing operations was one of the reasons for SHIPOWNERS P&I Club publishing a set of procedures with the aim of ensuring that the approaching operations are properly planned (Officer of the watch, 2016). According to the club's recommendations, diligent planning included the human element as a major factor during the organisation and assessment of an STS operation. The human element was also a major factor related to the assessment of STS operations indicated in an Online STS safety circular (Glykas, 2017).

The errors related to the human factor and operational procedures are recognized as the main reasons of incidents and accidents and are mainly related to the crew experience and training, as well as equipment maintenance and inspection. Some causal factors are directly linked to the crew experience or STS service provider expertise.

Human errors can be related to communication, work environment, mental and physical fatigue, knowledge, training, experience, and use of technical systems. They are addressed in codes, standards, and regulations, however, there are certain measures that have not been well-recognised so far, such as stress and attitude towards risk, which can both influence ship handling errors during STS operations. Carotenuto et al. (Carotenuto et al., 2012) published an analysis of stressors affecting seafarers and determined the most important mental, psychosocial, and physical stressors to be:

- separation from family;
- loneliness onboard;
- fatigue;
- collaboration with multi-national crew;
- limited physical exercise;
- poor sleep quality and short sleep duration.

Further investigations towards the influence of stress levels and personality traits on ship handling errors based on the results of psychological tests and trials performed by marine pilots and Ship Masters on a full mission ship handling simulator and physically manned models were presented by Hejmlich (Hejmlich & Abramowicz-Gerigk, 2017). The research on the operational and human factors affecting safety of STS approaching operations that focus on possible ship handling errors are described in the paper.

High-risk events related to human and operational factors during STS approaching operations

A risk assessment should consider the identified hazards and residual risks following the application of appropriate safeguards, controls, or mitigation measures. It is an important part of the pre-STS planning process and should consider the following factors (Guide, 2013):

- adequacy of navigational processes;
- training, experience, and qualifications of personnel;
- adequate number of personnel assigned to control and perform the transfer operation;
- adequacy of communication between ships and/or responsible persons;
- ship compatibility, including mooring arrangements;
- suitable preparation of ships for the proposed operations and sufficient control during operations;
- emergency planning and procedures.

Upon the completion of the operation, the appropriate risk management strategy should be developed to cover both physical and operational hazards to ensure that all identified risks are reduced to an acceptable level, with necessary additional mitigation measures (Guide, 2013). The STS approaching operation involves the tankers being exposed to the possibility of direct ship contact or collision, which could cause damage to them with the extent of damage dependent on the approach course and speed of the service ship (Guide, 2013).

A high-energy collision may occur as a result of inadequate navigational control by ships involved in STS transfer operations, resulting in significant equipment damage, fatalities, and loss of containment. To minimize the impact of a high-energy collision, STBLs are equipped with side-facing primary fenders on the sea surface that are designed to adsorb a portion of the energy of the approaching vessel.

Low-energy collisions may occur by inadequate control during berthing/unberthing and side-by-side operations with hull-to-hull contact/collision leading to physical damage to one or both ships. It may occur during the final stage of the berthing operation when the ship speeds are low, but the courses of the approaching tanker and STBL are not parallel. The hulls of both tankers should be protected by secondary rigged fenders, which should be re-positioned according to the situation.

Casual factors

Ship-to-Ship Procedures should consider the causal factors that are presented in the OCMF/ICS/SIGTTO/CDI STS guidelines (Guide, 2013) and the MARPOL Chapter 8 of Annex 1. The accepted operational causal factors that could contribute to high-level risks are presented in Figure 1.

The Bayesian network (BN) is a directed acyclic graph has been implemented to model the influence of human and operational factors on the total probability of an accident (Figure 2). The nodes of the

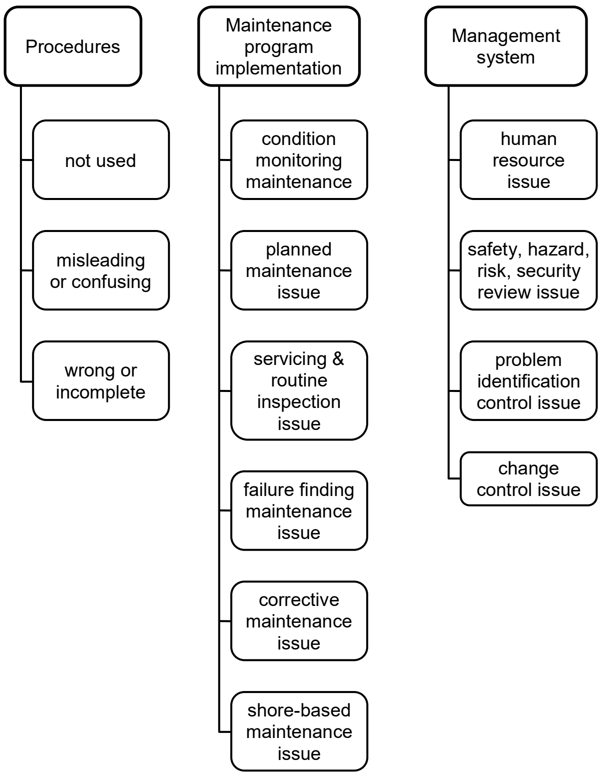

Figure 1. Operational factors contributing to high-level risk related to STS operation, based on (Guide, 2013)

network represent the random variables – the casual factors during STS approach operations, and the arcs signify direct causal relationships between the linked nodes.

The BN represents the joint probability distribution based on the chain rule and assumes independence between variables. The network presented in Figure 2 allows prediction of the total probability of human error due to the casual factors. The set

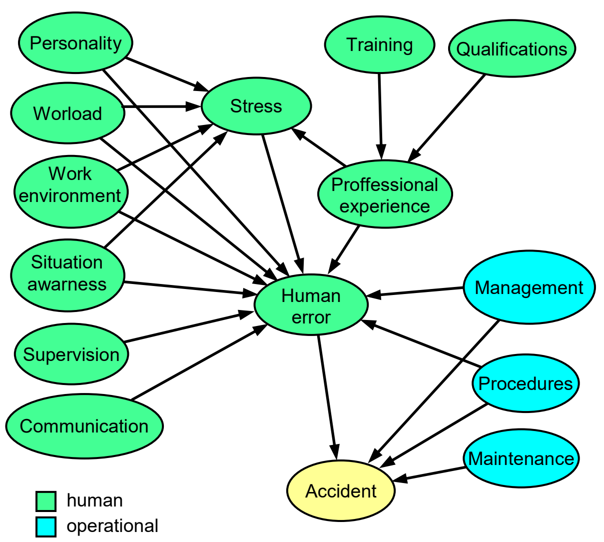

Figure 2. Bayesian network for the determination of the influence of human and operational factors on the probability of an accident

of factors related to the human element included in (Guide, 2013) was extended in the presented BN by Ship Master personality and stress level.

Poor training and negligence are included in the ISM Code and STCW Convention. The remaining components create a psychological profile of a human being that can be studied. In light of recent research, they are measurable and can be correlated with human performance (Hejmlich & Abramowicz-Gerigk, 2017).

Human factor study

A high stress level mainly disrupts the decision-making process and leads to erroneous actions or omissions. Stimulating risk leads to undertaking a riskier decision, thus a person with a high level of stimulating risk tends to perform actions without thinking of the consequences. A person with a high level of instrumental risk makes decisions only after considering the chances of success and possible losses as a result of their action.

Carotenuto et al. (Carotenuto et al., 2012) suggested that ship owners should provide coping strategies to lower the stress levels and improve the quality of life of their crew. Knowing the psychological profile of the Ship Master can significantly modify the impact of stress factors and allows the planning of preventive measures to reduce psychological stress (Makarowski, 2012; 2016).

Research on the human factor (Abramowicz-Gerigk, Burciu & Hejmlich, 2015; Abramowicz-Gerigk & Hejmlich, 2015; Hejmlich, 2016; Hejmlich & Abramowicz-Gerigk, 2017) was carried out with a group of 32 Ship Masters that were allowed to develop the list of stressors shown in Table 1. The underlined stressors in the table were selected by the Ship Masters as the most important.

Of the underlined stressors, the stressors printed in bold letters are related to external pressures (13, 14, 15, 16, 17, 18, 19, 20, and 23) imposed on the ship's staff, which can be limited or eliminated to enhance safety.

The psychological analysis of the questionnaires allows the psychological profile to be defined – personality, stress vulnerability level, and attitude towards risk (Hejmlich & Abramowicz-Gerigk, 2017).

Ship-to-ship manoeuvres should be carefully planned and precisely followed. This kind of human act is a feature of a person called a 'perfectionist,' and people performing tasks strictly according to plan are characterised by a high level of conscientiousness.

Table 1. Stressors

Stressor No.	Stressor description
1	Continuous wariness about ship's safety in aspect of fire, collision, grounding
2	Wariness about ship's safety in difficult weather conditions: storm, fog, ice
3	Continuous wariness about possible failure of ship's equipment: main engine, diesel generators, steering
4	Tiresomeness of navigation in dense traffic areas
5	Frequency of approaching and departing manoeuvres
6	Port manoeuvres in bad weather conditions, under strong current
7	Manoeuvers in restricted areas (small ports)
8	Prolonged manoeuvring
9	Continuous wariness about safety of the crew
10	Conflicts among the crew members
11	Low competency of crew members
12	Lack of internet access
13	**Lack of time to rest**
14	**Continuous inspections in port**
15	**Shortage of crew members on board**
16	**Time stress, continuous acting in haste**
17	**Pressure from ship owner**
18	**Pressure from charterers**
19	**Lack of competency of shore based office**
20	**Conflicts between ship and shore office**
21	Limited relax possibilities
22	Work at night
23	**Paper work overload**
24	Sleeping trouble due to time zones changing

Two approaching and berthing manoeuvres were performed on the Full Mission Simulator Simflex 4.6 with 95 participants – students of Gdynia Maritime University Faculty of Navigation. The appraisal of the tests included the following steps:

- preparation of a plan for approaching and berthing tasks;
- approaching the STBL;
- berthing to STBL.

The possible scores ranged from 0 to 1.

The percentage of students that correctly performed particular steps during the test is presented in Figure 3.

The number of students that correctly performed the approach and berthing operations with a score between 0.9 and 1.0 and a score of 1.0 are presented in Table 2.

The most common errors that were committed during the tests were the service ship approaching the STBL too closely and coming alongside the stern of the STBL.

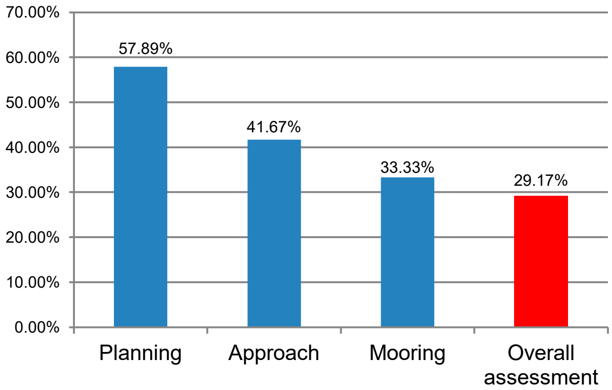

Figure 3. Percentage of students correctly performing particular steps of the test

Table 2. Number of students who performed the approach and berthing operations correctly with scores between 0.9 and 1.0 and a score equal to 1.0

1.0 > Score > 0.9	No. of students	55	40	31	28
	Percentage of the group	57.89%	41.67%	33.33%	29.17%
Score = 1.0	No. of students	36	20	17	3
	Percentage of the group	37.89%	20.83%	18.28%	3.13%

The sequence of manoeuvres during the approach of the service ship when performed with no errors is presented in Figure 4.

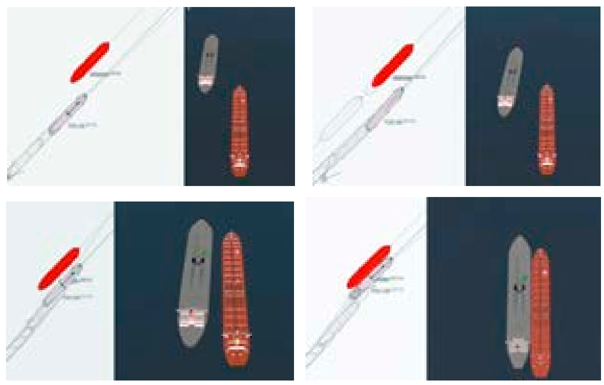

Figure 4. Service ship approaching STBL on the parallel course with the sufficient side distance, approaching parallel and adjusting speed with course 1° smaller than she goes

Ship handling errors during the STS approaching manoeuvre – too close approach and approach with wrong course of the service vessel resulting in a collision are presented in Figure 5.

The results of the STS approaching tests carried out with a group of 95 students are as follows:

- 29.94% of participants displayed a maximum level of conscientiousness;

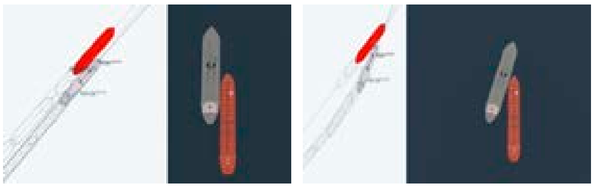

Figure 5. Ship handling errors during STS approaching manoeuvre – too close approach and approach with wrong course of the service ship relative to the STBL

- 29.17% of participants performed the task correctly.

To considerably reduce the risk of an accident, it is important to designate an appropriate operator that is not only well-trained and experienced, but also physically and psychologically fit to work under high-tension situations.

Conclusions

The main conclusion of this study is that the designation of an appropriate operator who is not only well-trained and experienced, but also physically and psychologically fit for work under high tension situations can considerably reduce the risk of an accident during an STS approaching operation.

Knowledge about causal factors was considered during the development of barriers and preventive measures that were aimed at minimizing the occurrence of associated risk (Gerigk, 2015).

Using a Bayesian network or Fuzzy logic modelling, we can estimate the influence of each component to the risk of a wrong decision and a ship handling error that leads to a near-miss, incident, or accident.

Risk reduction measures, along with their effectiveness and means by which they are managed, should be documented and applied to human and operational problems.

Procedures and checklists from the Ship ISM system are an important risk-management tool aimed at ensuring that operations are conducted safely. They are essential reminders of the principal safety factors to consider, but they should be supplemented by continuous vigilance throughout the entire operation (Wilczyński, 2014). Presently, all training centres offer a special ship-handling training on Full Mission Simulators to build experience, proper manners, and behaviours for bridge watch duties in different situations during an STS operation.

It should be noted that the checklists and questions that have been developed to specifically address factors relevant to the STS operation are supplementary to those contained in standard pre-transfer checklists, such as the International Safety Guide for Oil Tankers and Terminals (Wilczyński, 2014).

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