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Kapittel 8

LNG shipping: Exploring ship crew fatigue risks related to work environment for FSRUs compared to conventional LNG-tankers

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Abstract: This chapter encompasses seafarers' working and living conditions on-board FSRUs versus conventional LNG-tankers. While conventional LNG-tankers transport liquefied natural gas (LNG), FSRUs are stationary ships functioning as an import terminal, receiving LNG from LNG-tankers. The point of departure for this study concerns how the nature of LNG shipping operations, its commercial, organisational, and technical aspects, internally and externally in an LNG shipping company, impacts the work life on-board.

For FSRUs, the crew act as terminal operators and not seafarers, which partly falls outside the pre-existing governing rules and regulations set by the maritime industry. This may not be taken sufficiently into consideration by LNG shipping companies. An undesirable outcome may be situations of crew stress, which in the long run may lead to fatigue and have implications for safety orientation.

Workload and stress factors are introduced and analysed against existing knowledge of rules and regulations on fatigue mitigations. This study explores possible job stressors and changes in the psychological and social relations amongst the crew as a ship-board team for FSRUs versus LNG-tankers. The research question is: What are ship-crew fatigue risks related to the work environment on-board FSRUs compared to conventional LNG-tankers?

Keywords: seafaring, work stress, determinants of fatigue, gas tanker, safety at sea, liquefied natural gas (LNG), exploratory study

Introduction

The nature of LNG marine shipping includes safety risks linked to possible cargo spill during i) ship-to-ship (STS) transfer of LNG, ii) LNG storage on-board, iii) regasification of LNG, and iv) ship-to-shore transfer of gas (Bartlett, 2019), with potential hazards such as fires, explosions, and asphyxiation (Parihar et al., 2011). Two LNG vessel sub-types and segments are floating storage regasification units (FSRU) and conventional LNG-tankers for transport of LNG. LNG-tankers and FSRUs are nearly identically constructed and identically manned with conventional seafarers, certified – and usually employed – within one LNG shipping company (see for example Golar LNG, 2023). FSRUs operate as a stationary floating storage unit connected directly to the gas grid ashore, supplying the end-consumer with gas. Therefore, the crew (officers and rating) on-board FSRUs demands a different set of competence and skills than for an LNG-tanker. The LNG markets, including the marine shipping of LNG, are growing at a fast pace (see for example LNG industry, 2023).

This chapter includes field work on the LNG marine industry that enabled the observation and identification of job stressors among crewmembers. To our knowledge, this chapter is the first to examine seafarers' well-being and fatigue risks related to the work environment on-board FSRUs versus LNG-tankers. The objective is to identify job stressors and changes in the psychological and social relations among the crew as a team, including work roles and aspects seafarers can be involved in on-board FSRUs and not on-board LNG-tankers. The research question is: What are the ship-crew fatigue risks related to the work environment on-board FSRUs compared to conventional LNG-tankers?

The findings presented should be relevant for crew management departments and LNG shipping company strategy decision-makers linked to crewing strategy and crew training needs. Ship manning is key to safe operations and one of the assets for any shipping company; therefore, competent, motivated, and loyal seafarers are irreplaceable.

The next section provides a theoretical framework. Section 3 explains the study method. Section 4 describes limitations. Section 5 contains results and discussion. Section 6 concludes the study, presents managerial implications, and suggestions for future research.

Theoretical framework

Work environment and crew fatigue risks

According to Lorange (2010), many shipping companies employ crew who do not necessarily have the required competence to serve the dynamic growth of the company. Even though the professional career path of a seafarer starts at a maritime university and results in a certificate of proficiency – either in the engine department or deck – in accordance with the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) (IMO, 2019b), core competencies are unique strengths, deeply embedded within a firm and obtained through experience (Rothaermel, 2017). This implies taking on greater ownership of the diversity that exists on-board, which in turn may become an asset and a productive resource for the organisation (Adler & Gundersen, 2008).

Safety climate and psychosocial work environment have been reported to have an influence on seafarers' mental and physiological fatigue. Hystad et al. (2013) found that seafarers who reported high psychological demands and perceived the organisational-level safety climate negatively reported significantly more mental fatigue.

Although fatigue is an abstract concept, its symptoms can be decisive in many ways. Most commonly, it is a state of feeling worn-out, exhausted, or sleepy. Short-term fatigue is generally cured by a nap or a good night's sleep. Chronic fatigue is more persistent and causes more serious, enduring effects with a negative influence on performance and morale (Jepsen et al., 2017). According to Carotenuto et al. (2012), fatigue can be ascribed to combinations of loneliness, sleep deprivation, separation from family, long unpredictable working hours and shift work, inadequate qualifications of junior officers or other officers, and insufficient manning.

The International Maritime Organization (IMO) defines fatigue as

> A state of physical and/or mental impairment resulting from factors such as inadequate sleep, extended wakefulness, work/rest requirements out of sync with circadian rhythms and physical, mental or emotional exertion that can impair alertness and the ability to safely operate a ship or perform safety-related duties. (IMO, 2019a)

Jepsen et al.'s (2017) field study showed that chronic fatigue and stress at work can be a result of long work schedules, demanding mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep caused by shift work and crossing time zones. Human errors are considered among the reasons for maritime accidents, and fatigue has been listed as one of the causes (Grech et al., 2008; Jepsen et al., 2017). According to Jepsen et al. (2017), there is a need for a cultural change in the industry's attitude towards practical perception of performance, which involves ship's and shore staff as well as everyone else interacting with ships and personnel. Poor management structure and organizational factors may lead to crew fatigue.

Four sub-categories of potential risk factors for crew fatigue are specified by IMO (2019b): (1) Crew-specific factors, (2) Management factors, (3) Environmental factors, and (4) Ship-specific factors.

(1) Crew-specific factors:

Crew-specific factors are related to lifestyle behaviour, personal habits, and individual attributes. One example of a crew-specific factor is sleep deprivation (Skrede, 2016). Work-related stress delays the ability to adapt, and response time is slow or non-existent (Allen et al., 2008). According to Oldenburg et al. (2013), significant stress parameters can be divided into two main groups: psychosocial stress and physical stress. Psychosocial stress factors rely on the self-assessment of the person's own condition and on the degree of work-produced personal satisfaction. This entails career aspects, monotony, separation from home, long and irregular working hours, length of contract, perceived political situation, increased workload, and high level of leadership responsibility (time pressure and pressure related to decision making, inadequate qualification of subordinate crew). Physical stress factors pertain to the conditions in which work is carried out, e.g., noise, vibration, air pollution, temperature changes, and ship movement. McVeigh et al. (2019) suggest that dispositional resilience is an important factor with regards to perceived stress, as well as instrumental work support may be an important factor in relation to job satisfaction among merchant seafarers.

It must be recognized that seafarers are captives in their work environment, with no clear separation between work and recreation. In such an environment, interpersonal and group dynamics are important. Seafarers bring on-board patterns of behaviour that are nationally and culturally determined

(Håvold, 2007). These patterns do not change quickly or easily. Therefore, on-board ships, the integration between the individual and the hierarchical system is crucial. Access to the Internet can be important to keep in touch with family and friends and may have an impact on stress and fatigue. A sedentary lifestyle or lack of physical activity tends to have a negative impact both psychologically and physiologically (Carotenuto et al., 2012).

Management factors

According to the IMO guidelines (2019b), management factors refer to how the ship is organized and operated. The labour market for international shipping is vastly globalized, regulated, and standardized, according to IMO, ILO-implementation, and STCW (IMO, 2019b). Bjune (2015) points out that there is an increasing demand for seafarers from low-wage countries. Cultural differences in job satisfaction amongst European and Filipino crew members showed differences in the perception of safety, leadership, exposure to harassment, team cohesion, and intentions to leave (Nielsen et al., 2013). According to Lorange (2010), international shipping is a global enterprise; human resources still find themselves within cultural and national boundaries. This means that there may be a situation on-board a ship where crew skills and competencies within its cultural and national niche are among critical success factors. From a cognitive point of view, this is rather complex and difficult to handle, in which seafarers are the target of someone else's, the onshore management, change initiative. Unresolved conflicts can potentially become dangerous and result in a lack of motivated and loyal seafarers (Atkinson, 2012).

Environmental factors

Environmental conditions on-board are the main area where the classification societies' rules and guidance can be used to alleviate fatigue (DNVGL, 2018). However, there is a limit on what can be achieved through design intervention concerning the ambient environment. Considering this, the working environment and the working practices should be designed to reduce or compensate for crew fatigue (IMO, 2002). Environmental factors can be internal and external. Crew noise exposure on-board and undesirable noise levels at work have

become one of the most important physical design aspects of ships as far as human health, habitability, and environment are concerned (Turan et al., 2011).

Ship specific factors

Although the vessels' increasing complexity, advanced technology, and modern ship design have reduced the number of crew required on-board the ship, the role of a seafarer and their presence on-board is equally important today (Bjune, 2015). The ship design and equipment are often specific and built along with the development of freight service innovations (Dokkum, 2013). The FSRU regasification is a thermodynamic process that involves large energy quantities (Yoonho, 2019), which may lead to significant levels of noise and vibrations, affecting the crew working and living conditions in a different way than on-board an LNG-tanker. According to Martins et al. (2016), unloading an FSRU by vaporization of LNG (i.e., regasification) is a critical operation: although the accident rate of LNG facilities is low, it cannot be disregarded.

Minimum safe manning

The minimum requirements for the number of crew on-board are set by the flag state. Nevertheless, the company may imply an additional number of crew on-board, depending on the trade and factors such as the degree of automation, mechanical operations, and agreed crew budget (Stopford, 2009). Noticeably, the flag state only acts as an advisory organ in terms of minimum safe manning on-board ships. It is the company's responsibility, in accordance with the IMO Resolution A.890(21), "Principles of Safe Manning", to crew the vessels in an acceptable, safe, and appropriate manner. This ensures safe operation and prevention of pollution from ships affected by article III 1979 STCW Convention (IMO, 2019b). According to IMO (2002), one way of measuring the appropriateness of the manning level is to look at the work and rest hours.[1] According to the review study by Dohrmann and Leppin

1 Article 5 – under Appendix 4, part II – *Seafarers' hours of work and hours of rest*, states: (a) Maximum hours of work shall not exceed: i) 14 hours in any 24-hour period; and ii) 72 hours in any seven-day period; or (b) Minimum hours of rest shall not be less than: i) ten hours in any 24-hour period; and ii) 77 hours in any seven-day period.

(2017), work-time related factors are among the most frequent determinants of seafarer fatigue.

Research method

The adopted research strategy is a qualitative exploratory case study (Yin, 2017). Sources of data include literature reviews, personal communication, webpages, documents, and interviews, both on-board and in the office milieu on shore. The literature review was conducted by using academic databases and search engines. Primary data collection was achieved by semi-structured interviews. The interviews were conducted in 2018 by one of the authors. The interviewees were interviewed individually. Seven interviews were conducted. The questionnaires and information about voluntary participation were handed out to each of the interviewees before the interview commenced. The interviews were conducted during ship visits, and each interview lasted between 30 and 60 minutes. A follow-up phone call interview was done with one of the interviewees. The number of interviews performed, combined with our other sources of data as described above, achieved saturation of data.

A case shipping company was selected based on the following criteria:

1. The company should own and manage both LNG and FSRUs.
2. The company should be ready to share their practice and policy on ship manning.
3. Their managers should be willing to allow for on-board meetings with ship crewmembers in face-to-face scheduled interviews.
4. Primary data, from interviews and meetings, should comprise both senior officers, junior officers, and ratings, with representatives from all departments on-board.

One LNG shipping company, hereinafter called "the company", agreed to participate in the study. The informants are sourced from the same crew pool within the same ship-owner that has been operating both FSRUs and LNGs for approximately 12 years. They are qualified and in compliance with the requirements applicable for the rank and position according to prevailing standardised rules and regulations for seafarers employed to work on conventional LNG

carriers (LNG). The selected company holds a crew pool of approximately 700 employees. The interviewees have agreed to informed consent and were given the opportunity to refuse to answer – wholly or partly – any of the questions. None of the chosen participants refused to be interviewed nor withdrew from the interviews after they had begun.

This study has a dimension of field study, as one of the authors had the role of crewing manager in the same company. This role, among others, enabled interviews of crew members to be conducted on-board. Because the research design of this project is exploratory, the aim is to ask questions as well as to encourage further investigations of the required skills and competencies for FSRU crews. Previous examinations of ship-owners' attention to crew manning of FSRUs are limited. Therefore, an inductive approach was taken in order to identify and understand enablers, drivers, and impediments experienced by the LNG industry (2023) linked to human factors and enduring safe operations.

Study limitations

There are three limitations of the presented research. Firstly, the company that is the object of this study was not selected randomly. One of the authors' working relationship, as crewing manager, was conducive to the fulfilment of this study. Secondly, company data on operational safety-critical work tasks (e.g., shipping company safety management systems' procedures and investigation reports) could not be systematically investigated to seek causes and effects, and analytically reveal risk factors. However, in lieu of the rather modest, exploratory purpose of this chapter, it was decided to employ the interview data with seafarers as they were reported. Thirdly, a challenge associated with the chosen exploratory longitudinal case study design is the possible lack of generalizability, or external validity. This study is not designed to investigate empirical consistencies that are to be generalized to a wider group of LNG ship-owners than the one where material was collected. Therefore, generalizations from evidence presented in this chapter should be made to theory and not to a wider range of LNG ship-owners and managers.

Results and discussion. Stressors for crews serving on LNG-tankers versus FSRU

The well-being of crewmembers, and the possible differences between LNG and FSRUs, may relate to individual conditions such as rank, age, and belonging to a ship department. It appears that in FSRU service, interaction between ship-ports and between ship-terminals is more multi-faceted than in LNG. This frequently includes commercial aspects (e.g., hosting privileged guests from the port state), which may be imperative for the work environment. The amount of noise and vibration on an FSRU during regasification is significant and can play a role in stress and fatigue. Information flow between ship crew and their principal, i.e., the shipping company, is key and may differ for FSRU and LNG. Scheduled leisure time on an FSRU may be spent working on shore-based interaction, rather than resting. Some preconditions for serving on an FSRU for the seafarers as a buffer preventing work-related stress include good and low-cost internet availability on FSRU. The rationale behind increased accessibility to the internet on FSRU versus LNG-tankers is to mitigate fatigue risk factors such as depression, loneliness, distance from friends and family, banking, etc.; the isolation in cabins can create distance and have negative effects on social life on-board. The findings suggest that FSRUs' proximity to shore and thereby increased access to the internet has improved the well-being of juniors and ratings, while it is less important to senior officers. This phenomenon should be considered in depth in further studies. The prestige of working for companies with a good reputation in the LNG shipping industry contributes to the acceptance of serving on an FSRU. Access to more frequent shore leave on FSRU is a precondition and serves as a buffer against work-related stress.

The sometimes high political and economic importance of an FSRU for the host-port and the host-nation's energy supply situation (see for example TradeWinds, 2022; South China Morning Post, 2022; Mauren, 2018) may play a role in the FSRU crew's stress and motivation. Below we have listed themes and issues reported from crew regarded as potential stressors that may lead to fatigue in the long run.

Themes and issues for crews serving on LNG-tankers versus FSRU

(2) Crew-specific factors:

- The crew experienced rushed FSRU-equipment specific training, which they reported gave them a sense of not being in control over job performance and safety.
- Deck officers were required to obtain and maintain navigational skills. Whereas they expect to navigate the vessel, that is not required in the FSRU; hence they were left with other tasks, including frequent PR-activities. Stationed on an FSRU, the officers were concerned about their lack of sea-time record and experience. Commissioning and decommissioning lapses are too far apart – crew feel they forget their skills and how to sail/operate LNG/FSRU.
- Younger seafarers reported they wished to sail, not work on a terminal. This led to disappointment and frustration when they were stationed on an FSRU. On the other hand, older, more experienced seafarers were more satisfied with the predictability for crew changes that comes with the FSRU.

(3) Management factors:

- The company's technical superintendents reported they were reluctant to transfer crew between FSRU and LNG-tanker. Proper crew LNG versus FSRU requires different types of qualifications and competence. Special dedicated crew for particular clients upon request causes great complications for the company's ship manning strategy.

(4) Environmental factors:

- FSRU projects awarded to the company can mean sudden relocation of an FSRU vessel to unknown destinations. Being stationary on an FSRU in perceived high political risk areas requires more mental preparation for seafarers and their families and was reported as a stressor.
- The crew reported a fear of stationary FSRU as a target for terrorism.

(5) Ship specific factors:

- On FSRU: increased shore-based interaction with clients, prestigious guests, government officials, politicians, etc. FSRU crew complained about too much interaction with client shore-based/terminal operators. This led to uncertainty in terms of where to draw the line.
- Captains were exposed to a new role as a company representative, lacking training in PR management. They are trained to operate gas tankers, not to handle media, prestigious guests, e.g., presidents, authorities, etc. According to Jepsen et al. (2017, p. 5), "Captains suffer more than their colleagues from both fatigue and stress. Port work is particularly demanding […] [resulting in] […] no one on-board getting adequate sleep".
- Modification or conversion of LNG to FSRUs means working with additional equipment that creates a lot of vibration. This has been reported to create fear among the workers of "blowing up" when operating in regasification mode.

Summary and conclusions

This chapter examines human factors in the natural gas supply chain. The research question is: What are ship crew fatigue risks related to the work environment onboard FSRUs compared to conventional LNG-tankers?

The data collected shows that there are crew frustrations linked to the commercial aspects and excitement about the current FSRU business success. With an emphasis on the commercial aspect, a common concern stands out that FSRUs demand a different set of competence and skills. There is no training in their new roles, supporting the shift from "simple-minded seafarers" to "vessel terminal operators", including management of public relations as one of their work areas. Crew complaints of boredom and dissatisfaction with their work tasks are allegedly caused by the mismatching of work expectations against their current scope and job tasks. The engine department, however, seems to be suffering less from this predicament, as

they do not complain so much about it. In line with the authors' predetermined expectation, the engine department is less exposed to the shifts of segment between LNG-tanker and FSRU. The peculiarity connected with the low turnover rate and the high score on motivation and company loyalty is that the crew, regardless of position and segment, do not seem to want to resign because of the reasons discussed above.

This chapter suggests that communication across on-board departments may require a different approach and awareness in FSRU versus LNG. The senior officers did not display any signs of hesitance or poor leadership towards their junior officers. On the contrary, they showed interest and respectfully utilised the information obtained in a constructive way. This circumstance may enhance cooperation and decrease the amount of job stressors onboard. The contrast between ship and shore regarding communication and information flow is more visible. Two weaknesses in seafarer resource management are detected in the case company: lack of appropriate, task-oriented, on-the-job training, and the documented increase of expected array of skills and work tasks to be effectuated by seafarers on FSRU, compared to LNG. This study finds valid reasons to conclude that in the FSRU niche, there is insufficient time and resources invested into human resource management and the recognition of empowerment to their employees.

Managerial implications of this study point to how ship-owners can mitigate the possible crew fatigue risks documented in the findings. Through thorough information flow and encouraged participation between shore-company and crew individuals, as well as crew teams, a better harmonisation between ship and shore may take place. This would foster teams rather than opposite units. The results show that the general concept of similarities in manning and seafaring between traditional LNG ships does not apply onboard an FSRU. The generalisation of seafarers within one company may be built upon historical and traditional obsolete perceptions. The crew transfer between the LNG and the FSRU needs to be sufficiently prepared for by a shipping company. This is necessary to reduce possible hampering of seafarers' work environment and life, both at sea and on terminal. Moreover, to understand the value created by the seafarers, it is crucial to understand the contribution that human factors make to the company's success.

Suggestions for future research

To be investigated in further studies is the mapping of competencies for FSRUs crew and possible implications like dedicated training, assessment, and certification of the individual seafarer for terminal operation. This study does not comprise any fatigue measurements, nor health, safety, environmental, and quality (HSEQ)-related hard facts or statistics, nor any statistics on loss time injury (LTI) and quantifiable cost comparisons. Although in this exploratory study a Norwegian company was chosen as the case, Norwegian seafarers in general are not represented here. The sampling of the company in our study was purposive. We recommend, therefore, that future studies include the identification and the possible exclusion of extraneous impacts. This can be accomplished by applying more explanatory study designs, for example, by performing broader and more systematic efforts for assessing and statistically controlling such impacts.

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