International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

A Comprehensive Approach to – Fatigue Mitigation for Merchant Vessels

A.P. Chengalath , Suresh Pattibhiraman , C. Sridhar

Department of Marine Engineering, AMET deemed to be University, Kannathur, Chennai , India
Mail id: apchengalath@gmail.com

Abstract

Fatigue amongst sailors serving on small or large vessels has been a long standing problem of the industry for which no clear answers have emerged. Needless to say all interested party's, be they International maritime Organization (IMO), National (Australian Maritime Safety Authority - AMSA etc.), Regional and private bodies or institutions, have spent a fair amount of energies on this subject, but with very little achieved practically in terms of any real solution to address the issue of fatigue in the maritime industry.

The initial efforts to control fatigue was the adoption of International Convention on Standards of Training, Certification and Watch Keeping (STCW) 1978/1998. Progressively amendments have been made and ratified until as late as 2010.This was later followed by Marine Labor Convention (MLC) 2006 leading to regulation on minimum work and rest hours. However implementation of these regulations was found to be self-defeating due to conflict of interest in the senior officers who were required to implement these standards themselves and manage fatigue and operational requirements.

The poor compliance of the MLC 2006 Regulation has now prompted yet another an administrative procedure in the form Fatigue Risk Management (FRM) to be adopted as part of the International Safety Management (ISM) system on board to satisfactorily fulfill the guidelines.

The paper firstly redefines fatigue as an expression of the three primary parameters – work, manpower and time. It further goes to analyze and offer a pragmatic solution to mitigate fatigue by - reworking work schedules, providing alternative staffing and instituting a self-regulating tool - Crew Activity Mapping (CAM) for continuous monitoring fatigue on-board.

Keywords: maritime, fatigue risk management, crew activity mapping, safe manning, alternative staffing, work scheduling.

Introduction

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

The views expressed by the authors are their own, derived from the many decades of service onboard as Chief Engineer, onshore in Ship Repair sector and presently as faculty at AMET University an institution dedicated to training of personal for the maritime industry.

The experience of most if not all seamen has been that there is an urgency to find a pragmatic solution to the vexing issue of fatigue amongst seamen. It is also admitted much has been done over the years to introduce several safety related regulations by IMO and its associated organizations.

As recent as 2016 IMO with the concerted effort by AMSA and many such leading bodies have introduced the principle of Fatigue Risk Management. This new administrative document is to be adapted into the ISM system and accordingly a procedure be adopted in the ship's SMS list of procedures by owners and operators.

Needless to say, the continued focus on developing new methodology has further highlighted to the ship staff the importance of managing fatigue experienced by them on board. But the solution ends there in that it does not offer any concrete measures or technique to monitor, record or resolve issues leading to fatigue. The onus on mitigating fatigue continues to remain the single responsibility of ship staff with owners and operators having little or no visible role, which as earlier has been the stumbling block in its resolution.

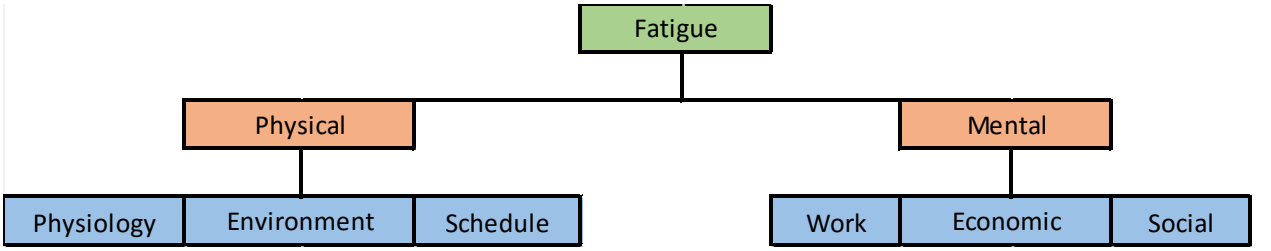
Solution eludes all parties as the resolution to the problem is only been seen as an administrative matter in nature and can be resolved by ship staff through cosmetic management processes. This very narrow approach has prompted the authorship of this paper. It is believed that unless all partners who have a stake in the operation of vessels are committed to finding a novel or disruptive solution in today's jargon, no tangible results will be forth coming.

Hence, the approach of this paper has been to firstly assess what has been the achievement on account of the measures taken hitherto, while simultaneously reporting the findings worldwide. The consensus amongst researchers is that dismal progress has been made for reasons expounded in the many research papers published by notable bodies and individuals. Therefore the dire need for a more rigorous study and an out of box *transformational solution* of this problem is today's call, less a *major calamity* in the oceans acts as the *trigger* to institute a more equitable and permanent *resolution* to this long standing problem of *fatigue management* at sea.

1.0 FATIGUE

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Fatigue can be expressed as a physiological and or psychological experience amongst humans caused due to work related factors. The experience is either induced by physical exhaustion or my mental stress.



1.1 PHYSICAL

Physical exhaustion when it overwhelms the human body, will not permit the person to safely carry out any further productive work without risk to the individual, people around him or the equipment or machinery.

1.1.1 PHYSIOLOGY

One the fundamental reason for work induced fatigue is its physical difficulty in executing the task at hand. The level of exhaustion experienced can be on account of not having (a) *man power* - due to insufficient personnel (b) *physical constitution* – individual bodily limitations/ disposition (Akhtar et al. 2014).

1.1.2 ENVIRONMENT

The *wor*k environment on a ship is influenced by two fundamental factors namely (a) *nature of location* - where the work needs to be carried out and (b) a*mbience* - on account of both weather and very nature of the location. Therefore lighting, noise, atmosphere, physical space and overall stability of the ship are significant factors contributing to fatigue experienced by the crew (Allen et al. 2008: Allen et al. 2005; Calhoun 2006).

1.1.3 SCHEDULE

Work on the ship in most cases is scheduled / planned or anticipated but there is a good percentage generated spontaneously by nature of maritime operations. Unlike any other industry the maritime industry has the unique distinction of work having to work executed 24x7 by a select minimum crew for a prescribed period of time. Hence, although working hours on ships is regulated (ILO2006), it is does not conform to normal human circadian rhythm. Further seafarer's at a personal level have over time reconciled to accepting the unwritten rule that it is incumbent on them to *execute tasks* both scheduled and more importantly unscheduled (Operational and /or Maintenance) at *untimely*

hours at all cost, leading to fatigue creeping into their wellbeing (Allen et al. 2008; Wadsworth et al. 2008; Arendt et al. 2006; Calhoun 2006; Louie et al. 2007).

1.2 MENTAL

This issue has probably not received as much attention that it deserves, although mental equilibrium of the crew can be a critical factor in determining the level of fatigue that he will experience. *Prolonged isolation* experienced by many seamen can greatly affect their *psychological balance* over an unpredictable period of time depending on the individual's body chemistry. Human behavior is a complex subject and therefore only being tagged here to record as yet another cause, contributing to growing fatigue endured by seamen (Oldenburg et al. 2013; IMO 2015).

1.2.1 WORK

Work *pressure* posed on account of the sheer quantum and complexity or the *intrinsic hardship* of the task to be performed in a *defined time frame* can be a contributory factor in aggravating the level of fatigue amongst the crew. Other work related pressure generated would be *lack of skill or training* (STCW 1978) received by the seamen. This is found to be evidently clear in many of the reports published by several researchers over time (Allen et al. 2008; Allen et al. 2005; Oldenburg et al. 2013; Wadsworth et al. 2008).

1.2.3 ECONOMIC

While STCW brings about a near uniformity of the level of training, knowledge and skills, economic disparity in the wage structure amongst seamen will cause added anxiety and frustration leading to poor performance and mental fatigue in the individual.

1.2.2 SOCIAL

The performance of every individual on the ship irrespective of his rank / position can and will affect the overall productive capability of the ship. Therefore the *social conditioning* of individuals although very subjective can have an impact on the overall health / productivity of the group. The characteristics of *mixed crew* be it nationality, language, color or religion could induce stress amongst crew members leading to fatigue. (Allen et al. 2008; Allen et al. 2005; Wadsworth et al. 2008; Arendt et al. 2006; Calhoun 2006; Louie et al. 2007).

2.0 MARITIME INDUSTRY

Competitive business models, dynamic nature of operations and reduced manning levels in the industry has warranted seafarers to progressively

adapt to the changing demands of shipping today. They are continuously subjected to – *long and irregular hours across extended periods of time, restricted and interrupted sleep, continuously rotating and changing work shifts, intense workload, untimely eating habits, poor sleeping conditions, no prescribed separation between work and rest hours with little or no recreation and limited social interaction with the outside*. (Allen et al. 2008; Allen et al. 2005; Akhtar et al. 2014; Wadsworth et al. 2008; Arendt et al. 2006; Calhoun 2006).

The work environment is further aggravated by operational aspects associated with shipping due *to changing trading patterns, length of sea passage, faster loading and discharging cycles and short recovery periods* (Allen et al. 2008; Allen et al. 2005; Oldenburg et al. 2013; Wadsworth et al. 2008).

All the above constraints categories this industry as no-other, requiring path breaking and brave solutions to mitigate fatigue.

3.0 INTERNATIONAL MARITIME ORGANIZATION

IMO is the designated governing body for world maritime affairs and has over the last several decades introduced several regulations and legislations governing - Safety, Operations, Construction, Training, Manning and Protection of the Marine Crafts and Industry which includes interests of - seafarers, environment, ship owners & managers and builders.

Recognition and dependence on merchant ships as the dominant (90%) mode of transport of bulk cargo across the globe, has led to a quantum leap in world tonnage in the last 2 to 3 decades (Michelle et al 2016). This development has highlighted the growing hazards to human life and environment, prompting IMO, national, regional and local organizations and institutions to deliberate and introduce several key legislations such as – Safety of Life At Sea (SOLAS) 1974, International Convention for the Prevention of Pollution from Ship's MARPOL 73/78, STCW 1978, ISM 1995, MLC (2006) to name a few.

4.0 HISTORY OF FATIGUE MANAGEMENT

Human fatigue has been identified as a fundamental cause in several marine accidents. Safety studies, accident surveys, investigations and near misses have concurred that 85% of marine accidents are due to human errors due to fatigue of some nature. Although this is true, ways to mitigate this phenomenon has not yielded positive results. Probably one of the primary

reasons for this failure could be this experience is very abstract and a subjective human behavior function, making its analysis complex (Michelle 2016).

Merchant vessels have seen several changes in their working norms over the many years to resolve this burning issue but with little success. This could primarily be because there has never been a major accident causing significant loss of human life or significant damage to environment on a scale as never seen before. Another possible reason could be that any radical change to resolve this problem successfully could incur a substantial cost to owners and operators. Consequently only administrative procedures to be adopted on board has been adopted till today. In reality the final solution to this phenomenon has been left to the ship staff to manage (Phillips 2014, Phillips et al. 2015).

4.1 FATIGUE RISK MANAGEMENT (FRM)

In recent years however several bodies have spent valuable time and effort in deciphering the intricacies of fatigue experienced by seamen and practical implementation of the existing regulations on board vessels. The more recent of these efforts has been to introduce a procedure to assess the quantitative risks envisaged due to fatigue in doing a task, prior to its commencement and thereby take measures to minimize the experience of fatigue (IMO 2015; IMO 2014; IMO 2001).

This concept termed Fatigue Risk Management which has been initiated in other industries shore is new to the maritime industry. The new managerial document is being integrated into the ISM system on board as part of ship's SMS procedures (IMO 2014; Michelle et al 2016) for effective implementation.

The proposed framework Fig.1 (below) for Fatigue Risk – Management principle is based on several layers of controls and safety assurance (Belenky et al. 2003; Dawson et al. 2005; Gander et al. 2009; Gander et al. 2010):

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

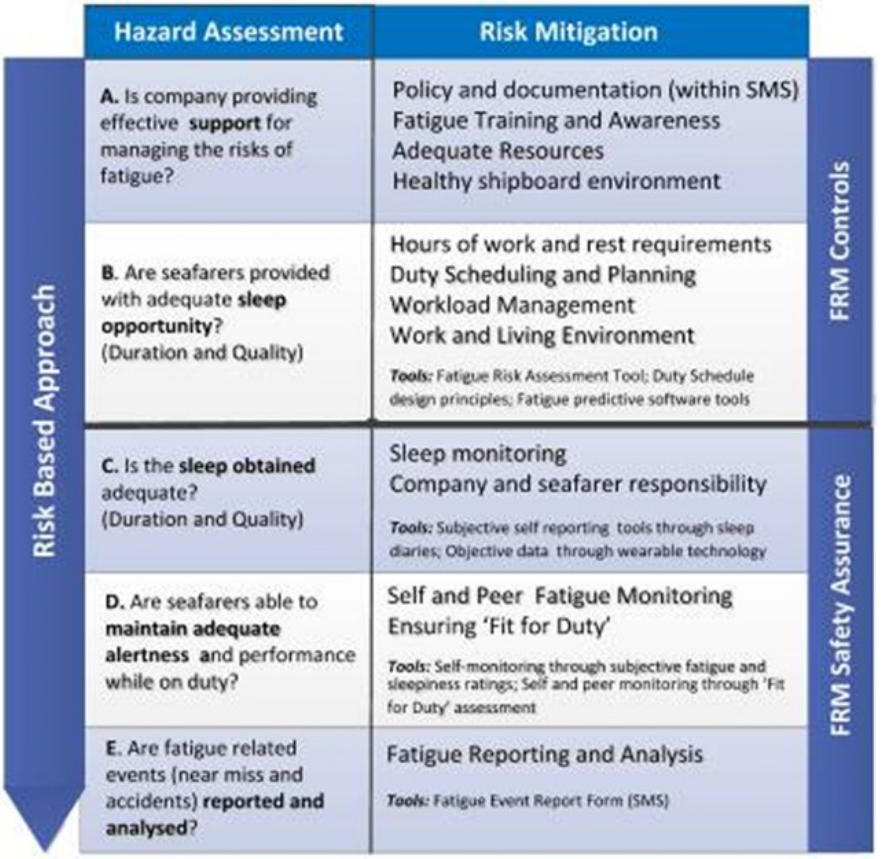


Figure - 1

Layer 1. Effective company support and commitment for managing and controlling the risks of fatigue.

Layer 2. Seafarers are provided with adequate opportunity for sleep, this ensures both duration and quality of sleep considered.

Layer 3. Ensures issues affecting seafarer's duration and quality of sleep provided is being fully captured.

Layer 4. Ensures seafarers obtain what is rightfully sufficient rest to maintain alertness and performance.

Layer 5. Ensures that formal processes are in place for identifying, assessing and reporting fatigue related events or incident.

Fatigue Risk Management principles needs to be integrated together with the Safety Management Systems (SMS) on board the ISM code for effective results (IMO 2013; Michelle 2016).

5.0 DEFINATION OF FATIGUE

Fatigue by its definition is attributed to exhaustion of Body and Mind, due to several associated factors. This exhaustion is caused

during the process of executing a task on account of magnitude and complexity.

Fatigue therefore can then be defined as an experience dependent on three fundamental parameters namely – work, manpower and time.

Fatigue may hence mathematically expressed as directly proportional quantum of work and inversely proportional to Manpower and Time available.

If Time is considered as a constant, because it is not a negotiable parameter.

Then, Fatigue $\propto$ Work

Manpower x Time

Or Fatigue = Work (Time consider a constant)

Manpower

From this relationship we can infer fatigue is directly proportional to Work and inversely proportional to Manpower.

Or Fatigue can be increasingly mitigated *by planning and reducing work* on board *or increasing manpower* or ideally a combination of all three instruments.

5.1 WORK MAPPING

Work emanating on a ship will broadly come under any of these 5 below mentioned headings. Further tasks under any of these 5 headings can be executed in any one or more of the ship's position.

Category	**Heading**	**OPERATION**	**SAILING TIME**			**IDLING TIME**		
	1.	Navigational	Sailing	Pilotage	Ship to ship			

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

I	2.	Statutory Inspections				Port	Anchor	Lay-Up
	3.	Training	Sailing			Port	Anchor	Lay-Up
II	4.	Cargo			Ship to ship	Port	Anchor	
	5.	Maintenance	Sailing			Port	Anchor	Lay-Up

Table 1

5.1.1 WORK PLANNING

The work emanating from Navigation, Cargo, Statutory Inspections and Continuous / Routine Maintenance is fundamental to the satisfactory and safe operation of the vessel, hence is not negotiable. Hence only Planned Maintenance and Training Programs during the vessels stay in (a) Port and (b) Idling can be reworked/ rescheduled.

The category of Maintenance can be further subdivided into

1.	Minor Repairs	2.	Major Repairs

Table 2

The jobs coming under the category of Minor Repairs would be either running or normal routine planned maintenance (e.g. Purifier Bowl, Condenser or Filters cleaning) for ship's day to day safe and trouble free functioning.

Major Repairs are such works requiring all engine room manpower excluding the duty watch keepers (e.g. Any major repairs on main equipment including main engine, auxiliary boiler survey etc.).

Training – Onboard can be rescheduled outside the port stay period for ship staff.

Fatigue impacts, when there is an overlap of any two or more of these five work categories mentioned in article (5.1) i.e. during

S.NO.	OPERATION	TASK 1	TASK 2	TASK 3
1.	ARR / DEP		Navigation	
2.	STS	Cargo	Navigation	
3.	PORT STAY	Cargo	Inspection	Maintenance

Table 3

From above it is easily deducible that fatigue is primarily experienced by ship staff during the vessel's *arrival*, *departure* and *stay in port* (Allen et al 2005). Therefore any measures taken towards *work reduction* during these periods will dramatically reduce if not *mitigate fatigue.*

5.1.2 WORK SCHEDULING

Work related to Navigation, Cargo, Statutory Inspection and Routine Maintenance Operations cannot be postponed, however major Planned Maintenance and Training programs can be rescheduled to suit ship's operational requirements minimizing its impact on crew fatigue.

Therefore **Work Scheduling** can be considered as one of the methods *to* ***mitigate fatigue.***

5.2 MANPOWER PLANNING

The cost of manpower is a major budgetary expense, however with development of automation there has been considerable downsizing of ship's compliment. Therefore automation together with modern ship board management principles and training systems, has permitted significant downsizing of ship's compliment has now been reduced to what is termed as the ***Minimum Safe Manning levels.***

The current process of determining the Minimum Safe Manning levels of crew is not a well

structured exercise at estimating the crew complement. The regulation does not recognize the need for a more systematic record keeping of work and rest hours on board nor for its inspection and monitoring by Administration. The onus for monitoring and inspection must lie with the Administration at regular intervals rather than operators to review the requirement.

5.2.1 ALTERNATIVE STAFFING

The concept of alternative staffing gained attention in United States shore industry in the late 90's. During this period company's where compelled to cut costs to remain profitable. This resulted in retrenching staff reducing operating cost, however still maintaining the flexibility of rehiring several of them temporarily on contract basis as required.

The shipping industry had earlier in the 80's experienced another novel employment policy under the title of sailing or riding squads. This was a practice by company's to provide much needed additional manpower assistance to ship staff to maintain, operate and in many an instance to upgrade the vessel. This very strategy to employ *additional / temporary staff* to carry out specific tasks, can today be seen as the solution to the perpetual problem of *mitigating fatigue* amongst seamen. This *shore team* will comprise of personnel highly skilled in the area of tasks they are being employed to do and could be sourced locally by the company's.

Through this modus of operandi it is proposed that owners and vessel operators schedules for *critical jobs* to be done in port and anchorages be *outsourced*. These jobs as detailed in article *5.1.1 Work Planning under Category 2* could range from cargo loading / discharging operations to major machinery maintenance.

The benefits of local *alternative staffing* as visualized above will most definitely provide *skilled and fresh crew* in ports and anchorages. The scheme could prove to be more cost effective, as the overheads of shore crew will be far less as compared to that of ship's sailing crew. Further the local crew will certainly be more productive during their short stay on board for obvious reasons of not being fatigued. This would permit *ship staff time to recoup,* so as to be available for other tasks such as inspections and for their primary sailing duties.

Therefore one of the emerging solutions to mitigating fatigue would be Alternative Staffing during vessel's port stay. Carving out specific work for maintenance and cargo operations to be executed by an *alternative staff*, during port stay

of the vessel can be the game changer solution to ***mitigating fatigue*** amongst seamen.

5.3 CREW ACTIVITY MAPPING

The existing IMO principles for determining Minimum Safe Manning Levels lays down very comprehensive guidelines for owners and operators. However as in the past there still *lacks a fool proof procedure* for monitoring and recording of work and rest hours on board.

It is strongly believed a more *structured and self-regulatory method* of both monitoring and recording of activities of crew personnel on board will go a long way to accomplish implementation of MLC 2006 regulation. It is proposed to institute a computerized software system, *integrated with other shipboard modules (operation, maintenance and training)* for a detailed mapping of man hours of every member of ship's crew be made mandatory as part of the SMS system. This *Crew Activity Mapping* (CAM) software must be made the new instrument replacing the existing work and rest hour record. The CAM report can be a tamper proof document for recording work and rest hours by the ship staff and later the same made available to Administration for monitoring *Fatigue Risk* on board at regular intervals.

The *CAM* report would entail each individual to enter every activity of his /hers during a 24 hour period for the full period of stay on board the ship. Every entry is to be made within a 24 hour or any reasonable window from the time of completion of the task / period. It is envisaged such a computerized process would very pointedly indicate, if crew members are working under adverse work environment not conforming to existing MLC regulations. This report can be generated on board anytime during an Administration inspection. Further this document would allow the Administration to review Minimum Safe Manning Certificate renewal after regular Administration inspections. It is also proposed that ***CAM Reports*** be vetted by PSC once every fixed interval for MLC compliance, keeping in view that vessel operating parameters are subject to change continuously. Hence, CAM report can *be considered as a* ***primary document / tool*** for monitoring ***fatigue*** and its ***mitigation*** in the future.

6.0 CONCLUSION

In conclusion what is proposed -

"Fatigue can be mitigated in a substantial way by incorporating the following principles:

1. ***Work Scheduling – during port stay.***
2. ***Alternative Staffing – during port stay.***

3. Crew Activity Mapping – for crew fatigue assessment. "

Acknowledgement

My sincere thanks to Mr.K.R.Chidambaram, Principle, Department of Marine Engineering, AMET University.

References

[1] International Labour Organization. Maritime Labour Convention. ILO; Geneva, Switzerland: 2006.

[2] International Maritime Organization. International Convention on Standards of Training, Certification and Watch Keeping for Seafarers. IMO; London, UK: 1978. 1978 as Amended.

[3] Allen P, Wadsworth E, Smith A. (2008). Seafarers' fatigue: A review of the recent literature. Int. Marit. Health. 591:81–92.

[4] Allen P, Wellens BT, McNamara R, Smith A. (2005) Contemporary Ergonomics. Taylor & Francis; London, UK: It's not all plain sailing. Port turn-arounds and seafarers' fatigue: A case study; pp. 563–567.

[5] Oldenburg M, Hogan B, Jensen HJ (2013).Systematic review of maritime field studies about stress and strain in seafaring. Int. Arch. Occup. Environ. Health. 86:1–15.

[6] Akhtar J, Utne IB. (2014). Fatigue at sea-A manning problem. J. Marit. Res 11:27–42.

[7] Wadsworth EJK, Allen PH, Wellens BT, McNamara RL, Smith AP. (2008). Patterns of fatigue among seafarers during a tour of duty. Am. J. Ind. Med 49:836–844.

[8] Arendt JB, Middleton P, Williams GF, Luke C. (2006). Sleep and circadian phase in a ship's crew. J. Biol. Rhythm. 21:214–221.

[9] Calhoun SR. (2006). Human Factors in Ship Design: Preventing and Reducing Shipboard Operator Fatigue. University of Michigan; Ann Arbor, MI, USA

[10] Louie VW, Doolen TL. (2007). A study of factors that contribute to maritime fatigue. Mar. Technol 44:82–92.

[11] Härmä M, Partinen M, Repo R, Sorsa M, Siivonen P. (2008). Effects of 6/6 and 4/8 watch systems on sleepiness among bridge officers. Chronobiol. Int. 25:413–423.

[12] Phillips RO. (2014). An Assessment of Studies of Human Fatigue in Land and Sea Transport. Institute of Transport Economics (TØI); Oslo, Norway 1354/2014.

[13] Phillips RO, Nævestad TO, Bjørnskau T. (2015). Fatigue in Operators of Land- and Sea-Based Transport Forms in Norway: Literature Review and Expert Opinion. Institute of Transport Economics; Oslo, Norway: 1395/2015.

[14] International Labour Organization (2015). International Labour Standards on Seafarers. ILO; Geneva, Switzerland

[15] Belenky G, Wesensten N, Thorne DR, Thomas ML, Sing HC, Redmond DP, Russo MB, Balkin TJ. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study. J. Sleep Res. 12:1–12.

[16] Dawson D. (2005). McCulloch K. Managing fatigue: It's about sleep. Sleep Med. Rev 9:365–380.

[17] Gander P, Hartley L, Powell D, Cabon P, Hitchcock E, Mills A, Popkin S. (2011). Fatigue risk management: Organizational factors at the regulatory and industry/company level. Accid. Anal. Prev 43:573–590.

[18] International Maritime Organization (2001). Guidance on Fatigue Mitigation and Management. IMO; London, UK

[19] Gander PH, Graeber RC, Belenkey G. (2010). Fatigue risk management. In: Kryger M.H., Roth T., Dement W.C., editors. Principles and Practice of Sleep Medicine. Saunders; Philadelphia, PA, USA: 760–768.

[20] International Civil Aviation Organization (2013). In: Fatigue Risk Management Systems—Manual for Regulators. ICAO, editor. ICAO; Montréal, QC, Canada.

[21] International Maritime Organization. (2014). ISM. International Maritime Organization; Exeter, UK: International safety management code. Resolution A.74 (18) as Amended by MSC.104(73), MSC.179(79), MSC.195(80), MSC.273(85) and MSC.353(92).

[22] Fatigue Risk Management (2016). A Maritime Framework by Michelle Rita Grech – Australian Maritime Safety Authority.