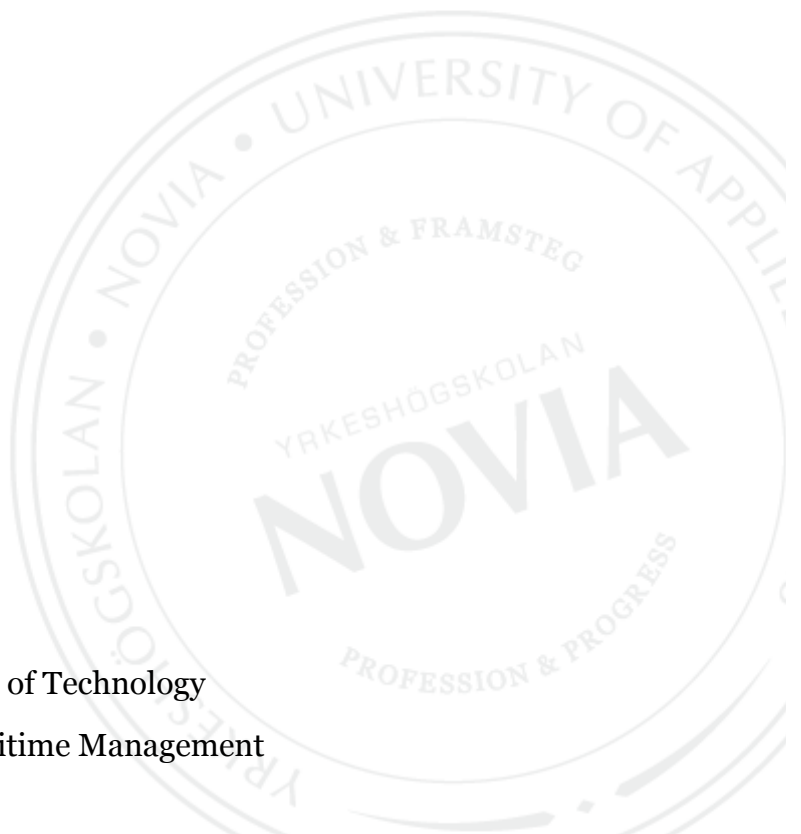




Designing the optimum  
watchkeeping schedule  
for a passenger vessel  
bridge team

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Degree Thesis for Bachelor of Technology  
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# BACHELOR'S THESIS

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## Summary

A well-designed watch schedule is the backbone of the working environment for the bridge team on board ships. The rhythm on passenger vessels is quite different when compared to cargo ships: there are more drills and more safety related work. Actual watchkeeping is also different due to more internal communication and alarm management. Understanding the unique features is paramount when setting up the watch system.

Sleep deprivation and fatigue causes health issues for the crewmembers but also put the safe navigation of the ship at risk as the watch-keeping officers are not as vigilant as they can be. Most collisions between ships happen during the so-called Red Zone when the human body is in its least alert state.

Designing the actual schedule is not just playing with numbers; good care needs to be taken to protect the sleep of the crewmembers following it.

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## EXAMENSARBETE

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### Abstrakt

Ett väl planerat vaktschema utgör basen för bryggteamets arbetet ombord. Rytmen ombord på ett passagerarfartyg är mycket olik den ombord på lastfartyg; arbetet är mer säkerhets- samt övningsbaserat och en viss uppmärksamhet krävs. Helheten är olik tack vare en delvis annorlunda arbetsomgivning, då fokusen ligger på kommunikation och alarmsystem ombord.

Under planering av vaktschema är omständigheterna mycket viktiga att tänka på. Förutom att för lite och dålig sömn orsakar hälsoproblem, ställs hela fartygets navigering i fara då fokusen inte är den bästa. De flesta olyckor sker under den så kallade "röda zonen" då fokusen är låg och tankarna på annat håll.

Att planera dessa schema, är inte bara att leka med tidtabeller utan den viktiga basen för att nå de bästa resultaten med tanke på säkerhet och välmående.

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Språk: Engelska

Nyckelord: Vaktkörning, passagerarfartyg

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## Tiivistelmä

Oikein laadittu vahtiaikataulu on toimivan työympäristön perusta laivan komentosillalla. Matkustaja-aluksilla työrytmi poikkeaa rahtilaivojen vastaavasta olennaisesti: tiheätahtisemmat harjoitukset ja turvallisuuslaitteisiin sekä -järjestelmiin liittyvät erityistyöt on otettava huomioon, kun työaikatauluja suunnitellaan. Myös vahdinajossa on omat erityispiirteensä, jotka vahtiaikataulun suunnittelijan on syytä ymmärtää täydellisesti. Näitä ovat esimerkiksi sisäisen kommunikaation ja eri hälytysten määrä.

Unen puutteella ja väsymisellä voi olla kohtalokkaita seurauksia. Vahtihenkilöstön terveydentila kärsii, sekä itse alus ja kyydissä olevat matkustajat ovat vaarassa, kun laivaa ohjaileva perämies ei ole valppaimmillaan. Suurin osa alusten välisistä yhteentörmäyksistä tapahtuu aamun varhaisina tunteina, jolloin ihminen on luonnollisen päivärytmin vuoksi vähiten valppaana.

Vahtiaikataulun suunnittelu ei myöskään ole pelkkää kellonaikojen pyörittelyä: on erityisen tärkeää pitää huolta vahtia ajavan henkilöstön unen laadusta.

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Kieli: Englanti

Avainsanat: vahdinajo, matkustaja-alus

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# 1 Glossary

**Bridge resource management system:** even though bridge resource management has been part of STCW training for deck officers, many shipping companies have their own Bridge resource management system that every officer needs to be familiar with. Some companies require simulator training for new officers to fully familiarize themselves with the company Bridge resource management system.

**Co-Navigator:** The person in charge of other bridge duties than controlling the ship such as logbook keeping, alarm management, internal and external communications. The Co-Navigator is also in charge of crosschecking the Navigator's decisions and challenging them if necessary.

**Junior watchkeeper:** The Assistant Officer of the Watch when double watchkeeping is taking place.

**Manning level:** passenger ships normally have three different manning levels according to the sea area, traffic level, visibility or a combination of these. Most often manning levels are: green, yellow and red with red being the most conservative. Shipping companies have different matrixes to define the correct bridge manning level for any given situation.

**Navigator:** The person having the control of the ship. In most Bridge resource management systems a double-manned bridge team consists of a Navigator and a Co-Navigator. The Senior watchkeeper will decide who is doing which role. He or she can always take over the Navigator duty from the Junior watchkeeper if needed.

**Officer of the Watch:** In single watchkeeping the officer on the bridge that has the control of the vessel. In double watchkeeping the Senior watchkeeper is the Officer of the Watch but does not necessarily have the control of the ship.

**Operations Director:** Senior staff member of the bridge team such as the master or the staff captain. In most cruise ship Bridge resource management systems in yellow or red manning level there is at least a third officer on the bridge acting as Operations Director keeping an overview of things and taking over the charge. Operations Director often handles the internal communication to the mooring stations.

**Second in command:** on cargo ships the chief officer is the next below the master in the ship hierarchy. On passenger vessels the Second in command can be called staff captain, deputy captain or the chief officer depending on the company ranking system.

**Senior watchkeeper:** The responsible officer on watch when double watchkeeping is taking place, the Officer of the Watch. On most cruise ships the senior watchkeeper has the rank of 2<sup>nd</sup> Officer but on some it is 1<sup>st</sup> Officer.

**Side duty:** Every deck officer working on board a passenger vessel has more duties than just watchkeeping on the bridge. They can be safety, lifesaving, administration, training or navigation related. Side duties are performed on the extra working hours outside the watchkeeping. These hours can be scheduled or they can also be under the person's own responsibility.

## 2 Introduction

Designing a watch schedule for the persons working on the navigational bridge of a passenger vessel is not an easy task. There are multiple factors in play and it is almost impossible to please everyone in the equation.

Even though ships have sailed for centuries the working environment on the navigational bridge has changed significantly and old schedules are not optimal for the modern day maritime world. The workload has increased and the amount of information that bridge officers need to process during watchkeeping demands for high level concentration all the time.

Passenger vessels sail mostly short sea voyages. Cruise ships call in ports normally during the daytime and set sail around sunset. RoPax ferries sail intensive routes between ports with very tight schedules. Bridge teams work quite often in high pace and they also need to be very focused all the time. Ship operations are on going 24 hours per day, which means bridge officers need to work in shifts to cover the whole working day.

Passenger vessels are different from other vessel types on many aspects. As human life is highly appreciated in the modern society passenger ships have elevated levels of safety and security measures compared to cargo ships. There are much more periodic drills that not only involve deck officers to participate but also they have to deliver the instruction during drills.



As per SOLAS a fire drill and an abandon ship drills needs to be organized every week on board a passenger vessel. Even if the watchkeeping officer would not need to participate, his or her resting hours are interrupted every time by sounding of the alarm systems throughout the ship, which is also a SOLAS requirement.

There are also a lot more safety and lifesaving systems on board that need periodic inspections and maintenance. Side duties besides the bridge watchkeeping have to be carried out outside the watchkeeping hours. Depending on the company the total number of deck officers on board can vary from the minimum safe manning to a much larger number of people that will split tasks more evenly but also deliver more costs in labour for the shipping company.

Some rules and regulations are mandatory to comply with and they are the limiting factors when designing a schedule that would suit otherwise persons involved.

In general the master of the vessel would like to have the watchkeeping officers well rested and focused while at work with a schedule that will comply with all regulations. The officers themselves would like to have long uninterrupted off-watch times to maximise good rest with other activities such as going ashore or socializing on board.

These two wishes do not meet every time.

It is also very hard to fit periodic meetings and drills within the bridge team without interrupting someone's rest. Any schedule is always a compromise.

The working day on board passenger vessels consists of navigational watchkeeping on the bridge, organizing and taking part in drills, making periodic checks of safety and lifesaving equipment as per the ship's Safety Management System, bridge watchkeeping in port, mooring operations, training of the crew, voyage planning, chart corrections and maintenance of navigational equipment. On some ships deck officers are also doing gangway duties and tender driving. On RoRo-passenger vessels deck officers take also part in cargo handling operations such as supervising loading and discharging.

Navigational watchkeeping takes most of the time. Very often the working day consist of 10 hours of which 8 are watchkeeping on the bridge. The extra 2 hours are to be spent performing other duties delegated to the person in question.

A working watch schedule is paramount on a passenger ship to ensure safe navigation of the ship having well-rested and vigilant officers on the bridge while the ship is at sea. On cruise ships officers work long contracts on board and accumulated fatigue will affect performance if the schedule is not done correctly.

The problem is how to split up the day in the optimal way. Recent scientific study shows that splitting up sleeping times is not necessarily a bad thing – it is the quality of the sleep that is most important. Measures need to be taken on board to ensure watchkeepers get the most out of their resting times.

This thesis looks at different watch schedules that are or have been used on several passenger ships. It tries to identify advantages and drawbacks in the schedules and moreover it tries to create an ideal schedule for one of the ships studied.

## 2.1 Rules and regulations

Maritime Labour Convention 2006, which ships need to comply, states on Article 6.5:4 that *The master organizes work such that work of the seaman after not more than 6 hours is succeeded by a break each time.* This rule limits the length of a single watch to 6 hours. MLC also states that the minimum amount of rest in any 24-hour period shall be 10 hours, which can only be split in two separate periods of which the longer one needs to be at least 6 hours. The calculation of the 24-hour period starts at the beginning of any rest period. Furthermore according to MLC 2006 seafarer's working time should not exceed 72 hours and resting time not be less than 77 hours in any 7-day period.

Minimum resting hours are also controlled by Standards of Training and Watchkeeping Convention (STCW) in Section A-VIII/1:

1. *All persons who are assigned duty as officer in charge of a watch or as a rating forming part of a watch shall be provided a minimum of 10 hours rest in any 24-hour period.*
2. *The hours of rest may be divided into no more than two periods, one of which shall be at least 6 hours in length.*
3. *The requirements for rest periods laid down in paragraph 1 and 2 need not be maintained in the case of an emergency or drill or in other overriding operational conditions.*

4. *Notwithstanding the provisions of paragraphs 1 and 2, the minimum period of ten hours may be reduced to not less than 6 consecutive hours provided that any such reduction shall not extend beyond two days and not less than 70 hours of rest are provided each seven-day period.*

Taking the regulations in consideration the average working day on board these days is 10 hours per day. Any rotating schedule needs therefore to be based on these limiting factors.

## 2.2 Contributing factors

The purpose of a bridge watchkeeping schedule is to ensure the navigational bridge is always manned properly with officers that have had adequate rest before the watch starts. This should be the primary contributing factor when designing the schedule.

### 2.2.1 Manning levels

The bridge manning level plays a big part. Different manning levels of the navigation bridge can vary: 1 officer of the watch and 1 lookout – 2 officers (Navigator and Co-navigator) – 2 officers and 1 lookout – 2 officers, 1 helmsman and 1 lookout – 3 officers (Navigator, Co-navigator and Operations Director) – master, 3 officers, 1 helmsman and 1 lookout. Manning levels are changed as the ship sails in different levels of risk; contributing factors are visibility, traffic and proximity of navigational hazards. Normally the officers that are scheduled for the watch stay on and additional officers are brought in to full fill the requirements of the manning level. A typical example is an arrival where the master and possibly the second in command join the officer or the two officers of the watch. In addition more officers are needed to handle the communication from the mooring stations. On a very strict bridge resource management system 6 deck officers are needed for an arrival.

On top of these ship specific or company standard manning levels there are very often apprentice officers on the bridge. The apprentices also need to be monitored and tutored as well as some tasks can also be delegated to them to be handled under the supervision of the watchkeeping officers.

### 2.2.2 Master's wishes

The master is normally most concerned which officers of the team occupy the watches at night – in the time when he or she is usually in the deepest sleep phase. Ideally the most experienced officers are placed in the watches between midnight and 0800 in the morning to satisfy this need. In the traditional cargo ship watch system the chief officer has the 0400–0800 watch, the second officer has the 1200–0400 and the least experienced third officer has the 2000–0000 watch, when the master is most likely to be still awake or at short notice. Ideally on a passenger ship the experience is spread more evenly and rotation between watches can also be arranged.

### 2.2.3 Drills

Drills need to be organised on a weekly basis on a passenger ship and they will always disturb someone's resting hours. All crew needs to participate once a month but it is hard not to wake up when the alarm is sounded to start the drill.

A suitable drill time needs to be established to suit most crewmembers and fit the sailing schedule. The bridge watchkeeping schedule needs to be adjusted accordingly. If possible, the officers that are scheduled off during the drill should also not be scheduled to participate in the drill. In some cases this means rotation in the emergency functions as deck officers might be placed in the fire teams.

On board passenger ships drills are not limited to what needs to be done to comply with SOLAS. Every shipping company has to have its own Safety Management System (SMS) that has to comply with the International Safety Management (ISM) code. Many more periodic drills such as security related drills, medical drills, damage control drills, environmental pollution protection drills and equipment malfunction drills are organized on board.

STCW allows drills to be organized during watchkeepers' resting hours, but according to MLC 2006: *“Musters, fire-fighting and lifeboat drills, and drills prescribed by national laws and regulations and by international instruments, shall be conducted in a manner that minimizes the disturbance of rest periods and does not induce fatigue”*.

#### 2.2.4 Meetings

Meetings need to be taken place on a pre-planned basis. Some meetings are short briefings as pre-departure or pre-arrival meetings but larger scale issues need to be discussed such as a voyage plan or drills. On some ships daily meetings are being held as per tradition and non-attendance will lead in ill will between the bridge team. As a meeting nearly always falls during someone's resting hours big care needs to be taken to carefully plan proper meeting times.

#### 2.2.5 Sailing schedule

When the ship is at sea schedules are easy to maintain. Passenger ships do not normally sail for long until coming to the next port. Extreme cases are RoRo-passenger vessel that might have multiple port calls in 24 hours. On the other end of the spectrum some cruise ships have itineraries with up to 6–7 sea-days in between ports.

Deck officers are needed for special tasks when the ship is manoeuvring in and out of port. Even though it is normal for the master or the second in command to do the actual ship handling, elevated bridge manning during the procedures are normally used. Also deck officers quite often man mooring stations for communication to the bridge.

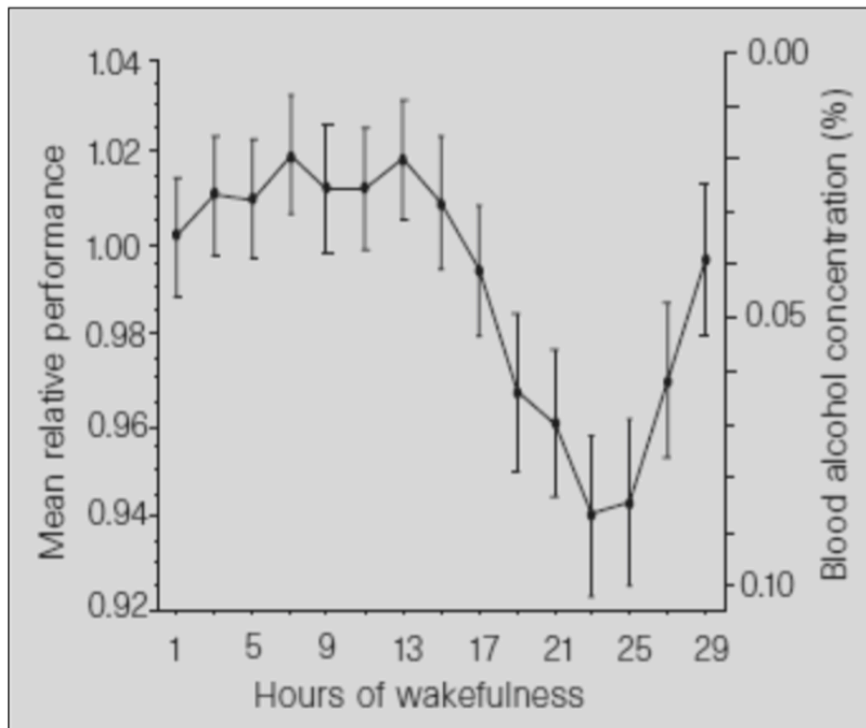
Port calls might mean alterations to the normal day-to-day schedule – or the schedule can be designed to cope with the special needs.

### 2.3 Effect of lack of sleep and fatigue

Sleep is as essential for the human body as is oxygen, food and water. The effect of sleep and sleep deprivation has been studied in multiple research projects.

There is consensus among the scientific world that on the average humans need between 7.5 to 8 hours of sleep per 24 hours to be fully functional. Even very little reductions in this, for example from 8 to 6 hours, can impair performance ([CARSKADON AND DEMENT 1981](#), [CARSKADON AND DEMENT 1982](#), [NATIONAL TRANSPORTATION SAFETY BOARD 1999](#), [VAN DONGEN ET AL 2003](#)).

Lack of sleep leads to impaired judgment, delayed reflexes and poor decision-making in uncertain conditions ([KILLGORE, BALKIN & WESENSTEN, 2006](#)). Another study showed that sleep-deprivation has the same effect on human body than alcohol consumption ([DAWSON & REID, 1997](#)). The maximum alcohol level in blood for seafarers on duty by STCW 2010 is 0.05% and according to the study being awake for 17 hours has the same effect.



**Relative performance and percentage blood alcohol concentration ([DAWSON & REID, 1997](#))**

Cumulative sleep loss has the same effect than staying awake for a prolonged time period. In a study it was found that alertness levels were reduced gradually each consecutive day when sleep was reduced to 4–5 hours per night over a 7-day period ([CARSKADON AND DEMENT 1981](#), [NTSB 1999](#)).

Cumulative sleep deprivation causes also fatigue, which leads to more problems. The definition of fatigue by dictionary is *physical or mental weariness resulting from effort or activity. It is a decreased capacity or complete inability to function normally because of excessive stimulation or prolonged exertion* ([THEFREEDICTIONARY.COM](#)).

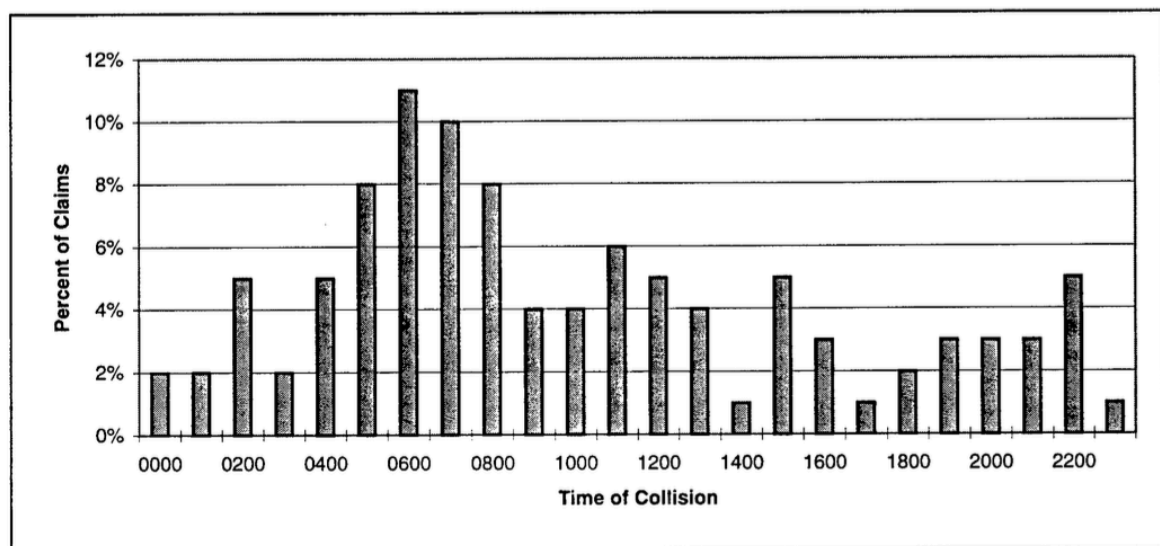
Fatigue is also defined in IMO MSC/Circ.813/MEPC/Circ.330 as: “A reduction in physical and/or mental capacity as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength, speed, reaction time, coordination, decision making or balance.”

Fatigue avoidance demands for adequate rest to cope with stress. One can say that improper rest leads to fatigue.

Fatigue is one of biggest factors causing accidents in transportation industry. Conclusions drawn by the European Road Safety Observatory (ERSO, [ec.europa.eu/transport](http://ec.europa.eu/transport)) state that:

- fatigue-related crashes are often associated with high injury levels
- fatigue is a major factor in a large proportion of road crashes
- several studies suggest that fatigue is associated with increased crash risk

Shipping accidents follow the same pattern. They tend to happen mostly during the late night and early morning hours.

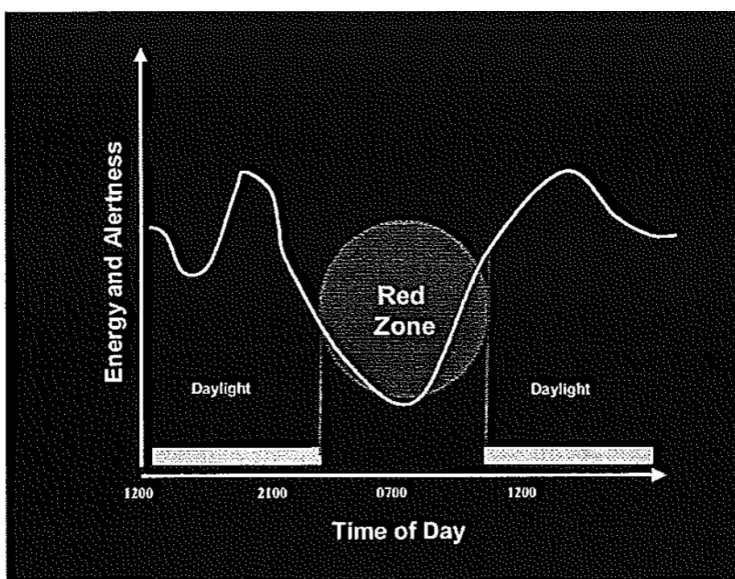


**Percent of shipping collisions at each hour of the day ([UK P&I CLUB 1992 AT SANQUIST ET AL 1997](#))**

### 2.3.1 Circadian system and the Red Zone

The human body and specifically the brain functions in a circadian time system. Circadian is Latin-based word combined with circa (around) and dian (day) meaning that the brain tries to follow a 24-hour rhythm with sleeping and staying awake. Once woken up the body starts to gain momentum until it reaches full alertness. From the peak level alertness starts to decline until it reaches a low point. The first one is normally around 1500–1700 in the afternoon as within the circadian 24-hour system there is also a 12-hour rhythm.

Again, the alertness will rise to another peak and then fall further. This is normally between 0300 and 0700, which is also referred in some publications as the Red Zone. At this time sleepiness reaches maximum levels, the amount of melatonin rises and all this can be measured by following the body temperature that is at its lowest during the Red Zone. Working during the Red Zone is unhealthy in the long term. The National Sleep Foundation of the United States reports that people that regularly work evening and night shifts suffer higher rates of gastrointestinal ailments, cardiovascular disease and sleep disorder ([AGUIRRE, CEREZO, RODRIGUEZ-VALDEZ, LOPEZ-AIRA 1990](#)). Another study shows that sleeping disorders lead to hypertension and Type II diabetes ([NIETO, YOUNG, LIND, SHAHAR, SAMET, REDLINE, D'AGOSTINO, NEWMAN, LEBOWITZ, PICKERING, 2000](#)).



**The Red Zone defined by the level of alertness in a Circadian System (Emond R., Crew Endurance Management: A Best Practice to Improve Mariners' Safety, 2003).**

Some well-known historical accidents, where the human factor has contributed in a major part, have happened during the Red Zone hours. Of these cases the Exxon Valdez (happened at 0015), Chernobyl (0128), Bhopal (0100) and Three Mile Island (0400) are prime examples.

A study conducted by United Kingdom's Maritime and Coastguard Agency (MCA) confirmed that:

- collision risk is greatest during early morning hours
- crew performance and alertness levels are adversely affected by rotating shift schedules
- rotating shift patterns also adversely impact mental health (Smith, Lane and Bloor, 2001)



Crewmembers on board ships working during the Red Zone hours – for example the 0400 to 0800 watch – are most vulnerable for the full effects. To avoid consequences these crewmembers should be protected. It has been proven that the Circadian rhythm can be shifted by “fooling” the brain. This includes changing the whole day rhythm for example forward: waking up 4–5 hours later than normally and adjusting meal times accordingly.

Daylight has also proven to have an effect so special lighting, over 1000 lux, can also be used for example in the deck office where deck officers work outside the bridge watch keeping hours. Shifting the Circadian system takes time. Short sailings do not necessary have adequate time for bridge watchkeepers to adjust to a new rhythm. On the other hand cruise ship contracts that extend normally from 12 to 16 weeks on board are ideal for that. Care needs to be taken when rotating crewmembers from one watch to the other given enough time to adjust. Changing the Circadian system takes time ([TAKAHASHI ET AL 2001](#), [KRYGER ET AL 2005](#)). Complete shifting of the Circadian rhythm to sleeping during the daylight hours takes around 5–6 days ([US COAST GUARD CREW ENDURANCE MANAGEMENT PRACTICES 2003](#)). It is therefore also important not to rotate watches too often.

### 2.3.2 Anchor sleep and napping

As mentioned before the need for sleep in a 24-hour period is between 7.5–8 hours on average. Adequate sleep can be obtained by sleeping it in one period or splitting it. In a split-sleep rhythm one sleeping period becomes the longest being the “anchor sleep” and it is supported by napping. A nap is defined as a period of sleep with a duration of less than 50% of the anchor sleep.

Many studies prove the beneficial effect of naps when measuring performance immediately after having one. Recent studies also show that splitting the sleeping time will have the same effect in maintaining performance than not splitting but the crucial element is total amount of sleep over 24-hour period ([MOLLICONE ET AL 2008](#), [JACKSON ET AL 2014](#), [KOSMADOPOULOS ET AL 2014](#), [SHORT ET AL 2014](#)).

A watchkeeping system can be designed having crewmembers either sleeping all necessary sleep in one period or splitting the sleep. Care must be taken to ensure that the quality of the sleep is good enough and that the crewmembers have adequate time to adjust for the system. In general, if the crewmembers are sailing short periods on board, splitting the sleep might not be the best system – it is better suited for long contracts on board.

### 2.3.3 Recovery from sleep deprivation and fatigue

Sleep deprivation is almost unavoidable while working as a watchkeeping officer on board a passenger ship. It is very often the officer's own responsibility to ensure enough recovery to maintain good health and alertness while continuing to work on board. The watch schedule needs to be designed to allow this and rest periods should also be designed to handle recovery from sleep deprivation. Preferably the anchor sleep rest period should be long enough to allow extended sleep in the event sleep deprivation occurs and compensation is needed for recovery. The 4 on 8 off watch schedule does not offer enough time for recovery sleep periods ([SANQUIST, RABY, MALONEY, 1996](#))

Current research does not show exact formulas of how much extra sleep is needed to recover from sleep deprivation and personal judgment need to be used to establish best possible recovery. A simple guidance to find out if extra sleep is needed is to sleep three days in a row and waking up naturally without an alarm. If after the third day one still feels tired, more sleep is needed.

## 2.4 Crew Endurance Management Systems

Designing the correct watch schedule for the vessel is part of the Safety Management System (SMS) of the ship, which is regulated by the International Safety Management (ISM) code. The International Maritime Organization (IMO) has been raising concern regularly for member countries to put emphasis on fatigue prevention. For example resting hours were targeted in the Port State Control audits in 2014.

Some local authorities such as the United States Coast Guard and the Australian Maritime Safety Authority (AMSA) have issued publications of best practices to manage crew endurance on board ships. These publications are based on several research projects on the matter and they have revealed that it is not only the quantity of the sleep that matters but the quality is of the equal importance.

On a survey performed in 1997 all of the 5500 Australian seafarers were asked questions about their health, performance and stress. The response rate was 36% meaning the poll was almost 2000. Of these 70% reported poor sleep quality and 50% reported less than 6 hours of daily sleeping time at sea. Australian seafarers were also found to be smoking, drinking and eating more sugar and fat and exercising less than the average Australian population. The survey results lead to recommendations concerning work scheduling and

sleep and the benefits of overall health such as nutrition, exercise and reduced alcohol consumption.

Another survey conducted in 2000 by the Senate of Australia to the whole transportation industry led to a recommendation to incorporate Fatigue Management Principles that shipping companies would implement. The Crew Endurance Management Systems recommended by the US Coast Guard are based on the same issue.

A working Crew Endurance Management System is based on first identifying the possible problems. The US Coast Guard Circular letter and the AMSA Principles provide a set of checklist that can be used for the preliminary identification process.

## 2.5 Different watch schedules

### 2.5.1 Stabilized and rotating systems

Watch systems utilized on ships can be separated in two main categories: stabilized and rotating systems. In a stabilized system crewmembers stand watch at exactly the same times every day. The benefit of such a system is that adjusting to a new rhythm can be established as long as enough time is given for it. The drawback of stabilized systems is that they are very rigid; it does not leave much room for alternatives as all systems need to comply with the MLC and STCW standards of resting hours, which are set on a 24-hour base.

In a rotating system watchkeeping times change all the time: the only non-changing element is the amount of hours of watchkeeping and off-watch. The most famous rotating system is the dog watch system, which is a variation of the standard 4 hours on, 8 hours off schedule with the afternoon watch split up in the first (1200–1400) and second (1400–1600) dog watch. This allowed the sailors to have dinner at the proper mealtime and not to stand watch at night always at the same time. If the system does not need to comply with a 24-hour timeframe there are much more alternatives to look for optimum work to rest ratios. These days the commercial maritime world works mostly with stabilized watchkeeping systems. Rotating systems – if used – are limited to the military vessels.

Many different watch schedules have been trialled and studied on board United States Navy vessels. At some point the work-rest unit used on board submarines was 18 hours instead of 24. In a study made in 1979 a study group of 11 subjects were found to adjust to

the 18-hour cycle in a similar way than in the circadian system ([SCHAEFFER ET AL, 1979](#)). The key to adjusting is time; work periods on board need to be long enough to allow crewmembers to shift away from the circadian rhythm.

It has been proven in many studies that the stabilized systems function far better than rotating systems if the ship otherwise works in a circadian system. Even the military seems to be moving back to stabilized systems. In a study from 2012 for Monterey Naval Postgraduate School a stabilized 3 hours on 9 hours off watch system was found to be far better than a rotating 5 hours on 15 hours off system ([YOKELEY, 2012](#)).

### 2.5.2 Common stabilized systems

There are several ways to split up the work on a navigational bridge that runs 24 hours per day 7 days per week. The first task on hand is to define the amount of groups that the working hours need to be split in between. According to the IMO resolution A.1047(27) adopted in 2011 flag states should ensure when issuing minimum safe manning documents for ships:

*“Except in ships of limited size, the provision of qualified deck officers to ensure that it is not necessary for the master to keep regular watches by adopting a three watch system.”*

It is therefore not common to run a two-watch system on board passenger ships that are in general rather large size vessels. The only exception would be a RoPax or other kind of ferry that would stay in port a portion of the 24 hour period every day and might not have the navigational bridge manned at all times.

As the maximum length of a single watch as defined by MLC is limited to 6 hours there are not that many ways to split up 24 hours three ways in equal lengths. In a normal three-watch system each watch does 8 hours per day and the question is weather to make all watches equally long or not.

The most commonly used watch schedule in a three-watch system is the traditional 4 hours on – 8 hours off system, where each watch is 4 hours long. The watch times can vary but the one best known is with watch-times 0000–0400 and 1200–1600, 0400–0800 and 1600–2000, 0800–1200 and 2000–2400.

The advantage of this schedule is short watches that guarantee focused watchkeepers. It is also easy to fit on board a ship that operates normally in a circadian rhythm. Additional

work hours besides watchkeeping can be organised during the daytime hours and it is also possible to organise daily meetings with the bridge team around the watch handover times.

The disadvantage is that the rest periods are relatively short. Sleep is always split in an anchor sleep and a nap and with an 8-hour off-watch period maximum actual sleep is restricted to about 7 hours. It is enough to prevent sleep deprivation and fatigue build up only if the anchor sleep time is guaranteed to be uninterrupted. The system does not allow much room for recovery in case of sleep deprivation as it is only possible to extend the nap-time for extra daily sleeping hours.

Care must be taken when fitting the extra hours besides watchkeeping to the 4 hours on 8 hours off schedule as the anchor sleep period should not be interrupted.

The alternative for the 4 hours on 8 hours off system is to have unequal watch lengths. One example is the 5 and 3 system that was designed by a large cruise ship corporation operating multiple vessels worldwide. The system is based on studies and the idea of it is to maximise uninterrupted resting hours for the bridge watchkeepers. The night watches are 5 hours long, followed by a 3-hour watch during the daylight hours. If organised properly each watch is guaranteed an uninterrupted rest period of 10 hours. A common way to split up the watches is: 0000–0500 and 1600–1900, 0500–1000 and 1300–1600, 1000–1300 and 1900–0000. To make it work the extra working hours have to be placed carefully to not interrupt the longest rest.

Watches can also be split in a ratio 6:2. A tanker company presented in the Finnish Accident Investigation Board report has a system with watches 0000–0600 and 0800–1000 (A), 0600–0800 and 1200–1800 (B), 1000–1200 and 1800–0000 (C). The deck officer in watch A is on watch for 6 hours, is off for two and then is on watch again for another two. Two extra hours could be done in between giving the officer an uninterrupted rest period of 14 hours. The officer in watch B has 4 hours off between watches but still gets 12 hours off with a possibility for a nap. The officer in the watch C only has 10 hours off but the rhythm is very close to the circadian system ([ONNETTOMUUSTUTKINTAKESKUS, 2004](#)).

### 2.5.3 Case studies of different watch systems

In the record of my own sleeping hours the same ship was used but two different watch systems were used on board. During the first contract on board the ship tried to implement the 5 and 3 system and even two versions were trialled. Most of the 4-month work period

on board the watches were: 2300–0400 and 1200–1500, 0400–0900 and 1500–1800, 0900–1200 and 1800–2300. Two factors made it not work properly: first there was a daily 1000 meeting between the bridge team, which interrupted the two officers in the 2300–0400 watch during their longest 8 hour rest period. Also the drills were always held at 1030 and the two same officers also had to attend every time by giving instruction for the abandon ship drills and taking part in the fire drill. They also had to attend all other SMS-related drills and trainings, which were all scheduled at 1030.

For the second period on board the ship had changed back to the 4 hours on 8 hours off schedule. Even though the 1000 meeting was still held every day the schedule worked better than the version of 5 and 3 trialled before as it is shown in the section 3.1 of this thesis.

Three different watch schedules were studied in the interviews. The Study persons 2 and 3 both work on a cruise ship implementing the 5 and 3 watch-schedule. The ship runs the schedule almost as it was designed and successfully. Both Study persons were happy with it and even with long working periods on board of 3 and 4 months neither felt sleep-deprived or fatigued.

### **3 Purpose and definition of research problem**

The purpose of this thesis work is to develop a checklist for passenger ships to aid in designing an optimum watch schedule. To accomplish that first needs to be specified the importance of a working watch schedule by identifying all problems and aspects that are involved. Also it is imperative to point out the specific needs of a passenger vessel compared to other ships.

The definition of the research problem is to find out if enough time for sleep is provided on board passenger ships that are running different watch schedules.

#### **3.1 Theoretical starting points**

Ships work 24 hours per day, which means that work has to be done in shifts to allow crewmembers adequate rest. The work rhythm on board ships is different to shift work on land in many ways. Particularly because the rest period has to be spent on board, which has an effect on sleep quality. The motion of the vessel combined with noise, vibration and

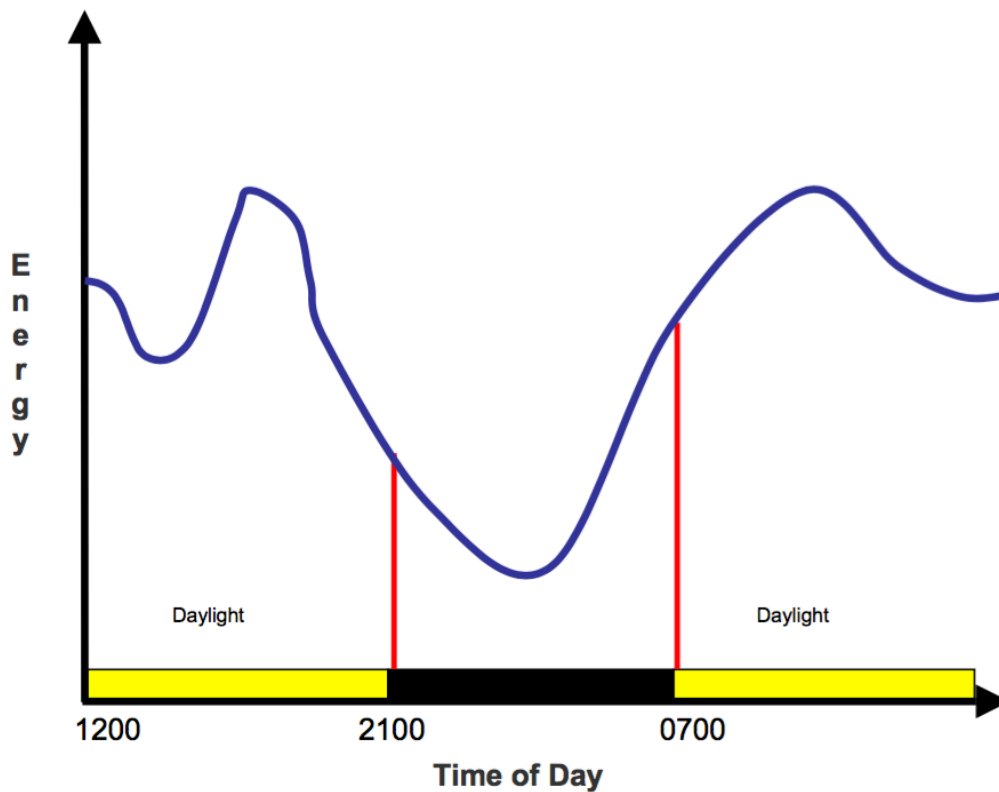
other interruptions all have a negative effect on sleep. Work to rest ratio is also controlled on board by international regulations that ships need to comply. It is therefore important to understand all aspects when it comes to designing a schedule for work.

Bridge watchkeepers work in an environment where the smallest error can lead to disaster; on passenger ships especially an accident can put thousands of lives at risk. Understanding these risks develops unavoidable stress to the watchkeepers and it is therefore very important to ensure that they are at their most alert state while working on the bridge.

Bridge watchkeeping can be stressful as it is. According to an Australian study conducted on pilots their heart rate increased to 160 during pilotage voyage ([BERGER, 1984](#)).

### 3.2 Theoretical background

The level of alertness at any given time can be measured in multiple different ways. For example by measuring reaction time and comparing it to another time of a day, measuring body temperature and comparing it to a temperature taken at another time of the day or performing precision tests and comparing results to same tests performed another time of the day. Using these tools an average level of alertness has been identified that follows the so-called circadian system, which is based on a 24-hour rhythm. When designing a watch schedule the circadian system must be taken in consideration and care must be taken to ensure watchkeepers working during the lowest level of daily level of alertness are supported.



**The level of alertness in the circadian system with two peaks and two lows. (Crew Endurance Management Practices: A guide for Maritime Operations, 2003)**

Even with the perfect schedule sleep deprivation and fatigue are very hard to avoid completely on board ships. The effect of both is well understood: easiest is to compare it to level of alcohol in the blood. Research shows that 17 hours of awakesness is fully comparable to having 0.05% alcohol in blood (BAC) and 24 hours has the same effect than 0.1% BAC. Accumulated sleep deprivation, which leads to fatigue, has exactly the same effect. To avoid impaired judgment and slowed reaction times during watchkeeping crewmembers need to recover from sleep loss by sleeping more than the needed 7–8 hours. The watch schedule needs to allow this. Research has shown that the traditional 4 hours on 8 hours off does not. Alternative systems need therefore to be designed and implemented.

### 3.3 Previous research

Watchkeeping schedules, circadian rhythms and efficiency were studied in a review of research in the University of Sussex in 1985. Stabilized and rotating systems were compared between each other and also different watch schedules were examined. The watch schedules examined from on board where from military ships, which at that time



mostly used rotating systems. Stabilized watch schedules researches viewed were conducted ashore in industrial establishments that used shift work.

Methods used in the studies varied from measuring the body temperature as evidence of alertness and interviews determining the result of altered sleeping patterns.

Note was made that major discrepancies occur when comparing results from research conducted ashore and on board but some conclusions can be made as adjusting to a non-circadian rhythm.

The military ships at the time used mostly rotating watch schedules and nuclear submarines even a non-24 hours rotational system. The review concluded that the only advantage of a rotational watch schedule is fairness in the social hours on board and that all systems on board commercial vessels should be based on stabilized watch schedules ([COLQUHOUN, 1985](#)).

In a National Cooperative Freight Research Program report with extensive studies conducted on Tug/towboat/barge industry in USA from 2016 it was noted that crewmembers ended with more sleep in the 6 hours on 6 hours off than 4 hours on 8 hours off watch schedule. This was due to the fact that 66% of crewmembers in 6 on 6 off watch split their sleep in two but only 49.1% of crewmembers in 4 on 8 of watch did so ([LUTZHFT ET AL 2010](#)).

In a research conducted in 2013 on solo offshore racing sailors participating in the Figaro racing series revealed that even relatively short times without proper sleep prolonged reaction times significantly ([HURDIEL ET AL, 2013](#)).

A field study conducted 1997 showed that maritime officers' average sleeping time per 24 hours when they are at sea is 6.6 hours and at home 7.9 hours. The study also revealed that officers sleep less than the rest of the crew ([SANQUIST, RABY, FORSYTHE, CARVALHAIS, 1997](#)).

## **4 Methods and procedures**

### **4.1 Records of sleeping hours**

I logged my own sleeping hours during two full 4-month contracts on board working as 3<sup>rd</sup> Officer on board a cruise vessel. I sailed both contracts on board the same vessel but two

different watch systems were used on board. For logging I used an application on my iPhone that I used as my alarm clock. If my sleep was interrupted for being called for unexpected duty I also logged it.

#### 4.1.1 First contract on board

The first contract on board was 16<sup>th</sup> December 2013 to April 27<sup>th</sup> 2014 and I worked as Junior and Senior watchkeeper and my side duty on board was navigation. My responsibility besides watchkeeping was voyage planning, chart and publication corrections and bridge equipment maintenance.

The ship had a big portfolio of charts as she sailed the summer season in Alaska from Vancouver and the winter season covered California, Hawaii, French Polynesia, South-America until Peru and the Caribbean until Florida. At the time the ship was equipped with approved ECDIS but the primary means of navigation was paper charts. This meant that all voyage planning had to be done in double: in both ECDIS and paper charts.

I was managing the department alone. At times I had a cadet officer to help catching up with chart corrections.

During my first contract we implemented the 5–3 watch system and watchkeepers were meant to rotate between the watches every 4 weeks. In reality I was first put in the 2300–0400 watch for about 6 weeks and the rest of the contract I was put as the Senior watchkeeper in the 1800–2300 watch. During my last month I was only doing the 1800–2300 watch and I worked my extra 5 hours between 0800–1300.

The watches in the system were: 2300–0400 and 1200–1500 (A), 0400–0900 and 1500–1800 (B), 0900–1200 and 1800–2300 (C). The first group did their extra 2 hours of work between 1000–1200, the second group did theirs 0900–1100 and the third group 1200–1400. Even though the system was designed to guarantee all watchkeepers at least one 10-hour resting time, the ship had a tradition of having a 1000 coffee meeting between the deck officers that everyone was supposed to attend. That meant the two officers in the 2300–0400 watch had only a 6-hour rest period after the night watch. In a 6-hour rest period effective sleep that can be obtained is about 4–5 hours.

Month	Watch	Average sleep	Deficit (8h)	Cumulative
December	A	6.49	1.51	10.55

January	A	6.55	1.45	37.58
February	C	7.97	0.03	0.62
March	C	7.67	0.33	9.98
April	C	7.95	0.05	0.65
<b>Totals</b>		<b>7.33</b>	<b>0.67</b>	<b>59.38</b>

First column indicates the month logged, second column indicates the watch that I was on, third column indicates the average daily sleeping time in hours, fourth column indicates the deficit in the daily average sleeping time to an average of 8 hours per day, the fifth column indicates the cumulated sleep loss in the month to an average of 8 hours per day.

**Analysis:** During the months of December and January average sleeping times per 24 hours (6.49 and 6.55) were significantly less than during the last months on board (7.97, 7.67 and 7.95). Another interesting finding is that even a small deficit per 24 hours in the month of March (0.33 hours per 24) leads to a significant cumulative sleep loss in a month (9.98 hours). With this system loss in alertness and performance is very likely.

#### 4.1.2 Second contract on board

My second contract on board was on the same vessel than the first. In signed on June 15<sup>th</sup> 2014 and I signed off November 2<sup>nd</sup> 2014. In between the watchkeeping system had been changed back to the traditional 4 hours on, 8 hours off as the drawbacks of the 5 and 3 system had been identified. The 1000 coffee time was still being kept and the officers working in the 0000–0400 watch still had the same problem of having only 6 hours of rest after their watch.

During the contract the rotation between the watches was actually going on. I worked my first month in the 0000–0400 and 1200–1600 watch (A), second month in the 0400–0800 and 1600–2000 watch (B) and the third month in the 0800–1200 and 2000–0000 watch (C). My fourth month I was put completely in day-work without any watchkeeping and my last two weeks I was in the 0000–0400 watch only and the other 6 hours I worked between 1000–1600. While at day-work I was very often called for unscheduled duty such as picking up a pilot or going to the mooring stations.

Month	Watch	Average sleep	Deficit (8h)	Cumulative
June	A	8.91	-0.91	-13.72
July	B	7.34	0.66	25.37
August	C	8.11	-0.11	-3.52
September	DW	7.62	0.38	11.40
October	DW/A	7.34	0.66	4.43
November	A	6.83	1.18	2.35
<b>Totals</b>		<b>7.69</b>	<b>0.30</b>	<b>54.06</b>

First column indicates the month logged, second column indicates the watch that I was on, third column indicates the average daily sleeping time in hours, fourth column indicates the deficit in the daily average sleeping time to an average of 8 hours per day, the fifth column indicates the cumulated sleep loss in the month to an average of 8 hours per day.

**Analysis:** All in all the 4–8 system worked better on board the ship than the 5 and 3 as both the average sleeping time went up (7.69 hours from 7.33) and the deficit towards 8 hours went down (0.30 hours from 0.67). Cumulative sleep loss during the contract was still about the same (54.06 hours from 59.38 hours).

## 4.2 Interviews

Several interviews were carried out to find out different watch systems that are being used on passenger vessels and also to find out the actual sleeping hours. Study persons were asked these questions:

1. What is your rank and what kind of ship you work currently?
2. How long is your actual working day and how many hours of watchkeeping you do every day?
3. Do you rotate through watches or are you always in the same?
4. If you rotate which one you prefer and why?
5. What are your actual sleeping hours in all the different watches?

#### 4.2.1 Study person 1:

1. 1<sup>st</sup> Officer on a RoPax-ferry with an itinerary of 17 hours at sea and three different ports every day
2. My overall working hours are 9.5–11 hours per day of which watchkeeping at sea 5–7.5 hours.
3. There are two watchkeeping deck officers on board, the 1<sup>st</sup> Officer and the 2<sup>nd</sup> Officer with specific scheduled watchkeeping hours. Both work 10-day periods on board and rotate between the tasks every other work period.
4. I can not really value one watch to the other as both have their advantages. In the 12–4 watch I get to work more by myself and sleep better so I am less tired. The 4–8 or as many call it also the 4–12 watch involves more archipelago navigation and offers the possibility to go ashore. But one will get less sleep and specially the morning hours can be very hard to stay awake.
5. In the 12–4 watch there are 4 off-watches in a 2-day period. The length of these off-watches are 6.5, 6.5, 7 and 7.5 hours. It is very hard to get adequate sleep in such a short off-watches. In the 4–12 watch there are also 4 off-watches in a 2 day period. The length of these off-watches are 5.5, 5.5, 7.5 and 9 hours. I am not a big fan of this watch schedule. In my opinion the system endangers the safety of the ship while navigating an intense archipelago fairway together with another officer that has had only 6.5 hours of rest before a watch that starts 0530 in the morning. I have always deviated from the designed schedule by making adjustments with colleagues to ensure longer sleeping times. Without this adjustment I would have two sleeps of only 4–5 hours in 24 hours every working period on board. Our sister ship does the exactly same run every other day. They have organized the watch schedule completely different from us: both deck officers work the whole 10 hours in one stretch having one 14 hour off-watch period every 24 hours.

**Analysis:** On this specific RoPax ferry the watch system is more or less dictated by the sailing schedule. The departure from one end is 1700 and the arrival is at 0945. What mixes things up is an extra port of call in the middle of night at 0415. On the return the departure is at 1745 and the arrival at 1030. The extra port of call is at 2345.

The 1<sup>st</sup> Officer works the so-called 12–4 watch, which is 1200–1600, 2230–0530, 1200–1600, 2330–0400. The longest off-watch is 7.5 hours. The cabins are situated

very close to the bridge and they are fairly quiet. The rhythm is very different from the circadian system and there is very little time to adjust as the period on board is only 10 days. For a decent anchor sleep / napping with a 6.5 hours anchor sleep it is only possible every other day. Sleep deprivation and fatigue build up is very probable.

The 2<sup>nd</sup> Officer works in the so-called 4–8 or 4–12 watch, on which the working hours are: 1630–1930, 0430–1100, 1700–2030, 0400–1100. The longest off-watch is 9 hours. The rhythm is closer to the circadian system so adjusting is quicker. Every other day there is a possibility to have an 8-hour uninterrupted sleep. Sleep deprivation and fatigue build up is still likely.

The watch system on the sister ship seems to be better with such short work period on board. Rotating between the two watches keeps the work more interesting but for the sake of adjusting to the rhythm it is probably more harmful than not rotating at all or rotating once a month or even less frequently.

#### 4.2.2 Study person 2

1. 2<sup>nd</sup> Officer on board a cruise ship with a worldwide itinerary. Typical cruise length is two weeks with 9 different ports.
2. 10 hours, of which 8 hours watchkeeping
3. Onboard our ship it's the Captain's decision when to change and who is doing which watch. The deciding factor is the experience of each officer. In general during a 3-month period on board I change watches 1 or 2 times.
4. In the 5–3 system I prefer the 0500–1000 & 1600–1900 watch as you can combine a social life onboard to an interesting watch with the arrivals and departures. It is also possible to have a proper sleep during the night.
5. In the 0000–0500 and 1000–1300 watch my sleeping hours are from 1900–2330 and 0515–0915:  $4.5 + 4 = 8.5$  hours  
In the 0500–1000 and 1600–1900 watch my sleeping hours are from 2100–0430 and 1330–1530:  $7.5 + 2 = 9.5$  hours  
In the 1300–1600 & 1900–0000 watch my sleeping hours are from 0100–0915 & 1730–1830:  $8.25 + 1 = 9.25$  hours

**Analysis:** This cruise ship has double watchkeeping at all times when the ship is at sea or at anchor. The senior watchkeeper is the 2<sup>nd</sup> Officer and the junior is the 3<sup>rd</sup> Officer. Normal manning on board is three 2<sup>nd</sup> Officers and four 3<sup>rd</sup> Officers that rotate between the watches. 2<sup>nd</sup> Officers normally work 3-month periods on board and 3<sup>rd</sup> Officers work 4 months on board.

Common practice is to rotate the officers through all the watches but very often there are interruptions in the rotation. These are due to master's wishes or shortage in the manning.

The 5 and 3 watch system is not designed to be run this way. The proper watches are supposed to be: 0000–0500 and 1600–1900, 0500–1000 and 1300–1600, 1000–1300 and 1900–0000 that would guarantee each watch an uninterrupted off-watch of at least 10 hours. In the system that is running the 0000–0500 and 1000–1300 watch has a very broken sleeping schedule with no proper anchor sleep / napping possibility. Sleep deprivation and fatigue build up to the two officers in that watch is very likely. In the other watches it is possible to get decent amount of sleep as long as other duties and drills do not interrupt too badly.

#### 4.2.3 Study person 3

1. 3<sup>rd</sup> Officer, cruise ship with a worldwide itinerary
2. 10 hours with 5 hours of watchkeeping
3. Rotation is up to captain's discretion, there is not a standard time or system for changing watch.
4. So far I only have done the Dogwatch (0000–0500) combined with working in safety from 0800–1200 and then 1300–1400. In total it is 10 hours of work with a nice afternoon to spend ashore or to relax for a while. There have also been occasions that I have been called for arrival mooring stations before 0800 and then I have stopped working at 1200. That has not been bad either as then I have had 12 hours off.
5. When doing the Dogwatch I try to sleep 1730–2330 but I am not always able to fall to sleep that early. Then I take a nap from around 0530 to around 0730. If I do an arrival in the morning on mooring stations, the nap in the morning is reduced to an hour or less. I try to go to bed then at around 1600 or 1700. Again, not always easy to fall asleep. I also worked in a rhythm of starting safety work at 1000. In that

rhythm I would sleep between 0500–1000 but then I was not able to sleep in the evening and ended up sleeping a few hours before watch and then a few after. I prefer to have a block of 6 to 8 hours of sleep and then a little nap during the day.

**Analysis:** The Study person 3 works on the same vessel that Study person 2 and the watch schedule is the same. The problem of the officers working in the 0000–0500 watch is clearly pointed out. If one has to start at 1000 the anchor sleep period becomes too short. In this case the officer only does the watch at night and he is able to choose his own hours for the remaining of the working day. Starting safety at 0800 or going to mooring stations even earlier moves the anchor sleep to the evening and the nap to the morning. This demands of changing the circadian rhythm, which is possible when working long periods of up to 4 months on board.

Another possibility is to have the person start his other 5 hours in the afternoon, for example at 1300. Then the anchor sleep would be closer to the circadian system. The problem with it is that the voyage plan meetings are held normally at 1000 and the drills at 1030. The meetings should be changed to the afternoon and this person should be given an emergency task that would not involve him/her in each drill every week.

#### 4.2.4 Study person 4

1. 3<sup>rd</sup> Officer, sailing passenger ship with a worldwide itinerary
2. 12 hours at sea of which 8 hours watchkeeping on the bridge
3. No rotation, 3<sup>rd</sup> Officer always does 0800–1200 and 2000–0000 watches
4. I work now as 2<sup>nd</sup> Officer and even though I sleep less I don't experience any difference in how I feel
5. Sleep 0100–0715 of which 6 hours effective + 1700–1900 sleep of which 2 hours effective

**Analysis:** This sailing passenger vessel runs two different watch systems. At sea the system is 4 hours on, 8 hours off. Each deck officer runs his/her own department and manages the extra 4 hours to be done whenever most suitable. In port or at anchor everyone works more or less 10 hours from 0800 to 1800. The 3 deck officers split the Officer of the Watch duty between each other so that one stays on board and is on call



from 0800 to 0800 the next day. If there is scheduled duty after 1800 in the evening the OOW of the next day takes over during 1200–1800.

The sleeping times represented here are from when the ship is at sea. The longest sailing times are the Atlantic crossings that can take up to 3 weeks.

In the traditional 4 hours on 8 hours off system sleep is always divided in two: the anchor sleep and a nap. In the 0800–1200 and 2000–2400 watch the rhythm is as optimal as it can be. The anchor sleep follows closely to the circadian system and the ship is most quiet at that time.

On board the ship in question the wake up is at 0715 and breakfast is served 0730–0800. There is a special dinner at 1930–2000 for this watch, which guarantees a proper time for a nap in the afternoon.

#### 4.2.5 Study person 5

1. 2<sup>nd</sup> Officer, sailing passenger vessel with a worldwide itinerary
2. 12 hours at sea of which 8 hours watchkeeping on the bridge
3. No rotation, 2<sup>nd</sup> Officer always does the 0000–0400 and 1200–1600 watches
4. I used to work as 3<sup>rd</sup> Officer but even now when I sleep less I feel about the same
5. Sleep 0500–1030 (often interrupted around 0900), 4–5 hours effective. Sleep 2130–2340, 2 hours effective

**Analysis:** The Study person 5 is the same person than Study person 4 but is now working as the 2<sup>nd</sup> Officer. The 2<sup>nd</sup> Officer on board this ship suffers most. The off-watch times are interrupted with noises on board and a daily meeting at 1115. The 2<sup>nd</sup> Officer can only get a maximum of 7 hours of sleep per day and very often even less. Sleep deprivation is almost inevitable and build up of fatigue is very probable.

#### 4.2.6 Study person 6

1. 3<sup>rd</sup> Officer, sailing passenger vessel with a worldwide itinerary
2. 12 hours at sea of which 8 hours of watchkeeping on the bridge
3. No rotation, 3<sup>rd</sup> Mate in the 2000–0000 watch.

4. No rotation.
5. Sleep 0045–0715 (6.5h) and 1800–1940 (1.8h).

**Analysis:** The Study person 6 is another 3<sup>rd</sup> Officer on the same vessel than the Study person 4. This person opted to have dinner at 1730 instead of 1930 extending the pre-watch sleep closer to the actual watch. The anchor sleep is 6.5 hours, which is closer to optimal and the study person averages 8.3 hours of sleep every day. In this rhythm sleep deprivation could be kept to minimum but care must be taken as it does not leave much room for recovery.

#### 4.2.7 Study person 7

1. 2<sup>nd</sup> Officer, sailing passenger vessel with a worldwide itinerary
2. 12 hours at sea of which 8 hours of watch keeping on the bridge.
3. No rotation, 2<sup>nd</sup> Mate in the 1200–0400 watch.
4. No rotation.
5. Sleep 0430–1045 (6.25h), sleep 2130–2340 (2.1h).

**Analysis:** The Study person 7 is the same person than Study person 6 but when the person was working as 2<sup>nd</sup> Officer on the same ship. The 2<sup>nd</sup> Officer position is the worst when it comes to sleeping but this person has taken the most out of it. Still the anchor sleeping time of 6.25 hours is probably not enough and even if the person averages 8.35 hours per day sleep deprivation and accumulated fatigue is likely to happen. There is absolutely no room for recovery if sleep deprivation does occur.

#### 4.2.8 Study person 8

1. 1<sup>st</sup> Officer, sailing passenger vessel with a worldwide itinerary
2. 12 hours at sea of which 8 hours of watch keeping at the bridge
3. No rotation, 1<sup>st</sup> Mate in the 0400–0800, 1600–2000 watch
4. No rotation
5. Sleep 2140–0340 (6h), sleep 1300–1540 (2,6h)

**Analysis:** The Study person 8 is the same person than Study persons 7 and 6 but at the 1<sup>st</sup> Officer position. The person only sleeps a 6-hour anchor sleep as it is very hard to fall to sleep earlier due to the circadian system and noises on board. The average 8.6 hours per day is enough to prevent sleep deprivation and accumulated fatigue build-up and there is also a possibility to extend the anchor sleep to allow recovery after interrupted sleep.

## **5 Results and their interpretation**

### **5.1 Results of records of own sleeping hours**

The records clearly show that the 4 hours on 8 hours off system worked much better on board the same ship than the wrongly implemented 5 and 3 schedule. My average sleeping hours were significantly longer during the second contract even though I rotated through all the three watches and at some point was taken out of the watches completely.

The 5 and 3 watch system needs to be implemented as it was designed to actually benefit from it. The daily meeting has to be changed from 1000 to the afternoon or otherwise the sleep of the people working at night is dangerously compromised. Drills will still interfere the sleep during the morning hours but the 5 and 3 system allows for extra sleep to recover from interrupted sleep.

### **5.2 Results of interviews**

Deck officers from three different ships were interviewed. Each ship was running their own watch-schedule that was also very different from each other. Each system had flaws and benefits and it was evident that at least some sleep deprivation and accumulated fatigue build up were most probable to happen on board.

On board the RoPax ferry especially the 1<sup>st</sup> Officer watch schedule was very demanding. Care must be taken by the officer to ensure proper sleep was achieved. The anchor sleeps were always shorter than ideal. The rhythm was also very hard on the circadian system and as the period on board was only 10 days very little time for adjustment was given.

As the sister ship was managing the same itinerary with the same manning with a system of working 10 hours in one stretch that system should at least be investigated and even trialled on board.

On board the cruise ship the deck officer watch schedule was very close to optimum. There was only the two officers working in the 0000–0500 watch that were suffering from an anti-circadian rhythm and sleeping time with frequent interruptions for drills and meetings.

## **6 Critical examination and discussion**

The design process of a working watch schedule should start with a proper assessment of all the aspects that have an effect on the working rhythm on board. Good tools for this are for example the ones provided by the US Coast Guard for Crew Endurance Management programs.

Good practice would be to set up a work group that will gather an appraisal of the situation first and analyse it carefully. It is important to identify all possible aspects that have an effect on bridge watchkeepers performance. Among other thing these include:

- Bridge team members experience
- Noise level in the watchkeepers' cabins
- Regular drill times
- Periodic meeting times
- Workload split between members of the bridge team
- Sailing schedule including arrivals and departures
- Sailing area stress factors (traffic, navigational hazards, speed, weather)
- Length of the period of work on board
- Ship standard meal times
- Lighting on the bridge and the deck office
- Air-conditioning adjusting possibilities
- Bridge ergonomics

When the appraisal and the analysis has been completed it is time to judge if the current watch schedule meets the standards. The specific questions are:

- Are all bridge team members able to have 8 hours of uninterrupted sleep every 24-hour period?
- If not, are they able to have one 6.5-hour uninterrupted anchor sleep period combined with a 2–3-hours nap every 24-hour period?
- If sleep is interrupted by unscheduled or scheduled call to work or sounds of alarm for drills does the schedule allow for extra sleep to compensate for sleep deprivation?
- Is the importance of the Red Zone completely identified and if shifting of the circadian system is needed for crewmembers working during the Red Zone hours, is there enough time allowed for them to adjust fully?
- What kind of rotation shall be used?

## **6.1 Case example**

The sailing passenger ship on which Study persons 4, 5, 6, 7 and 8 worked runs the traditional 4 hours on 8 hours off watch schedule. Especially the 2<sup>nd</sup> Officer can only get maximum 7 hours of sleep per day and the schedule does not allow any compensation if sleep deprivation occurs. The daily need is to run a three-watch system and everyone works 12 hours per day.

An extra need is to have one daily meeting between the Management team (MT) and another between the whole crew. Currently the MT has the meeting at 1115 and the whole crew meets at 1200. Drills cause problems every week as well. The 0400–0800 watch normally works their extra hours 0800–1200 but on drill days they have off-watch in the morning and work 1200–1600. Rotation causes sleep deprivation.

A 5 and 3 watch schedule would work much better on board. The watch times would be:

1<sup>st</sup> Officer: 0300–0800 and 1100–1400. Extra hours 0800–1100 and 1400–1500. Off: 1500–0300 (12 hours)

2<sup>nd</sup> Officer: 2200–0300 and 1400–1700. Extra hours 1300–1400 and 1700–2000. Off: 0300–1300 (10 hours) and 2000–2200 (2 hours)

3<sup>rd</sup> Officer: 0800–1100 and 1700–2200. Extra hours 1100–1500. Off: 1500–1700 (2 hours) and 2200–0800 (10 hours).

The daily MT meeting could be at 1300 and the daily crew meeting at 1445. Everyone on board would be working every day between 1300–1500, which would allow for drills to be organized without disturbing anyone's rest.

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