Uğurlu, Ö, Köse, E, Başar, E, Özkök, M and Wang, J

Simulation modelling of chief officers' working hours on short sea shipping

Simulation modelling of chief officers' working hours on short sea shipping

[a]Özkan UĞURLU, [b]Ercan KÖSE, [c]Ersan BAŞAR, [d]Murat ÖZKÖK and [e]Jin WANG

[a]Maritime Transportation and Management Engineering Department, Ordu University, Ordu, Turkey, ougurlu@odu.edu.tr; ozkanugurlu24@hotmail.com, 00905058179839 (corresponding author)
[b] Naval Architecture and Marine Engineering Department, Karadeniz Technical University, Trabzon, Turkey, ekose@ktu.edu.tr
[c]Maritime Transportation and Management Engineering Department, Karadeniz Technical University, Trabzon, Turkey, ebasar@ktu.edu.tr
[d]Naval Architecture and Marine Engineering Department, Karadeniz Technical University, Trabzon, Turkey, muratozkok@ktu.edu.tr
[e]Liverpool Logistics, Offshore and Marine (LOOM) Research Institute, Faculty of Engineering and Technology, Liverpool John Moores University, Liverpool, UK, j.wang@ljmu.ac.uk

ABSTRACT

Short sea shipping poses significant problems for many seafarers, particularly for officers employed in oil tankers as chief officers. This study examines chief officers' working conditions on short sea shipping. In this study, Simio simulation software was utilised to evaluate the working hours of chief officers. The results demonstrate that the rest periods of the chief officers have been less compromised as the navigation period increases in oil tankers operated on short sea shipping. To comply with the relevant regulations, a navigation period of 24-28 hours is the minimum condition for an oil tanker to have a chief officer; however, an additional officer may be required for shorter voyages. The findings of the research provide some recommendations to maritime authorities to achieve safe short sea shipping.

Keywords: Human performance modelling, working hours, seafarer, fatigue, simulation modelling

1. INTRODUCTION

As a result of economic and technological development, the need for raw materials, manufactured goods, electronics, and petroleum products has led to the increased numbers of vessels on maritime transportation (Equasis 2008). However, this growth in marine trade has created problems for shipping companies to adequately staff their ships. Therefore, ships' safe manning in the maritime transportation industry has attracted attention to many researchers in maritime safety (Obando-Rojas 1999; Uğurlu 2016). As in many land-based industries, vessels are operated in shifts. The standard work schedule of watchstanders on merchant marine vessels involves the 4 h on and 8 h off watch schedule (Sanquist et al. 1997; Strauch 2015; Van Leeuwen et al. 2013). This is usually a fixed schedule of work in merchant ships, with the first officer standing the 04.00-08.00 and 16.00-20.00 watch, the second officer standing the midnight to 04.00 and 12.00- 16.00 watch, and the third officer standing the 08.00- 12.00 and 20.00-24.00 watch. In addition to keeping watch, officers have other duties to fulfil. They are responsible for the protection of the ship, cargo, personnel and the environment.

Ship operations should be led by qualified, competent and rested deck officers. Seafarers working on oil tankers are subject to a significant amount of pressure (Mitroussi 2008), often passed to the crew from the shipping company. Ship masters are pressured to clean cargo tanks faster, arrive at the next port faster, or to use the shortest rather than the safest sea passages (Arslan, 2008). These pressures adversely affect the working conditions of seafarers working in oil tankers. Although maritime authorities, owners, and trade unions are aware of such conditions, the measures taken are insufficient. Improper working conditions may increase fatigue levels of seafarers (Zhao et al. 2020). It is a significant health and safety concern at sea since fatigue strongly affects the frequency of errors being made (Jones et al. 2005). Many studies in the literature emphasise that fatigue triggers accident formation (Akhtar and Utne 2014; Bal Beşikçi et al. 2016; Fan et al. 2018; Uğurlu et al. 2015).

The conditions that seafarers have to work in are becoming increasingly difficult (Akhtar and Utne 2015; Nguyen et al. 2014). Officers are faced with unfavourable working conditions such as rough seas, wind, storm, dense traffic, shipowner pressure, increased workload, internal-external audits and fast crew cycle while performing their duties (Bloor et al. 2004; Phillips 2000; Uğurlu 2015; Uğurlu et al. 2018). Many studies have investigated deck officers' work conditions, including inappropriate environmental conditions, excessive workload, inconvenient rest hours, and lack of social opportunities (Andresen et al. 2007; Bloor et al. 2004; Leung et al. 2006; Louie and Doolen 2007; McNamara et al. 2000; Miller et al. 2011; Orosa et al. 2011; Pik 2007; Reyner and Baulk 1998; Robert 2007; Uğurlu 2015; Yıldız et al. 2016).

Tanker transportation, as a dangerous mode of transport, puts a heavy workload on chief officers. Chief officers are responsible for the navigational watch, tank cleaning, loading and unloading operations, shipboard equipment testing and controls, and training (Uğurlu 2016). Shorter travel times often do not provide chief officers with sufficient time to complete such tasks. For this reason, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) concerning officers' rest time is frequently violated. Short sea shipping negatively affects seafarers, especially in terms of deck officers' work and rest hours. Seafarers' fatigue is directly related to their workload and working hours. Factors that increase the workload on seafarers include the short distance between ports, frequency of cargo operations, tank cleaning operations, high-frequency ship manoeuvres, supplies (fuel, provisions, water, *etc.*), planned maintenance, drills, tests and controls, time pressure to arrive early in port, and inadequate safe manning (Jepsen et al. 2017; Pauksztat 2017b; Shan and Neis 2020; Van Leeuwen et al. 2020). Deck officers' improper working hours are one of the most significant issues threatening navigational safety throughout coastal waters. In addition, the consequences of accidents involving oil tankers are much more severe than with other types of ships, as they negatively affect not just the ship or crew but also the natural environment and ecosystem (Navas de Maya et al. 2020). Therefore, rest hours of deck officers working on oil tankers are of great importance.

Uğurlu (2016) examined the deck officers' working and rest hours (chief officer, second officer and third officer) in the oil tanker operating on a fixed-line in short sea shipping. The navigation period of the oil tanker in the study was limited to a maximum of 6 hours. The findings were that chief officers' working hours were not compatible with the STCW Convention's specifications (IMO 2011) and ILO/MLC (2006). The working hours of the second and third officers were observed to comply with the convention. They had the working times ranging from 10 to 12 hours per day on board. Unlike the studies in the literature, the relationship between the working and rest hours of the chief officer working in an oil tanker operated in short sea shipping with the navigation period was examined in this research. The second and third officers' working and rest hours were not included in this study since they were compatible with the STCW and ILO/MLC requirements. Simio software was used to examine the relationship in the said study.

2. REGULATIONS AND CONVENTIONS FOR SEAFARERS' WORKING HOURS

The ILO/MLC (2006) Convention regulates seafarers' work and rest hours. According to the ILO/MLC (2006) Convention and the STCW Convention (IMO 2011), all staff who are assigned duty as the officer in charge of a watch and those whose duties involve safety, security, and prevention of pollution shall be provided with a rest period of not less than:

a- Minimum of 10 hours of rest in any 24-hours period.

b- 77 hours in any 7 days.

c- The hours of rest may be divided into no more than two periods, one of which shall be at least 6 hours in length, and the intervals between consecutive periods of rest shall not exceed 14 hours. The requirements for rest periods laid down in the above paragraphs need not be maintained in case of an emergency or other overriding operational conditions. Musters, firefighting and lifeboat drills, and drills prescribed by national laws and regulations and international conventions, shall be conducted to minimise the disturbance of rest periods and does not induce fatigue.

d- Notwithstanding the provisions of the above paragraphs, a period of ten hours may be reduced to not less than 6 consecutive hours. Any such reduction shall not extend beyond two days and not less than 70 hours of rest are provided every seven days. Exceptions from the weekly rest period provided for in (77 hours in any 7 days) shall not be allowed for more than two consecutive weeks.

Administrations shall require that records of hours of rest of seafarers be maintained and that such records be inspected by the authorities to ensure compliance with regulations concerning rest periods.

3. SIMULATION MODELS

Simulation software is a useful tool for improving an existing system's functioning and analysing systemic effectiveness and efficiency (Uğurlu et al. 2014). Simulation applications allow real events to be modelled in a computer environment. These programs do not require high investment costs and enable advanced planning and foresight into problems in the future.

Simulation is utilised in almost every field, such as engineering, science, and technology. Simulation systems have been increasingly adapted to a variety of applications. In the maritime industry, simulations are generally used to analyse marine accidents, maritime traffic, the ship construction processes, complex port operations and port operational efficiency (Goerlandt and Kujala 2011; Hirsch et al. 1998; Kim et al. 2004; Köse et al. 2003; Lee et al. 2003; Uğurlu et al. 2014).

When creating a real event simulation model, firstly information about the current state of that event is collected. This is a crucial step for the real event to be accurately modelled on the computer. After the actual data is gathered, the event's simulation model is modelled in a computer environment, and the collected or calculated data is manually input to the simulation model. The model is then run for a certain period, and the results are evaluated for the current situation. Suppose some improvements are desired to be made on the current situation. In that case, each scenario's effects on the current situation are analysed by applying several scenarios within the created simulation model. In the final stage, how much improvement has been made is determined by comparing the current situation scenarios.

3.1. Simio

Simio software is used in many service sectors such as factories, supply chains, emergency departments, airports, and supermarkets to simulate 3D animated models (Simio 2019). Simio uses the combined objects to represent physical components. An item (or model) is defined by its properties, states, events, external view, and logic, which are the key concepts for building and using objects. Properties are the input values that the object's user can select. For example, an object representing a server might have a property that specifies the service time, which should be set in the facility model. Models in Simio are defined within a project. A project may contain any number of models and associated experiments. A project will typically have a main model and an entity model. A new project will automatically include the main model and entity model to the project, and it is possible to add additional models to create sub-models that are then used to build the main model (Kelton et al. 2013).

The simulation software used in the study is coded based on queue theorem. Generally, in the simulation models prepared by using simulation software, various measures such as Average Waiting Time in the Queue (Wq), Average Waiting Time in the System (W), Average Number of Queues Waiting in the Queue (Lq), and Average Number of Pieces Waiting in the System (L) are utilised. The efficiency of the simulation model is determined by evaluating these performance indicators. The Lq value is one of the indicators that shows the bottleneck status in the system. If this value is measured high in any workstation buffer area, there may be a bottleneck in the said workstation. There are certain relationships between these parameters or indicators, and the following are the most important equations according to Little's Law (Kelton et al. 2013):

$$L = \lambda \times W \tag{1}$$

$$L_q = \lambda \times W_q \tag{2}$$

$$W = W_q + E(S) \tag{3}$$

$$W_q = {}^{L}\!/_{\lambda} - E(S) \tag{4}$$

Taking the above equations into consideration, λ represents the range of arrivals of entities within the simulation model. The E(S) value indicates the expected value of any server's processing time distribution (*e.g.* a machine). According to Little's rule, a simulation model's performance values can be found by using the equations above. However, as the model volume grows, manual calculations are replaced by simulation programs programmed in a specific software language. The simulation software used in this study is called Simio where similar evaluation criteria are used with some variations such as “TimeInSystem”, “NumberInSystem”, “TimeInStation” and “NumberInSttaion”. It is desirable to know how much time (average and maximum) the entities spend in the system. This is referred to as "TimeInSystem" in the simulation software. However, it is also desirable to know the population of the entities within the system in a certain period. This is equivalent to "NumberInSystem" in Simio software. In this case, it is needed to take a look at "TimeInStation" and "NumberInStation" values (Figure 1). These parameters indicate how many entities are waiting in front of any server and how long they spend in the queue.

Figure 1. a) Simio presentation of “NumberInSystem” and “TimeInSystem” b) Simio presentation of “NumberInStation” and “TimeInStation”

4. METHODOLOGY

As a result of the global crisis that emerged in the financial markets at the beginning of the 2000s, the falling freight prices and earnings had a negative impact on maritime transportation (Pantuso et al. 2014). Shipping companies with the intention of competing with the rivals have chosen to work at the most affordable cost and reduced their crew numbers on ships. The operation of ships with a minimum crew has enabled companies to save on personnel costs. However, the requirements of companies to operate their ships with minimum seafarers have increased the workload of seafarers. The increase in workload has adversely affected the working conditions of seafarers. One of the main problems of seafarers in today's maritime transport is the improper working hours (Lützhöft et al. 2011). Chief officers of ships operated in short sea shipping are exposed to intense workload and improper working conditions (Uğurlu 2016). Improper working conditions are one of the main risk factors in the occurrence of marine accidents (Kim et al. 2004; McNamara et al. 2000). Consequences of oil tanker accidents are usually catastrophic. For this purpose, the working hours of chief officers working in oil tankers operated in short sea shipping were analysed in a simulation environment. The results of the study provide some advice to maritime authorities on manning of oil tankers with seafarers.

There are many simulation software tools such as Arena, Awesim, Witness and Flexsim in the literature (Zheng et al., 2010). In this research, Simio was chosen as a simulation tool. Simio has visual, interactive and interpretative modelling functions and supports large-scale implementation for discrete and continuous system modelling (Zheng et al. 2011). In the study, the relationship between the navigation period and the working hours of the chief officer was evaluated. The working and rest hour periods of the seafarers on ships are evaluated on weekly periods under ILO/MLC (2006) and STCW (IMO, 2011) Conventions. Therefore, in this study, scenarios were run in Simio software for one week. The working hours of the chief officer were analysed for two different conditions (best condition and worst condition) and 6 different navigation periods. The worst condition represents the working hours that the chief officer can be most intense during a voyage, while the best condition represents the most optimistic situation. Since it was stated in previous studies (Uğurlu et al. 2012; Uğurlu 2016) that the working hours of the second and third officers were within the conventions' limits, their working hours were not included in this study. The scenarios were simulated for 6 different navigation periods ranging from 4 to 28 hours. In addition, in the study, in the case of an extra officer on board for worst condition scenarios, the working hours of the chief officer were checked for compliance with the relevant conventions. In addition to officer scenarios, the chief officer is exempted from the watch in port and navigation. The chief officer is responsible for managing the cargo operations at the port and protecting the ship, cargo, personnel, and the environment during navigation.

Primarily, in order to determine the working hours of the chief officer, the work done by the deck officers during a voyage was specified. For this purpose, task and time definitions were made for all officers in the study. In other words, timesheets were created for them. Task and time definitions have been created based on the studies presented by Uğurlu (2016) and Uğurlu et al. (2012). The tasks performed by the officers of the ship during a voyage are divided into 3 main groups as the general duties and the duties at the port and the navigation. Later, all task definitions and times were defined in the simulation software. All scenarios were run in Simio for one week. The ISF Watchkeeper program was utilised to check the compliance of the working and rest hours of the chief officer with ILO/MLC (2006) and STCW (IMO, 2011) Conventions. The ISF Watchkeeper program records seafarers' working hours in a computer environment. This program is frequently used on ships to check the compliance of working hours with the relevant conventions. It aims to control the fatigue of the ship's crew and is recognised by the OCIMF (Oil Companies International Marine Forum) (Uğurlu 2016). It is used to check the compliance of seafarers' working hours with relevant conventions on more than 8,000 merchant ships worldwide (ISF watchkeeper, 2012). It has been used in scientific studies to analyse and interpret seafarers' working hours (Nersesian and Mahmood 2010; Simkuva et al. 2016; Uğurlu 2016).

4.1. Work Allocation and Determination of Periods

At this stage of the study, timesheets were built for the work fulfilled by the deck officers during a voyage. The basis of many simulation studies in the literature is based on timesheets (Guizzi et al. 2009; Ignaccolo 2003; Uğurlu et al. 2014). Real-time timelines allow simulation models to give consistent results and the system's problems to be detected. In this study, the timesheets for the deck officers working in the oil tanker were presented, based on the literature studies (Uğurlu et al. 2012; Uğurlu 2016) (Table 1- Table 6). Table 1 - Table 5 explain the work done by the deck officers during a voyage; on the other hand, Table 6 depicts the time spent on these works. Table 6 summarises the task definitions from Table 2 to Table 5 for chief officers and represents the inputs of the simulation system.

Table 1. Deck officers' general duties

Table 2. Deck officers' duties while sailing to a discharge port

Table 3. Deck officers' duties at a discharge port

Table 4. Deck officers' duties while sailing to a loading port

Table 5. Deck officers' duties at a loading port

Table 6. Operation times (the inputs of the simulation system)

The simulation model in this study begins with the ship navigation to the discharging port and follows the steps from Table 2 to Table 5. Once one voyage cycle of the ship is completed, the ship starts the next voyage. The work done in another voyage continues in the same cycle from Table 2 to Table 5. The simulation is terminated when a week is over. Figure 2 provides a flow chart illustrating the Simio simulation of a short sea voyage of an oil tanker. The scenarios in the study are simulated as a normal distribution between the limits given in Table 6. In the scenarios, only the duration of voyage varies.

Figure 2. Simulation flow chart of an oil tanker voyage

5. RESULTS AND DISCUSSION

All scenarios were run for 7 days, and the results were analysed against the ILO/MLC (2006) and STCW (IMO 2011) Conventions. Figure 3 depicts the first scenario results (worst condition-first day) to illustrate the analytical method. In this figure, the chief officer is on duty when y = 1, and off duty (rest) otherwise. In addition to the duties described previously, the chief officer also keeps watch on the bridge or in the cargo office. The chief officer's watchkeeping hours appear as a blue rectangle in Figure 3.

Figure 3. Chief officers' daily work-rest hours

Tables 7 and 8 provide the analytical results obtained from the simulation, highlighting the chief officer's daily work and rest hours in a week for both the best and worst-case scenarios and the comparison against the ILO/MLC (2006) and STCW (IMO 2011) Conventions, respectively.

Table 7. Chief officers' average work and rest hours

Table 8. Simulation results illustrating non-compliance with ILO/MLC (2006) and STCW (IMO 2011) Conventions

There are three basic rules related to work and rest hours, explained earlier in Section 3. According to the results in Table 8, when the worst cases are considered for chief officers, none of the ILO/MLC (2006) and STCW (IMO 2011) criteria is met for all scenarios. For the best case, the requirement for a minimum of 6 consecutive hours of rest and no less than 10 hours of rest in a 24-hours period is almost never met in the first 5 scenarios that include watchkeeping, although it was met in the sixth scenario. Additionally, the chief officer receives less than 10 hours of rest on average per day in the first 5 scenarios. In the sixth scenario, average daily rest time for the week is more than 10 hours. Except for the first 3 scenarios, the total weekly rest hours are more than 77 hours.

The results illustrate that the chief officer's work hours are closely related to navigation period. When the chief officer is exempt from the watch, the work and rest hours for all scenarios comply with the relevant conventions. Therefore, it is important to review the transit or navigation period to determine whether to staff an additional officer. The first six scenarios show that rest times improve as the time at sea increases (navigation period). Therefore, a 24 – 28 hours voyage period is a critical time in terms of determining if an additional officer should be employed to comply with the working hour regulations. Many studies in the literature emphasised that ship crews working in short sea shipping have an excessive workload (Pauksztat 2017a; Smith et al. 2006). In this study, the intensive working tempo of the ship's chief officer in oil tankers was revealed with numerical data by Simio simulation modelling. When the scenarios are examined, it is seen that as the navigation period decreases, the number of days in which the chief officer has a working time of 15 hours or more is quite high. These results reveal the necessity of an extra officer in order to reduce the workload of the chief officer in oil tankers operated in short sea shipping.

6. CONCLUSION

Maintaining compliant working hours for watchkeeping officers (especially the chief officer) employed on short sea oil tankers is a common problem. This study demonstrates that as the transit distance increases, chief officers' working hours decrease. Additionally, chief officers' working hours increase with the number of ports of call. Combined with these excessive working hours, the inadequate conditions, company and charter pressure on the crew, the intensity of audits, preparation for these audits, and the risks present in tanker transportation make short distance tanker transportation undesirable for officers. Furthermore, the combination of these working conditions undoubtedly constitutes a significant risk in terms of the safety of both the cargo and crew. This study illustrates that chief officers' work and rest hours on short sea oil tankers with transit times less than 24-28 hours do not comply with ILO/MLC (2006) and STCW (IMO 2011). Therefore, tankers with transit times less than 24 – 28 hours should consider staff an additional officer to ensure compliance with the relevant conventions.

REFERENCES

Akhtar MJ, Utne IB. 2014. Human fatigue's effect on the risk of maritime groundings–A Bayesian Network modeling approach. Safety Science 62:427-440.

Akhtar MJ, Utne IB. 2015. Common patterns in aggregated accident analysis charts from human fatigue-related groundings and collisions at sea. Maritime Policy & Management 42(2):186-206.

Andresen M, Domsch M, Cascorbi A. 2007. Working Unusual Hours and Its Relationship to Job Satisfaction: A Study of European Maritime Pilots. Journal of Labor Research 28:714-734.

Arslan, O., & Er, I. D. (2008). SWOT analysis for safer carriage of bulk liquid chemicals in tankers. *Journal of Hazardous Materials*, *154*, 901-913.

Bal Beşikçi E, Tavacıoğlu L, Arslan Ö. 2016. The subjective measurement of seafarers’ fatigue levels and mental symptoms. Maritime Policy & Management, 43(3):329-343.

Bloor M, Pentsov D, Levi M, Horlick-Jones T. 2004. Problems of Global Governance of Seafarers' Health & Safety. Seafarers International Research Centre.

Equasis. 2008. The world merchant fleet in 2007. Retrieved 02/02/2013.

Fan S, Zhang J, Blanco-Davis E, Yang Z, Wang J, Yan X. 2018. Effects of seafarers' emotion on human performance using bridge simulation. Ocean Engineering 170:111-119.

Goerlandt F, Kujala P. 2011. Traffic simulation based ship collision probability modeling. Reliability Engineering & System Safety 96:91-107.

Guizzi G, Murino T, Romano E. 2009. A discrete event simulation to model passenger flow in the airport terminal. Mathematical methods and applied computing 2:427-434.

Hirsch BE, Kuhlmann T, Schumacher J. 1998. Logistics simulation of recycling networks. Computers in Industry 36:31-38.

Ignaccolo M. 2003. A simulation model for airport capacity and delay analysis. Transportation Planning and Technology 26(2):135-170.
ILO/MLC. 2006. Guidelines for port state control officers. London: International Labour Office.
IMO. 2011. STCW Including 2010 Manila Amendments STCW Conventions and STCW Code. London: IMO Publishing.
Isfwatchkeeper. 2019. ISF Watchkeeper. Accessed December 3, 2019. http://home.isfwatchkeeper.com
Jepsen JR, Zhao Z, Pekcan C, Barnett M, Van Leeuwen WM. 2017. Risk factors for fatigue in shipping, the consequences for seafarers' health and options for preventive intervention. Maritime Psychology. Springer, Cham.
Jones BC, Dorrian J, Rjaratnam MWS, Dawson D. 2005. Working hours regulations and fatigue in transportation: A Comparative Analysis, Safety Science 43:225-252.
Kelton WD, Smith JS, Sturrock DT. 2013. Simio and Simulation: Modeling, Analysis, Applications Third Edition, Simio LLC.
Kim H, Park JH, Lee D, Yang YS. 2004. Establishing the methodologies for human evacuation simulation in marine accidents. Computers & Industrial Engineering 46:725-740.
Köse E, Başar E, Demirci E, Güneroğlu A, Erkebay Ş. 2003. Simulation of marine traffic in Istanbul Strait. Simulation Modelling Practice and Theory 11:597-608.
Lee TW, Park NK, Lee DW. 2003. A simulation study for the logistics planning of a container terminal in view of SCM. Maritime Policy & Management 30:243-254.
Leung AWS, Chan CC, Nq JJ, Wong PC. 2006. Factors contributing to officers' fatigue in high- speed maritime craft operations. Applied Ergonomics 37:565-576.
Louie VW, Doolen TL. 2007. A study of factors that contribute to maritime fatigue. Marine Technology and Sname News 44:82-92.
Lützhöft M, Grech M R, Porathe T. 2011. Information environment, fatigue, and culture in the maritime domain. Reviews of human factors and ergonomics 7(1):280-322.
McNamara R, Collins A, Matthews V. 2000. A Review of Research into Fatigue in Offshore Shipping. Maritime Review 118-122.
Miller NL, Shattuck LG, Matsangas P. 2011. Sleep and fatigue issues in continuous operations: a survey of U.S. Army officers. Behav Sleep Med. 9:53-65
Mitroussi K. 2008. Employment of seafarers in the EU context: Challenges and opportunities. *Marine Policy 32:*1043-1049.
Navas de Maya B, Arslan O, Akyuz E, Kurt RE, Turan O. 2020. Application of data-mining techniques to predict and rank maritime non-conformities in tanker shipping companies using accident inspection reports. Ships and Offshore Structures, 1-8.
Nersesian R, Mahmood S. 2010. International Chamber of Shipping & International Shipping Federation. In Handbook of Transnational Economic Governance Regimes. Brill Nijhoff.
Nguyen TT, Ghaderi H, Caesar LD, Cahoon S. 2014. Current challenges in the recruitment and retention of seafarers: an industry perspective from Vietnam. The Asian Journal of Shipping and Logistics 30(2):217-242.
Obando-Rojas B. 1999. A system dynamic analysis of officer manpower in the merchant marine. Maritime Policy & Management 26:39-60.
Orosa JA, Santos R, Pérez JA. 2011. A practical case study of the relationship between work risk prevention and fatigue at work in Spanish merchant ships. Human Factors & Ergonomics in Manufacturing & Service Industries 21:484-492.
Pantuso G, Fagerholt K, Hvattum LM. 2014. A survey on maritime fleet size and mix problems. European Journal of Operational Research 235(2):341-349.
Pauksztat B. 2017a. Effects of job demands and social interactions on fatigue in short sea cargo shipping. Maritime Policy & Management 44(5):623-640.
Pauksztat B. 2017b. 'Only work and sleep': seafarers' perceptions of job demands of short sea cargo shipping lines and their effects on work and life on board. Maritime Policy & Management, 44(7):899-915.
Phillips R. 2000. Sleep, Watchkeeping and accidents: a content analysis of incident at sea reports. Transportation Research Part F: Traffic Psychology and Behavior 3:229-240.
Pik KR. 2007. The Alternative Watch System: A Critical Analysis. Crew Endurance Management Newsletter 4:2.
Reyner L, Baulk S. 1998. Fatigue in ferry crews: a pilot study. Cardiff: Seafarers International Research Centre
Robert S. 2007. Fighting Fatigue: The Alternative Watch System. Crew Endurance Management Newsletter, 4,
Shan D, Neis B. 2020. Employment-related mobility, regulatory weakness and potential fatigue-related safety concerns in short-sea seafaring on Canada's Great Lakes and St. Lawrence Seaway: Canadian seafarers' experiences. Safety Science, 121:165-176.
Simio. 2019. Simio. Accessed September 5, 2019. http://www.simio.com/index.php

Simkuva H, Purins A, Mihailova S, Mihailovs IJ. 2016. Optimisation of work and rest hours for navigation officers on the ship. 4th International Interdisciplinary Scientific Conference Society. Health. Welfare (SHS 2014) 22-23 November, Riga, Latvia.

Smith, AP, Allen, PH, Wadsworth, EJK. 2006. Seafarer fatigue: The Cardiff research programme

Sanquist TF, Raby M, Forsythe A, Carvalhais AB. 1997. Work hours, sleep patterns and fatigue among merchant marine personnel. Journal of Sleep Research 6(4):245-251.

Strauch B. 2015. Investigating fatigue in marine accident investigations. Procedia manufacturing 3:3115-3122.

Uğurlu Ö, Köse E, Başar E, Yüksekyıldız E, Yıldırım U. 2012. Investigation of Working Hours of Watchkeeping Officers on Short Sea Shipping: A Case Study in an Oil Tanker. IAME 2012, 6-8 September, Taipei, Taiwan.

Uğurlu Ö, Yüksekyıldız E, Köse E. 2014. Simulation Model on Determining of Port Capacity and Queue Size: A Case Study for BOTAS Ceyhan Marine Terminal. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation 8:143-150.

Uğurlu Ö. 2015. Application of Fuzzy Extended AHP Methodology for Selection of Ideal Ship for Oceangoing Watchkeeping Officers. International Journal of Industrial Ergonomics 47:132-140.

Uğurlu Ö. 2016. A case study related to the improvement of working and rest hours of oil tanker deck officers. Maritime Policy & Management 43(4):524-539.

Uğurlu Ö, Yıldız S, Loughney S, Wang J. 2018. Modified human factor analysis and classification system for passenger vessel accidents (HFACS-PV). Ocean Engineering 161:47-61.

Van Leeuwen WM, Kircher A, Dahlgren A, Lützhöft M, Barnett M, Kecklund G, Åkerstedt T. 2013. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiology international 30(9):1108-1115.

Van Leeuwen WM, Pekcan C, Barnett M, Kecklund G. 2020. Mathematical modelling of sleep and sleepiness under various watch keeping schedules in the maritime industry. Marine Policy, 104277.

Yıldız S, Uğurlu O, Yüksekyıldız E. 2016. Occupational Issues and Expectations of Turkish Deck Cadets. TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 10(3):403-408.

Zhao Z, Wadsworth E, Jepsen JR, Van Leeuwen WM. 2020. Comparison of perceived fatigue levels of seafarers and management approaches in fatigue mitigation: Case studies from two Chinese and two European shipping companies. Marine Policy 103897.

Zheng Q, Shen J, Liu ZQ, Fang K, Xiang W. 2011. Resource allocation simulation on operating rooms of hospital. In 2011 IEEE 18th International Conference on Industrial Engineering and Engineering Management, 3-5 September, Changchun, China.

Zheng Q, Chen SF, Shen J, Liu ZQ, Fang K, Xiang W. 2010. Simulation modeling of the operating room based on SIMIO. In Applied Mechanics and Materials 37:1162-1166.

Table 1. Deck officers' general duties

Duties	Chief officer	2nd officer	3rd officer
Fulfil the orders given by the captain	✓	✓	✓
Assist the chief officer if needed	-	✓	✓
Ensure navigational safety	✓	✓	✓
Apply international, national and local rules	✓	✓	✓
Take precautions to prevent pollution	✓	✓	✓
Assist the safety officer if needed	-	✓	-
Act as a health officer of the ship	-	✓	-
Give personnel training	✓	-	-
Do maintenance	✓	-	-
Responsible for ship security	✓	-	-
Take over the duty of the captain, if necessary	✓	-	-
Ensure the adaptation of the crew to the ship	✓	✓	-
Establish a safe working environment for works on the ship	✓	-	-
Manage ship drills	✓	-	-
Make radio and telephone communication	✓	✓	✓
Watch navigation warning, weather messages, etc.	✓	✓	✓
Carry out routine controls for GMDSS equipment	✓	✓	✓

Table 2. Deck officers' duties while sailing to a discharge port

Duties	Abbreviation	Chief officer	2nd officer	3rd officer
Preparing documents related to cargo and discharging port	SDP 1	✓	-	-
Routine tests and controls of cargo and safety equipment	SDP 2	✓	✓	-
Pre-arrival checks on the bridge and deck for berthing	SDP 3	✓	✓	✓
Preparing customs documents, agent documents, and ship bag	SDP 4	-	-	✓
Navigation watch	NW	✓	✓	✓

Table 3. Deck officers' duties at a discharge port

Duties	Abbreviation	Chief officer	2nd officer	3rd officer
Berthing maneuvering	DP 1	✓	✓	✓
Filling cargo documents with the terminal authority and surveyor after berthing until the start of discharging	DP 2	✓	-	-
Checking discharging plan, trim and stability calculations	DP 3	✓	-	-
Preparing cargo lines and valves for operation	DP 4	✓	-	-
Starting the cargo pumps and starting the discharging	DP 5	✓	-	-
Supervising discharging operation	DP 6	✓	-	-
Port watch	PW	✓	✓	✓
Stripping last cargo and completing discharging	DP 7	✓	-	-
Empty tank check, hose disconnecting and preparing discharging documents	DP 8	✓	-	-
Assisting the chief officer to prepare cargo documents after discharging	DP 9	-	✓	✓
Preparing customs documents, agent documents, and ship bag	DP 10	-	-	✓
Before departure, preparing the maneuvering area	DP 11	✓	✓	✓
Departure maneuvering	DP 12	✓	✓	✓

Table 4. Deck officers' duties while sailing to a loading port

Duties	Abbreviation	Chief officer	2nd officer	3rd officer
Tank washing operation	SLP 1	✓	-	-
Preparation of documents related to stability	SLP 2	✓	-	-
Preparation of cargo operation orders and briefing to the personnel regarding the loading	SLP 3	✓	-	-
Preparation of cargo documents	SLP 4	✓	-	-
Routine tests and controls of cargo equipment	SLP 5	✓	-	-
Before arrival, prepare the manoeuvring area	SLP 6	✓	✓	✓
Prepares port documents, agent documents and ship bag	SLP 7	-	-	✓
Navigation watch	NW	✓	✓	✓

Table 5. Deck officers' duties at a loading port

Duties	Abbreviation	Chief officer	2nd officer	3rd officer
Berthing maneuvering	LP 1	✓	✓	✓
Filling cargo documents with the terminal authority and surveyor after berthing	LP 2	✓	-	-
Controlling loading plan, trim and stability calculations	LP 3	✓	-	-
Preparing cargo lines and valves for operation	LP 4	✓	-	-
Starting the loading	LP 5	✓	-	-
Supervising loading operation	LP 6	✓	-	-
Port watch	PW	✓	✓	✓
Managing topping off cargo tanks	LP 7	✓	-	-
Taking measurement (ullage) from all cargo tanks after loading complete	LP 8	✓	-	-
Cargo calculations	LP 9	✓	-	-
Hose disconnecting	LP 10	✓	-	-
Assisting the chief officer after discharging	LP 11	-	✓	✓
Preparing customs documents, agent documents, and ship bag	LP 12	-	-	✓
Before departure, preparing the maneuvering area	LP 13	✓	✓	✓
Departure maneuvering	LP 14	✓	✓	✓

Table 6. Operation times (the inputs of the simulation system)

		Scenarios (1-6) & Time period (h)					
Duties	**Process**	1.	2.	3.	4.	5.	6.
SDP 1, SDP 2, SDP 3, SDP 4, SDP 5, SDP 6 (Table 2)	Duties while sailing to a discharge port	2-3	2-3	2-3	2-3	2-3	2-3
	Length of stay of the ship at the discharging port	22-26	22-26	22-26	22-26	22-26	22-26
DP 1, DP 2, DP 3 (Table 3)	Before discharging	4-5	4-5	4-5	4-5	4-5	4-5
DP 4, DP 5, DP 6 (Table 3)	At the beginning of discharging	1-1.5	1-1.5	1-1.5	1-1.5	1-1.5	1-1.5
NW/PW	Watchkeeping (for per day)	8	8	8	8	8	8
DP 7, DP 8 (Table 3)	At the end of the discharging	1-2	1-2	1-2	1-2	1-2	1-2
DP 11, DP 12 (Table 3)	After discharging	1-2	1-2	1-2	1-2	1-2	1-2
	Navigation to loading port	4-8	8-12	12-16	16-20	20-24	24 - 28
SLP 1, SLP 2, SLP 3, SLP 4, SLP 5, SLP 6 (Table 4)	Duties while sailing to a loading port	3-4	3-4	3-4	3-4	3-4	3-4
	Length of stay of the ship at the loading port	20-24	20-24	20-24	20-24	20-24	20-24
LP 1, LP 2, LP 3 (Table 5)	Before loading	3-4	3-4	3-4	3-4	3-4	3-4
LP 4, LP 5, LP 6 (Table 5)	At the beginning of loading	1-1.5	1-1.5	1-1.5	1-1.5	1-1.5	1-1.5
LP 7, LP 8, LP 9, LP 10 (Table 5)	At the end of the loading	3-4	3-4	3-4	3-4	3-4	3-4
LP 13, LP 14 (Table 5)	After loading	1-2	1-2	1-2	1-2	1-2	1-2
	Navigation to discharging port	4-8	8-12	12-16	16-20	20-24	24 - 28

Table 7. Chief officers' average work and rest hours

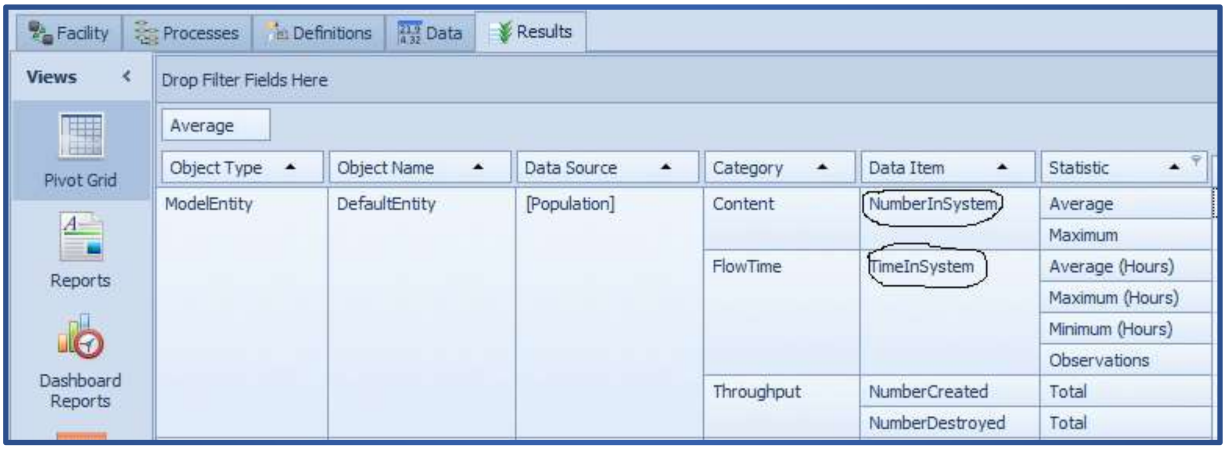
	Worst condition for Scenario1		Best condition for Scenario1		Worst condition for Scenario 2		Best condition for Scenario 2	
	Work	Rest	Work	Rest	Work	Rest	Work	Rest
1. Day	16	8	9.5	14.5	16	8	9.5	14.5
2. Day	13.5	10.5	13.5	10.5	14.5	9.5	14.5	9.5
3. Day	20.5	3.5	14	10	19	5	12.5	11.5
4. Day	18.5	5.5	16	8	16	5.5	16	8
5. Day	17.5	6.5	14.5	9.5	16	6.5	10.5	13.5
6. Day	17	7	16	8	17	7	16	8
7. day	16.5	7.5	15	9	17	7.5	16	8
Total	119.5	48.5	98.5	69.5	115.5	49	95	73
	Worst condition for Scenario 3		Best condition for Scenario 3		Worst condition for Scenario 4		Best condition for Scenario 4	
	Work	Rest	Work	Rest	Work	Rest	Work	Rest
1. Day	16	8	9.5	14.5	16	8	9.5	14.5
2. Day	14.5	9.5	13.5	10.5	15	9	15.5	8.5
3. Day	18.5	5.5	13	11	15.5	8.5	13	11
4. Day	16.5	7.5	15.5	8.5	15.5	8.5	11.5	12.5
5. Day	15.5	8.5	13	11	14.5	9.5	16	8
6. Day	16	8	12	12	17.5	6.5	12.5	11.5
7. Day	15.5	8.5	14	10	12	12	11	13
Total	112.5	55.5	93	75	106	62	89	79
	Worst condition for Scenario 5		Best condition for Scenario 5		Worst condition for Scenario 6		Best condition for Scenario 6	
	Work	Rest	Work	Rest	Work	Rest	Work	Rest
8. Day	14.5	9.5	11	13	14.5	9.5	9.5	14.5
9. Day	16	8	11.5	12.5	11.5	12.5	11.5	12.5
10. Day	15	9	12.5	11.5	14.5	9.5	12.5	11.5
11. Day	12	12	12	12	15	9	12	12
12. Day	14.5	9.5	11.5	12.5	15.5	8.5	11.5	12.5
13. Day	12	12	12	12	10.5	13.5	12	12
14. day	14	10	14.5	9.5	14	10	12.5	11.5
Total	98	70	85	83	95.5	72.5	81.5	86.5

Table 8: Simulation results illustrating non-compliance with ILO/MLC (2006) and STCW (IMO 2011) conventions

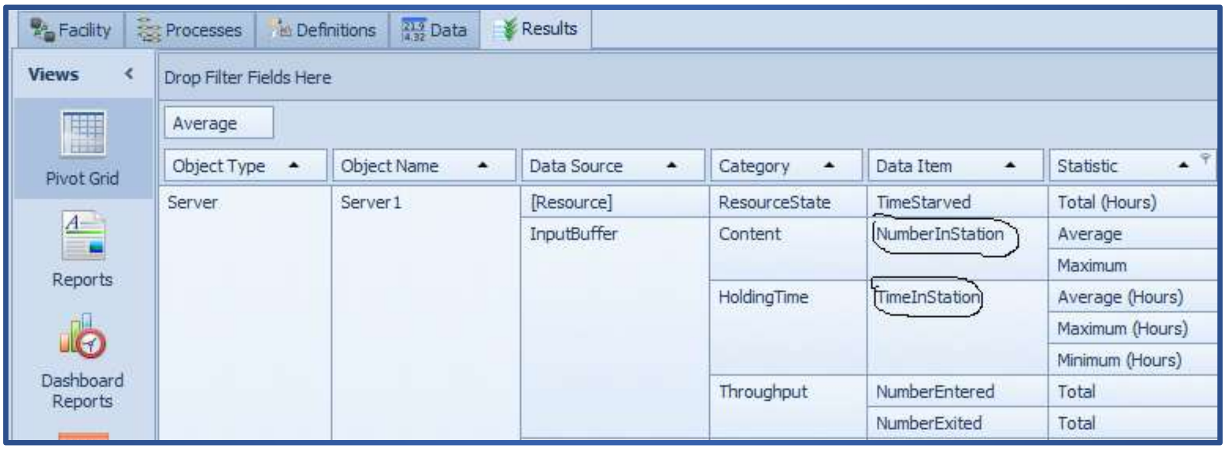
	Rules	No minimum 6 hours consecutive rest period (STCW 2010-ILO 180/MLC 2006)			Less than 10 hours total rest in 24 hours period (STCW 2010-ILO 180/MLC 2006)			Less than 77 hours rest in 7 days period (STCW 2010-ILO 180/MLC 2006)		
		A[1]	B	C	A[1]	B	C	A[1]	B	C
1. Scenario	1.Day	x			x					
	2.Day		x		x	x				
	3.Day	x			x					
	4.Day	x	x		x	x				
	5.Day	x	x		x	x				
	6.Day	x	x		x	x				
	7.Day	x	x		x	x		x	x	
2. Scenario	1.Day	x			x					
	2.Day		x		x	x				
	3.Day	x			x					
	4.Day	x	x		x	x				
	5.Day	x			x					
	6.Day	x	x		x	x				
	7.Day	x	x		x			x	x	
3. Scenario	1.Day	x			x					
	2.Day		x		x	x				
	3.Day	x			x					
	4.Day	x	x		x	x				
	5.Day	x			x					
	6.Day	x	x		x	x				
	7.Day	x	x		x	x		x	x	

	Rules	No minimum 6 hours consecutive rest period (STCW 2010-ILO 180/MLC 2006)			Less than 10 hours total rest in 24 hours period (STCW 2010-ILO 180/MLC 2006)			Less than 77 hours rest in 7 days period (STCW 2010-ILO 180/MLC 2006)		
		A[1]	B	C	A[1]	B	C	A[1]	B	C
5. Scenario	1.Day	x			x					
	2.Day		x			x				
	3.Day		x		x	x				
	4.Day	x			x					
	5.Day	x	x		x	x				
	6.Day	x			x	x				
	7.Day	x			x			x		
5. Scenario	1.Day	x			x					
	2.Day	x	x		x	x				
	3.Day	x			x					
	4.Day	x								
	5.Day	x			x					
	6.Day		x							
	7.Day					x		x		
6. Scenario	1.Day	x			x					
	2.Day		x		x					
	3.Day	x			x					
	4.Day	x								
	5.Day	x								
	6.Day									
	7.Day	x			x			x		

A[1]: Scenarios for worst conditions
B: Scenarios for best conditions
C: Scenarios without the chief officer's watchkeeping



a)



b)

Figure 1. a) Simio presentation of "NumberInSystem" and "TimeInSystem" b) Simio presentation of "NumberInStation" and "TimeInStation"

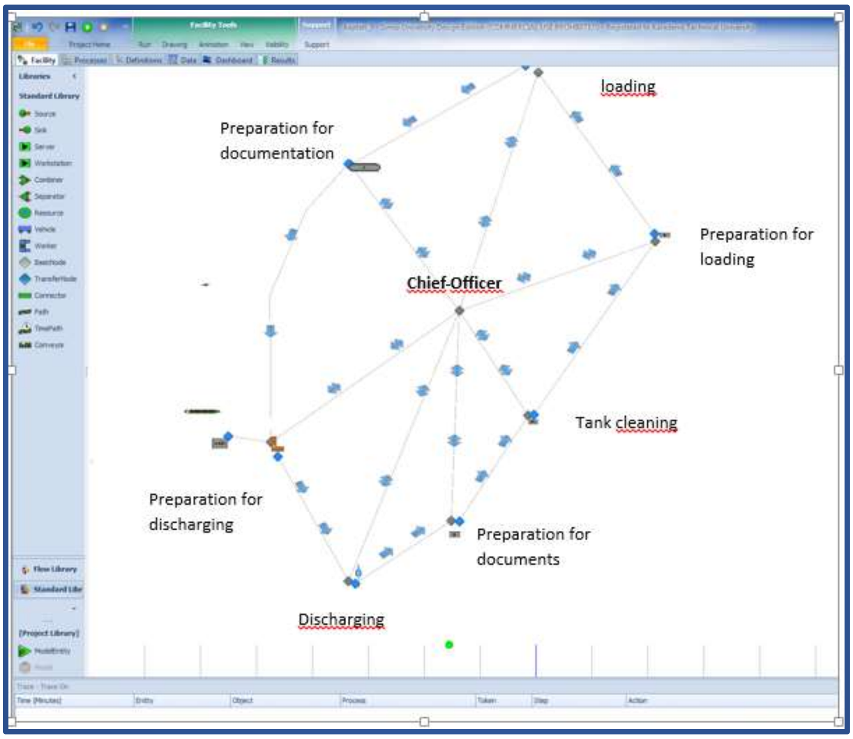


Figure 2. Simulation flow chart of an oil tanker voyage

Figure 3. Chief officers' daily work-rest hours