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Contents

ANALYSIS FOR PHYSICAL ERGONOMIC FACTORS IN OIL TANKER CASE STUDY

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المستخلص
من المتوقع أن يزدهر النقل البحري على مدى السنوات الخمس القادمة بمعدل زيادة سنوية يبلغ ٣.٤٪ وبالرغم من ذلك تستمر الحوادث البحرية في الزيادة مما يهدد السلامة والتكلفة. ورغم ذلك تحدث الحوادث البحرية لأسباب متنوعة منها الموائمة وهي دراسة عن كيفية تفاعل الأفراد مع المكونات الأخرى للنظام من خلال استخدام النظريات والمفاهيم والبيانات والنهج لتحسين رفاهية الإنسان والاداء الكلي للنظام. تهدف هذه الورقة إلى تقييم عناصر الموائمة الفيزيائية وعرض الدراسات السابقة المترابطة بالمجال البحري؛ بالإضافة الي اختيار مجموعة متنوعة من عوامل الموائمة الفيزيائية لتقييمها في سفينة بترول كدراسة حالة واستخدام الدراسة الإحصائية لتقييم تلك العوامل في السفن التجارية الأخرى وتحليلها ومقارنتها بنتائج دراسة الحالة لمعرفة مستوى التشابه، تم اكتشاف أن غالبية عوامل الموائمة الفيزيائية كانت غير مرضية بما في ذلك العواقب الوخيمة نتيجة لسوء تصميم مكان العمل مثل الإضاءة غير الكافية ودرجة الحرارة الشديدة والضوضاء.

Abstract
Over the next five years, shipping industry is predicted to grow at a 3.4% annual rate. However, marine accidents are on the rise, threatening both safety and expenses. Marine accidents happen for a variety of causes, including ergonomic issues, ergonomics is the study of how individuals interact with other components of a system, and it employs theory, concepts, data, and approaches to optimize human well-being and overall system performance. This paper aimed to assess physical ergonomic elements and reviewed the previous studies related to ergonomic factors, particularly those related to the marine industry; furthermore, a variety of physical ergonomic factors were selected to be evaluated in a tanker ship as case study. Using statistical analysis to assess physical ergonomic elements in other merchant ships and to compare the results to case study result for finding out the level of similarity, it was discovered that the majority of physical ergonomic factors were unsatisfactory, including severe consequences as a result of poor workplace design such as inadequate lighting, extreme temperature and noise.

KEYWORDS: Maritime transport, Marine accidents, Physical ergonomic factors, Lighting, Noise, Inclined ladder, Spare parts control.

Introduction

Shipping, which is responsible for transporting the largest proportion of the total volume of world trade, is truly the lifeblood of the global economy. Around 80 percent of the volume of international trade in goods is carried by sea, and the percentage is even higher for most developing countries (United Nations Conference on Trade and Development, 2021), Between the range of 1990 and 2015 sea transport expanded by 151.5% compared with an 87.1% increase in worldwide gross domestic product (Profillidis & Botzoris, 2018).

Even though, Ship's crews suffer injuries in a range of work-related accidents every year, including falls from great heights and repetitive stress injuries and could finally lead knee injuries, head injuries, burns, toxic exposure, broken bones, tendon and muscle strains, neck and back injuries, fear and anxiety, nightmares and trouble sleeping, Maritime accidents effect on ships and could lead to Fire, grounding, sinking, flooding or capsizing of a vessel.

The majority of marine incidents between the years of 2002 and 2016 were caused by a variety of factors such as human and non-human (Acejo, 2018). The majority of them were examined, and it was shown that ergonomic factors contributed for the majority of them.

As a result of the annual reports of maritime organizations, which show the increasing number of marine accidents and the accompanying death or physical or psychological marine injuries to some crew members of the ship, damage to the hull of ships or pollution to the environment and the consequent economic problems, the investigators in marine accidents confirmed that they are the result of reasons related to physical, cognitive and organizational ergonomics factors, The problem of the study stems from the study and analysis of some physical inside an oil tanker ship and statistical study to reduce the increasing number of marine accidents which agree with study show Human factors have accounted for over 80% of maritime industry accidents (Wróbel, 2021).

Background

Ergonomic is the scientific study of people and their working conditions, especially done in order to improve effectiveness (Cambridge, 2022), According to (Middleworth, 2017) there are three broad domains of ergonomics: physical, cognitive, and organizational.

There have been many previous studies that have evaluated physical ergonomic factors such as study of Casado, et al., (2012) which examined the impact of awkward postures on workers to prevent work-related musculoskeletal disorders of Spanish Fishermen and the result was work areas aboard a fishing vessel present typical examples of a work environments that pose risks to workers also the study found a new simulating for the workplace and work postures to be an effective tool for assessing the workplace and preventing musculoskeletal disorders aboard fishing vessels. Longo, et al., (2022) studied unsuitable postures for operators who are responsible in Lashing and de-lashing operations of containers cargo on board container ships, The results of the analyses indicated that there are several activities that are categorized as critical for the working postures (interventions to modify the working postures are required immediately or as soon as possible) and some of the body muscles undergo an excessive strain.

Case study

Some aspects of physical ergonomic factors were selected to be examined in oil tanker such as lightening factor, temperature extreme factors, Noise factor, forceful exertions factor and engine room design factor for spare parts store and gauges

Information was collected through a set of tools such as interview, survey and personal judgment

- The interview allowed the researcher to learn more about the study by asking the ship's crew questions and receiving their responses.
- Personal judgement and inspection, which allow the researcher to gather data for the study.

1.1 Lightening factor

- Regarding lighting factor in oil tanker and By using Lux light meter which is one of the programs to measure illuminations of lighting it show defects were shown in table 1 :-

Table 1 Actual and standard illuminations lighting level in Engine room

Location	Actual illumination	Standard illumination
Electrical room	200: 287 lux	200:500 lux
Spare parts room	0: 40 lux	50:200 lux
Mechanical workshop	110: 184 lux	300:750 lux

Source (Archtoolbox, 2021)

Table 1 indicate that there is lack in illuminations lighting level in Electrical room, Spare parts room and mechanical workshop which lead to complains from Engine room crew about lack of lighting illumination while maintenance and while searching for spare parts in store also eye flicker for some of crew.

1.2 Temperature extreme factor

- Regarding extreme temperature factor in oil tanker and By using temperature sensor inside purifier room deficiency shown in table 2 :-

Table 2 Actual and standard Temperature in workplace

Location	Actual temperature	Ideal temperature
Temperature in purifier room	37 Celsius	20° Celsius

Source: (Olli Seppänen, 2006)

Table 2 indicate extreme temperature in purifier room which lead to oiler from engine room crew lose consciousness in purifier room after sweating large amount of water during maintenance.

1.3 Noise factor

Regarding noise factor in oil tanker and By using sound meter decibel tool deficiency was found as shown in table 3:-

Table 3 Actual and standard Noise level in ships

Location	Actual Noise	Standard Noise
Crew accommodation B floor	97 decibels	60 decibel

Source: (ABS, 2018)

Table 3 indicate that noise level is high in surrounding crew cabins which lead to complains signed from crew due to noise of air handling unit which prevent quiet sleep after working.

1.4 <u>Forceful exertions factor for inclined ladder</u>

- Regarding the inclined ladder in engine room of oil tanker and by using Clinometer bubble level to measure angle of inclination for engine room ladder deficiency was as shown in table 4 :-

Table 4 Actual angle of inclination for engine room ladder and standard angle of inclination

Location	Actual degree	Standard degree
Inclination degree for engine room ladder	65 degree	45 to 60 degree

Source: (ABS, 2018).

Table 4 show that the angle of the inclination ladder is more than the maximum limit of standard angle which lead to many complains about pain in knees from repeatedly climbing the inclined ladder in engine room of that oil tanker and more than six oilers and engineers for that ship crew were exposed to tear in inner meniscus in their leg knee that could be mainly due to many reasons one of them was the degree of inclined ladder in engine room.

1.5 <u>Engine room Spare parts control</u>

Regarding spare parts control in oil tanker as shown in figure 1 defects were:

- No effective system on the ship for inventorying spare parts.
- Mainly new spare parts are purchasing from local store and aren't original.
- No minimum ROP (reorder point) for spare parts for each equipment which is the minimum number of units that a business needs to have in stock to prevent stock outs and ensure order fulfillment.
- Used Spare parts stored with new spare parts.
- Used Spare parts aren't updated in inventory.
- No system to differentiate between new received spare parts original or not

Which lead to

- New spare parts could be lost as it stored with used spare parts
- Damage could happen to equipment due to using local spare parts
- In case of emergency situations for any equipment it could lead to stock out as No ROP which could lead to ship off hire

Figure 1 spare parts store in engine room

1.6 Safe limit indicator for gauges

Regarding design and layout engine room in oil tanker it was found that all parameters for operation of all machines and equipment's is without color shape ranges to indicate safe limit of working operation as shown in Figure 2

Figure 2 analog gauges fixed beside generators in engine room

Which lead to

- Complain from engine room crew about taking too much time to be familiar with system and equipment's safe parameters limit which lead to be bad effect in watch keeping objectives
- ❖ Guidance notes on the application of ergonomics to marine systems (ABS, 2018) it shows that operating values fall within a range, the ranges may be identified by a color applied to the face of the display as red for danger and green for normal.

Analyzation of Physical Ergonomic Factors

The statistical study was carried out in order to analyze physical ergonomic factors and organizational ergonomic in other commercial ships and to compare the results to the case study result to find out the level of similarity. In this section 15 ergonomic elements are selected for further study on statistical research to represent organizational ergonomic factors and physical factors and 13 of those ergonomic elements where previously studied in case study , the questionnaire contained 34 questions represented those 15 ergonomic elements and distributed to 50 marine engineer with different ranks and different years of experience then the result of this questionnaire is computed by Statistical Package for the Social Sciences (SPSS) twentieth edition to analyze the study and the result obtained from SPSS where analyzed.

1.7 Questionnaire final form

➢ The questionnaire contained two main parts:

- The first part: is preliminary information about the study sample (Name, years of experience, current job rank, and current company).
- The second part: includes a set of (34) questions distributed on two dimensions as follows
  - The first dimension, which expresses the challenging organizational ergonomic factors in merchant ships and it consists of 23 questions
  - The second dimension, which expresses the challenging physical ergonomic factors in merchant ships and it consists of 11 questions.

1.8 Study sample

The researcher used purposive sampling in the statistical study and the characteristics of the study sample individuals were described through the following basic data (functional grade, number of years of experience) by calculating the repetitions and percentages as Figure 3 and table 5 :-

Table 5 Sample distribution according to job rank qualification percentage

Educational qualification	N=50	٪
Third engineer	12	24.0
Second engineer	24	48.0
Chief engineer	14	28.0
Total	50	100.0

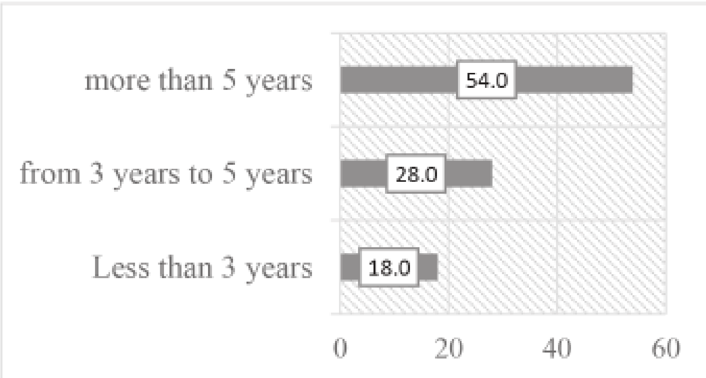

Figure 3: Sample distribution according to years of experience

1.9 Reliability of the Questionnaire

As shown in table 6 the values of Cronbach's alpha coefficients for the questionnaire of the elements of compatibility in the maritime field on some personnel working on ships range between (0.702-0.808), which are acceptable values and are a strong indicator of the stability of the questionnaire and its validity for application.

Table 6 Cronbach's alpha coefficient for every statement

Question No	Cronbach's coefficient	Question No	Cronbach's coefficient	Question No	Cronbach's coefficient
1	0.765	13	0.734	25	0.803
2	0.748	14	0.712	26	0.676
3	0.766	15	0.703	27	0.808
4	0.769	16	0.710	28	0.781
5	0.708	17	0.722	29	0.788
6	0.769	18	0.712	30	0.765
7	0.725	19	0.702	31	0.790
8	0.738	20	0.707	32	0.767
9	0.702	21	0.704	33	0.791
10	0.754	22	0.791	34	0.773
11	0.705	23	0.773	Total ergonomic factors	0.852
12	0.722	24	0.799		

According to (Saidi & siew, 2019) provided acceptable lower limits for Cronbach's alpha as acceptable limits range from 0.7 to 1 and regarding table 6 show that the value of Cronbach's alpha coefficient for the questionnaire of the analyzing ergonomic factors in the maritime field is (0.852), which is an acceptable value and is a strong indicator of the stability of the questionnaire.

1.10 Validation

The Pearson correlation coefficient between each score of the questionnaire questions and the total score of the questionnaire as shown in table 7

Table 7 Correlation coefficients between the statement score and the total score of the questionnaire

Question No	Correlation coefficients	Question No	Correlation coefficients	Question No	Correlation coefficients	Question No	Correlation coefficients
1	0.310 *	10	-0.314 *	19	-0.378 **	28	- 0.563 ***
2	- 0.569 ***	11	0.593 ***	20	0.575 ***	29	-0.592 ***
3	0.572 ***	12	0.352 *	21	0.356 *	30	0,434 **
4	-0.565 ***	13	0.521 ***	22	0,570 ***	31	-0.527 ***
5	- 0.503 ***	14	0.319 *	23	-0.372 **	32	0.356 *
6	0.351 *	15	0.431 **	24	0.537 ***	33	0.482 ***
7	0.393 **	16	0.571 ***	25	-0.592 ***	34	0.505 ***
8	0.578 ***	17	0.519 ***	26	0.360 *		
9	0.510 ***	18	0.522 ***	27	0.392 **		

* A function at a significance level of 0.05   ** A function at a significance level of 0.01

*** A function at a significance level of 0.001

Table 7 show that all questions of the questionnaire of the ergonomic factors in the maritime field on some of the personnel working on the ships were associated with statistically significant correlation coefficients at the levels of significance (0.05, 0.01, 0.001) which indicates the validity of the internal consistency and its validity for application.

- According to (Toresano, 2016) value of Correlation coefficients ranged from -1 to +1

While 0 mean indicate no relation.

1.11 Statistical treatments used in the study

1. Mean value is the average value of the dataset and it's calculated through

$$\bar{X} = (\sum Y)*3) + (\sum N)*1) / (R*3)$$

Where

R=Number of all respondents

$\bar{X}$ = Mean value $\sum Y$= Sum of all answer yes $\sum N$= Sum of all answer No

2. Relative weight is a way to measure relative importance for every variable in questionnaire and it's calculated by:-

$$(W) = \sum(Y)*(3) / (R *(3))$$

Where

W=relative weight Y =Number of yes answers R=Number of all respondents

Discussion

- Related to the problems related to physical ergonomic factors in merchant ships analysis of physical questions are:-

Question No.23 which stated does the noise caused by the operation of any equipment in the ship sometimes affect your sleep?

- The majority of respondents to this question, which is a poor factor, answered "yes," with a relative weight of 70% and a mean value of 2.40, placing it as the eighth most important factor. This high percentage was obtained from 65.7% of engineers with senior ranks, such as chief engineer and second engineer, which is strong proof of a poor factor. Factor is widespread, and the result corresponds to the flaws mentioned in the case study, further demonstrating the suffering factor.

- According to national library of medicine (Huang, 2021) which study the relation between sleep and injury it was noted that there is a significant evidence that noise effect on sleep as represented in question No.23.
- This result agree with (Cui, Wang, Yang, & Liu, 2022) who studied the impact of marine engine noise exposure on seafarer they found sleep efficiency decreased with the growing engine noise levels and the higher number of engine noise events.

- Regarding noise factor in question No.23 and also case study it was obvious that noise factor effect badly on most of seafarers

Question No.24 which stated do you sometimes feel a little pain in your knees as a result of frequent boarding of the stairs of the ship's machine room??

- This is a poor factor, and some respondents answered "yes", placing it at number 14 with a relative weight of 48% and a mean value of 1.96. This high percentage was gathered from 75% of engineers with senior ranks, such as chief engineer and second engineer, and it is clear evidence of this. Additionally, the case study's defects are matched with the factor, which is more proof that the factor is poor.
- Researcher believe that reasons is Poor design of ladders with high inclination degree.
- ❖ This result agree with (Coulter & Bawab, 2017) that there is effects of Navy ship ladder descent on the knee internal joint reaction forces.
- ❖ Regarding inclination degree for ladders in engine room as mentioned in question No.24 and also case study it was obvious inclination degree for ladders in engine room effect badly on seafarers

Question No.25 which stated Are there places in the ship where lighting is insufficient and affects your job in engine room?

- This question signifies a negative characteristic and most of the respondents determined yes with relative weight 40% with mean value 1.80 which ranked this factor as number 17 and this high percentage is been collected from 50 % of engineers with years of experience over 5 years which is evidence of poor factor besides Factor is common and Result is matched with defects mentioned in case study which is an additional evidence of suffering factor.
- Researcher considered all negative answers because bad design of engine room lighting and Ship owner want to save money instead of lighting costs

- ❖ This result agree with (Newsham & Tosco, 2005) that lighting effects on office worker satisfaction and performance, and energy efficiency.

- Regarding lighting factor in question No.25 and also case study it was obvious lighting factor is poor

Question No.29 which stated does high temperature in purifier room affect you on your job?

- This refers to an adverse perspective, and some respondents answered "yes", placing it 17th overall with a relative weight of 40% and a mean value of 1.80. Additionally, 60% of engineers with senior ranks, such as chief engineer and second engineer, contributed to this high percentage, which is reflective of a bad factor. Factor is common, and the results indicated that 40% of engineers have flaws similar to those discussed in the case study.
- Researcher assumed that the following are the main reasons are bad design of engine room workshop and bad design of purifier room

- ❖ These results agree with (Manuputty, Andarini, & Riniwati, 2020) that the performance variable is influenced by work environment such as temperature, behavior and health variables by 52.10%.
- Regarding work place design factor mentioned in question No.29 and also case study it was obvious work place design factor is poor for most of engineers.

Conclusion

The majority of physical ergonomic factors were found to be unsatisfactory, physical ergonomic factors with extreme consequences such as bad work place design particularly high inclination degree for engine room stairs, poor lighting, high noise surrounding ship's crew cabin, all of the above ergonomic factors have a direct impact on human causing knee problems, sleep disruption, and circadian changes, which could eventually lead to an increase in the number of injuries and deaths, as well as a decrease in human performance, resulting in the project's objectives not being met.

Recommendations

- For shipping industry in order to achieve ideal ergonomic factors for seafarers and economic objectives the following aspects related to ergonomic elements are recommended
  - It was necessary to have an optimum inclination degree for ladders, Optimum design for the purifier room, optimum design for air handling units and Take prompt corrective actions to correct all ship ergonomic factors related to physical.
- Related to research the following items need further and deeply research
  - The rest of the factors related to organizational and cognitive ergonomic which haven't studied deeply in this study and modeling for ergonomic factor and apply in marine industry.

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