QUANTIFIED INVESTIGATION OF NAVIGATION OFFICERS’ FATIGUE RELATED ERRORS ON SHIPS

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ABSTRACT

Maritime industry is still a human-centered industry in spite of latest technologies which has developed for reducing marine accidents. Human based errors cause marine accidents more than equipment based problems do. These accidents cause catastrophic consequences about human life and marine environment. Fatigue of navigation officers plays effective role on these human-based errors and marine accidents. There are several factors that effect navigation officers’ fatigue. In this study, relationship between fatigue of navigation officers and marine accidents will be examined; factors which are affecting fatigue of navigation officers determined with SWOT (strengths, weaknesses, opportunities and threats) analysis method and weighting of the factors determined by using AHP (Analytic Hierarchy Process) Method. With this analysis, strategic action plans were developed for minimizing fatigue related human errors on-board taking into account this SWOT factors and the weighting factors.

Keywords: SWOT-AHP, Fatigue, Navigation Safety

1. INTRODUCTION

Fatigue can be defined as temporary loss of strength and energy resulting from hard physical or mental work. Fatigued people usually experienced difficulties in maintaining task performance at an adequate level. This can have major consequences. There are several studies available which are about link between fatigue, human performance and human errors.[1,2,3] There are two types of fatigue: physical and psychological (mental). Psychological fatigue is the result of effort/reward imbalance [4]. Human based errors are causing marine accidents more than equipment based problems. According to the many of research studies, it has been recognized that almost 70 to 80% of maritime incidents are caused by human errors[5]. Violation of rules, mistakes, slips and lapses are causing accidents. Fatigue is playing important role on especially these slips and lapses. According to a research, 23% of cases that fatigue were a contributory cause among 98 ship casualty reports [6].

SWOT analysis method is used in this study to analyze factors which affect fatigue level of navigation officers in order to make strategy formulation for reducing human errors and maritime causalities respectively. The present investigation is attempted to examine the strengths and weaknesses affecting fatigue level of navigation officers, as well as the opportunities and threats in the external working environment for ships and her officers who are in charge of the navigation. The intention of this study is to develop strategy of action plan for ship management companies and seafarers through SWOT analysis and AHP with a view to make safer navigational operations for the prevention of marine casualties.

2. METHODS USED IN THIS STUDY

2.1. SWOT Analysis

Every program and system has its strengths, weaknesses, opportunities and threats. SWOT is an acronym for these factors. Considering these internal factors: strengths, weaknesses and external factors: opportunities and threats (SWOT); strategies, which will convert the threats into opportunities and off-setting the weaknesses against the strengths will be produced [7]. SWOT analysis is designed to be used in the preliminary stages of decision-making and strategic management. The SWOT approach involves systematic thinking and comprehensive diagnosis of factors relating to a new product, technology, management, or planning [8].

2.2. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) as a decision analysis tool is used in this study with SWOT Analysis method which is a mathematical method for analyzing complex decision problems with multiple criteria[9]. AHP can deal with qualitative attributes as well as quantitative ones. It is a useful decision analysis technique which can be used during strategic planning. AHP is used in many fields such as planning, selecting the best alternative, resolving conflicts, optimization problems with other techniques such as linear programming, fuzzy logic, quality function deployment etc. [10] By utilizing AHP, linguistic variables can be quantified.

2.3. Aim and Method of SWOT Cascaded with AHP

SWOT analysis is a qualitative analysis method and has no means of determining the importance or intensity of SWOT factors analytically. SWOT analysis has become insufficient due to this factor. The AHP is a mathematical method for analyzing complex decision problems with multiple criteria, and can deal with qualitative attributes as well as quantitative. By utilizing the AHP in SWOT analysis, SWOT factors can be weighted and rated quantitatively [11]. When SWOT and AHP used in combination, the SWOT approach can
provide a quantitative measure of the importance of each factor in decision making[12].

Consequently, AHP and SWOT are both simple and widely used methods, and they are relatively easy to understand.

3. METHODOLOGIES FOR SWOT-AHP APPLICATION

In this study, negative factors as weaknesses and threats which are causing and increasing fatigue level of navigation officers were observed by considering seafarers’, crewing department of shipping companies’ and lecturers’ opinions and experiences (See Fig.1).

Then positive factors as opportunities and strengths which can reduce the fatigue level of navigation officers were observed (See Fig.2). Then the factors were clustered. The pair wise comparisons are carried out within SWOT factors by the ship masters (5 persons) who are actively working as master on ocean-going ships, operation manager and crewing manager of shipping company (3 persons) who are working at least for five years on same position, lecturers at Istanbul Technical University Maritime Faculty (2 persons), ratings (3 persons) and Maritime Faculty students (2 persons) whom are completed their 12 months sea period.

![Diagram showing classification of factors causing fatigue of navigation officers]

Figure 1. Classification of factors that are causing fatigue of navigation officers

Positive factors (strengths and opportunities) and negative factors (weaknesses and threats) are weighted separately so that the sum of the weighting of negative factors is 1.0 and the sum of positive factors is 1.0 also.
Figure 2. Classification of factors which are reducing fatigue of navigation officers

Pair wise comparisons have done among each factors shown in Fig.3. ‘Super Decisions’ software (www.superdecisions.com) is used for computing the priority of precautions by utilizing the results of pair-wise comparison intensities.

Figure 3. Pair-wise Comparisons between Factors

4. SWOT FACTORS THAT AFFECTING FATIGUE LEVEL OF NAVIGATION OFFICERS

4.1. The Probable Strengths for Reducing Fatigue Related Human Errors:

- **Equipping of ships with new technologies:** New innovations or technologies such as ECDIS and AIS reduce navigation officers’ workload and they have been developed to lighten considerably the navigation workload with enforcing reduced human errors. Automated control of loading/discharging systems especially on tankers and machinery area reduce officers’ and other ratings’ workloads and they have been developed to lighten considerably the port operation workload with enforcing reduced human errors.
- **Application of ISM system and increasing safety culture on board:** Safety on board has become a critical issue in the last decades. Application of ISM system regularly reduced workloads of seafarers and increased safety culture on board [13].
- **Increasing communication facilities:** Being far away from family is the most common problem for seafarers on board [14]. This reality increases seafarer's psychological fatigue level on board. Increasing communication facilities on board reduces psychological fatigue on board.
- **Increasing nutrition possibilities on board:** Regular and sufficient nutrition reduces fatigue level. Nutrition possibilities and quality of nutrition were increased on ships compared with before.
4.2. The Probable Weaknesses which are Increasing Fatigue Related Human Errors:

4.2.1. Technical Factors

Technical factors can be shortly described as the factors which are directly related with the nature of ship. These factors are:

- **Noise – vibration:** According to the nature of job, ships are moving from one port to another. Because of this movement and ship’s engine, there is a continuous noise and vibration on board.
- **New technology needs new skills and educations:** Every new technology which is considered to increase navigational safety has brought new skills and new compulsory training such as ARPA Radar and ECDIS training.
- **Adaptation to automation systems:** All automation systems such as automated engine room or automated controlled loading/discharging systems need adaptation period for officers.

4.2.2. Operational Factors

Operational factors are directly related with the nature of job. These factors are:

- **Insufficient rest times:** Due to the watchkeeping periods and heavy duties, navigation officers can not find rest times enough. Sleeping less than seven hours a day causes poorer health and fatigue level. Quality of sleep is one another factor which increases fatigue level of seafarers. Insufficient rest between work periods increases navigation officers’ fatigue level [15].
- **Excessive workload:** Watchkeeping, maintenance, maneuvering, port operations, preparing ship for inspections and paper works about procedures are consisting of main body of navigation officers’ workloads.
- **Working at nights:** Watchkeeping, port operations and maneuvering are the main purposes of working at nights.
- **New procedures bring more paper work on board:** New procedures which though to increase ship safety and such as ISM and ISPS procedures, they naturally have brings extra workload for navigation officers.

4.2.3. Human Related Factors

Human related factors are directly related with the nature of human being. These factors are:

- **Shipboard comfort:** Shipboard comfort is related with the comfort of cabinets, messrooms, nutrition and communication facilities, stability of ship and other social facilities on board.
- **Multinationality and multilanguage:** On several ships, crew’s nationalities are different than others. These factors affect the satisfaction of navigation officers.
- **Low satisfaction of seafarers about their occupation:** Crew members who display care and loyalty are less likely to produce claims. Ship owners and operators can achieve a high level of continuity and competence by providing crew with secure employment and by taking into account the factors such as recruitment, health, training and general awareness of shipboard best practice and by monitoring satisfaction in terms of monitoring expectation of crew members [14].
- **Homesickness:** According to latest surveys, homesickness is one of the most important factor which is reducing satisfaction level of seafarers [14].
- **Insufficient amount of spare part and store supply:** Because of the nature of the job, officers can not get any spare part, store supply or any other needs.

4.3. The Probable Opportunities for Reducing Fatigue Related Human Errors:

- **High maneuvering capability of new building ships and new maneuvering equipments:** Word merchant fleet is renewing and new-built ships have high maneuvering capabilities when compared with the last decade built ships. This reality reduces maneuvering times of ships.
- **Shortening of seafarer's contract durations:** The seafarers’ durations of contracts are shortened especially in world's leading ship management companies. This situation reduces chronic fatigue of seafarers taking into account the fatigue clause of STCW Code [16].
- **Ergonomic bridge and accommodation design of new-building ships:** Ergonomic issues have become more popular in ship-building sector. Ergonomic bridge design arranges safe look out and reduces workload of masters and navigation officers. Ergonomic design of accommodation places also increases seafarers' satisfaction and arranges acceptable living conditions [17,18].
- **Improvements on technologies:** New technologies about navigation or ship construction reduce navigation officer's workloads. They are assisting tools for them to enable efficient maneuvering and offering more comfortable navigation infrastructure.
- **Establishing of TSS regimes, VTS systems and Pilotage on narrow/heavy traffic areas:** Established Traffic Separation Scheme (TSS) and Vessel Traffic Service (VTS) Stations arrange safer navigations for ships and ships can make efficient decisions by the help of VTS centers [17].

4.4. The Probable Threats which are Increasing Fatigue Related Human Errors

4.5.  

4.5.1. Sea Life Characteristics

These factors which are directly related with the nature of sea life can be described as following:

- **Bad weather conditions:** Bad weather conditions such as gales and dense fog situations
increase workload of navigation officers and master. Also, seasickness is a factor that increases mental and physical fatigue which directly reduces job satisfaction [17].

- **Terror threats, piracy and ISPS application:** Terror threats for ships and related ISPS application tasks restrict seafarers’ social life during stay at port.

- **Currents, tides, and darkness:** Currents and darkness are the two dominant factors causing marine casualties especially in coastal traffic area and narrow channels [18].

- **Construction of new ports far away from city centers:** New-constructed ports and terminals are generally constructed far away from city centers. On restricted port days, seafarers cannot go outside from ship for relaxing.

- **Working on different climate/location:** Because of the movement of ships from one port to another, officers’ working environment continuously changes, therefore, climate conditions, weather conditions and time zones continuously change too.

### 4.4.2. Commercial Pressures

- **Intensive ship traffic:** There are around 52000 ships in service at sea, and number of ships is increasing regularly per annum. Increasing number of ships and new-built faster ships cause collision risks. Watch conditions are closely related with ship traffic. In intensive traffic conditions, an extra watchman should look out in Navigation Bridge [18].

- **Trend of decreasing seafarer number on board:** One another commercial pressure appears as decreasing number of seafarers to minimum standards as it is mentioned in the Minimum Safe Manning Certificate of ship. This reality increases workload and fatigue of navigation officers.

- **Limited port stay days:** The time period when ships spend while lying in ports are decreased due to the developed cargo handling facilities.

- **Continual inspections on restricted port days:** Port state and flag state inspections and oil major companies’ vetting inspections are increased on restricted port days. Shortened port days and increased inspections directly cause seafarers’ fatigue and response.

### 5. RESULTS OF AHP APPLICATION, CONSIDERATIONS AND DERIVED STRATEGIES FROM SWOT – AHP APPLICATION

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SWOT Factors</th>
<th>Overall Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weaknesses</strong></td>
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<td></td>
<td>Weaknesses</td>
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<td>Technical Factors</td>
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<td>New technology-new skill</td>
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<td>Adaptation to automation systems</td>
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<td>Operational Factors</td>
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<td></td>
<td>Insufficient rest times</td>
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<td></td>
<td>Excessive workload</td>
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<td>Working at nights</td>
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<td>New Procedures</td>
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<td>Human-Related Factors</td>
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<td></td>
<td>Shipboard comfort</td>
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<td></td>
<td>Multinationality and multilanguage</td>
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<td></td>
<td>Low satisfaction about job</td>
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<td></td>
<td>Homeliness</td>
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<td></td>
<td>Insufficient amount of spare part and store supply</td>
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<td><strong>Threats</strong></td>
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<td></td>
<td>Threats</td>
<td>0.23095</td>
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<tr>
<td></td>
<td>Sea life characteristics</td>
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<tr>
<td></td>
<td>Bad weather conditions</td>
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<tr>
<td></td>
<td>Terror threats and piracy</td>
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<tr>
<td></td>
<td>Currents – tides</td>
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<td>Far away construction of ports from city centers</td>
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<td>Working on different climate/location</td>
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<td></td>
<td>Commercial pressures</td>
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<td></td>
<td>Decreasing seafarer numbers on board</td>
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<td>Limited port stay days</td>
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<td>Intensive ship traffic</td>
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<td>Continual Inspections</td>
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<td><strong>Weaknesses – Threats</strong></td>
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<td></td>
<td>Physical</td>
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<tr>
<td><strong>Weaknesses - Threats</strong></td>
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<tr>
<td></td>
<td>Psychological</td>
<td>0.54440</td>
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</table>
Pair-wise comparisons have been done by utilizing AHP. Priorities and weighting factors which cause fatigue on navigation officers is shown in Table 1. When the results are considered, internal negative factors (weaknesses) play more important role on fatigue of navigation officers than external negative factors (threats) do. When weaknesses are considered, human related factors are most important factors on navigation officer’s fatigue. Commercial pressures on ship and navigation officers are most important external factor that causing fatigue on navigation officers. Priorities and weighting factors which can reduce fatigue on navigation officers are shown in Table 2.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SWOT Factors</th>
<th>Overall Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>Equipping of ships with new technologies</td>
<td>0.21200</td>
</tr>
<tr>
<td></td>
<td>Application of ISM system and developing safety culture on board</td>
<td>0.21544</td>
</tr>
<tr>
<td></td>
<td>Increasing nutrition possibilities on board</td>
<td>0.12771</td>
</tr>
<tr>
<td></td>
<td>Increasing communication possibilities on board</td>
<td>0.04486</td>
</tr>
<tr>
<td>Opportunities</td>
<td>High maneuvering capability of new - built ships</td>
<td>0.04058</td>
</tr>
<tr>
<td></td>
<td>Shortening of seafarers contract durations</td>
<td>0.13640</td>
</tr>
<tr>
<td></td>
<td>Ergonomic bridge and accommodation design</td>
<td>0.07754</td>
</tr>
<tr>
<td></td>
<td>Improvement on technologies</td>
<td>0.08558</td>
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<tr>
<td></td>
<td>Establishing of TSS regimes and Pilotage on narrow/heavy traffic areas</td>
<td>0.05991</td>
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<tr>
<td>Strengths - Opportunities</td>
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<tr>
<td>Strengths - Opportunities</td>
<td>Psychological</td>
<td>0.49929</td>
</tr>
</tbody>
</table>

Internal factors (strengths) have more important role for reducing fatigue of navigation officers than external factors (opportunities) have. Developing safety culture on board and equipping ships with new technologies are two dominant factors which are reducing fatigue of navigation officers. Graphical results of pair-wise comparisons of SWOT groups and factors are shown in Figure 4. There is not any pair-wise comparison done between positive and negative factors, so the sum of the weighting factor of positive quadrants (strengths and opportunities) is 1, 0. The sum of the weighting factors of negative factors (weaknesses and threats) is also 1, 0.

Psychological factors are as important as physical factors on fatigue. Factors which cause fatigue and which reduce fatigue of navigation officers are both physical and Psychological. The number positive and negative factors and their Psychological and physical weights are summarized in Figure 5. While considering the overall factors of strengths, weaknesses, opportunities and threats mentioned in the
section 4 and section 5 of this study, the following strategies will be defined: Besides the risk assessment of each process can easily be handled if the threats or weaknesses are properly identified. It should also be taken into account that a human factor has a great significant impact on threats or weaknesses as it is identified in section 5 of this study. When the overall contribution of SWOT analysis is examined, the following comments can be interpreted for reducing fatigue level of seafarers and fatigue related human errors on board. Workload management should be applied on board because of fatigue plays important role on human errors. Precautions which will increase seafarer's satisfactions should be taken by ship management companies. Loyalty of seafarers should be provided by ship management companies by taking several precautions. On board procedures should be shortened that officers will need less time for paper works. New training programs about new technologies should be developed. New rules should bring into force for reducing fatigue of seafarers. Sea and sea life must be encouraged. Social facilities about seafarers at port should be developed. Navigation bridges and accommodation places should be designed by taking into account ergonomic aspect too. Widespread use and equipping new technologies such as ECDIS and automated loading-discharging systems on board should be maintained.

6. CONCLUSIONS

In maritime industry, human errors are have been still causing accident and incidents in spite of presence of latest navigational technologies and fatigue is playing important role on these errors. In this study, it is aimed to identify the positive and negative factors which affecting the fatigue level of seafarers by applying SWOT (Strength, Weakness, Opportunities and Threats.) analysis and weighting these factors by applying Analytic Hierararchy Process (AHP). Taking into account above mentioned strengths, weaknesses, opportunities and threats and the priorities of weighting factors, several practical solutions are suggested in order to reduce fatigue related human errors on shipboard operations.

This study originally suggests the main management tool which is specifically applied for reducing fatigue of seafarers and consequently enhancement of safety and ship management performance to prevent accidents and casualties in maritime transportation.

7. REFERENCES


