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# Investigation of non-fatal occupational accidents and their causes in Turkish shipyards

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## ABSTRACT

This study reports new data for 1028 non-fatal occupational accidents dated between January 2010 and April 2015 by applying the analytical hierarchy process (AHP) technique. A comprehensive survey was conducted at four shipyards in Tuzla, Istanbul and Yalova regions in Turkey and a workplace questionnaire appropriate for the AHP technique was carried out. The obtained results indicated that inadequate safety equipment and protective clothing, unsuitable usage of machines and tools, and disobeying occupational health and safety (OHS) procedures were the most common risk factors for the accidents. Hence the preventive measures could be identified by analyzing non-fatal accident data. After the identification of the descriptive measures, the priority order of these measures was asked of the occupational safety professionals in the shipbuilding industry, and we used the AHP method to evaluate the results.

## KEYWORDS

non-fatal; occupational accidents; risk analyses; shipyards

## 1. Introduction

The main activity in shipyards is the new construction of ships or the maintenance works of ships that have come to the shipyard. Mostly, the nature of construction and the maintenance work of these ships are carried out in the open air at an elevated height. The completion of these projects is generally dependent on the labor-intensive work of the workers. For this reason, occupational safety in shipyards is considered a significant issue that needs to be addressed. Shipbuilding is a sector where different basic production lines come together from the starting point to the end. The entire multi-deck segments of the hull are built elsewhere in the shipyard, transported to the building dock and then lifted into place; this process is known as block construction. The assembly procedure of shipbuilding consists of pre-installing equipment, panel fabrication, air conditioning, surface preparation and coatings, electrical cable fitting, pipe routing and other components in blocks carried out to minimize the efforts needed to assemble components deep within the hull once it is welded together. After completing the entire assembly process, the ship is taken for a cruise test and, finally, the ship is ready for delivery. The fact that shipbuilding brings together different business lines together causes more problems in terms of occupational safety. For instance, when a risk assessment is made in a construction workplace, the probability of risks such as fire and explosion comes under very low risks, while falling from a high elevation, material crashing and squeezing fall under the very high-risk category. On the other hand, for a chemical plant, the risk factors are reversed. Thus, risk assessment and occupational safety studies and research in the shipbuilding sector are of great importance and complicated.

Numerous articles have been published in the field of occupational accidents in shipyards [1–9]. Similarly, several studies have investigated in detail risk analyses of marine accidents

[10,11]. A programmable logic controller (PLC)-based communication system has been proposed and is expected to reduce accidents in the shipyard by providing an uninterrupted communication environment and safer working conditions [12].

Kim et al. [2] attempted to identify the differences in safety climate and occupational stress. A detailed survey has been conducted using the safety climate scale and Korean occupational stress scale and classified the participants into four groups, working for accident departments within the same workplace in the shipbuilding industry [2]. Iwańkiewicz and Rosochacki [4] have developed a risk assessment method for the production processes of large-size steel ship hulls. They used a quantitative-probabilistic approach with the involvement of the clustering technique to analyze the database of accidents and predict the process risk.

Lee et al. [13] acquired a combination of feedforward and feedback controls using both a gantry and a floating crane under various environmental conditions. Their methodology findings can be applied for appropriate control of the risk-free block erection operations in shipyards. Jeong [14] compared the characteristics of occupational accidents between skilled workers and novices in the shipbuilding industry in South Korea and analyzed factors affecting death and disability accidents. Cebi and Ilbahar [15] proposed an integrated risk assessment method including fuzzy sets, a rule-based inference system, an analytic hierarchy process and a bow-tie technique to reduce occupational risks at shipyards. In their study, the magnitudes of occupational risks are obtained by considering all the possible outcomes of a potential accident. Gundogdu and Seyfi-Shishavan [16] developed a two-stage risk assessment method based on spherical fuzzy sets (SFSs) by combining two decision-making methods, the analytical hierarchy process (AHP) and Vlekraterijumsko KOMpromisno Rangiranje (VIKOR), that was applied in real shipyard cases. The causality of

**Table 1.** Number of employed workers, fatalities and fatality rates in Turkish shipyards occurring between 2004 and 2014 [20].

Year	Number of employed	Number of deaths	Fatality rate (1/100,000)
2004	14,750	6	40.7
2005	24,200	13	53.7
2006	28,580	10	35.0
2007	33,000	12	36.4
2008	26,910	29	107.8
2009	19,179	15	78.2
2010	21,449	11	51.3
2011	20,516	3	14.6
2012	16,000	8	50.0
2013	17,000	15	88.2
2014	20,334	4	19.7
–	–	$\Sigma = 126$	Average = 52.3

occupational accidents that occurred in a Portuguese shipyard between 2014 and 2015 was investigated [17]. Their objectives are to identify the immediate causes of the accidents and their underlying causal factors at the organizational level and to discover a quantitative model using cause-to-effect relationships.

A comprehensive background review of fatal occupational accidents and the strategies proposed to minimize the fatalities at shipyards have been reported by Barlas [18]. Similarly, the risk analysis methods on occupational health and safety (OHS) in shipyards have been investigated and reported in Turkish [19]. The situation of the workplace such as work safety, suitability and the adequacy of the measures taken from the sides of the employees were discussed by Barlas and Izci [20]. Also, the physical and personal factors causing the accidents were analyzed.

Although occupational accidents in Turkish shipyards are common, there are still no reports on the state-transmitted statistical data. For instance, very few researchers have contributed to the study on occupational fatal accidents in Turkish shipyards [18,20,21]. Among occupational accidents, non-fatal accidents are considerably more remarkable than fatal ones. Non-fatal accidents can be classified by their severity rates. The article mainly focuses on the non-fatal occupational accidents according to the records of shipyards in the Yalova Shipyards Area and Tuzla Shipyards Area between 2010 and 2015. These accidents were evaluated in terms of their occurrence, time, place, day and the loss of workdays caused by the accidents, and thus we focus mainly on these factors as possible sources and precautions which have been addressed.

Moreover, the relationship between fatal and non-fatal occupational accidents in Turkish shipyards will be investigated. The data on the national statistics of fatal occupational accidents that occurred in Turkish shipyards are being managed by the Social Security Institution and the details are presented in Table 1.

Correspondingly, the same relationship can be seen to fit the Turkish construction sector accidents. The study implores that analyzing the non-fatal occupational accidents in a shipyard environment and using the obtained results could prevent further fatal accidents. To determine the priority of the measures to be taken in this study, the questions of the survey were directed to professionals having more than 10 years of experience in occupational safety in shipyards.

## 2. Materials and methods

The Ministry of Labour and Social Security for Turkey has very limited occupational accident data for shipyards. Occupational accident data have been recorded in some Turkish shipyards since 2010. There is no standard for recording accident data. Every shipyard has its data-collecting criteria. Accident data can be used in many different contexts for categorizing patterns in the data and classifying them. The data used for the current study contain 1028 non-fatal occupational accidents that happened between January 2010 and April 2015 in four shipyards located in Tuzla, Istanbul and Yalova regions. After a thorough investigation of the accident data, occupational accidents were categorized into three different accident severity levels: minor, mediocre and major. The accidents were marked as minor if the resting period was less than 5 days; for mediocre the resting period will be between 5 and 20 days; and in case of major accidents, the resting period would be more than 20 days. We have examined these categories and the causes of the accidents were made into a questionnaire. Professionals with more than 10 years of experience in occupational safety in shipyards were asked to answer these survey questions and the results were evaluated by the AHP method.

The AHP method is a multi-criteria decision analysis that has been considered a significant method due to its mathematical properties of methods applicable to solving complex judgment problems [21–24]. The appropriate data have been derived by using a set of pairwise comparisons in which the decision-maker considered two alternatives at a time. These comparisons were used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each decision criterion. The AHP technique gives the suitable decision that best suits the goals and evaluates alternative solutions. The main advantage of the AHP technique is its ability to rank choices in the order of their effectiveness in meeting differing objectives. If judgments are made about the relative importance of the objectives, then the AHP technique guides inevitably the logical consequence of those judgments [24–26]. Shortly, the AHP is a useful technique for discriminating between competing options taking a range of objectives to be met into consideration. The theory and mathematics of the AHP method were investigated and reported [21–26]. The pairwise comparison alternatives were presented in pairs. They are given by  $\{A_1, A_2, \dots, A_n\}$  and current weights by  $\{w_1, w_2, \dots, w_n\}$ , where  $n$  is the number of compared alternatives. The matrix of the ratios of all weights can be given in the following form:

$$W = \begin{bmatrix} \frac{w_i}{w_j} \\ \frac{w_j}{w_j} \end{bmatrix} \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix}$$

The matrix of pairwise comparisons  $A = [a_{ij}]$  represents the intensities of the questionnaire respondent's preference between individual pairs of alternatives ( $A_i$  versus  $A_j$  for all  $i, j = 1, 2, \dots, n$ ), chosen from the scale for judgments in the AHP method presented in Table 2.

Given  $n$  alternatives  $\{A_1, A_2, \dots, A_n\}$ , the questionnaire respondent compares pairs of alternatives for all the possible pairs, and a comparison matrix  $A$  is obtained, where the element  $a_{ij}$  shows the preference weight of  $a_i$  obtained by

**Table 2.** Scale for judgments in the AHP method.

Scale	Judgment
1	Equal – indifference
2	Between equal and moderate
3	Moderate preference
4	Between moderate and strong
5	Strong preference
6	Between strong and very strong
7	Very strong preference
8	Between very strong and extreme
9	Extreme preference

Note: AHP = analytical hierarchy process.

comparison  $a_j$ :

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2j} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 1/a_{1j} & 1/a_{2j} & \dots & a_{ij} & \dots & a_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1/a_{in} & \dots & 1 \end{bmatrix}$$

If matrix  $A$  is consistent, it is noticed that  $A = W$  and the principal eigenvalue is equal to  $n$ , i.e.,  $\lambda_{\max} = n$ . The relations between the weights and the judgments are defined by  $w_i/w_j = a_{ij}$  for  $i, j = 1, 2, \dots, n$ . The weights are obtained using the eigenvector method [24,25]. The structure of the comparison matrix follows the assumption that alternative 1 is  $k$  times better than alternative 2, and then we can deduce that alternative 2 is  $1/k$  as good as alternative 1. If  $A$  is an  $n \times n$  primitive matrix, i.e., the matrix to be a non-negative irreducible matrix with a positive element on the main diagonal, then one of its eigenvalues  $\lambda_{\max}$  is positive and greater than or equal to all other eigenvalues. There is a positive eigenvector  $w$  corresponding to that eigenvalue as follows:

$$Aw = \lambda_{\max}w,$$

where  $w$  = weight vector. The eigenvector method for obtaining the weights in the AHP method yields a way of measuring the consistency of the questionnaire respondent's preferences arranged in the comparison matrix. If a pairwise comparison matrix is not consistent, two different situations may be considered; a contradictory matrix and a matrix neither totally consistent nor contradictory. The consistency index ( $CI$ ) can be defined as:

$$CI = \frac{\lambda_{\max} - n}{n - 1}.$$

Small changes in  $a_{ij}$  imply small changes in  $\lambda_{\max}$ , with the difference between  $\lambda_{\max}$  and  $n$  being a good measure of consistency. If the questionnaire respondent is completely consistent, then  $CI = 0$ . However, it is idealistic to require  $CI = 0$ . The randomly generated reciprocal matrix uses scale and get the random consistency index for to see if it is about 10% or less. If the order of the matrix is 13, the random index  $(RI)_{13}$  is taken as 1.555 [27]. In practice, one should accept matrices with a consistency ratio ( $CR$ ) value less than 0.1. By dividing the  $CI$  value by  $RI_{13} = 1.555$ , one obtains the  $CR$  value. A value of  $CR = 0.1$  means that the judgments are 10% as inconsistent as if they had been given randomly. If the  $CI$  is greater than 0.1 then a revision of judgments is required until a value of  $CR$  smaller than 0.1 is reached [24].

**Table 3.** Non-fatal occupational accident types and the number of accidents at shipyards.

Accident type	Number of accidents	%
Being struck by or struck against	275	26.8
Falling from a height	162	15.8
An object falling from above	162	15.8
Caught in between (squeeze)	133	12.9
Burning	80	7.8
Exposure to welding metal burr	70	6.8
Cut and incision	47	4.6
Sprain	32	3.1
Strain	25	2.4
Poisoning	22	2.1
Electrocution	11	1.1
Other	9	0.3
Total	1028	100

### 3. Results and discussion

#### 3.1. Characteristics of non-fatal occupational accidents in shipyards

For the classification of the database about occupational accidents at shipyards, a study was conducted by analyzing a workplace survey appropriate for the AHP technique. Barlas [28] reported earlier on 78 registered non-fatal occupational injuries between the years 2009 and 2016 in a reputable shipyard in Istanbul. Similarly, this study found that non-fatal occupational accidents have underlining additional factors such as age, work experience, work duration in a shipyard, category of the worker, size of the shipyard, type of accident, time of the accident, weather and climate that have influence on the severity of accidents. Common causes of occupational accidents are high elevation, flammable and explosive gases, moving machinery, work close to haphazard established heavy structures, ship holds and hatches, misuse or failure of personal safety equipment, poor ergonomics, being untidy, poor illumination, exposure to general hazards including electricity, work in closed spaces and inadequate protective clothing. The non-fatal occupational accident types occurring between January 2010 and April 2015 in four shipyards can be classified into 11 major categories as presented in Table 3.

The 11 foremost typical non-fatal occupational accidents in shipyards can be classified into being struck by or struck against, falling from a higher elevation to a lower level, material falling from above, caught in between (squeeze), burning, exposure to welding metal burr, cut and incision, sprain, strain, poisoning and electrocution.

##### 3.1.1. Being struck by or struck against

Being struck by or struck against accidents were associated with works close to haphazard established structures and scaffoldings, misuse of cranes and lifting operations, being struck by a motor vehicle and pressing between hydraulic hatches. In addition, as a result of non-controlled work done with pressure tools and machines, hoses, pipes, etc., machine crashes can occur. Likewise, these types of accidents could be seen in different sectors of material stock areas like the marble industry [29].

### 3.1.2. Falling from height

Most of the work done in shipyards is in the form of working at an elevated height. Accidents of falling from height can be seen in the works carried out on the scaffolds, on the deck, on the stairs and on the mobile scaffolds. Similarly, special vehicles like a cherry picker and scissor lift can be used in shipyard high-place operations, and further working on these vehicles also can cause falling from height accidents.

### 3.1.3. Falling object

A falling object from above accidents were often associated with risks through falling objects from scaffoldings, decks and cranes. At the same time, machines that were not transported correctly and materials that are left incorrectly on the benches are examples of an object falling from height accident types.

### 3.1.4. Caught in between (squeeze)

The working areas in the shipyard and on the ship are very narrow. For this reason, caught in between (squeeze) accidents may occur as a result of contact with moving working machines and tools in those areas. Besides, wheeled vehicles like forklifts, trucks and cranes can cause these kinds of accidents.

### 3.1.5. Fire and explosion

Burning accidents are generally associated with cutting and welding operations in closed spaces. Liquefied petroleum gas (LPG), liquefied natural gas (LNG), oxygen, hydrogen, acetylene and other gases can cause fire and/or explosions in closed low or non-ventilated spaces. Hot surfaces were also another root of burning accidents.

### 3.1.6. Exposure to welding metal burr

Exposure to welding metal burr accidents was observed during welding and cutting operations. The common cause of burns is related to inexperience and not using personal protective equipment (PPE).

### 3.1.7. Cut and incision

Cut and incision accidents have been associated with carrying sharp objects and working with cut-risk machinery like a grinder. Using a snap-blade knife can cause cut and incision accidents.

### 3.1.8. Sprain and strain

Sprain and strain accidents were associated with scattered cables, uneven ground and poor housekeeping. Because of the shape of ship ladders (too long and vertical), workers cannot step easily and they can be exposed to sprain and strain accidents.

### 3.1.9. Poisoning

Poisoning accidents have mostly happened by exposure to dangerous gases and toxic vapors. Paints and paint solvents may present substantial hazards due to breathing especially when painting in closed spaces.

### 3.1.10. Electrocution

Electrocution accidents have occurred during different types of operations, i.e., contact with electrical hand tools with no grounding, presence of an open arc jump, exposed electrical distribution panels with no grounding systems, etc.

**Table 4.** Non-fatal occupational accidents by day of week.

Day of week	%
Monday	17.4
Tuesday	21.6
Wednesday	15.9
Thursday	16.4
Friday	13.5
Saturday	10.9
Sunday	4.3
Total	100

**Table 5.** Non-fatal occupational accidents by time of day.

Time of day	%
1	8.0
2	6.8
3	22.8
4	20.7
5	5.5
6	7.2
7	8.9
8	20.3
Total	100

### 3.1.11. Other accidents

Other accidents are usually associated with non-work-related factors like heart attack, cerebral hemorrhage or fighting.

## 3.2. Non-fatal occupational accidents by day of week

In previous studies, fatal work accidents were mostly seen on Mondays and Saturdays [18]. The present study revealed that non-fatal accidents were mostly experienced on Tuesdays (see Table 4).

The reason for this can be assumed that the high level of attention of the workers during the work that coincides with the middle of the week may prevent the consequences of the accidents from reaching a more serious dimension.

## 3.3. Non-fatal occupational accidents by time of day

A similar situation for the days when non-fatal accidents are most common is also observed during working hours. Previous studies about the shipbuilding industry have shown that fatal accidents occur mostly during the first and fifth working hours [30], while we observed that non-fatal accidents occur mostly during the third and fourth working hours (Table 5).

Also, a different study about steelwork factories has shown that the more labor-intensive morning shifts displayed a higher accident rate [31]. The reason for the high accident rate might be due to the attention of the workers being lower in the third and fourth working hours, unlike the first working hour and the successive first working hour after rest, preventing the accidents from having more severe consequences.

## 3.4. Accident severity types

The accident severity levels are marked as minor if the resting period is less than 5 days, as mediocre if the resting period is between 5 and 20 days, and as major if the resting period is

**Table 6.** Number and percentage of non-fatal occupational accident severity at shipyards.

Accident severity	Number of accidents	%
Minor	652	63.45
Mediocre	220	21.35
Major	116	15.20

**Table 7.** Accident places and several non-fatal occupational accidents at shipyards.

Accident place	Number of accidents	%
On the ship	514	49.6
Shipyards production areas	154	14.9
Shipyards other areas	126	12.2
Crane area	79	7.6
Factory	70	6.8
Scaffolds	69	6.7
In the ship's tank	11	1.1
Shipyards office	9	0.9
Other	4	0.4
Total	1028	100

more than 20 days. As presented in Table 6, a big part of non-fatal occupational accidents (63.45%) are the minor kind, the mediocre kind has occurred less than the minor kind (21.35%) and major accidents are the least common type.

Non-fatal accidents can occur in various ways. Evaluating the seriousness of these according to the days away from work will give healthier results. To give an example of object fall accidents, the fall of a hand-held hammer and the falling of a sheet metal plate to the ground causing injury are examples of falling object accident types. While the worker will be able to continue work immediately after a hammer falls, he will have to stay away from work for a long time as a result of the plate falling. Also, the attention of workers and the lack of using PPE are issues that significantly affect the severity of accidents. If we look at the burr accidents, accidents can be avoided slightly if glasses are used, while workers can be seriously harmed as a result of not wearing glasses.

### 3.5. Accident places of non-fatal occupational accidents at shipyards.

As presented in Table 7, almost more than half of the non-fatal occupational accidents have occurred on the ship and in shipyard production areas.

A significant portion of the work accidents in shipyards occur during the work done on the ship. Occupational accidents are seen intensely during the works carried out on the ship due to both the structural features of the ships and the inconvenience of the working area. The steep stairs inside the ship, rough areas and closed narrow environments make it more difficult to take adequate occupational safety precautions. The shipyard production area is the place where assembling the block parts of the ship takes place. In these areas, carrying parts with a forklift or crane and working in a high place, sharp surfaces are the most vital cause of non-fatal occupational accidents. In the shipyard, other areas include the place for blasting, grinding and welding. The crane area is another dangerous place for accidents. An object falling and crashing accidents may occur during the carrying of loads. Crane

**Table 8.** Reasons and priorities for non-fatal occupational accidents in shipyards.

Reasons	AHP	Rank
Inadequate safety equipment	0.16	1
Unsuitable equipment usage	0.14	2
Disobey OHS procedures	0.10	3
Deficiency of periodic maintenance and controls of equipment	0.09	4
Lack of OHS training	0.08	5
Deficiency of OHS culture	0.08	6
Problems with incorrect equipment usage	0.08	7
Disobey production instructions	0.06	8
Selection of unsuitable staff	0.06	9
Lack of on-site inspection	0.06	10
Housekeeping of workplace environment	0.04	11
Lack of business organization and work procedures	0.04	12
Failure to provide occupational hygiene	0.02	13

Note: AHP = analytical hierarchy process; OHS = occupational health and safety.

operations must be carried out carefully under supervision. In the factory part of the shipyards, there are machines and workbenches such as computer numerical control (CNC), and a casting bench. During the use of the machines, accidents such as jamming and cutting accidents have been observed. Scaffolds are usually used in shipyards for reaching high places in painting and sandblasting operations. Also, small scaffolds can be attached to tanks, machine rooms, etc. Working on scaffolds can cause falling accidents. Lastly, ship tanks and shipyard offices were also included in the occupational accidents.

### 3.6. Reasons and priorities for non-fatal occupational accidents in shipyards

To detect the reasons and priorities for non-fatal occupational accidents in shipyards, site engineers and occupational safety engineers (with more than 10 years of experience), as well as experienced labor inspectors (total of 26 experts) working between 10–20 years in the sector, were interviewed and surveyed. The application of the AHP technique to the study case was performed using Microsoft Excel 2016. Thirteen reasons were determined for each cause of the non-fatal occupational accidents in shipyards. This survey aimed to determine the importance of the various causes and recommendations. They were asked to rate the relative importance of each item in the reasons listed in each category when filling out the survey. The left side of each item is compared to the right side. When a number on the right side is selected, the item on the right is given more priority, and vice versa. Finally, both objects are equally essential if they were granted unity. The scale for judgments is presented in Table 2. The reasons and priorities for the non-fatal occupational accidents in shipyards and their ranks according to the AHP technique are presented in Table 8. The table displays the highest priority (rank 1) to the lowest priority (rank 13) order. The *CI* is less than 0.1 ( $CI = 0.043$ ), indicating that no further correction of judgments is needed.

From Table 8 it is clear that inadequate safety equipment (guards that prevent contact with dangerous rotating parts of the machine) is the most important factor in occupational accidents. Not using the right equipment properly, e.g., using ladders where scaffolding is required for the job to be done, and

not following the occupational safety instructions are among the most important factors that cause occupational accidents. The lack of periodic controls and maintenance was given priority compared to other reasons. The lack of OHS training, deficiency of OHS culture and problems with incorrect personal safety equipment usage has the same importance according to experts. Training and culture are very important to change the view of OHS. Other important reasons according to experts include disobeying the production instructions, selection of inappropriate staff and lack of on-site inspection. The production instructions are also important keys to completing the work with ease and safely. Failure to act under these instructions may cause problems with the usage of equipment like tools and machines resulting in occupational accidents. Although field inspections were considered a more important factor in occupational safety organizations, the impact factor was found to be very low when compared to other reasons due to the instantaneous development of accidents. House-keeping of the workplace environment was also found to be low when compared to other reasons since employees work in the same environment for a long time and are aware of the risks. This prevents accidents from occurring frequently. Lack of business organization and work procedures and failure to provide occupational hygiene were evaluated as the least effective causes by experts. Although both issues are important for the workplace environment, the absence of these two issues rarely directly causes work accidents.

### **3.6.1. Inadequate safety equipment**

Working without a protective cover, moving parts that are at risk of contact and having no appropriate safety equipment to stop the equipment from unintentional contact may cause a direct accident. At the same time, protective equipment measures become the forefront as they provide active security compared to other measures.

### **3.6.2. Unsuitable equipment use**

Use of unsuitable equipment like tools and machines is one of the important factors affecting accidents after the use of protective equipment. Inappropriate tools and machines can be used to finish temporary jobs quickly. For example, since it may take time and effort to build a safe scaffold for work at height, work can be done on temporary mobile machines instead.

### **3.6.3. Disobey OHS procedures**

Disobeying OHS procedures is another important reason for occupational accidents in shipyards. Occupational safety instructions are generally a set of rules that have emerged as a result of painful experiences. It is very important to comply with the instructions issued by the production team of the workplace, the occupational safety team and the machine manufacturers for the respective equipment.

### **3.6.4. Deficiency of periodic maintenance and controls of equipment**

The use of machines and tools that are not maintained and or checked regularly causes serious accidents. Particularly, failing to perform periodic checks of the lifting equipment may cause object falling accidents via breaking the carrier ropes. Again, the absence of periodic controls of the electrical installation, electric shock, fire, etc. can also cause accidents.

### **3.6.5. Lack of OHS training**

Every workplace environment contains its risks. The employees should be trained about workplace-specific risks. This training should also be repeated when changes are made to the workplace environment or new tools and machines are purchased.

### **3.6.6. Deficiency of occupational safety culture (OHS) culture**

OHS represents the occupational safety habits in a workplace. Placing a safety culture on employees is very important in preventing accidents because, in the field observations, the same subcontractor and respective workers show different habits in obeying the rules in different workplaces, which reflects the effect of workplace safety culture on working habits.

### **3.6.7. Problems with incorrect equipment usage**

Choosing the right safety equipment is very important in preventing accidents as well as maintaining faster and healthier work. Therefore, a risk assessment should be made before the completion of work and the most suitable safety equipment should be selected for the specific work, and if possible, the design should be expanded according to the characteristics of the work nature and its location, respectively

### **3.6.8. Disobey production instructions**

To ensure occupational safety, it is very important to comply with the production instructions as well as the occupational safety instructions. Production instructions should be created as a result of previous experience in the workplace or other workplaces operating in the same sector.

### **3.6.9. Selection of inappropriate staff**

An important study to be carried out to prevent occupational accidents in the workplace is to select an appropriate person for the job. Each employee has different personal characteristics, health status, attention and interest level. For this reason, in recruitment to be made, personal characteristics should be analyzed well and the suitability list of the recruited employee should be evaluated by experts.

### **3.6.10. Lack of on-site inspection**

Site inspections act as a significant deterrent for workers to comply with safety and production instructions agreed upon at the workplace. At the same time, they provide observations for the improvement of work habits and occupational safety measures.

### **3.6.11. Housekeeping of workplace environment**

Failure to provide the necessary order in the workplace, damaging or unprotected machines in the wrong place and forgetting hand equipment can cause work accidents. For this reason, it is very important to ensure order in the working environment.

### **3.6.12. Lack of business organization and work procedures**

Organizational plans to be made in the workplaces, determining the dangerous works to be done in the same area at the same time, determining the duration of the work to be done in an optimum way and not forcing employees to work quickly can be considered as very important measures in preventing workplace accidents.

### 3.6.13. Failure to provide occupational hygiene

Environmental measurements made to ensure occupational hygiene in the workplace enable the examination of the effects of hazard sources such as noise, dust and chemicals in the workplace.

## 4. Conclusions

We have reported the data on 1028 non-fatal occupational accidents dated between January 2010 and April 2015 and the reasons and priorities for non-fatal occupational accidents in shipyards were investigated. The investigation was carried out by analyzing the results of a questionnaire appropriate for the AHP technique. Especially, 26 experts were surveyed and the main purpose of this survey is to determine the order of possible explanations for non-fatal occupational accidents in shipyards and possible provisions and precautions that should be considered. Moreover, investments can be made by determining the measures according to the priority order as stated earlier. Inadequate safety equipment for machines and tools has the highest impact ratio according to experts. Subsequently, defective or unsuitable safety equipment provided by the employer scores second place. Moreover, the deficiency of periodic maintenance and controls of the safety equipment related to the same topic takes fourth place. However, the periodic maintenance of the equipment should be completed to operate at full capacity and failure results in breakdown and causing accidents. Disobeying OHS procedures, lack of OHS training and deficiency of OHS culture hold third, fifth and sixth place, respectively. In such a scenario, failure to follow health and safety procedures results in serious injuries or fatalities, and may also damage the shipyard's productivity and reputation. Using incorrect safety equipment, violating production instructions and being an unfit or unsuitable candidate for the job score seventh, eighth and ninth place, respectively, and these measures can have far-reaching consequences for any shipyard. But hiring talented workers at shipyards is generally hard in Turkey, so the importance of these measures holds lower rank. Lack of on-site inspection, housekeeping of workplace environment, lack of business organization and work procedures, and failure to provide occupational hygiene are in the bottom row for the measures according to the priority order.

Nevertheless, the present study can be expanded by examining new non-fatal accident data that occurred in a wider environment and with more participants for future work. Likewise, new causes of accidents can be compared. The authors are aware that the research has some limitations that must be considered in evaluating the study's findings. We believe that our results will be unique to the Turkish shipyard sector. Generalizations about other countries that have similar working conditions should be made wisely.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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